UNDERSTANDING DISCOURSE PRODUCTION IN PERSONS WITH APHASIA THROUGH VERBAL FLUENCY AND EXECUTIVE FUNCTION TASKS

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CERTIFICATE

This is to certify that this dissertation entitled **"Understanding discourse production in persons with aphasia through verbal fluency and executive function tasks"** is a bonafide work submitted as part of fulfilment of the degree of Master of Science (Speech Language Pathology) of the student with Registration Number P01II24S123019. 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.

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CERTIFICATE

This is to certify that this dissertation entitled **"Understanding discourse production in persons with aphasia through verbal fluency and executive function tasks"** has been prepared under my supervision and guidance. It is also being certified that this dissertation has not been submitted earlier to any other university for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled **"Understanding discourse production in persons with aphasia through verbal fluency and executive function tasks"** 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
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“उद्धरेदात्मनाऽत्मानं नात्मानमवसादयेत् ।

आत्मैव ह्यात्मनो बन्धुरात्मैव रिपुरात्मनः ॥”

Translation

“One must elevate oneself by one’s own mind, and not degrade oneself.

The mind can either be one’s greatest friend or one’s greatest enemy.”

~BG 6.5

This verse felt relatable throughout my journey. There were days when my mind motivated me to complete chapters, analyse data, and discuss *semantic verbal fluency* as if I had invented it myself. And then there were days when the same mind convinced me that even opening SPSS was an act of bravery. Somewhere between panic, overthinking, and deadlines, this journey taught me that persistence is really about learning how to keep going and behaving like one’s own greatest friend.

This dissertation may carry my name on the cover page, but honestly, it is more like a group project, and people repeatedly saying, *“Khatam hojaega yaar.”*

Firstly, I would express my gratitude to my family. Papa, Mummy, Dada, and Dadi for being my source of strength. Trusting me even when my sleep schedule, eating habits, and laptop screen time looked *terrible!* More importantly, thank you for not questioning me when I used to say, *“Is baar ghar nhi apaunga?”* and instead allowing me to stay back and complete this dissertation. That level of patience deserves co-author status at this point.

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This dissertation no longer feels like just *my* work. It feels like a shared effort built by everyone around me.

Somewhere between discourse tasks, clustering and switching scores, trail making tests, endless corrections, and random breakdowns, this dissertation slowly became a reflection of not just my effort, but of all of us *together*.

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CHAPTER I
INTRODUCTION

According to Le et al. (2014), aphasia is an acquired language disorder caused by brain damage, typically to the left hemisphere, that affects the understanding and expression of spoken and written language. It is not explained as a disorder of intelligence, but rather a disruption in language skills, often occurring post-stroke, traumatic brain injury, or other focal damage.

Individuals with aphasia also demonstrate impairments at both linguistic and cognitive-linguistic levels. Linguistic impairments involve difficulties in language processing, whereas cognitive-linguistic impairments involve deficits in cognitive processes that support language.

Linguistic level abilities can further be divided into micro-linguistic and macro-linguistic skills. Micro-linguistic skills refer to word- and sentence-level processing and are reflected in measures such as Content Word Fluency (CWF), Percentage Correct Information Unit (%CIU), semantic verbal fluency output, clustering, and switching. Macro-linguistic skills talk about the overall informativeness of discourse and are measured through narratives, picture description tasks, spontaneous speech, etc.

In addition, cognitive-linguistic deficits may be present, characterised by impaired attention, reduced working memory, and executive dysfunction. These deficits may affect both the supporting linguistic content and communication as a whole (Nicholas & Brookshire, 1993).

Assessment of aphasia requires evaluation of linguistic as well as cognitive-linguistic abilities. Micro-linguistic skills contribute to word retrieval and sentence formulation, macro-linguistic skills support discourse and informativeness, whereas cognitive-linguistic skills add attention, working memory, and executive control during communication. Therefore, assessment across these domains is important for understanding the overall profile of persons with aphasia (PWA).

But in everyday clinical settings, persons with aphasia are examined using several standardised assessment tests such as Western Aphasia Battery-Revised (WAB-R), Boston Diagnostic Aphasia Examination (BDAE), etc. These tests are very comprehensive and lengthy. For example, administering WAB-R on a client takes roughly 45 minutes to 2 hours, and 1.5 hours to 3 hours in administering BDAE (Goodglass et al., 2001; Kertesz, 2007).

These tests provide detailed information; however, their lengthy administration time taxes PWA and causes fatigue, reduced attention, and cognitive overload. Therefore, there is a need for clinically efficient measures that can account for the essential features of aphasia in a shorter duration while still providing information on communication skills.

In this regard, assessment of three important domains, that is, semantic verbal fluency, discourse production, and executive functioning, provides a focused yet comprehensive understanding of micro-linguistic, macro-linguistic, and cognitive-linguistic impairments in aphasia.

Semantic Verbal Fluency (SVF) reflects micro-linguistic processing by examining lexical retrieval, semantic organisation, and verbal output. SVF tasks are simple to administer and are sensitive to language impairments. Also, they help identify the interaction between lexical retrieval and executive control skills during word production.

Discourse assessment reflects macro-linguistic processing as it evaluates the ability to organize, maintain, and convey information in connected speech. Indices of discourse assessment, such as Main Concept Analysis (MCA), Content Word Fluency (CWF), and Percentage Correct Information Unit (%CIU), provide information regarding discourse informativeness and coherence.

Executive function assessment reflects cognitive-linguistic processing as it examines cognitive mechanisms that support language performance. For example, attention, cognitive flexibility, inhibition, and working memory are important for maintaining discourse, shifting between ideas, and suppressing irrelevant responses.

Together, assessment of semantic verbal fluency, discourse, and executive functioning provides a holistic understanding of the linguistic and cognitive-linguistic profile of PWA, each of which is examined in the following subsections.

In the following section, verbal fluency tasks will be discussed because they provide insight into lexical retrieval and the cognitive control processes underlying word generation (Bose et al., 2022).

1.1 Verbal Fluency in Persons with Aphasia

Verbal fluency tasks analyse a person's ability to find, retrieve, and produce words provided in their mental lexicon. It requires participants to produce as many words as possible from a given category within a designated time frame, usually 60 seconds (Karousou et al., 2023).

Semantic Verbal Fluency performance is associated with both discourse abilities and executive functioning in PWA. Studies have reported that reduced verbal fluency is related to lesser discourse informativeness (Boucher et al., 2022; Dalton & Richardson, 2015). In addition, SVF tasks are known to involve executive processes such as cognitive flexibility and inhibition (Bose et al., 2022; Dutta & Murray, 2023).

Hence, in order to assess this relationship and provide insight into both linguistic and cognitive-linguistic functioning in PWA, a variety of SVF parameters are used, including the total number of correct responses (CR), clustering, switching, within-cluster pause duration, and between-cluster pause duration.

Starting with **clustering**, which involves grouping words within a subcategory. For example, if a participant says: "dog, cat, horse, cow", they produce items from the same subcategory (domestic/farm animals). This is called clustering, that is, retrieving semantically related items grouped together.

The other strategy is called **switching**, which is the ability to shift effectively to a novel category of words when a subcategory is wasted, for example, if the participant moves from "cow" to "lion, tiger, elephant". They have shifted from the domestic animals' cluster to the wild animals cluster. This shift in subcategory is called switching. Switching requires *cognitive flexibility* and the *ability to disengage* from one semantic cluster while initiating a search in another (Troster et al., 1998; Troyer et al., 1997).

Clustering and switching are the components that decide the number of words produced. Most studies quantify the ability to switch between subcategories by reporting on the number of switches and clusters produced. More precisely, a change of subcategory (between two consecutively placed clusters, between a cluster and a single word, or between two single words of different subcategories) (Troyer et al., 1997). However, there is another way to measure switching, that is, by counting the total number of clusters produced, hence, giving importance only to the planned and performed switches/clusters and simply not to random un-clustered utterances.

Clustering is majorly affected by lexico-semantic skills. It is found to be more closely associated with temporal lobe activation (N'Kaoua et al., 2001; Testa et al., 1998; Troyer et al., 1998). Switching, on the other aspect, is supposed to indicate a more controlled step, linked with executive skills such as initiation, working memory, set-shifting, and cognitive flexibility. It is mainly linked with frontal lobe activation.

In addition to these skills, choosing words that meet constraints and avoiding repetition depends on the executive processes (Shao et al., 2014; Troyer, 2000). Hence, the unity of both linguistic and executive control skills is important for proper performance on a semantic verbal fluency test. And this varied nature of the fluency task has made it a quick and easy test for linguistic and/or executive control skills in typical and atypical populations (Bose et al., 2017).

Although verbal fluency is commonly used in both clinical and research assessments, there is limited data collected on the quantitative (number of correct responses produced) and qualitative (switching, clustering, and/or timing characteristics) aspects in PWA (Kiran et al., 2014). Quantitatively*,* according to the available literature, PWAs produce fewer words than healthy controls; however, little information exists about the quality of their output compared with healthy controls (Baldo et al., 2010). The research by Baldo et al. (2010) found that people with Wernicke's aphasia exhibit decreased cluster sizes, while those with Broca's aphasia do not exhibit any impairment in cluster size*.* Talking more qualitatively, the performance time (timing to produce correct words) as well as the amount of time needed to produce a given word based upon its location in the sequence of words provides important signs regarding the linguistic and executive control strategies that are used by them (Crowe, 1998; Hurk et al., 2004; Tröster et al., 1998).

In the same context, the temporal analysis of verbal fluency performance also helps in understanding the mechanisms of word retrieval in aphasia. Studies have found that most words, both in healthy individuals and in PWA, are produced within the first 30 seconds, with performance declining progressively thereafter (Hurks et al., 2010). This temporal decline is thought to reflect the progressive wasting of exemplars from the mental lexicon, requiring increasing effort to retrieve less-activated items. In PWA, this rate of decline may be further steepened by the reduced availability of lexical items within each semantic subcategory, meaning that clusters are exhausted more rapidly, and the individual is forced to switch to a new subcategory sooner, or else produces pauses and ultimately stops the verbal output. Analysing within-cluster pause duration and between-cluster pause duration therefore provides a window into the moment-by-moment variations in lexical access that other simple measures cannot reveal (Bose et al., 2022).

SVF performance also depends upon the type of semantic category used for elicitation. Using the category of animals has been the most widely studied and standardised paradigm across research in both typical and atypical populations (Troyer et al., 1997). The animal category is particularly useful because it is a familiar, high-frequency semantic category that most participants, even those with moderate language impairments, can access to some extent. This makes it sensitive across a wide range of aphasia severity, avoiding floor effects that might occur with less familiar categories. Furthermore, animals can be readily subcategorised along multiple dimensions (e.g., domestic versus wild, large versus small), reliably eliciting both clustering and switching behaviours, allowing the full range of verbal fluency strategies to be observed and quantified (Karousou et al., 2023).

The theoretical basis for interpreting verbal fluency impairments in aphasia draws on two frameworks. The first is a storage-based account, which states that aphasia disrupts the structural integrity of semantic representations in the mental lexicon, such that the conceptual features associated with individual words are degraded, less richly interconnected, or inconsistently accessible (Randolph et al., 1993). Under this account, PWA would be expected to produce fewer correct items and smaller cluster sizes, reflecting a reduction in the number of co-activated exemplars within each subcategory. The second is a retrieval-based account, which attributes verbal fluency impairments to deficits in the processes by which intact or partially intact semantic representations are accessed, selected, and inhibited during production (Luo et al., 2010). Under this account, impaired fluency reflects an inability to efficiently search and monitor the lexical-semantic space rather than the degradation of the knowledge itself. In practice, the available evidence suggests that both mechanisms contribute to verbal fluency deficits in aphasia, with their relative contributions varying across individuals and aphasia subtypes (Bose et al., 2022). Distinguishing these contributions has direct clinical implications, as storage-based and retrieval-based deficits may respond differently to treatment approaches.

1.2 Discourse in Persons with Aphasia

Discourse is the language use that extends beyond the sentence level and is organised to convey meaning. Halliday and Hasan (1976) defined discourse as "language that is meaningful and unified, serving as a communicative whole". For a person to engage in successful discourse, many cognitive and linguistic skills must work together. These include microlinguistic and macrolinguistic skills (Dipper et al., 2021), as well as cognitive skills such as working memory (Tchakoute et al., 2017) and executive functions (Dutta et al., 2023).

To have a holistic discourse assessment, structuralist methods (including type-token ratio, T-units, and mean length of utterance) are used to assess the microlinguistic aspects of an individual's use of language, while functionalist methods (including communicative effectiveness, conversational repair, and turn-taking) are used to assess the macrolinguistic aspects of an individual's ability to convey a message. There are other methods of measuring discourse that do not easily fit the structuralist or functionalist categories, but are very important (Armstrong, 2000).

However, this strict distinction between structuralist and functionalist approaches may not capture the informativeness and communicative adequacy in PWA. An individual may produce appropriate utterances yet fail to convey essential information of the message, while others may communicate key ideas despite reduced syntactic complexity. Therefore, measures of discourse informativeness such as Main Concept Analysis (MCA), Correct Information Units (CIUs), and content-word fluency have gained importance in aphasia research. These measures provide clinically relevant information on discourse performance that may not be adequately represented within the traditional micro- and macro-linguistic bifurcation.

Discourse tasks provide a more ecologically valid assessment of communicative competence than traditional linguistic measures, since they reflect real-life narrative and descriptive demands.

Discourse is also important for adding information that cannot be collected using typical neuropsychological assessments (Ahmed et al., 2013). Furthermore, there is evidence suggesting that discourse analysis may reveal subtle language impairment during potential cognitive decline, and/or subtle presentations of language impairment following a brain injury. Overall, discourse analysis may be useful for distinguishing language function changes and will be able to determine whether an individual has sufficient language damage to warrant a referral for Speech-Language Therapy Services following a stroke.

Discourse sampling can be either interactional or monologic. Most institutions follow monologic forms because of reduced conversational abilities in PWA. Within the monologic form, picture description tasks are the most common type of elicitation for individuals with aphasia (Bryant et al., 2016). Most of the standardized assessment batteries for communication impairment include this type of task (e.g., Goodglass and Kaplan, 1972; Kertesz, 2007).

In a picture description task, the client is presented with a relatively complex visual scene and is required to describe the scene. Picture descriptions have been said to reduce memory demands in persons with aphasia and may indicate language problems. This task also requires them to use vocabulary specific to describing the exact picture, as there are limitations to the correct vocabulary that can be produced. These limitations in correct vocabulary may suggest the presence of phonologic and lexical-semantic deficits; for example, an individual who has had a stroke may not be able to produce appropriate vocabulary, may produce words that are either unrelated or non-specific (e.g., "that one"), or may produce one of many mistakes (e.g., "dog" instead of "lion") (Mueller et al., 2018).

In a study by Alyahya (2025), the author measured discourse using a *checklist* of essential features (e.g., objects, people, locations, actions) or through units of information that are contained in the picture without the need to perform time-consuming transcription and coding. They came out with a checklist of content word fluency and main concepts.

Main concepts represent the core ideas that should be conveyed in a description, while content word fluency provides an index of lexical access and semantic richness in connected speech. For instance, in narrative tasks such as picture descriptions, main concepts are rigorously identified by expert consensus or statistical frequency among unimpaired speakers. Conversely, disruptions in lexical-semantic processing, such as those observed in preclinical Alzheimer's disease, can manifest as a reduction in specific content words, even in the absence of overt lexical or syntactic deficits.

1.3 Executive Function in Persons with Aphasia

EFs include planning, monitoring, inhibiting, and flexibly shifting between tasks and directly supporting discourse organisation (Dutta et al., 2023). When executive control is compromised, individuals may produce disorganised or incomplete narratives, despite relatively preserved linguistic knowledge. Therefore, assessing how people perform executive functions is a valuable addition to assessing language skills in PWA.

A lot of research has been done regarding the link between executive functions (EFs) and language function in PWAs, documenting poor performance. However, the relationship between language and EFs in PWAs remains debated. There is less agreement as to whether this relationship relates to the type of aphasia or specific aspects of language or EF components being assessed (Vuković & Chen, 2025).

Three major executive functions affect how we produce language- 'Inhibition control', 'Working memory', and 'Cognitive flexibility.' (Miyake et al., 2000). Inhibitory control is a foundational element within Executive Functions, encompassing the capacity to manage attention, actions, thoughts, or feelings so that you do not give in to impulses or distractions. It allows individuals to engage in more suitable or necessary actions. It includes two primary skills- interference control (managing selective attention and cognitive inhibition) and self-control (regulating behaviour). 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. Thus, inhibition makes Humans "thinking" creatures. Inhibitory control also plays a direct and often underappreciated role in verbal fluency and discourse production in aphasia. During an SVF task, individuals must continuously suppress previously produced items to avoid perseveration, inhibit semantically related but phonologically inappropriate responses, and resist returning to an exhausted subcategory before switching to a novel one (Shao et al., 2014). In PWA, these inhibitory demands may be compounded by the already elevated effort required for lexical retrieval, creating a situation where executive resources are taxed simultaneously at the lexical and monitoring levels. Similarly, during discourse production, inhibitory control is necessary to prevent intrusions, irrelevant digressions, and topic drift, all of which can render connected speech less informative and coherent. Deficits in inhibitory control in persons with aphasia have been documented using tasks such as the Stroop Color-Word Test, where PWA show disproportionate interference effects relative to controls (Vuković & Chen, 2025). The clinical implication is that aphasia rehabilitation targeting inhibitory control, in addition to lexical retrieval, may yield broader communicative benefits at the discourse level.

Working memory (WM) is the capacity to retain and actively manipulate mental representations of information, despite the fact that they are not currently being viewed in the environment (Vuković & Chen, 2025). 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, as it helps in holding and manipulating information over short time periods, essential for maintaining referential continuity across sentences, tracking the thematic thread of a narrative, and monitoring one's own output for errors and revisions (Mayer & Murray, 2012).

In the context of a picture description task, working memory supports the speaker in keeping track of which elements of the scene have already been described, which remain to be mentioned, and how individual propositions relate to one another in building a coherent discourse structure. PWA frequently show reduced working memory capacity relative to neurotypical peers, even on non-verbal tasks that minimise language demands (Dutta et al., 2023). This reduction in working memory may contribute to the disorganised discourse profiles observed in aphasia, independent of, or in interaction with, the lexical retrieval difficulties that are more typically the focus of clinical attention.

Cognitive flexibility represents the third essential executive function. It is set-shifting, mental flexibility, or mental set-shifting. There are several definitions of Cognitive flexibility, each trying to explain it through a different perspective. For example, it encompasses the capacity to alter viewpoints spatially, such as visualising 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. Cognitive flexibility is essential in allowing individuals to modify their thinking as per the way in which the environment changes. It permits individuals to update information easily and change their attentional set, which is necessary for navigating through dynamic settings. It is also recognised as a meta-competency needed for processing novelty, enabling adaptive performance in complex, information-rich environments. It is the ability of an individual to adapt the techniques they use to think about unanticipated events or new situations, and is considered one of the central executive functions associated with adapting to changes in an individual's environment through shifting their set of mental processes and overcoming automatic responses (Hommel et al., 2022). Another facet of cognitive flexibility pertains to modifying our thought patterns and fostering innovative thinking. It is commonly explored through various tasks involving task-switching and set-shifting tasks.

EF assessment is usually performed in clinical settings, for healthy as well as aphasic populations. But an attribute that influences assessment in aphasia is the heterogeneity of executive function profiles. As Dutta et al. (2023) documented in a large-scale examination, some individuals show pronounced executive deficits with relatively mild language impairment, while others show the reverse pattern. This dissociation suggests that executive dysfunction in aphasia is not simply an epiphenomenon of language impairment or of the extent of left hemisphere damage, but reflects a partially independent dimension of cognitive functioning that warrants dedicated assessment. In clinical practice, the failure to assess executive functions separately from language may lead to misattribution of discourse deficits. A clinician observing disorganised, incomplete picture description output may attribute this entirely to word-finding difficulty when, in fact, impaired planning, monitoring, or set-shifting may be equally or more responsible.

Most EF tasks revolve around a pair of tasks, which could encompass tasks like discerning if an alphabet is a vowel or a consonant, determining a number's even or odd status, 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 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 (De Oliveira-Souza et al., 2000). 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 (Longman et al., 2014). 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.

While previous research has demonstrated that persons with aphasia show reduced performance on semantic verbal fluency tasks due to impaired lexical retrieval and weakened executive control (Shao et al., 2014; Troyer et al., 1997), the functional implications of these deficits for connected speech remain less clearly understood. Discourse production, such as in picture description tasks, requires not only access to semantic knowledge but also the ability to organize, monitor, and switch between lexical items in a coherent manner. Similarly, executive function tasks like the Trail Making Test capture set-shifting and processing speed abilities that may influence discourse fluency. However, only limited studies have systematically examined the **relationship between semantic fluency performance, executive control, and discourse informativeness in persons with aphasia**. Establishing these links is essential to better understand the underlying mechanisms of communication breakdowns in aphasia and to design assessment protocols that integrate both linguistic and cognitive measures.

1.4 Need for the study

Discourse impairment is one of the most debilitating consequences of aphasia, directly affecting individuals' ability to participate in meaningful everyday communication (Dalton &

Richardson, 2015; Nicholas & Brookshire, 1993). Therefore, there is an urgent need to establish objective, quantifiable measures that capture how micro-level lexical retrieval processes relate to macro-level discourse outcomes such as informativeness and main concept accuracy (Kim et al., 2018). Establishing these links will help move beyond surface-level descriptions of impairment toward mechanistic explanations of communication breakdowns in PWA.

A second rationale arises from the relatively understudied role of executive functions in aphasic discourse. Cognitive processes, including set-shifting, inhibition, working memory, and planning, are essential for both verbal fluency performance and the organization of extended discourse. While impairments in these domains have been documented in PWA (Dutta et al., 2023; Purdy, 2002), their contribution to discourse production remains poorly understood, particularly when assessed with executive function tasks adapted to minimize confounds of language or motor impairment. Without such evidence, the clinical validity and interpretability of discourse assessments remain incomplete, as it is often unclear whether breakdowns in connected speech reflect primarily linguistic deficits, executive dysfunction, or an interaction of both.

Finally, this study holds strong clinical significance. By systematically examining the relationships between clustering and switching in verbal fluency, executive control measured through the Trail Making Test, and discourse informativeness assessed via content word fluency and main concept analysis, it will be possible to disentangle semantic from executive contributions to discourse deficits (Alyahya et al., 2021; Dutta et al., 2024). This knowledge will enable clinicians to make more precise diagnostic interpretations, distinguish whether a patient's discourse difficulties stem from lexical-semantic limitations or executive control deficits, and subsequently design more targeted, individualized interventions. Furthermore, identifying objective outcome measures across these domains will provide therapists with quantifiable benchmarks to monitor progress and treatment effectiveness. Ultimately, the findings of this study will not only advance theoretical models of language-cognition interaction in aphasia but also contribute directly to improving the rehabilitation outcomes and communicative participation of persons with aphasia.

1.5 Aim of the study

1. To compare discourse production, semantic verbal fluency, and executive function performance between PWA and neurotypical adults (NTA).
2. To examine the relationship between discourse production, semantic verbal fluency, and executive functions in PWA and NTA.

Objectives of the study

1. To quantify discourse output on a picture description task using a predefined checklist of Main Concepts (MCs), the total number of content words (CWF) between PWA and NTA.
2. To quantify Semantic Verbal Fluency (SVF) performance between persons with aphasia (PWA) and neurotypical adults (NTA).
3. To assess executive control using the Trail Making Test (TMT A and B) between PWA and NTA.
4. To evaluate the correlation among discourse performance, SVF, and TMT in PWA and NTA.

Hypothesis

1. Null hypothesis- There is no significant difference in quantitative discourse output using a predefined checklist of Main Concepts (MCs), the total number of content words (CWF) on a picture description task between persons with aphasia and neurotypical adults.

2. Null hypothesis- There is no significant difference in semantic verbal fluency performance (total number of correct animal names, cluster counts, switching counts, reaction times) between PWA and NTA.
3. Null hypothesis- There is no significant difference in executive control as measured by TMT-A and TMT-B between PWA and NTA.
4. Null hypothesis- There are no significant associations between discourse outcome measures (MC, CWF), semantic verbal fluency measures (total correct, clustering, switching, RTs), and Trail Making Test indices (TMT-A, TMT-B), in the present study sample; specifically, SVF measures do not predict or correlate with discourse measures, and TMT measures do not mediate or moderate any relationship between SVF and discourse.

CHAPTER II

REVIEW OF LITERATURE

This chapter reviews the literature relevant to semantic verbal fluency, discourse production, and executive functioning in persons with aphasia. The review is organised into four sections. The first section discusses semantic verbal fluency in aphasia, followed by discourse production and executive function. The final section synthesises the literature on the relationships among these domains and identifies the gap that forms the basis for the present study.

2.1 Semantic verbal fluency in persons with aphasia

Most individuals who have difficulty speaking as a result of brain damage (apraxia, aphasia, stroke) are commonly assessed with verbal fluency tests because they are easy to administer and allow assessment of language, cognition, and language skills in general. Research consistently demonstrates that PWAs produce significantly fewer items than healthy individuals when asked to perform a verbal fluency task; however, it is not definitively known whether their reduced word production is solely due to word-finding difficulties or whether dysexecutive deficits also contribute. Recent findings indicate that the use of temporal features, clustering and switching measures, pause durations, and executive function measures can help elucidate the lexical and cognitive bases of fluency in PWA. In contrast to healthy participants, PWA exhibited significantly greater difficulty in letter (phonemic) fluency conditions, showed prolonged latencies to response (as measured by within- and between-cluster pause times) during retrieval, and switched less frequently than healthy individuals. Although these differences indicate that PWA experience significant difficulties retrieving items, both groups demonstrate equivalent declines in the rate of recall of previously learned items and exhibit relatively similar cluster sizes.

Faroqi-Shah & Milman (2018) examined verbal fluency performance in PWA by comparing three tasks: semantic, action, and phonemic fluency. The study included 29 PWAs and 40 healthy controls, analysing both quantitative (total responses, clusters, perseverations) and qualitative (word frequency, age of acquisition, syllable length) aspects of performance. Results indicated that PWA performed more poorly than controls across all tasks, with semantic fluency most impaired and action fluency least affected. Additionally, animal and action fluency were strongly associated with overall language abilities, whereas phonemic fluency was relatively independent, reflecting greater reliance on executive control. Qualitative analysis revealed that PWA used simpler words, suggesting compensatory strategies for impaired lexical retrieval. Overall, the findings emphasise that semantic fluency is a sensitive indicator of language impairment in aphasia and provides valuable implications for clinical assessment and intervention.

Extending this, researchers examined how cognitive control interacts with lexical access, specifically in bilingual individuals with aphasia, offering a complementary perspective on the executive demands of verbal fluency tasks.

The study by Carpenter et al. (2020) aimed to understand how cognitive control interacts with lexical access in bilingual people with aphasia (BPWA). They assessed this relationship using semantic and letter fluency tasks. A total of 13 BPWAs and 22 healthy bilingual participants completed semantic category and letter fluency tasks under different language conditions. The findings indicated that BPWA produced fewer accurate responses overall and were more affected by increased cognitive-control demands, particularly in conditions requiring language switching. Notably, performance in less demanding conditions (self-switch) was comparable between groups, suggesting that reduced cognitive load facilitates lexical access in BPWA. The study concluded that verbal fluency tasks effectively capture the combined impact of cognitive-control and lexical-access deficits in bilingual aphasia and have important implications for assessment and rehabilitation.

Alongside cognitive control, lesion characteristics were also found to shape verbal fluency profiles. Studies have investigated how the damaged hemisphere and aphasia status jointly influence fluency performance.

Lesion lateralisation and site also appear to shape fluency strategies and outcomes. Pagliarin et al. (2022) compared phonemic and semantic verbal fluency performance across control participants and patients with unilateral brain damage. Patients with left-hemisphere damage and aphasia (LHDa) demonstrated poorer performance, producing fewer words, fewer clusters, and fewer switches in both fluency tasks. Patients with right-hemisphere damage (RHD) showed fewer switching productions compared with controls, whereas left-hemisphere damaged patients without aphasia (LHDna) produced fewer words than controls during the first 30-second block. These findings indicate that both hemisphere and aphasia status influence not only total output but also the temporal and structural characteristics of fluency.

Building on these lesion-based and cognitive-control findings, Bose et al. (2022) provided a detailed temporal analysis of lexical retrieval in aphasia, focusing specifically on clustering and switching dynamics.

Specifically, Bose et al. (2022) reported that, compared with healthy individuals, PWA had longer within- and between-cluster pauses, indicating that retrieval speed was slowed within and between semantic categories. Despite these duration difficulties, cluster size was similar between PWA and healthy individuals. Executive control measures correlated primarily with letter fluency variables rather than semantic fluency variables in PWA, suggesting that the executive control demands of semantic and letter fluency tasks may differ and that the difficulties in semantic fluency observed in aphasia are more closely linked to lexical rather than executive control deficits. These findings highlight that difficulties in verbal fluency in aphasia reflect a combination of lexical and executive control deficits.

Together, these studies establish that semantic verbal fluency is consistently impaired in PWA and serves as a sensitive indicator of both language dysfunction and cognitive-linguistic impairment.

More recently, researchers have extended work by employing a semantic network approach to examine how the structural organisation of the mental lexicon itself differs in aphasia.

The research by Pham et al. (2025) examined lexical retrieval in persons with fluent and non-fluent aphasia using a semantic network approach. Researchers sought to determine how lexical-semantic organization differs between healthy controls and PWA, as well as across aphasia subtypes. A total of 120 healthy adults and 127 people with aphasia completed a semantic fluency task, and the authors analysed their responses using graph-theoretic metrics to examine semantic networks. They found that PWAs had less-integrated, more fragmented semantic networks, characterised by longer path lengths, fewer clusters, and greater modularity. The authors also found that these disruptions were more pronounced in individuals with non-fluent aphasia than in those with fluent aphasia. Additionally, the efficiency and resilience of lexical networks were significantly reduced in people with aphasia, as assessed using spreading activation and percolation analyses. They concluded that semantic network analysis provides a more sensitive and comprehensive description of lexical retrieval impairment in aphasia because it captures both structural and functional impairments of the mental lexicon.

A critical question that emerges from the body of literature is whether the verbal fluency deficit observed in PWA is primarily a storage-level phenomenon, reflecting degraded semantic representations, or a retrieval-level phenomenon, reflecting impaired strategic access to intact representations. This distinction has direct clinical relevance, as it determines whether intervention should target semantic knowledge rebuilding or the executive and strategic processes that govern lexical search. The semantic network analyses of Pham et al. (2025) suggest that the structure of the mental lexicon itself is disrupted in aphasia, particularly in non-fluent subtypes, with reduced connectivity, longer retrieval paths, and greater fragmentation. In contrast, the findings of Bose et al. (2022), showing that PWA and healthy controls have similar cluster sizes but differ in switching frequency and pause durations, point to a predominant deficit at the retrieval and executive control level rather than semantic storage per se. These frameworks are not mutually exclusive, and the weight of current evidence supports the view that both levels of impairment contribute to reduced SVF in aphasia, with their relative contributions varying across individuals and aphasia subtypes (Faroqi-Shah & Milman, 2018).

Beyond overall lexical retrieval deficits, researchers have also explored how specific linguistic characteristics, lesion variables, and cognitive-control demands influence verbal fluency performance.

Building on the need to disentangle lexical and executive contributors, Park et al. (2025) specifically compared noun and verb (action) fluency tasks in PWA and cognitively healthy adults (CHA). Both groups showed significantly lower accuracy on action fluency than on noun fluency. They suggested that this difference arises because the action-fluency task does not strongly constrain verb types and therefore may not require highly controlled verb selection, potentially obscuring specific difficulties in verb retrieval.

Recent methodological developments have further expanded the understanding of verbal fluency by examining the temporal dynamics of lexical retrieval.

From a methodological standpoint, the measurement of within-cluster and between-cluster pause durations represents one of the most promising recent developments in verbal fluency research in aphasia. These temporal indices, which require audio or video recording and acoustic analysis software such as Praat (Boersma, 2001), provide a window into the real-time dynamics of lexical retrieval that simple response counts cannot capture. Within-cluster pauses index the effort required to retrieve successive items within an active semantic subcategory, while between-cluster pauses index the time cost of transitioning to a new subcategory following the decision to switch. In healthy adults, within-cluster pauses are typically shorter than between-cluster pauses, reflecting the relative ease of co-activation within an established semantic cluster versus the greater executive effort required to initiate a new search in a different subcategory (Troyer et al., 1997). In PWA, this relationship may be altered or reversed, reflecting the combined effects of degraded lexical access within clusters and impaired executive switching between them. The inclusion of within-cluster and between-cluster pause duration measures in the present study extends the analysis beyond simple counting approaches and provides a richer characterisation of the temporal dynamics of lexical retrieval in aphasia.

Taken together, these studies show that PWAs produce fewer correct items on fluency tasks and exhibit altered temporal and organisational profiles (Bose et al., 2022), that verbs and nouns may be differentially affected (Park et al., 2025), and that lesion site and hemisphere modulate clustering and switching behaviour (Pagliarin et al., 2022). This pattern of evidence underscores the importance of a detailed, multi-metric approach to investigating verbal fluency.

2.2 Discourse Task in persons with aphasia

Discourse analysis has become an important component of aphasia assessment because it provides insight into an individual's ability to communicate meaningful information in connected speech. Unlike isolated naming or sentence-level tasks, discourse assessment captures communication as it occurs in more naturalistic settings, thereby offering greater ecological validity. Over the years, several approaches have been developed to quantify discourse performance, with particular emphasis on discourse informativeness and communicative effectiveness.

Nicholas and Brookshire (1993) developed the Correct Information Unit (CIU) analysis as a standardised system to measure the informativeness and efficiency of connected speech in PWA. A CIU was defined as a word that is intelligible in context, accurate in relation to the picture or topic, and informative about the content. Using this approach, differences were found between healthy individuals and PWA on all five CIU-based measures. The authors reported that the three calculated measures- words per minute, %CIUs, and CIUs per minute distinguished the two populations at the individual level rather than solely on CIU counts, demonstrating the clinical utility of measures of discourse informativeness.

Building on discourse informativeness frameworks, researchers subsequently developed structured systems to evaluate the essential content conveyed in discourse samples. In addition, checklist-based research provides support for the use of discourse analysis in PWAs. For example, checklists associated with Main Concept Analysis (MCA) include descriptive statistics on the performance of healthy individuals on the Cat in the Tree and Refused Umbrella narrative tasks, along with specific written instructions for determining whether the coder was accurate and/or complete. The MCA provides information on which narrative tasks are critical and which are non-critical. These components of the checklist are required for the accurate coding of the narrative tasks; the coding system is one of the most essential features of MCA, as numerous studies have found that the number and presence of error coding may represent the most important criterion for distinguishing between typical and clinical populations (Nicholas & Brookshire, 1993).

The error codes within MCA further improve the sensitivity of discourse analysis. An Accurate-Incomplete (AI) code is assigned when the speaker provides correct information but omits essential details, making the concept only partially conveyed. For example, if the target concept is “The boy is climbing the ladder to rescue the cat” and the participant says “The boy is climbing the ladder,” the idea is accurate but incomplete. An Inaccurate-Complete (IC) code is used when the response is structurally complete but contains incorrect information. For instance, "The boy is climbing the ladder to rescue the dog" substitutes an incorrect detail (a dog instead of a cat) while still conveying the full concept. The Inaccurate-Incomplete (II) code applies when the response is both factually inaccurate and missing essential information. For example, "The girl is climbing" misrepresents the actor and fails to capture the full event. Hence, these codes are important for tracking progress and treatment-induced change.

Alongside the development of formal coding systems, early work also began to examine how discourse elicitation conditions themselves influence the type and quality of language produced. Studies are done to investigate the role of discourse genre in shaping verb use and coherence, highlighting that the structure of the elicitation task significantly affects the nature of the output obtained.

Olness (2006) examined the relationship between discourse genre, verb use, and coherence in picture-elicited discourse among adults with aphasia. The study aimed to explore how descriptive and narrative discourse genres influence verb form and function, and thereby contribute to discourse coherence. Twelve individuals with mild to moderate aphasia were asked to produce discourse responses to pictorial stimuli under different elicitation conditions, including those with and without explicit temporal sequencing instructions. The findings showed that, under typical clinical instructions, participants predominantly produced descriptive discourse characterised by present or non-finite verb forms serving background and setting functions. However, when temporal sequencing was explicitly requested, many participants shifted to narrative discourse, marked by increased use of past-tense verbs and storyline functions. The study concluded that discourse genre significantly influences verb production and coherence, highlighting that narrative discourse better supports coherent language organisation, whereas descriptive discourse often results in fragmented output. These findings underscore the importance of considering discourse-level factors in the assessment and treatment of aphasia.

Following this evidence that discourse characteristics vary by task structure, Richardson and Dalton (2015) sought to establish a standardised lexical benchmark for comparing discourse performance across speakers by identifying a core lexicon from a widely used picture-description task.

In addition to checklist-based approaches, corpus-driven methods have also been used to identify critical lexical targets within discourse samples.

Complementing checklist and coding approaches, corpus-based work has identified lexical targets that aid comparison across speakers. Richardson and Dalton (2015) sought to identify the core lexicon of a picture-description task using transcripts from the AphasiaBank database and to determine differences in core-lexicon usage between control speakers and persons with aphasia (PWAs). A 24-item core lexicon was identified. Significant differences were found between control speakers and PWAs for both core-lexicon and main-concept scores. Importantly, core-word production and main-concept performance were positively related, supporting the validity of using predefined lexical and conceptual lists in discourse scoring.

Extending the focus from lexical benchmarks to modality differences in discourse, Vandenborre et al. (2018) examined whether speech and writing yield equivalent information about discourse abilities in aphasia.

According to Vandenborre et al. (2018), analysing both modalities (speech and writing) at the discourse level allows simultaneous assessment of micro- and macro-linguistic skills and their interrelations in individuals with aphasia (IWA). Their findings suggest that connected writing is more sensitive in discriminating IWA from healthy controls than connected speech.

Building on traditional discourse measures, recent studies have focused on developing clinically efficient approaches to quantify discourse performance without requiring extensive transcription and coding.

Building on these methodological advances, Alyahya et al. (2021) developed a clinically efficient checklist-based approach to quantify content word production in discourse, providing a practical tool that reduces the transcription burden associated with traditional measures.

Alyahya et al. (2021) examined Content Word Fluency (CWF) during discourse in PWA and found that they produced fewer content words than healthy individuals. Their study indicated that this deficit was primarily related to the quantity, rather than the lexical-semantic complexity, of the words produced. In other words, PWA tended to produce content words similar to those produced by healthy individuals, but in smaller numbers. The authors also developed a checklist-based index of CWF that could be applied without full transcription and demonstrated its validity across two discourse tasks in both PWA and healthy individuals.

Complementing this approach, Boucher et al. (2022) examined how confrontation naming ability relates to discourse informativeness in the early post-stroke period, highlighting lexical retrieval as a key contributor to connected speech performance. Boucher, Marcotte, et al. (2022) evaluated discourse using a picture-description task to measure the quantity of connected speech and its relationship to performance on a confrontation naming task in early post-stroke aphasia (8–14 days post-stroke). The authors found that confrontation naming ability was most closely related to discourse informativeness during picture description. These findings suggest that lexical retrieval abilities may contribute substantially to discourse performance and communicative effectiveness.

Further extending the understanding of the linguistic bases of discourse impairment, Kuvač Kraljević et al. (2023) examined discourse production at the level of main concept formation, exploring how conceptual and linguistic deficits interact to affect connected speech.

The study aimed to investigate differences in the number, accuracy, and completeness of main concepts produced by PWA and healthy controls, as well as their relationships with language measures such as productivity, informativeness, and grammaticality. A total of 38

PWA and 38 controls were asked to describe a standardised picture stimulus, and their discourse was analysed using measures such as Correct Information Units (CIUs), clauses, and verb production. The findings showed that PWA produced significantly fewer main concepts, which were often incomplete or inaccurate, indicating impairments in linguistic encoding. Only informativeness measures, particularly CIUs, demonstrated strong correlations with main concept production, whereas other linguistic variables were less strongly associated. The study suggested that discourse impairments in aphasia arise from an interaction between conceptual and linguistic deficits, highlighting the importance of analysing both levels for a comprehensive understanding of communication difficulties.

Taken together, these studies demonstrate that discourse impairments in aphasia extend beyond isolated language deficits and affect the ability to convey meaningful information efficiently. Foundational measures such as CIUs and MCA provide reliable indices of discourse informativeness, while newer approaches such as CWF and core-lexicon analysis offer clinically feasible alternatives for discourse assessment. Furthermore, discourse performance appears to be influenced by lexical retrieval abilities, discourse genre, and communication modality. Collectively, these findings support the use of structured MC checklists and core-lexicon items (CWF) in picture-description discourse protocols to maximise reliability, sensitivity, and clinical relevance.

2.3 Executive Function Task in persons with aphasia

Executive functions (EFs) are higher-order cognitive processes involved in planning, monitoring, inhibition, working memory, and cognitive flexibility. These processes play a crucial role in language comprehension and production by supporting the organization, maintenance, and regulation of information during communication. Increasing evidence suggests that many PWA exhibit executive dysfunction in addition to language impairment, highlighting the importance of assessing cognitive as well as linguistic abilities.

Early evidence that PWA may demonstrate deficits across a range of executive processes comes from Purdy's work. In 2002, 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 experienced difficulties with cognitive flexibility, as evidenced by their performance on the WCS task. Additionally, the TOH task, which required elevated cognitive flexibility and attentional resource allocation, posed significant challenges for the aphasia group. These findings imply that individuals with aphasia may exhibit deficiencies in cognitive flexibility and working memory.

Building on evidence of executive dysfunction in aphasia, subsequent research has sought to identify specific executive components affected and to develop clinically feasible measures for their assessment.

In parallel, Murray (2012) provided a comprehensive review of the broader cognitive deficits co-occurring with aphasia, including attentional impairments, and examined the extent to which these non-linguistic cognitive factors predict language performance.

They reviewed the evidence regarding attentional and other cognitive deficits in PWA and their relationship to language impairments. The review analysed how attention-related impairments co-occur with language impairments and considered the extent to which cognitive measures predict language performance. This work highlights the importance of considering the relationship between non-linguistic cognitive assessments and language outcomes when evaluating PWA and demonstrates that the correspondence between the two is not always direct or uniform.

Informed by this broader understanding of cognitive-linguistic relationships, Mayer and Murray (2012) subsequently focused on working memory specifically, evaluating the n-back paradigm as a clinically feasible measure of working-memory deficits in aphasia.

They evaluated the n-back paradigm as a potential clinical tool for quantifying working-memory (WM) deficits in aphasia. They examined the feasibility, reliability, and internal coherence of n-back performance in 14 adults with aphasia and 12 matched control individuals using n-back tasks with varying stimulus types and levels of WM load. The study investigated broad influences on working-memory performance, including WM load, reaction time, and age, while also considering language-specific factors. Results suggested that the n-back could serve as a clinically useful measure of working memory in aphasia. Both groups showed similar performance across stimulus types, with better WM accuracy when stimuli were nameable. Importantly, increasing WM load had a larger negative effect on the aphasia group than on controls, while reaction-time effects mirrored accuracy patterns. These findings suggest that working-memory deficits represent an important component of the cognitive profile observed in aphasia.

More recently, large-scale investigations have examined the extent and variability of executive dysfunction in aphasia using a broader range of verbal and nonverbal measures.

In a study by Dutta et al. (2023), the researchers conducted a large-scale empirical examination of executive functions in PWA and healthy controls using an array of verbal and nonverbal EF assessments. The verbal EF assessments included the List Sorting Working Memory Task (NIHTB-LSWM), the Test of Everyday Attention (TEA), the Test of Verbal Conceptualisation and Fluency (TVCF), and the Comprehensive Test of Nonverbal Intelligence (CTONI)-Second Edition. In contrast, the nonverbal EF assessments were designed to impose fewer language demands while assessing visual-spatial and attentional control. These assessments included the NIHTB Flanker Task, NIHTB Dimensional Change Card Sort

(DCCS), Ruff Figural Fluency Test (RFFT), TVCF Trails C subtest, and CTONI-Second Edition Geometric Categories.

Overall, PWA scored significantly lower on most EF assessments compared to healthy controls, with the largest relative differences observed in verbal EF tasks. However, substantial variability was observed within the aphasia group, with some individuals demonstrating no measurable executive deficits. Furthermore, no consistent relationship was found between aphasia severity and EF scores. These findings suggest that executive dysfunction represents a partially independent dimension of impairment rather than merely a consequence of language deficits.

The heterogeneity observed in executive-function performance has prompted researchers to investigate whether the relationship between language and executive functions differs across aphasia subtypes.

In a study by Vuković and Chen (2025), the relationship between language abilities and executive functions was investigated in individuals with transcortical motor aphasia (TMA) and Broca's aphasia (BA). A total of 19 participants with TMA, 19 with BA, and 25 healthy controls were assessed using verbal fluency, Stroop, and Trail-Making tests, along with the Boston Diagnostic Aphasia Examination (BDAE) for aphasic individuals. The findings revealed that both aphasia groups performed significantly poorer than healthy controls across all EF tasks. Additionally, individuals with BA performed better than those with TMA on the Stroop and Trail-Making tests, while no difference was observed in verbal fluency performance. Notably, EF performance showed significant correlations with language abilities in the TMA group but not in the BA group. The study concluded that executive function deficits are present across multiple aphasia types and that their relationship with language impairment varies by aphasia subtype and the specific cognitive-linguistic components assessed.

Among the various executive-function measures available, the Trail Making Test (TMT) has received particular attention for its relatively low language demands and suitability for use with individuals with expressive language impairments.

Of particular relevance to the present study is the TMT's role as an executive function measure in aphasia research. The TMT-A requires participants to connect numbered circles in sequence, providing an index of processing speed and visual scanning, whereas TMT-B requires alternation between numbers and letters, placing additional demands on cognitive flexibility and set-shifting (Arbuthnott & Frank, 2000). Importantly, the TMT does not require spoken language production, making it one of the few neuropsychological EF measures that can be administered meaningfully to persons with expressive aphasia.

Vuković and Chen (2025) demonstrated that individuals with Broca’s aphasia and transcortical motor aphasia exhibited significantly elevated TMT completion times relative to healthy controls, with EF performance correlating with language abilities only in the transcortical motor group. This subtype-specific pattern underscores that the relationship between executive control and language is not uniform across aphasia and that the TMT is sensitive to this variability.

The derived TMT metrics, specifically TMT-D (the difference between TMT-B and TMT-A times) and TMT-R (the ratio of TMT-B to TMT-A times), are increasingly recognised as superior measures of the set-shifting component of cognitive flexibility because they partial out the contributions of processing speed and visual scanning that are captured by TMT-A alone (Strauss et al., 2006). In individuals with aphasia, who may already demonstrate elevated TMT-A times due to left-hemisphere processing-speed deficits, reliance on TMT-B alone as an index of cognitive flexibility risks conflating processing-speed impairment with set-shifting impairment. The use of TMT-D and TMT-R in the present study, therefore, represents a methodologically important refinement that allows more precise attribution of executive dysfunction to the set-shifting component specifically relevant to verbal fluency switching and discourse organisation.

Taken together, these studies demonstrate that executive dysfunction is a common but heterogeneous feature of aphasia. Deficits have been documented across multiple executive domains, including cognitive flexibility, working memory, attention, and set-shifting. Furthermore, executive impairments may occur independently of aphasia severity and may vary across aphasia subtypes. The growing body of evidence supporting the use of aphasia-friendly measures, such as the TMT, highlights the importance of routinely assessing executive functions alongside language abilities. Such an assessment may provide a more comprehensive understanding of communication difficulties and help clarify the cognitive mechanisms underlying language performance in aphasia.

2.4 Person with aphasia on semantic verbal fluency, discourse, and executive function tasks

Although semantic verbal fluency (SVF), discourse production, and executive functions (EF) have often been examined independently in persons with aphasia (PWA), growing evidence suggests that these domains are closely interconnected. Effective communication requires not only successful lexical retrieval but also the ability to organise semantic information, maintain discourse coherence, monitor responses, and flexibly shift between concepts during language production. Consequently, impairments in any one of these domains may influence performance in the others.

Several studies have highlighted the relationship between semantic verbal fluency and executive functioning in aphasia. Semantic verbal fluency tasks require individuals to retrieve words from a specified category while simultaneously organising lexical search, inhibiting previously produced responses, and shifting between semantic subcategories. Bose et al. (2022) reported that PWA produced fewer correct responses, switched less frequently between semantic categories, and demonstrated longer within-cluster and between-cluster pause durations than healthy controls. These findings suggest that verbal fluency performance is influenced not only by lexical-semantic retrieval but also by executive processes involved in strategic search and cognitive control. Similarly, Faroqi-Shah and Milman (2018) found that semantic and action fluency were strongly associated with overall language abilities, whereas phonemic fluency appeared to rely more heavily on executive control mechanisms. Together, these findings indicate that successful SVF performance depends on the interaction between lexical retrieval abilities and executive processes, including cognitive flexibility, inhibition, and monitoring.

Evidence also suggests a close relationship between semantic verbal fluency and discourse production. Both tasks require efficient access to lexical-semantic representations and the ability to convey meaningful information. Boucher et al. (2022) demonstrated that confrontation naming ability was strongly associated with discourse informativeness during picture-description tasks in individuals with post-stroke aphasia. Likewise, Alyahya et al. (2021) reported that PWA produced significantly fewer content words than healthy individuals, indicating reduced lexical productivity during connected speech. Similarly, Kuvač Kraljević et al. (2023) found that reductions in main-concept production were associated with lower discourse informativeness, particularly as measured through Correct Information Units (CIUs). Collectively, these findings suggest that the lexical retrieval difficulties reflected in verbal fluency tasks may directly influence the informativeness of discourse and the successful communication of essential information.

The contribution of executive functions to discourse production has also received increasing attention. Discourse production requires speakers to organise information, maintain topic relevance, suppress irrelevant responses, and shift appropriately between ideas. These processes depend heavily on executive functions such as working memory, cognitive flexibility, planning, and inhibitory control. Dutta et al. (2023) reported that many PWA exhibit executive deficits independent of aphasia severity, suggesting that executive dysfunction may contribute uniquely to communication difficulties. Murray (2012) similarly highlighted that attentional and cognitive deficits frequently coexist with language impairments and may influence communicative performance. Furthermore, Vuković and Chen (2025) demonstrated significant associations between executive-function performance and language abilities in individuals with transcortical motor aphasia, emphasising that executive dysfunction can affect language outcomes beyond the effects of linguistic impairment alone.

The interaction between executive functions and semantic verbal fluency may have important implications for discourse production. Successful discourse requires continuous retrieval of relevant lexical items, monitoring of previously expressed information, and flexible transitions between concepts. These processes closely resemble the clustering and switching mechanisms observed in semantic verbal fluency tasks. Individuals who demonstrate reduced switching ability, prolonged retrieval pauses, or impaired cognitive flexibility may therefore experience difficulties in maintaining discourse informativeness and coherence. Consequently, examining verbal fluency and discourse performance together may provide valuable insight into the mechanisms underlying communication breakdowns in aphasia.

Among executive-function measures used in neuropsychological practice, the Trail Making Test (TMT) is particularly relevant to investigating these relationships. The TMT assesses processing speed, visual attention, and cognitive flexibility while minimising spoken language demands. Because of its relatively low linguistic requirements, it can be administered meaningfully to individuals with expressive aphasia. Vuković and Chen (2025) demonstrated that individuals with Broca's aphasia and transcortical motor aphasia exhibited significantly poorer TMT performance than healthy controls. However, relatively few studies have examined whether performance on executive-function measures, such as the TMT, is associated with semantic verbal fluency parameters (clustering, switching, and pause durations) or with discourse measures (Main Concepts [MCs] and Content Word Fluency [CWF]).

Across studies, persons with aphasia exhibit a characteristic profile: they produce fewer correct words during semantic verbal fluency tasks, show slower initiation and longer retrieval latencies, and demonstrate reduced switching between semantic clusters, although cluster size is sometimes preserved relative to controls depending on aphasia subtype and task characteristics (Bose et al., 2022). In discourse tasks, PWA typically demonstrate reduced informativeness, reflected in lower CIU scores, fewer main concepts, and reduced core-lexicon coverage (Boucher et al., 2022; Dalton & Richardson, 2015). Executive dysfunction, particularly in cognitive flexibility, working memory, inhibition, and set-shifting, is also frequently observed in aphasia and may contribute to poorer fluency and discourse performance. However, the relationship among these domains appears heterogeneous, with some individuals showing predominantly lexical-semantic deficits, others demonstrating marked executive dysfunction, and many exhibiting a combination of both.

Despite growing evidence linking semantic verbal fluency, discourse production, and executive functioning, relatively few studies have examined these relationships within the same group of individuals with aphasia. Furthermore, limited evidence exists on how clustering, switching, and temporal measures of semantic verbal fluency relate to discourse-informativeness indices such as Main Concepts and Content Word Fluency, particularly when executive control is assessed with clinically feasible measures, such as the Trail Making Test. Understanding these relationships is important because it may help distinguish whether discourse breakdowns arise primarily from lexical-semantic deficits, executive dysfunction, or an interaction between the two. This gap in the literature provides the rationale for the present study.

2.5 Summary of Literature Review

The literature reviewed in this chapter demonstrates that semantic verbal fluency, discourse production, and executive functioning are important domains affected in persons with aphasia. Studies examining semantic verbal fluency have consistently shown that PWA produce fewer correct responses, exhibit slower retrieval processes, and demonstrate alterations in clustering and switching behaviour compared to healthy individuals (Bose et al., 2022; Faroqi-Shah & Milman, 2018). Recent investigations have further suggested that these deficits may arise from a combination of lexical-semantic impairments and executive-control difficulties, with their relative contributions varying across aphasia subtypes (Pagliarin et al., 2022; Pham et al., 2025). Furthermore, the inclusion of temporal measures such as within-cluster and between-cluster pause durations has expanded the understanding of the real-time processes underlying lexical retrieval in aphasia.

The review of discourse studies indicates that persons with aphasia experience significant difficulties in producing informative and coherent connected speech. Measures such as Correct Information Units (CIUs), Main Concepts (MCs), Content Word Fluency (CWF), and Core Lexicon analyses have been shown to provide valuable information regarding discourse informativeness and communicative effectiveness (Alyahya et al., 2021; Nicholas & Brookshire, 1993; Richardson & Dalton, 2020). Evidence further suggests that discourse impairments reflect the combined influence of lexical retrieval difficulties, conceptual processing limitations, and linguistic encoding deficits (Kuvač Kraljević et al., 2023). In addition, factors such as discourse genre, naming ability, and modality of communication have been shown to influence discourse performance in aphasia (Boucher et al., 2022; Olness, 2006; Vandenborre et al., 2018).

The literature on executive functioning demonstrates that many persons with aphasia exhibit impairments in cognitive flexibility, working memory, attention, inhibition, and set-shifting abilities (Mayer & Murray, 2012; Purdy, 2002). Importantly, executive deficits are not always directly related to aphasia severity and may represent an independent source of communicative difficulty (Dutta et al., 2023). Recent studies have highlighted the value of executive-function measures such as the Trail Making Test in identifying cognitive flexibility deficits in aphasia and have suggested that the relationship between executive functioning and language performance may vary across aphasia subtypes (Vuković & Chen, 2025).

Collectively, the reviewed literature suggests that semantic verbal fluency, discourse production, and executive functioning are interrelated processes that contribute to successful communication. Lexical retrieval abilities appear to influence both verbal fluency and discourse performance, while executive functions support strategic search, monitoring, cognitive flexibility, and discourse organisation. Despite growing recognition of these relationships, the majority of previous studies have examined these domains independently or have focused on only two of the three domains simultaneously.

A review of the available literature reveals several important gaps. First, relatively few studies have investigated semantic verbal fluency, discourse performance, and executive functioning within the same group of persons with aphasia. Second, limited evidence exists regarding the relationship between specific semantic verbal fluency measures, such as clustering, switching, and temporal pause-duration variables, and discourse measures such as Main Concepts and Content Word Fluency. Third, although executive-function impairments have been documented in aphasia, their contribution to both semantic verbal fluency and discourse performance remains insufficiently understood. Finally, very few studies have examined these relationships using aphasia-friendly executive-function measures such as the Trail Making Test and its derived indices (TMT-D and TMT-R).

Therefore, there is a need to simultaneously examine semantic verbal fluency, discourse production, and executive functioning in persons with aphasia, and to explore the relationships among these domains. A better understanding of these associations may contribute to more comprehensive assessment approaches and provide insights into the cognitive-linguistic mechanisms underlying communication difficulties in aphasia. This need forms the basis for the present study.

CHAPTER III

METHOD

The study aimed to examine the relationships among discourse production (picture description), semantic verbal fluency (clustering and switching), and executive control (Trail Making Test) in persons with aphasia (PWA) and in matched-by-age and gender neurotypical adults (NTA).

The present study also aimed to quantify lexical/semantic organization, executive functioning, and their relationship to discourse informativeness (main concepts, content-word fluency), using both accuracy and timing measures.

3.1 Research Design

The present study is a standard group comparison to investigate relationships among (a) discourse informativeness measured by Content-Word Fluency (CWF) and Main Concept Analysis (MCA) on a picture description task, (b) semantic verbal fluency, specifically clustering and switching, and (c) executive control measured by the Trail Making Test between persons with aphasia and neurotypical adults.

The cross-sectional design allows characterization of cognitive-linguistic profiles in persons with aphasia (PWA) compared to neurotypical adults (NTA), and testing of correlational models addressing the interplay among lexical, executive, and discourse processes.

3.2 Participants

The participants included are fifteen neurotypical individuals, constituting Group I, and fifteen persons with aphasia, constituting Group II. Thus, a total of 30 participants were recruited for the study. All participants were in the age range of 18–59 years and native speakers of Kannada.

3.3 Participants selections

3.3.1 Ethical Considerations

Persons with aphasia, as participants in the present study, were enrolled for assessment procedures. The purpose, nature, and details about the study tasks (Picture Description for Discourse Analysis, Semantic Verbal Fluency, and Trail Making Test) were explained to each participant and, where applicable, to their parents or caregivers. Written informed consent in Kannada/ English was obtained before the initiation of data collection (APPENDIX A). The study was conducted in accordance with the Ethical Guidelines of Bio-Behavioral Research Involving Human Subjects (Basavaraj & Venkatesan, 2009) under the approval of the Ethical Committee at the All India Institute of Speech and Hearing, Mysuru.

The informed consent form included a verbal information sheet and a consent form. The verbal information sheet contained information on the title and objectives of the study, the type and number of participants, and details of the tasks to be administered. The sheet highlights any potential risks/benefits of participation and assures participants that they can seek clarification of any doubts at any stage of the study. Special emphasis was placed on ensuring the privacy, confidentiality, and anonymity of participants. The information sheet described the study introduction, procedures, expected duration, data handling, results sharing, confidentiality policies, and the right to refuse or withdraw without consequence, along with contact details of the investigator. The consent form served as a certificate of consent, written in the first person, and was signed by all participants or their caregivers before participation.

3.3.2 Source of the Participants

The participants were recruited from the All India Institute of Speech and Hearing, Mysuru, with reference to the clinical population, and the neurotypical population was selected from workplaces or residential areas in and around Mysuru. All participants were considered for inclusion in the study only after fulfilling the specific selection criteria.

The neurotypical population as participants of the study were selected based on the following inclusionary criteria**:**

1. Participants with no history or complaint of speech, language, hearing, or other comorbid condition.
2. Performance on Montreal Cognitive Assessment- Kannada (MOCA-K) score above 26, which is considered the normal range (Nasreddine et al., 2005).
3. All participants in the study were native speakers of Kannada.
4. All participants were required to have at least 10 years of formal education.

The Persons with Aphasia as participants of the study were selected based on the following inclusionary criteria**:**

1. A single episode of stroke involving the left hemisphere determined by neurological and radiological examination.
2. All participants were diagnosed with Aphasia on a standardized test for Aphasia (Western Aphasia Battery in Kannada- WAB-K), with an AQ <93.8. (Chengappa & Kumar, 2008). Based on the availability of cases, the participants were grouped as fluent aphasic or non-fluent aphasic.
3. Participants were right-handed (pre-morbidly).
4. Participants with 5 or more scores on Auditory Verbal Comprehension of WAB-K were considered.
5. Participants having persisting Aphasia at least 12 months post-stroke to rule out the effect of spontaneous recovery on test results.
6. Single-word comprehension and production were assessed using the Boston Naming Test Kannada- BNT-K; (Chengappa & Kumar, 2009) and Action Naming Test Kannada- ANT-K; (Girish & Shyamala, 2015). Participants who can perform with a minimum of 50% accuracy were recruited for the study.

7. All participants were required to have at least 10 years of formal education in __________ medium of instruction.
8. All participants in the study were native speakers of Kannada. Hence, L1 was Kannada.

The candidates were excluded from the study based on the following exclusion criteria:

1. Participants with other neurological illnesses, psychiatric disorders, a history of or ongoing substance abuse, visual field, or other sensory-perceptual deficits.
2. Participants with severe cognitive deficits were ruled out using the Montreal Cognitive Assessment.

The table 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 in both groups

NTA Group			PWA Group			
Participant	**Age/Gender**	**Education (Years)**	**Participant**	**Age/Gender**	**Education (Years)**	**Diagnosis**
P1	49/M	12	P16	50.6/M	12	AA
P2	32/M	12	P17	32/M	12	BA
P3	51/M	15	P18	57/M	15	WA
P4	28/M	15	P19	26/M	13	CA
P5	50/M	15	P20	48/M	12	BA
P6	56/F	17	P21	59/F	17	TSA
P7	57/M	15	P22	59/M	15	WA
P8	33/F	15	P23	30/F	15	WA
P9	34/M	15	P24	37/M	15	WA
P10	35/M	15	P25	43/M	15	WA
P11	59/M	13	P26	33/M	13	WA
P12	42/M	15	P27	42/M	15	CA
P13	18/M	12	P28	45/M	12	AA
P14	24/F	15	P29	36/F	12	WA
P15	37/M	15	P30	35/M	14	BA

Note: P= Participant; CA= Conduction Aphasia; AA= Anomic Aphasia; WA= Wernicke's Aphasia; BA= Broca's Aphasia; TSA= Transcortical Sensory Aphasia

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 a table with the investigator facing them. A computer laptop was used for certain tasks (Semantic Verbal Fluency), and one task was paper-and-pencil-based (Trail Making Test). As much as possible, all possible distractions were reduced from both ends (participant and clinician).

3.4.2 Domains of tasks involved-

This study examined discourse production (picture description), verbal fluency (animals), and executive control (Trail Making Test).

Table 3.2

Task domains and their purpose of measurement

Task	Primary purpose
1. Picture Description Discourse (Forest image)	Measure discourse informativeness, content-word fluency, and main-concept coverage (CWF and MCA).
2. Semantic Verbal Fluency (SVF - Animals)	Measure lexical productivity and semantic organization (Clusters and Switching)
3. Trail Making Test - Part A (TMT-A)	Assess visual scanning, processing speed, and attention.
Trail Making Test - Part B (TMT-B)	Assess set-shifting, cognitive flexibility, and executive switching (TMT-D and TMT-R).

3.4.2.1 Task 1- Discourse Task: Picture Description (Forest Image)

A culturally appropriate, high-resolution Indian forest scene (Figure 3.1), (width**-** 7.60 inches, height**-** 9.10 inches), containing the target animals (dog, cat, horse, cow, elephant, lion, tiger, deer, pig, sheep, zebra, squirrel) and environmental features (stream, trees, ranger) was presented to the participants after validation from three experienced Speech-Language Pathologists. A forest scenery was chosen that contained a variety of animals and environmental features that naturally elicit content words, making it directly comparable to the semantic verbal fluency task for the animal category. Additionally, the complexity of the scene allowed assessment of both micro-linguistic and macro-linguistic skills, thereby offering a comprehensive measure of discourse abilities in persons with aphasia.

Figure 3.1

Forest Scene

Preparing Content Word Fluency (CWF) checklists (before data collection)

A pilot study was conducted with approximately 15 neurotypical individuals and 2–3 persons with aphasia (PWA) in order to identify the common content words produced (targeted) for the selected picture stimulus. Based on responses from the pilot study, a checklist of frequently occurring content words was developed to facilitate live scoring during data collection. The checklist prepared for this purpose is presented in Tables 3.3 and 3.4.

Table 3.3

Checklist of Content words produced by the participants in the pilot study- Nouns

S.No.	Nouns	IPA Transcription
1	Elephant	/aːne/
2	Water	/niːɾu/
3	Tiger	/huli/
4	Tree	/məɾə/
5	Deer	/dziŋke/
6	Plants	/səsjəgəɭu/
7	Monkey	/koːt̪i/
8	Grass	/hullu/
9	Peacock	/n̪ʌʋilu/
10	Man	/mənuʂjə/
11	Duck	/batukoli/
12	Camera	/kjæmeɾaː/
13	Fish	/miːn̪u/
14	Turtle	/aːme/
15	Snake	/haːʋu/

16	Frog	/kappe/
17	Rabbit	/mola/
18	Bird	/pəkʂi/
19	Forest	/kaːɖu/
20	Jungle	/əɾəɲjə/
21	River	/n̪əd̪i/

Table 3.4

Checklist of Content words produced by the participants in the pilot study- Verbs

S.No.	**Verbs**	**IPA Transcription**
1	Drinking	/kuɖijuvud̪u/
2	Swimming	/iːd͡ʒuvud̪u/
3	Flying	/haːɾuvud̪u/
4	Sitting	/kuɭit̪iɾuvud̪u/
5	Standing	/n̪int̪iɾuvud̪u/
6	Watching	/noːɖut̪t̪iɾuvud̪u/

Preparing Main Concept (MC) lists (before data collection)

The investigator prepared a list of Main Concepts (MCs) based on the pilot data obtained from neurotypical individuals. Essential main concepts were identified as those produced by at least 70% of the neurotypical participants, such as “elephant drinking at the stream,” “tiger resting under the tree,” “squirrel on the branch,” and “deer grazing.” In addition to these essential concepts, the investigator also noted non-essential contextual details that enriched the scene description but were not considered critical for conveying the primary meaning, such as “the river water is flowing” or “the trees are green.” Furthermore, for each identified main concept, acceptable paraphrases and scoring criteria were defined with appropriate examples to ensure consistency and reliability during scoring, as presented in Table 3.5.

Table 3.5

Checklist of Main Concepts produced by the participants in the pilot study.

Serial Number	Main Concept In Kannada (Translated into English)
1	/mənuʂjə pɾa:ɳigaɭənnu no:ɖut̪t̪iɾuvud̪u/ *(A man is observing animals)*
2	/a:ne ni:ɾinalli nint̪id̪e athəʊa kuɖijut̪t̪id̪e/ *(An elephant is standing/drinking in the river)*
3	/huli nadiyinda ni:ɾu kuɖijut̪t̪id̪e/ *(A tiger is drinking water from the river)*
4	/dʒiŋke ni:ɾina hət̪t̪iɾa nint̪id̪e/ *(A deer is standing near the water)*
5	/ba:t̪uko:ɭigaɭu nadiyalli i:d͡ʒut̪t̪iʊe/ *(Ducks are swimming in the river)*
6	/mi:nugaɭu ni:ɾina oɭage i:d͡ʒut̪t̪iʊe/ *(Fish are swimming under water)*
7	/pakʂigaɭu ha:ɾut̪t̪iʊe athəʊa maragaɭa me:le kuɭit̪iʊe/ *(Birds are flying or sitting on trees)*
8	/ko:tigaɭu maragaɭa me:le iʊe/ *(Monkeys are on the trees)*
9	/nəʊilu ka:ɖina athəʊa ni:ɾina hət̪t̪iɾa id̪e/ *(A peacock is near the water/forest area)*
10	/a:me nadiya hət̪t̪iɾa bhūmiyalli id̪e/ *(A turtle is on land near the river)*
11	/ha:ʊu nelada me:le id̪e/ *(A snake is on the ground)*
12	/kappegaɭu ni:ɾina hət̪t̪iɾa athəʊa ni:ɾinalli iʊe/ *(Frogs are near/in the water)*
13	/haləʊa:ru pɾa:ɳigaɭu ni:ɾina sut̪t̪a se:ɾid̪aʊe/ *(Multiple animals are gathered around the water source)*
14	/idu ka:ɖina athəʊa aɾaŋjada d̪ɾʂjə/ *(The scene is a forest/jungle environment)*

Instruction and administration: The investigator began by starting the audio or video recording and then presenting the picture to the participant, giving the instruction, and starting the stopwatch once the participant began speaking. The investigator allowed up to two minutes for the response, repeating the instruction once if requested. While the participant was describing the picture, the investigator marked Content Word Fluency (CWF) live on the checklist (made during the pilot study) and also noted the presence of Main Concepts (MCs), with all speech being recorded for transcription and secondary scoring.

The instructions given before testing were: "Please look at this picture carefully and describe everything you see happening in the picture, in the Kannada language. You may speak in complete sentences or phrases. Tell me as much as possible."

Scoring:

1. For CWF scoring, a target was ticked whenever the participant produced that content word or an accepted alternative, even if produced later in the description, with immediate repetitions excluded. The CWF score for each task represented the total number of distinct target items produced.
1. For MCA scoring, each listed MC was coded using the five-code system: AC (Accurate Complete), AI (Accurate Incomplete), IC (Inaccurate Complete), II (Inaccurate Incomplete), or AB (Absent). The MC score per participant was then calculated using the weighting system, with (#AC × 3) + (#AI × 2) + (#IC × 2) + (#II × 1) + (#AB × 0).
2. Other discourse outcome measures were calculated as follows. The percentage of Correct Information Units (%CIU) was calculated by dividing the CIU count by the total number of intelligible words and multiplying by 100, based on the CIU rules of Nicholas and Brookshire (1993), where a word was counted as a CIU if it

was intelligible, accurate, and informative about the picture. Finally, the content words per minute (CWF/min) was computed by dividing the CWF score by the total speaking duration in minutes.

3.4.2.2 Task 2- Semantic Verbal Fluency

It measured lexical productivity, semantic organization, and temporal dynamics of retrieval for the animal category. We used an audio recorder and Praat for this purpose.

Instructions and administration: "In this task, I want you to name as many animals as you can. You will have one minute. Try to say as many different animals as you can, in the Kannada language. If you repeat a word, that's okay, just keep going. When I say 'start,' begin." (Repeating the instructions once if requested; no prompts during the 60s.) Participants' responses were recorded using Praat Software (Boersma, 2001).

Scoring and Outcome measures: In the scoring process, correct responses were counted when the participant produced unique animal names, each understood as a target word, and these received a score of 1. Phonemic paraphasias, where a recognizable word is produced with phonemic errors that still clearly indicate the intended animal, were also treated as correct and scored as 1. Incorrect or unintelligible responses, as well as neologisms, received a score of 0. Perseverations, if they occurred, were identified separately but were not included in the correct response count. Repetitions, meaning exact repeats of previously produced animal names, were not credited as additional correct responses. Intrusions, defined as non-animal words, were recorded but not scored as correct.

Outcome measures

a. CR (Correct Responses)- Total number of correct unique animal words in 60 s (exclude repeats, intrusions).

b. *Clustering and Switching*

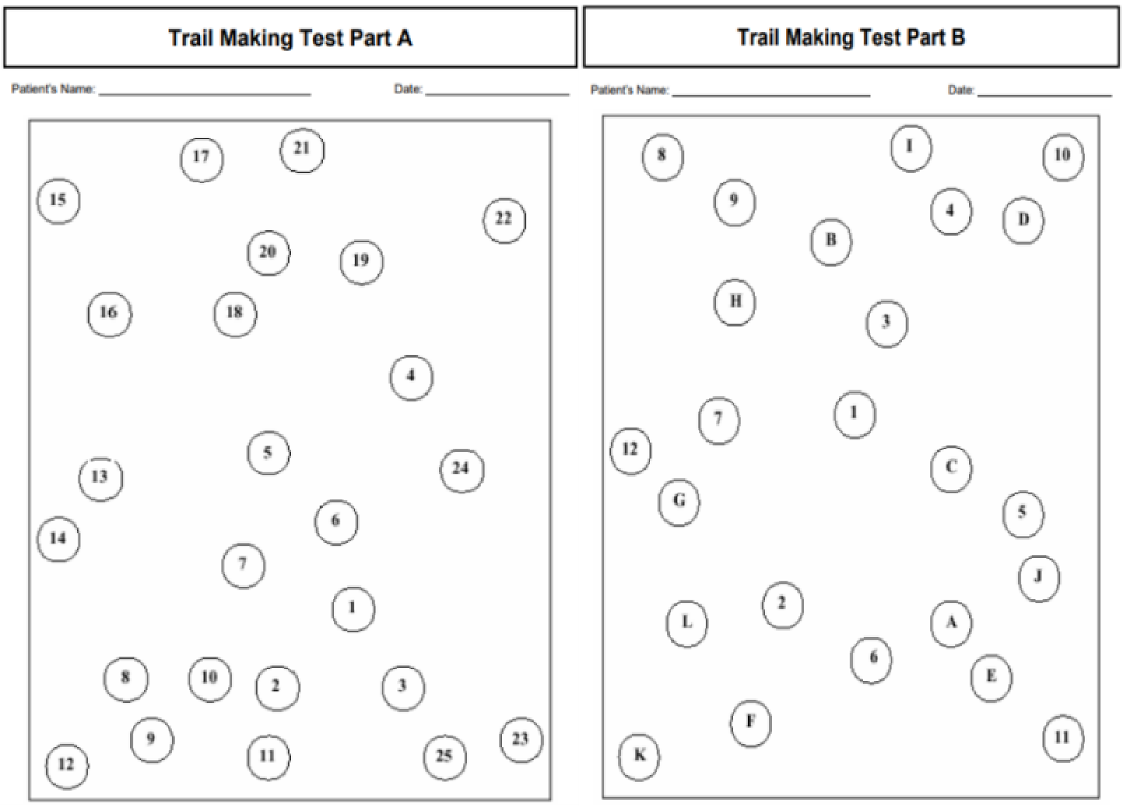
1. *Cluster size (CS)* refers to the total size of a cluster produced by a participant. The cluster size was calculated by scoring the number of words produced in a cluster; for instance, in a cluster of 3 words, *Tiger, Lion,* and *Cheetah*, the first word was given a score of 0, the second word a score of 1, and the third word a score of 2. Hence, the total size of the cluster determined was 2. Similarly, if another cluster consisted of the words *Cow, Goat, Sheep,* and *Buffalo*, the cluster size was calculated as 3 (0 for *Cow*, 1 for *Goat*, 2 for *Sheep*, and 3 for *Buffalo*). Therefore, if a participant produced these two clusters, the total cluster size would be 5 (2 + 3), and the mean cluster size would be obtained by dividing the total cluster size by the total number of clusters, i.e., 5/2 = 2.5.
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 using PRAAT.
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.
4. *Between-cluster pauses (BCP)* are defined as the intervals between the final word of one cluster and the commencement of the subsequent word (cluster/singlet). The average BCP was calculated by summing all the BCPs across the trial and dividing them by the Number of Switches.

3.4.2.3 Task 3- Executive Function Test

EF was assessed using the Trail Making Test (Reitan, 1958), a paper-and-pencil task comprising two parts, namely Part A and Part B, as shown in Figure 3. 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. The total time required for Part B is termed TMT-B (Trail Making Time B).

Figure 3.2

Stimuli for the Trail Making Test



Instruction: For TMT-A- ‘‘On this page (point to 1) are some numbers. Begin at number 1 (point to ‘‘1’’) and draw a line from one to two (point to 2), two to three (point to 3), three to four (point to 4), and so on, in order, until you reach the end (point to the circle marked ‘END’). Draw the lines as fast as you can. Do not lift the pencil from the paper. Ready. Begin.’’

For TMT-B- ‘‘On this page are both numbers and letters. Do this the same way as the practice. Begin at number one (point to 1) and draw a line from one to A (point to A), A to two (point to 2), two to B (point to B), B to three (point to 3), three to C (point to C), and so on, in order, until you reach the end of the test (point to the end). Remember, you have to start with a number (point to 1), then a letter (point to B), and so on. Do not skip around, but go from one circle to the next in the proper order. Draw the lines as fast as you can. Ready. Begin.’’

Scoring: The time required to complete each part of the task was recorded in seconds. The time span was calculated from the task's start to its end. The participants were first given the Trail Making Test-Part A, followed by Part B. 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 seconds. This was the general analysis. For cluster analysis, the difference between the time taken to complete the two tasks (Trail Making Test Difference or TMT-D=TMT A-TMT B) and the ratio (Trail Making Test Ratio 40 or TMT- R = TMT B/TMT A) of the time taken for both tasks were computed. The difference between the two tests and the ratio of the time taken to complete the two tests indicate test-switching ability (Sánchez-Cubillo et al., 2009).

3.5 Statistical analysis

The data shall be tested for normal distribution, and appropriate statistical analysis shall be used. Through the use of a suitable correlational analysis, the relationship between discourse, executive control and verbal fluency measure shall be determined.

CHAPTER IV

RESULTS

The main objective of the study was to compare discourse production, semantic verbal fluency, and executive function performance between the two groups, PWA and NTA. The study also aimed to understand the relationship among discourse, semantic verbal fluency measures, and executive functions in both groups, with emphasis on understanding the contribution of lexical-semantic and executive skills to discourse abilities in PWA.

To attain these objectives, discourse, semantic verbal fluency, and executive function assessments were done for both PWA and NTA. The measures obtained were analyzed to understand group differences and to find the interrelationship among discourse, semantic verbal fluency, and executive measures within each group.

The participants went through a discourse task using a picture description task involving a culturally fit forest scene. Discourse performance was quantified using measures such as Main Concept (MC), Content Word Fluency (CWF), and percentage of Correct Information Units (%CIU).

Semantic verbal fluency was examined using a generative naming task. Participants were instructed to say as many animal names as possible within 60 seconds. The semantic verbal fluency analysis included the total number of correct responses (CR), mean cluster size (CS), number of switches (NoS), within-cluster pauses (WCP), and between-cluster pauses (BCP).

Executive function was examined using the Trail Making Test (TMT), consisting of Part A and Part B. The total time taken to complete each part was TMT-A and TMT-B, respectively. Also, the Trail Making Test Difference (TMT-D) and Trail Making Test Ratio (TMT-R) were calculated.

The previously mentioned measures were subjected to analysis under two levels: Quantitative Analysis (QA) and Cluster Analysis (CA). The Quantitative Analysis (QA) included measures of overall performance across the domains examined in the study. In the semantic verbal fluency task, the CR and NoS were analyzed. In the executive function task, TMT-A, TMT-B, and TMT-D scores were taken. And in the discourse task, MC, CWF, and %CIU score were considered. The Cluster Analysis (CA) involved the evaluation of temporal organizational characteristics within the semantic verbal fluency task. These measures were used to assess semantic organization, clustering ability, switching efficiency, and temporal dynamics of lexical retrieval during verbal fluency performance. The parameters are represented in the Table 4.1.

Table 4.1

Enumeration of parameters evaluated within each test category in the present study

Tests Administered	**Quantitative Analysis**	**Cluster Analysis**
	Discourse task	
Picture Description Task	Main Concept Analysis (MCA) Content Word Fluency (CWF) % Correct information units (%CIU)	---
	Semantic verbal fluency task	
Semantic Verbal Fluency	Total Correct Responses (CR) Number of Switches (NoS)	Mean Cluster Size (CS) Number of Switches (NoS) Mean Within-Cluster Pause (WCP) Mean Between-Cluster Pause (BCP)
	Executive function task	
Trail Making Test (TMT)	Trail Making Test-Part A (TMT-A) Trail Making Test-Part B (TMT-B) Trail Making Test Difference (TMT-D)	---

These evaluations were performed on a total of 30 participants (Healthy Controls: N=15, Clinical Group: N=15). 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 semantic verbal fluency, discourse, and executive function tests were analyzed using the statistical package for the Social Sciences (SPSS) software (version 26.0). The data was first subjected to the test of normality.

4.1 Test for normality

Upon conducting the Shapiro–Wilk test of normality, it was observed that some parameters exhibited a normal distribution ($p > 0.05$), whereas others deviated significantly from normality ($p < 0.05$). These findings indicate that the dataset comprised both normally and non-normally distributed variables. The detailed results of the normality analysis are presented in Table 4.2.

Table 4.2

Compilation of discourse, semantic verbal fluency, and executive function parameters categorized into normally distributed and non-normally distributed groups in PWA and NTA

Tests Administered	Quantitative Analysis	Cluster Analysis
	Discourse task	
Picture Description Task	PWA: <u>Content Word Fluency (CWF)</u>, Main Concept (MC), % Correct information units (%CIU) NTA: <u>Content Word Fluency (CWF), Main</u>	---

	Concept (MC), % Correct information units (%CIU)	
	Semantic verbal fluency task	
Semantic Verbal Fluency (Animal Naming Task)	PWA: Correct Responses (CR), Number of Switches (NoS) NTA: Correct Responses (CR), Number of Switches (NoS)	PWA: Mean Cluster Size (CS), Number of Switches (NoS), Within-Cluster Pause (WCP), Between-Cluster Pause (BCP) NTA: Mean Cluster Size (CS), Number of Switches (NoS), Within-Cluster Pause (WCP), Between-Cluster Pause (BCP)
	Executive function task	
Trail Making Test (TMT)	PWA: TMT-B, TMT-D, TMT-R, TMT-A NTA: TMT-B, TMT-D, TMT-A, TMT-R	---

Note. The parameters underlined follow Normal distribution

The data analysis procedure was divided into three distinct sections. The initial section, designated as **Section I: Descriptive statistics**, was carried out to compute the mean, standard deviation, minimum, and maximum. In the next section, **Section II: Between-group comparison** involving NTA and PWA, the Mann-Whitney U Test was done. This was done to understand which group had a superior performance based on the parameters.

Then, transitioning to **Section III: The correlation between the Semantic Verbal Fluency, Discourse, and Executive function test parameters at the level of Quantitative,**

and Cluster Analysis, in which relationships among the parameters were analysed using Spearman correlation separately for PWA and NTA.

4.2 Section I: Descriptive statistics

4.2.1 Descriptive statistics for the Semantic Verbal Fluency Test Parameters

The results of descriptive statistical analysis for the semantic verbal fluency task for both NTA and PWA are shown in Table 4.3.

Table 4.3

Descriptive Statistics of the Semantic Verbal Fluency Test

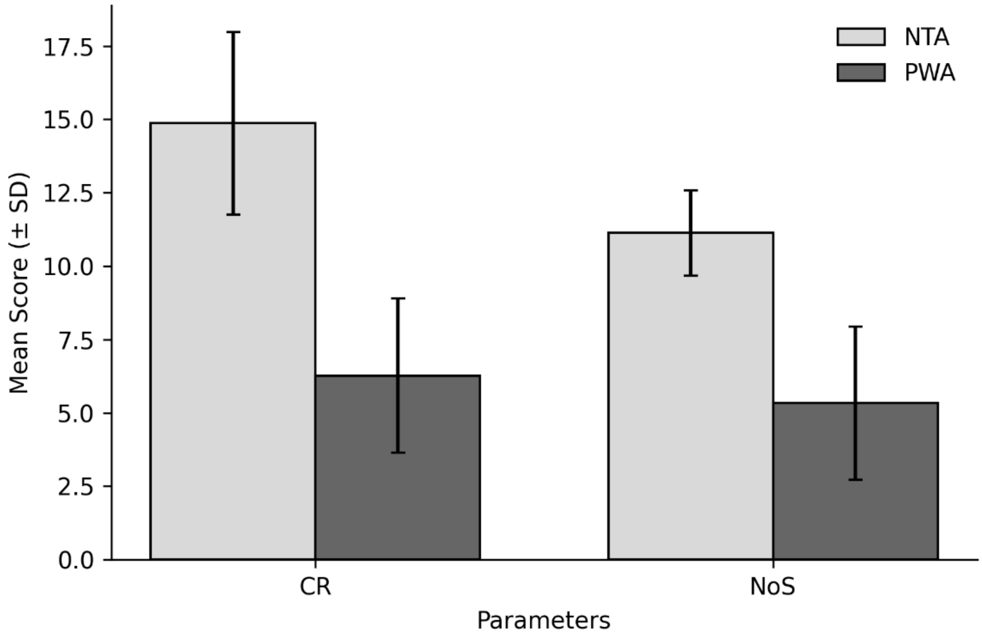
Parameters	**NTA (N=15)**				**PWA (N=15)**			
	Mean	SD	Min	Max	Mean	SD	Min	Max
NoS	11.13	1.46	9.00	13.00	5.33	2.61	0.00	9.00
CR	14.86	3.11	10	20	6.266	2.631	1.00	10
CS	1.26	0.27	1.00	1.67	0.47	0.52	0.00	1.00
WCP	0.91	0.90	0.08	2.71	0.64	1.07	0.00	3.65
BCP	3.22	0.61	2.28	4.79	3.48	1.23	0.00	5.59

Note. NoS=Number of Switches; CS=Cluster Size; WCP=Within Cluster Pause; BCP = Between Cluster Pause; CR=Correct Responses; Min and Max represent the minimum and maximum values, respectively.

The descriptive statistics presented in the preceding tables are further illustrated through graphical representations. The following figures (Figure 4.1 and 4.2) depict the mean performance of neurotypical adults (NTA) and persons with aphasia (PWA) across the semantic verbal fluency tasks. Error bars indicate ±1 standard deviation from the mean.

Figure 4.1

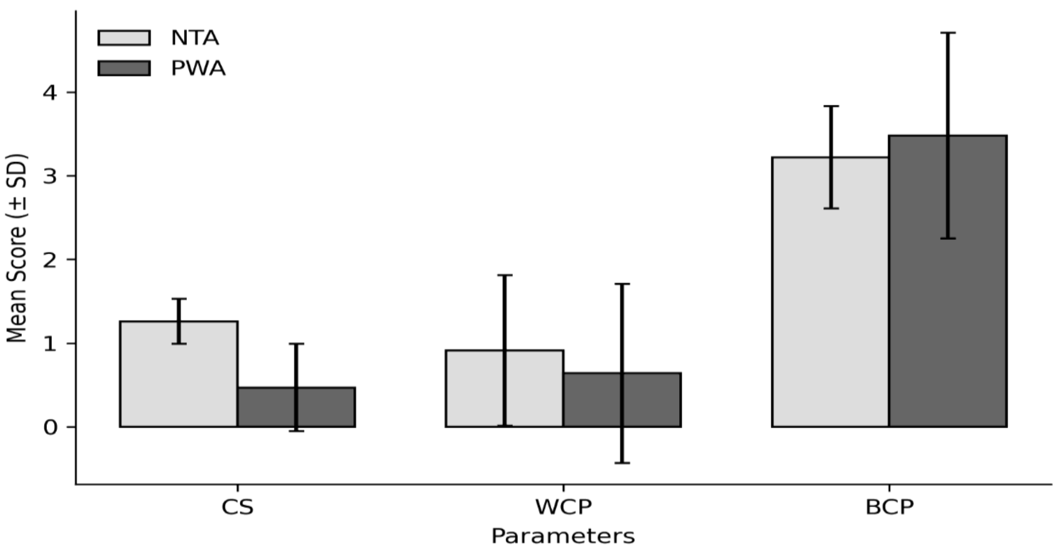
Mean Performance of Neurotypical Adults (NTA) and Persons with Aphasia (PWA) on Semantic Verbal Fluency Measures- CR and NoS



Note. Error bars represent ±1 standard deviation. CR = Correct Responses; NoS = Number of Switches.

Figure 4.2

Mean Performance of Neurotypical Adults (NTA) and Persons with Aphasia (PWA) on Semantic Verbal Fluency- CS, WCP and BCP

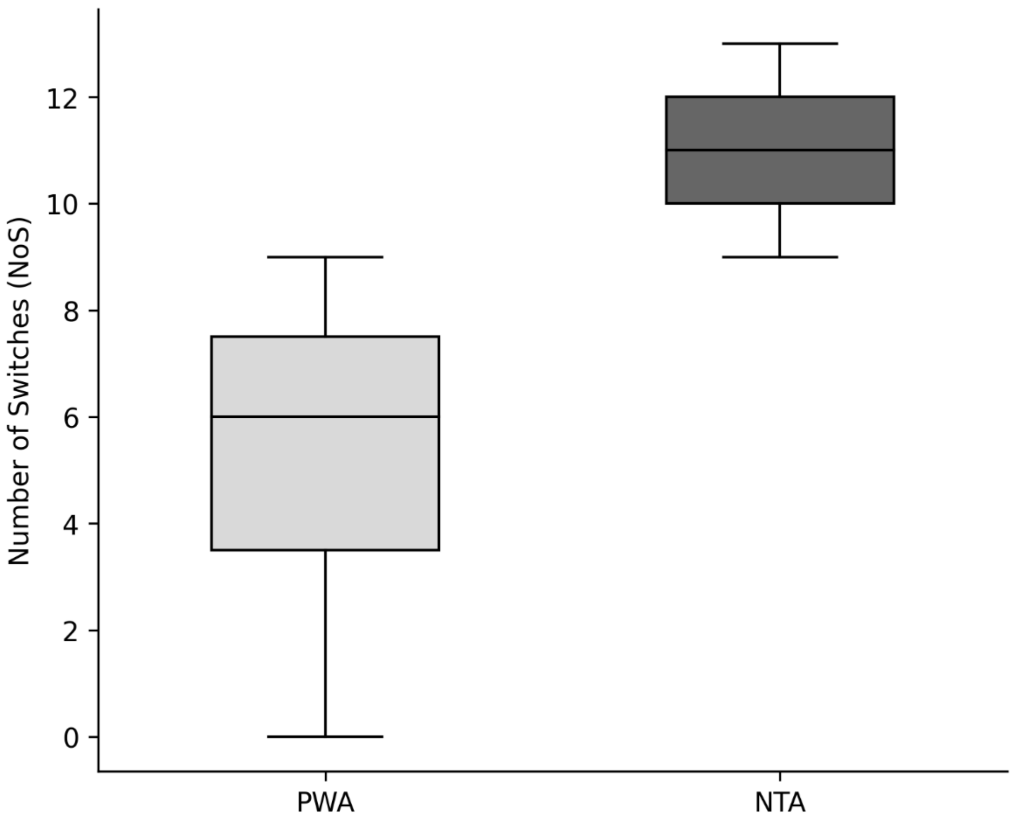


Note. Error bars represent ±1 standard deviation. CS = Cluster Size; WCP = Within-Cluster Pause; BCP = Between-Cluster Pause.

Also, box-and-whisker plots were constructed to illustrate the distribution of scores obtained by the neurotypical adults (NTA) and persons with aphasia (PWA) across the study variables, shown in Figures 4.3, 4,4, 4.5, 4.6 and 4.7.

Figure 4.3

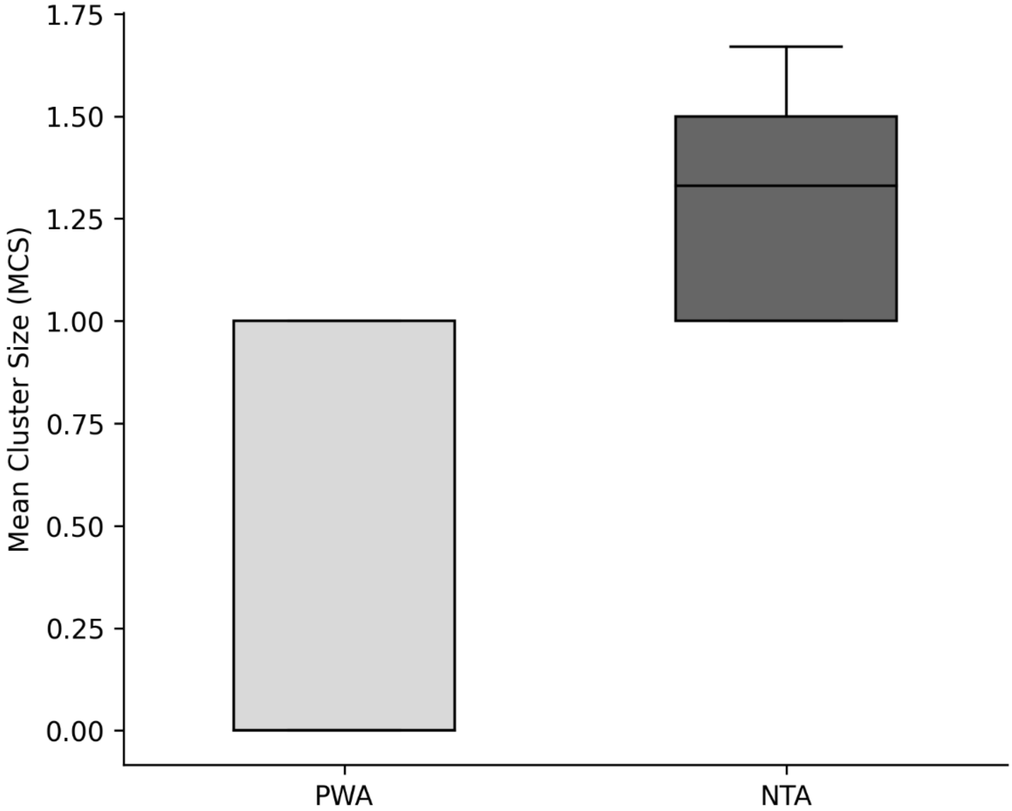
Distribution of Number of Switches (NoS) Scores in Persons with Aphasia (PWA) and Neurotypical Adults(NTA)



Note. The horizontal line within each box represents the median. The box represents the interquartile range (IQR), and the whiskers represent values within 1.5 times the interquartile range. Circles indicate potential outliers. Light gray represents persons with aphasia (PWA), and dark gray represents neurotypical adults (NTA).

Figure 4.4

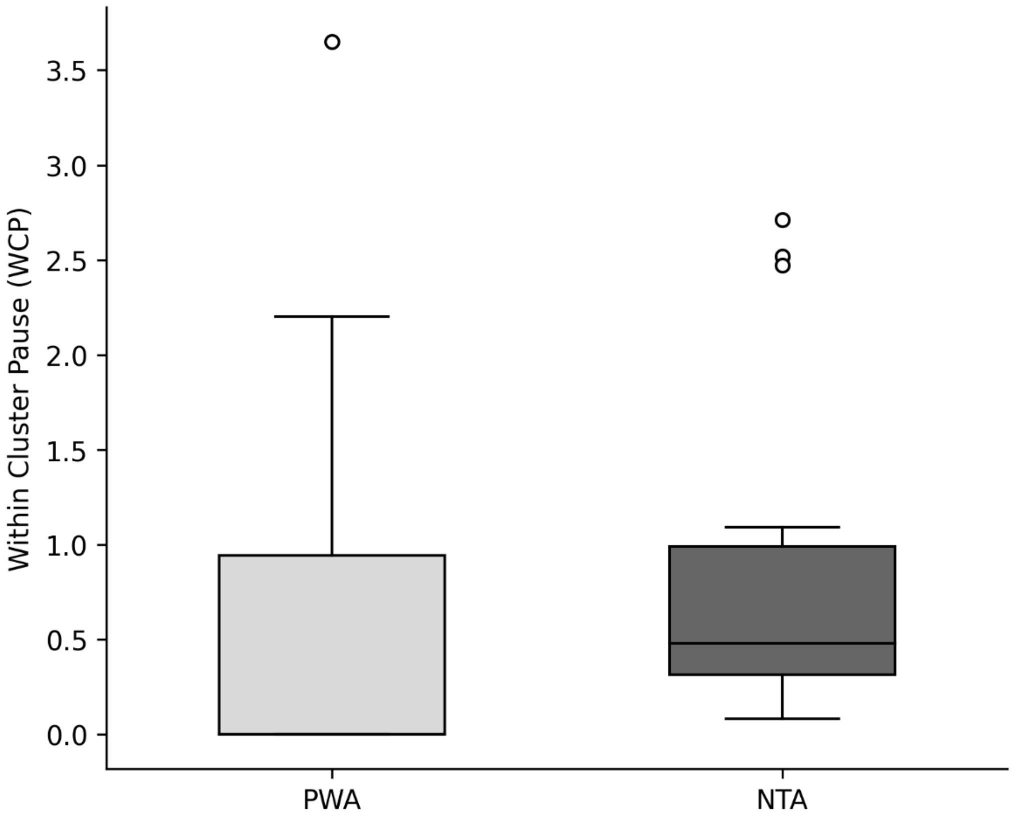
Distribution of Mean Cluster Size (MCS) Scores in Persons with Aphasia (PWA) and Neurotypical Adults (NTA)



Note. The horizontal line within each box represents the median. The box represents the interquartile range (IQR), and the whiskers represent values within 1.5 times the interquartile range. Circles indicate potential outliers. Light gray represents persons with aphasia (PWA), and dark gray represents neurotypical adults (NTA).

Figure 4.5

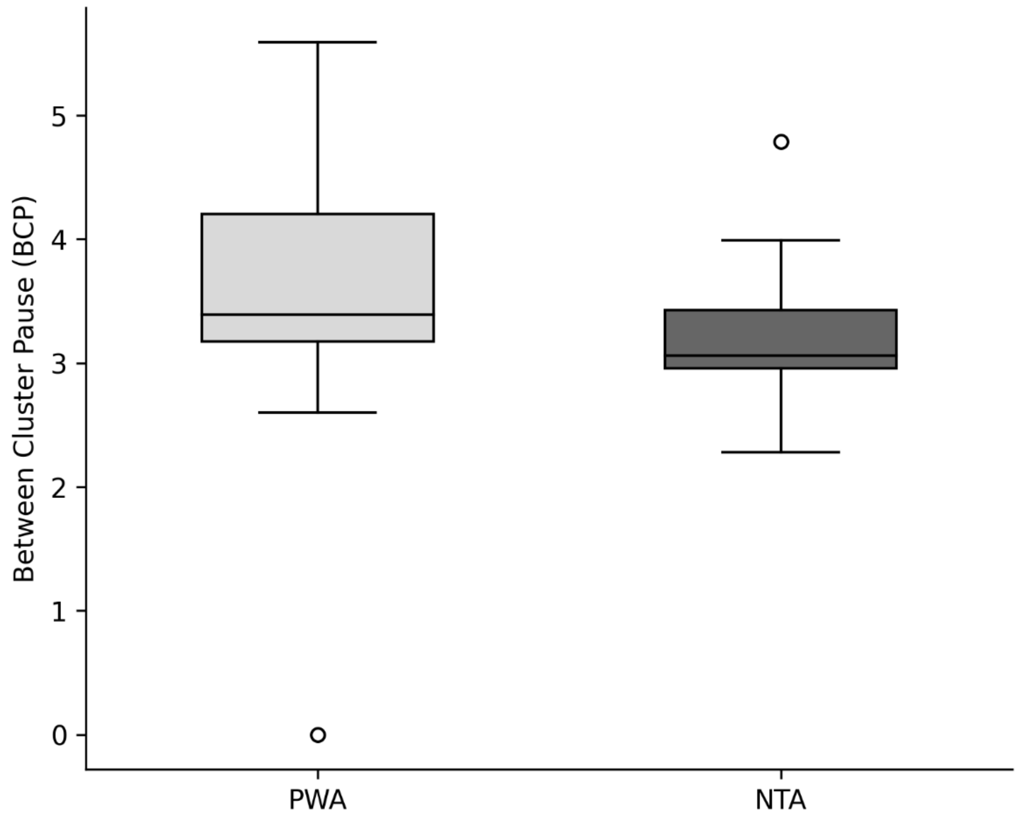
Distribution of Within Cluster Pause (WCP) Scores in Persons with Aphasia (PWA) and Neurotypical Adults (NTA)



Note. The horizontal line within each box represents the median. The box represents the interquartile range (IQR), and the whiskers represent values within 1.5 times the interquartile range. Circles indicate potential outliers. Light gray represents persons with aphasia (PWA), and dark gray represents neurotypical adults (NTA).

Figure 4.6

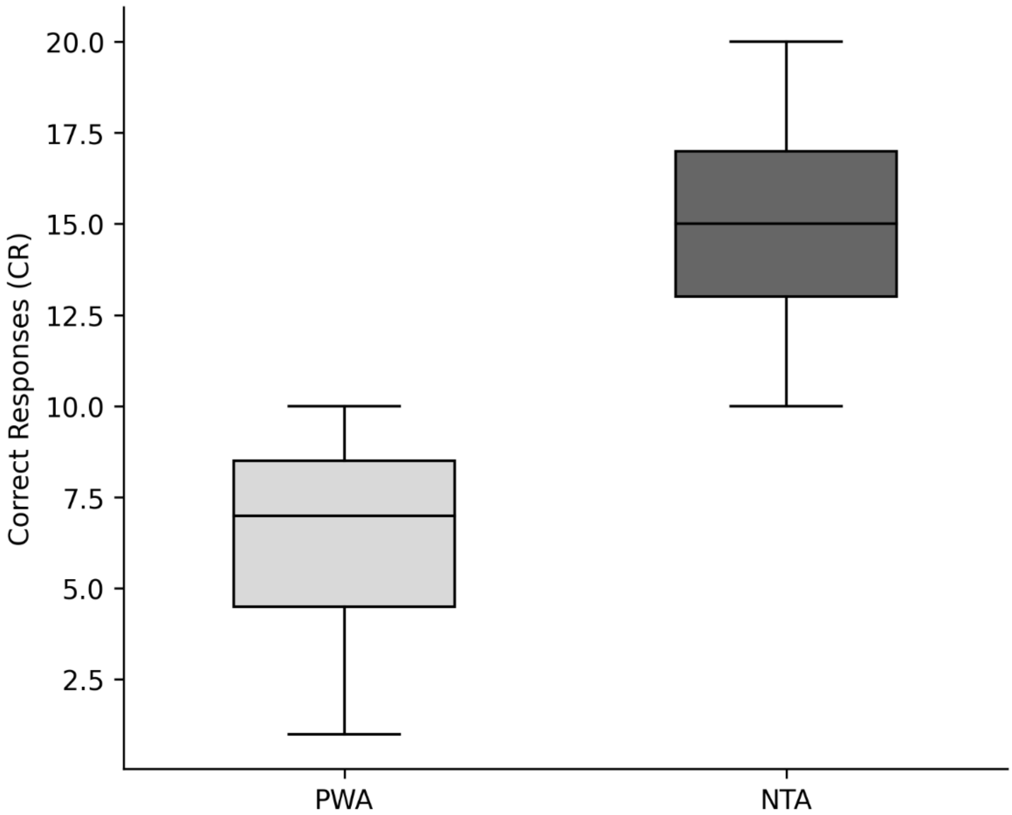
Distribution of Between Cluster Pause (BCP) Scores in Persons with Aphasia (PWA) and Neurotypical Adults (NTA)



Note. The horizontal line within each box represents the median. The box represents the interquartile range (IQR), and the whiskers represent values within 1.5 times the interquartile range. Circles indicate potential outliers. Light gray represents persons with aphasia (PWA), and dark gray represents neurotypical adults (NTA).

Figure 4.7

Distribution of Correct Responses (CR) Scores in Persons with Aphasia (PWA) and Neurotypical Adults (NTA).



Note. The horizontal line within each box represents the median. The box represents the interquartile range (IQR), and the whiskers represent values within 1.5 times the interquartile range. Circles indicate potential outliers. Light gray represents persons with aphasia (PWA), and dark gray represents neurotypical adults (NTA).

In lexical productivity, the NTA group had a higher mean CR score, along with higher minimum and maximum response values. In contrast, the PWA group had a lower mean CR score with comparatively restricted response production.

In terms of semantic organization, the NTA group had a higher mean NoS and Mean Cluster Size (CS) compared to the PWA group. The NTA group also had higher minimum and maximum values for both parameters. Conversely, the PWA group showed greater variability in performance as reflected by higher standard deviation values.

The temporal parameters, WCP, were comparatively higher in the NTA group, whereas the PWA group showed greater variability. For BCP, the PWA group demonstrated a slightly higher mean duration and greater spread of scores compared to the NTA group.

Hence, the NTA group performed better than the PWA group in measures of SVF.

4.2.2 Descriptive statistics for the Discourse Test Parameters

The results of descriptive statistical analysis for the discourse task for both NTA and PWA are shown in Table 4.4

Table 4.4

Descriptive Statistics of Discourse Task Parameters

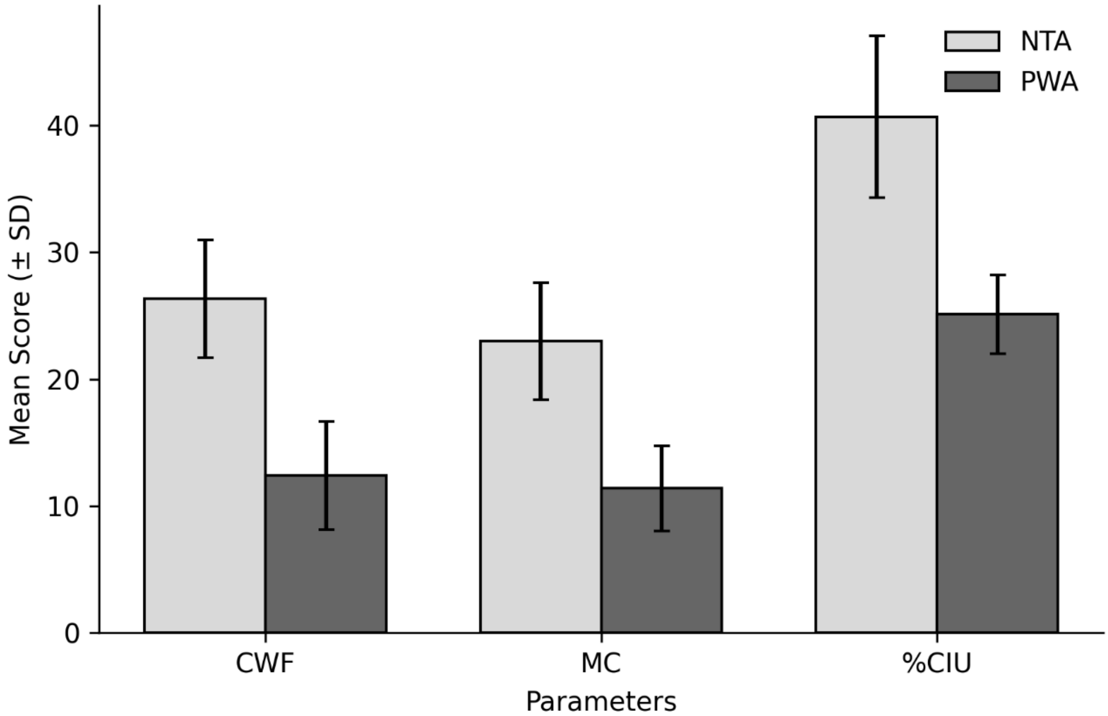
Parameter	**NTA (N=15)**				**PWA (N=15)**			
	Mean	Standard Deviation (SD)	Min	Max	Mean	Standard Deviation (SD)	Min	Max
CWF	26.33	4.65	20.00	36.00	12.40	4.27	7.00	19.00
MC	23.00	4.61	15.00	30.00	11.40	3.36	5.00	15.00
%CIU	40.69	6.40	29.40	50.00	25.12	3.10	21.10	28.90

Note. CWF=Content Word Fluency; MC=Main Concept; %CIU=Correct Information Units; Min and Max represent the minimum and maximum values, respectively.

The descriptive statistics presented in the preceding tables are further illustrated through graphical representations. The following figures (Figure 4.3) depict the mean performance of neurotypical adults (NTA) and persons with aphasia (PWA) across the discourse tasks. Error bars indicate ±1 standard deviation from the mean.

Figure 4.8

Mean Performance of Neurotypical Adults (NTA) and Persons with Aphasia (PWA) on Discourse Measures

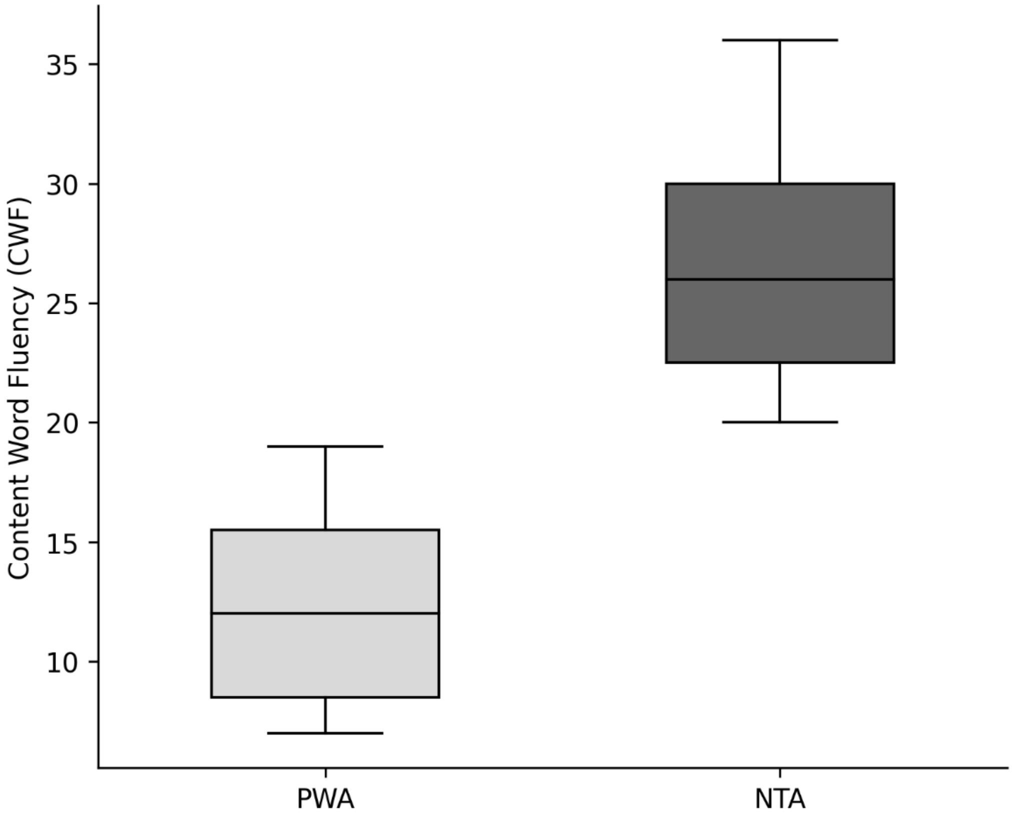


Note. Error bars represent ±1 standard deviation. CWF = Content Word Fluency; MC = Main Concept; %CIU = Percentage of Correct Information Units.

Also, box-and-whisker plots were constructed to illustrate the distribution of scores obtained by the neurotypical adults (NTA) and persons with aphasia (PWA) across the study variables, shown in Figures 4.9, 4,10, and 4.11.

Figure 4.9

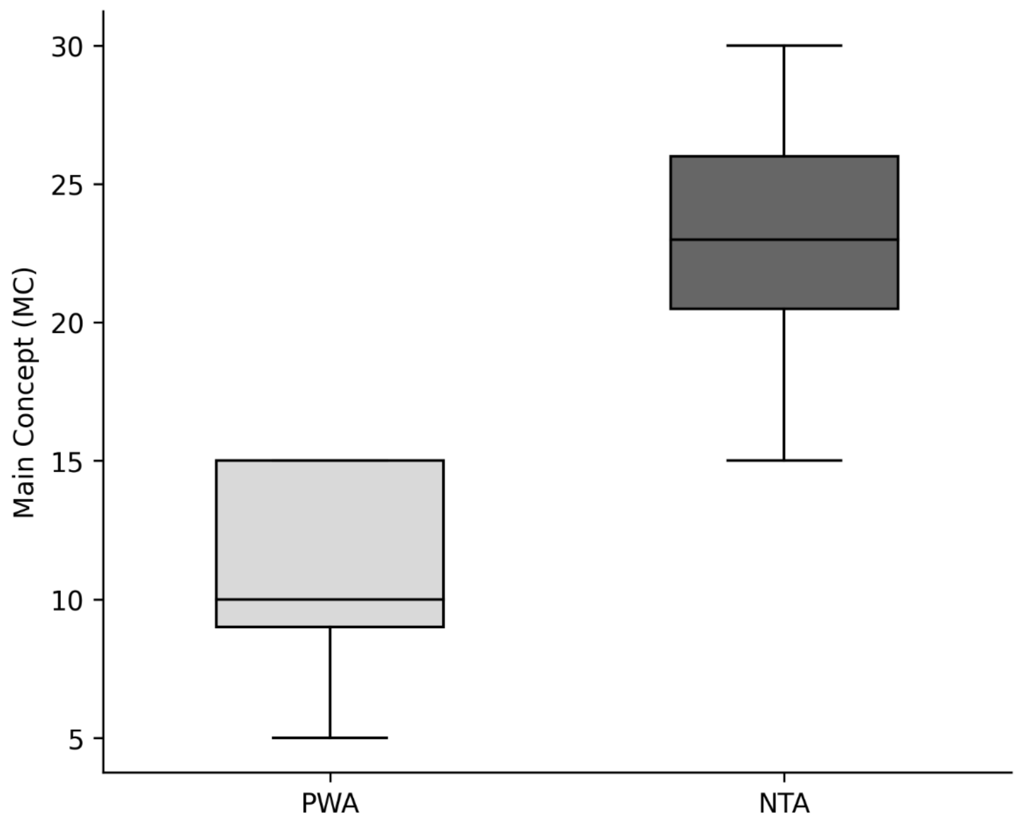
Distribution of Content Word Fluency (CWF) Scores in Persons with Aphasia (PWA) and Neurotypical Adults (NTA)



Note. The horizontal line within each box represents the median. The box represents the interquartile range (IQR), and the whiskers represent values within 1.5 times the interquartile range. Circles indicate potential outliers. Light gray represents persons with aphasia (PWA), and dark gray represents neurotypical adults (NTA).

Figure 4.10

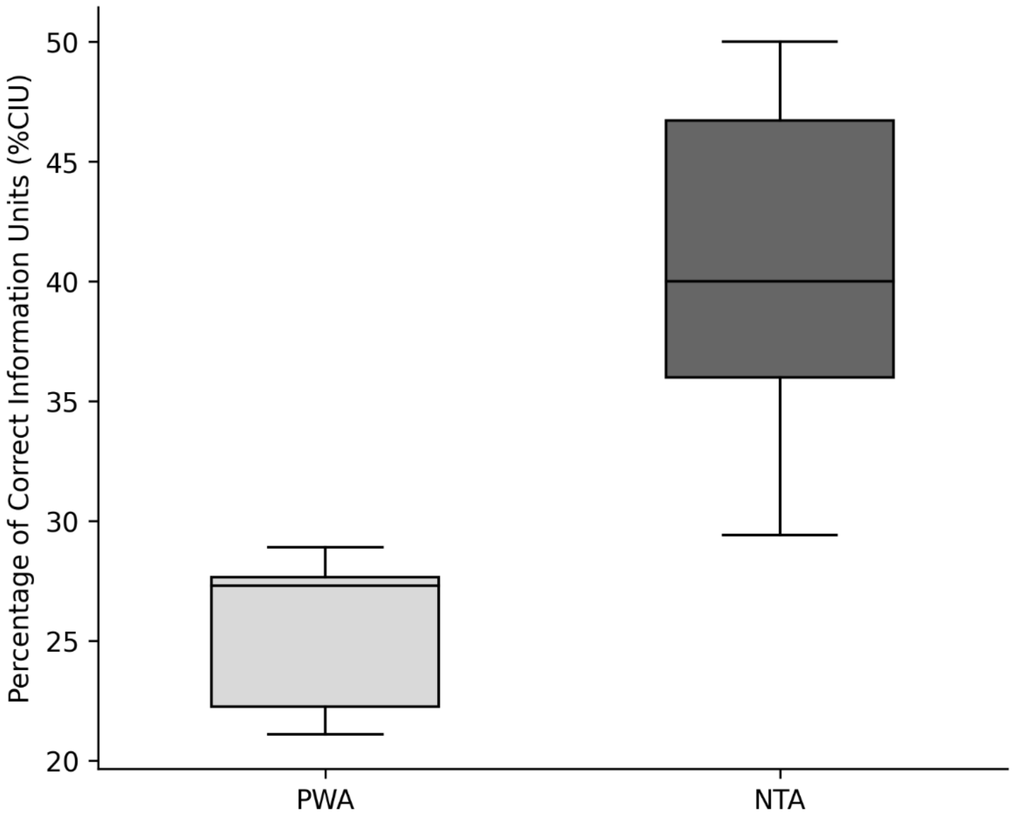
Distribution of Main Concept (MC) Scores in Persons with Aphasia (PWA) and Neurotypical Adults (NTA).



Note. The horizontal line within each box represents the median. The box represents the interquartile range (IQR), and the whiskers represent values within 1.5 times the interquartile range. Circles indicate potential outliers. Light gray represents persons with aphasia (PWA), and dark gray represents neurotypical adults (NTA).

Figure 4.11

Distribution of Percentage of Correct Information Units (%CIU) Scores in Persons with Aphasia (PWA) and Neurotypical Adults (NTA).



Note. The horizontal line within each box represents the median. The box represents the interquartile range (IQR), and the whiskers represent values within 1.5 times the interquartile range. Circles indicate potential outliers. Light gray represents persons with aphasia (PWA), and dark gray represents neurotypical adults (NTA).

In relation to CWF, the NTA group got a higher mean score, along with higher minimum and maximum values. In contrast, the PWA group had a lower mean CWF score with comparatively restricted output.

Similarly, for MC scores, the NTA group showed a higher mean score than the PWA group. The PWA group had lower mean MC scores, indicating reduced production of discourse concepts during the task.

For %CIU, the NTA group showed higher mean scores compared to the PWA group. The NTA also had higher minimum and maximum values, whereas the PWA group had comparatively lower informative content in their discourse output.

Hence, the NTA performed better in the discourse task than the PWA group.

4.2.3 Descriptive statistics for the Executive Function Test Parameters

The results of descriptive statistical analysis with respect to mean, standard deviation, minimum, and maximum values for Executive Function tests for both NTA and PWA are shown in Table 4.5

Table 4.5

Descriptive Statistics of Executive Function Task Parameters

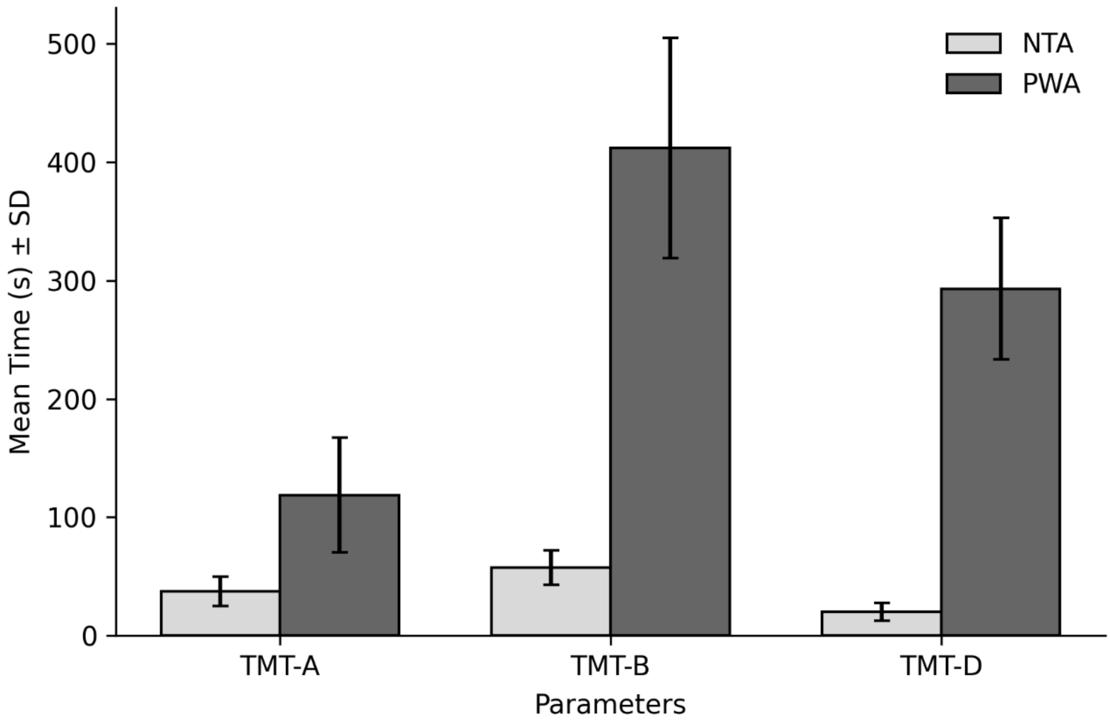
Parameter		**NTA (N=15)**				**PWA (N=15)**		
	Mean	Standard Deviation (SD)	Min	Max	Mean	Standard Deviation (SD)	Min	Max
TMT-A	37.38	12.47	20.51	67.00	118.80	48.32	66.00	227.00
TMT-B	57.27	14.57	37.50	90.00	411.87	93.30	276.00	632.00
TMT-D	19.89	7.54	11.00	40.22	293.07	59.59	200.00	405.00
TMT-R	1.58	0.29	1.27	2.31	3.71	0.94	2.45	6.19

Note. TMT =Trial Making Test, whereas A, B, C, and D represent Part A, B, Difference, and ratio, respectively; Min and Max represent the minimum and maximum values, respectively.

The descriptive statistics presented in the preceding tables are further illustrated through graphical representations. The following figures (Figures 4.4 and 4.5) depict the mean performance of neurotypical adults (NTA) and persons with aphasia (PWA) across the executive function tasks. Error bars indicate ±1 standard deviation from the mean.

Figure 4.12

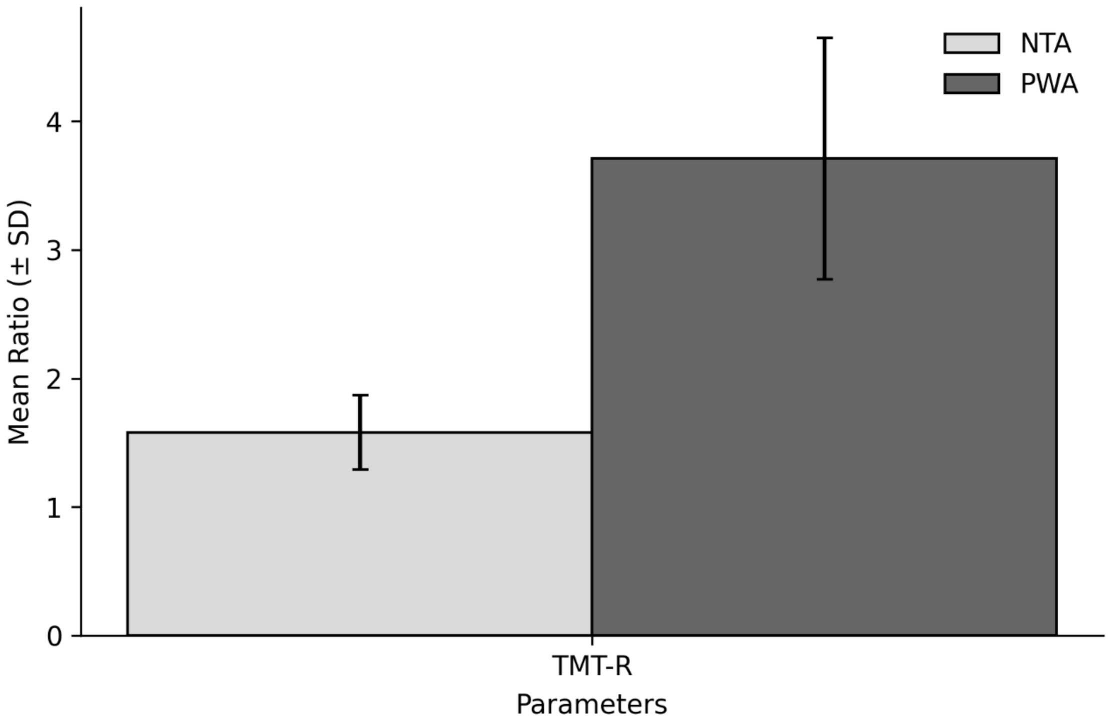
Mean Performance of Neurotypical Adults (NTA) and Persons with Aphasia (PWA)on Executive Function Measures- TMT-A, TMT-B and TMT-D.



Note. Error bars represent ±1 standard deviation. TMT = Trail Making Test; TMT-A = Part A; TMT-B = Part B; TMT-D = Difference Score.

Figure 4.13

Mean Performance of Neurotypical Adults (NTA) and Persons with Aphasia (PWA) on TMT-R.

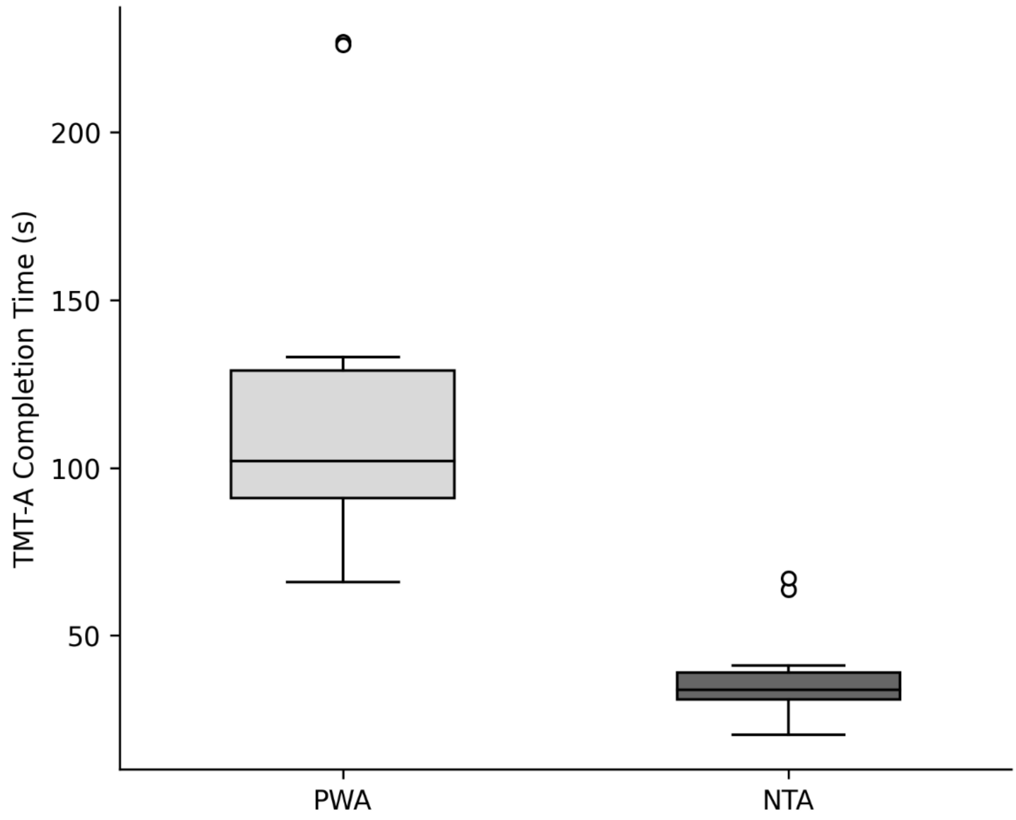


Note. Error bars represent ±1 standard deviation. TMT-R = Trail Making Test Ratio.

Also, box-and-whisker plots were constructed to illustrate the distribution of scores obtained by the neurotypical adults (NTA) and persons with aphasia (PWA) across the study variables, shown in Figures 4.14, 4,15, 4.16, 4.17 and 4.18.

Figure 4.14

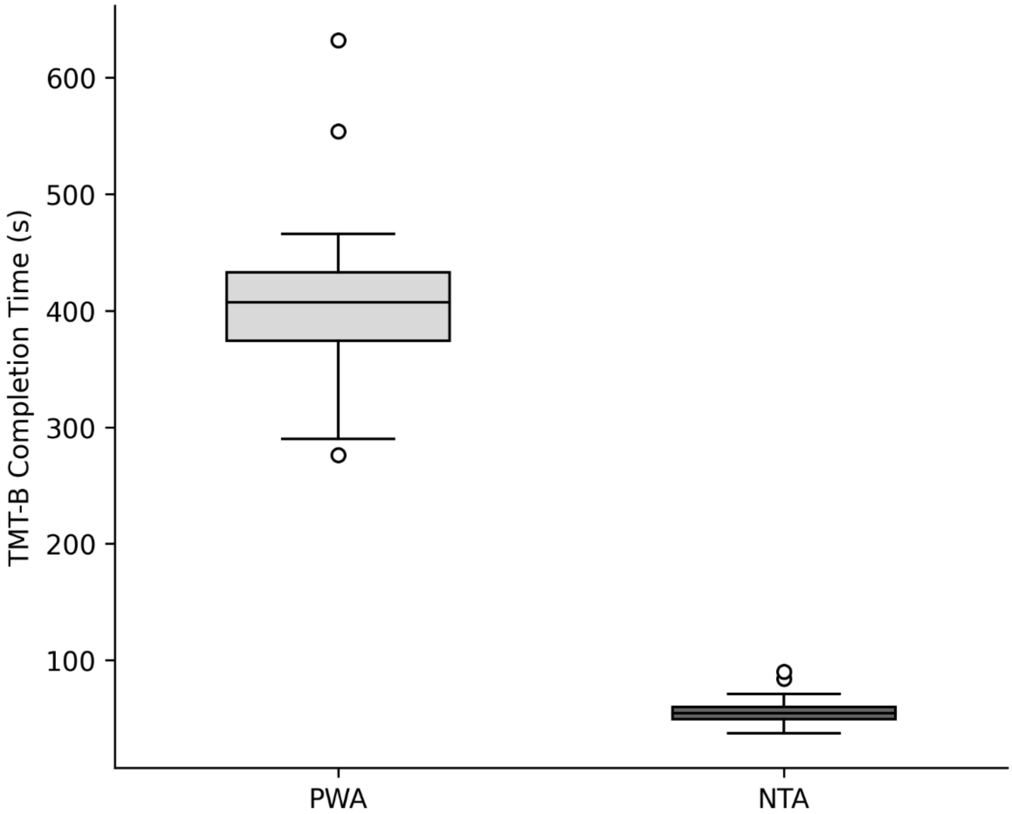
Distribution of Trail Making Test–Part A (TMT-A) Completion Times in Persons with Aphasia (PWA) and Neurotypical Adults (NTA)



Note. The horizontal line within each box represents the median. The box represents the interquartile range (IQR), and the whiskers represent values within 1.5 times the interquartile range. Circles indicate potential outliers. Light gray represents persons with aphasia (PWA), and dark gray represents neurotypical adults (NTA).

Figure 4.15

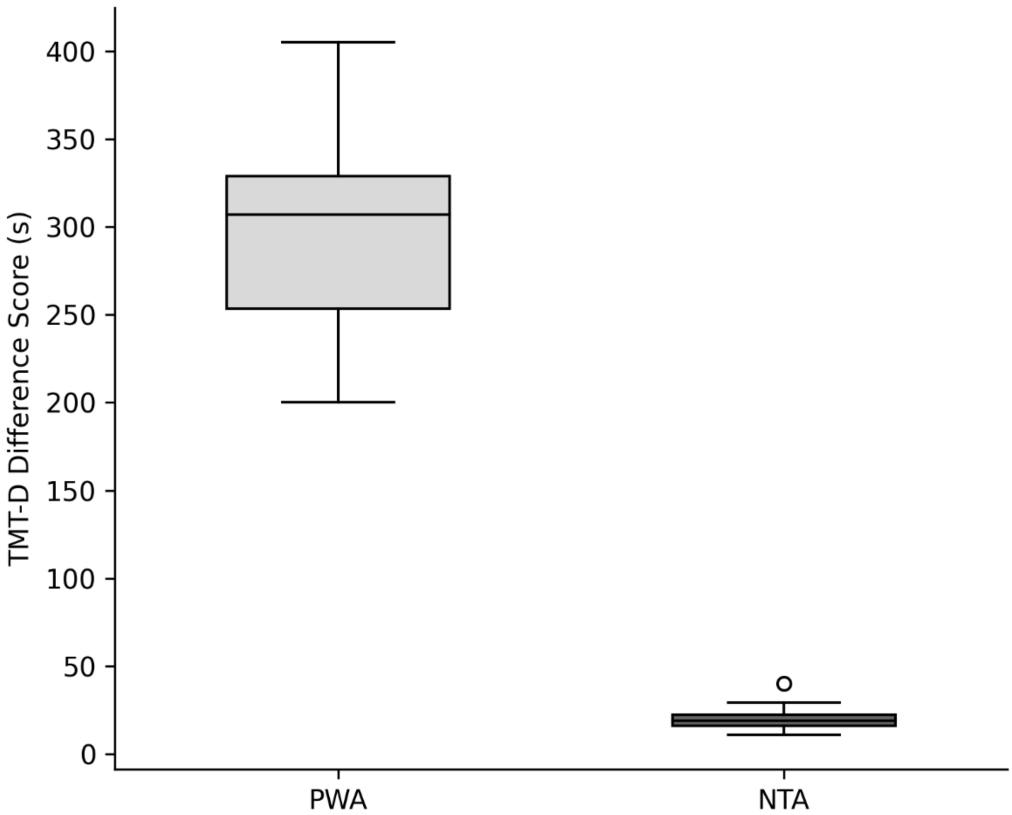
Distribution of Trail Making Test–Part B (TMT-B) Completion Times in Persons with Aphasia (PWA) and Neurotypical Adults (NTA)



Note. The horizontal line within each box represents the median. The box represents the interquartile range (IQR), and the whiskers represent values within 1.5 times the interquartile range. Circles indicate potential outliers. Light gray represents persons with aphasia (PWA), and dark gray represents neurotypical adults (NTA).

Figure 4.16

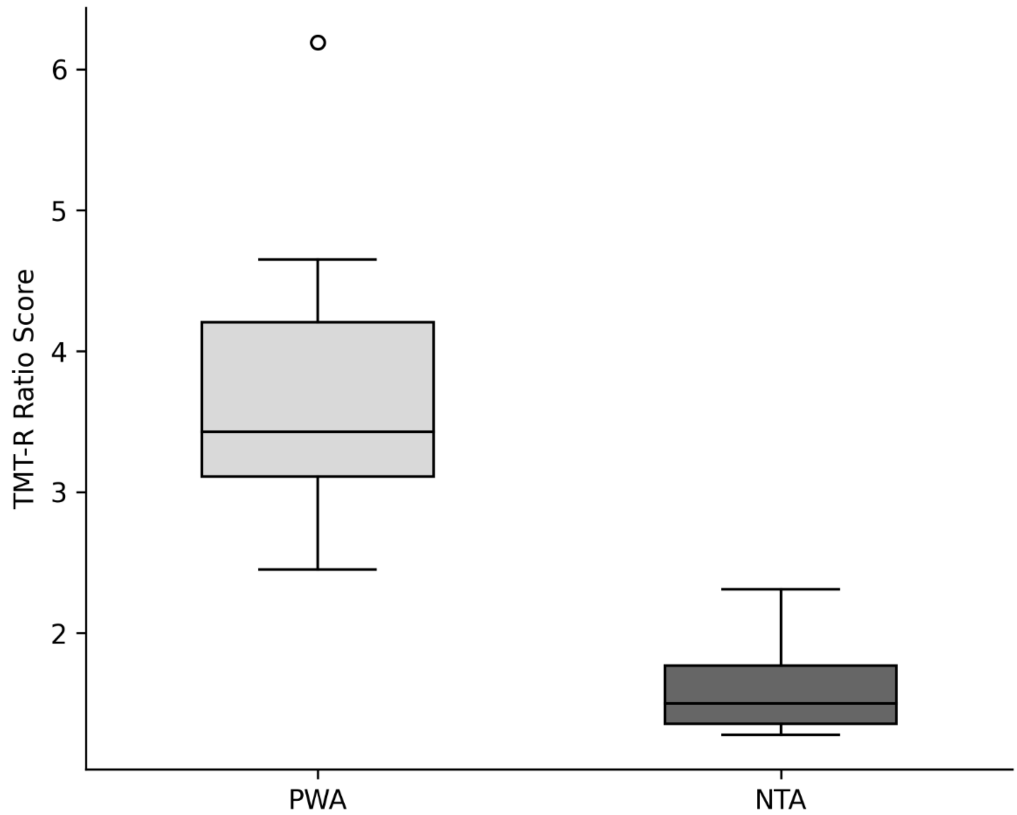
Distribution of Trail Making Test Difference Scores (TMT-D) in Persons with Aphasia (PWA) and Neurotypical Adults (NTA).



Note. The horizontal line within each box represents the median. The box represents the interquartile range (IQR), and the whiskers represent values within 1.5 times the interquartile range. Circles indicate potential outliers. Light gray represents persons with aphasia (PWA), and dark gray represents neurotypical adults (NTA).

Figure 4.17

Distribution of Trail Making Test Ratio Scores (TMT-R) in Persons with Aphasia (PWA) and Neurotypical Adults (NTA).



Note. The horizontal line within each box represents the median. The box represents the interquartile range (IQR), and the whiskers represent values within 1.5 times the interquartile range. Circles indicate potential outliers. Light gray represents persons with aphasia (PWA), and dark gray represents neurotypical adults (NTA).

The NTA group demonstrated comparatively superior executive function performance across all the evaluated Trail Making Test parameters. In relation to TMT-A, the NTA group exhibited a lower mean completion time, along with lower minimum and maximum values when compared to the PWA group. Conversely, the PWA group demonstrated substantially higher completion times and greater variability in performance.

Similarly, for TMT-B, the NTA group demonstrated lower mean task completion times than the PWA group. The PWA group showed markedly elevated mean, minimum, and maximum scores, indicating increased task completion duration during the set-shifting and cognitive flexibility component of the Trail Making Test.

With respect to TMT-D and TMT-R, the NTA group again demonstrated lower mean scores compared to the PWA group. The PWA group exhibited considerably higher values and greater variability across both parameters.

Overall, across all executive function measures, the neurotypical adults demonstrated comparatively better performance than the persons with aphasia, as reflected by shorter completion times and lower Trail Making Test indices.

4.2 Section II: Comparison between the NTA and the PWA (Between-Group Comparison).

The between-group comparison with respect to Quantitative Analysis for the different domains was performed using the Mann-Whitney U Test based on the normality of the parameters and the results are shown in Table 4.9.

Table 4.6

Between-Group Comparison (NTA vs PWA) of Discourse, Semantic Verbal Fluency, and Executive Function Parameters – Quantitative Analysis using Mann–Whitney U Test

Parameters	**Mann–Whitney U Test**	
	| Z |	**p value**
	Semantic verbal fluency task	
1. NoS	4.623	< 0.001*
2. CR	4.640	< 0.001*
	Executive function task	
1. TMT-B	4.667	0.000*
2. TMT- A	4.626	0.000*

2. TMT-D	4.667	0.000*
Discourse task		
1. CWF	4.675	0.000*
2. MC	4.497	0.000*
3. %CIU	4.671	0.000*

Note. NoS=Number of Switches; CS=Cluster Size; WCP=Within Cluster Pause; BCP= Between Cluster Pause; CR=Correct Responses; CWF=Content Word Fluency; MC=Main Concept; %CIU=Correct Information Units; TMT =Trial Making Test, A, B, and D represent Part-A, B and Difference, respectively; Min and Max represent the minimum and maximum values, respectively; $p < .05$.

For the Semantic Verbal Fluency task, the quantitative parameters analyzed included the NoS and CR. The results revealed statistically significant differences between the two groups for both parameters, indicating differential performance between the NTA and PWA groups.

Within the Executive Function task, the parameters analyzed were TMT-A, TMT-B and TMT-D. Significant differences were observed between the two groups for all executive function measures.

For the Discourse task, the parameters analyzed included CWF, MC, and the %CIU. The results demonstrated statistically significant differences between the NTA and PWA groups across all discourse parameters. Overall, significant between-group differences were observed across all quantitative parameters evaluated in the present study, with the NTA demonstrating comparatively better performance than the PWA.

The Between-Group Comparison for Cluster Analysis of the Semantic Verbal Fluency Parameters has been provided in Tables 4.7 below.

Table 4.7

Between-Group Comparison (NTA vs PWA) of Semantic Verbal Fluency Task Parameters – Cluster Analysis using Mann–Whitney U Test

Parameters	**Mann–Whitney U Test**	
	| Z |	p value
NoS	4.623	0.000*
CS	3.894	0.000*
WCP	1.968	0.049*
BCP	1.597	0.110

Note. NoS=Number of Switches; CS=Cluster Size; WCP=Within Cluster Pause; BCP= Between Cluster Pause; $p < .05$.

From Table 4.7, the Mann–Whitney U test was used to assess the differences between the neurotypical adults (NTA) and persons with aphasia (PWA) groups for the cluster analysis parameters of the Semantic Verbal Fluency task.

The parameters analyzed included the Number of Switches (NoS), Mean Cluster Size (CS), Within-Cluster Pause (WCP), and Between-Cluster Pause (BCP). Significant differences were observed between the NTA and PWA groups for the Number of Switches (NoS), Mean Cluster Size (CS), and Within-Cluster Pause (WCP).

However, no significant difference was observed between the two groups for the Between-Cluster Pause (BCP) parameter. Overall, the results indicated significant between-group differences across most cluster analysis parameters of the Semantic Verbal Fluency task, with neurotypical adults demonstrating comparatively better performance than persons with aphasia.

4.3 Section III: The correlation between the Semantic Verbal Fluency, Discourse, and Executive function test parameters at the level of Quantitative, and Cluster Analysis

The results of the correlation analysis between the different tests at the level of quantitative analysis are shown in Table 4.8.

Table 4.8

Spearman correlation between Semantic Verbal Fluency, Executive Function, and Discourse Parameters-Quantitative Analysis for PWA and NTA

PWA

(N=15)

Variables	NoS	CR	TMT-A	TMT-B	TMT-D	CWF	MC	%CIU
NoS	1.00	0.90**	-0.75**	-0.39	-0.20	0.48	0.31	-0.03
CR	0.90**	1.00	-0.80**	-0.29	-0.05	0.50	0.52*	0.14
TMT-A	-0.75**	-0.80**	1.00	0.56**	0.26	-0.39	-0.29	0.01
TMT-B	-.39	-0.29	0.56**	1.00	0.90**	-0.38	0.027	0.34
TMT-D	-0.20	-0.05	0.26	0.90**	1.00	-0.22	0.16	0.47
CWF	0.48	0.50	-0.39	-0.38	-0.22	1.00	0.74**	0.40
MC	0.31	0.52*	-0.29	0.02	0.16	0.74**	1.00	0.65**
%CIU	-0.03	0.14	0.01	0.34	0.47	0.40	0.65**	1.00

NTA

(N=15)

Variables	NoS	CR	TMT-A	TMT-B	TMT-D	CWF	MC	%CIU
NoS	1.00	0.64**	-0.11	0.11	0.31	0.02	-0.36	-0.38
CR	0.64**	1.00	-0.19	-0.10	-0.10	-0.14	-0.10	-0.45
TMT-A	-0.11	-0.19	1.00	0.63*	-0.08	0.19	-0.07	-0.16
TMT-B	0.11	-0.10	0.63*	1.00	0.66**	-0.15	-0.40	-0.22
TMT-D	0.31	-0.10	-0.08	0.66**	1.00	-0.23	-0.42	-0.04
CWF	0.02	-0.14	0.19	-0.15	-0.23	1.00	0.56*	0.48
MC	-0.36	-0.10	-0.07	-0.40	-0.42	0.56*	1.00	0.64**
%CIU	-0.38	-0.45	-0.16	-0.22	-0.04	0.48	0.64**	1.00

Note. Spearman's rho correlations are reported; NoS=Number of Switches; CS=Cluster Size; WCP=Within Cluster Pause; BCP= Between Cluster Pause; CR=Correct Responses; CWF=Content Word Fluency; MC=Main Concept; %CIU=Correct Information Units; TMT =Trial Making Test, A, B, and D represent Part A, B and Difference, respectively.

For the PWA group, a strong positive correlation between Number of Switches (NoS) and Correct Responses (CR) is present. A strong negative correlation between Number of Switches (NoS) and TMT-A scores is present, indicating that increased switching performance was associated with lower completion times on TMT-A. Similarly, Correct Responses (CR) showed a strong negative correlation with TMT-A scores. Within the executive function parameters, TMT-A showed a significant positive correlation with TMT-B, and TMT-B showed a strong positive correlation with TMT-D.

Within the discourse parameters, Content Word Fluency (CWF) showed a strong positive correlation with Main Concept (MC) scores. Main Concept (MC) scores also showed a significant positive correlation with percentage of Correct Information Units (%CIU).

Additionally, a significant positive correlation was observed between Correct Responses (CR) and Main Concept (MC) scores.

For the NTA group, a significant positive correlation between Number of Switches (NoS) and Correct Responses (CR) is present. Within the executive function parameters, TMT-A showed a significant positive correlation with TMT-B, while TMT-B demonstrated a strong positive correlation with TMT-D.

Among the discourse parameters, Content Word Fluency (CWF) showed a significant positive correlation with Main Concept (MC) scores. Main Concept (MC) scores demonstrated a strong positive correlation with percentage of Correct Information Units (%CIU).

Overall, the quantitative correlation analysis showed significant associations among semantic verbal fluency, executive function, and discourse measures in both groups. However, stronger interrelationships between semantic verbal fluency and executive function parameters were observed in the PWA group compared to the NTA group.

The results of the correlation analysis between the different tests at the level of Cluster analysis is shown in Table 4.9

Table 4.9

Correlation between Semantic Verbal Fluency Parameters-Cluster Analysis for PWA and NTA

		PWA (N=15)		
Variables	**NoS**	**MCS**	**WCP**	**BCP**
NoS	1.00	0.60*	0.57*	0.16
MCS	0.60*	1.00	0.93**	0.15
WCP	0.57*	0.93**	1.00	0.12
BCP	0.16	0.15	0.12	1.00

NTA (N=15)

Variables	NoS	MCS	WCP	BCP
NoS	1.00	0.07	0.14	-0.27
MCS	0.078	1.00	0.29	-0.18
WCP	0.14	0.29	1.00	0.01
BCP	-0.27	-0.18	0.01	1.00

Note. Spearman's rho correlations are reported. NoS=Number of Switches; CS=Cluster Size; WCP=Within Cluster Pause; BCP = Between Cluster Pause.

The results of the correlation analysis among the semantic verbal fluency parameters at the cluster analysis level are presented separately for persons with aphasia (PWA) and neurotypical adults (NTA).

For the PWA group, a significant positive correlation was observed between Number of Switches (NoS) and Mean Cluster Size (MCS). A significant positive correlation was also found between Number of Switches (NoS) and Within-Cluster Pause (WCP). In addition, Mean Cluster Size (MCS) showed a strong positive correlation with Within-Cluster Pause (WCP). However, Between-Cluster Pause (BCP) did not show a significant correlation with Number of Switches, Mean Cluster Size, or Within-Cluster Pause in the PWA group.

For the NTA group, no significant correlations were observed among the cluster analysis parameters. The correlations between Number of Switches (NoS), Mean Cluster Size (MCS), Within-Cluster Pause (WCP), and Between-Cluster Pause (BCP) were weak and did not reach statistical significance.

Hence, the cluster-level correlation analysis indicated significant associations among switching, clustering, and within-cluster pause measures in the PWA group, whereas there were no significant associations seen in the NTA group.

CHAPTER V

DISCUSSION

The present study examined discourse, semantic verbal fluency (SWF), and executive function skills in persons with aphasia (PWA) and neurotypical adults (NTA). Using a picture description task, SVF, and Trail Making Test (TMT), the study characterises the extent to which lexical-semantic and executive processes contribute to discourse production in PWA.

The findings suggest that PWA performed at a significantly lower level than NTA across all three domains that were tested. In the discourse task, PWA produced fewer content words (CWF), fewer main concepts (MC), and a lower proportion of CIUs. In the SVF domain, PWA retrieved fewer CR's, reduced switching, and smaller cluster sizes, and had significant differences in WCP, relative to NTA. In the EF domain, PWA required more time to complete both parts of the TMT, and their difference and ratio scores indicated a reduced capacity for cognitive flexibility and set-shifting.

The correlation analyses suggested that certain relationships among these domains differed between the two groups. In particular, PWA showed a significant positive association between SVF (CR) and discourse (MC), a relationship that was absent in the NTA group. Cluster-level analyses further indicated that switching, clustering, and WCP were significantly intercorrelated in PWA but not in NTA, pointing to a distinct organisation of lexical retrieval in this population.

5.1 To quantify discourse output on a picture description task using a predefined checklist of MC, CWF between PWA and NTA:

5.1.1 Content Word Fluency (CWF):

The results showed a statistically significant difference between the two groups across all discourse measures, with PWA exhibiting poor performance than NTA on CWF, MC, and %CIU ($p < .001$ for all parameters).

With respect to CWF, the NTA produced a higher mean number of content words (M = 26.33, SD = 4.65) in comparison to PWA (M = 12.40, SD = 4.27), with the Mann–Whitney U test assuring this difference to be highly significant ($z = -4.675$, $p < .001$). This finding shows that PWA generated fewer lexically specific, information-carrying words during the picture description task. The reduced CWF in PWA is consistent with clinical studies that word retrieval difficulties constitute pervasive impairment across aphasia subtypes (Alyahya et al., 2021; Boucher et al., 2022). From a theoretical point of view, content words carry the primary semantic load in the utterance, and their reduced production suggests not only a deficit in lexical access but also a reduction in the discourse informativeness as a whole.

The findings align with Alyahya et al. (2021), who reported deficits in content word production during discourse in persons with post-stroke aphasia and attributed these deficits to affected lexical retrieval rather than to the lexical-semantic complexity. In this study, the CWF measure provided an index of lexical productivity tied directly to the picture discourse, eliciting a direct comparison of word production across groups.

5.1.2 Main Concept Analysis (MC):

The MC scores showed a significant between-group difference ($z = -4.497$, $p < .001$), with NTA having a higher mean MC score ($M = 23.00$, $SD = 4.61$) compared to PWA ($M = 11.40$, $SD = 3.36$). The lower MC scores in PWA indicate that the deficit in discourse production extends beyond reduced word production and encompasses a failure to express core content with completeness and accuracy.

This finding aligns with previous work by Kuvač Kraljević et al. (2023), who found that PWA produced fewer and less complete MC than healthy controls during picture description, and attributed this to an interaction between affected conceptual encoding and lexical-phonological access. Similarly, Nicholas and Brookshire (1993) established that the discourse skills (MC) are consistently reduced in PWA. The present results extend this evidence to a culturally adapted, Indian-context stimulus, supporting the cross-cultural application of MC-based discourse assessment.

The wide performance range observed within the PWA group (MC scores ranging from 5 to 15) may reflect the heterogeneous nature of the sample within the PWA group, severity, and chronicity. Individuals with relatively spared lexical access may have been able to convey more complete concepts, whereas those with more severe word retrieval deficits may have produced only partial or absent main concepts.

5.1.3 Percentage of Correct Information Units (%CIU):

The %CIU, was also significantly lower in PWA ($M = 25.12\%$, $SD = 3.10$) relative to NTA ($M = 40.69\%$, $SD = 6.40$; $z = -4.671$, $p < .001$).

The lower %CIU in PWA suggests that a greater share of their verbal output consisted of less informative elements, such as repetitions, revisions, non-meaningful verbalisations, or empty words relative to NTA. This is consistent with the established understanding that persons with aphasia frequently employ compensatory strategies during discourse, including circumlocution, indefinite reference (e.g., "that thing"), and verbal fillers, which inflate total word count without contributing to informational content (Dalton & Richardson, 2015; Nicholas & Brookshire, 1993). The %CIU measure thus provides a sensitive and clinically meaningful complement to CWF and MC scores, capturing the qualitative dimension of discourse efficiency that raw word counts alone cannot reveal.

Taken together, the results pertaining to Objective 1 confirm that the null hypothesis is rejected since there are significant differences in discourse output between PWA and NTA across all three measures. The findings suggest that discourse production in PWA is affected at multiple levels- lexical productivity as indicated by CWF, propositional completeness as indicated by MC, and communicative efficiency as indicated by %CIU.

5.2 To quantify SVF performance between PWA and NTA.

5.2.1 Correct Responses (CR) and Number of Switches (NoS)- Quantitative Analysis:

The second objective examined SVF performance between PWA and NTA. Quantitative analysis indicated highly significant between-group differences in both CR ($z = -4.640$, $p < .001$) and NoS ($z = -4.623$, $p < .001$). NTA produced more correct animal names ($M = 14.87$, $SD = 3.11$) than PWA ($M = 6.27$, $SD = 2.63$), and produced a higher mean NoS (NTA: $M = 11.13$, $SD = 1.46$; PWA: $M = 5.33$, $SD = 2.61$).

The significantly reduced CR in PWA corroborates a well-established pattern in the aphasia literature: individuals with aphasia consistently produce fewer items on semantic verbal fluency tasks than neurotypical adults, reflecting impairments in lexical retrieval from intact or partially degraded semantic representations (Bose et al., 2022; Faroqi-Shah & Milman, 2018). The extent of the group difference observed here, with PWA producing on average fewer than half the correct responses of NTA, is consistent in magnitude with prior reports (Baldo et al., 2010; Kiran et al., 2014) and indicates a clinically substantial lexical-access deficit in the present sample.

The significantly reduced NoS in PWA reflects impairment in the strategic aspect of verbal fluency performance. Switching between semantic categories is understood to reflect executive control skills, specifically the skills for cognitive flexibility and set-shifting. The finding that PWA switched significantly less than NTA suggests that these individuals also demonstrate a reduced capacity for cognitive flexibility, a pattern consistent with executive dysfunction reported in aphasia (Dutta et al., 2023; Purdy2002).

5.2.2 Cluster Size (CS), Within-Cluster Pause (WCP), and Between-Cluster Pause (BCP)-Cluster Analysis:

At the cluster analysis level, significant between-group differences were observed for Mean Cluster Size (CS; $z = -3.894$, $p < .001$) and Within-Cluster Pause (WCP; $z = -1.968$, $p = .049$), but not for Between-Cluster Pause (BCP; $z = -1.597$, $p = .110$). NTA produced larger mean cluster sizes ($M = 1.26$, $SD = 0.27$) relative to PWA ($M = 0.47$, $SD = 0.52$), indicating that NTA generated longer runs of semantically related items within subcategories before switching.

The reduced cluster size in PWA suggests that the semantic subcategory networks underlying animal knowledge are less effectively utilised or less richly organised in this population, such that PWA exhaust available co-activated items more quickly before being forced to switch. This finding is consistent with Baldo et al. (2010), who documented reduced cluster sizes in persons with Wernicke's aphasia, and with Kiran et al. (2014), who reported smaller clusters across both languages in bilingual persons with aphasia. Clustering is theorised to rely primarily on the integrity of lexico-semantic representations and temporal lobe activation (N'Kaoua et al., 2001; Testa et al., 1998); the present results therefore implicate degraded or less accessible semantic networks as a contributor to the fluency deficit observed in PWA.

The significant difference in WCP, with PWA showing greater variability in within-cluster pause durations (*M* = 0.64, *SD* = 1.07) compared to NTA (*M* = 0.91, *SD* = 0.90), is noteworthy and warrants nuanced interpretation. WCP indexes the time taken to retrieve successive items within a semantic subcategory and thus reflects the efficiency of within-cluster lexical access (Bose et al., 2022; Tröster et al., 1998). The significantly greater variability in WCP within the PWA group, combined with the lower mean WCP observed in this group, may be interpreted in light of two related factors. First, when individuals produce predominantly singleton or very short clusters, fewer within-cluster intervals are available for computation of the mean WCP, as the scoring methodology assigns a size of zero to single-item clusters, thereby reducing the number of pause intervals that contribute to the mean (Troyer et al., 1997). Second, those individuals within the PWA group who do produce multi-item clusters may experience prolonged within-cluster pauses as a consequence of effortful and slowed lexical retrieval from degraded or less accessible semantic subcategories (Bose et al., 2022; Tröster et al., 1998). The co-occurrence of these two patterns within a heterogeneous clinical sample — some individuals producing very short clusters with minimal within-cluster intervals, and others producing longer clusters with effortful retrieval — may thus account for the wide variability and attenuated mean WCP observed in the PWA group in the present study. This interpretation is further supported by the substantially smaller mean cluster sizes recorded in PWA, which independently confirm that within-cluster retrieval opportunities were constrained in this group (Bose et al., 2017; Troyer et al., 1997).

In contrast, BCP- which indexes the time between the final word of one cluster and the first word of the next- did not significantly differ between groups. This finding suggests that the temporal cost of transitioning between semantic subcategories, once the decision to switch has been made, does not meaningfully differentiate PWA from NTA. One possible interpretation is that the initiation of a new semantic cluster, once triggered, proceeds at a comparable speed in both groups; what differs is the capacity to sustain within-cluster retrieval. Alternatively, BCP may be less sensitive to aphasia-related differences in the present sample size. This selective pattern of impairment affecting within-cluster but not between-cluster pausing represents an informative contribution to the temporal characterisation of verbal fluency in aphasia (Bose et al., 2022; Crowe, 1998).

Overall, the results pertaining to Objective 2 reject the null hypothesis and confirm that SVF performance is significantly impaired in PWA relative to NTA across quantitative (CR, NoS) and most cluster-analysis parameters (CS, WCP), with BCP representing the sole non-significant measure. These findings collectively suggest that the fluency deficit in PWA reflects both impaired lexical access (reduced CR, smaller CS) and reduced strategic switching (reduced NoS), with additional evidence of altered within-cluster retrieval dynamics (WCP).

5.3 To assess executive control using the Trail Making Test (TMT A and B) between PWA and NTA.

5.3.1 TMT-A and TMT-B:

The third objective was to understand executive control using the TMT (TMT-A and TMT-B) between PWA and NTA. Results suggested highly significant between-group differences for TMT-B ($z = -4.667$, $p < .001$) and TMT-D ($z = -4.667$, $p < .001$). The descriptive data indicated important differences: PWA required longer durations to complete both TMT-A (PWA: *M* = 118.80 s, *SD* = 48.32; NTA: *M* = 37.38 s, *SD* = 12.47) and TMT-B (PWA: *M* = 411.87 s, *SD* = 93.30; NTA: *M* = 57.27 s, *SD* = 14.57).

The large difference in TMT-A times between groups indicates that PWA experience difficulties with visual scanning and processing speed, even in the absence of the set-shifting demands introduced in TMT-B. This finding is consistent with evidence, that left hemisphere damage interrupts attentional and processing speed, extending beyond language-specific impairment (Dutta et al., 2023).

TMT-B requires participants to alternate between numbers and letters in ascending order, placing additional demands on cognitive flexibility and the ability to shift between two mental sets. The elevated TMT-B completion times in PWA (mean exceeding 411 seconds, compared to 57 seconds in NTA) indicate impairment in this capacity.

5.3.2 TMT-D and TMT-R:

The TMT-D and TMT-R scores were calculated to isolate the set-shifting and cognitive flexibility component of TMT. PWA had higher TMT-D scores (*M* = 293.07, *SD* = 59.59) relative to NTA (*M* = 19.89, *SD* = 7.54), and higher TMT-R values (PWA: *M* = 3.71, *SD* = 0.94; NTA: *M* = 1.58, *SD* = 0.29).

The magnitude of the TMT-D difference indicates that PWA takes more task completion time when set-shifting demands are added. This suggests a true and clinically significant impairment in cognitive flexibility in PWA, above and beyond their general processing speed deficit. These findings are consistent with Purdy (2002), whose study documented significant difficulties in cognitive flexibility tasks (Wisconsin Card Sorting Test, Tower of Hanoi) in PWA, and with Dutta et al. (2023), who reported that PWA performed significantly poorer than healthy controls across multiple executive function tasks.

Also, the higher TMT-R in PWA (mean ratio 3.71) compared to NTA (mean ratio 1.58) reflects a poor skills in alternating between sets. The higher ratio in PWA suggests attentional inertia (Longman et al., 2014) which is, difficulty in alternating from one mental set and transitioning to another and is consistent with impaired fronto-executive regulation following left hemisphere stroke.

The high degree of variability in TMT scores within the PWA group (TMT-B ranging from 276 to 632 seconds; TMT-D from 200 to 405 seconds) further highlights the heterogeneity of executive function profiles in this population. As Dutta et al. (2023) noted, there is no stable relationship between aphasia severity and executive function scores, with some individuals showing minimal difficulties and others having severe difficulties. This instability has important clinical implication: it warns against the assumption that executive function is uniformly impaired in aphasia.

Altogether, the results pertaining to Objective 3 reject the null hypothesis, confirming significant differences in executive control between PWA and NTA. The findings indicate that PWA experience impairment not only in processing speed (TMT-A) but also in cognitive flexibility and set-shifting capacity (TMT-B, TMT-D, TMT-R), with intra-group variability reflecting the heterogeneous executive function profiles of PWA.

5.4 To evaluate the correlation among discourse performance, SVF, and TMT in PWA and NTA:

5.4.1 Quantitative-Level Correlations within the PWA Group:

5.4.1.1 CR and MC: The Lexical–Discourse Association:

The fourth objective evaluates the correlations among discourse, SVF, and EF, separately within PWA and NTA. The most significant finding of the correlation analysis came in the PWA group: a significant positive correlation between CR on the SVF task and MC scores on the discourse task (rs = .521, $p < .05$). This relationship was absent in the NTA group (rs = −.107, $p > .05$), representing a qualitative difference between the groups.

This finding is important in theoretical aspects. In NTA, discourse informativeness (as indicated by MC) appears to be relatively independent of verbal fluency productivity (CR), showing that when lexical access is spared, discourse informativeness is not affected by the skills of word retrieval. On the other side, the significant CR-MC correlation in PWA indicates that the same individuals who retrieve more correct exemplars on the fluency task also convey more MCs during discourse, suggesting that lexical retrieval constitutes a limiting factor for discourse production in PWA. In other words, in PWA, limited lexical access appears to trend upward to affect the informativeness of connected speech, consistent with a lexical bottleneck effect of discourse production in PWA (Alyahya et al., 2021; Bose et al., 2022).

This finding also has clinical implications. It suggests that SWF performance may function as a meaningful index for discourse informativeness in PWA, enabling clinicians to predict discourse outcomes from fluency scores without requiring full discourse sampling. Also, it supports the hypothesis that word retrieval therapy may yield benefits for discourse skills (Dalton & Richardson, 2015).

5.4.1.2 Within-Domain Correlations: SVF, Discourse, and EF:

Both groups showed a significant positive correlation between NoS and CR within the SVF task (PWA: rs = .909, $p < .001$; NTA: rs = .645, $p < .01$), showing that individuals who switch more frequently also produce more correct responses. This is consistent with evidence stating that switching between semantic categories is a key strategy for maintaining productivity during fluency tasks (Troyer et al., 1997). The strong correlation in PWA may reflect that switching is especially significant for total output in this group, where within-cluster items are limited, and each switch to a new subcategory provides entry to a fresh pool of items.

Within the discourse domain, a significant positive correlation was observed between CWF and MC in both groups (PWA: rs = .746, $p < .01$; NTA: rs = .563, $p < .05$), and between MC and %CIU in both groups (PWA: rs = .659, $p < .01$; NTA: rs = .642, $p < .01$). These within-domain associations confirm that the three discourse measures- CWF, MC, and %CIU tap related but partially distinct aspects of connected speech production, and that greater content word production is associated with more complete main concept and higher communicative efficiency in both groups. These relationships are consistent with previous work showing convergent results across informativeness measures (Nicholas & Brookshire, 1993; Richardson & Dalton, 2020).

Within the executive function domain, TMT-B showed a strong positive correlation with TMT-D in both groups (PWA: rs = .904, $p < .001$; NTA: rs = .667, $p < .01$), confirming that the two measures are closely related. Additionally, TMT-A showed a significant positive correlation with TMT-B in both groups (PWA: rs = .566, $p < .01$; NTA: rs = .636, $p < .05$), confirming that participants who were slower on the basic visual scanning and sequencing component of the TMT (Part A) also tended to take longer on the more demanding set-shifting component (Part B). This within-domain pattern is expected and confirms the internal consistency of the executive function data, reflecting that processing speed and cognitive flexibility, share variance in both clinical and healthy populations (Sánchez-Cubillo et al., 2009).

5.4.1.3 SVF–EF Correlations in the PWA Group: TMT-A as a Significant Predictor:

A key findings is the significant negative correlation observed between TMT-A and both SVF parameters (NoS and CR) in the PWA group. Specifically, NoS showed a strong negative correlation with TMT-A ($r_s = -.754$, $p < .01$), and CR showed an even stronger negative correlation with TMT-A ($r_s = -.803$, $p < .01$). These relationships were absent in the NTA group, where TMT-A did not significantly correlate with either NoS or CR.

The direction and magnitude of these correlations indicate that, in PWA, those individuals with slower processing speed and visual scanning abilities (higher TMT-A times) also produce fewer correct responses and make fewer switches on the SVF task.

This finding is theoretically significant for two reasons. First, it suggests that basic processing speed, as indexed by TMT-A (rather than the more demanding TMT-B) is related to lexical productivity and strategic organisation in aphasia. This suggests that the cognitive capacity required for the attentional demands of processing speed are shared with those required for lexical search and retrieval during verbal fluency. Second, it highlights that TMT-A, often treated primarily as a baseline measure for the purpose of computing TMT-D and TMT-R, may itself carry clinically relevant predictive information about SVF performance in PWA.

The absence of a corresponding TMT-A- SVF association in the NTA group further supports a differential discussion. In NTA, processing speed is sufficiently intact that it does not constitute a constraint on verbal fluency performance. In PWA, however, where processing speed is reduced (as evidenced by significantly elevated TMT-A times: PWA $M = 118.80$ s vs. NTA $M = 37.38$ s), the slowed processing may add upon the lexical retrieval difficulties already present, creating a situation in which the speed of cognitive mechanisms limits the rate and organisation of verbal output during the fluency task. This interpretation is consistent with the literature documenting that processing speed is a general cognitive resource that supports multiple language functions in aphasia (Dutta et al., 2023; Vuković & Chen, 2025).

It is important to note that, in contrast to the significant TMT-A and SVF correlations observed in PWA, TMT-B nor TMT-D didn’t showed significant correlations with SVF or discourse measures in either group. This dissociation between TMT-A and the other TMT indices (TMT-B, TMT-D), in their relationship to language performance, is itself important. TMT-B and TMT-D assess set-shifting and cognitive flexibility over processing speed; the present findings suggest that while processing speed relates to SVF performance in PWA, the additional cognitive flexibility component (represented by TMT-B and TMT-D) does not contribute additional variance to language outcomes in the present sample.

One possible explanation is that the set-shifting demands of verbal fluency are not adequately captured by the visuo-motor alternation paradigm of TMT-B, consistent with Murray's (2012) argument that attentional and executive contributions to aphasia are best indexed through tasks that approximate the specific cognitive demands of language production.

The significant TMT-A and SVF relationship, points to processing speed as the primary EF-related predictor of verbal fluency productivity in PWA.

5.4.1.4 Absence of Discourse–EF Correlations:

While TMT-A showed significant correlations with SVF parameters in the PWA group, no significant correlations were observed between TMT parameter and discourse measures (CWF, MC, or %CIU) in either group. The absence of a TMT–discourse association requires interpretation.

One explanation for the pattern where TMT-A correlates with SVF but not with discourse may lie in the nature of the tasks themselves. The SVF task is a timed, structured, single-domain task requiring rapid and sustained lexical production within a fixed 60-second window. The temporal demands of this task may make it more sensitive to processing speed, such that slower processing directly reduces the number of items retrievable. Discourse production, by nature, is a less time-pressured, and a more open-ended task in which participants may compensate for slower processing by producing fewer words at a slower rate without reducing the informational content of what they say. The picture description task used in the present study did not impose a strict time limit, which may have allowed PWA to partially compensate for slowed processing during discourse in a way that was not possible during the timed SVF task.

A second interpretation is that discourse informativeness is more strongly governed by lexical-semantic access (as evidenced by the significant CR and MC correlation) than by executive control. Under this account, the absence of TMT-discourse correlations reflect the relative primacy of the lexical bottleneck in constraining discourse production, with processing speed playing a secondary, less direct role. This is consistent with the view that discourse involves multiple compensatory strategies and higher-level communicative planning that can partially buffer the effects of slowed processing, whereas verbal fluency output is more directly constrained by the rate of lexical access (Alyahya et al., 2021; Bose et al., 2022).

Taken together, processing speed, as indexed by TMT-A, is significantly related to verbal fluency productivity and switching in PWA. However, neither processing speed nor set-shifting indices correlate with discourse measures in either group, suggesting that EF contributions to discourse production are not adequately captured by TMT performance in the present sample.

5.4.2 Cluster-Level Correlations within PWA and NTA:

The cluster-level correlation analysis revealed a strikingly divergent pattern between PWA and NTA. In the PWA group, significant positive correlations were observed between NoS and MCS (rs = .607, $p < .05$), between NoS and WCP (rs = .573, $p < .05$), and a particularly strong correlation between MCS and WCP (rs = .939, $p < .001$). In the NTA group, none of these cluster-level parameters were significantly intercorrelated.

The very strong MCS-WCP correlation in PWA is particularly revealing. It indicates that, in aphasia, individuals who produce larger clusters also spend more time pausing within those clusters. This tight coupling suggests that within-cluster retrieval in PWA is a highly effortful, time-consuming process: as the cluster size grows, the temporal cost of accessing each successive item within the cluster increases proportionally. In NTA, by contrast, within-cluster retrieval appears to be a relatively automatic process that proceeds independently of cluster length, such that larger clusters do not incur proportionally greater within-cluster pausing. This dissociation is consistent with accounts of impaired automatic lexical access in aphasia, in which co-activated, semantically adjacent items require greater controlled retrieval effort to produce (Faroqi-Shah & Milman, 2018; Pham et al., 2025).

The significant NoS-MCS and NoS-WCP correlations in PWA further suggest that switching, clustering, and within-cluster pausing operate as a more tightly interdependent system in this population than in NTA. This may reflect a compensatory retrieval strategy in PWA, in which switching decisions are closely contingent on cluster exhaustion: as within-cluster resources become depleted (signalled by lengthening within-cluster pauses and shrinking cluster size), the probability of switching increases. In NTA, switching appears to be a more independently initiated process, less closely coupled to within-cluster dynamics (Bose et al., 2022; Troyer et al., 1997).

The absence of any significant cluster-level correlations in NTA is consistent with the interpretation that, in the context of intact lexical resources, clustering, switching, and retrieval pausing operate as functionally separable and relatively independent processes. The emergence of significant intercorrelations only in PWA therefore, points to a reorganisation of the retrieval system under conditions of impaired lexical access, in which the strategic and temporal components of fluency performance become more tightly linked as individuals struggle to maintain output.

Taken together, the correlation findings pertaining to Objective 4 indicate that the null hypothesis is partially rejected. Significant associations were observed within domains (SVF–SVF, discourse–discourse, EF–EF) and between domains (CR–MC in PWA; cluster parameters in PWA). The specific cross-domain association between SVF productivity and discourse informativeness in PWA, which is absent in NTA, represents the most clinically and theoretically novel finding of the present study, providing evidence for a lexical bottleneck model of discourse production in aphasia. The absence of significant EF–language correlations, while informative, underscores the need for future research employing more linguistically proximal measures of executive control in studies of aphasia.

CHAPTER VI

SUMMARY AND CONCLUSION

6.1 Summary

The present study aimed to understand discourse production in persons with aphasia (PWA) through semantic verbal fluency and executive function tasks. The study also aimed to examine the relationship among discourse production, semantic verbal fluency (SVF), and executive function (EF) performance in both groups- persons with aphasia and neurotypical adults (NTA)- with an emphasis on understanding the contribution of lexical-semantic and executive processes to discourse abilities in PWA.

The objectives of the study were: (1) to quantify discourse output on a picture description task using a predefined checklist of Main Concepts (MC), the total number of Content Words (CWF), and percentage of Correct Information Units (%CIU) between PWA and NTA; (2) to quantify SVF performance between PWA and NTA; (3) to assess executive control using the Trail Making Test (TMT-A and TMT-B) between PWA and NTA; and (4) to evaluate the correlation among discourse performance, SVF, and TMT in PWA and NTA.

Thirty participants took part in the study. The participants were divided into two groups. The first group consisted of 15 neurotypical adults (NTA), and the second group consisted of 15 persons with aphasia (PWA). All NTAs were age and education-matched with the PWA group. The age range of all participants spanned from 18 to 59 years. All participants had acquired aphasia following a single episode of left hemisphere stroke and were diagnosed with aphasia on a standardized aphasia test. Participants with other neurological illnesses, psychiatric disorders, a history of substance abuse, visual field deficits, or cognitive impairments were excluded from the study.

Three assessments were done in the study: discourse, semantic verbal fluency, and an executive function task. For the discourse assessment, participants did a picture description using a forest scene stimulus. Discourse outcome was quantified using three parameters: Main Concept Analysis (MC), Content Word Fluency (CWF), and percentage of Correct Information Units (%CIU). These parameters were used to understand discourse informativeness, lexical productivity, and efficiency of connected speech production.

Semantic Verbal Fluency was assessed using a generative naming task, in which participants were asked to say as many animal names as they could within 60 seconds. The SVF analysis was done at two levels. The quantitative analysis included Total Correct Responses (CR) and Number of Switches (NoS). The cluster analysis included Mean Cluster Size (CS), Number of Switches (NoS), Mean Within-Cluster Pause (WCP), and Mean Between-Cluster Pause (BCP). These parameters were used to examine lexical productivity, semantic organisation, switching ability, and the temporal aspects of lexical retrieval.

Executive function was examined using the Trail Making Test (TMT), comprising Part A and Part B. The total time to complete each part was recorded as TMT-A and TMT-B respectively. Also, the Trail Making Test Difference (TMT-D) and Trail Making Test Ratio (TMT-R) were used to understand cognitive flexibility, set-shifting ability, and processing speed.

All the parameters mentioned above were analysed under three sections: Section I: Descriptive Statistics, Section II: Between-Group Comparison (NTA vs PWA), and Section III: Correlation Analysis, conducted separately for PWA and NTA at the levels of quantitative analysis and cluster analysis.

The descriptive statistics revealed that the NTA group performed better than the PWA group across all three domains. In the discourse domain, NTA obtained a higher CWF scores than PWA. Similarly, for MC, NTA obtained a higher score than PWA. For %CIU, NTA performed better than PWA. This indicated that NTA produced more content words, more main concepts, and a higher proportion of informative content during the discourse task.

In the SVF domain, NTA performed better than PWA. Similarly, for NoS, NTA performed significantly better than PWA. A similar trend was observed for cluster analysis parameters, wherein, NTA scores were better than PWA. And higher WCP durations was observed for PWA. However, the PWA group had higher between-cluster pause (BCP) durations than the NTA group. Altogether, NTA performed better than PWA across all SVF parameters.

For the executive function domain, NTA performed better in all TMT parameters such as TMT-A, B, D and R. However, there was variability in the scores within the PWA group in all TMT parameters, indicating the heterogeneous executive function profiles characteristic of this population.

The between-group comparison using the Mann-Whitney U Test revealed statistically significant differences between NTA and PWA for all quantitative parameters. In the SVF domain, significant differences were found for CR and NoS. In the executive function domain, significant differences were found for TMT-A, TMT-B, and TMT-D. In the discourse domain, significant differences were found for CWF, MC, and %CIU, with NTA demonstrating better performance than PWA across all parameters.

For the SVF task cluster analysis, significant between-group differences were observed for NoS, CS, and WCP. However, no significant between-group difference was found for BCP. This finding revealed that while PWA showed impaired clustering, switching, and within-cluster retrieval compared to NTA, the between-cluster transition time did not differ significantly between the two groups.

The correlation analysis that was performed using Spearman's rank correlation indicated significant associations within and across domains.

For the PWA group, a positive correlation was found between NoS and CR, revealing that individuals who switched more also produced more correct responses in the SVF task. A significant positive correlation was also found between CR and MC, suggesting that higher lexical productivity in the verbal fluency task was associated with higher discourse informativeness in the picture description task. Within the executive function domain, a positive correlation was found between TMT-B and TMT-D. Within the discourse domain, CWF showed a positive correlation with MC, and MC had a significant positive correlation with %CIU. There were no significant correlations observed between TMT parameters and any of the SVF or discourse measures in the PWA group.

Importantly, the PWA group also showed significant negative correlations between TMT-A and SVF parameters: NoS and TMT-A and CR and TMT-A. This indicates that PWAs who were slower on the basic processing speed component of the TMT also produced fewer correct responses and fewer switches on the SVF task. These relationships were absent in the NTA group, where TMT-A did not significantly correlate with any SVF or discourse parameter. No significant correlations were observed between any TMT parameter and discourse measures in either group.

For the NTA group, a significant positive correlation was found between NoS and CR, TMT-A and TMT-B, TMT-B and TMT-D, CWF and MC, and MC and %CIU. Notably, the significant CR-MC and TMT-A- SVF correlations observed in the PWA group were absent in the NTA group.

The cluster-level correlation analysis revealed a strikingly divergent pattern between the two groups. In the PWA group, significant positive correlations were found between NoS and CS, NoS and WCP, and a strong correlation between CS and WCP. In the NTA group, no cluster-level parameters were significantly correlated. These findings reveal that in PWA, switching, clustering, and within-cluster pausing operate as a tightly coupled and interdependent system, reflecting effortful lexical retrieval. In NTA, these processes function as relatively independent processes.

To summarise, the key findings of the study were as follows. First, PWA performed significantly poorer than NTA across all discourse, SVF, and executive function parameters, confirming significant group differences in all three domains. Second, a significant positive correlation between CR and MC was observed exclusively in the PWA group, indicating a lexical bottleneck effect in which word retrieval efficiency directly limits discourse informativeness in PWA, a relationship absent in NTA, where lexical access is intact. Third, significant negative correlations between TMT-A and SVF parameters (CR and NoS) were found in the PWA group, indicating that slower processing speed was associated with reduced verbal fluency productivity. This relationship was absent for other TMT indices (TMT-B, TMT-D) and also absent with discourse parameters, suggesting that processing speed selectively limits timed lexical output but does not directly limit discourse informativeness. Fourth, within the PWA group, significant intercorrelations among cluster-level SVF parameters (CS, NoS, WCP) indicated a tightly coupled and effortful retrieval system in aphasia, a pattern absent in NTA. Fifth, BCP did not significantly differ between groups and was not significantly correlated with other cluster parameters in either group, suggesting that the temporal cost of transitioning between subcategories is relatively preserved in PWA.

6.2 Implications

The findings of the present study have important implications for clinical and theoretical understanding of aphasia.

From a clinical view, the finding of impaired discourse production in PWA across all three measures- CWF, MC, and %CIU highlights the importance of multi-dimensional discourse assessment. Since each measure examines a distinct aspect of connected speech, using CWF, MC analysis, and %CIU together is recommended for a comprehensive language assessment. The culturally adapted forest scene stimulus and Kannada-based scoring also demonstrate the feasibility of such assessment in Indian clinical settings.

The significant positive correlation between CR and MC in the PWA group suggests that SVF performance can serve as a quick and clinically efficient predictor of discourse informativeness. Clinicians can use a brief 60-second animal naming task not only to assess lexical retrieval but also to anticipate how informatively a person with aphasia is likely to communicate in connected speech without requiring time-consuming discourse transcription and scoring.

The significant negative correlation between TMT-A and SVF parameters (CR, NoS) in the PWA group adds an important clinical dimension. It indicates that processing speed assessed by TMT-A is related to verbal fluency productivity in aphasia. This finding suggests that TMT-A should not be treated solely as a baseline measure for computing TMT-D and TMT-R; it may independently signal the degree to which slowed cognitive processing is limiting a patient's word retrieval during timed language tasks. Clinicians should therefore consider assessing processing speed alongside language measures, as reduced processing speed may add to lexical access difficulties and limit overall verbal output in PWA.

The findings also highlight the importance of incorporating executive function assessment into the routine clinical evaluation of PWA. The substantial impairment documented across all TMT parameters in the PWA group demonstrates that executive deficits are consistently present in post-stroke aphasia. Clinicians should assess executive function as a distinct domain, as residual executive deficits may constrain recovery and limit the effectiveness of language-focused rehabilitation.

From a theoretical perspective, the significant CR-MC correlation observed exclusively in PWA supports a lexical bottleneck model of discourse production in aphasia, in which the efficiency of word retrieval constitutes a rate-limiting factor for the informativeness of connected speech. In NTA, where lexical resources are intact, discourse informativeness is not limited by fluency productivity. The selective TMT-A–SVF relationship further reveals that processing speed limits verbal fluency productivity in aphasia. The absence of this relationship in NTA confirms that processing speed only becomes a limiting factor when it is substantially impaired, as in the present PWA group. Together, these findings indicate that the communication difficulties of PWA arise from an interaction between lexical access deficits and reduced processing speed, with each domain exerting its influence at a different level of language performance.

6.3 Limitations and Future Directions

Some methodological limitations of the present study must be acknowledged. First, the sample size of 15 participants per group is modest, which may have limited statistical power to detect small-to-moderate correlations, particularly those involving executive function measures.

Future studies employing larger samples would allow for more robust generalisation of the present correlation findings.

Second, the cross-sectional design of the present study precludes causal inferences. It is not possible to determine, on the basis of the present data, whether impaired verbal fluency is causally antecedent to reduced discourse informativeness or whether both constructs are independently constrained by a shared underlying deficit. Longitudinal designs tracking changes across the course of recovery would help elucidate the directional nature of these relationships.

Finally, the study did not include measures of specific lesion characteristics (e.g., lesion volume, lesion location), which are known to influence both language and executive function outcomes. Incorporating these variables as covariates or stratification factors in future analyses would provide important context for interpreting the present finding.

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APPENDIX A

Informed Consent

ಈ ಅಧ್ಯಯನದಲ್ಲಿ ನಡೆಯುವ ವಿಧಾನಗಳ ಬಗ್ಗೆ ನನಗೆ ವಿವರವಾಗಿ ತಿಳಿಸಲಾಗಿದೆ. ಈ ಅಧ್ಯಯನದಲ್ಲಿ ಭಾಗವಹಿಸುವುದರಿಂದ ಉಂಟಾಗಬಹುದಾದ **ಅಪಾಯಗಳು ಮತ್ತು ಪ್ರಯೋಜನಗಳು** ನನಗೆ ಸ್ಪಷ್ಟವಾಗಿ ತಿಳಿದಿವೆ.

ನಾನು ಈ ಅಧ್ಯಯನದಲ್ಲಿ ಭಾಗವಹಿಸಲು **ನಿರಾಕರಿಸುವ ಹಕ್ಕು** ನನಗಿದೆ ಎಂಬುದನ್ನು ತಿಳಿದಿದ್ದೇನೆ. ಹಾಗೆಯೇ, ನಾನು ಯಾವಾಗ ಬೇಕಾದರೂ ನನ್ನ **ಒಪ್ಪಿಗೆಯನ್ನು ಹಿಂಪಡೆಯುವ ಹಕ್ಕು** ಹೊಂದಿದ್ದೇನೆ.

ಈ ಅಧ್ಯಯನದಲ್ಲಿ ಭಾಗವಹಿಸುವುದರಿಂದ, ಸಂಶೋಧನಾ ತಂಡದಿಂದ ಕೆಲವು ಪರೀಕ್ಷೆಗಳು ನಡೆಸಲು ನಾನು **ಸ್ವಲ್ಪ ಹೆಚ್ಚು ಸಮಯ ನೀಡಬೇಕಾಗಬಹುದು** ಎಂಬುದನ್ನು ನನಗೆ ತಿಳಿಸಲಾಗಿದೆ. ಈ ಪರೀಕ್ಷೆಗಳು ನನಗೆ ನೇರವಾಗಿ ಯಾವುದೇ ಪ್ರಯೋಜನ ನೀಡದೇ ಇರಬಹುದು ಎಂಬುದನ್ನೂ ನಾನು ತಿಳಿದಿದ್ದೇನೆ.

ಈ ನಿಯಮಗಳನ್ನು ಯಾರಾದರೂ ಉಲ್ಲಂಘಿಸಿದರೆ, ನಾನು **AEC ಅಧ್ಯಕ್ಷರಿಗೆ (Chairman, AEC)** ಪತ್ರ ಬರೆಯುವ ಸ್ವಾತಂತ್ರ್ಯ ಹೊಂದಿದ್ದೇನೆ. ಅದರಿಂದ ಈ ಸಂಸ್ಥೆಯಲ್ಲಿ ನನಗೆ ಸಿಗಬೇಕಾದ **ವೈದ್ಯಕೀಯ ಸೇವೆಗಳು ಅಥವಾ ಹಕ್ಕುಗಳು ಯಾವುದೇ ರೀತಿಯಲ್ಲಿ ತಪ್ಪಿಸಲಾಗುವುದಿಲ್ಲ** ಎಂಬುದನ್ನೂ ನನಗೆ ತಿಳಿಸಲಾಗಿದೆ.

ನಾನು, ______________________________________
(ಕೆಳಗೆ ಸಹಿ ಮಾಡುವ ವ್ಯಕ್ತಿ), ಈ ಅಧ್ಯಯನ / ಸಂಶೋಧನೆ / ಕಾರ್ಯಕ್ರಮದಲ್ಲಿ **ಪಾಲ್ಗೊಳ್ಳಲು ನನ್ನ ಒಪ್ಪಿಗೆಯನ್ನು ನೀಡುತ್ತೇನೆ**.

ಪೋಷಕರ / ಸಂರಕ್ಷಕರ ಸಹಿ
(ಹೆಸರು ಮತ್ತು ವಿಳಾಸ)

APPENDIX B

Quantitative and Cluster Analysis for Discourse, semantic verbal fluency, and executive functions tests.

Main Concept Analysis Scoring Protocol

The scoring of each main concept was performed according to the following criteria:

1. Accurate and Complete (AC)

The main concept was produced with all essential information and conveyed accurately.

Score: 3

2. Accurate but Incomplete (AI)

The main concept was produced accurately but lacked one or more essential elements.

Score: 2

3. Inaccurate but Complete (IC)

The main concept contained all required elements but included inaccurate information.

Score: 2

4. Inaccurate and Incomplete (II)

The main concept was partially produced and contained inaccurate information.

Score: 1

5. Absent (AB)

Inaccurate main concept and information

Score: 0

Forest Scene Example:

Target Main Concept- *A monkey is sitting on a tree branch.*

AC (3) = A monkey is sitting on the branch of the tree.

AI (2) = A monkey is sitting.

IC (2) = A squirrel is sitting on the branch.

II (1) = An animal is there.

AB (0) = No mention of the monkey.

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