**

**A Remote Malay Executive Function Assessment for People with Aphasia: Evidence from Healthy Malay Speakers**

Zhamayne Fakharuzi

A thesis submitted in partial fulfilment of the requirements for the degree of

Doctor of Philosophy

The University of Sheffield

School of Allied Health Professions, Nursing and Midwifery

Faculty of Health

February 2024

*Psychometric tests have been developed in some specific cultures and are strongly biassed by the modal culture values observed in these cultures. Nonetheless, these specific values and behavioural styles do not necessarily represent universal values and behaviours. Understanding these cultural assumptions, and developing assessment procedures correctly tailored to other cultures, represents a major endeavour for twenty-first century neuropsychology.*

— Ardila, 2005: p.193

**Acknowledgements**

I owe my greatest gratitude to my supervisors, Professor Patricia Cowell, and Dr Ozge Ozturk, for their continued support and enthusiasm throughout this project. I consider myself fortunate to have in my supervisors exceptional experts and female role models in Health Science. Their deep insights and passion in research are truly inspiring, and I aspire to follow in their footsteps one day.

To the MARA committee who granted me the doctoral funding and made this enriching experience possible.

To Dr Rhianan Ellis, Dr Rebecca Dennis and Dr Gareth Walker, who introduced me to the fulfilling world of teaching, from which I gained invaluable knowledge and insights.

To my PhD peers, Dalal, Deya, Meryem, Pascal, Sarah, Tugay, and Xinxin, my heartfelt gratitude for your support and friendship. It has been a real pleasure to have your companionship as a constant source of motivation throughout my PhD.

To all my participants, for helping me learn as much about life as I did about my research. Without your willingness to participate, my thesis would not have been possible.

To Mama and Baba, your unwavering commitment to our education has made a profound impact on my academic journey. Thank you for your examples of perseverance, of which has shaped my path.

To Irene, Sheila, and Zandria - for your constant motivation, support and love through the highs and lows of this academic journey. I am fortunate to have such strong, inspiring women as my sisters.

And finally, to Dave for showing me firmness of purpose in life and for your patience and unwavering love.

*Zhamayne Fakharuzi*

*London, December 2024*

**Abstract**

**Introduction**

Executive functions (EF), also known as executive control or cognitive control, encompass a set of top-down cognitive processes essential for activities requiring sustained attention. There is strong evidence that EF impairments commonly co-occur in aphasia and influence language profiles and outcomes (Murray, 2012; Villard & Kiran, 2016; Penn et al., 2016). Such relations between language abilities and cognitive functions (EF) are to be expected given the interrelationships among both processes. Thus, the implication of EF abilities in people with aphasia (PWA) should be considered within the context of understanding PWA cognitive profile and the clinical management of aphasia (Murray, 2017). Therefore, the measurement of EF should form a crucial part of clinical and research in understanding PWA. However, there remains significant gaps in assessing EF in different linguistic populations because many EF tests are mainly developed in Western countries for English speakers (Amunts et al., 2021; Kusi-Mensah et al., 2022).

**Research aim**

The aim of this thesis is to develop a Malay Executive Function Test Battery (M-EF) for future use with people with aphasia (PWA) through (i) developing healthy performance baseline data for the M-EF battery from younger and older Malay-speaking adults, and (ii) considering M-EF performance measures in relation to published norms for comparable tasks in other languages.

**Methods**

In Study 1, ten speech and language therapists (SLTs) based in Malaysia participated in a questionnaire survey to understand the current provision of EF assessment in Malaysia and clinicians’ perspectives on using remote assessment tools.

In Study 2, fifty-one healthy younger adults and twenty healthy older adults took part in the M-EF assessment, consisting of three verbal EF tasks, Verbal Fluency Test (VFT), Digit Span (DS), Malay-Hayling Sentence Completion Test (M-HSCT) and 1 non-verbal EF task (SFT). Number of correct responses were measured in each task and response time was measured for one verbal EF task, M-HSCT.

**Results**

In Study 1, it was found that the options of test batteries available in Malay are limited and the majority of SLTs are delivering EF tests in the English language. The number of remote assessments carried out was limited due to lack of standardised assessment tools for usage in remote settings and poor internet connectivity on the patient's end.

In Study 2, the group level comparisons between the younger and older participants demonstrated the existence of age-related declines in the verbal tasks DS, VFT and HSCT. For the non-verbal EF task (SFT), the healthy older adults group performed slightly better than the younger group. The pattern of performance across the three verbal component tasks (DS, VFT, M-HSCT) showed similar results to previous cross-linguistic studies in healthy adults.

**Conclusion**

Results from Study 1 suggest that there is an immediate need for a validated EF assessment tool which can improve practicality of usage by clinicians and addresses accessibility in terms of culture, language, and physical location.

Findings from Study 2 confirms the presence of age-related decline in healthy Malay speakers across the EF domains comparable to performance in other linguistics groups. Importantly, this research extends the number of available EF assessments for a new linguistic and cultural group as well as enables the future usage of the normative data gathered with PWA.

**\*\*\*\*\*\***

**Table of Contents**

|  |  |
| --- | --- |
| **Acknowledgement**  **Abstract** | *iii*  *iv* |
| **Chapter 1 Executive Function and Language**  **1.1 Frontal Lobe and Executive Functions**  **1.1.1 Behavioural Observations of Frontal Lobe Patients**  **1.1.2 Neuropsychological Assessment of Frontal Lobe Patients**  **1.1.3 Summary of Frontal Lobe Research**  **1.2 Defining Executive Functions**  **1.2.1 Models of Executive Functions**  **1.2.2 Bridging Different Definitions of Executive Functions**  **1.2.3 Importance of Defining EF to the Present Study**  **1.3 Executive Function and Language in Healthy Population**  **1.3.1 EF and Language Processing in Adults**  **1.3.2 EF and Language Processing in Older Adults**  **1.4 Executive Function and Language in Atypical Population**  **1.4.1 EF and Language in Age-Related Acquired Language Disorders**  **1.4.2 EF and Language in Traumatic Brain Injury (TBI)**  **1.4.3 EF and Language in Aphasia** | 1  2  4  6  8  8 - 13  13  17  17  18  19  22  22  24  26 |
| **Chapter 2:  Aphasia, Language and Executive Function**  **2.1 Aphasia**  **2.1.1 Types of Aphasia: From a Neurolinguistics and Aphasiology Perspectives**  **2.1.2 Bilingual Aphasia**  **2.2 Relationship between Executive Function and Language in Aphasia**  **2.2.1 Evidence of Executive Function Deficits in Aphasia**  **2.2.2 EF and Language Behaviour**  **2.2.2.1 Language Processing**  **2.2.2.2 Communication**  **2.2.3 EF and Response to Treatment in Aphasia**  **2.3 The Malaysia Context: Aphasia and Language**  **2.3.1 Aphasia Research in Malaysia**  **2.3.2 Linguistic features of Malay**  **2.3.3 Malay Culture** | 30  32 - 36  37  40  41  43  47  49  51  53  54 |
| **Chapter 3 Executive Functions Assessment and Considerations for PWA and Culturally Diverse Populations**  **3.1 EF Assessments and Measurement of EF Domains from Aphasia Studies**  **3.1.1 Summary of Common EF Tests in Aphasia Studies**  **3.1.2 Assessment Consideration for Assessing EF in PWA**  **3.2 Other relevant considerations for assessing EF in PWA**  **3.2.1 Mode of delivery of EF Assessment**  **3.2.2 Assessment of EF in Different Languages and Cultures**  **3.2.3 Considerations for Translation and Cultural Adaptation of Executive Functions Test Battery**  **3.3 The Present Study: Selected EF tests** | 56  56  63  65  65  68  71  72 |
| **Chapter 4: Study 1 Questionnaire Consultation with SLTs**  **4.1 Questionnaire Design**  **4.2 Methods**  **4.2.1 Participants recruitment, consent, and ethics**  **4.2.2 Design**  **4.2.3 Materials**  **4.2.3.1 Screening survey**  **4.2.3.2 Questionnaire**  **4.2.3.3 Data analysis**  **4.2.4 Results**  **4.2.5.1 Participants’ Background**  **4.2.5.2 Familiarity with the term EF**  **4.2.5.3 Identifying current usage of EF assessment with PWA**  **4.2.5.4 The need for Malay EF test battery**  **4.2.5.5 Opinion on Malay EF test battery**  **4.2.5.6 Telehealth practices in Malaysia**  **4.2.5.7 Opinion on telehealth services**  **4.3 Discussion**  **4.3.1 Limitations and future research**  **4.4 Conclusion** | 76  78  78  79  80  80  81  82  82  82  84  86  86  88  91  93  95  95 |
| **Chapter 5: Development of the Malay Language Executive Function Test (M-EF)**  **5.1 Introduction**  **5.1.1 Preparation of data from Study 1**  **5.1.2 Study 2: design and research aims**  **5.2 Development of Malay Executive Function Assessment (M-EF)**  **5.2.1 Verbal Measures of Executive Function**  **5.2.1.1 Verbal Fluency Test (VFT)**  **5.2.1.2 Malay Hayling Sentence Completion Test (M-HSCT)**  **5.2.1.3 Digit Span Forward and Backward**  **5.2.2 Non-Verbal Measures of Executive Function**  **5.2.2.1 Spatial Fluency Test (SPT)**  **5.3 Inter-rater reliability test**  **5.3.1 Participants**  **5.3.2 Procedure**  **5.3.3 Result**  **5.3.3.1 Demographics**  **5.3.3.2 Performance on EF tests**  **5.3.4 Discussion**  **5.3.4.1 Implication on the M-EF battery development**  **5.3.4.2 Patterns of performance in the M-EF battery** | 97  97  98  99  101  101  104  132  136  136  137  137  138  138  140  144  144  144 |
| **Chapter 6: M-EF Assessment: Normative Data from Malay Speaking Healthy Young Adults**  **6.1 Introduction**  **6.2 Method**  **6.2.1 Assessment procedure**  **6.2.2 Recruitment Procedure**  **6.2.3 M-EF Assessment Procedure**  **6.2.4 Data analysis framework and procedure**  **6.3 Results**  **6.3.1 Demographic characteristics**  **6.3.2 M-EF Performance Score**  **6.3.3 Underlying cognitive domains for the M-EF tasks**  **6.3.3.1 Correlations within tasks**  **6.3.3.2 Correlation between tasks**  **6.4 Discussion**  **6.4.1 Individual task performance and correlation within-tasks**  **6.4.2 Correlation between-tasks** | 146  146  146  146  147  148  148  150  150  152  155  155  159  162  163  170 |
| **Chapter 7: M-EF Assessment: Normative Data from Malay Speaking Healthy Older Adults**  **7.1 Introduction**  **7.2 Method**  **7.2.1 Participants**  **7.2.2 Ethics and consent**  **7.2.3 Assessment procedure**  **7.2.4 Data analysis**  **7.3 Results**  **7.3.1 Demographic characteristics**  **7.3.2 M-EF Performance Score**  **7.3.3 Correlations within tasks**  **7.3.4 Correlations between tasks**  **7.4 Discussion**  **7.4.1 Individual task performance and correlation within-tasks**  **7.4.2 Correlation between-tasks** | 171  171  172  172  173  173  173  174  174  175  179  183  186  186  193 |
| **Chapter 8: General discussion**  **8.1 Discussion of results from PPI questionnaires in Study 1**  **8.2 Summary of findings from Study 2**  **8.3 Discussion of results comparing the M-EF performance of younger and older Malay speakers**  **8.3.1 Discussion of results comparing younger and older participants**  **8.3.2 Discussion on comparison of correlations between-tasks in the younger and older participants**  **8.4 Implications of the current study**  **8.4.1 Novel findings and Strengths of Research**  **8.4.2 Research limitations**  **8.4.3 Future directions**  **8.4.3.1 Research implications**  **8.4.3.2 Clinical implications**  **8.5 Conclusion** | 196  197  199  200  201  208  211  211  212  213  213  214  215 |
| **References**  **Appendix** | 216-239  240 - 276 |

**Chapter 1 Executive Function and Language**

This chapter begins with an introduction to executive function (EF), which is the key element in the present study. A brief overview of early frontal lobe studies is presented, aiming to show how frontal functions are linked to the control mechanism of EF. This is followed by a discussion on different EF models and the association to the adopted definition of EF that shapes the present study. While the remaining part of this chapter presents the link between EF and language profile in different populations by evidencing how (a) EF supports access to and processing of linguistic knowledge and (b) how EF deficits are associated with and attributed to language impairment in clinical groups.

**1.1 Frontal Lobe and Executive Functions**

The main aim of this section is to unravel the origin of executive functions as psychological constructs, which can be achieved by discussing the historical linkage between frontal lobe studies and EF. A comprehensive review of frontal studies is however beyond the scope of this paper, therefore in this chapter the key behavioural and cognitive studies of frontal patients and their findings were selected for review. The first two subsections present a brief chronological overview of frontal lobe research which demonstrates the role of frontal lobe in providing control mechanisms for human behaviours, emotions, and cognition These studies began as a means of understanding frontal lobe functions, which incidentally became the groundworks that elucidated the concept of EF. *Section 1.1.1* describes how early frontal lobe studies began with behavioural observations of patients with frontal lobe injuries. *Section 1.1.2* discusses the shift from behavioural observations to neuropsychological assessments of frontal patients. Finally, *Section 1.1.3* summarises decades of frontal lobe research findings from several review papers, which evidently point towards the conceptualisation of executive function. The summary is framed to reflect the development of frontal studies in identifying ‘frontal lobe syndrome’, a term often used interchangeably with executive function (Godefroy, 2003).

**1.1.1 Behavioural Observations of Frontal Lobe Patients**

Early work to understand executive function (EF) primarily expanded from the observation and assessment of patients with frontal lobe lesions (Alvarez & Emory, 2006; Goldstein et al., 2014). One of the first observations contributing to the understanding of frontal lobe symptoms was given by Harlow in 1848 (cited in O’Driscoll & Leach, 1998). In his report, Harlow described marked personality change and animal propensities observed in a patient, Phineas Gage who suffered damage to his frontal lobe. Following Harlow's (1868) report, other lesion studies continue to document personality and behavioural characteristics in frontal lobe patients which later came to be known as the “frontal lobe syndrome” (cited in O’Driscoll & Leach, 1998).

By the late 19th century, several clinical reports documented diverse behavioural disorders in relation to frontal lobe pathology. In 1888, Welt published an extensive account of a patient who suffered penetrating frontal injury following a fall (cited in Wagner & Heatherton, 2017). Five days post-trauma, Welt observed significant change in the patient’s behaviour characterised by aggression and insensitive actions. After her patient’s death, the autopsy report disclosed trauma to the mesial region of the frontal lobe. Welt went on comparing this result with eight other brain trauma autopsied reports, proposing that this behavioural disturbance is the result of lesion to the orbital and mesial region of the frontal lobe (cited in Wagner & Heatherton, 2017).

In the same year, Jastrowitz (1888) observed behavioural symptoms of a patient, Panjas, who was initially diagnosed with epilepsy and incurable mental illness (cited in Erickson et al., 2016). Based on the observation, Panjas manifested pathological giddiness and inappropriate euphoria which Jastrowitz termed as ‘moria’. In addition, Panjas at times exhibit episodes of aggression and agitation which last for approximately 15 minutes. Following Panjas’s death, an autopsy report revealed a large tumour in his frontal lobe. The autopsy findings led Jastrowitz to observe 12 other cases of frontal lobe disease and found similar symptoms of moria across all cases. Jastrowitz concluded that moria is not exclusive to frontal lobe tumours but may also accompany other diseases affecting the frontal lobe. Jastrowitz further confirms that symptoms of moria are not observed in studies of lesions or tumours involving other brain regions (cited in Erickson et al., 2016). On a similar account in 1890, Oppenheim investigated behavioural manifestation in four right frontal tumour patients and identified common symptoms of addiction to trivial and excessive jokes among all the patients. He coined the term ‘witzelsucht’ to describe this symptom of addiction to jokes. Like Jastrowitz, Oppenheim suggests that witzelsucht is a distinct characteristic of frontal lobe disease (cited in Erickson et al., 2016).

Although the frontal lobe symptomatology reviewed thus far were observed for the most part in frontal tumour patients, all three patients’ cases reviewed (Welt, 1888, cited in Wagner & Heatherton, 2017; Jastrowitz, 1888; Oppenheim, 1890, cited in Erickson et al., 2016) concur that these behavioural disorders *(aggression, moria, witzelsucht)* accompany other conditions involving the frontal lobe. Welt (1888), however, specifically associated the orbital and mesial region to manifestation of frontal lobe symptoms (cited in Wagner & Heatherton, 2017). Welt’s (1888) initial attempts at localising behavioural disturbances to a focal region within the frontal lobe has set the preliminary ground for defining “frontal lobe syndrome” which continued extensively in the 1900s (Benton, 1991).

The term “frontal lobe syndrome” was first conceptualised by Feuchtwanger (1923) in the earliest work comparing behavioural changes in frontal and non-frontal injured patients (cited Ardila, 2008). According to Ardila (2008), Feuchtwanger proposed that frontal lobe pathologies were associated with behavioural disturbances that are not directly related to memory, speech, or sensorimotor deficits. In his observation of 200 veterans with penetrating frontal lesions and 200 with non-frontal damage, Feuchtwanger found lack of attention, impulsivity and unstable emotions exhibited by most frontal patients. He emphasised that behavioural changes related to frontal lobe trauma are associated with motivation and emotions (cited in Ardila, 2008). Findings from this comparison study also corroborates the behavioural changes associated with frontal tumour patients as described in 1888 by Jastrowitz and in 1890 by Oppenheim. Furthermore, Feuchtwanger’s (1923) comparison study contributed significantly to the characteristics of frontal lobe syndrome, indicating the absence of specific behavioural change in non-frontal patients. Overall, behavioural observation of frontal patients either as a consequence of trauma or neoplasm up to this point have established that frontal lobe damage may produce marked emotional changes, reduced attention and loss of interest in patients of this group, symptoms which are absent in non-frontal patients.

In 1944, Goldstein expanded the concept of frontal lobe syndrome to include disturbance in abstract attitude - which correlates to mental flexibility and initiation. According to Goldstein (1944) impairment in abstract attitude is sensitive to frontal lobe damage and is not manifested ‘purely’ in non-frontal patients. Goldstein further argues that the indication of emotional and intelligence impairment in an individual should not be considered as the primary defects in frontal lobe patients. This is because emotional and intelligence impairments are obvious deviations from the norm which makes these traits easily identifiable and thus easily misdiagnosed in frontal lobe patients. Up to this point in time, frontal lobe lesions had been characterised by a wide-spectrum of behavioural and cognitive changes which are not observable in non-frontal patients. As a result of these findings, numerous intelligence and neuropsychological assessments were constructed and used to assess frontal lobe functions, such as sorting and categorising tasks: sorting tasks (Weigl, 1927; Goldstein & Scheerer, 1941), Halstead Category Test (Halstead, 1940, , Wisconsin Card Sorting Test (Grant & Berg, 1948; Milner, 1963; Heaton, 1981) and planning and trail making tasks: Porteus Maze Test (Porteus, 1950); Trail Making Test (Reitan, 1971). Although some of these tests are not developed for assessing frontal lobe per se, the application with frontal lobe patients suggests its sensitivity to frontal lobe pathology. The next section will review some of the assessment outcomes in frontal lobe patients.

**1.1.2 Neuropsychological Assessment of Frontal Lobe Patients**

The diversity of symptoms reported in frontal patients led to the development of several tests, which were designed to tap into the frontal lobe function. Henceforward, studies to understand frontal lobe symptoms expanded from behavioural observations to include standardised intelligence and neuropsychological assessments.

One of the earliest frontal studies that compared IQ performance pre- and post- operative was conducted by Brickner (1934, 1936). In a case study of a brain tumour patient, Brickner (1934, 1936) contrasted a patient’s behaviour and IQ performance pre-surgery and one month post removal of his meningioma. Behavioural observation indicates the patient exhibited aggression, impulsivity and addiction to trivial jokes which are not present before the operation. These behavioural observations corresponded to symptoms observed in previous studies of frontal tumour patients (Jastrowitz, 1888; Oppenheim, 1890 cited in Erickson et al., 2016). In addition, when comparing the patient’s IQ performance pre- and post-operation, Brickner (1934) reported a significant decline in IQ performance one-month post-surgery. In terms of cognition, Bricker noted that the patient showed difficulty engaging in abstract reasoning and rational thinking. Based on the observations and test administered, Brickner (1934, 1936) concluded that decrease in IQ performance, difficulty engaging in complex tasks and impaired abstract reasoning are indications of frontal lobe lesions.

Besides measures of IQ, neuropsychological assessments were also administered to brain lesioned patients to investigate frontal lobe functions. In 1964, Milner introduced the Wisconsin Card Sorting Task (WCST) to compare the sorting ability of frontal and non-frontal patients. All 94 subjects characterised with varying known brain surgical excision location had undergone brain surgery for the treatment of epilepsy. Seventy-one patients were assessed both before and after surgery while 23 patients were assessed post-surgery only. It was found that dorsolateral frontal patients performed more poorly than non-frontal patients during the sorting tasks. Based on the results obtained, Milner (1964) further concluded that the ability to shift from one sorting rule to the other is impaired in frontal patients due to the perseverative interference of the previous sorting rule imposed.

Another neuropsychological test often used to assess frontal patients is the verbal fluency test (Milner, 1964; Benton, 1968; Baldo & Shimamura, 1998; Baldo et al., 2000). This test measures the patient's ability to generate words based on a given cue. In most cases, there are two types of cues, phonemic (e.g., words beginning with the letter A) and semantic/category (e.g., words belonging to the group of animals). In 1998, Baldo and Shimamura compared the performance of frontal patients with healthy controls on FAS letter fluency and category test. The fluency tests were administered to twelve patients with unilateral frontal damage and twelve age-matched healthy controls. Findings showed that patients with frontal damage exhibited significant impairment on both letter and category fluency tests compared to the control group. In addition, the study found no performance difference between types of fluency tasks (letter vs. category) in the patient group, Hence, the authors concluded that the frontal lobe is necessary for both phonemic and semantic retrieval of words. Furthermore, Baldo and Shimamura (1998) suggest that the frontal lobe plays an important role in inhibitory control and monitoring of the working memory as depicted in the performance of both groups in the fluency tests.

As a result of various evidence pointing towards cognitive impairment in frontal patients (Milner, 1963; Baldo & Shimamura, 1998), it gradually became a prominent topic in frontal lobe studies. Consequently, more studies began assessing specific cognitive processes in frontal patients such as attention (Wilkins e al., 1987) and working memory (Owen et al., 1990). In a study investigating the correlations between frontal lobe lesion and sustained attention, Wilkins and colleagues (1987) found the performance of frontal-damaged patients was relatively slower than patients with non-frontal lesions in responding to a series of stimuli presented in the three different tests (1) auditory clicks, (2) tactile pulses on right index finger and (3) tactile pulses on left index finger (1987). The same experiment was replicated in another patient sample and confirmed similar findings. In the replication study, frontal patients exhibited impaired ability across the tasks requiring sustained attention (Wilkins et al., 1987). Thus, the study suggests the association between frontal lobe and the ability to sustain attention. In another study, Owen and colleagues compared the performance of 26 frontal lobe patients with healthy controls using a computerised version of the Tower of London test to measure working memory and planning ability (1990). It is found that frontal lobe patients took significantly longer to complete the task compared to the healthy group. From the findings, Owen et al., (1990) suggest that frontal damaged patients experience difficulties in evaluating problems and generating solutions, which are not manifested by the healthy group. Both studies (Wilkins et al., 1987; Owen et al., 1990) established the premise that damage to the frontal lobe has negative effects on attention, memory and problem solving/reasoning skills.

In summary, the initial effort to understand the frontal lobe through behavioural observations and subsequent neuropsychological assessments has led to an increased understanding of the frontal functions. Throughout the decades, these studies have collectively identified the complex functions of the frontal lobe and its involvement in regulating behaviours, emotions and cognitive processes. Due to the significant number of frontal research, several efforts to succinctly categorise frontal pathology were put forward. Thus, the following section will briefly summarise the findings of frontal research described in several review papers.

**1.1.3 Summary of Frontal Lobe Research**

Beginning in the mid-19th century, several authors reviewed the myriad frontal lobe studies to identify the common frontal pathology. In a review paper, Luria (1969; translated version in Vinken & Bruyn, 2012) reviews several accounts of patients with frontal lobe lesions and identifies three distinctive symptoms: (1) disturbance in organised, goal-directed behaviour (2) emotional disturbances and (3) lack of self-awareness. Luria (1969) regards the “frontal lobe syndrome” as specific to symptoms of frontal lesions and are distinguishable from the symptoms following non-frontal injuries. Additionally in another review paper, Stuss and Benson (1984) identified six prefrontal functions extracted from multiple frontal lobe studies, which includes the ability to handle sequential action, ability to monitor personal behaviour and ability to handle interference. The highlights of frontal lobe syndrome identified in the work of Luria (1969) and Stuss and Benson (1984) are that these frontal functions described are parallel to aspects of executive function, which were only used several years later.

Although the term ‘executive function’ was not used in either paper (Luria, 1969; Stuss & Benson, 1984), frontal functions described by the authors correspond to cognitive processes conceptualised in the different definitions of executive functions we know today (Diamond, 2013; Sira & Mateer, 2014; Cristofori et al., 2019). Interestingly, the concept of executive function (EF, henceforth) predates the coinage of the term executive function. The first usage of the term ‘executive’ was attributed to Pribram (1973), who wrote:

*The frontal cortex appears critically involved in implementing executive programs when these are necessary to maintain brain organisation in the face of insufficient redundancy in input processing and the outcomes of behaviour (p. 312)*

The term ‘executive’ used by Pribram (1973) at the time was tied to the then-view of the frontal lobe as the main cerebral region regulating human cognition and behaviour. However, it is important to note that no single part of the brain works in isolation. Recent evidence indicates that executive functioning is the by-products of different brain regions operating and interacting together. The issue of EF and brain localisation, however, will not be discussed further in this paper as it is less pertinent to the scope of the current study.

The discussion so far suggests that the conceptualisation of executive functions have been significantly driven by observation and assessment of frontal lobe patients, who became unable to monitor their behaviours/emotions and showed reduced ability to process and respond to internal and external stimulus. The history of frontal lobe studies discussed is necessary to lay down the origination of EF constructs. Over the years, various EF models have been proposed in the effort to define the term EF and its domains. The next section revisits several models of EF and demonstrates how these EF models represent the present study understanding and appreciation of EF.

**1.2 Defining Executive Functions**

To date, there exist more than 30 different definitions of EF (Goldstein et al., 2013), however, none has been universally adopted as the core definition of EF. One of the reasons for lack of agreement in defining EF is the various EF models and definitions proposed, leading to the investigations of EF moving into different directions (Hunter & Sparrow, 2012). Despite the plethora of EF definitions, there seem to be common themes shared among all of them. Therefore, the following subsections aim to capture the common, shared concepts of EF. First, *Section 1.2.1* briefly discusses the different EF models and its concepts. *Section 1.2.2* highlights three aspects of commonality from the postulated EF models and presents several EF definitions matching with the shared constructs identified. Finally, *Section 1.2.3* presents a brief note highlighting the importance of defining EF for the present study.

**1.2.1 Models of Executive Functions**

Several conceptual models of EF have attempted to define EF and the components; however, the definition of EF remains far from a consensual proposition among researchers (Salthouse, 2005). Despite the lack of agreement, several studies have attempted to classify different EF models based on the shared notions (Garon et al., 2008; Stezler et al. 2014). These common characteristics are the guiding tool to operationally define EF. Besides echoing the work of Goldstein et al. (2013) and McCloskey and Perkins (2012), seeking unity within the diverse definitions of EF seems a reasonable approach to understanding this complex concept, EF. Thus, in this section, a selection of EF models containing the shared, overlapping concepts of EF domains will be presented. Subsequently, *Section 1.2.2* concludes by demonstrating how the adopted EF definition emerges from the dynamic theories discussed.

**(a) Filter Model**

In 1953, Broadbent proposed the filter model to describe the process of directing attention to relevant input while ignoring irrelevant, competing stimuli in the environment. It is important to note that not all psychologists would place Broadbent’s work as a precursor of EF. Goldstein et al., (2013) described the automatic and controlled processes discussed by Broadbent (1953) as a notion closely related to selective attention in EF. Using dichotic listening tasks, Broadbent demonstrated his notions of ‘attentional filter’. According to this model, there are two processes involved during information processing. In the first phase the auditory stimuli presented are received in the sensory buffer; a system serves as a filter that distinguishes between relevant and irrelevant information. In the sensory buffer, inputs are filtered based on physical characteristics of the stimuli, for example, speaker’s gender or the type of sound. At this stage, relevant input is selected, and all irrelevant information is inhibited. The selected input then travels to the perceptive system, where the meaning of the input is extracted and matched to the appropriate response. According to Broadbent (1953), this filtering process prevents the information-processing system from being overwhelmed with unnecessary information as irrelevant inputs are inhibited early in the system. A major contribution of Broadbent’s model is that it was one of the early theories attempting to describe the selective attentional system. In short, this model introduced the notion of selective attention and automatic and controlled processes which is closely related to the concept of executive functioning.

**(b) Controlled Information Processing**

The distinction between automatic and controlled processes was refined by Shiffrin and Schneider (1977), who proposed a dual-processing model to explain detection, search and attention phenomena. In the set of companion papers published by these researchers, they outlined two information-processing mechanisms: (i) automatic process and (ii) controlled process. The authors define automatic process as activation of previously learned information, stored in long term memory and does not require active control or attention by the subject. In contrast to automatic processes, Shiffrin and Schneider (1977) defined controlled processes as temporary activation of a sequence of nodes activated under control and requiring attention. Controlled processing is slow, effortful and is engaged during encounters with new tasks/situations. Overall, this model is important to understanding EF because (1) it provides an elaborate description of automatic and controlled processes and (2) it sets out to explain the execution of controlled processes during novel situations. As noted in several EF definitions, the term ‘controlled processes' is mentioned in Hughes et al., (2004) whereas the role of EF in novel situations is mentioned in the work of a few others namely, Banich (2009) and Miyake and Friedman (2012).

**(c) Cognitive Control**

Posner and Snyder (1975) introduced the term cognitive control to explain how information is consciously selected or inhibited during demanding attentional tasks. This model illustrates the human capacity to consciously focus attention on selected information depending on the situation. Using this model, the authors distinguished between automatic and strategic processing. Automatic processing is fast-acting and strategy free whereas strategic processing occurs with intent and is goal dependent. Posner and Snyder (1975) demonstrate how cognitive control is utilised during specific higher-level tasks, for example in digit search, lexical decision, and matching tasks. During these tasks, subjects are required to inhibit automatic but inaccurate responses to direct their behaviours towards the goal. The concept of goal-directed decision-making described in this model is analogous to several definitions of EF available today (Goldstein et al., 2014).

**(d) Supervisory Attentional System**

Norman and Shallice (1986) in turn proposed two distinct systems that control thoughts and actions: contention scheduling and supervisory attentional system (SAS). This model assumes the presence of schemas in the cognitive system, these schemas represent an abstract structure of previously learned skills or habitual actions. The schemas are triggered by external stimuli or internal cues and their activation depends on the activation values. During a task, several schemas may be activated; however, the selected schemas will have the highest activation value exceeding other competing schemas. This process is regulated by contention scheduling, a mechanism that regulates routine, familiar and automatic actions. It ensures the relevant schema is activated while suppressing conflicting schemas. The mechanism of contention scheduling is consistent, rapid, and automatic. On the other hand, the supervisory attentional system regulates actions and thoughts during voluntary, conscious, and novel situations. SAS also oversees the functioning of contention scheduling, ensuring only the appropriate schemas are activated. Besides that, SAS is responsible for resolving issues when habitual/automatic responses are unsatisfactory. In other words, the operation of SAS is necessary when faced with novel circumstances and when repressing dominant habitual actions is required (Norman & Shallice, 1986). The operation of SAS elucidates how willed actions are achieved similar to the general aspect of EF involving self-monitoring and self-regulation (Goldstein et al.,2014; Diamond, 2013). Moreover, this model proposed the integration of different cognitive processes (i.e., routine/automatic, non-routine/controlled, activation, inhibition) in mediating thoughts and behaviours. The multiple control processes highlighted are parallel to the cognitive process involved during executive functioning.

**(e) Hierarchical Model of EF**

Stuss (1992) offers a hierarchical view of cognitive processing, proposing there are lower and higher levels of cognitive functions. The first level is a low level of cognitive process involved in facilitating routinised, overlearned, and repetitive behaviours. The second level involves processing of EF or supervisory control. The goal of this level is to consciously direct behaviours towards the goal by adjusting the lower-level activities. Stuss identified several functions of the second level: planning, goal selection, attentional control, and behaviour monitoring. At this level processing is slower, effortful and requires conscious deliberation (Stuss, 1992). The third and highest level is described as ‘the ability to be aware of oneself and the relation of self to the environment’ (Stuss, 1992:5). This level represents consciousness - the ability to self-reflect and self-monitor. According to Stuss, processing at the highest level requires involvement of the two lower levels. This proposed notion of ‘different processes collectively operating to perform higher cognitive functions’ is described in several definitions of EF (Roberts & Pennington, 1996; McCloskey et al., 2008; McCloskey & Perkins, 2012). In addition, the identification of different cognitive processes involved in the second level representing EF is compatible with the current view of EF as an umbrella term encompassing different cognitive processes.

**(f) Cross Temporal Synthesis**

Fuster (1997) proposed a model of EF consisting of three components: working memory, planning and inhibitory control. According to Fuster, the purpose of all three components is to achieve ‘cross-temporal organisation of behaviours’ (1997: 157) or in other words goal-directed behaviour. This can be accomplished by ‘cross-temporal synthesis’, a process integrating EF domains and aligning them to the purpose/goal. The cross-temporal synthesis does not require a single/central executive unit, contrasted with Baddeley’s (1996) theory of working memory which attributed executive functioning to a central executive unit or homunculus. In this EF model, Fuster also includes aspects of emotion and motivation which may influence goal-directed behaviour. Central to our appreciation of EF is how this model discussed the integration of different EF processes to perform a goal-directed action. This model also demonstrated that EF processes do not work in isolation rather they interoperate to achieve the goal/purpose. This view is further supported by the unity/diversity EF model.

**(g) Unity and Diversity of EF**

The notion of ‘unity’ and ‘diversity’ was originally proposed by Teuber (1972) to describe frontal lobe functions. According to Teuber (1972), ‘… there is some unity in the diversity of frontal lobe symptoms, because all of the superficially different symptoms have some family resemblance’ (p. 645). This notion has since been examined with domains of EF in individual differences studies (Miyake et al., 2000; Fisk & Sharp, 2004; Friedman et al., 2008). The unity/diversity model characterised EF domains as correlated (i.e., showing unity) but they also constitute separable, individual processes (Miyake & Friedman, 2012). In 2000, Miyake et al., conducted individual differences study with healthy participants to examine the relations between three EF domains: (i) inhibition, (ii) shifting and (iii) WM updating. These EF domains are selected because all three involve some aspect of inhibitory processes, thus it is plausible to hypothesise the correlations between the EF domains (Miyake et al., 2000). Using latent variable analysis from data of nine EF tasks (three tasks tapping each construct), Miyake et al., (2000) concluded the three EF domains are indeed correlated but are also separable. In a review paper, Miyake and Friedman (2012) summarises decades of work on unity/diversity of EF and elaborated the terms used in this model. According to the authors, the ‘unity’ of the three EF domains (i.e., inhibition, shifting, updating) is termed as common EF (2012). Common EF refers to ‘the ability to actively maintain task goals and goal-related information’ (Miyake & Friedman, 2012:3). The authors indicate that common EF underlies the operation of all three EF domains, however it is most closely related to inhibitory control. In contrast, two aspects of ‘diverse’ EF are identified: (i) updating-specific and (ii) shifting-specific (Miyake & Friedman, 2012). It is suggested that inhibitory control is not separable due to its nature as the shared aspect underlying all three EF (Miyake & Friedman, 2012). To put it simply, the absence of inhibition-specific makes sense because inhibitory control is isomorphic to common EF. Both updating-specific and shifting-specific are necessary for gating of information and controlling retrieval of information from long term memory (Miyake & Friedman, 2012).

It is the current author’s view that the main contribution of the unity/diversity framework is in understanding the nature and interaction between different EF domains. This explanation is unavailable in previous EF models, the unity/diversity model specifically elaborates on the relation between EF domains (i.e., common EF). Furthermore, the notion of unity/diversity of EF warrants meticulous selection of EF domains and the corresponding EF tasks when developing any EF test batteries. It is necessary to take into account that these EF domains each play their own role but also work in conjunction with one another to facilitate goal-directed actions. Similarly, analysis and interpretation of EF task performance should anticipate the possibility of correlations between EF domains. The fact that EF constructs are correlated may give rise to the issue of task impurity problem (Miyake et al., 2000). Because an EF domain operates along other components, it indicates that any single EF construct is implicated by other EF domains not directly relevant to the target EF (Miyake et al., 2000). Thus, it is necessary to ensure careful planning of EF domains and tasks when developing EF test batteries. This issue of task impurity problem will be discussed further in Chapter 3 of this thesis. In sum, the unity/diversity framework demonstrates plausible correlations between different EF domains and this knowledge has helped improve development of EF assessment.

**1.2.2 Bridging Different Definitions of Executive Functions**

While the aforementioned EF models differ in some important ways, they also have many points of convergence and in many aspects, they agree on some concepts of EF. Taken together, the EF models mainly highlight three common features, (i) EF as a construct that coordinates goal-directed actions, (ii) EF allows for human adaptive behaviours in response to novel situations (iii) EF consists of a collection of interrelated components. In fact, these common concepts underlying EF are established in several definitions of EF see **Table 1(i)**

**Table 1(i):** Common themes and EF definitions

|  |
| --- |
| **Theme 1: EF as a construct that coordinates goal-directed actions** |
| Miller and Cohen (2001): “executive control involves the active maintenance of a particular type of information: The goals and rules of a task.” (p. 185)  Best, Miller, and Jones (2009): “Executive function (EF) serves as an umbrella term to encompass the goal-oriented control functions of the PFC [prefrontal cortex].” (p. 180)  Delis (2001): “Executive functions reflect the ability to manage and regulate one’s behaviour in order to achieve desired goals.” (p. 14)  Karbach & Kray (2016): “Executive function (EF) refers to the ability to control one’s processing along external and internal goals, including working memory, inhibition, cognitive flexibility, and multitasking.” (p. 93) |
| **Theme 2: EF allows for human adaptive behaviours in response to novel situations** |
| Gioia, Isquith, Guy, and Kenworthy (2000): “The executive functions are a collection of processes that are responsible for guiding, directing, and managing cognitive, emotional, and behavioural functions, particularly during active, novel problem solving.” (p. 1)  Godefroy (2003): “Executive functions refer to high-order functions operating in non-routine situations such as novel, conflicting or complex tasks.” (p. 1)  Baron (2004): “Executive functioning skills “allow an individual to perceive stimuli from his or her environment, respond adaptively, flexibly change direction, anticipate future goals, consider consequences, and respond in an integrated or commonsense way.” (p. 135)  Gilbert & Burgess (2008): “Executive functions are the high-level cognitive processes that facilitate new ways of behaving and optimise one’s approach to unfamiliar circumstances.” (p. 1)  Diamond (2013): “Executive functions (EFs) make possible mentally playing with ideas; taking the time to think before acting; meeting novel, unanticipated challenges; resisting temptations; and staying focused. Core EFs are inhibition [response inhibition (self-control—resisting temptations and resisting acting impulsively) and interference control (selective attention and cognitive inhibition)], working memory, and cognitive flexibility (including creatively thinking “outside the box,” seeing anything from different perspectives, and quickly and flexibly adapting to changed circumstances).” (p. 135) |
| **Theme 3: EF consists of a collection of interrelated components** |
| Lezak (1995): “Executive functions refer to a collection of interrelated cognitive and behavioural skills that are responsible for purposeful, goal-directed activity, and include the highest level of human functioning, such as intellect, thought, self-control, and social interaction.” (p. 42)  Funahashi (2001): “Executive function is considered to be a product of the coordinated operation of various processes to accomplish a particular goal in a flexible manner.” (p. 1) |

In **Table 1(i)**, the different definitions of EF are grouped into three common themes. This categorisation provides a clear understanding of EF and the underlying processes involved. Definitions grouped under the common themes may not be entirely equivalent; however, in this author’s view stepwise it achieved the goal to establish a general agreement between the myriad EF definitions based on common theoretical grounds. Taking these EF definitions together, it appears to be there is yet no single agreed definition of EF, however, the consensus on what constitutes EF seems promising in conceptualising the different facets of cognitive processes involved during executive functioning. In general, the key components of EF are widely agreed to include, but not limited to working memory, inhibitory control, cognitive flexibility, problem-solving, updating, attention and reasoning. Some of the EF domains may be referred to using different terms in different studies but principally they refer to the same processes. For example, shifting sometimes is referred to as switching in some studies (Mohapatra & Marshall, 2020).

Theoretical implications drawn from these EF models give us insight into how EF works in general and when and where the system is required. The perspective shared across the EF models reviewed here suggests that EF consists of multiple cognitive processes essential to accomplish various tasks. Due to the nature of EF as facilitators of high-level cognitive processes, there may be a strong relation to language and communication. Studies that have investigated the relationship between EF and language will be reviewed in *Section 1.3* and *Section 1.4*. Some of the EF models also emphasise on possible methodological issues in EF assessment (i.e., task impurity problem). The prevailing issue with assessing EF will be further discussed in Chapter 3 of this thesis. In summary, given the constraint imposed by the lack of consensus in defining EF, an appropriate way to elucidate this is to investigate the overlapping aspects of EF in the different framework proposed. Given the aim for the present study, a review of literature to explore the extent of EF in facilitating language processes in different populations will be presented.

**1.2.3 Importance of Defining EF to the Present Study**

The present study aims to develop a Malay language executive functions (M-EF) test battery for future use with linguistically diverse people with aphasia (PWA) in Malaysia. To the best of our knowledge, this is the first study to do so, and hence as a pioneer in conducting linguacultural adaptation of EF test battery in the Malay language, understanding the underlying concepts of EF is a necessary first step. So far, the existing conceptual models of EF describe when EF is employed and how EF can be measured. Despite increasing diversification of global populations, there is yet no EF model that captures how facets of culture and language may impact executive functioning in this population.

The social and environmental influence on cognition was mentioned by Ardila (1996), who supports the need for an appropriate cross-cultural neuropsychological tool. In my opinion, one reason for the absence of cross-cultural EF models is because the term EF originated in the West and is continuously investigated and normed in Western populations. As a result, there are still insufficient culturally appropriate EF assessment tools for Asian populations and languages especially in Southeast Asia, where access to neuropsychological tests and facilities remains limited and costly to this day. By understanding the concept of EF and highlighting the different EF definitions proposed, I hope to use this knowledge to traverse from a Western perspective and to acknowledge how the notion of EF may change from a culturally and linguistically diverse perspective. Furthermore, acknowledging the mechanisms underlying executive functioning facilitate better understanding on how the two cognitive processes, EF and language are interrelated. As the current study aims to develop the M-EF test battery for assessing Malay speaking PWA, it is essential to first understand the correlation between EF and language processes. Likewise, it is crucial to present adequate findings on EF in individuals with language impairment in comparison with healthy populations to explore the possible influence of EF on language and communication in atypical populations. Thus, the next section brings the discussion of EF and language processes in healthy and atypical groups allowing for comparison of how EF are employed in the different groups.

**1.3 Executive Function and Language in Healthy Population**

Language processing has been investigated and defined in different disciplines including, linguistics (Poirier & Shapiro, 2012), neurophysiology (Friederici, 2011; Friederici & Singer, 2015) and cognitive psychology (Kelly & Reiter, 2018). From a psycholinguistic perspective, Poirier and Shapiro describe language processing as ‘an intricate cognitive function that appears to be sensitive to different sorts of information, some linguistic, some not’ (2012: 144). The authors also describe the interaction between language processes and different cognitive functions (i.e., attention, memory). In cognitive psychology, language processing is described as behaviour produced to some extent by cognitive processes which are not specific to language (Kelly & Reiter, 2018). Take for example, lexical retrieval which involves retrieval of information from long-term memory, directing attention to target information and inhibiting any competing representations. In short, word retrieval ability is achieved through integration and implementation of different cognitive processes. One obvious assumption derivable from these definitions (Poirier & Shapiro, 2012; Kelly & Reiter, 2018) is that language processes and cognitive functions are interrelated to form a dynamic system. Thus, the next question to be addressed is which cognitive functions (i.e., EF domains) are involved in language processes and whether the role of EF in language processing differs across age groups. Thus, this section brings together the findings from several EF studies in young and older adults to examine the role of EF in supporting different aspects of language processes.

**1.3.1 EF and Language Processing in Adults**

In adult samples, EF domain, working memory (WM) has been the main subject of investigation in relation to performance in syntactic comprehension tasks (Friederici et al., 1998; Moser et al., 2007) and sentence production (Slevc, 2011). Whereas the role of inhibitory control is often linked to bilinguals’ language processing, such as in lexical retrieval (Linck et al., 2009) and phonological processing (Darcy et al., 2016).

In 1998, Friederici and colleagues investigated the influence of WM capacity during the process of untangling syntactic ambiguity in young adults aged between 21 to 30. All twelve German-speaking participants were first assessed for verbal WM using the German version of the Reading Span Test. Participants were then grouped into Low Span and High Span readers. The participants’ performance in processing syntactic ambiguity is examined using an on-line measure (event-related brain potentials, ERP) and off-line measure, involving question-answer sessions. The off-line data showed that participants in the high span group responded more accurately than low-span participants. When the preceding sentences include a long-lasting ambiguity, low span participants made more errors than high span participants. Similarly, on-line measures indicated that high span participants are more efficient at processing ambiguity structure compared to low span readers. The ERP also showed evidence of differential performance between high and low span depending on sentence type. It is concluded that differences in working memory spans influence the ability to process garden-path sentences (Friederici et al., 1998). In sum, these individual differences study confirms the role of EF in supporting language processes in adults.

In another study examining the correlation between non-verbal WM and sentence parsing ability was investigated with English-speaking adults aged between 21 to 27 years. All 31 participants completed four tasks; three of which were online. The online tasks included assessment of nonverbal WM task, sentence-parsing plausibility task and lexical decision control task. An additional nonverbal WM task was administered offline. Data suggests that performance on the nonverbal WM tasks were predictive of sentence parsing performance. However, there is no strong association between WM and lexical decisions. It is hypothesised that this relation lies within the demand of assigning thematic role during sentence comprehension. In order to assign a thematic role, one must extract meaning from a sentence, and be able to store the information temporarily for manipulation and reasoning. The nature of WM as a mental workspace supports the process of assigning thematic role, substantiating its correlation to sentence parsing ability. However, function of WM is not required during lexical decision tasks. The findings suggest that different aspects of EF are employed for different language processing tasks depending on the mechanism underlying the EF and language processes. Both EF studies in healthy adults reviewed necessitate the function of EF in different language processes and in one study (Friederici et al., 1998) demonstrated the relation between varying EF capacity in language performance.

**1.3.2 EF and Language Processing in Older Adults**

It is widely accepted that even in the absence of pathological ageing processes such as dementia, changes occur to cognitive functioning in normal ageing (Glisky, 2007; Princiotta et al., 2014). Studies investigating EF abilities in healthy older adults demonstrated a general decline in different components of EF; interference control and planning (Crawford et al., 2000), inhibitory control (Wecker et al., 2000) and planning, attention, and initiation (Lin et al., 2007). Corresponding to evidence of EF declines with advancing age, several studies investigated the correlation between declining EF abilities and language skills in older adults.

One study was conducted to examine the correlation between specific EF domains with word retrieval performance in older adults aged between 55-84 (Higby et al., 2019). Three EF measures investigated were cognitive flexibility, inhibition, and fluency. To measure EF, Higby et al., employed six EF tasks - two tasks tapping into each EF construct. To evaluate naming ability, two picture naming tasks were included: Boston Naming Test (BNT) and Action Naming Test (ANT). Lexical retrieval abilities for both object and action words are measured based on accuracy and response time. The study found strong correlations between two aspects of EF, cognitive flexibility, and fluency in predicting certain aspects of naming performance. Better cognitive flexibility scores are linked to high naming accuracy for both action and object words, whereas high fluency score is linked to reduced response time in both naming tasks. Fluency also predicted naming ability for object words. The study also found a decline in EF performance in older age participants which is in line with the concept of age-related cognitive decline. Higby and colleagues concluded that specific EF domains are related to lexical retrieval abilities (i.e., accuracy and response time).

The involvement of working memory and cognitive flexibility in auditory sentence processing is also found in older adults between 55 and 88 years (Goral et al., 2011). To evaluate EF, the researcher employs the use of four EF tasks: computerised Wisconsin Card Sorting Test (WCST), Stroop Test, Trails Test and Month-Ordering Task. The EF tasks measure three EF domains: WM, cognitive flexibility, and inhibitory control. Goral and colleagues administered two sentence-processing tasks, Embedded Sentences Task and Multiple Negatives Task. To measure sentence processing ability, response accuracy to the auditory stimuli were recorded. Data analysis showed that all three EF processes are related to age; however, WM and cognitive flexibility were the two components of EF strongly associated with higher accuracy performance in sentence processing tasks. It was found that groups with deficits in both WM and cognitive flexibility showed difficulty in processing complex sentences. However, individuals with only one compromised EF domain showed preserved ability to process complex sentences. The researchers postulated that this might be because they are able to compensate for one compromised EF component. Goral and colleagues suggested that WM is linked to the ability to process syntactically complex sentences whereas switching can account for integration and interpretation of new information with previously heard sentences. Hence, deficits in both WM and cognitive flexibility can significantly reduce sentence processing ability.

A recent study by Polsinelli and colleagues offered a new method to investigate the role of EF in natural, conversational language use. The study aimed to investigate whether individual differences in everyday natural speech can give information about the integrity of EF in older adults (Polsinelli et al., 2020). Speech data were collected from 102 healthy older adults and the participants were assessed for three EF abilities, WM, cognitive flexibility and inhibition. Some of the EF tasks administered are Keep Track, Consonant Updating, Global-Local, Letter-Number and Stroop Task. Overall, performance on EF tasks showed evidence of age-related decline. Correlational analysis found that WM has the highest correlation with aspects of speech and communication. Participants with better WM scores showed higher usage of analytical, complex and specific words. Also, their speech showed fewer usage of common verbs and nouns. Whereas cognitive flexibility is linked to frequent usage of complex and specific words. However, there was no significant correlation between inhibitory control and language variables. Interestingly, Polsinello and colleagues found that overall high EF scores are linked to high-frequency usage of profanity and sexual words. This is presumed to be the case due to the informal and conversational nature of the speech. In general, this study showed that analysing speech style and complexity of language use, may shed light on the executive functioning of the speaker. The authors concluded that natural conversational speech may reflect the integrity of EF, particularly WM which may be difficult to capture in clinical and experimental settings.

Essentially, the numerous findings presented demonstrate that various language processes interact with different components of EF, such as WM, cognitive flexibility and inhibitory control. The apparent correlations between specific EF domains and aspects of language processes shed light on the role of EF in diverse aspects of language processing at lexical and syntactic level. Additionally, the overall data from ageing studies demonstrating the implication of reduced EF capacity on language abilities raise the possibility that in individuals with language impairment, we may find evidence of concomitant EF deficits. Hence, the important next step is to review studies that investigate the integrity of EF in individuals with language disorders to obtain a more comprehensive understanding of EF and language.

**1.4 Executive Function and Language in Atypical Population**

The relationships between language and EF have been vastly investigated in healthy subjects. It is posited that different EF domains are recruited in a variety of language processes (e.g., WM in ambiguous sentence comprehension). In a review paper examining the relationship between EF and language in adults with acquired language disorder, Goncalves and colleagues affirm that language difficulty is not an isolated impairment rather EF abilities are often impacted alongside language impairment (e.g., aphasia, dementia) (Goncalves et al., 2018). This section seeks to bridge the gap between the two processes and improve our understanding of the underlying correlations between the EF and language. Parts that follow discuss the manifestation of EF impairments and language deficits in atypical populations.

**1.4.1 EF and Language in Age-Related Acquired Language Disorders**

Along with visible physical changes, the human central nervous system also undergoes functional cognitive ageing changes (Peters, 2006). Due to changes in brain volume and neurotransmitter, incidence of neurological disorders such as dementia increases with age. There have been numerous studies investigating cognitive changes in neurological disorders such as dementia, and the most common EF deficit found is WM. This section will first discuss the findings in the Alzheimer's group and subsequently review findings from Parkinson’s disease.

The significant interest in studying sentence processing abilities in individuals diagnosed with Alzheimer’s disease stems from the ongoing debate about the nature of the decline in these patients' sentence processing mechanisms. Specifically, the disagreement focuses on whether the decline affects the lexical-semantic or the syntactic processing ability (Small et al., 2000). Some researchers argue that verbal WM is responsible for the overall sentence processing difficulties in Alzheimer’s disease (Rochon et al., 2000). Due to numerous studies investigating sentence processing and WM in AD and dementia groups, the two papers reviewed below will present findings from this topic of research. However, for the sake of brevity, the processing mechanism will not be discussed in detail in this thesis.

Small and colleagues (2000) measured the performance of 13 mild to moderate AD and 22 healthy adults (matched for age and education level) in their sentence processing ability using sentence repetition task. Six types of sentences used vary in sentence length with three factors of syntactic complexity: (i) canonicity of thematic role assignment, (ii) branching direction of embedded clause and (iii) number of verbs. Additionally, all participants were measured using four WM tasks, digit span tests (forward and backward) and days and months span tasks (forward and backward). The AD group performance in sentence repetition was poor across all sentence-type except passive construction when compared to the healthy group. The poor performance was significant particularly for sentences with syntactic complexity. Using partial correlation analysis, performance in WM tasks were compared with their score in sentence repetition. It was found that there is a strong correlation between the performance on the four WM tasks and sentence-repetition tasks. It was concluded that AD performance was not only influenced by grammatical factors but also by the cognitive processing demands associated with the task (WM load). Small et al., (2000) noted that higher demand for WM relates to sentence length and syntactic complexity. It was observed that when the sentence is lengthy and highly complex, the AD group exhibits significantly poor sentence repetition suggesting that the extra load on WM resulted in difficulty in sentence processing ability in Alzheimer’s participants.

Another study investigating the link between WM and sentence comprehension in dementia of the Alzheimer’s type (DAT) found correlations between WM and sentence comprehension ability (Rochon et al., 2000). The performance of 15 DAT individuals with 15 healthy controls in a series of WM tasks (digit span, dot working memory span, pursuit tracking) were measured. Additionally, participants' sentence comprehension abilities were measured using nine sentence-types varying in sentence complexity. DAT patients’ performance in WM tasks were significantly lower than that of healthy controls, and the DAT group were reported facing difficulties understanding sentences with two propositions in the sentence processing tasks (i.e., sentence-picture matching and video verification task). Hence, Rochon and colleagues concluded that DAT group performance in WM tests were correlated to sentence comprehension ability for sentences with more than one prepositions. The authors concluded that patients with DAT have poor ability to map meanings of sentences to depictions of events due to WM impairment. This supports the presence of WM deficits in Alzheimer's, as shown in both Small et al. (2000) and Rochon et al. (2000), affecting language processing.

Moving on to Parkinson’s disease (PD), neuropsychological assessments in PD patients showed cognitive deficits from the early onset of the disease manifestation (Dubois & Pillon, 1997). Additionally, language evaluation of PD also noted frequent language processing impairments in patients (Grossman et al., 1991). From the findings of early studies, causal research was conducted to investigate the link between language and cognitive performance in PD. Several studies have suggested that both impairments are associated with one another (Caplan & Waters, 1990; Hochstadt et al., 2006).

Hochstadt et al., (2006) investigated the EF domain (WM and cognitive flexibility) linked to comprehension deficits in PD. Forty-one PD patients were assessed using a series of language, cognitive flexibility and verbal and nonverbal WM tests. Some of the EF tasks employed are reading aloud, Reading Span test of WM, Test of Meaning from Syntax, and The Odd Man Out test. Measure of syntactic comprehension used is a sentence-picture matching task. The sentences used varied in structural complexity, voice, and semantic constraint. Overall, patients exhibited good comprehension for simple sentences but reduced comprehension for complex sentences. Correlation analysis found that impaired verbal WM influenced sentence comprehension ability in PD. In PD individuals with low verbal WM, they showed poor comprehension for passive structures. In summary, across all three studies mentioned sentence comprehension errors appeared to be mostly related to WM capacity in dementia and Parkinson’s. An important takeaway from these findings is the fact that EF domain and language abilities are interdependent, a deficit in one aspect can be attributed to the other or it may influence the operation of the other.

**1.4.2 EF and Language in Traumatic Brain Injury (TBI)**

Numerous studies have reported the link between EF ability and language impairment following post traumatic brain injury (TBI) (Rousseaux et al., 2010; Coelho et al., 2013; Goncalves et al., 2018; LeBlanc et al., 2020). The most common EF deficits reported in previous TBI studies is disturbance in WM (Goncalves et al., 2018). These studies also found links between WM and aspects of productive language (Rousseaux et al., 2010; Coelho et al., 2013). Additionally, recent findings (LeBlanc et al., 2020) suggested that cognitive-communication assessments in mild TBI may help determine intervention plans and patients’ rehabilitation needs.

Rousseaux et al. (2010) investigated social communication abilities of sixteen patients at rehabilitation phase (2-12 months post-traumatic brain injury) and 18 patients following severe TBI. Communication was measured using the Lille communication test (LCT) which comprises three parts: (i) participation to communication, (ii) verbal communication and (iii) non-verbal communication. Speech samples were collected in three settings, natural interaction, directed interview and open discussion. Additionally, patients were also assessed using a series of EF tests: Stroop test, trail-making test, and categorical evocation. The study found all patients following TBI showed severe impairment in the ability to communicate across the three language tasks in LCT, however communication is more severe in patients at rehabilitation stage than at chronic phase. Patients generally manifest difficulty producing intelligible utterances despite most of them showing fairly preserved attention to the interlocutor's speech. Ability to understand non-verbal gestures were also relatively poor across all patients; however, the ability to recognise gestures referring to physical or emotional state (e.g. sleep, eat, happy, angry) were moderately intact. Besides language impairment, EF measures found patients were mostly impaired in attention and inhibitory control. Correlational analysis found that some aspects of verbal communication are linked to performance in the EF tests. This study concluded that TBI can lead to a lasting impact on both communication and EF abilities even 48 months post injury. Moreover, findings from the correlational analysis suggest that executive dysfunction plays a role in communication ability, especially in aspects of verbal communication.

Coelho and colleagues (2013) on the other hand compared the performance of TBI individuals and non-brain injured (NBI) individuals using a discourse analysis of story narratives elicited from both groups. The discourse was measured based on cohesive adequacy, coherence, story grammar, completeness, and reliability. Performance in four cognitive measures tapping into participants EF ability, WM, immediate memory, and intelligence were also examined. There are a few significant differences between the discourse produced by TBI and NBI groups. First, NBI produced longer stories, the storyline was more organised and complete. Whereas the TBI group produced stories that consist of fewer words, less complete sentences, and lack order. Comparing cognitive measures of TBI and NBI groups, the researchers found significant differences in immediate memory, WM, and IQ. Coelho et al. study confirmed the link between EF and language processing ability from analysing the TBI group performance. Coelho et al. suggest future research to identify the specific EF domain influencing language function in TBI patients, to support rehabilitation.

A more recent study conducted by Le Blanc and colleagues (2020) investigated how performance in EF and language tasks determine care outcome following mild TBI. A total of 128 patients aged between 18 - 98 years were assessed for language and cognitive functions using a series of tests including, Verbal Fluency Test (VFT), Boston Naming Test (BNT) and Boston Diagnostic Aphasia Examination (BDAE). It was observed that poor performance in specific cognitive and language tasks are linked to poor functional outcome (i.e., longer length of hospitalisation and prolonged rehabilitation treatment). Specifically, patients who manifested low performance in semantic category naming, letter category naming and conversational discourse were linked to longer hospitalisation and a longer period of rehabilitation. Additionally, poor performance in the language areas was linked to impairment in EF. For example, poor performance in letter-category naming is associated with both aspects of language and executive functioning. The study further suggests the importance of measuring EF and language abilities in TBI cases to determine cognitive and communicative rehabilitation needs.

The association between EF deficits and language impairments in the TBI group are evident from these studies. Despite utilising different methodological approaches to investigate the relation between EF and language, these studies demonstrated confluence proof of EF and language deficits co-occurring in TBI patients. Also, as reported by Le Blanc et al., (2020) there seems to be a correlation between EF and language performance during the acute stage in determining patient care outcome. Hence, these studies further emphasise the need to assess EF and language abilities in different patient groups to improve rehabilitation outcomes.

**1.4.3 EF and Language in Aphasia**

Damasio (1992) defines aphasia as “disturbance of the comprehension and formulation of language caused by dysfunction in specific brain regions” (p. 531). Patterns of language difficulty in people with aphasia (PWA) are heterogeneous ranging from phonological deficits (Kohn, 1988) to difficulty engaging in routine conversation (Johansson et al., 2012). The source of language impairment in aphasia extends beyond faulty linguistic systems; research evidence suggests a causal relation between EF and language ability in PWA (Purdy, 2002). In fact, multiple investigations found that integrity of EF supports language and communication success in PWA (Purdy, 2002; Kalbe et al., 2005; Frankel et al., 2007; Yeung & Law, 2010; Murray, 2012; Kendrick et al., 2019; Gilmore et al., 2019; Schumacher et al., 2019). These studies concur that with deficient language ability, PWA rely on other cognitive functions (e.g., EF) to compensate for the compromised aspects of language, evident in the findings discussed below.

In a study, Kalbe and colleagues (2005) assessed 154 adult PWA and 106 healthy controls were assessed using Aphasia Checklist (ACL). ACL is an instrument developed to provide a comprehensive measure of language and non-verbal cognitive abilities in PWA. The language measures incorporate aspects of language production, comprehension and reading and writing. On the other hand, the cognitive measure was constructed to measure three EF domains: memory (short term memory and immediate term memory), attention and reasoning. Results found that 94% PWA showed impairment in at least one of the four cognitive function parameters. Furthermore, PWA language performance showed varying levels of severity across the language tasks. A correlational analysis found significant correlation between performance in cognitive and language tasks in PWA, especially between reading comprehension, auditory comprehension, naming and semantic word production with cognitive abilities such as memory, attention and reasonings. Given that 94% of PWA exhibited cognitive impairments, it underscores the need to assess cognitive domains alongside language functions in PWA. In conclusion, both measures of language and cognitive performance are valuable for aphasia diagnostics, rehabilitation planning, and progress assessment.

Secondly, there is significant evidence of EF deficits in natural conversation of PWA. In 2007, Frankel et al. explored the relation between aspects of EF and conversational strategies used in speech of a person with aphasia, MS. The conversation data was recorded and assessed for three aspects of conversational strategies: turn-taking, repair and topic management. In addition, EF ability was evaluated using a series of tests including, digit span, Stroop test, Trail Making Test, Tower of London, and Wisconsin Card Sorting Test (WCST). Overall MS’s performance in EF tests indicated deficits in shifting attention, WM, fluency/initiation, and concept formation. It was found that the specific EF deficits were parallel to communication difficulty evident in MS’s speech. For example, MS’s EF performance suggests poor WM, and this manifested in her speech where she faced difficulty with tracking meaning when topics and speakers of the conversation changed rapidly. In general, despite MS showing preserved turn-taking and topic management, her communication was characterised with obvious difficulty for conversational repair (inability to shift away from inefficient strategies that did not facilitate communication). This impairment is accounted for by the cognitive deficient in shifting attention and concept formation. Based on the findings, the authors assert that EF deficits account for different manifestations of communication difficulties in PWA. It is therefore essential to carry out EF testing as an explanatory basis for communication symptoms in PWA and for facilitating rehabilitation planning. As noted by Frankel et al., (2007), cognitive assessment is a type of “poor man’s neuroimaging”, certainly relevant in a context like Malaysia, where access to neurodiagnostic tools is deficient and costly.

Next, in a study aimed to explore the relationship between EF and language in PWA, Murray (2012) compared the performance of 39 PWA with healthy controls on a series of EF tests which include measure of attention, short-term memory, WM, planning and cognitive flexibility. In addition, PWA were also assessed for language and communication ability. Across all EF measures, PWA’s performance was considerably lower than healthy controls. This supports the view that EF deficits are present in PWA. It is reported that PWA obtained poor scores on all measures of attention (selective attention, sustained attention, visual and auditory attention) which correlates to patterns of their language impairment. Although all aspects of EF are impaired in PWA, only attention measures are significantly associated with language abilities *(i.e., poor auditory comprehension, spoken language and communication abilities)*. Whereas the other aspects of EF showed a lesser correlation to language impairment than attention (Murray, 2012). Clinically, this study provides support for comprehensive EF testing with PWA as clinicians cannot predict the extent of EF impairment solely on the severity of aphasia symptoms without a comprehensive assessment.

A more extensive investigation into EF deficits in PWA was conducted to measure the EF profile of 38 PWA with chronic post-stroke aphasia in relation to language performance and MRI reports (Schumacher et al., 2019). The neuropsychological profile of each person with aphasia was obtained through a series of non-verbal EF tests in comparison to normative scores of healthy controls. Some of the EF tests are Go/NoGo, Divided Attention, Design Fluency, Trail Making Test and Delis-Kaplan Executive Function System. To establish participants’ language abilities, participants are assessed on three aspects of language: phonology, semantics, and speech quanta. The study reported that all PWA performed below normal range in at least one EF measure. In terms of language profile, 30 PWA were impaired in at least half of the language tests whereas five participants were impaired in all language measures. Schumacher and colleagues found a correlation between volume of lesions to performance in language tasks and non-verbal EF tests. Language ability and EF severity correlated significantly with lesion volume but is not related to age, education, or duration post-stroke. Understanding these correlations is important in the study of aphasia as it extends our knowledge of post-stroke aphasia and its relation to other underlying factors (EF ability, patient characteristics, lesion sites), given that such factors have been shown to instigate or aggravate language symptomatology in PWA (Kalbe et al., 2005; Murray, 2012; Schumacher et al., 2019). The correlations between aphasia, EF and language will be further discussed in the following chapter, which aim to show how aphasia literature informs the design of the present study.

In conclusion, considering the findings discussed in this Chapter, it seems that language impairment reflects both language and cognitive deficits, rather than an isolated, specific impairment of linguistic knowledge. The evidence discussed so far necessitated neuropsychological assessment of patients exhibiting language impairment to better understand the underlying factors implicating language ability and hence, guide clinicians in structuring effective rehabilitation plans and outcomes. The following Chapter 2 will discuss the multidimensionality of aphasia and the role of EF in PWA communication.

\*\*\*\*\*\*

**Chapter 2:  Aphasia, Language and Executive Function**

This chapter brings together discussion on (i) aphasia and bilingual aphasia, (ii) the correlation between EF and language in people with aphasia, and (iii) contextual background on the Malay language and cultural contexts. Since the concept of aphasia permeates most parts of this study, it is imperative to define aphasia and outline the common symptoms associated with this condition. Hence, *Section 2.1* begins with a brief discussion on aphasia and the different ways in which aphasia symptoms are classified. This section also brings together information on bilingual aphasia, comparing its symptoms, recovery patterns and cognitive profile of bilingual people with aphasia (bPWA).

*Section 2.2* explores how EF and language interact in PWA by discussing specific EF domains and its relation to language functions. In this section, a brief discussion of how EF affects language treatment outcomes in PWA is also included. In the final part of this chapter, a background on aphasia research in Malaysia and contextual aspects of the Malay language and its users are presented. The discussion presented in this Chapter is the precursor to understanding the importance of EF in aphasia management and rehabilitation. Additionally, the discussion will provide evidence from aphasia literature on how EF facilitates speech and communication in PWA.

**2.1 Aphasia**

Numerous definitions of aphasia have been proposed over the years, reflecting advancement of knowledge and new research in aphasia. Many of the proposed aphasia definitions are contributed by multidisciplinary fields, involving a combination of approaches from medical, psychological and linguistics models (Berg et al., 2020). Under the World Health Organisation (WHO), the International Classification of Functioning, Disability and Health (ICF) describes aphasia in three aspects: (i) impairments, (ii) activities and participation and (iii) contextual factors (WHO, 2001). Firstly, in terms of impairments of body function and structure, ICF describes aphasia by linking it to observable physical impairments, in this case damage to parts of the nervous system (i.e., the brain). Secondly, ICF characterised aphasia based on its impact on functions of everyday life, referring to impairment in speech and communication abilities. Lastly, the ICF definition of aphasia includes description of the external factors that may facilitate or impede an individual with aphasia. For example, availability of facilitative communication resources appropriately designed for people with aphasia (e.g., signage, printed material) can markedly impact the quality of life of PWA (*for details on application of ICF in aphasia, see;* Simmons-Mackie & Kagan, 2007).

On the other hand, linguists have traditionally been attempting to describe aphasia based on patterns of language impairment in PWA (*for a review, see;* Garraffa & Fyndanis, 2020). Patterns of PWA’s performance on various language tasks have been linked to different linguistic theories, firstly to evidence the linguistic processing system and secondly as a diagnostic tool to identify the nature of aphasia. For example, Martinez-Ferreiro et al., (2019) recently investigated speech performance of Spanish-speaking individuals diagnosed with fluent and non-fluent aphasia. The researcher adopted a usage-based grammar theory (originally developed by Boye & Harder, 2012) which provides a theoretical distinction between lexical and grammar. According to this theory, lexical items are the primary information and are independent from other linguistic elements. Whereas grammatical items are secondary information which relies on lexical items. Based on this theory, it is predicted that processing grammatical items are more demanding than lexical. Hence, Martinez-Ferreiro and colleagues hypothesised that individuals with fluent aphasia will manifest lexical difficulty whereas non-fluent aphasia will experience more difficulties with grammatical items. As predicted, the findings of this study are consistent with usage-based grammar theory whereby non-fluent aphasia showed greater difficulties with grammatical items and fluent aphasia showed deficits in lexical items. The study confirms that language performance can inherently act as a diagnostic tool to identify the types of aphasia. One drawback of linguistic definitions of aphasia is that it only highlights the impairment aspects of aphasia (i.e., linguistic deficits), however, it fails to include the effects of aphasia on functional everyday life (Berg et al., 2020).

Due to the different espoused definitions of aphasia, several works have been done to update the current knowledge and definition of aphasia to include all three aspects highlighted in the ICF (Papathanasiou et al., 2017; Berg et al., 2020). Papathanasiou et al., (2017) highlighted four common elements agreed upon in any definition of aphasia: (i) aphasia is a language-level problem, (ii) aphasia comprises of receptive and expressive language components, (iii) aphasia symptoms are multimodal in nature, and (iv) aphasia is caused by damage to parts of the brain.

The first and second elements highlighted by Papathanasiou and colleagues (2017) are obvious across most if not all definitions of aphasia. Language impairment in PWA can be present in one or more language domain: phonology (Kohn, 1988; Meier et al., 2016), lexicon (Goodglass & Wingfield, 1995; Raymer, 2011; Rohrer et al., 2008), syntax (Caramazza et al., 1981; Caplan et al., 2013) and semantics (Blumstein et al., 1982). Similarly, aphasia impacts language abilities across all modalities: expressive language (Blom Johansson et al., 2012) and receptive language (Bates et al., 1987). In addition, language impediment and degree of impairment in aphasia vary across individuals (Edward & Salis, 2004).  In severe forms of aphasia, the ability to produce speech may entirely be compromised along with very limited or no comprehension. At the mild end of the spectrum, PWA may experience occasional word-finding difficulty with slight speech impediment. However, no two individuals diagnosed with the same type of aphasia exhibit the same patterns of language impairment (Edward & Salis, 2004). This symptomology reflects the multimodal nature of aphasia whereby symptom profiles vary across aphasic groups (Papathanasiou et al., 2017).

Finally, the fourth shared element identified by Papathanasiou et al., (2017) centred on the onset of aphasia. The most common cause of aphasia is stroke, but cerebral damage due to traumatic brain injury such as head injury following a vehicle collision, or a gunshot may also lead to aphasia. Aphasia that is caused by stroke or traumatic event is termed non-progressive aphasia. In contrast, primary progressive aphasia occurs when language impairment arises gradually due to brain tumour, brain infection or neurological progressive conditions such as Alzheimer’s disease (Edwards & Salis, 2016). It is recognised that lesion to the left hemisphere is often linked to aphasia (Damasio, 1992; Clark & Cummings, 1999) however, some studies also found evidence of aphasia in individuals with right hemispheric brain damage (Alexander et al., 1989; Coppens et al., 2002; Dewarrat et al., 2009). These findings suggest the occurrence of aphasia following neurological insult to language areas of the brain regardless of hemispheric dominance, the right or left hemisphere. A brief neuronal organisation of language is discussed further in Section 2.1.2.

Therefore, for the purpose of the present study, all four common elements have been adopted to operationally define aphasia as an acquired communication disorder resulting from focal and/or diffuse lesions to the brain area that is responsible for language processes, which affect the person’s communicative and social functioning ability. Understanding the different types of aphasia is useful in setting the foundation for this study, allowing us to evaluate the relations between aphasia, the impacts on language and cognitive functions on PWA social functioning, which are central to developing a suitable EF assessment for PWA. The following Section 2.1.1 will expand the discussion on aphasia, by exploring the classification of its symptoms based on two different approaches: neuroanatomy and aphasiology.

**2.1.1 Types of Aphasia: From a Neurolinguistics and Aphasiology Perspectives**

There exist numerous approaches in classifying aphasia symptoms, however, two complementary frameworks will be considered in this chapter: (i) neuroanatomy and (ii) aphasiology frameworks. The neuroanatomy framework typically classifies aphasia symptoms based on neuroanatomic relation to language while the latter categorises aphasia symptoms based on aspects of language impairments. Most neuroanatomy research on aphasia were evidenced through clinical observation and brain-imaging studies, whereas aphasiology approaches to aphasia were derived from different fields psychological, linguistics and social perspectives to understand the affected language functions in aphasia.

**Types of Aphasia from a Neurolinguistics Perspective**

The study of behaviour-structural relationships prevailed in early study of aphasia where scientific studies were conducted to seek explanations for language disorders and how the deficits are represented in the brain.  The first classification of aphasia based on the area of lesion stemmed from seminal work of Broca, 1861, 1865 (cited in Prins & Bastiaanse, 2006) In Broca’s 1861 paper on language-brain relationships, Broca observed a patient, Louis Leborgne, whose symptoms were characterised as severe difficulty producing language and for most of the time he was only able to utter a single word, ‘tan’. Upon examining Leborgne’s brain, Broca found damage to an area in the left inferior frontal gyrus (later known as Broca’s area). Based on the observation, Broca concluded that language function can be attributed to specific areas of the brain leading to the brain localisation view - specific brain regions serve specific functions (cited in Prins & Bastiaanse, 2006).

In 1865, Broca published another paper based on eight aphasic cases. In the observation, Broca found critical evidence that suggests the dominant role of the left hemisphere for language function. The new findings lend support in favour of localised speech function centred in the left hemisphere. Leborgne’s condition later became known as Broca’s aphasia (also known as expressive aphasia). The main symptoms associated with Broca’s aphasia are effortful speech, communication mainly using limited nouns and/or verbs with little to no function words.

Decades later, Wernicke (1874), published a monograph on different clinical forms of aphasia (cited in Prins & Bastiaanse, 2006). Wernicke was the first to uphold connectionist theory; multiple areas of the brain are involved during different brain functions. In his work, Wernicke (1874) observed two patients with language impairment and found contrasting symptoms from those identified in Broca’s aphasia. Despite both patients being able to speak fluently, their speech was incomprehensible and nonsensical. Brain autopsy report of one of the patients showed that the first temporal gyrus is damaged from cerebral infarct. The first temporal gyrus (which later became known as Wernicke’s area) lies in close proximity to the auditory cortex, which led Wernicke to propose that this brain region is responsible for receiving auditory input and assigning meanings.

In his work, Wernicke also suggested a model of language function involving both Wernicke’s and Broca’s areas to explain deficits transferring information from the receptive area to the production region. According to this model, Wernicke’s area is responsible for generating representations of meaningful speech which then sends signals to Broca’s area, responsible for sending inputs to the motor cortex involved in speech production (e.g., vocal cord, tongue, lips). Wernicke concluded that lesions to the fibres between Broca’s and Wernicke’s area led to disconnection aphasia, which is characterised as difficulty repeating speech sounds (cited in Prins & Bastiaanse, 2006).

While Broca suggested the notion of expressive language function is localised in the cerebral gyri, Wernicke, in turn, suggested the notion of *information flow* between two regions of the brain which supports different language function. His approach became known as the connectionist model and became an influential way of classifying aphasia symptoms based on areas of brain lesions (Caplan, 1987). The symptoms associated with Wernicke’s aphasia (also known as receptive aphasia) are fluent speech but lacking meaning, impaired comprehension, difficulty repeating words/phrases and lack of unawareness of errors.

The work of Wernicke (1874) was expanded by Lichtheim (1885) to include five types of aphasia: conduction aphasia, transcortical sensory aphasia, transcortical motor aphasia, subcortical sensory aphasia, and subcortical motor aphasia (cited in Prins & Bastiaanse, 2006). Lichtheim expanded Wernicke’s model of language processing by incorporating the primary auditory cortex (Heschl’s gyrus), Wernicke’s area, connections from Wernicke’s area to Broca’s area, Broca’s area and the motor cortex (Lichtheim, 1885). Lichtheim also posited that the left cerebral cortex contains an area which transmits acoustic information from Wernicke’s area to Broca’s area, termed as ‘concept centre’ or ‘Lichtheim’s house’ (cited in Prins & Bastiaanse, 2006).

According to this Lichtheim (1885), when auditory input is received, it is analysed in Heschl’s gyrus before passing to Wernicke’s area, where representations of phonemes are activated (cited in Prins & Bastiaanse, 2006). The phonemic information then passes through the concept centre where the information is elaborated before sending it to Broca’s area which transfers the information to the motor cortex for articulation. This model not only accounts for Broca’s and Wernicke’s aphasia but includes five additional classifications of aphasia (cited in Prins & Bastiaanse, 2006). Lichtheim (1885) model accounts for conduction aphasia, transcortical sensory aphasia, transcortical motor aphasia, subcortical sensory aphasia, and subcortical motor aphasia.

The basic tenet of the Lichtheim (1885) model was then adopted by Benson and Geschwind (1971), adding three additional types of aphasia: anomic aphasia, global aphasia, and mixed transcortical aphasia. Benson and Geschwind asserted that the central perisylvian area is crucial for language processes and damage to this area could produce other forms of aphasia. This aphasia classification system later became known as the Boston classification system which has become a widely recognised approach for patient classification (Caplan, 1987).

**Types of Aphasia: From Aphasiology Perspectives**

We now turn to consider the aphasiology approach to characterising aphasia, which includes a qualitative description of language impairment in PWA that played a guiding role in clinical practice and research. One of the aims of aphasiology research is to allow for the possibility of diagnosing PWA based on features of abnormal speech produced. Nature of abnormal speech patterns - phonemic paraphasia, semantic disturbance in word formation, lexical or syntactic repetition difficulties and other linguistic features of aphasia are added to the classical description of aphasia to deepen the understanding of language breakdown in PWA.

One of the early classifications of aphasia based on language disturbance was proposed by Luria, 1969; as cited in Vinken & Bruyn, 2012). He grouped aphasia symptoms based on language features identified in PWA. Originally, Luria (1969) introduced six types of aphasia (efferent motor, afferent motor, acoustic-agnostic, acoustic-amnestic, semantic, dynamic aphasia). However, a new category, amnesic aphasia, was introduced in his later work in 1976. Luria’s framework is based on the language modalities disrupted, for instance, acoustic-agnostic indicates reduced phonemic discrimination ability and semantic aphasia involves difficulty in comprehending logical-grammatical constructions, hence the term ‘semantic’ (Luria, 1969; as cited in Vinken & Bruyn, 2012)

For efferent motor aphasia, the primary language impairment is in articulation of single sounds or sounds combinations in words. As identified by Shinn and Blumstein (1983) in patients with efferent motor aphasia, there are several forms of articulatory impairments (e.g., perseverations of syllables/words, simplification of syllable structure). For afferent motor aphasia, the most common characteristic of this type of aphasia is impairment of the articulatory motor functions or impaired ability to perform speech movements. With dynamic aphasia, Luria describes this as impairment in the inner speech schemata, in which patients experience difficulty expressing themselves although they have a concept/idea about it. Following Luria’s work, subsequent work were conducted to investigate features of abnormal speech in various aphasia groups, Broca’s aphasia (Goodglass, Gleason, Bernholtz & Hyde, 1972; Kean, 1977), Wernicke’s aphasia (Danly, Cooper & Shapiro, 1983; Stark & Stark, 1990; Niemi & Laine, 1997), anomic aphasia (Bastiaanse & Jonkers, 1998; Martin, Roach, Brecher & Lowery, 1998) and conduction aphasia (Caramazza, Basili, Koller & Berndt, 1981; Kohn, 1984).

Despite proposing one of the early categorisations of aphasia, many argue that Luria’s descriptions of aphasia are outdated, and current classification should be considered (Akhutina, 2016). In a more recent work, Ardila (2010) proposed a new system of classifying aphasia symptoms. This system distinguishes types of aphasia based on (i) disturbance to primary language function (i.e., phonology, lexicon, semantics), (ii) disturbance of the mechanism of language production and (iii) impairment of executive control causing inappropriate use of language. From this classification, Ardila (2010) proposed three groups of aphasias: primary (central) aphasias, secondary (peripheral) aphasias and dysexecutive aphasia. Both Wernicke-type and Broca-type aphasia are categorised under primary aphasia, conduction and motor aphasia as secondary type aphasia and transcortical motor aphasia is categorised under dysexecutive aphasia which is characterised as impairment in the executive control of language.

In general, different taxonomies of aphasia symptoms exist based on either localisation of brain lesions and/or patterns of language impairment. Taken together, both approaches indicate a salient element of language and communication functions in describing aphasic symptoms. The next section moves on to discuss aspects of bilingual aphasia and how manifestation of aphasia differs from monolingual individuals.

**2.1.2 Bilingual Aphasia**

The term ‘bilingual’ here is used to refer to a person that uses more than one language daily (Grosjean, 1994). Many researchers agree that bilingual individuals cannot be treated as one homogenous group (Grosjean, 1994; Fabbro, 2001; Paradis, 2004; Khachatryan, Vanhoof, Beyens, Goeleven, Thijs & Van Hule, 2016). Bilinguals differ along several factors from degree of proficiency, age and manner of language acquisition and pattern of language use (Paradis, 2004). Considering these variations in bilingual individuals, it is therefore important to explore how these aspects may impact bilingual individuals with aphasia. Given that the present study explores EF abilities in healthy bilingual adults as the groundwork for the future study of bilingual PWA, it is crucial to briefly explore (1) characteristics specific to bilingual aphasia (bPWA), (2) bPWA recovery patterns and (3) bPWA cognitive profiles. This will provide some insights to consider when developing the M-EF battery.

Despite most of the world’s population being bilingual, common aphasia classification systems do not distinguish between symptoms of aphasia in monolingual and bilingual speakers, for instance, the Boston Aphasia Classifications (Khachatryan et al., 2016). Many of the aphasia classification systems assume no interference between languages spoken by a bilingual individual (see Khachatryan et al., 2016 for review). Although the diagnosis of aphasia in bilingual individuals indicates manifestations of symptoms similarly found in monolingual PWA (mPWA), among these symptoms, there are some specifically present only in bPWA. Khachatryan et al., (2016) identified three common symptoms found only in bPWA, (1) pathological mixing, (2) pathological switching and (3) translation disorders. Pathological mixing refers to using both languages during a single utterance, whereas pathological switching is characterised by changing the language from one utterance to another. Bilingual PWA also exhibits translation disorders, which is characterised by difficulty translating, spontaneous translation and translation without comprehension (Khachatryan et al., 2016). It is also important to note that impairment in cognitive control also plays a significant role in the development of some of the impairment patterns in bPWA, for example, severe inability to suppress one language when using the other during a single utterance may be exacerbated by inhibitory control impairments.

In addition to specific aphasia symptoms in bilinguals, bPWA also demonstrates differential recovery patterns relative to their two languages in **Table 2(i)**. Paradis (2004) identified six recovery patterns found in bilingual aphasia: (1) parallel recovery, (2) differential recovery, (3) antagonistic recovery, (4) alternating antagonism, (5) mixed/blending recovery (6) selective aphasia and (7) successive recovery. Paradis argues that these recovery patterns can be quite distinct from monolingual PWA (2004).

**Table 2(i):** Bilingual PWA recovery patterns

|  |  |
| --- | --- |
| **Recovery pattern** | **Language characteristics** |
| Parallel recovery | Recovery of language abilities parallel to premorbid relative abilities. |
| Differential recovery | One language recovers much better than the other relative to premorbid fluency |
| Antagonistic recovery | One language recovers initially, and as the other language becomes available, the initial language becomes unavailable |
| Alternating antagonism | Similar patterns as antagonistic recovery, but available and unavailable language switch more than once over time |
| Mixed/blending recovery | Uncontrollable mixing of words and grammatical constructions, unable to only use one language at a time |
| Selective aphasia | Presence of aphasia symptoms in only one language without measurable deficits in the other language |
| Successive recovery | Recovery of one language before the other |
| *Adapted from Paradis (2004)* | |

Furthermore, the demands placed by bilingualism on brain functions is believed to promote cognitive advantage in bilingual individuals. Despite numerous evidence pointing towards bilingual cognitive advantage (Green, 1998; Bialystok, 2011; Hilchey & Klein, 2011 & Valian, 2015) in healthy bilinguals as compared to monolinguals, there seems to be mixed findings in the cognitive profile of bilingual PWA. Penn and colleagues (2010) investigated the correlation between EF abilities of bilingual PWA (bPWA) and monolingual PWA (mPWA) with the conversational strategies used in natural speech (Penn, Frankel, Watermeyer & Russell, 2010). The study compared the ability of two bPWA with seven mPWA on an EF test battery measuring inhibition, working memory, problem-solving and reconstitution. It was found that the performance of bPWA in the EF tasks was significantly better than the mPWA. Additionally, it appears that the enhanced EFs are also evident in the compensatory strategies used by the bPWA in their conversation as compared to mPWA. The findings from this study confirm the view of EF advantage in bilinguals with aphasia positively influence language ability.

However, evidence of bilingual cognitive advantage is not consistent across bPWA groups as found by Faroqi and colleagues (2018). This study investigated bilingual cognitive advantage in relation to naming ability, comparing the performance of bilingual and monolingual PWA in a computerised, cognitive task, Stroop test (Faroqi-Shah et al., 2018) with age-matched healthy controls. The EF performance was compared to word retrieval ability in naming and category fluency tasks. The PWA were divided into three groups: (i) English speaking mPWA residing in US (ii) bPWA residing in India with Tamil as their first language (L1) and English as second language (L2), (iii) bPWA residing in the United States with L1 English and either Spanish, Russian, French or Hungarian as L2. It was found that EF is compromised in all PWA groups, irrespective of language status (bilingual or monolingual). However, bilingual advantage is only found in L1 English bPWA but not in L1 Tamil bPWA. Interestingly, despite the better EF ability in L1 English bPWA, it appears there was no difference in performance in the word retrieval tasks across all bPWA groups and mPWA. This evidence suggests better EF ability may not necessarily contribute to better word retrieval ability.

Given that L1 English PWA performed better in the Stroop test, this finding may further suggest that there are possible influences of culture, demographic and language differences in attributing to bilingual cognitive advantage in PWA (Faroqi-Shah et al., 2018). While this study demonstrated impaired EF ability in all PWA, the differential cognitive advantage across bPWA groups should be addressed. The absence of bilingual advantage in one bPWA group may potentially be attributed to the choice of EF measure selected in this study, the Stroop test. In addition, cultural relevancy, and familiarity with the context of the task may influence the performance of Tamil-English bPWA. Such factors will be further explored in Chapter 3.

Understanding of many issues pertaining to bilingual aphasia is still limited despite the growing bilingual population (Lorenzen & Murray, 2008). Bilingual groups are not only linguistically and culturally diverse, but bilingualism may be affected by factors such as colonisation and migration. Thus, research on bilingual aphasia should be extended and replicated in different bilingual populations to address the unique characteristics of bilingual PWA. Likewise, other factors contributing to aphasia symptoms such as cognition, education, culture, and demographics should be further explored to better understand and manage bilingual aphasia. This brings us to the discussion in *Section 2.2*, exploring the relationship between EF and language in aphasia.

Despite a growing understanding of bilingualism and the various recovery patterns identified with bilingual aphasia, there remains a dire need for empirically validated management techniques, particularly in terms of determining which language to target, identifying which aspects of various languages are most vulnerable to insult as well as most responsive to treatment, and establishing how to exploit language similarities to maximise treatment efficiency.

**2.2 Relationship between Executive Function and Language in Aphasia**

This section extends the discussion on aspects of EF deficits that concurrently present in aphasia and the evidence suggesting that speech and language success of PWA may depend on the integrity of EF. To begin with, *Section 2.2.1* briefly outlines evidence of EF deficits in aphasia. Subsequent *Section 2.2.2* discusses the correlation between EF deficits and language symptomology in PWA. Finally, this section concludes by exploring evidence of how rehabilitation involving EF is linked to aphasia recovery and better treatment gains.

**2.2.1 Evidence of Executive Function Deficits in Aphasia**

There is increasing evidence of executive dysfunction in PWA from numerous aphasia studies (Glosser & Goodglass, 1990; Purdy, 2002; Keil & Kaszniak, 2002; Frankel, Penn & Ormond-Brown, 2007; Zinn, Bosworth, Hoenig & Swartzwelder, 2007; Murray, 2012; El Hachioui, Visch-Brink, Lingsma, van de Sandt-Koenderman, Dippel, Koudstaal & Middelkoop, 2014; Mayer, Mitchison & Murray, 2016; Murray 2017; Mohapatra & Marshall, 2020).

Glosser and Goodglass’s study (1990) are one of the early experimental studies to specifically examine executive functioning ability in PWA. Four EF tasks (Non-verbal Continuous Performance, Graphic Pattern Generation, Sequence Generation Test and Tower of Hanoi) were administered to 22 left-brain damaged PWA, 19 right-brain damaged PWA and 49 healthy controls. PWA were further divided into groups according to lesion sites namely prefrontal, retrolandic and mixed. EF performance of PWA with frontal lobe lesions was significantly lower across all EF tasks compared to PWA with non-frontal lobe lesions. In addition, the localisation of frontal lobe lesions, left or right hemisphere indicated selective deficits in certain EF tasks. Further analysis found that the observed EF impairment was independent of the PWAs’ language impairments.

In another study, Purdy (2002) reported that EF deficits of PWA are consistent with EF disorder. Performance of fifteen PWA and twelve healthy controls were compared using four EF tests: Wisconsin Card Sorting Test, Porteus Maze Test, Tower of London and Tower of Hanoi. Three aspects of performance were analysed (accuracy, speed, and efficiency) to determine participants' ability to plan and monitor their performance. Comparing the performance of PWA and healthy controls, significant differences were found in speed and efficiency variables across most of the EF tasks. Analysis of accurate responses showed poor EF in PWA primarily in cognitive flexibility. Similar to Glosser and Goodglass (1990), Purdy made no mention of the link between EF and language impairment. However, Purdy recommended future studies to investigate the role of EF and its relationship with language in PWA.

Moving away from the traditional measures of EF, Murray (2017) adopted the design fluency approach in examining the integrity of EF and its relationship to language performance in PWA. The design fluency method allows for a measure of executive functioning skills such as planning, initiation, and cognitive flexibility. The cohort was divided into three groups: 36 healthy controls, 15 right-brain damaged and 36 left-brain damaged. All left-brain damaged participants were diagnosed with mild to moderately severe aphasia according to the Aphasia Diagnostic Profile. Whereas right-brain damaged participants presented a mild to severe form of cognitive-communicative impairment. All participants completed a non-verbal fluency test, Ruff Figural Fluency Test (RFFT) and formal cognitive-linguistic test battery. Performance results were qualitatively (i.e. number and length of orderly patterns, number, and types of non-repetition errors) and quantitatively (i.e. perseverative error ratio, number of unique designs) analysed. Quantitative analysis revealed poorer performance in both groups, PWA and right-brain damaged individuals compared to healthy controls. The study also confirmed that EF deficits may occur simultaneously with symptoms of aphasia in PWA. This result corroborates with previous findings (Glosser & Goodglass, 1990; Purdy, 2002; Murray, 2012) despite employing a different approach in measuring EF performance.

A more recent study, investigating the integrity of EF abilities in relation to aphasia recruited participants from three different cohorts: 30 healthy young adults, 30 healthy older adults and 10 PWAs (Mohapatra & Marshall, 2020). In the study, four EF domains (updating, inhibition, set-switching and dual task processing) were evaluated using different EF tasks. Four EF tasks administered were: Conners’ Continuous Performance Test II, n-back, Colour Trails Test and divided attention task, with each task tapping into different EF domains. Overall, PWA demonstrated poorer performance on all EF tasks in comparison to both healthy groups (i.e., young and older adults). Further analysis indicated that aphasia severity correlates strongly with diminished performance on specific EF domains. This result broadly supports the work of previous aphasia studies linking impaired EF ability with symptoms in PWA. The findings presented thus far support the need to consider the EF profile in PWA to better understand and serve the needs of PWA. To strengthen the aim of this thesis, the next section will discuss evidence of EF abilities influencing PWA performance in specific language processes.

**2.2.2 EF and Language Behaviour**

The integrity of EF in PWA has been the subject of numerous aphasia studies (Purdy, 2002; Kalbe, Reinhold, Brand, Markowitsh & Kessler, 2005; Frankel, Penn & Ormond-Brown, 2007; Fucetola, Connor, Strube & Corvette, 2009; Yeung & Law, 2010; Murray, 2012; Hachioui, Visch-Brink, Lingsma, van de Sandt-Koenderman, Dippel, Koudstaal and Middlekoop, 2013; Gilmore, Meier, Johnson & Kiran; 2019). However, despite a long-standing acknowledgement of executive dysfunction in the aphasia population, studies exploring the effect of EF deficits on language impairments have only emerged a few decades ago (Odell & Tseng, 1991; Murray, 2000; Murray, 2012). The following sections aim to discuss the influence of EF deficits on specific linguistic abilities in PWAs. The literature presented has been divided into two subsections: 2.2.2.1 EF and language processing and 2.2.2.2 EF and communication.

**2.2.2.1 Language Processing**

Several lines of evidence suggest decreased EF abilities in PWA (aforementioned in Section 2.2.1). Based on this evidence, a number of studies have begun to examine the nature of EF deficits in relation to patterns of language impairment in PWA. It appears that EF deficits influence language processing ability in PWA at various linguistics levels: phonemes and semantic (Martin, Kohen, Kalinyak-Fliszar, Soveri & Laine, 2012), semantic (Kohen, Martin, Kalinyak-Fliszar, Bunta & Dimarco, 2007; Allen, Martin & Martin, 2012), syntactic (Caplan, Michaud & Hufford, 2013; Thothathiri & Mauro, 2017; Peristeri, Tsimpli, Dardiotis & Tsapkini, 2020), morphosyntactic (Fyndanis, Arcara, Christidou & Caplan, 2018), lexical retrieval (Murray, 2000; Martin, Kohen, Kalinyak-Fliszar, 2010; Minkina, Martin, Spencer & Kendall, 2018) and discourse production (Cahana-Amitay & Jenkins, 2018). Three EF domains have been the focus of investigation in relation to language processing ability in PWA, namely, working memory (WM), attention, and short-term memory (STM).

First, the effect of increased WM demand on semantic and phonological processing abilities has been observed in PWA (Martin et al., 2012). Martin and colleagues evaluated the effects of increased verbal WM load on the performance of judgement tasks: semantic similarity and phonological similarity in 31 PWA and 11 healthy controls. Both judgement tasks (synonymy and rhyming) were administered to both groups in two conditions, high and low verbal WM load. Two sets of data analyses were conducted, first to identify the effect of increased verbal WM on participants’ performance and second, to determine whether WM load or any other EF abilities influence performance of the synonymy and rhyming tasks. It is reported that increasing WM load during both judgement tasks reduced the rate of accurate responses in the PWA. The second analysis revealed that two EF abilities, semantic STM and inhibition ability contribute to the verbal WM load effects in both judgement tasks.

Additional studies investigated the influence of WM in discourse (Cahana-Amitay & Jenkins, 2018) and morphosyntactic production (Fyndanis et al., 2018). These studies found that WM is significantly involved in both these language processes. Cahana-Amitay and Jenkins investigated the influence of WM in discourse production involving retelling a famous children’s story, Cinderella in three groups of PWA: Broca’s aphasia, Wernicke’s aphasia and anomic aphasia. In addition to discourse production, WM tasks consisting of W1 word span, W2 sentence span and W3 unique sentence span were administered. Multi-level discourse analysis in terms of micro (lexical diversity, grammatical complexity, narrative length) and macro (local coherence, global coherence, and story organisation) were measured and intergroup performances were compared. Data analysis revealed that some components of WM (WM1 and WM2) influence macro-level discourse components and these effects may be sensitive to aphasia type. However, there is no evidence for influence of WM on micro-level discourse components which the researchers attributed to familiarity of the children’s story masking semantic difficulties faced by participants.

Fyndanis et al., (2018) on the other hand investigated the effects of verbal WM in morphosyntactic production of eight agrammatic aphasics and 108 healthy Greek speakers. The study also aimed to explore the interaction between verbal WM and verb-related morphosyntactic categories such as, tense/time reference, subject-verb agreement, and aspect. Participants' verbal WM capacity was measured using the Greek version of digit ordering span task, backward digit span task. Whereas, morphosyntactic production was measured using sentence completion tests. The results showed poor WM capacity adversely affecting accurate morphosyntactic production of tense and aspect for all eight PWAs and eight of the healthy controls. However, it appears that performance for subject-verb agreement was only slightly affected by poor WM. Fyndanis et al.’s (2018) findings indicate that WM plays an essential role in facilitating the production of morphosyntactic structure in the Greek language in both PWA and healthy adults.

Another EF domain postulated to some extent causing language deficits in PWA is attention. Several studies proposed that aphasia is a result of injury to attentional processes which support language processing ability rather than damage to linguistic knowledge (Tseng, McNeil & Milenkovic, 1993; Hula & McNeil, 2008; see review Villard & Kiran, 2017). Peristeri et al., 2020 investigated the relation between attention and sentence comprehension by measuring the ability to resolve garden path sentences in nonfluent PWA. Syntactic comprehension ability of 15 PWA and 15 healthy controls was measured using a self-paced reading grammaticality judgement task which includes object-subject ambiguous sentences. After reading each sentence aloud, participants were signalled to rate the sentence as grammatically correct or incorrect by pressing a red/green coloured button. Accuracy and response time was measured for each group. Following that, a global-local attentional control task was administered to measure local-to-global and global-to-local attentional switching ability. Overall, PWA showed slower response time and lower accuracy scores than controls when disambiguating garden path sentences. Also, PWA exhibited attention shifting deficits and greater difficulty than controls in disassociating attention from global information to focusing on specific local information. However, healthy controls showed no attention shift deficits in either global-local or local-global levels. The authors interpreted PWA's reduced ability in resolving ambiguous sentences as the result of the increased demands posed by these types of sentences as well as attention shifting deficits presented by PWA. PWAs’ impaired ability to switch focus from global to local perceptual level increased the difficulty in disambiguating garden path sentences.

Attention has also been examined in relation to word retrieval in aphasia (Murray, 2000). The study hypothesised that if attentional resources necessary to complete a task exceeds capacity, performance of the task is reduced. In order to measure this, Murray administered a phrase completion task in two conditions: in isolation and in competition with a secondary tone discrimination task. The dual-task versus single-task conditions will manipulate the degree of attentional demands required. In addition, attentional demands are also manipulated by varying phase constraints (closed versus open set phrase stems). Performances of 14 PWA, eight right-brain damaged (RBD) individuals and nine healthy controls were analysed, and group performance was compared. Murray (2000) reported optimal performance in the isolation sentence completion task for PWA, however, when dual tasks were administered, PWAs’ word retrieval ability deteriorated. PWAs’ responses were not only inaccurate for most sentences in dual-task condition, but they also completed fewer sentences than RBD and healthy controls. Another important finding is PWAs’ inability to retrieve words for open set phrase stems (e.g He likes to eat \_\_\_) which suggests PWAs’ inability to retrieve target word from a large number of likely candidates compared to when a target word is chosen from a smaller set of likely words (e.g It’s raining cats and \_\_\_\_). Given the performance of PWAs in the study, Murray concluded that impairment of attentional capacity significantly increased the difficulty for lexical retrieval in PWA. Both studies (Murray 2000; Peristeri et al., 2020) concluded that attention deficit comorbid with aphasia impacts language processing ability in this population.

The final component of EF that will be reviewed in this section is short-term memory (STM). The effect of STM has been identified in sentence comprehension (Caplan, Michaud & Hufford., 2013; Thothathiri & Mauro, 2017), semantic processing (Allen, Martin & Martin, 2012) and word retrieval (Minkina, Martin, Spencer & Kendall, 2018) in aphasia.

Caplan and colleagues (2013) hypothesised that deficits in mechanisms that support STM resulted in impairment in syntactic comprehension ability in PWA. Sixty-one individuals with aphasia with a single left hemisphere stroke and forty-six controls participated in this study. Participants' STM abilities were assessed using a series of ten STM tests (i.e. six tests measure immediate serial recall and four tests assess retention and manipulation of items). Four measures of STM components were identified: “forward, simple”, “demanding, complex”, The Phonological Similarity Effect and The Word Length Effect. To test syntactic comprehension, participants were given object manipulation and sentence-picture matching tasks in two conditions: full sentence and self-paced listening tasks. These syntactic comprehension tasks measure participants’ ability to parse, interpret varying clause types and their ability to combine operations for relative clauses using a reflexive or a pronoun. It is reported that PWA with lower STM consistently performed poorly across parsing and interpretation tasks. The overall pattern of sentence type, tasks and STM performance suggest a facilitatory function of STM in supporting aspects of the comprehension processing in aphasia.

In another study investigating the relationship between word retrieval and STM, Minkina and colleagues (2018) administered picture naming and verbal STM tasks to twenty-four PWA. To measure word retrieval ability, the Philadelphia Naming Test (PNT) consisting of 175 nouns varying in frequency and imageability was administered. Participants’ responses were recorded, and error responses were categorised according to error type. To measure verbal STM, a word pair repetition task was administered, where participants were instructed to repeat each word pair in order immediately after hearing them. Whereas nonverbal STM was assessed using the Corsi block span test. A significant positive correlation was found between verbal STM and word retrieval accuracy, however no correlation was found between word retrieval and non-verbal STM. Overall, PWA with higher scores in verbal STM showed greater accuracy in word retrieval. The study concluded the STM mechanism which supports word retrieval is language-specific, with verbal STM affecting word retrieval ability in PWA but not the non-verbal component.

These findings suggest EF acts as a support system for effective language processing. The evidence of impairment in specific EF domains in relation to different language processes indicates that different EF domains may be utilised for different language processes. Hence, it is important to provide an EF evaluation in all PWA so that EF can be considered during language intervention for aphasia.

**2.2.2.2 Communication**

Communication is characterised as a demanding activity that requires not only linguistic knowledge but also EF abilities. Specific EF domains are vital for planning appropriate sequencing of speech, paying attention to communication partners, and shifting communicative strategies when necessary (Miyake, Emerson & Friedman, 2000; Ramsberger, 2005; Olsson, Arvidsson & Blom Johansson, 2019). Due to significant correlations between communication and EF abilities, PWA with impaired EF abilities may face limitations engaging in functional communication. Thus, numerous studies have explored the relationship between EF ability and communication in PWA to help informed understanding and treatment of language in aphasia (Fridriksson, Nettles, Davis, Morrow & Montgomery 2006; Frankel, Penn, Ormond-Brown, 2007; Penn, Frankel, Watermeyer & Russell, 2010; Nicholas, Sinotte & Helm-Estabrooks, 2011; Olsson, Arvidsson & Blom Johansson, 2019 Spitzer, Binkofski, Willmes & Bruehl, 2020).

In an exploratory study, Frankel and colleagues' (2007) investigated the relationship between EF abilities and conversational strategies in a case study of a person with aphasia, MS. A recording of MS’s conversation and performance across a series of adapted EF tasks were gathered. The recordings were analysed using conversation analysis practice (i.e., turn-taking, topic management and repair). The results from MS’s EF performance showed intact functions for sustained attention, memory, planning and inhibitory control. These preserved areas of EF are linked to topic management and turn-taking ability in which MS presented neither significant deficits nor difficulty. However, MS demonstrated poor ability in other domains of EF, shifting attention, verbal WM, and non-verbal WM. These EF domains are linked to the ability to self-repair. Analysis of MS’s conversation indicated poor ability to use communication strategies to revise her initial speech errors which are linked to her poor EF performance. The influence of specific EF domains in the manifestation of communication difficulties in PWA is clear from this case study.

EF has also been studied in relation to functional communication (Fridriksson et al., 2006; Olsson, Arvidsson & Johansson, 2019). Functional communication refers to the ability to communicate effectively and independently, ranging from the ability to process information from communicative partners to getting messages across in an appropriate manner (Fridriksson et al., 2006).

To determine the effects of decreased EF ability on functional communication, Fridriksson and colleagues assessed twenty-five PWA characterised with post-stroke aphasia. A series of tests were administered to all PWA to measure EF, functional communication, and language impairment. Measures of EF include two tests: Colour Trails Test (CTT) and Wisconsin Card Sorting Test (WCST). American Speech-Language Hearing Association Functional Assessment of Communication Skills for Adults (ASHA FACS) was used to measure functional communication and Bedside Evaluation Screening Test (BEST 2) was administered for evaluation of language impairment. It was reported that PWA exhibiting poor scores in the EF tasks also showed poor performance in measures of functional communication. Furthermore, a strong correlation between functional communication and measures of severity of language impairment, where PWA with greater language impairment showed decreased functional communication ability. Fridriksson et al. concluded that decreased EF ability in PWA correlates to reduced functional communication ability.

Olsson et al., (2009) findings confirm the association between EF and functional communication in PWA. The study employed forty-seven native Swedish speakers with severe aphasia. Participants were divided into verbal (n= 23) and nonverbal (n= 24) subgroups, based on the severity of aphasia and verbal output. All participants were assessed for EF, linguistic ability and functional communication. Four subtests from Cognitive Linguistic Quick Test (CLQT) were used to measure EF. Whereas language ability was measured using the language component of Comprehensive Aphasia Test (CAT). And functional communication was measured using two different tests: formal testing using Scenario test and rating of daily conversation by a significant other using Communicative Effectiveness Index (CETI). The findings showed 79% of participants scored below the threshold score for normal EF performance in CLQT. Further analysis of EF scores and linguistic ability suggests significant correlations between the two components confirming the association between language and EF. Additionally, subgroup analyses found that in nonverbal PWA functional communication greatly depends on the integrity of EF. However, this is not the case for verbal PWA, no correlation between EF, language ability and functional communication were found. Overall, functional communication ability varies between severe aphasia subgroups. Within each subgroup (verbal and nonverbal) factors associated with functional communication are linguistic ability and EF respectively.

The correlations reported by Olsson et al., involve additional factors such as verbal output and severity of aphasia which were not included in Fridriksson et al.’s (2006) exploratory study. With these new findings, the authors acknowledge the influence of EF in successful and effective communication in aphasia. Likewise, Olsson and colleagues highlighted the importance of evaluating executive functioning skills on top of the measure of language competency of PWA in communication intervention. Deeper understanding of language and EF impairment profiles of PWA would allow for better development and implementation of rehabilitation plans to support speech and communication of PWA. The findings which suggest correlation between EF and language impairment in PWA lead to the discussion in the next section on the role of EF in the treatment of aphasia.

**2.2.3 EF and Response to Treatment in Aphasia**

This section briefly discusses findings supporting the role of EF in predicting successful aphasia therapy. Several promising indicators of aphasia recovery such as age, education and lesion size have been informative in predicting PWA rehabilitation improvement. However, some argue that it remains difficult to predict aphasia recovery post-treatment (Simic, Bitan, Turner, Chambers, Goldberg, Leonard & Rochon, 2019). Such factors (e.g., age) do not provide an adequate explanation for differential patterns of recovery in aphasia (Lazar & Antoniello, 2008) nor an explanation for PWA everyday communication behaviour (Ramsberger, 2005). It was discovered that EF is the ‘most robust cognitive predictor of poor functional recovery after stroke’ in a large-scale study of 200 patients 1 year after the onset of stroke (Lesniak, Bak, Czepiel, Seniow, Czlonskowska, 2008). As a result, EF has been increasingly investigated as a potential predictor of aphasia treatment success.

In several recent studies, it was found that nonlinguistic cognitive pretreatment influences aphasia therapy outcomes (El Hachioui, Visch-Brink & Lingsma, 2013; Gilmore, Meier, Johnson & Kiran, 2019). In one study, Gilmore and colleagues (2019) investigated the likelihood of pretreatment EF abilities in predicting language treatment outcomes following naming and sentence comprehension treatments. Several EF tests were administered namely Forward and Backward Digit Span, Pyramids and Palm Trees Test, Corsi Block Test and Doors and People Test. It was found that PWA with higher pretreatment EF ability demonstrated higher naming accuracy both after semantic-based naming treatment and 12 weeks after treatment completion. Given the findings, the authors support the assessment of EF abilities prior to language treatment in predicting PWA’s language treatment outcomes. Similarly, a study by Dignam et al., (2017) found significant evidence pointing towards the influence of verbal short-term memory (STM) on naming therapy gains (Dignam, Copland, Brien, Burfein, Khan & Rodrigues, 2017). Besides STM, Dignam et al., (2017) also found that domain-general EF influences therapy success for treated words in PWA. Taken together, these studies suggest that EF is an important variable to consider prior to aphasia therapy in order to predict treatment outcomes.

Other EF domains such as cognitive flexibility (CF) is also linked to better treatment outcomes in PWA (Simic et al., 2019; Spitzer, Binkofski, Willmes & Bruehl, 2021). Spitzer et al., (2021) conducted a study investigating whether CF therapy in addition to aphasia therapy would lead to higher improvement in ten PWA. It was found that EF therapy results in a higher improvement in language skills, daily communicative abilities, and verbal cognitive flexibility in ten PWA. By using a newly developed combined treatment of CF and language, Spitzer and colleagues found that this therapy is especially effective for PWA with severe expressive language abilities. As a result, such combined treatment can potentially improve PWA’s social participation compared to conventional aphasia therapy. EF domain, inhibitory control (IC) has also been linked to higher treatment gains in naming therapy (Yeung, Law & Yau, 2010; Simic et al., 2020). In a study of five Chinese speaking PWA, it appeared that participants with higher inhibitory control scores demonstrated significant improvement in naming untreated words. As a whole, these studies revealed the role of executive function in predicting rehabilitation outcomes of PWA which are useful for an effective aphasia treatment plan. Although in general, EF has been established as an important indicator of aphasia treatment success, much work is needed to understand at which stages of post-stroke is this effective and whether different EF domains predict different outcomes.

In summary, Section 2.2 has highlighted the significance of EF in PWA, especially in supporting various language functions and predicting aphasia treatment outcomes. As a result, the significance of EF in understanding aphasia symptoms cannot be disregarded. Despite the critical need for clinicians and healthcare providers to understand the nature of EF and its relation to language and communication, there are currently no available EF tests that are linguistically and culturally relevant for assessing Malay PWA in Malaysia. Hence owing to this unavailability, this study aims to develop a Malay language executive function test battery suitable for Malay speakers in Malaysia. This next section draws together information on aphasia research in Malaysia and the linguistic aspects of the Malay language to facilitate our understanding of the target language users.

**2.3 The Malaysia Context: Aphasia and Language**

This next section provides background information on the target population under study. It includes information on the research of aphasia in Malaysia and linguistic features of the Malay language pertinent to the development of M-EF test battery in the present study.

**2.3.1 Aphasia Research in Malaysia**

Aphasia research in Malaysia is still in its infancy, with several recent research exploring the management of multilingual PWA in Malaysia (Hassan et al., 2023) and language and clinical profile of PWA in Malaysia (Aziz et al., 2023). Presently, aphasia management in Malaysia is managed by speech language therapists in hospitals, rehabilitation centres, nursing homes and personal homes by SLTs in the private sector (Hassan et al., 2023). From the survey conducted by Hassan et al., (2023, the current management of aphasia in Malaysia includes individual assessment and treatment sessions, group therapy sessions, and limited teletherapy sessions. Intervention delivery for aphasia is varied across regions, from once every week to once every three to six months (Hassan et al., 2023). The study also reported that there is an extensive use of informal assessment approaches to compensate for the lack of standardised aphasia tests in the local languages. The two common standardised aphasia tests used in the local language are Boston Diagnostic Aphasia Examination and Western Aphasia Battery. Due to the limited number of standardised assessments in the local languages, some SLTs reported that they did not use the materials or follow the administration protocol of the standardised assessments with PWA.

In terms of clinical and demographic profile of PWA in Malaysia, most individuals experiencing aphasia were stroke survivors (Aziz et al., 2023). However, the proportion of stroke survivors experiencing aphasia in Malaysia is significantly lower compared to other countries such as the United States and Australia. With regards to age, older and middle-aged adults are more likely to suffers from aphasia. All ethnic groups are found to experience aphasia following a stroke, suggesting the specific challenges posed in aphasia assessments and interventions in a linguistically diverse country, Malaysia (Aziz et al., 2020; Aziz et al., 2023).

The lack of standardised intervention methods and higher aphasia incidence among Malay speakers warranted the need to develop a linguistically and culturally relevant aphasia assessment tools for Malay speakers (​​Van Dort, Vong, Razak, Mustafa Kamal & Hooi, 2007; Jalil, Liow, Keng, 2011; Noorsham, Abdullah, Abdul Halim, Ghani, Idris, Abdullah, 2020). The attempts to address gaps in aphasia service provision marked an important milestone in aphasia research in this country. As a diverse, multilingual country, speech assessment for individuals in Malaysia has been a huge challenge (Noorsham et al., 2020; Hassan, Heng & Mustafa Kamal, 2020). These challenges arise due to the multiple languages spoken in Malaysia, differences in customary practices and cultural etiquettes of patients and clinicians (Hassan et al., 2020). Moreover, despite the attempts to develop Malay language aphasia assessment, many of these tests were found to be culturally irrelevant to the Malaysian population. For example, in the adapted Malay version Boston Naming Test (BNT) only 48.3% of items are culturally relevant to the Malaysian population. The other items are unfamiliar and less relevant to the Malaysian experience (e.g., acorn, wreath).  As a result, most practitioners opt for translations or using informal tests when assessing PWA (Jalil et al., 2011). A survey distributed to speech-language practitioners (SLP) involved in the rehabilitation of aphasia in Malaysia found that linguistic barriers and lack of standardised tests are two major challenges in assessing PWA (Hassan et al., 2020). Language and cultural diversity complicate the development of aphasia resources; however, considerations of these two aspects may improve the accuracy of diagnosis and effectiveness of rehabilitation. In practical terms, the development of EF assessment from this study can inform service provision for Malay speaking PWA and contribute to the efforts of developing a standardised assessment tool in Malaysia. Thus, the need to address the lack of culturally and linguistically appropriate aphasia assessment tools for Malay speaking PWA provides the rationale for this study.

**2.3.2 Linguistic features of Malay**

The Malay language belongs to the Austronesian language family and is a national language of four countries in southeast Asia, Malaysia, Brunei, Singapore and Indonesia (Koran, 2015). The structure of Malay is subject-verb-object (SVO) (Asmah Omar, 1993). Unlike English, Malay verbs are not marked with tense or numbers. Aspects of modality are indicated by a group of words such as ‘sudah’ (already), masih (still), ‘akan’ (will). Malay is a language rich in productive derivational morphology but does not contain inflectional morphology (Goddard, 2002; Sulaiman, Gasser & Kubler, 2011). Malay words can be divided into distinct morphemes with clearly defined boundaries (root, prefix, suffix, infix, circumfix) (Sulaiman et al., 2011). The productive nature of Malay morphology also sometimes results in a change of syntactic category. For example, the verb ‘baca’ (read) when combined with the prefix ‘pe-’ in ‘pembaca’ (reader) becomes a noun. Another important feature of Malay derivational morphology is that verbs are also marked with affixes to denote meaning change. For example, the prefix ‘ter’ marks unintentional, nonvolitional or completed action.

Malay word formation also includes reduplication (Sharum, Hamzah, Abd. Wahab & Ismail, 2010). There are three common forms of reduplication (i.e., full reduplication, partial reduplication, rhythmic reduplication). Another form of reduplication ‘free-form reduplication’ is yet to be understood (Sharum et al., 2010). Full reduplication involves repeating the entire base word such as makan-makan (eat). Partial reduplication involves duplicating the root word after a prefix+verb or before a prefix+verb. For instance, ‘berjalan-jalan’ (strolling) and ‘pukul-memukul’(hitting each other). Another form of partial reduplication is first syllable reduplication for instance ‘pepatung’ (dragonfly). Rhythmic reduplication involved repeating certain elements in the root word. For instance, ‘kucar-kacir’ (clutter/mess) and ‘riuh-rendah’ (loud/rowdy). Finally, there are reduplicated words in Malay that have yet to be categorised into any types, free-form reduplication. For example, ipar-duai (brother and sister-in-law). The formation process of these words remains undefined however, some linguists argue that these word formation might be influenced by suprasegmental aspects such as pitch and stress (Musa, 1993).

The information on Malay language derived here represents the standard variety, or as termed by Koran (2015) ‘educated variety of Malay’. The colloquial Malay often used in informal conversations are less documented. The colloquial Malay differs from standard Malay in terms of grammar and lexical forms (Koran, 2015). Words in colloquial Malay are often phonologically reduced. For example, ‘tahu’ (know) is reduced to ‘tau’ and ‘tidak’ (no) is realised as ‘tak’ in colloquial Malay. These aspects of the Malay language are important to be considered when developing the verbal part of the executive function test. Further details of syntactic and lexical structure of Malay language are discussed in Chapter 5.

**2.3.3 Malay Culture**

The information in this section is from both scholarly sources as well as from the researcher’s native Malay perspective. Malay are among the indigenous people in the Malay archipelago (Mastor, Jin & Cooper, 2000). In this study, the term Malay is specifically used to refer to Malays who are Malaysian citizens and are differentiated from the other two major Malaysian ethnic groups, Indians, and Chinese. In general, the facets of Islam permeate most aspects of the Malay way of life however, other customs also play a part in moulding the Malay culture. Some customary traditions originated from early Malay beliefs (e.g., animism, Hinduism, Buddhism) while others are influenced by other nations (e.g., Thailand, Java, Sumatra). These customary practices are still relevant within the Malay community and remain a visible aspect of a Malay’s cultural identity.

The Malays have a strong sense of community which can be reflected in events such as weddings, funerals, and birth of a child. Malay culture also emphasises manners or ‘adab’ as a way of life (Mastor et al., 2000). Another important concept of Malay culture is the social emotion of shame or propriety (malu). The Malay community regard having a sense of ‘malu’ as a virtuous act and an element of basic goodness in a person. Within Malay culture, there remain many topics that are still considered taboo. For example, discussing divisive racial issues, abortion and addiction are considered as inappropriate within this cultural group. Aspects of Malay culture and traditions should be considered when developing an executive function test battery for this population. Ensuring inappropriate and unfamiliar test items that contain nudity, religiously sensitive or racially divisive items are avoided.

So far Section 2.3 draws together background information on the target population under study. Along with discussion on aspects of Malay language and culture, some aspects of aphasia research in Malaysia were also highlighted. Features of the language and its users are important factors to consider when developing a Malay EF test battery. This chapter has established understanding on the correlation between aphasia, EF, and language processes. Along with some background information on the target population understudy. The following Chapter 3 will discuss the conceptual, methodological, and lingua-cultural considerations of developing the Malay Executive Function (M-EF) battery for the present study.

\*\*\*\*\*\*

**Chapter 3 Executive Functions Assessment and Considerations for PWA**

This chapter begins with a brief review of previously employed EF tests for administration in PWA. This discussion will support the selection of EF tasks for M-EF battery which will be used for future assessment with PWA. Following that, Section 3.2 draws together relevant considerations pertinent to the development of EF measures for different linguistics/ethnic groups. Section 3.3 provides information about the EF tasks selected in the present study.

**3.1 EF Assessments and Measurement of EF Domains from Aphasia Studies**

There are several frequently used EF assessments for evaluating PWA, all of which differ in terms of task specification and the underlying EF domains. This section presents some of the EF assessments selected in previous research for assessing PWA. Some limitations to the EF tests with regards to suitability for PWAs will also be briefly discussed.

**3.1.1 Summary of Common EF Tests in Aphasia Studies**

A review was conducted on February 26th, 2021, using the PubMed database by searching the terms “executive function assessment”, “aphasia” and “stroke”. Articles that fulfilled the following criteria were included: i) published between 2010 - 2021; ii) participants aged more than 18; and iii) participants diagnosed with aphasia and/or language impairment post-stroke. The exclusion criteria were: i) participants with psychiatric or neurological conditions; ii) review studies, and iii) journals unavailable in English. The search results in **Table 3(i)** yielded twenty-seven articles of which eight articles were excluded

**Table 3(i):** Summary of EF tasks used in 19 aphasia studies with reference to the predominant EF domain.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **No** | **Reference** | **EF assessment used** | **EF domains** | **Sample characteristics** |
| 1 | Alyahya. Halai, Conroy & Lambon Ralph ([2018](https://www.sciencedirect.com/science/article/pii/S2213158218300238?via%3Dihub#s0025)) | Forward Digit Span Backward Digit Span | Working memory | English-speaking stroke patients with chronic aphasia (n=48) |
| Raven’s Coloured Progressive matrix | Planning |
| Brixton Spatial Anticipation Test | Cognitive flexibility |
| 2 | Bonini & Radanovic (2015) | Trail Making Test | Cognitive flexibility | Brazilian-Portuguese speaking PWA (n=21) |
| Forward Digit Span Backward Digit Span  Praxis and Constructional Praxis Recall (CERAD) | Working memory |
| Gesture Praxis Protocol (BDAE)  Visual Memory  Word List Memory; Recall; Recognition | Short-term memory |
| Clock-Drawing Test | Planning |
| 3 | Demeyere, Riddoch, Slavkova, Bickerton & Humphreys (2015) | Oxford Cognitive Screen (OCS) | Executive functions  Working memory  Cognitive flexibility | Acute stroke patients aged between 25 to 96 (n=208) |
| 4 | Dignam, Copland, O’Brien, Burfein, Khan & Rodriguez (2017) | Elevator Counting  Elevator Counting with Distraction | Sustained attention  Selective attention | English-speaking PWA diagnosed with chronic aphasia (n=34) |
| Hopkins Verbal Learning Test - Revised | Verbal short-term memory |
| Forward Digit Span  Reverse Digit Span | Working memory |
| Delis-Kaplan Executive Function System (D-KEFS) | Cognitive flexibility |
| D-KEFS Switching | Concept formation |
| D-KEFS Sorting | Problem solving |
| 5 | El Hachioui, Visch-Brink, Lingsma, van de Sandt-Koenderman, Dippel, Koudstaal &  Middelkoop (2014) | Matrix reasoning  the Wechsler Adult Intelligence Scale–III  (WAIS-III) | Abstract reasoning | Dutch-speaking PWA diagnosed with acute aphasia (n=147) |
| Visual Semantic Association Test  Modified Pyramids and Palm Trees Test | Short-term memory |
| Trail Making Test  Weigl Sorting Test  Wisconsin Card Sorting Test (WCST) | Cognitive flexibility |
| 6 | Fonseca, Raposo & Martins (2019) | Matrix Reasoning | Abstract thinking | Spanish -speaking stroke patients with and without aphasia (n=39) |
| Tower of Hanoi | Planning and problem solving |
| Clock Drawing Test | Planning |
| Motor Initiative of the Lisbon Battery for Assessment of Dementia (BLAD) | Task switching |
| Memory for Faces Test  5 Objects Memory Test  Spatial Span | Working memory |
| Symbol Search of the Wechsler Adult Intelligence Scale (WAIS)  Cancellation Task of BLAD | Sustained attention |
| 7 | Gilmore, Meier, Johnson & Kiran (2019) | Block Design  Raven’s Coloured Progressive Matrices | Planning | English-speaking PWA (n=67) |
| Corsi block tapping test  Digit span forward  Digit span backward  Doors visual recognition  Geometric Inclusion  Geometric Matching  Pyramid and Palm Tree | Working memory |
| Cognitive Linguistic Quick Test (CLQT) | Attention  Working memory |
| 8 | Kokubo, Suzuki, Hattori, Miyai & Mori (2015)  *This study categorise memory and attention under the umbrella term EF* | Digit span  Visual span  Sequencing subtest of Wechsler Adult Intelligence Scale (WAIS-III) | Working memory | Japanese-speaking stroke patients (n=15). |  |
| Trail Making Test Wisconsin Card Sorting Test (WCST) | Cognitive flexibility |  |
|  |
| 9 | Lacey, Skipper-Kallal, Xing, Fama & Turkeltaub (2017) | Cognitive Linguistic Quick Test (CLQT)  Digit Span  Pyramids and Palm Trees | Executive function | English-speaking PWA with chronic left hemisphere stroke (n=38) |  |
| BDAE Semantic Probe  WAB Sequential command  WAB Yes/No  WAB word recognition  Word-to-picture matching | Working memory |  |
| 10 | Law, Young, Pinsker & Robinson (2015) | Digit Span | Working memory | English-speaking stroke patients aged between 47-84 with mild EF deficits (n=18) |  |
| Hayling Sentence Completion Test (HSCT) | Inhibitory control |  |
| Word fluency  Design fluency | Cognitive flexibility  Working memory |  |
| Raven’s Advanced Progressive Matrices (APM) | Abstract reasoning |  |
| 11 | Mancuso, Demeyere, Abbruzzese, Damora, Varalta, Pirrotta, Antonucci, Matana, Caputo, Caruso, Pontiggia, Coccia, Ciancarelli, Zoccolotti & Italian OCS Group (2018) | Oxford Cognitive Screen (OCS) | Executive function  Working memory  Attention  Task switching | Italian-speaking PWA aged between 18- 90 (n=325) |
| 12 | Niessen, Ant, Bode, Salinger, Karbe, Fink, Stahl & Weiss (2020) | Go/No Go Task | Inhibition | Participants diagnosed with left hemispheric ischemic stroke (n=33) |
| Trail Making Test | Cognitive flexibility |
| 13 | Olsson, Arvidsson & Blom Johansson (2020) | Cognitive Linguistic Quick Test (CLQT) | Attention  Working memory | Swedish-speaking PWA (n=38) |
| 14 | Pulsipher, Stricker, Sadek & Haaland (2013) | Neuropsychological Assessment Battery (NAB) | Selective/Divided Attention  Cognitive Flexibility  Working Memory | English-speaking PWA (n=69) |
| 15 | Rodrigues, Machado, Da Fontoura, Almeida, Brondani, Martins, Bandeira, de Salles (2019) | Brief Neuropsychological Assessment Battery NEUPSILIN | Memory  Executive functions | Brazilian-born PWA (n=49) |
| 16 | Schumacher, Halai & Lambon Ralph (2019) | Test of Attentional Performance  Alertness  Go/NoGo  Divided Attention | Attention | English speakers aged between 45 - 88 with a single left hemispheric stroke |
| Raven’s Coloured Progressive Matrices  Tower of London | Planning |
|
| Trail Making Test  Brixton Spatial Anticipation Test  Design Fluency | Cognitive flexibility |
|
| 17 | Votruba. Rapport, Whitman, Johnson & Langnecker (2013) | Stop Signal Task | Inhibitory control | English speakers aged between 20-85 with expressive language deficits post-stroke. |
| Trail Making Test | Cognitive flexibility |
| Warrington Recognition Memory Test | Short-term verbal memory |
| Repeatable Battery for the Assessment of Neuropsychological Status–Figure  Copy and Figure Recall | Short-term non-verbal memory |
| 18 | Willer, Pedersen, Forchhammer & Christensen (2016)  *This study explores a novel cognitive test* | Cognitive Assessment at Bedside for iPad (CABPad)  Subtests include:  Arrow Stroop  Memory for Pattern Locations  Attention span | Working memory  Attention | Dutch speakers aged between 30-90, with either ischaemic or haemorrhagic stroke |
| 19 | Yeung & Law (2010) | Test of Nonverbal Intelligence | Attention  Problem solving | Cantonese speakers with chronic aphasia, 6 months post stroke. |
| Attention Network Test (ANT) | Attention  Inhibitory control |

Overall, the 19 studies reviewed in **Table 3(i)** demonstrated three key aspects of EF assessment in PWA: (i) differences in number of EF tasks used, (ii) the underlying EF domain used, and (iii) medium of language used for the assessment.

The first key difference found from all the studies in **Table 3(i)** was the number of EF tasks selected to measure the underlying EF domain. Some of the studies mentioned above employed a single EF task to investigate the underlying EF domain. For example, in the study examining EF ability of inhibition and cognitive flexibility in post-stroke participants, one EF task was used as an underlying measure of each EF domain which are Go/No go Test and Trail Making Test, respectively (Niessen et al., 2020). Whereas other studies selected multiple EF tasks to evaluate a single underlying EF domain, cognitive flexibility. For instance, Schumacher and colleagues (2019) administered a series of EF tasks (e.g., Trail Making Test Brixton Spatial Anticipation Test, Design Fluency) that taps into elements of cognitive flexibility in thirty-eight PWA under study.

Another important aspect to highlight from the studies reviewed in **Table 3(i)** is that all studies investigated more than one domain of EF. The EF domains predominantly evaluated are working memory, cognitive flexibility, and attention. In terms of medium of language, majority of these EF assessments were in English with six in other languages: Cantonese (Law & Young, 2010), Dutch (El Hachioui et al., 2014; Willer et al., 2016), Brazilian Portuguese (Bonini & Radanovic, 2015; Rodrigues et al., 2019) and Japanese (Kokubo et al., 2015). The paucity of EF tests in other languages than English is not surprising. This is largely due to the clinical and research work in EF and aphasia is predominantly conducted in the global north and still at its early stages in most parts of the world.

The review of 19 aphasia studies in **Table 3(iii)** provided the present study with the perspectives on the current EF assessments used in research and clinical settings, the common underlying EF domains measured in PWA, and the medium of language used in the EF assessment. The following **Section 3.1.2** will discuss the key considerations for assessing EF in PWA in greater detail.

**3.1.2 Assessment Consideration for Assessing EF in PWA**

A closer look at some of the EF assessments in **Table 3(i)** revealed four factors to consider when developing and delivering EF assessments for administration with PWA. Some key points to consider are: (a) to be cautious when using EF tests that have high linguistic loading in the assessment of PWA; (b) to consider length of assessment to limit cognitive fatigue; (c) to increase the EF test availability in world languages; and (d) balance the consideration of fatigue with the potential validity problems surrounding single task-per-domain ratios.

**Linguistic loading**

Despite the increasing recognition of EF deficits in aphasia populations, measuring executive abilities in this patient group remains problematic. This is partly contributed by characteristics of EF tests and aphasia symptomatology. First, the literature on EF assessments demonstrated a significant number of verbally based assessments. Secondly, the language profile of individuals with aphasia is heterogeneous, however one general characteristic of PWA is difficulty with language and/or communication. Despite the known characteristic of aphasia, some EF tests for administration in PWA involve high linguistic loading and language components, which some argued as inappropriate for use with this population (Marinelli, et al., 2017). Despite this criticism, the usefulness of verbal EF assessments has been found in multiple studies (Schumacher et al., 2022; Bose et al., 2022). While careful consideration is warranted when administering verbally based assessments to PWA, not administering such assessments might also overlook the opportunity to gain a better understanding of some of the specific cognitive impairments these patient groups are facing with respect to language processing and EF (Schumacher et al., 2022). Some solutions suggested including simplifying any forms of language required for task completion (e.g., comprehension of verbal stimuli, verbal/written output to given stimuli) by using simple language, repeating instructions if necessary.

**Length of assessment**

Another issue surrounding some of the EF tests presented in **Table 3(i)** is the lengthy duration of the assessment resulting in PWA’s fatigue. In a survey of speech language pathologists’ perception of fatigue in PWAs, 80% reported observing patients’ fatigue during assessment and treatment (Riley, 2017). Prevalence of fatigue has also been discussed in post-stroke patients: acute post-stroke phases (Hinckle, Becker, Kim, Choi-Kwon, Saban, McNair & Mead, 2017) and in acute and chronic post-stroke (De Doncker, Dantzer, Ormstad & Kuppuswamy, 2018). Length of assessment is one of the contributing factors towards PWAs’ fatigue in the clinical settings. Some studies mentioned above administered a series of EF tests for more than an hour which may lead to exhaustion, difficulty to sustain attention and loss of interest. Lengthy assessment is also not practical in clinical settings due to other instrumental factors such as limited staff, interference from other healthcare professionals and limited assessment resources and facilities. In one of the studies mentioned above, 25 behavioural tests were administered to 38 chronic post-stroke participants to investigate cognitive, language and neuroanatomical factors underlying performance in frequently used aphasia tests (Lacey et al., 2017) For each participant, assessments were completed in a day and took between 3 - 5 hours. Although participants were given breaks when needed, fatigue may significantly influence task performance. Hence, careful deliberation of task choice should include duration of assessment and the different phases of strokes.

**Availability of EF assessments in world languages**

The review of EF assessments in **Table 3(i)** demonstrated that there is still a lack of EF assessments for different linguistic and cultural groups. This supports findings from previous studies (e.g., Franzen et al., 2022) calling for more development of validated neuropsychological test batteries to support diverse societies. Franzen et al., (2022) also recommended that validation and standardisation of neuropsychological tests are made cross-culturally and clinical training of psychologists/neuropsychologists in culturally sensitive neuropsychological assessments were developed and implemented.

**Task impurity issue**

A final consideration from the review of EF assessments in **Table 3(i)** is usage of a single EF test to evaluate an underlying EF domain (Votruba et al., 2013; Niessen et al., 2020). According to Miyake, Emerson & Friedman (2000), each EF test has idiosyncratic requirements which are specific to that task making it difficult to obtain a “pure” measure of EF. As a result, usage of a single EF test to measure a targeted EF domain may lack construct validity. Miyake et al., (2000) suggested the use of multiple EF tests for each EF domain to reduce this problem. When using multiple EF tests (Kokubo et al., 2015; Willer et al., 2016; Schumacher et al., 2019), an aggregation of the results should be conducted to derive a common factor across the multiple EF tests hence obtaining a more representative measure of the targeted EF domain.

In summary, this section has identified several commonly used EF tests and the underlying EF domains when assessing PWA from several aphasia studies. Several practical issues drawn from reviewing the EF tests provided insight into key issues to consider when delivering EF assessments to PWA (e.g., language component, duration of test). It is suggested that careful planning of EF assessments is essential in assessing clinical populations such as aphasia. While knowledge of EF tests from previous aphasia studies will help supplement knowledge and understanding of the commonly used EF assessments for the present study, understanding other key factors such as PWA’s characteristics and testing conditions can enhance testing protocols for individuals with aphasia. Hence, the next section will discuss other key considerations for assessing EF in PWA.

**3.2 Other relevant considerations for Assessing EF in PWA**

**3.2.1 Mode of delivery of EF Assessment**

Traditionally, cognitive assessments are delivered in-person using the brick-and-mortar approach where clinicians present individuals with task stimuli and instruct them to produce relevant responses. The traditional method of cognitive assessment poses various feasibility issues such as not enough therapists and insufficient test equipment (i.e., test manual, testing room). Patients also experience difficulty when accessing the EF assessment, they need for example due to lack of transportation to the hospital, geographical distance, schedule constraints and fatigue. Consequently, cognitive assessment and diagnosis becomes a problem and quite fragmented for patients’ post-stroke. However, since COVID-19, there has been a significant shift in delivery of cognitive testing and rehabilitation (Segura & Pompeia, 2021). The onset of COVID-19 has made remote cognitive assessments an imperative tool to provide care for individuals with cognitive impairment. It is not just cost and time-efficient, but it provides a safe means for vulnerable patients and their carers to continue getting access to neuropsychological testing and rehabilitation (Geddes et al., 2020).

Telehealth or telemedicine is defined as a two-way, real time interactive communication between patients and practitioner at a distant site (Geddes et al., 2020). In such an approach, diagnosis and assessment are delivered via telephone or video conferencing software such as Google Meet. A few studies have shown that there are no or very little performance differences between in-person and remote assessment for children (Worhach, Boduch, Zhang & Maski, 2021), adults (Kirkwood, Peck & Bennie., 2000) and older adults (Geddes et al., 2020). Kirkwood and colleagues (2000) conducted a study aimed to investigate the reliability of using telehealth cognitive assessment. Kirkwood et al., (2000) recruited 27 males, with a history of alcohol abuse. Participants were divided into two groups: (i) individuals received face-to-face cognitive assessment and (ii) individuals received online cognitive assessment. It was found that there is no difference between performance in face-to-face and remote assessment. Additionally, the online cognitive assessments were found to lower participants' performance anxiety, partly because practitioners were not present in the same room. Another study on thirty-two healthy adults aged between 18-57 in Norway was conducted to measure the reliability of online cognitive assessment and participants’ preference for administration format (Svenn et al., 2002). Participants were given a series of 12 visual, verbal and performance tests (e.g., digit span, Seashore Rhythm Test, Benton Visual Retention Test) either via face-to-face or videophones. The findings indicate that performance in neuropsychological assessment via conventional methods were highly consistent to that of online assessment (Svenn et al., 2002). Additionally, reliability testing of the measures was comparable with other findings across all tests. Svenn and colleagues highlighted practitioners and healthcare provider’s perspectives on delivery of online cognitive assessment. **Table 3(ii)** below summarises the points mentioned.

**Table 3(ii):** Summary of practitioner and healthcare provider’s perspectives on online cognitive assessment

|  |  |
| --- | --- |
| **Practitioner’s perspectives** | **Healthcare provider’s perspectives** |
| Reliance on verbal communication and maintaining eye-contact can be quite demanding | Online cognitive assessment can increase specialist reach whenever this type of competence is required |
| Precludes reading from a test manual to ensure eye contact can be maintained with participant | Reduce travel time associated with outreach services |
| Any test material needs to be within reach and well organised | Operating costs should be taken into consideration this includes expenses used to send test equipment to the patient’s testing location or the costs involved to provide internet connectivity to rural healthcare providers |
| Avoid unnecessary movement as this can distract the participant |  |
| Communication between participant and practitioner depends on quality of technical equipment (i.e., sound quality, internet connectivity) and practitioner familiarity with using the technology |  |

*(Cited from Svenn et al., 2002: pg. 477)*

In a systematic review study aimed to develop a framework for remote cognitive assessment for cognitively impaired patients, Geddes and colleagues (2020) highlighted key guidance for the delivery of remote cognitive and behavioural assessment for individuals with cognitive impairment. Some of the points mentioned include (i) logistical recommendations, (ii) choice of neuropsychological assessments and (iii) method of delivery. Firstly, in terms of logistical requirements, the authors suggested that practitioners put privacy and confidentiality measures in place and ensure that any platform used for remote assessment is universally compatible across devices. Additionally, Geddes et al., (2020) suggested that prior to testing practitioners and patients should check internet connectivity and ensure that there is adequate bandwidth to reduce frustration from weak connectivity. It is also recommended that clinicians confirm with patients they have sufficient audio and visual input and have access to any audio/visual aids they require (e.g., eyeglasses, hearing aids). In terms of neuropsychological tests employed the authors recommended that the tests employed are validated and normed for remote usage and ensure that any tests used take into account patients’ sensorimotor limitations, aids, distractions or anything that render the test scores invalid. For verbally administered tests, it is suggested to ensure test performance will not be affected by videoconference administration. Based on Geddes et al.’s (2020) systematic review they found that verbal tasks such as verbal fluency, digit span and list learning are not affected by video conferencing administration; however, scores for Boston Naming Test (BNT) were slightly lower in remote assessment compared to in-person.

Furthermore, in terms of (iii) method of delivery the authors recommended practitioners to consider videoconference wherever possible over telephone assessment, since many assessments require visual cues. In addition, videoconferences allow for measure of domains that are difficult to assess via telephone, for instance, visuospatial function, facial recognition, and emotional processing. For example, Clock Drawing Test (CDT) which involves drawing of the clock face and hands cannot be administered over the telephone, but can be drawn during videoconference and displayed to the camera. The studies and recommendations highlighted in this section are pertinent to the development and delivery of EF assessment. The considerations highlighted can be used to help guide work on developing and standardisation of the EF test batteries for PWAs. Based on the discussed PWAs’ characteristics, methodological issues and method of EF assessment delivery, a list of EF tests has been selected for the purpose of the present study. The following Section 3.2 will provide information on measures of EF cross-culturally and justify the choice of EF tests for the present study in more detail.

**3.2.2 Assessment of EF in Different Languages and Cultures**

It is increasingly argued that cultural context markedly affects cognitive functioning (Triandis, 1996; Nisbett & Norenzayan, 2002). The basic assumptions of cognitive processes is that human beings from different cultures and ethnic backgrounds rely upon the same neural network, however an individual's life experiences shape the contents of this basic structure (Triandis, 1996; Kelkar, Hough & Fang, 2013; Pornpattananangkul et al., 2016). Hence, this section attempts to identify this intricate interplay of culture in different executive functioning tasks by reviewing evidence from different cross-cultural studies to expand understanding of cultural influences on cognitive assessment and performance.

In a study investigating the effect of culture on verbal reasoning and executive function tasks, a group comparison study was conducted with 22 Indian born individuals and 20 American born individuals (Kelkar et al., 2013). All participants were assessed on (i) Auckland individualism-collectivism scale, (ii) functional assessment of verbal reasoning and executive strategies (FAVRES) and (iii) four tasks from Delis-Kaplan Executive Function System (DKEFS). Results indicated a significant influence of culture across measures of cognitive and communicative functioning with American-born participants completing the tests more rapidly and with higher scores compared to Indian born participants. For executive functioning assessment, American-born participants demonstrated higher scores in verbal switching tasks compared to Indian-born participants. Indian-born participants on the other hand performed better in all the tasks of the Trail Making Test (visual perception, letter sequencing) which involved holistic perception of the visual field as a whole.

In another study comparing the influence of race and culture on performance on attentional tasks, Masuda and Nisbett (2001) found that East Asians are more attentive to context and relationships compared to Americans. In the first study that was conducted, 36 American participants and 41 Japanese participants were presented with vignettes of underwater scenes. Following the stimuli presentation, participants were asked to recall the scene they saw. The researchers found that Japanese participants reported more objects in the background environment compared to the American participants. Although the two groups do not differ in their memory performance, Japanese participants are less accurate at object recall tasks when the background of the image is changed or removed. The results support that East Asian cultures focus more on relations between objects and contexts when attending to complex visual display. This is partly justified by the various concepts and beliefs originating from East Asia where objects are bound to context. For example, the concept of Feng Shui, an ancient science of topography (Walters, 1991) is widely applied in building structures and interior designing.

Apart from cultural differences in visual memory tasks, another study found cultural differences in semantic recalling (Gutchess et al., 2006). The researchers conducted two studies to investigate the differences in recalling ability for categorically related and categorically unrelated words. A total of 112 young and 112 older adults from two cultures (American and Chinese) were presented with the word lists in their native language and were asked to recall as many words as they could remember. Analysis of the number of accurate words recalled and the degree of clustering by category were conducted. Overall, it was found that American participants recall words based on taxonomic categories more than the Chinese participants. Older Chinese participants show little tendency to recall words using organisational strategy such as clustering and categorising. However, there are no significant differences in memory ability across both cultures. This study shows that despite the influence of neurobiological ageing, older adults are still able to express cognitive strategies (i.e., categorical recall, clustering strategies) which reflect their culture.

The differences between cultures in inhibitory control tasks has also been evident in research on neural basis using functional neuroimaging. A study investigating the differences in inhibitory tasks, Go/No Go among Caucasian-American, Japanese-Americans living in the United States and native Japanese living in Japan found that cultural value and cultural groups influence different aspects of inhibitory-control brain activity (Pornpattananangkul et al., 2016). The study compares the difference between behavioural consistency and performance in inhibitory control tasks. It was hypothesised that collectivistic culture (associated with East-Asian culture) will result in high self-control which is linked to higher activity in the left inferior frontal gyrus during inhibition activity compared to those living in individualistic culture (i.e., associated with those living in the West). Moreover, the authors hypothesised that individuals living in individualistic cultures tend to be more consistent with their behaviour hence creating higher activity in the rostral anterior cingulate cortex (rACC) during the inhibition task. This is supported by their findings in which superior activation of the left inferior frontal gyrus (L-IFG) is found in native Japanese speakers compared to those living in the United States. Whereas participants who showed higher levels of behavioural consistency across all situations (Caucasian-Americans and Japanese-Americans) both groups elicited stronger activation in the rostral ACC (Pornpattananangkul et al., 2016). The findings support the insight on how culture modulates neural activity during inhibitory control tasks.

In conclusion, this section has reviewed several pieces of evidence that supports the view that cultural perspectives affect how people perceive, explain and respond to different scenarios (Triandis, 1996). The evidence reviewed so far provides insight into human cultural differences and its influence on cognitive functioning in various tasks measuring EF. The evidence also provides support for the need to develop culturally and linguistically suitable EF assessment for each target population to reduce effects of bias and misinterpretation of performance scores. This issue has been partially addressed through a growing number of studies which conducting translation of neuropsychological tests such as Wechsler Intelligence Scales (Wechsler, 2004) and Montreal Cognitive Assessment (Nasreddine et al., 2005) into different languages and norming and validating the tests with different ethnic samples. Thus, it is essential that the next subsection briefly discuss some of the key considerations for developing lingua-culturally relevant EF test batteries which will provide guidance on the process of the M-EF test development.

**3.2.3 Considerations for Translation and Cultural Adaptation of Executive Functions Test Battery**

Before proceeding to demonstrate task design for each EF task selected, it is necessary to review the principles of translation and cultural adaptation of EF tests for different clinical populations. Cross-cultural adaptation of health assessment for use in a new country, language or culture calls for systematic methods to reach equivalence between the original source and target language (Beaton et al., 2000). Aside from linguistic translation, it is also crucial for appropriate cultural adaptation of test stimuli to maintain content validity of the instrument at conceptual level (Beaton et al., 2000).

Currently despite numerous studies administering EF tasks to non-English speaking PWAs, many of these researchers did not describe the process of lingua-cultural translation of the test battery (Zakarias et al., 2013; El Hachioui et al., 2015; Kokubo et al., 2015). However, there are very few EF test adaptation studies that provide in-depth description of the adaptation procedures (Beerten-Duijkers et al., 2019; Hurtado-Pomares et al., 2021). The adaptation procedures in these papers (Beerten- Duijkers et al., 2019; Hurtado-Pomares et al., 2021) are based on several guidelines published for cross-cultural adaptation of patient reported measures (Beaton et al., 2000; Wild et al., 2005; Muniz et al., 2013).

Hurtado-Pomares and colleagues (2021) in their study translating and culturally adapting the Frontal Assessment Battery for detection of executive dysfunction into Spanish employed the standard procedures proposed by Beaton et al., 2000 and Muniz et al., 2013. There are five steps highlighted for the translation process: 1) forward translation from English to Spanish (two translations), 2) expert review, 3) back translation, 4) expert review and 5) pilot testing and analysis of items, instructions, and participants' feedback. The final step, pilot study, assists in verifying that the items evaluate what they intended to evaluate and whether the instructions can be clearly understood (Hurtado-Pomares et al., 2021). These five steps for adapting an EF test are judged viable for this study as it affords the opportunity to develop a linguistically and culturally appropriate EF assessment for the targeted population.

It is relevant to note that presently there is a scarcity of EF test battery in the languages spoken in Malaysia i.e. Malay, Malaysian English, Malaysian varieties of Mandarin and Tamil. This situation warrants development of an appropriate EF test battery for the majority Malay speakers in Malaysia. The EF test battery developed in this study will specifically target the aphasia population as EF deficits are reportedly high in this patient group across multiple aphasia studies. In summary, the need to address the lack of standardised EF assessment for Malay speakers with aphasia provides the rationale for this study.

**3.3 The Present Study: Selected EF tests**

This section presents a brief overview of the selected tasks for the Malay Executive Function (M-EF battery). An overview of each EF task selected will be presented in **Table 3(iii)** below.

The EF tests selected for the present study are a series of tests which involve moderate verbal load and one non-verbal task.  Three of the EF tasks are verbal tasks, which requires following verbal instructions, processing verbal information, and providing verbal responses. One task, the spatial fluency task (SFT), is a non-verbal EF task requiring participants to draw their responses; however, it also relies on following verbal instructions. All of the EF tasks chosen do not involve any reading or writing skills as this is an important aspect to consider when assessing PWA, and to ensure accessibility for those from low-income areas in Malaysia where literacy skills may be quite poor due to socioeconomic and educational background. Secondly, the reason for selecting the EF tasks in **Table 3(iii)** is its practicality and feasibility for remote, online delivery via GoogleMeet.

**Table 3(iii):** Summary of EF tasks selected for the Malay Executive Function (M-EF) battery in the present study

|  |  |  |
| --- | --- | --- |
| **Domain of EF** | **EF tests** | **Description of test** |
| Inhibitory control | Malay Hayling Sentence Completion Test (M-HSCT) | Participants are orally presented with 30 sentences to complete. For automatic conditions, participants are asked to complete 15 sentences read to them with a meaningful word which completes the sentence. For inhibition conditions, participants are required to provide words which do not make sense to the sentences read to them.  Common measures: Number of correct responses, response latencies |
| Working memory | Digit Span task | Participants listen to a series of digits ranging from two to eight digits read to them, each series of digits containing two sets, sequences will continue to be read until participants produce two consecutive errors. For Forward, the participants are required to repeat the sequence of numbers in the same order as they are read.  For Backward, participants are required to repeat the numbers in reverse order.  Common measures: span, number of correct sequences. |
| Cognitive flexibility | Verbal Fluency Test (VFT) | Participants are required to produce as many words as possible in 60 seconds. In the semantic task there were two categories: animals, supermarket items. In the letter-based task there were also two condition words beginning with the letter [A] and the letter [M]. The four VF subtasks were presented to all participants in the same order.  Common measures: Number of correct items, switching and clustering. |
| Spatial Fluency Test (SFT) | Participants are required to draw as many shapes and patterns as possible in 60 seconds. Participants are first required to draw using only 3 lines and then 4 lines.  Common measures: Number of correct drawings. |

The three EF domains selected for the M-EF battery were based on the EF model proposed by Diamond (2013) and their documented correlation in PWA. The first domain of EF chosen is inhibition which has been commonly found to be impaired in PWA (Penn, Frankel, Watermeyer & Russell, 2009; Kuzmina & Weekes, 2016; Simic et al., 2020). Deficits in inhibitory control are linked to reduced language processing in PWAs (Wiener, Connor & Obler, 2004).

The second EF domain chosen is working memory (WM). There are two main reasons influencing the decision to examine WM in PWAs in the present study. First, the presence of working memory deficits in individuals with aphasia is ubiquitous (Potagas, Kasselimis & Evdokimidis, 2011; Mayer & Murray, 2012; Murray, 2012) and second the evidence of WM deficits contributing to linguistics processing difficulties in PWA (Caspari, Parkinson, LaPointe & Katz, 1998; Friedmann & Gvion, 2003; Sung, McNeil, Pratt, Dickey, Hula, Szuminsky & Doyle, 2009; Christensen & Wright, 2010, Cahana-Amitay & Jenkins, 2018). Moreover, several studies have reported the prognostic value of WM capacity in predicting response to aphasia therapy (Seniow, Litwin & Lesniak, 2009; Lambon Ralph, Snell, Conroy & Sage, 2010; Harnish & Lundine, 2015). Findings from these studies support the need to incorporate assessment of working memory in individuals with aphasia in order to ascertain the presence and severity of WM impairment, planning appropriate aphasia rehabilitation and documentation of treatment outcomes.

Cognitive flexibility is selected as the third domain of EF in the M-EF battery due to significant evidence of cognitive flexibility impairmen*t (also described as shifting/switching)* reported in individuals with aphasia (Chiou & Kennedy, 2009; Spitzer, Binkofski, Willmes & Bruehl, 2020). Furthermore, the integrity of cognitive flexibility has been linked to conversational success in PWA (Ramsberger, 2005; Beckley, Best, Johnson, Edwards, Maxim & Beeke, 2013). Since impairment of cognitive flexibility can impede communicative abilities, screening in PWA should include evaluation of this underlying EF domain.

Overall, this chapter began by reviewing EF assessments used in recent aphasia studies and describing the key considerations surrounding development of the EF test battery for PWA. A review of Malaysia's linguistic and cultural factors were also discussed to demonstrate how these factors will be taken into account in the development of the M-EF battery. The chapter concludes by providing an overview list of EF domains and the specific EF tests that are selected for the M-EF battery.

\*\*\*\*\*\*

The three literature review chapters presented so far aimed to provide background information and rationale for the present study. This research aims to translate and adapt a series of EF tasks for Malay speakers (M-EF) to lay the foundation for assessing EF in PWA. The M-EF development work carried out is presented in Chapter 5.

This research comprises two studies. In Study 1, a survey with speech language pathologists in Malaysia was conducted. In Study 2, healthy younger and older participants took part in the M-EF assessment. The aims and procedures of each study are detailed in the following chapters. Results of this work are anticipated to be of interest to cultural psychologists and neuropsychologists alike. The general discussion in Chapter 8 comments on findings with reference to their clinical implications for expansion of the assessment to PWA.

**Chapter 4: Study 1 Questionnaire Consultation with SLTs**

This chapter describes Study 1 of the present study which was carried out in the form of a two-part questionnaire with speech language therapists (SLT) who are involved in supporting individuals with aphasia in Malaysia. A questionnaire-based approach was chosen to provide a rich account of clinical users’ perceptions on usage of Malay language EF assessments and to explore the current practice for assessing EF in Malaysia.

Section 4.1 provides information about the development of the PPI questionnaire. This includes a brief overview of the questionnaire, the adaptation process involved in the questionnaire design and how the questionnaire informs current knowledge of assessing EF in Malaysia’s clinical settings. Section 4.2 discusses the procedures used, from the recruitment of participants and collection of the data. Finally, Section 4.3 describes the results from the questionnaire responses and explains how the findings inform the development of a culturally and linguistically relevant EF test battery for Malay speakers in Malaysia for use in Study 2 of this doctoral research.

**4.1 Questionnaire Design**

**Preparing the questionnaire**

The questionnaire employed was expanded from Webb, Kantou & Demeyere’s (2022) study investigating the impacts of COVID-19 on the modality of cognitive assessment, face-to-face versus remote assessment. Webb et al. (2022) developed a web-based questionnaire consisting of 34 items to fulfil the aims of their study. Items in the questionnaire concerned the rate of cognitive assessment before and during the COVID-19 pandemic and the perceived benefits and challenges of remote assessment of cognition.  The questionnaire also includes optional questions on the usage of Oxford Cognitive Screen (OCS) prior to and after March 2021. Webb et al. (2022) reported an increased usage of remote cognitive assessment *(via telephone and video conferencing)* since the beginning of the pandemic across the UK and in several countries globally. Furthermore, it was found that the same cognitive tests were used pre-and post-pandemic, implying that the tests were not validated in the new remote format (Webb et al., 2022). In terms of benefits for remote assessment, most respondents reported that remote assessments are economic, time saving and facilitate accessibility for patients who have difficulty commuting or lived in rural areas. Whereas the challenges faced by most respondents (i.e., healthcare professionals who have experience overseeing cognitive assessment) are difficulties observing subtleties of patients’ behaviours during test administration and patients’ lack of knowledge in using technology (e.g., laptop, video conferencing app). Other frequent concerns highlighted are the lack of standardised and normed assessments to use for remote assessments. Although the study had a limited number of non-UK respondents to draw firm conclusions on the global use of remote assessments, the findings at least, capture the increase in usage of remote cognitive assessments because of the pandemic. The findings further support the need for more standardised cognitive tests for remote administration.

Study 1 of the current study explores healthcare professionals' experiences of administering the different modalities of EF assessment (i.e., face-to-face, and remote assessment) to people with aphasia (PWA) in various clinical settings in Malaysia. As reported by Webb et al., (2022) there is a significant increase in remote cognitive assessments post-COVID-19 pandemic which necessitates a standardised and validated remote EF assessment. This also implies that more research is needed to expand evidence-based EF assessment for clinical use. Webb and colleagues however only explore the need for remote EF assessments in Western countries (i.e., UK, Canada, Australia) with a limited sample size from non-Western clinicians (e.g., only one participant from Pakistan). In the present study, we consider the need for remote EF assessments in Malaysia’s clinical settings, both in private and government healthcare institutions. In addition, Study 1 builds upon Webb et al.’s (2022) study to explore the need for a culturally and linguistically appropriate EF test battery for assessing Malay speakers with aphasia in Malaysia.

Several cross-cultural studies of cognitive assessments identified the crucial need for a culturally and linguistically suitable cognitive measure for assessing other cultural and socioeconomic populations in developing countries (Rock & Price, 2019; Ikanga et al., 2019; Zanini et al., 2021). A study investigating the barriers of administering cognitive assessments in aboriginal groups in central and northern Australia argues that mainstream cognitive tests typically rely on western concepts, contents and values which is less appropriate and impractical for assessing cognition in non-western populations (Dingwell et al., 2014). Another study aimed to conduct a translation of Loewenstein Occupational Therapy Cognitive Assessment for Geriatrics (LOTCA-G) into the Malay language also noted that existing cognitive assessments are difficult to use with patients in Malaysia due to lack of appropriate cultural and conceptual significance of the content in test materials, in addition to lack of test availability in the different languages spoken in Malaysia (Mohd Natar et al., 2015). Zanini et al., (2021) highlighted several factors that give rise to differences in cognitive performance; these include age, sex, cultural differences, and socioeconomic status. Considering the characteristics which influence performance in cognitive assessments, it seems opportune to propose a test battery that addresses these limitations in the context of multicultural Malaysia by first exploring healthcare professionals’ opinions on a Malay language EF test battery. The study by Webb et al., (2022) explored only the different modalities of cognitive assessment (in-person versus online) because of the recent pandemic. Study 1 expands upon Webb’s study by incorporating further questions to explore the need for culturally and linguistically suitable EF tests for assessing Malay speakers in Malaysia.

The overarching aims of Study 1 are:

1. To examine the current practice of assessing executive functioning in people with aphasia and clinicians’ opinions across two different modalities (in-person and remotely)
2. To explore the views of healthcare professionals on usage of a Malay language EF test battery and factors to consider for the development of an EF test battery in the Malay language for PWA in Malaysia

**4.2 Methods**

**4.2.1 Participants recruitment, consent, and ethics**

All potential participants were identified through the researcher’s professional networks within the Malaysian Association of Speech Language and Hearing (MASH) committee. Recruitment emails were sent with a copy of participant information sheet to potential participants the researcher was aware of and those fitting the sampling criteria. In addition, a professional virtual network was contacted via email through a former university association and networks within government and private rehabilitation clinics and hospitals across Malaysia. The professional virtual networks cut across academics within speech pathology sectors. The study received ethical approval from the University Research Ethics Committee of the Division of Human Communication and Sciences, Health Sciences School at the University of Sheffield *(see Appendix A)*.

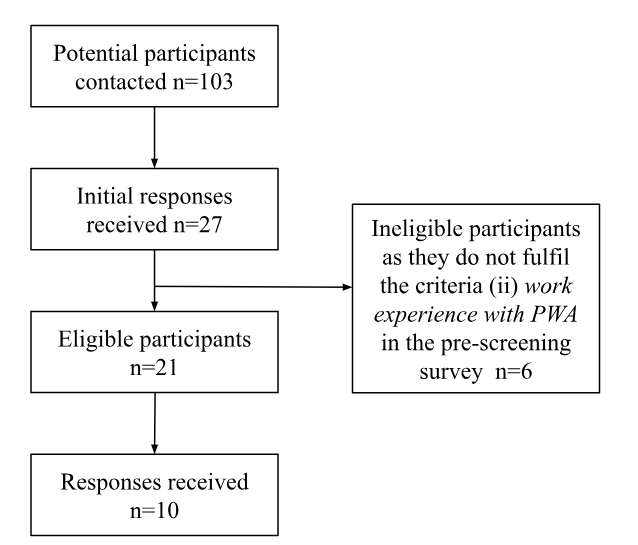
All potential participants self-identified as fitting the sampling framework and an initial brief pre-screening survey link was emailed to those that expressed interest to partake in the study. Digital informed consent is obtained from all participants who met the eligibility criteria prior to taking part in the questionnaire. In addition, all participants were given a digital copy of the information sheet, containing information regarding the study, regulation on how participants’ data are stored and the researcher’s contact details.

**4.2.2 Design**

All potential participants first took part in a brief screening process aimed to determine whether the participants have the appropriate professional background that makes them eligible to participate in the study. Participants that are deemed ineligible for the study were automatically eliminated from taking part in the questionnaire and no personal information were gathered from them.

All eligible participants took part in the questionnaire which was created in two languages: Bahasa Malaysia and English. Participants followed an anonymised link to the questionnaire presented via Google forms and completed the questionnaire in the language version requested by them in the pre-screening survey. Participants completed the questionnaire at their convenience.

**Figure 4i:** Flowchart of participant recruitment in Study 1



**4.2.3 Materials**

**4.2.3.1 Screening survey**

Before collecting participants’ responses on the main questionnaire, participants are first given a pre-screening survey. The pre-screening survey was created and hosted on Google Forms. The initial survey was designed to ensure all participants worked in a professional capacity that fit within the scope of the study and exclude any respondents who were not suitable for the intended purpose. There are two yes/no questions to identify whether the participants have worked or are working with people with aphasia and whether participants have experienced administering/assisting cognitive assessment for PWA. An additional question at the end of the survey is created to note participants’ language preferences for the questionnaire *(see Appendix B)*.In total, there are 27 potential participants who responded to the pre-screening questionnaire; however, six respondents did not fulfil the inclusion criteria (i.e., have no experience assisting or administering cognitive assessments for PWA).

**4.2.3.2 Questionnaire**

The questionnaire instrument was developed by the researcher specifically for this study, based on the objectives of the current study and guided by previous questionnaire findings from Webb et al., (2021). The online questionnaire consisted of two parts with 26 questions in total *(See Appendix C)*. Part 1 of the questionnaire consists of two sections: (1a) professional background and (1b) EF assessment. Section (1a) professional background consisted of 4 multiple choice questions aimed to establish an understanding of the participant’s professional role and their frequency and type of professional interactions with people with aphasia (PWA).

Section (1b) of the questionnaire consists of 12 questions of which 3 are short answer questions, 5 yes/no questions and 4 multiple-choice questions. The questions in Section (1b) were designed to provide information on participants’ previous experience administering EF assessments and their opinion on using a Malay version of an EF test. The first two questions in Section (1b) were generated to gain insight into participants' understanding of the term EF and especially to note any differences between ‘mainstream’ psychological EF definitions and the perceived EF definitions from Malaysia’s clinical practitioners. Subsequently, questions 3-8 were in line with the first objective of the project, to explore current practices in delivering EF assessment in clinical settings across Malaysia. This includes questions on the specific types of EF tests used, frequency of assessment for PWA and administration of EF tests in other languages spoken in Malaysia. Questions 9-12 in Section (1b) were framed to capture participants’ perceptions and opinions on the usage of EF tests in Malay language. In addition, Section (1b) of the questionnaire includes questions exploring SLTs’ preference on using Malay language EF test battery with Malay speaking PWA, which provided answers to the second aim of the research. In general, the order of questions was based on the participant’s answers *(see Appendix D for the flowchart of questionnaire logic)*. For instance, a ‘No’ answer for Q3 in Section (1b) directs the participant to Q8 as questions 4-7 become irrelevant to the participant.

Part 2 of the questionnaire consists of 10 questions on remote EF assessment. There are 4 yes/no questions and 6 multiple-choice questions with the option to provide short answers. The first four questions were formulated to provide insight into the usage of telehealth services available to the participants in their current workplace, which includes the medium for telehealth services and the specific EF tests used for remote assessment. Besides being designed to meet the first research objective, questions 1-4 were used to establish a comparison between in-person and remote EF assessments practise in Malaysia. Next, the purpose of questions 5 and 6 was to gain participants’ opinions on why their current workplace utilises or does not utilise remote EF assessment. The answer choice available in questions 5 and 6 were guided by responses gathered in Webb et al., (2021) findings that indicate the reasons why workplaces do/do not provide telehealth services. Question 7 specifically asked participants whether they will use remote EF tests in the Malay language if it becomes available to them. Questions 8 and 9 were used to explore participants’ opinions on the advantages and disadvantages of remote EF assessment based on their professional opinions. The answer options for questions 8 and 9 were adapted from Webb et al., (2021) findings from the responses of clinicians administering cognitive assessments in their study. The final question in Part 2 is a yes/no question aimed to obtain participants’ views on whether remote EF assessment will benefit the PWA population in Malaysia.

**4.2.3.3 Data analysis**

The online questionnaire allowed for automatic data storage into Excel spreadsheets which was stored directly on the University of Sheffield’s Drive. Descriptive statistics were used to characterise numerical data and any free text responses were organised and presented using descriptions of individual responses in combination with descriptions of shared content in cases where more than one response incorporated the same type of information (e.g., all mentioned patient needs).

**4.2.5 Results**

**4.2.5.1 Participants’ Background**

To explore the current usage of EF test batteries in Malaysia’s clinical settings, respondents were first asked to answer three multiple choice questions and one open ended question regarding their current role and the type and frequency of interaction with PWA. All ten respondents were working within the Speech Therapy Unit in their current workplaces as Speech and Language Therapists. Furthermore, all respondents reported that their interactions with PWA involved both assessment and rehabilitation treatment of speech and cognitive deficits with people with aphasia (PWA).

In terms of frequency of interaction with PWA, 8 respondents reported having between 1-10 interactions per month with PWA while two respondents reported having the most interaction: 130 and 20 interactions respectively per month in**Table 4(i)**.

**Table 4(i): Frequency of interaction with PWA**

|  |  |
| --- | --- |
| **Frequency of interaction** | **No. of respondents** |
| 3 or  less | 2 |
| 5-10 | 6 |
| More than 20 times | 2 |

**4.2.5.2 Familiarity with the term EF**

In Part 2 of the Questionnaire, two questions on the term EF were asked to check respondents’ familiarity with this cognitive construct. The first short answer question asked respondents to define EF based on their professional experiences. Two themes were identified based on the given responses: (i) daily life skills and (ii) cognitive process/skill. For 5 respondents, the definition of EF provided falls under both themes. One respondent described EF only as a cognitive process/skill whereas two respondents describe EF only as daily life skills. Two respondents did not respond to the question.

**Table 4(ii): Definitions of EF (n=10; short-answer responses=8)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Respondent** | **Responses** | **Themes** | |
| **Daily life skills** | **Cognitive process/skill** |
| 1 | *It comprises of skills that helps an individual in activities of daily living. This includes but not limited to: working memory, social thinking/planning, and self-regulation.* | **✓** | **✓** |
| 2 | *Mental skills that important for daily activities i.e. memory, follow command* | **✓** | **✓** |
| 3 | *A set of cognitive processes that are prerequisites for cognitive control, selecting and monitoring behaviours that facilitate the attainment of desired goals.* |  | **✓** |
| 4 | *The skills needed to navigate life smoothly* | **✓** |  |
| 5 | *No answer* |  |  |
| 6 | *Mental skill required for planning, flexibility and perform daily tasks* | **✓** | **✓** |
| 7 | *Are cognitive aspects important to apply in daily routine* | **✓** | **✓** |
| 8 | *No answer* |  |  |
| 9 | *Important skills for day-to-day routine* | **✓** |  |
| 10 | *Cognitive skills that people need in their daily life which involve problem solving, memory skill, attention, follow directions, control their emotion.* | **✓** | **✓** |

Furthermore, respondents were asked to identify the common signs of EF impairment from a fixed list of options based on their professional experience. From the total 41 response choices selected, the most common symptoms of EF impairment identified by SLTs were difficulty in problem solving (24%), difficulty switching between tasks (22%) and difficulty in organising and planning (22%). Only one respondent mentioned ‘difficulty to initiate action’ and two respondents mentioned ‘poor working memory’ as a sign of EF impairment.

**4.2.5.3 Identifying current usage of EF assessment with PWA**

To understand the current usage of EF assessment in Malaysia’s clinical settings, three questions were presented to examine the frequency of assessing EF and to identify the EF tests used by clinicians with PWA. **Table 4(iii)** below summarises the frequencies of EF assessments delivery by the respondents in the last year.

**Table 4(iii): Frequency of delivering EF assessments based on respondents’ descriptions (n=27)**

|  |  |
| --- | --- |
| **Number of respondents** | **Frequency of delivering EF assessments in the last year** |
| 1 | More than 500 |
| 7 | 10-20 |
| 9 | 20-30 |
| 10 | 2-5 |

Six respondents elaborated on which standardised EF tests they have previously administered to PWA. The three most used EF tests that have been delivered within respondents' clinical practice are Wisconsin Card Sorting Test (WCST), Stroop Colour and Word Test, and Digit Span Backward and Forward *(see* ***Table 4(iv)*** *for full list)*.

**Table 4(iv): Standardised tests used to measure EF in PWA (multiple choice responses=18)**

|  |  |  |
| --- | --- | --- |
|  | | Frequency |
| Standardised tests used to measure EF in PWA | Stroop Colour and Word Test | 3 |
| Wisconsin Card Sorting Test (WCST) | 3 |
| Digit Span Forward and Backward | 3 |
| Clock Drawing Test (CDT) | 1 |
| Trail Making Test (TMT) | 1 |
| Semantic Verbal Fluency Test | 1 |
| Letter Verbal Fluency Test | 1 |
| Tower of London | 1 |
| Other - The ministry of health's assessment toolkit | 1 |
| Other - Design generation test from Cognitive Linguistic Quick Test (CLQT) | 1 |
| Other - Informal tests | 1 |
| Other - Mini Mental State Examination (MMSE) | 1 |

**4.2.5.4 The need for Malay EF test battery**

The questionnaire also seeks to understand the need for a standardised EF test battery in the Malay language, this is achieved by asking four questions relating to this topic. Firstly, respondents were asked if they have previously administered EF tests in languages other than English (e.g., Malay, Mandarin, or Tamil). Only 2 out of 10 respondents reported they have completed EF measures in other languages. A further question was given to the two respondents to identify the EF tests that they have previously used in other languages. The three tests conducted in languages other than English are the Ministry of Health Informal Toolkit, Wisconsin Card Sorting Test (WCST) and Design Generation Test from Cognitive Linguistic Quick Test (CLQT) which were administered in the Malay language.

A further question was asked on their opinion for the need of an EF test battery in the main languages spoken in Malaysia (e.g., Malay, Mandarin, and Tamil). All ten participants answered ‘yes’ to the need of this standardised test.  Moreover, a further question was asked whether clinicians would use a Malay EF test battery to assess their Malay patients. All respondents answered ‘yes’ to using an EF test in Malay for their patients from a Malay ethnic background.

**4.2.5.5 Opinion on Malay EF battery**

The last part of the questionnaire asked respondents’ opinion on using a Malay EF test battery. A multiple-choice question was used to understand the potential benefits of using a Malay language EF test battery. Majority of the respondents reported three main benefits of Malay EF test battery: (1) ease of usage for patients in terms of understanding task instruction; (2) ease of usage for clinicians without the need for translating during assessment/screening; and (3) increase patient’s willingness to participate during screening/assessment in **Table 4(v)**. Furthermore, one respondent mentioned that employing a Malay EF test battery will assist in obtaining a more reliable performance of patients. Overall, the reported benefits of the Malay EF test battery were expressed by respondents as serving the needs of both patients and clinicians during the assessment period.

**Table 4(v): Potential benefits of delivering Malay EF test to Malay PWA speakers (respondents n=10; multiple choice responses n=40)**

|  |  |
| --- | --- |
| ***Potential benefits of standardised Bahasa Malaysia EF assessments for Malay speakers with aphasia*** | **Frequency** |
| Ease of usage for clinicians without the need for translating during assessment/screening | 10 |
| Ease of usage for patients in terms of understanding task instructions and task stimuli | 10 |
| Increase patient’s willingness to participate during screening/assessment | 9 |
| Reduce participants' lack of interest in assessment/screening | 5 |
| Reduce time of assessment for Malay patients | 5 |
| Other - To obtain a more reliable performance of patients | 1 |

A multiple-choice question was also asked to understand the main considerations when developing a Malay EF test battery. Respondents were asked to select from the given options and the two most reported factors are suitability for Malay speakers (i.e., language use, instruction, familiarity, suitable context) and considerations for Malay culture (e.g., avoid using offensive/culturally inappropriate words/images). One participant chose the ‘Other’ option and elaborated that ‘EF assessment for usage with Malaysian population is better to develop a test which is non-linguistic that will enable the use for multilingual and multi dialect population’.

**Table 4(vi): Aspects to consider for Malay EF test development (respondents n=10; multiple choice responses n=27)**

|  |  |
| --- | --- |
| **Aspects to consider for Malay EF test development** | **Frequency** |
| Suitability for Malay speakers (language use, instruction, familiarity, suitable context) | 10 |
| Consideration for Malay culture (e.g., avoid using offensive/culturally inappropriate words/images) | 10 |
| Consideration for cultural relevant task stimuli (e.g., avoid using image of plants that are not native to Malaysia i.e., strawberry plant) | 5 |
| Other - Consideration for linguistic and phonological variants of Malay language used in Malaysia e.g., Sabahan Malay and West Malaysian Malay differ greatly from one another; similarly for Kelantan and Sarawak | 1 |
| Other - For Malaysian scenario it’s better to develop a test which is non-linguistic that will enable the use for multilingual and multi-dialect population | 1 |

Moreover, respondents were asked a ‘yes’ or ‘no’ question to help understand the need for availability of Malay EF test batteries in other dialects of Malay language. Nine respondents reported affirmatively that there is a need for developing EF assessment in different dialects of Malay and only one respondent said ‘no’.

**4.2.5.6 Telehealth practices in Malaysia**

Part 3 of the questionnaire consisted of ten questions seeking to understand the current usage of telehealth services within the respondents’ current practice and future need for telehealth.

Only three respondents reported that they have used telehealth services with their patients whereas the majority of SLTs have not previously used telehealth service. Out of the three respondents, all reported using a phone app (e.g., WhatsApp). Two of the respondents reported using video calls (e.g., Skype, Zoom, Google Meet) and one respondent mentioned using email as part of their telehealth service. From the three respondents who reported using telehealth services, only one respondent reported carrying out EF assessment remotely. It was mentioned that the Ministry of Health Informal Toolkit was used to assess EF remotely. Following that, the respondent who reported using telehealth services was asked to provide an opinion on why they think their current practices choose to conduct EF assessment via telehealth **Table 4(vii**). This respondent also commented that the current workplace “has been providing remote services prior to COVID-19’ because the hospital is the only tertiary hospital in the state.

**Table 4(vii): Opinion on why current clinical practice is using telehealth services to conduct EF assessment (respondent n=1; multiple choice responses n= 5)**

|  |
| --- |
| To continue care services provided by therapists to individuals at home during the pandemic |
| Reduce the risk of COVID-19 transmission |
| Reach a wider population of individuals who may have restricted mobility or live further away from the clinic |
| Reduce the use of resources in health centres |
| Other - Our hospital has been providing remote services prior to COVID-19 as we are the only tertiary hospital in the state |

For respondents that reported they have not used telehealth services, a similar question was asked to understand why they think their current practice is not delivering remote assessment of EF. Based on the responses gathered, two main key factors on challenges delivering remote cognitive assessments were identified: (i) patients and (ii) clinical practice/clinician. This is summarised under the ‘key factor’ column in *Table 4(viii)*. The majority of respondents reported a lack of standardised EF test that can be used for remote assessment and poor internet connectivity on the patient's end. Two respondents selected ‘Other’ option and reported patients’ factors contributing to the reduced usage of telehealth services i.e., patient’s preference for face-to-face therapy and patient’s ability to use technology.

**Table 4(viii): Opinion on why current clinical practice is not using telehealth services to conduct EF assessment (respondents n=9; multiple choice responses n=27)**

|  |  |  |
| --- | --- | --- |
|  | **Frequency** | **Key factor** |
| Lack of standardised EF tests for online usage | 7 | Clinical practice/clinician |
| Poor internet connectivity on patient’s end | 7 | Patient |
| Lack of appropriate training for delivery of telehealth | 4 | Clinical practice/clinician |
| Concerns on clinical quality of medical services provided | 3 | Clinical practice/clinician |
| Poor internet connectivity on clinician/therapist’s end | 2 | Clinical practice/clinician |
| Lack of suitable devices to conduct online assessment/therapy (e.g., computer, laptop, webcam) on clinician/therapist’s end | 2 | Clinical practice/clinician |
| Other - Patients are generally not tech savvy, depends on children for help and most of the time no carer to assist in setting up tele sessions , especially for elderly patients | 1 | Patient |
| Other - Reluctant from patient's commitment on telehealth. They prefer to do face to face therapy | 1 | Patient |
| **Total impact on clinical practice/clinician factors:** | 18 | |
| **Total impact on patient factors:** | 9 | |

Furthermore, the research sought to understand if respondents would use a remote EF assessment tool, if the resources are available for post-stroke patients. All participants reported ‘Yes’ to usage of remote EF assessment for this patient group.

**4.2.5.7 Opinion on telehealth services**

Furthermore, a multiple-choice question was asked to seek SLTs’ opinion on potential benefits of using remote EF assessment. Based on participants' responses, the two typology themes identified highlighting the benefits of remote EF are (i) patient benefit and (ii) clinician benefit. All respondents reported benefits for the patients in terms of (1) reducing travel time and cost for patients to visit hospital/clinic and (2) increasing accessibility for assessment/screening for patients living far from hospital/clinic. Other potential benefits selected were in terms of increasing the number of patients and flexibility of appointment time in**Table 4(ix)**.

**Table 4(ix): Potential benefits of using remote EF assessment by frequency of selection (respondents n=10; multiple choice responses n=44)**

|  |  |  |  |
| --- | --- | --- | --- |
| Answer options | **Frequency** | **Patient benefit** | **Clinician benefit** |
| Reduce travel time and/or cost for patients to visit hospital/clinic | 10 | **✓** |  |
| Increase accessibility for assessment and/or screening for patients living far from hospital/clinic | 10 | **✓** |  |
| Economic, time and environmental cost savings | 9 | **✓** | **✓** |
| Flexibility of appointment time | 8 | **✓** | **✓** |
| Increase the number of patients to receive assessment/screening daily | 7 | **✓** |  |

The same method was used to seek respondents’ opinion on any potential challenges of conducting remote EF assessment. Two key themes were identified from the responses on potential challenges of conducting remote EF assessment which are (i) Challenge for patients and (ii) Challenge for clinicians. From the responses it was found that the majority of respondents identify the potential challenges in relation to patient experience. The most often selected potential challenges are ‘Difficulty controlling distractions in a patient's surroundings (e.g., noise, help from family members)’ and ‘Limited technological equipment in patient’s home (e.g., laptop/desktop with a webcam, internet)’. One participant also reported that it may be difficult to conduct remote assessment if a carer is not present. The two least selected answers are challenges from the perspective of delivering clinical services which are ‘Lack of technological expertise among therapists/clinicians’ and ‘Limited technological equipment in clinician’s setting/workplace’.

**Table 4(x): Potential challenges of using remote EF assessment by frequency of selection (respondents n=10; multiple choice responses n=40)**

|  |  |  |  |
| --- | --- | --- | --- |
| Key themes | **Frequency** | **Challenge for Patient** | **Challenge for Clinician** |
| Lack of technological expertise among patients | 8 | **✓** |  |
| Lack of technological expertise among therapists/clinicians | 3 |  | **✓** |
| Difficulty controlling distractions in patient’s surroundings (e.g., noise, help from family members) | 9 | **✓** |  |
| Limited technological equipment in patient’s home (e.g., laptop/desktop with a webcam, internet) | 9 | **✓** |  |
| Limited technological equipment in clinician’s setting/workplace | 2 |  | **✓** |
| Difficulty assessing patients with reduced mobility due to injuries or stroke | 8 | **✓** |  |
| Other - Difficulty assessing if carer not present | 1 | **✓** |  |

The final question asked from respondents aimed to understand whether remote assessment and rehabilitation therapy will benefit patients with aphasia in Malaysia. Nine out of ten respondents reported that a remote assessment and rehabilitation therapy will benefit people with aphasia. Whereas one respondent reported ‘No’ and mentioned that it will depend on the ‘severity and type of aphasia’.

**4.3 Discussion**

The study presented findings from an online questionnaire that investigated the current situation of assessment of EF in Malaysia. A sample of 10 speech and language therapists from various clinical practices in Malaysia, including from private and government settings, responded to the survey. This sample was representative of the relatively small number of speech language pathologists (SLP) across Malaysia. According to Chu et al., (2019), there are only 300 SLPs in Malaysia with a minimal number of SLPs working on adult cases.  The key aims were to reflect the clinical reality of assessing EF in Malaysia and to understand clinicians’ needs when delivering assessment of EF. Despite the limitations of the findings due to small sample size, the accounts from SLTs were a testament to the exigency and demand for standardised EF test batteries for Malaysian users.

Through the broad findings, we found that there is a strong need for an EF assessment in the Malay language both for in-person and remote delivery. To allow for a detailed understanding of the results, we analysed the different subsections within the questionnaire separately. From this, we found that overall SLTs are familiar with the term EF and measuring EF abilities are within the job scope of SLTs in Malaysia. In terms of the current situation of assessing EF in Malaysia, the three most frequently used EF tests that have been delivered within respondents' clinical practice are Wisconsin Card Sorting Test (WCST), Stroop Colour and Word Test and Digit Span Backward and Forward. Interestingly, only one respondent reported using EF assessment in languages other than English, which implies the lack of availability of EF test batteries available in languages spoken in Malaysia (e.g., Malay, Mandarin, and Tamil). The potential benefits of using Malay language EF test batteries are evident by respondents’ responses, where the majority mentioned the need for having EF test in the Malay language to administer with users whose primary language is Malay.

Respondents highlighted several potential benefits for using EF assessment tools in major languages spoken in Malaysia (i.e., Malay, Mandarin, and Tamil).  The two main benefits reported were beneficial for patients in terms of increasing understanding and willingness to participate during screening sessions. Another frequently reported benefit was reducing the need for translation during assessment.

Indeed, it was found that more than half of the respondents reported they have used telehealth services and only one respondent reported delivering remote EF assessment. There was limited testing used remotely; in this case only one EF test has been used for remote delivery which was the Ministry of Health Informal Toolkit. An important point to note is that the test was not validated in the new remote format, potentially affecting the interpretation of test performance, and making clinical decisions complicated. Thus, there is a clear need for improvement in developing and validating tests for remote usage as well as improving training and availability of these validated test batteries as soon as they become available.

With regards to the benefits and challenges of remote assessment of EF, respondents reported that remote assessment had time and cost-savings benefits for patients and increasing accessibility for hard-to-reach patients. On the other hand, SLTs felt that limited technological equipment in patient’s homes and difficulties controlling distractions in patient’s surroundings represent potential challenges with remote assessment of EF.

From the current findings, the needs, and key benefits of culturally and linguistically translated cognitive assessment tools to assess Malay speakers were clearly needed. The need for cognitive assessments for non-English speaking people are similar to findings from Logiudice et al., (2012) scoping review highlighting a clear gap in validated translated assessments for culturally and linguistically diverse groups. With regards to the benefits and challenges of remote cognitive assessments, our findings support evidence from Webb et al.’s 2020 questionnaire in which remote assessment has economic and time saving implications.

**4.3.1 Limitations and future research**

To advance the evidence based on the need for a standardised EF test battery in the Malay language, the findings from the current research were intended to be used to inform the process of developing a Malay language EF test battery that takes into consideration linguistic and cultural aspects of the target population. All respondents recruited were speech language therapists, despite attempts for a wider distribution through social media and emails to different professional associations and medical departments (e.g., Department of Neurology). As such, we did not have sufficient data for analysis that could compare the usage of EF assessments both in-person and remotely across different professional roles and departments. Instead, we focussed on descriptive analyses on usage of EF assessment tools by SLTs and conducted an in-depth, item by item exploration of the data gathered. In the future, to garner a larger and potentially more generalisable sample, greater collaboration between different healthcare professionals and the inclusion of different medical departments or other relevant professional bodies could be conducted.

Based on the outcome of this research, it is imperative to develop a standardised, validated, and feasible tool to assess EF suitable for use with Malaysian user in-person or via remote modalities. This is instrumental in allowing clinicians to provide a reliable and effective assessment of EF and to plan for an effective rehabilitation therapy for people with aphasia.

**4.4 Conclusion**

The current study investigated the current practice in the formal assessment of EF by speech and language therapists in Malaysia’s clinical settings. It was found that the options of test batteries available in Malay are limited and the majority of SLTs are delivering EF tests in the English language. The number of remote assessments carried out was limited due to lack of standardised assessment tools for usage in remote settings and poor internet connectivity on the patient's end. This study highlighted the immediate need for a validated EF assessment tool which can improve practicality of usage by clinicians and addresses accessibility in terms of culture, language, and physical location.

The contributory factors found in Study 1 shed light on the technicalities, logistics and practicalities of the M-EF test battery that was developed in Study 2. The questionnaire, however, was not meant as a tool to determine the specific EF domains and tasks to be included in the Malay EF test battery. There are two rationales for this decision, (i) all participants in Study 1 study are recruited on the basis of their healthcare professions and the questionnaire does not ask about participants academic and/or clinical research experience in the field of psychological testing, and (ii) considering the term ‘executive function’ as a subject-specific terminology often used in cognitive science research, the facet of EF may not be equally or sufficiently familiar to all healthcare professionals. Therefore, the factors investigated from the questionnaire are aspects covering professional opinions and experience in clinical practice with PWA. On the other hand, published literature on EF and aphasia which are reviewed in Chapter 1, 2 and 3 will provide the main source of evidence to inform the selection of EF domains and tasks.

\*\*\*\*\*\*

**Chapter 5: Development of the Malay Language Executive Function Test (M-EF)**

This chapter describes in detail the process of M-EF development for Study 2 of the present study. This chapter consists of three sections: **(i) Section 5.1** recaps some of the key findings from Study 1 which investigated the need of a lingua-culturally adapted EF test battery for assessing Malay speakers. Section 5.1 also includes the follow-up study design and research aims for Study 2. **(ii) Section 5.2** represents the bulk of this chapter which brings together information on the development process of M-EF which includes information on (i) how each task is developed, (ii) administration protocol, and (iii) scoring procedure. **(iii) Section 5.3** describes the inter-rater reliability for scoring M-EF which was conducted for the first 10 participants from a group of healthy young adults.

**5.1 Introduction**

**5.1.1 Preparation of data from Study 1**

Study 1 of the current study involved obtaining healthcare professionals’ opinions on the current usage and need for the M-EF battery for assessing PWA. The main aim of Study 1 was to understand the need for a lingua-culturally sensitive measure of EF for Malay speakers and any additional requirements needed to develop the battery.

From the PPI questionnaire in Study 1, two main aspects from the responses were used to inform the development of the M-EF battery: (i) EF test characteristics, and (ii) lack of appropriate test batteries. Firstly, participants in Study 1 suggested that the M-EF development should consider not only linguistic and cultural aspects of Malay speakers but should also account for the impact of communication deficits in PWA. Some practical suggestions were also mentioned such as ensuring the battery is easy to use and clinicians are provided with appropriate training to administer it. Secondly, the PPI survey highlighted the lack of test batteries for the Malay-speaking population, and it was suggested that there should be more effort to improve the functional perception of EF assessment and treatment for this patient’s group, particularly among SLPs. Taking all this into account, we will capture both linguistic and cultural aspects of the Malay language and culture whilst ensuring steps for battery administration and scoring are clear.

**5.1.2 Study 2: design and research aims**

Study 2 included three separate research stages: (i) M-EF test development, (ii) pilot baseline study with healthy younger adults (*see Chapter 6*), and (iii) pilot baseline study with healthy older adults (*see Chapter 7*). In the first stage, selected EF tasks were adapted and translated to suit the target population. This process included steps to ensure test items were linguistically relevant to the Malay language and test items in the verbal test (M-HSCT) consisted of familiar items to speakers of Malay language and were culturally appropriate. Test items were adapted based on the researcher's familiarity and experience with the Malay language and culture and analysis of the participants’ responses.

The second and third stages outlined in (ii) and (iii) above will involve a pilot study with healthy younger adults and older adults to: (a) obtain overall performance score from healthy Malay speakers of different age groups; (b) inform and refine study protocol implementation (e.g., data collection, time taken, scoring data);  (c) detect any barriers to assessment completion; and (d) obtain healthy baseline performance to inform the next stage of research testing and battery adaptation for adults with post-stroke aphasia (PWA). In this research, a two-age-group study design is employed to explore age effects on M-EF performance across two different age groups, aligning with the research question. The two-age group design is also selected to allow for comparison with healthy adults investigated in other studies (*see Chapter 6 and 7)*. Further, Study 2 is a part of the primary efforts to identify and address issues that may occur with respect to future usage of the M-EF test battery.

Thus, the overarching aims for Study 2 are as follows:

1. To develop and obtain performance measures for a novel M-EF battery that includes measures that capture three underlying EF domains (inhibitory control, cognitive flexibility and working memory) which are linked to effective functional communication and higher treatment outcomes in aphasia *(see Chapter 2 for background information)*;
2. To develop a culturally and linguistically relevant EF test battery for assessing Malay speakers *(see Chapter 3 for background information)*;
3. To evaluate the feasibility and practicality of administering remote EF test protocol by comparing test performance in two different age groups (i.e., response accuracy, number of accurate responses compared to reports of comparable tasks in the literature).

**5.2 Development of Malay Executive Function Assessment (M-EF)**

For the present study, four EF tasks have been chosen to tap into the three often postulated EF domains: inhibitory control, working memory and cognitive flexibility. The selected tests and their underlying EF domains are explained in **Table 5(i)** below.

**Table 5(i):** Summary of EF tasks selected for the present study

|  |  |
| --- | --- |
| **EF tests and its underlying EF domains** | **Description of test** |
| **Malay-Hayling Sentence Completion Test (M-HSCT)**  **Primary:** Inhibitory control  **Secondary:** Cognitive flexibility  **Tertiary:** Working memory  In M-HSCT inhibition, participants are required to suppress the prepotent response by providing an irrelevant word to complete the sentence. Therefore, the second part of M-HSCT is supposed to measure inhibitory control.  **Test modality:** Verbal | Participants are orally presented with 30 sentences to complete. For automatic conditions, participants are asked to complete 15 sentences read to them with a meaningful word which completes the sentence. For inhibition conditions, participants are required to provide words which do not make sense to the sentences read to them. |
| **DS-Forward**  **Primary:** Working memory  In DS-F which requires immediate recalling of digits in the same order, this test condition represents a measure of working memory.  **DS- Backward**  **Primary:** Working memory  **Secondary:** Cognitive flexibility  **Tertiary:** Inhibitory control  In DS-B, WM is required when mentally rearranging the digits in reversed order. Cognitive flexibility is activated when participants move from simply remembering the sequence of digits to the operation of reordering them.  **Test modality:** Verbal | Participants listen to a series of digits ranging from two to eight digits read to them, each series of digits containing two sets, sequences will continue to be read until participants produce two consecutive errors. For Forward, the participants are required to repeat the sequence of numbers in the same order as they are read.  For Backward, participants are required to repeat the numbers in reverse order. |
| **Verbal Fluency Test (VFT)**  **Primary:** Cognitive flexibility, WM  **Secondary:** Inhibition  VF tasks require cognitive flexibility when switching between responses produced, for example between different items activated (e.g., food and toiletries). Inhibition is also activated to suppress competitive responses, avoid perseverative errors, and break from cluster sets that hold the fluency in a non-productive mode.  **Test modality:** Verbal | Participants are required to produce as many words as possible in 60 seconds. In the semantic task there were two categories: animals, supermarket items. In the letter-based task there were also two condition words beginning with the letter [A] and the letter [M]. The four VF subtasks were presented to all participants in the same order. |
| **Spatial Fluency Test (SFT)**  **Primary:** Cognitive flexibility  **Secondary:** Inhibitory control  Similar to VFT, SFT activates cognitive flexibility when switching between new drawings both within-task and between-task conditions. Inhibitory control is also activated to suppress previously drawn responses.  **Test modality:** Non-verbal | Participants are required to draw as many shapes and patterns as possible in 60 seconds. Participants are first required to draw using only 3 lines and then 4 lines. |

The following subsections describe each individual task, adaptation process, administration procedure and scoring criteria in detail.

**5.2.1 Verbal Measures of Executive Function**

The first three aforementioned EF tasks *(i.e. HSCT, VFT and Digit Span)* were developed based on existing tasks (Burgess & Shallice, 1996; Troyer et al., 1998). However, for each task the instructions, stimuli and scoring criteria were amended to suit the language and culture of the target population under study, Malay speakers.

In this study, three tasks (VFT, M-HSCT, DS) are categorised as verbal measures of EF because they involve verbal administration from the researcher, verbal material as the cognitive content, and verbal response from participants. All three are language-based tasks which rely on EF as an additional cognitive process and have been used in clinical and research settings to assess EF. SFT is the only non-verbal EF task in the M-EF battery, which was developed based on the framework of the Ruff Figural Fluency Test (RFFT) (Ruff et al., 2009).

EF tests are often criticised for requiring spoken outputs and processing of highly verbal information (Kendrick et al., 2019). However, many studies reported the overlap between the neural systems involved in executive functioning and language functions (Ye & Zhou, 2009). For this reason, it is vital to establish the measure of EF which involves different levels of language load particularly when assessing PWA. All three tasks chosen for the M-EF involve varying levels of verbal functioning, from low (SFT), moderate (DS) to high (M-HSCT and VFT).

**5.2.1.1 Verbal Fluency Test (VFT)**

The verbal fluency test (VFT) is a rapid, short test measuring aspects of verbal language functioning (Benton, 1968; Newcombe, 1969; Whiteside et al., 2016) in a manner that also taps into executive functions (Henry & Crawford, 2004; Luo et al., 2010; Shao et al., 2014). Additionally, fluency tasks are sensitive to frontal lobe dysfunction (Henry & Crawford, 2004), making them frequently administered across a range of clinical populations including Alzheimer’s disease, stroke and Parkinson’s disease (Henry & Crawford, 2004; Troyer et al., 1998). The quick nature of administration and little use of equipment has made VFT a widely used task in clinical and research settings (Thiele et al., 2016).

A traditional verbal fluency test consists of one or both of the following two tasks: (i) semantic fluency (sometimes called category fluency) and (ii) letter fluency (and the related task of phonemic fluency). In the typical version of the task (Lezak, 1995), participants are given 60 seconds to produce as many words as possible within (i) a given semantic category (Benton, 1968) or (ii) starting with a given letter (Newcombe, 1969). It is argued that both components of VFT provide a good measure of EF domains. In order to perform in the VFT semantic, cognitive flexibility is required to build semantic associations. Performance in the VFT lexical on the other hand, requires inhibition of grouping words with shared associations if needed (Goncalves et al., 2017). Besides VFT contributions in measuring both linguistic and EF components in the differential task conditions, VFT is widely included in neuropsychological assessment because of its high reliability, good norms, ease and rapidness of administration and moderate ecological validity (Henry & Crawford, 2004). It is perhaps the reason for a wide-spread use of VFT as a cognitive screening instrument in various patient populations: Alzheimer’s disease (Henry et al., 2004), focal brain damage (Henry & Crawford, 2004) and bilingual aphasia (Carpenter et al., 2020; Patra et al., 2020).

In general, it is hypothesised that poor performance in VFT may indicate either language or EF deficits. However, there exist differences in opinions on which aspects of the verbal fluency tasks (semantic vs. phonemic) are more sensitive to language or executive dysfunction (Perret, 1974; Shao et al., 2014; Whiteside et al., 2016).

Overall, based on current evidence examining the underlying cognitive components involved in each fluency task, it is suggested that phonemic fluency is more sensitive to EF deficits than semantic fluency (Perret, 1974; Luo et al., 2010; Shao et al., 2014; Paap et al., 2017). It is argued that performance in semantic fluency resembles the routine language behaviour of retrieving lexical items based on their meaning (Patra et al., 2020). For semantic fluency, participants can revisit existing links in their mental lexicon that relates to a given concept, for example animal category. Despite this argument, the semantic fluency test is not entirely free from EF. Several studies suggested that semantic fluency performance is a measure of working memory (Henry & Crawford 2004; Bose et al., 2017; Pakhomov et al., 2018;). To successfully perform in the semantic fluency tasks, one has to systematically search and retrieve words within the mental lexicon which requires activation of the working memory. One such strategy that uses WM is clustering, which involves the production of words within a subcategory.  and the other is switching referring to the ability to efficiently shift to a new category when a subcategory is exhausted (Troyer et al., 1997; Bose et al., 2017).

On the other hand, some argue that the constraint of retrieving words by initial letter is non-routine and more challenging (Patra et al., 2020). To successfully perform a letter or phonemic fluency task, one must come up with new strategies of searching for target words which involve the suppression of frequently used strategies of finding words by semantic relations (Luo et al., 2010; Goncalves et al., 2016). Thus, it is argued that successful performance in letter/phonemic fluency imposes higher demands on executive functioning hence greater demand on the frontal lobe (Patra et al., 2020; Goncalves et al., 2016). Due to its face validity as a test measuring both language and executive functioning, VFT is often included in neuropsychological test batteries, both in clinical and research settings (Goncalves et al., 2016).

Despite available norms for VFT (Henry & Crawford, 2004) in different populations *(i.e., monolingual, bilingual, healthy and atypical populations)*, such data are currently lacking for Malay-English bilinguals. It remains an open question: (i) whether VFT is suitable for measuring linguistic and EF performance of Malay-English bilinguals; (ii) whether healthy younger and older Malay-English bilinguals perform differently in semantic and letter fluency tasks compared to healthy adults in different language/cultural group; (iii) whether Malay-English bilinguals’ performance would be mediated by specific aspects of the task or language. Another rationale for selecting VFT for the target population is to add to the nascent literature of performance in VFT for Austronesian languages (Patra et al., 2020).

**Malay adapted version of VFT Procedure**

On each VFT trial, participants are asked to provide as many words as possible within 60 seconds on each of two semantic categories and two initial letters categories. The semantic fluency task is administered first followed by the phonemic fluency task. The order of semantic categories, as well as the order of letters was constant across participants. For each test session, video recordings were made, and responses were transcribed verbatim following each session for analysis.

Semantic fluency was assessed using the following two semantic categories: (i) animals and (ii) supermarket items. Instructions in Malay given were as follows: “Dalam 60 saat, anda perlu berikan sebanyak mungkin perkataan dalam Bahasa Malaysia yang terdiri daripada kategori (i) haiwan; (ii) buah - buahan dan sayur-sayuran. Anda boleh menyebut apa apa perkataan seperti kucing, cicak, durian, bayam dan sebagainya. Apabila anda bersedia untuk mula, skrin komputer akan menunjukkan masa yang tinggal untuk menyelesaikan tugas yang diberikan”. The English translation instruction and full assessment protocol is in **Appendix F**.

Letter-based phonemic fluency was assessed by obtaining the number of words generated in one minute for each of the letters (/a/) and (/s/). Instructions in Malay language given were as follows: “Dalam 60 saat, saya mahu anda berikan sebanyak mungkin perkataan dalam Bahasa Malaysia yang bermula dengan huruf \_. Anda boleh menyebut apa-apa perkataan dalam bentuk kata dasar, seperti mandi, manggis dan muncul. Selain itu, anda tidak boleh memberikan perkataan bagi nama orang dan nama tempat, seperti Ali, Perlis atau KLCC. Selain itu, anda harus menggunakan perkataan yang berbeza dan bukannya perkataan yang sama dengan menambahkan imbuhan. Jika anda berikan kata kerja, seperti ‘lari’ anda tidak  boleh memberikan perkataan yang sama dengan menambahkan imbuhan contohnya, ‘larikan’. The English translation of the instruction can be found in **Appendix F**.

**VFT Scoring Procedure**

To score the VFT responses, the total number of unique, real words that an individual can produce in 1 minute for each subcategory (i.e. animal, supermarket item, letter A and letter M) is counted. Error responses are categorised as (i) repetitions, (ii) non-Malay words, (iii) proper nouns (e.g., name of places, people) and (iv) nonsense words, and are scored ‘0’.

**5.2.1.2 Malay Hayling Sentence Completion Test (M-HSCT)**

Hayling Sentence Completion Task (HSCT) is a measure of verbal initiation and inhibition (Burgess & Shallice, 1996). Difficulties with verbal initiation and inhibition have been reported in patients with frontal lobe injuries (references) and PWA (references). Measure of initiation and inhibition abilities in patients with neurological illnesses can be difficult, due to the demanding nature of the task. HSCT allows for both components of initiation and inhibition to be examined with minimal changes to the task instruction and characteristics (Burgess & Shallice, 1996). Hence the nature of HSCT reduces the demand for participants to understand different task instructions which may impact performance in EF tests. In HSCT, participants are presented with sentences in which the last word is omitted. The sentences chosen such that there is a high probability of initiating a particular response from the participant. The prompted word is strongly cued by the preceding context (e.g., in this sentence ‘the farmer is milking the \_\_). The task is to complete the sentence, with a rational word in the first condition (automatic condition) and in the second condition (inhibition condition) with a word which makes no sense in the context (Burgess & Shallice, 1996).

HSCT is often used in clinical and research studies due to its ease of administration, short time to complete and can be administered with individuals with visual impairment or motor difficulties (Cervera-Crespo & Gonzalez-Alvarez, 2017). HSCT was initially designed to be used with English-speaking adults (Burgess & Shallice, 1996) and has been adapted into different languages such as French (Andres & Van der Linden, 2000) and Italian (Spitoni et al., 2018). Despite HSCT being translated into multiple languages, the test is currently not available in the Malay language. Therefore, the aim of this section is to fill the gap in HSCT development for Malay speaking individuals.

**M-HSCT Procedure**

The Malay language adaptation of the Hayling Sentence Completion Task (M-HSCT) consists of two parts (a) automatic and (b) inhibition. There are 15 sentences in each part, all of which have the final word omitted. The sentences used in the M-HSCT were translated from either the English (Burgess & Shallice, 1996) or the French version of the HSCT (Bayard et al., 2017) into Malay. The reason for choosing French HSCT in addition to the original English HSCT for adaptation to Malay is to ensure that the sentences adapted and translated are from existing validated HSCT tests as much as possible. However, due to the differences in Malay linguistic and cultural context compared to English and French, some of the sentences had to be further changed to suit the Malay syntactic structure.

The decision to create new sentences for M-HSCT was made as some original English and French sentences were deemed unsuitable for adaptation and translation into Malay. Two main reasons influenced this decision, first there are no syntactic equivalents of the French and English sentences in Malay and second the context and/or lexical choices used were culturally irrelevant to the target language user. Thus, some sentences were created by the researcher to suit the linguistic and cultural realities of the Malaysian population. See **Table 5(ii)** for further information on the sentences used for M-HSCT.

**M-HSCT Procedure**

There are two conditions (automatic and inhibition), for which different sets of 15 sentences were assigned. In both conditions (automatic and inhibition), the researcher read aloud the incomplete sentence to the participant. The automatic condition was tested first and the inhibition condition was conducted immediately after. Before each condition, two practice sentences were initially presented.

Participants’ responses were recorded, and the total number of responses and accurate responses were measured in both conditions. Additionally, time of response latency was measured by recording the time between when the last word of the sentence had been read by the researcher and stopped when participants began responding. In accordance with Burgess and Shallice (1997), the response latencies are measured in whole second units and are rounded up to the nearest second. For example, a time between 1 to 1.99 was scored as 1 second. No time limit was given for participants to respond. Latency measure was not conducted as part of the inter-rater reliability test, however measures of total scores for M-HSCT were included.

**Part (a): Automatic**

Participants were given spoken instructions in Malay which contained the crucial part (translated here in English), “I want you to listen carefully to each sentence and when I have finished reading it, your task is to give me a word you think would fit at the end of the sentence as quickly as possible.” The assessment begins after the two practice sentences given and if the participant was still unsure about the task, further explanation was given.

**Part (b) Inhibition**

Spoken instructions were given in Malay which contained (translated here in English), “This time I want you to give me a word which makes no sense at all in the context of the sentence. The word you give me should be unrelated to the sentence.”  Similarly, two practice sentences were given.

**Materials**

The following table illustrates the test items in both conditions (a) automatic and (b) inhibition. A total of seventeen sentences were translated from the original English and French HSCT.  The decision to select sentences from validated English and French HSCT versions is to have a bigger pool of sentences to select for the new language, Malay. Both French and English share similar sentence structure to Malay, with subject-verb-object word order. However, some sentences were untranslatable as they are idiomatic sentences, hence for this the sentences developed either adapted the syntactic structure or context of the original sentence from English or French HSCT into the Malay language and context. Sentences that were linguistically and/or culturally adapted into Malay consist of seven sentences altogether. Additionally, six sentences were replaced with original Malay sentences by the researcher. To ensure that the sentences were grammatically and culturally appropriate for the target population, the sentences were checked by a native Malay speaker, who is a Malay linguistic graduate and has been teaching IGCSE Malay language for the past 12 years. The **Figure 5(ii)** below describes how each test item in Malay HSCT is developed. Each sentence goes through the same process of adaptation.

**Figure 5(ii): Decision Tree for Development of M-HSCT**

A screenshot of a computer

Description automatically generated

*A diagram keys with arrows

Description automatically generated*

The decision tree above summarises the decision-making process for adapting each sentence from the original HSCT in English and French version. The full list of sentences used in the M-HSCT is described in **Table 5(ii)** below. For each sentence in part (a) automatic, the accurate response which completes the sentence is provided in the ‘response’ column. On the other hand, to complete (b) inhibition conditions, responses must not be listed in the ‘response’ column. Additionally, the source of each sentence is described in the last column.

**Table 5(ii): M-HSCT Sentence Prompts**

|  |  |
| --- | --- |
|  | Translated from the original English or French HSCT |
|  | Adapted from the original English or French HSCT (i.e., context, syntactic structure, response type) |
|  | Developed by researcher |

**Part (a): Automatic**

|  |  |  |  |
| --- | --- | --- | --- |
| **No.** | **Sentences** | **Response**  **(word class - expected response)** | **Source** |
| **1** | **Seorang posman digigit oleh seekor \_\_**   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Seorang | posman | digigit | oleh | seekor | | n. classifier human | n. | Prefix (di-) for passive + v. | adv. | n. classifier animal | | A (for human) | postman | is bitten | by | a (for animal) |   **English version:** A postman is bitten by a dog  **Version française:** Le facteur s’est fait mordre par un chien. | kata nama am - anjing  noun - dog | English/French HSCT |
| **2** | **Bomba sedang memadam \_\_**   |  |  |  | | --- | --- | --- | | Bomba | sedang | memadam | | n. | adv. time | Prefix (me-) for active + v. | | Firefighter | is | extinguishing |   **English version:** The firefighter is extinguishing the fire  **Version française:** Les pompiers ont éteint le feu | kata nama am - api  noun - fire | French HSCT |
| **3** | **Saya memasukkan adunan kek itu kedalam \_\_**   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Saya | memasukkan | adunan | kek | itu | kedalam | | Pro. | v. | n. | n. | det. | prep. | | I | put | batter | cake | that | into |   **English version:** The hot dough is put in the oven  **Version française:** J’ai jeté mes déchets à la poubelle. | kata nama am - oven/ketuhar  noun - oven | Context adapted from English HSCT and the syntactic structure adapted from French HSCT  *Contextual changes made from French HSCT as the equivalent of ‘bin’ in Malay is a compound word ‘tong sampah’ (direct translation: bin rubbish)* |
| **4** | **Monyet-monyet itu gemar memakan \_\_**   |  |  |  |  | | --- | --- | --- | --- | | Monyet - monyet | itu | gemar | memakan | | n.  (plural reduplication) | det. | v. | Prefix (me-) for active + v. | | Monkeys | that | like | to eat |   **English version:** He bought them in the sweet store  **Version française:** Les enfants adorent le gâteau au chocolat | Kata nama am - pisang  noun - banana | Syntactic structure adapted from French HSCT  *Contextual changes made as the prompt ‘kids love eating \_\_’ in Malay will produce a number of possible responses (e.g., sweets, chocolate, cake). Therefore in this case, retaining the syntactic structure whilst changing the nouns in the sentence to ensure the relevant and most familiar prompt will be given by participants.*  *The syntactic structure of the English sentence cannot be translated into Malay.* |
| **5** | **Sebelum makan, jangan lupa basuh \_\_\_**   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Sebelum | makan | jangan | lupa | basuh | | prep. time | v. | adv. negate | v. | v. | | Before | eating | don’t | forget | (to) wash |   **English version:** Before eating don’t forget to wash your hands  **Version française:** Avant de manger lavez-vous les mains | kata nama am - tangan  noun - hands | English/French HSCT |
| **6** | **Dia melawat ibunya yang tenat di \_\_**   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Dia | melawat | ibunya | yang | tenat | di | | pro. | Prefix (me-) for active + v. | n. + poss | adv. | adj. | prep. | | He/she | visit | his/her mother | is | ill | at |   **English version:** While running I sprained my ankle  **Version française:** En courant, je me suis foulé(e) la cheville. | kata nama am - hospital  noun - hospital | Constructed for M-HSCT  The original sentence from English/French HSCT cannot be translated due to unsuitable syntactic structure (i.e., SOV and possessive suffix in Malay). Further the word ‘ankle’ in Malay is a two word ‘buku lali’ which will break the task requirement.  The new sentence created reflects the common experience of the target population, which gives great importance to the concept of filial piety. |
| **7** | **Mereka pergi ke sekolah menaiki \_\_**   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Mereka | pergi | ke | sekolah | menaiki | | pronoun | v. | prep. | n. | Prefix (me-) for active + v. | | They | go | to | school | Verb for taking a transport |   **English version:** The hen laid an egg  **Version française:** La poule a pondu un œuf. | kata nama am - bas/bas sekolah  noun - bus | Constructed for M-HSCT  Reflect common experience of the target population = travelling to school with school bus is common practice in Malaysia  The original sentence from English/French HSCT is syntactically impossible to translate to Malay - word order, omission in Malay. The verb ‘lay’ in Malay doesn’t require the noun ‘egg’ as the verb is considered as an intransitive verb. |
| **8** | **Untuk mengait buah cempedak, ayah menggunakan \_\_**   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Untuk | mengait | buah | cempedak | ayah | menggunakan | | det. | v. | n. | n. | n. | Prefix (me-) for active + v. | | To | Action of collecting large fruit from tall trees | fruit | jackfruit | father | use |   **English version:** She called her husband on the telephone  **Version française:** Pour l’appeler, il me faut son numéro de téléphone. | kata nama am - galah  noun - a tool used to collect fruits from tall trees | Syntactic structure similar to French HSCT  (i) Context is changed to reflect the common experience of the target population (i.e., the response elicited is a common tool used in Malay’s household). (ii) The context was changed from the original version due to the noun being prompted to include possession suffix -nya.  (iii) The context are familiar to the target population as it is also found in traditional children’s quatrain |
| **9** | **Penternak lembu itu sedang memerah \_\_**   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Penternak | lembu | itu | sedang | memerah | | n. | n. | det | adv. time | Prefix (me-) for active + v. | | Farmer | cow | that | is | milking |   **English version:** The farmer is milking the cow.  **Version française:** Le fermier doit traire les vaches / chèvres. | kata nama am - susu  noun - milk | English/French HSCT |
| **10** | **Untuk mencegah kaviti, kita perlu gosok \_**   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Untuk | mencegah | kaviti | kita | perlu | gosok | | Conj. | v. | n. | pronoun | modal v. | v. | | To | prevent | cavity | we | should | brush |   **English version:** To prevent cavities we should brush our teeth.  **Version française:** Pour prévenir la carie, il faut se brosser les dents. | kata nama am - gigi  noun - teeth | English/French HSCT |
| **11** | **Lebah menghasilkan \_\_**   |  |  | | --- | --- | | Lebah | menghasilkan | | n. | v. | | Bee | produce |   **English version:** The bee produces honey.  **Version française:**  La vache donne du lait. | kata nama am - madu  noun - honey | Syntactic structure adapted from French HSCT  Context was changed to suit the familiarity of the target population and their daily life experience. |
| **12** | **Untuk menenangkan perasaannya, dia mendengar \_\_**   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Untuk | menenangkan | perasaannya | dia | mendengar | | Prep. | v. | n. | pronoun | v. | | To | relax | his mind | he | listens |   **English version:** To relax his mind, he listens to music.  **Version française:** Pour se détendre, on écoute de la musique | kata nama am - muzik/lagu  noun - music/song | English/French HSCT |
| **13** | **Hujan lebat pada musim tengkujuh mengakibatkan \_\_**   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Hujan | lebat | pada | musim | tengkujuh | mengakibatkan | | n. | adj. | det. | n. | n. | v. | | Rain | heavy | at | season | monsoon | caused |   **English version:** The whole town came to hear the major’s speech.  **Version française:** On dit que les loups sortent les soirs de pleine lune | kata nama am - banjir  noun - flood | Constructed for M-HSCT  The contexts of the English/French original sentences are unfamiliar for the target population (e.g., from the French sentence, wolves are not native to Malaysia and wolves often only appear in non-local children’s stories only e.g., Three Little Pigs)  The Malay sentence replaced here reflects the common experience of Malaysians |
| **14** | **Sebelum melintas jalan, pandang kiri dan \_\_**   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Sebelum | melintas | jalan | pandang | kiri | dan | | prep. | v. | n. | v. | n. | conj. | | Before | crossing | road | look | left | and |   **English version:** Before crossing look left and right.  **Version française:** Avant de traverser la rue, il faut regarder des deux côtés. | kata nama am - kanan  noun - right | English/French HSCT |
| **15** | **Angin kencang menumbangkan beberapa batang \_\_**   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Angin | kencang | menumbangkan | beberapa | batang | | n. | adj. | Prefix (me-) for active + v. | det. | n. classifier for long object | | Wind | rough | bring down | several |  |   **English version:** We saw his picture on the newspaper page.  **Version française:** Dans le journal, on voit sa photo en première page. | kata nama am - pokok  noun - tree | Constructed for M-HSCT  The sentence cannot be translated from English/French HSCT due to unsuitable syntactic structure. When translated, the prompted word is not a noun but an adjective ‘front’. Hence, it was decided to construct a new sentence for this.  The chosen sentence for M-HSCT contains two words *(v. tumbang n. classifier batang)* which is expected to prompt the response ‘tree’ |

**Part (b): Inhibition**

|  |  |  |  |
| --- | --- | --- | --- |
| **No.** | **Sentences** | **Inaccurate response** | **Source** |
| **1** | **Apabila ibu mendengar berita buruk itu, dia \_\_\_**   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | Apabila | ibu | mendengar | berita | buruk | itu | dia | | Conj. | n. | v. | n. | adj. | det. | pro. | | When | mother | hear | news | bad | that | she |   **English version:** When she heard the bad news, she cried  **Version française:** Lorsqu’elle a appris la mauvaise nouvelle, elle a versé des larmes | ≠menangis  ≠cry | English/French HSCT |
| **2** | **Nenek sedang membancuh kopi di \_\_**   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Nenek | sedang | membancuh | kopi | di | | n. | adv. time | Prefix (mem-) for active + v. | n. | prep. | | Grandmother | is | brewing | coffee | in |   **English version:** The two newlyweds went on their honeymoon.  **Version française:** Les deux mariés sont partis en voyage de noces | ≠dapur  ≠kitchen | Constructed for M-HSCT  (i) The context is more familiar to Malaysian experience, rather than the original sentence containing the context of ‘newlyweds and honeymoon’  (ii) The term ‘honeymoon’ in Malay is a loan word from English and may not be familiar to all bilingual Malay speakers due to cultural and religious factors. |
| **3** | **Dia mengirim surat tanpa menampal \_\_**   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Dia | megirim | surat | tanpa | menampal | | pro. | v. | n. | prep. | Prefix (me-) for active + v. | | He/she | post | letter | without | sticking |   **English version:** None of the books made any sense.  **Version française:** Il a posté la lettre sans y mettre un timbre. | ≠setem  ≠stamp | French HSCT  The English syntactic structure is not suitable for translating into Malay. |
| **4** | **Untuk mengelakkan dirinya dibasahi hujan, dia membawa \_\_\_**   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | Untuk | mengelakkan | dirinya | dibasahi | hujan | dia | membawa | | prep. | v. | pro. (for self) | Prefix (di-) for passive + v. | n. | pro. | Prefix (mem-) for active + v. | | To | prevent | himself | getting wet | rain | he | brings |   **English version:**  **Version française:** Pour se protéger de la pluie, il a ouvert son parapluie / pébroque / pépin | ≠ payung  ≠ umbrella | French HSCT |
| **5** | **Kebiasaannya, anak-anak penyu menetas di waktu \_\_**   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Kebiasaannya | anak-anak | penyu | menetas | di | waktu | | adv. | n. | n. | Prefix (me-) for active + v. | prep. | n. | | Usually | baby | turtle | hatch | at | time |   **English version:** The child cried for his mother.  **Version française:** Le bébé pleure pour appeler sa mère / maman. | ≠ senja/malam  ≠ dusk/night | Adapted from English/French HSCT - the original sentence ‘The baby cried for his  \_\_’ cannot be translated into Malay (i) the verb ‘cry’ is an intransitive verb in Malay and (ii) Even by adding the word ‘for’ following the verb ‘crying’ there are no one possible automatic response for this sentence  For the new sentence, the context chosen is much more familiar to Malaysians (i.e., hatching of turtles on the East Coast) |
| **6** | **Tukang masak itu menyiang ikan menggunakan \_\_**   |  |  |  |  | | --- | --- | --- | --- | | Tukang masak | menyiang | ikan | menggunakan | | n. | v. used specifically to describe the action of cleaning fish | n. | v. | | Chef | cleans | fish | using |   **English version:** The carpenter hammered a nail with a hammer.  **Version française:** Le menuisier a cloué un clou avec un marteau. | ≠pisau  ≠knife | Syntactic structure adapted from English/French HSCT  It is not possible to translate the sentence from the original version as the verb ‘to nail’ in Malay is an intransitive verb which does not require a noun following it |
| **7** | **Untuk membantu penglihatannya, dia memakai \_\_**   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Untuk | membantu | penglihatannya | dia | memakai | | prep. | v. | n. + suffix poss. | pronoun | Prefix (me-) for active + v. | | To | help | is vision | he/she | wears |   **English version:** Most sharks attack very close to sea.  **Version française:** Pour améliorer sa vision, il porte des lunettes | ≠kaca mata  ≠glasses | French HSCT  The context for the English sentence is not familiar to Malay speakers as sharks and shark attacks are not common in Malaysia. |
| **8** | **Setelah seharian bekerja, dia pulang ke \_\_\_**   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Setelah | seharian | bekerja | dia | pulang | ke | | prep. | adv. | v. | pro. | v. | prep. | | After | all day | working | he/she | return | to |   **English version:** After a whole day of working he returns home.  **Version française:** Après sa journée de travail, il est rentré à la maison. | ≠rumah  ≠home/house | English/French HSCT |
| **9** | **Angkasawan itu selamat kembali ke \_\_**   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Angkasawan | itu | selamat | kembali | ke | | n. | det. | adj. | v. | prep. | | Astronaut | that | safely | return | to |   **English version:** The astronaut returns back to earth.  **Version française:** Il était tellement bizarre, on aurait dit qu’il venait d’une autre planète | ≠bumi  ≠earth | Adapted from English HSCT  The French original sentence ‘It was so weird, it looked like it was from another \_\_’ cannot be translated due to syntactic constraint in Malay. |
| **10** | **Kita disarankan untuk makan tiga kali \_\_\_**   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Kita | disarankan | untuk | makan | tiga | kali | | pro. | Prefix (di-) for passive + v. | prep. | v. | adv. | prep. | | We | (are) advised | to | eat | three | times |   **English version:** We are advised to eat three times a day.  **Version française:** Il est bon de manger trois fois par jour | ≠sehari  ≠a day | English/French HSCT |
| **11** | **Kucing itu sedang mengejar seekor \_\_**   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Kucing | itu | sedang | mengejar | seekor | | n. | det. | adv. time | v. | n. classifier animal | | Cat | that | is | chasing | a (for animal) |   **English version:** The cat runs after the mouse.  **Version française:** Le chat court après la souris | ≠tikus  ≠rat | English/French HSCT |
| **12** | **Sebelum tidur, saya akan menutup \_\_\_**   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Sebelum | tidur | saya | akan | menutup | | prep. | v. | pro. | v. future marker | Prefix (me-) for active + v. | | Before | sleeping | I | will | close (switch off) |   **English version:** Before sleeping, I will switch off the lights.  **Version française:** Avant d’aller au lit, on éteint la lumière | ≠lampu/tingkap  ≠light/window | French HSCT  *The equivalent of ‘switch off’ in Malay is ‘tutup’ translated as ‘close’. This verb is used for ‘closing’ light/window/door.* |
| **13** | **Terdapat banyak buku di \_\_**   |  |  |  |  | | --- | --- | --- | --- | | Terdapat | banyak | buku | di | | adv. | adj. | n. | prep. | | There (are) | a lot of | book(s) | at |   **English version:** None of the books made any sense.  **Version française:** Il y a beaucoup de livres dans la bibliothèque | ≠perpustakaan  ≠library | French HSCT  The English sentence cannot be translated into Malay because the Malay word ‘sense’ must be preceded by the verb ‘masuk’ [enter] in Malay. This syntactic structure is problematic as it can prompt different words in the Malay language. |
| **14** | **Kami mendeposit duit simpanan di \_\_\_**   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Kami | mendeposit | duit | simpanan | di | | pro. | v. | n. | adj. | prep. | | We | deposit | money | savings | at |     **English version:** We deposited the money at the bank.  **Version française:** On dépose notre argent à la banque | ≠bank  ≠bank | French HSCT |
| **15** | **Nelayan itu turun ke laut membawa \_\_**   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Nelayan | itu | turun | ke | laut | membawa | | n. | det. | v. | prep. | n. | Prefix (mem-) for active + v. | | Fisherman | that | down | to | sea | bring |   **English version:** They went as far as they could.  **Version française:** Pendant le repas, toute la famille est assise autour de la table. | ≠jala, bot  ≠fishing net, fishing boat | Constructed for M-HSCT  Culturally relevant to the target population  The original sentence in English/French cannot be translated due to syntactic constraint in Malay. For example, in the French sentence the word for dining table in Malay is translated as ‘table dining’. Hence, the prompted word will be ‘dining/eat’ rather than ‘table’. |

**M-HSCT Scoring Procedure**

For M-HSCT, the total number of correct scores (based on all responses including errors) were computed for each participant; separately for each condition (automatic and inhibition).

For measuring response latency, the audio files were firstly prepared by converting the video file to audio file using Microsoft Clipchamp for each participant. The audio files used for making the response latency measurements consisted of 51 recordings which spanned the entire length of M-HSCT assessment from start to finish, capturing all researcher and participant utterances which were saved in the form of wav. file. Each participant has 30 audio recordings (15 for automatic and 15 for inhibition), which were prepared in Praat (Boersma & Weenink, 2016). **Figure 5(iii)** below showed an example of a spectrogram image from Praat, extracted from the automatic condition response for question 1.

**Figure 5(iii):** Measurement of response latencies. Pictured is the Praat interface, loaded with an audio file extracted from M-HSCT automatic condition. The specific target response here is the word ‘anjing’ - ‘dog’. Praat shows both the waveform of the audio data and the time taken.  In this example, at the end of the researcher’s audible utterance, the waveform and spectrogram show other non-speech sounds  (i.e., researcher’s breathing noise) which were not included.

A screenshot of a computer

Description automatically generated

Response latency was measured from the time elapsed at the end (offset) of the researcher’s sentence ending to the beginning (onset) of the respondent’s answer. The onset of the participants’ answer was measured at the time point of the first sound produced for their verbal response. For example, for the target response for ‘book’, its onset is the first sound in ‘book’ which is the /b/ sound. Response latencies were recorded with whole seconds units rounded to 2 decimal places. Noises and sounds which are not related to the response, for instance breathing noise, tapping or fillers such as ‘ahh’ were not included.

The average latency was calculated by dividing the total latency with 15 for each participant. For correct responses, the latencies were divided by the number of correct responses produced by each participant; for error responses, the latencies were divided by the number of errors produced by each participant.

**M-HSCT Testing Procedure**

The M-HSCT typically takes no more than 5 minutes to complete with healthy adult participants. The following **Table 5(iii)** details the assessment procedure (i.e., instructions and practice sentences read to participants).

**Table 5(iii):** Details of M-HSCT Test Procedure

|  |
| --- |
| **Part (a) Automatic**  **Arahan:** Sekarang, saya akan mulakan ujian kedua. Ujian ini mengandungi dua bahagian. Untuk bahagian pertama ini, saya mahu anda mendengar dengan teliti setiap ayat yang saya akan bacakan. Apabila saya telah selesai membacanya, tugas anda ialah untuk memberi saya perkataan yang anda fikir paling sesuai untuk mengisi tempat kosong pada akhir ayat yang dibacakan.  **Instruction:** Now, I will begin with the second test. This test contains two parts. For the first part of the test, I want you to listen carefully to each sentence. When I finish reading, your task is to give me a suitable word to fill the blank at the end of each sentence.  **Practice sentence:**   1. Sebelum keluar rumah, jangan lupa kunci \_\_ (pintu)   ENG: Before leaving the house, don’t forget to lock the \_\_ (door)   1. Pesawah itu sedang menanam \_\_ (padi)   ENG: The rice farmer is planting \_\_ (paddy) |
| **Inhibition condition**  **Arahan:** Sekarang kita akan mulakan bahagian kedua. Kali ini, saya mahu anda berikan perkataan yang tidak relevan atau tidak masuk akal sama sekali bagi konteks ayat yang dibaca. Perkataan yang anda berikan mestilah tidak berkaitan dengan ayat yang dibaca.  **Instruction:** Now we will start the second part of the test. This time, I want you to provide words that are irrelevant or do not make sense at all for the context of the sentence. The words you provide must be irrelevant to the sentence being read.  **Practice sentence**  1. Mereka bermain bola sepak di \_\_ (≠padang)  Translation: They [are] playing football at [the] \_\_ ((≠field)  2. Pihak polis membawa banduan itu ke \_\_ (≠penjara)  Translation: [The] police officer brings the prisoner to [the] \_\_ (≠prison)  **Prompt for repeatedly completing the sentence *(two consecutive response)* rather than giving an unrelated word.**  Anda diingatkan untuk memberi saya perkataan yang tidak relevan bagi ayat yang dibacakan.  **English translation:** You are reminded to provide a word which does not make sense to the sentence read. |

**5.2.1.3 Digit Span Forward and Backward**

Digit span forward (DSF) and digit span backward (DSB) are a measure of verbal working memory commonly used in clinical and research settings in both healthy and clinical populations (Wilde et al., 2004; Coinski et al., 2020). Digit span tasks require participants to repeat a sequence of 2-8 digits. When participants fail to repeat two consecutive trials the task is discontinued.

DSF has been characterised as a simple span test and is used to measure the ability to store and maintain components of WM whereas DSB is believed to provide a measure of ability to store information and mentally reordering of information (Wilde et al., 2004; Laures-Gore et al., 2011). It is thus argued that DSB puts a greater demand on WM skills. This is evident in several studies reporting shorter spans in DSB compared to DSF in various populations such as healthy older adults (Choi et al., 2014) and PWA (Laures-Gore et al., 2011). However, such interpretation cannot be extended to Malay speaking populations as there is currently no available published normative data for DS tasks for Malay speakers. In addition to the need to investigate the difference in DSF and DSB performance in healthy Malay speaking individuals, the evidence suggesting WM deficits influence language abilities in PWA *(see Chapter 3)* also supports the need to translate the DS tasks for assessing Malay speakers.

**Malay DSF/B procedure**

In the Malay adapted version of digit span, all digits were translated into the Malay language and is adapted from the original digit span test developed by Wescheler (1981). There are two parts for the Malay Digit Span, Forward and Backward are administered separately. In Digit Forward (DF), participants were asked to verbally repeat the digits in the manner they were presented (forward span). In the Digit Backward version (DB) participants are asked to recall the stimuli in the reverse order with which they were presented (backward span). The task begins with a series of two digits orally presented to each participant and continuing to a maximum of eight digits. The sequence of digits presented are constant for all participants (see Table 7 for details). Both parts of Digit Span (forward and backward), consisted of 2 levels (2–8-digit sequences). There are two sequences per digit level. For example, for Level 3, participants are presented with two different sequences of three digits, one at a time. The sequences of digits were presented orally at a rate of one digit per second (Weschler, 1981).

Throughout the task, when participants respond incorrectly on two consecutive occasions the test terminates (Wechsler, 1981). For each sequence, 1 point is given for correct response or 0 point for incorrect or no response. The total score for all correct responses in both conditions (DSF and DSB) is 32 points. Because this task measures working memory, repetition of the sequence is not allowed on both Digit Span Forward and Backward.

**Materials**

The list of digit sequences is presented in **Table 5(iv)** below.

**Table 5(iv): Digit Span Level and Sequence**

|  |  |
| --- | --- |
| **Digit Span Forward** | |
| Level 2 | 53, 94 |
| Level 3 | 762, 238 |
| Level 4 | 6837, 5916 |
| Level 5 | 16357, 84621 |
| Level 6 | 458213, 971384 |
| Level 7 | 3795148, 7261584 |
| Level 8 | 68174523, 35184692 |

|  |  |
| --- | --- |
| **Digit Span Backward** | |
|  |
| Level 2 | 24, 38 |  |
| Level 3 | 456, 943 |  |
| Level 4 | 9837, 5264 |  |
| Level 5 | 68742, 76425 |  |
| Level 6 | 179365, 468719 |  |
| Level 7 | 2374659, 8235746 |  |
| Level 8 | 31427685, 57486129 |  |

**Digit Span Protocol**

To ensure the digits’ presentation rate is consistent across all items, they were read at a rate of approximately one digit per second.  This is conducted to avoid the most common administration errors which is presenting the numbers faster than one per second. Additionally, this was done to avoid inconsistent pitch that may facilitate use of chunking strategy.

**Task instruction**

|  |
| --- |
| **Digit span forward**  **Arahan:** Bagi ujian ini, anda perlu mendengar dengan teliti nombor siri yang akan disebutkan. Anda akan diminta untuk mengulangi nombor siri tersebut dalam susunan yang sama seperti yang disebutkan. Bilangan nombor siri yang anda akan dengar akan meningkat, contohnya kita akan mula dengan dua nombor, kemudian tiga, empat dan berikutnya.  *English translation: For this task, you will have to listen carefully to the sequence of numbers which I will read aloud. Your task is to repeat the sequence of numbers in the same order that  I read them. We will begin with sequences of two numbers, then three, four and so on.*  Sebelum kita mulakan ujian ini, saya akan mulakan dengan beberapa praktis latihan. Adakah anda bersedia?  *English translation: Before we start this task, we will start with some practice. Are you ready?*  Praktis 1: 387  Praktis 2: 96354  Sekarang saya akan memulakan ujian yang sebenar, adakah anda mempunyai apa-apa pertanyaan tentang ujian ini.  *English translation: Now I will begin with the real task, before we start this do you have any question?* |

|  |
| --- |
| **Digit span backward**  Arahan: Untuk ujian berikutnya, anda akan mendengar nombor siri seperti ujian sebelum ini. Tetapi kali ini, anda perlu mengulangi nombor siri tersebut dalam susunan terbalik dengan apa yang disebutkan. Seperti sebelum ini, kita akan mulakan dengan beberapa praktis latihan.  *English translation: For this task, you have to listen carefully to the sequence of numbers which I will read aloud. You will be asked to repeat the sequence of numbers in reverse order of the sequence I read them.We will begin with sequences of two numbers, then three, four and so on. Before we start this task, we will start with some practice. Are you ready?*  Praktis 1: 5239  Praktis 2: 27481  Adakah anda mempunyai apa-apa pertanyaan mengenai ujian ini? Sekarang saya akan memulakan ujian berikutnya.  *English translation: Now I will begin with the real task, before we start this do you have any question?* |

**Digit Span Scoring**

The video recording of participants’ responses was transcribed verbatim. For both Digit Span Forward and Backward, the total number of correct items and span score were calculated. The span score refers to the length of the longest correctly repeated sequence.

**5.2.2 Non-Verbal Measures of Executive Function**

**5.2.2.1 Spatial Fluency Test (SPT)**

For the Malay EF test battery, one non-verbal task was chosen which involved spatial drawing as a measure of cognitive flexibility and inhibition. Drawing performance is often used for the identification of cognitive impairments in adults, as it is quick and easy to administer and sensitive to degeneration processes (e.g., Clock Drawing Test, RFFT). Furthermore, some argued that non-verbal cognitive tests are more sensitive to detecting changes in executive functioning over time (Bryan & Luszcz, 2000). Additionally, there is substantial evidence indicating there is a link between non-verbal cognitive abilities with language skills in PWA (Ramsberger, 2005; Fucetola et al., 2009). It is therefore justifiable to include a non-verbal EF measure in the Malay EF test battery to (i) detect differences in executive functioning ability over time and (ii) to support the aim of the current test battery which is developed for use with PWA. It is believed that by including non-verbal measures of EF may provide a useful comparison of EF outside the more verbally loaded tasks.

The spatial fluency test (SPT) which was developed and included in the M-EF is adapted from a traditional framework of a non-verbal EF task, the Ruff Figural Fluency Test (RFFT) (Ruff et al., 1987). RFFT is a pen-and-pencil test assessing non-verbal fluency by asking participants to connect squares using two or three lines to create new figures each time. According to Ruff et al., (1987), the RFFT provides a measure of working memory and response inhibition by asking participants to draw new patterns each time and avoid making duplicate designs. Additionally, the RFFT is also believed to provide a comparable measure of EF components to VFT (Ross et al., 2019). The following subsections details the test development process, administration and scoring methods.

**Spatial Fluency Test Protocol**

The Spatial Fluency Test (SPT) is the only pen-and-paper measure of EF included in the M-EF test battery. Prior to the test session, participants were asked to have with them the answer sheet provided and a pen or pencil. The answer sheet provided consists of 8 equal size squares per page. The spatial fluency test consists of two trial conditions, (i) participants are asked to draw novel patterns using three lines and in the second condition (ii) participants are instructed to draw as many shapes/patterns using four lines. For each trial, participants are given 60 seconds to draw as many novel/unique patterns as possible the squares provided. After the first 60 seconds interval, participants are asked to use a new page on the answer sheet provided for the second condition. At the end of the test, participants are asked to hold the A4 paper on their webcam so the examiner can take a screenshot of their drawing, alternatively participants are given the option to take photos of their responses and send them to the researcher following the assessment.

**Scoring Procedures: SFT**

For SFT, the total number of correct drawings drawn in 1 minute were calculated for each participant in both the task conditions: 3 lines and 4 lines.

**5.3 Inter-rater reliability test**

Following development of the M-EF battery, a reliability analysis was conducted on the first 10 healthy participants. The aim of this analysis was to (a) establish the inter-rater reliability of scoring for the M-EF and (b) identify any changes if required to the test items, instructions or delivery method of the M-EF prior to conducting the large-scale data collection on healthy younger and older adults. The following subsections details the reliability test conducted.

**5.3.1 Participants**

To test the inter-rater agreement, the first ten participants' responses were chosen. Participants ranged in age from 23 to 28 years (M=25, SD=1.76), and were recruited from Malay-English bilingual young adults studying at the University of Sheffield. Any participants with a history of neurological disease, psychiatric illness and severe long-term illness were excluded. Participants’ informed consent was obtained, and each participant’s raw data (video data) is transcribed verbatim, and each file is assigned anonymised participant numbers in order to protect participants’ confidentiality. Summary of participants’ demographic background can be found in **Table 5(v).**

**5.3.2 Procedure**

All participants completed a language background questionnaire, a health background questionnaire and a series of four M-EF tests (i) Malay Hayling Sentence Completion, (ii) Verbal fluency test, (iii) Digit span and (iv) Spatial Fluency test. M-EF tasks were assigned using counterbalancing 4x4 Latin square design to help control for sequencing effects. The M-EF assessment is delivered remotely via Google Meet.

All participants’ responses are transcribed verbatim and rated by the primary researcher (Rater 1). In the evaluation of the inter-rater reliability, an independent rater (Rater 2) who is a native Malay speaker and a third-year medical student at the University of Sheffield blind rated the scores using the initial established guidelines. Rater 2 is blind to the research objectives and what each EF task measures. The inter-rater guidelines can be found in **Appendix G.** In the rater guidelines, the rater was provided with administration procedure and scoring guide for each task in M-EF.

Data were analysed using SPSS version 29.0. Descriptive statistical analysis was performed to summarise group demographic variables. Pearson’s and Spearman’s correlations were used to measure agreement between the raters. The reason for choosing both parametric and non-parametric statistics in this inter-rater reliability analysis relates in part to the small sample size (n=10) and the newness of the tests being developed. The analysis is a straightforward way to evaluate if scores derived from two raters’ scoring of participants’ responses shows any systematic differences. This reliability scoring is also conducted to measure the extent to which the scoring of M-EF will yield the same score each time it is administered, all other things being equal (e.g., remote administration/ no true change to the attribute being measured has occurred).

**5.3.3 Result**

**5.3.3.1 Demographics**

Ten Malay speaking participants participated in this study who were primarily well educated with at least a college diploma level or higher and have spent some time living in the UK. In addition, study participants were all healthy, all ten participants did not report any major medical conditions. Characteristics of the 10 participants used for the inter-rater reliability comparison are summarised in **Table 5(v)** below.

**Table 5(v):** Summary of the Frequency and Central Tendency Measures for Sociodemographic Characteristics of Participants included in the Inter-Rater Reliability Test (n=10)

|  |  |
| --- | --- |
| **Baseline characteristics** | **Frequency** |
| **Gender**  Female  Male | 7  3 |
| **Highest educational level**  Diploma  Bachelor’s Degree  Masters | 4  2  4 |
| **Number of years in the UK (in years)**  1 year  2 years  3 years | 4  5  1 |
| **Self-reported Malay language fluency**    Spoken Malay fluency  Quite fluent  Very fluent    Understanding Malay language  Quite fluent  Very fluent | 2  8  2  8 |
| **Baseline characteristics** | **Central tendency, variation, and range** |
| **Age**  Mean±SD  Median (min, max) | 25±1.764  25 (23, 28) |
| **Number of years in the UK (in years)**  Mean±SD  Median (min, max) | 1.70±.675  2 (1,3) |

All participants reported high levels of speaking fluency and comprehension of the Malay language with 80% reporting very fluent ability in both language domains *(i.e., spoken and understanding)*. All participants spent most of their time in Malaysia with the highest number of time spent in the UK being 3 years for only one participant (10%).

**5.3.3.2 Performance on EF tests**

To test the inter-rater reliability, correlations were performed between the scores obtained by the two raters *(Rater 1 and Rater 2)* for all the M-EF tasks. Summary statistics, and in some cases the actual item by item scores, were also examined to evaluate the absolute level of agreement between raters. It is important to note that for the inter-rater reliability test in this Chapter, latency scoring was not included.

The inter-rater reliability yielded a 100% agreement for three tests from the M-EF namely digit span, M-HSCT and spatial fluency test. The correlation for one subtask within VFT (animal category) was near perfect with Pearson’s correlation (p<.999) and Spearman’s rho (ρ<.997). The inter-rater reliability scoring results for each task are summarised in **Table 5(vi)**.

**Table 5(vi):** Inter-rater summary statistics and inter-rater correlations for each M-EF task

a. Digit Span (DS) Forward and Backward number of correct items.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **DS - Forward** | | **DS - Backward** | |
|  | **Rater 1** | **Rater 2** | **Rater 1** | **Rater 2** |
| **Mean** | 9.4 | 9.4 | 6.1 | 6.1 |
| **Median (min, max)** | 9.5 (8,11) | 9.5 (8,11) | 6.0 (4,8) | 6.0 (4,8) |
| **Correlation** | **DS - Forward** | | **DS- Backward** | |
| **Pearson** | 1.000 | | 1.000 | |
| **Spearman’s rho** | 1.000 | | 1.000 | |

1. M-HSCT - Total score (number of correct items)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **M-HSCT**  **Automatic** | | **M-HSCT**  **Inhibition** | |
|  | **Rater 1** | **Rater 2** | **Rater 1** | **Rater 2** |
| **Mean**  **Total score** | 14.30 | 14.30 | 14.60 | 14.60 |
| **Median (min,max)**  **Total score** | 14.00 (13,15) | 14.00 (13,15) | 15.00 (13,15) | 15.00 (13,15) |
| **Correlation** | **M-HSCT Automatic** | | **M-HSCT Inhibition** | |
| **Total score**  Pearson  Spearman’s rho | 1.000  1.000 | | 1.000  1.000 | |

1. VFT - semantic and letter category number of correct words.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **VFT animals** | | **VFT supermarket items** | | **VFT letter [A]** | | **VFT letter [M]** | |
|  | **Rater 1** | **Rater 2** | **Rater 1** | **Rater 2** | **Rater 1** | **Rater 2** | **Rater 1** | **Rater 2** |
| **Mean** | 19.20 | 19.10 | 20.10 | 20.10 | 11.40 | 11.40 | 10.30 | 10.30 |
| **Median (min, max)** | 18.50 (14,29) | 18.00  (14,29) | 21.00 (14,27) | 21.00 (14,27) | 12.00  (8,15) | 12.00  (8,15) | 10.50  (8,13) | 10.50  (8,13) |
| **Correlation** | **VFT - animal** | | **VFT - supermarket items** | | **VFT - letter [A]** | | **VFT - letter [M]** | |
| **Pearson** | .999 | | 1.000 | | 1.000 | | 1.000 | |
| **Spearman’s rho** | .997 | | 1.000 | | 1.000 | | 1.000 | |

1. Spatial Fluency - 3 lines and 4 lines condition number of novel drawings.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **SFT - 3 lines** | | **SFT - 4 lines** | |
|  | **Rater 1** | **Rater 2** | **Rater 1** | **Rater 2** |
| **Mean** | 4.60 | 4.60 | 4.60 | 4.60 |
| **Median (min,max)** | 4.00 (3,6) | 4.00 (3,6) | 5.00 (3,7) | 5.00 (3,7) |
| **Correlation** | **Spatial fluency - 3 lines** | | **Spatial fluency - 4 lines** | |
| **Pearson** | 1.000 | | 1.000 | |
| **Spearman’s rho** | 1.000 | | 1.000 | |

For DS forward and backward, correlations between Rater 1 and Rater 2 were perfect. The mean scores between Rater 1 and Rater 2 were identical with a mean of 9.4 items for forward and 6.1 items for backward. The median and range of scores for DSF and DSB across both raters were also identical. The maximum accurate response for forward condition is higher compared to backward condition, and similar evidence has been found in different languages. This finding is parallel to reports in other literature on digit span in non-English speaking individuals (Korean speakers, Choi et al., 2014; Indian speakers Tripathi et al., 2015; Italian speakers, Monaco et al., 2013).  This will be further discussed in Chapter 7, where the M-EF battery is administered with a larger sample size.

For M-HSCT, the correlations for all scores obtained were perfect across both conditions between Rater 1 and Rater 2 in**Table 5(vi)**. The means for the total score was similar across both raters.

For VFT, correlations for semantic category supermarket items and letter category [A] and [M] were perfect across both raters. There is a slightly lower correlation between Rater 1 and Rater 2 in the semantic category for animals with Pearson’s correlation (r=0.999) and Spearman’s rho (rho=.997). As shown in **Figure 5(iv)**, there was a perfect linear association between Rater 1 and Rater 2 scores on VFT supermarket items, this was also the case across VFT letter [A] and letter [M]. However, there was a slight difference between the scoring of the VFT animal category by Rater 1 and Rater 2. Inspection of the scoring for individual participants showed that the raters differed on only one item for one participant. The mean, median and range of scores for VFT supermarket items, letter [A] and letter [M] were identical across both raters. For the VFT animal category, the median score was 18, which was slightly lower than the median score of 21 for the supermarket items category. Across letter fluency, the total score was higher for words beginning with letter [A] compared to [M]. This is consistent with the Malay language corpus where there are more words beginning with letter [A] compared to [M].

With regards to spatial fluency tasks, the overall absolute agreement between Rater 1 and Rater 2 was perfect across both conditions (3 lines and 4 lines). The mean scores are identical for both raters, for both 3 lines and 4 lines conditions, however the median was higher for 4 lines condition compared to 3 lines. The maximum score for spatial fluency 3 lines is slightly lower than 4 lines. This may be due to a learning effect as participants were first instructed to draw novel patterns using 3 lines followed by the second condition, drawing using 4 lines.

Overall, the findings showed perfect inter-rater reliability scoring in terms of linear and ranked consistency in three subtasks in M-EF *(i.e., DS, M-HSCT, SFT)* for both raters. Scoring was identical, in terms of both consistency and absolute values across all three subtasks *(i.e., DS, M-HSCT, SFT)* between the two raters. For VFT, inter-rater scoring of three out of four subtasks showed perfect reliability, except for one task, the VFT animal category. For the VFT animal category, there was a single item of disagreement between the raters indicating a near perfect agreement at 99.4%.

**5.3.4 Discussion**

**5.3.4.1 Implication on the M-EF battery development**

This Chapter presents the development of the M-EF battery for use in remote settings, aimed to be a lingua-culturally suitable EF assessment for Malay speakers. This chapter demonstrated that the items in M-EF can be scored via transcript and audio review of recorded M-EF administration and that scoring using this method exhibited excellent inter-rater reliability. Importantly, consistent interpretation was observed despite both raters completed ratings at their own time and using different mediums (i.e., R1 using the video data and R2 using transcription data). This further suggests little added variability in score agreement when scoring using different formats.

**5.3.4.2 Patterns of performance in the M-EF battery**

The findings shed light on the pattern of performance in the M-EF battery. It was found that for DS, the number of correctly recalled digits were higher in the forward condition compared to backward. This is expected across different languages, as participants typically achieve higher scores when recalling items in their original order (forward), relative to reverse order (Li & Lewandownsky, 1995). Additionally, cross-linguistic comparisons of digit span showed that participants’ capacity to recall digits within a particular language depends on the time required to pronounce the digit in the language. This word length effect has been documented in comparison between English and (i) Mandarin (Chen et al., 2009) and (ii) Welsh (Ellis and Connely, 1980). The Malay language used in M-EF is a multi/poly-syllabic word structure, with a minimum of bisyllabic structure such as ‘satu’ for number ‘one’ (Lee et al., 2013). In Malay, eight out of ten digits from 1-10 are bisyllabic words. Two digits 9 and 10 have polysyllabic word structure. In comparison to digits 1 to 10 in English, there is only one bisyllabic word which is number 7 and the rest is a single-syllable word form.

For M-HSCT, both Rater 1 and Rater 2 showed agreement in scoring of all ten participants’ responses in all the scores obtained for this task. Similarly, correlations for M-HSCT automatic and inhibition conditions were perfect between Rater 1 and Rater 2, with identical scores range for both conditions. Based on initial observation of participants’ response in the inhibition condition, most participants employed a strategy to facilitate retrieval of unconnected words. Participants were found to use the name of objects around the room such as ‘curtain, book, cup, pen’. This strategy implementation facilitates suppression of prepotent responses.

The differences in inter-rater reliability score for VFT animal category highlight an important part of conducting translation and scoring of EF test batteries. Rater A scored the word ‘jaguar’ as correct whereas independent Rater B scored it as incorrect as the word is not a word in the Malay language. Rater A’s justification for rating ‘jaguar’ as correct is because the Malay word for ‘jaguar’ which is ‘harimau bintang’ is not commonly used and often Malay speakers borrow the English word ‘jaguar’ to name the animal.

In summary, it was found that there is a high inter-rater reliability for M-EF when assessing healthy younger adults with 100% percentage agreement in three tasks in the M-EF. These findings established, in part, a foundation to use a performance-based executive function test (M-EF) in healthy adult Malay speakers. A more detailed discussion on the performance in the M-EF battery for healthy younger adults will be provided in Chapter 6.

\*\*\*\*\*\*

**Chapter 6: M-EF Assessment: Normative Data from Malay Speaking Healthy Young Adults**

**6.1 Introduction**

Within aphasia literature, there is growing evidence indicating that EF impairments commonly co-occur with aphasia and may influence language ability and outcomes (Purdy, 2002; Murray, 2012; Villard & Kiran, 2016; Murray 2017). While there is increasing evidence of a positive correlation between EF and functional language recovery in PWA (Lambon Ralph et al., 2012; Penn et al., 2016), the availability of EF tests across different languages and cultures remains scarce. Thus, this leaves a strong need to develop linguistically and culturally compatible methods of assessment for EF, especially for multicultural and multilingual populations (Penn et al., 2016).

To date, there are little to no neuropsychological assessments available in the Malay language *(see Chapter 4)*. To address this concern, the M-EF battery was developed *(see Chapter 5 for details on test development)*. This chapter reports results from healthy younger adults in the M-EF battery in Study 2. The main aim is to provide a comprehensive analysis of the M-EF performance in healthy Malay speakers to establish a baseline set of results for the targeted population, PWAs. Hence, Chapter 6 will provide analysis of the M-EF test battery to assess:

* Performance in terms of central tendency and variation for each task.
* Correlations across subtasks and tasks.
* Consideration of performance measures in relation to published norms for comparable tasks in other languages.
* Consideration of subtask and cross-task correlations in relation to published correlations for comparable tasks in other languages.

**6.2 Method**

**6.2.1 Assessment procedure**

To ensure that the criteria for the administration of the tests, the data recording, and scoring procedures were uniform, using Google Meet and following the M-EF assessment protocol **(Appendix F).**

All participants underwent no more than 50 minutes of assessment over one online session. Following the study consent process, all participants were asked a series of questions on language and health background. The language questionnaire consisted of four questions to understand participants’ fluency in speaking and understanding the Malay language. Following that, the M-EF test was administered.

**6.2.2 Recruitment Procedure**

A total of 51 participants were recruited from January to April 2023 at the University of Sheffield and Sheffield Hallam University. Participants were recruited via email invitation, word of mouth and flyers that were distributed during University’s event and community meeting points *(e.g., Malaysian Society events and national celebration events e.g., Eid celebration)*.

Potential participants were informed about the study through referrals and study information posters posted in the community and via email invite. Participants were targeted if they were aged between 18-35 years; were native or fluent Malay speakers; had access to the internet and a device for joining Google Meet during the test session. Participants were excluded if they reported any neurological or major psychiatric conditions, previous severe illnesses (e.g., stroke), or history of learning disabilities.

Participants received an information sheet that explained the aims and procedure of the study and the exclusion criteria. Participants who agreed to take part in the study completed an online consent form and chose a suitable date and time for the assessment. Following an agreed time and date, a copy of the answer sheet for the spatial fluency task was sent to the participants either via email for printing or via hard copy. A Google Meet link was sent to all participants. During the Google Meet session, participants were first asked whether they still consented to continue with the study. All procedures received ethical approval from the University Research Ethics Committee of the Division of Human Communication and Sciences, Health Sciences School at the University of Sheffield (ethics application no: 039324). Participation in this study was voluntary.

**6.2.3 M-EF Assessment Procedure**

The M-EF test battery consists of 4 tests which were adapted and modified from currently existing EF tests to the characteristics of Malay culture and language *(see Chapter 5 for test development procedure)*. Participants were tested remotely using Google Meet, a video conferencing application which does not require specific apps for laptops and allows easy access via laptop and tablet. Participants sat in front of their personal computers or tablets in a quiet room and listened to the researcher’s instructions. All data collection was made through Google Meet. Data storage of video recording was kept in University of Sheffield’s Google Drive. To control for sequencing effects, a counterbalanced latin square design was employed.

There were four tests administered in M-EF, with a total of 10 subtasks altogether. Each of the tasks measured different domains of EF. For the development of the M-EF, Diamond’s EF model (2013) was selected as the core conceptual structure for the battery design, and selection of tasks that measure WM, inhibition, and cognitive flexibility. A schematic summary is described in the *Section 6.2.4* below as a framework for the data analysis approach that was applied. *Table 6(i)*provides a brief description of each of the M-EF tasks and its corresponding measures of EF.

**6.2.4 Data analysis framework and procedure**

There were four tests in the M-EF battery, with a total of 10 subtasks altogether. Most of the subtasks measure more than one EF domain. For the purpose of the M-EF development, these EF domains were classified as primary, secondary and tertiary measures, which are based on Diamond’s (2013) theoretical framework and the specific task components. *Table 6(i)* describes each index measure in detail. *Table 6(ii)* illustrates the hypothesised relationships between the underlying cognitive domains (WM, CF, IC) of EF and performance measures on each task.

**Table 6(i):** Explanation of index measure of the M-EF

|  |  |
| --- | --- |
| **Type of relationship** | **Explanation** |
| Primary | Provides a relatively strong underlying cognitive dimension of task performance |
| Secondary | Provides a relatively moderate/partial underlying cognitive dimension of task performance |
| Tertiary | Provides a relatively weak underlying dimension of task performance |

**Table 6(ii):** Listing of M-EF tasks by the measure of EF domains

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Component (verbal/non-verbal modality)** | **WM**  **Domain** | **Cognitive flexibility**  **Domain** | **Inhibitory control Domain** |
| M-HSCT - automatic | Verbal |  |  |  |
| M-HSCT - inhibition | Verbal | Tertiary | Secondary | Primary |
| DS - Forward | Verbal | Primary |  |  |
| DSB - Backward | Verbal | Primary | Secondary | Tertiary |
| SFT - 3 lines | Non-verbal |  | Primary | Secondary |
| SFT - 4 lines | Non-verbal |  | Primary | Secondary |
| VFT - animal | Verbal | Primary | Primary | Secondary |
| VFT - market | Verbal | Primary | Primary | Secondary |
| VFT - [A] | Verbal | Primary | Primary | Secondary |
| VFT - [M] | Verbal | Primary | Primary | Secondary |

*Developed based on Diamond EF model (2013)*

Participants’ performance across all 10 sub-tasks in the M-EF was evaluated. Additionally, paired sample t-tests were used to evaluate subtask effects in performance within each of the four M-EF tasks. The associations between task performance and underlying EF domains were evaluated with Pearson’s correlations. This was conducted in two steps, first the within-task followed by the between-task analysis. The within-task analysis was conducted for each subtask (i.e. M-HSCT, VFT semantic, VFT letter and Digit Span) to investigate the correlation between task performance across the M-EF battery.

Furthermore, between-task analysis was conducted to examine the degree of association/disassociation between the tasks. The framework for evaluating the correlations between tasks is based on Table 1(ii). Where correlations are high between tasks, it is postulated that the task combination measures the same domain of EF. However, lower/zero correlation between tasks indicates the tasks do not measure the same underpinning EF domain(s).

Based on Table 1(ii), three hypotheses were postulated. Firstly, it was hypothesised that high correlation between DS and VFT will indicate a common underlying shared EF domain, WM.  Secondly, it was hypothesised that high correlation between SFT and VFT will indicate a common underlying shared EF domain, cognitive flexibility. Thirdly, it was hypothesised that high correlation between M-HSCT, VFT and SFT will indicate a common underlying shared EF domain of inhibition. It is important to note that for the third hypothesis, the correlation between M-HSCT and the other two tasks: VFT and SFT is not expected to be high because the two fluency tasks are hypothesised to provide only moderate measures of inhibitory control. All statistical analysis was performed on Statistical Package for Social Science (SPSS) version 26.

**6.3 Results**

**6.3.1 Demographic characteristics**

All participants were bilingual Malay-English speakers. A total of 51 healthy younger adults completed the study. The demographic characteristics of the sample were shown in **Table 6(iii)** below.

**Table 6(iii):** Participants demographic characteristics (n=51)

|  |  |
| --- | --- |
| **Baseline characteristics** | **Frequency (Percentage)** |
| **Gender**  Female  Male | 27 (52.9%)  24 (47.1%) |
| **Highest educational level**  Diploma  Bachelor’s Degree  Masters  PhD | 2 (3.9%)  32 (62.7%)  16 (31.4%)  1 (2.0%) |
| **Number of years in the UK (in years)**  1 year  2 years  3 years  4 years  5 years | 15 (29.4%)  23 (45.1%)  11 (21,6%)  1 (2.0%)  1 (2.0%) |
| **Self-reported Malay language fluency**    Spoken Malay fluency  Quite fluent  Very fluent     Understanding Malay language  Quite fluent  Very fluent | 6 (11.8%)  45 (88.2%)  6 (11.8%)  45 (88.2%) |
| **Baseline characteristics** | **Central tendency** |
| **Age**  Mean±SD  Median (min, max) | 24.25±1.917  24.00 (21,29) |
| **Number of years in the UK (in years)**  Mean±SD  Median | 2.02±.883  2 (1,5) |

**6.3.2 M-EF Performance Score**

Overall, all 51 participants did not show any difficulties in performing the tasks remotely. **Table 6(iv)** provides the summary statistics of participants' performance across all M-EF tests.

**Table 6(iv):** Summary statistics of performance scores across all M-EF tasks (n=51)

|  |  |  |
| --- | --- | --- |
| **M-EF tasks** | **Mean±SD** | **Median (min,max)** |
| **DS - Forward**  Number of correct items  Span score | 9.43±.900  5.96±5.28 | 9.00 (8,11)  6.00 (5,7) |
| **DS Backward**  Number of correct items  Span score | 6.47±.784  4.47±.578 | 6.00 (4,8)  4.00 (3,6) |
| **SFT - 3 lines** | 5.29±.986 | 5.00 (3,7) |
| **SFT - 4 lines** | 4.65±.868 | 5.00 (3,7) |
| **VFT - animal** | 20.39±2.765 | 20.00 (14,29) |
| **VFT - supermarket** | 20.43±2.500 | 21.00 (14,27) |
| **VFT - [A]** | 11.10±1.868 | 11.00 (8,16) |
| **VFT - [M]** | 9.86±1.844 | 9.00 (7,15) |
| **HSCT - automatic**  Number of correct items  Total time latency (TL) - *includes correct and error responses* | 14.63±.528  8.93±.243 | 15.00 (13,15)  8.86 (8.50, 9.41) |
| **HSCT - inhibition**  Number of correct items  Total time latency (TL) - *includes correct and error responses* | 14.75±.493  45.48±2.92 | 15.00 (14,15)  45.58 (38.15, 50.41) |

For DS tasks, two scores were obtained on each task condition: (a) total number of responses produced, excluding errors and (b) span scores. The number of correct items produced was significantly higher in forward than backward condition (t=19.645, df=50, p< .001). Moreover, participants showed higher span scores in the forward compared to backward condition (t=15.128, df=50, p<.001). These scores revealed a consistent pattern that participant performed significantly better when asked to repeat items in the forward order.

For the VFT, the total number of correct words, excluding errors and repetitions on each task condition was obtained. The overall performance comparison revealed participants performed significantly better in the semantic tasks (animal and supermarket items) compared to letter tasks (A and M) (t=30.08, df=50, p<.001). Further examination within each VFT condition, showed there was no significant difference in performance in the semantic tasks (t=-.105, df=50, p=.917). However, there was a significant difference in performance found within the letter tasks (t=3.76, df=50, p< .001), where the total number of correct responses produced for letter [A] were significantly higher compared to letter [M].

For scoring M-HSCT performance, five scores were obtained in automatic and inhibition conditions: (a) total number of correct items, (b) total latency and (c) average latency scores for all responses, including correct and error (d) average latency for correct responses and (e) average latency for error responses. Firstly, there was no significant difference in the number of correct responses produced between the automatic and inhibition conditions (t=-.814, df=50, p =.420). The total latency score analysis yielded a significant difference between the total latencies in automatic and inhibition conditions (t=-90.38, df=50, p<.001), where participants showed a significantly faster response time in the automatic compared to inhibition condition.

**Table 6(iv)** below provides the average latency scores for both conditions. For correct responses, the latencies were divided by the number of correct responses produced by each participant; for error responses, the latencies were divided by the number of errors produced by each participant. For average correct latencies, there was a significant difference between the automatic and inhibition condition (t=-89.995, df=50, p<.001), where participants demonstrated slower average response times in the inhibition condition compared to automatic.

**Table 6(iv):** Average time latencies for M-HSCT automatic and inhibition conditions

|  |  |  |
| --- | --- | --- |
|  | **Mean latency ±SD** | **Median latency (min,max)** |
| **M-HSCT Automatic condition**  Average all responses (n=51)  Average correct (n=51)  Average error (n=18) | 0.62±0.12  0.58±0.162  0.90±0.073 | 0.59 (0.5, 1.12)  0.58 (0.5, 0.82)  0.89 (0.82, 1.12) |
| **M-HSCT Inhibition condition**  Average all responses (n=51)  Average correct (n=51)  Average error (n=13) | 3.03±0.195  3.09±0.200  1.16±0.990 | 3.04 (2.54, 3.36)  3.10 (2.54, 3.46)  0.78 (0.51, 3.49) |

In terms of error responses, not all participants made errors. In both conditions, each participant with an error made only one error, except one participant in the automatic condition who made 2 errors. For the average error latency scores in **Table 6(iv)**, the mean latency score was higher in the inhibition compared to the automatic condition. In the automatic condition, the error latency scores were between 0.82 and 1.12 seconds, whereas in the inhibition condition most errors were between 0.51 to 0.60, with exception of two errors made at 3.21 and 3.49s. Generally, the time taken for making error responses in the inhibition condition were more rapid compared to the automatic condition.

Based on the small sample size and features of the error latency distributions, (in the automatic condition the data appeared more normally distributed whereas in the inhibition condition it was flat distribution with 2 outliers), a non-parametric Mann-Whitney test was applied. The Mann-Whitney test indicated that the average error latency in the automatic condition was not significantly higher than in the inhibition condition (U=79.50, z=-1.505, p=.132).

For the SFTs, there was a significant difference in performance between the two tasks (t=4.231; df=50; p=<.001), where the performance in 3 lines condition was better compared to 4 lines, despite the score range of accurate drawings being the same across both conditions. This difference can be accounted for by the distribution of the scores between both conditions, where the distribution of total scores for SFT 3 lines were clustered between 5 and 6 and SFT 4 lines between 4 and 5.

**6.3.3 Underlying cognitive domains for the M-EF tasks**

Based on the hypotheses postulated in Table 1(ii), the present study aims to investigate the relationships between the three EF domains in all four M-EF tasks.  This section of the analysis will specifically examine the extent to which they shared common underlying cognitive domains, in a sample of 51 healthy younger adults.

For this purpose, a two-pronged approach was employed. In **Section 6.3.3.1** we investigated the correlations within the M-EF tasks (e.g., DS forward and DS backward) using Pearson correlations. In **Section 6.3.3.2**, we examined the correlations between tasks in the M-EF test battery as postulated in Table 1(ii).

**6.3.3.1 Correlations within tasks**

**(i) Digit span forward and backward**

For DS tasks, there was a strong correlation between the total score and span score within both DSF and DSB, respectively in **Table 6(v)**. However, between DSF and DSB there were lower correlations for total score and span scores, suggesting weaker relationships between conditions.

**Table 6(v):** Correlations between DS tasks

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measures** | **1** | **2** | **3** | **4** |
| 1. **DSF - total score** | **—-** |  |  |  |
| 1. **DSF - span** | .879\*\* | **—-** |  |  |
| 1. **DSB - total score** | .188 | .191 | **—-** |  |
| 1. **DSB - span** | .179 | .193 | .870\*\* | **—-** |

\**p* < .05

 \*\**p* < .01

**(ii) Verbal fluency test (VFT) semantic and letter**

For VFT, there was a significant positive correlation between the two semantic tasks *Table 6(vi)*, indicating that participants who performed well in VFT animal also performed well in VFT market items. However, there was no significant correlation between the two letter tasks. Additionally, there was no other significant correlation found between the semantic and letter tasks, suggesting that performance in one task condition (e.g., market items) was not associated with performance in the other condition (e.g., letter [M]) *(see Table 6(vi) below).*

**Table 6(vi):** Correlations between VFT tasks

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measures** | **1** | **2** | **3** | **4** |
| 1. **VFT animal** | **—** |  |  |  |
| 1. **VFT market** | .487\*\* | **—** |  |  |
| 1. **VFT - [A]** | .140 | .235 | **—** |  |
| 1. **VFT - [M]** | .160 | .152 | .201 | **—** |

\**p* < .05

 \*\**p* < .01

**(iii) M-HSCT automatic and inhibition**

For M-HSCT, firstly the correlations for the two measures (total correct, total latency) obtained within both task conditions were calculated. In the automatic condition, there was a significant negative correlation between the total scores and total latency *(see* ***Table 6(vii)*** *below)*, suggesting that participants who produced more correct responses tended to initiate the responses more quickly. In the inhibition condition, there was no significant correlation found between the total correct responses produced and total latency.

**Table 6(vii):** Correlations between total correct scores and latency scores in M-HSCT tasks

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measures** | **1** | **2** | **3** | **4** |
| 1. **M-HSCT Auto**   Total correct scores (n=51) | **—** |  |  |  |
| 1. **M-HSCT Auto**   Total latency scores, includes error (n=51**)** | -.571\*\* | **—** |  |  |
| 1. **M-HSCT Inhib**   Total correct scores (n=51) | -.073 | .109 | **—** |  |
| 1. **M-HSCT Inhib**   Total latency scores, includes error (n=51) | -.056 | .207 | .217 | **—** |

\**p* < .05

 \*\**p* < .01

Additional correlation analysis between the two conditions was conducted for the two total correct and two total latency measures(**Table 6(vii)**).  There was no significant correlation found for the total number of accurate responses between  the two conditions: automatic and inhibition. Similarly, there was no significant correlation for the total time latency, including correct and error responses (n=51) between the two conditions, indicating that the time taken to complete the sentences in one condition are not associated with the time latency in the other.

For both conditions, correlations among the average correct and error latencies were also analysed. It is important to note that for error latencies, there was a limited sample size due to so few participants making errors in both conditions *(see* ***Table 6(viii)****).* As a result, this limits the interpretation obtained from the correlation analysis. For example, not all participants made errors in both conditions, hence the correlation analysis in Table 8 only included participants who made error responses. For the automatic condition, there was no significant correlation found between the average correct and error latency scores. However, in the inhibition condition, there was a significant positive correlation between the average time latency for correct and error responses (r=.569). This implies that participants who demonstrated longer average latency for correct responses tended to have longer average latency for error responses. Between the two conditions, there was no significant correlation found for correct or error response latencies *(see* ***Table 6(viii)****).*

**Table 6(viii):** Correlations between average correct and error latency scores in M-HSCT tasks. The sample sizes listed under each correlation column correspond to the number of participants who made error responses, which was included in the analysis.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measures** | **1** | **2** | **3** | **4** |
| 1. **M-HSCT Auto**   Average correct latency (n=51) | **—** |  |  |  |
| 1. **M-HSCT Auto**   Average error latency (n=18) | -.071 (n=18) | **—** |  |  |
| 1. **M-HSCT Inhib**   Average correct latency (n=51) | .154 (n=51) | .087 (n=18) | **—** |  |
| 1. **M-HSCT Inhib**   Average error latency (n=13) | -.116  (n=13) | .271  (n=13) | .569\*\*  (n=13) | **—** |

\**p* < .05

 \*\**p* < .01

**(iv) Spatial Fluency Test (3 and 4 lines)**

For SFT, there was a moderate but non-significant positive correlation between the performance in both tasks (3 lines and 4 lines) *(****Table 6(ix)****)*.

**Table 6(ix):** Correlations between SFT 3 lines and 4 lines

|  |  |
| --- | --- |
| 1. **SFT - 3 lines** | .311 |
| 1. **SFT - 4 lines** |

\**p* < .05

\*\**p* < .01

**6.3.3.2 Correlation between tasks**

To test the three hypotheses postulated in *Table 1(ii)*, three sets of correlation tests were conducted. The associations among tasks in M-EF were investigated using Pearson’s correlation to investigate the underlying EF domains: (i) WM, (ii) cognitive flexibility and (iii) inhibition.

**(i) Working memory**

To investigate the common underlying domain of WM between-tasks, the correlations between VFT and DS were conducted *(see* ***Table 6(x)****)* based on: (a) number of correct responses in VFT, (b) number of correct responses in DS and (c) total span score in DS. A moderate negative correlation was found between VFT animal category and DS forward condition, implying that as performance in one task increases, there was a corresponding decrease in performance in the other task. However, no other significant between-task correlations were found.

**Table 6(x):** Correlations between digit span and VFT. The blue squares represent the correlations between-tasks.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Measures** | **1.** | **2.** | **3.** | **4.** | **5.** | **6.** | **7.** | **8.** |
| 1. **VFT animal** | **—** |  |  |  |  |  |  |  |
| 1. **VFT market** | .487\*\* | **—** |  |  |  |  |  |  |
| 1. **VFT - [A]** | .140 | .235 | **—** |  |  |  |  |  |
| 1. **VFT - [M]** | .160 | .152 | .201 | **—** |  |  |  |  |
| 1. **DSF - correct** | -.383\*\* | -.155 | -.240 | .000 | **—** |  |  |  |
| 1. **DSF - span** | -.291 | -.048 | -.158 | .035 | .879\*\* | **—** |  |  |
| 1. **DSB - correct** | .005 | -.177 | -.141 | .004 | .188 | .191 | **—** |  |
| 1. **DSB - span** | .007 | -.116 | .049 | .137 | .179 | .193 | .870\*\* | **—** |

\**p* < .05

 \*\**p* < .01

**(ii) Cognitive flexibility**

To investigate the underlying EF domain of cognitive flexibility, the correlations analysis were conducted between VFT and SFT based on the total number of correct responses. There was no significant correlation observed between the spatial and verbal fluency tasks, as postulated in Section 6.2.4.This observationis consistent with the hypothesis that there may not be a significant correlation between tasks of different modality (i.e., verbal and non-verbal EF tasks).

**Table 6(xi):** Correlation between SFT and VFT. The blue squares represent the correlations between-tasks.

| **Measures** | **1.** | **2.** | **3.** | **4.** | **5.** | **6.** |
| --- | --- | --- | --- | --- | --- | --- |
| 1. **VFT animal** | **—** |  |  |  |  |  |
| 1. **VFT market** | .487\*\* | **—** |  |  |  |  |
| 1. **VFT - [A]** | .140 | .235 | **—** |  |  |  |
| 1. **VFT - [M]** | .160 | .152 | .201 | **—** |  |  |
| 1. **SFT - 3 lines** | .060 | -0.69 | -.211 | -.219 | **—** |  |
| 1. **SFT - 4 lines** | .201 | .090 | -.052 | -.168 | .311\* | **—** |

\**p* < .05

 \*\**p* < .01

**(iii) Inhibition**

To investigate the underlying domain of inhibition, three tasks were chosen: VFT, SFT and M-HSCT inhibition. For VFT and SFT the total number of accurate responses were obtained. For M-HSCT inhibition two scores were used: (a) total latency, including correct and error responses and (b) average correct latency (n=51). A significant negative correlation was observed between the number of responses in SFT 4 lines and the average correct latencies in M-HSCT inhibition, suggesting that participants who produced more responses in the SFT 4 lines tended to have shorter average correct latencies in the M-HSCT inhibition condition. However, no other significant between-task correlations were found *(****Table 6(xii)****).* This result was expected as almost all tasks were considered to have inhibition as a secondary or tertiary underlying cognitive domain except for M-HSCT inhibition.

**Table 6(xii):** Correlation between M-HSCT inhibition, SFT and VFT. The blue squares represent the correlations between-tasks.

A screenshot of a table

Description automatically generated

\**p* < .05

 \*\**p* < .01

**6.4 Discussion**

The aim of this chapter was to provide a comprehensive analysis of data from a newly developed M-EF test battery, which was administered remotely.

For this purpose, the performance data of 51 healthy younger adults were analysed. Overall, results from this study demonstrated that healthy younger participants were able to cope with the task demands of the novel M-EF test battery. Additionally, the results demonstrate the possible use of M-EF in remote settings.

**6.4.1 Individual task performance and correlation within-tasks**

The overall pattern of performance across several M-EF tasks (i.e., DS, VFT and M-HSCT) showed similarities with performances across other healthy adult populations. In within-task correlation, some correlations were found between the three M-EF tasks, DS, VFT and M-HSCT), however no correlations were observed in SFT. For correlations between the M-EF tasks, sporadic task performance associated with the underlying cognitive domain of WM and inhibition were observed, however no correlations were found between the M-EF tasks postulated to provide underlying cognitive indicators of cognitive flexibility. These findings are summarised for each of the four M-EF tasks below.

**Digit Span (DS)**

For digit span, better performance in forward span compared to backward was found. This result is similar to performances in healthy adults across other cultural and linguistic populations: Italian speakers (Monaco et al., 2015), Chinese speakers (Hedden et al., 2002; Chen et al., 2009) and Sinhala speakers (Dassanayake et al., 2021).

Comparison between healthy adults’ performance in this study with previously published data from Chinese and English speakers are presented in ***Table 6(xiii)***. It is important to note that the participants' age ranges for Mandarin and English speakers were larger than the Malay speakers *(see* ***Table 6(xiii)*** *for details)*. Cross-linguistic differences were significant, with Malay speakers showing a shorter span. The overall language group differences (Malay, English and Chinese) were consistent with previous studies comparing digit-word length and verbal WM ability (Chen et al., 2009; Baddeley et al., 2023) using DS tasks.

**Table 6(xiii):** Mean span score comparison with Mandarin and English speakers

|  |  |  |  |
| --- | --- | --- | --- |
|  | Malay-English bilinguals (n=51) | Mandarin speakers (n=30) | English speakers  (n=30) |
| Age | 21-29 | 21-48 | 20-48 |
| DSF: Mean span score | 5.96 | 9.3 | 7.1 |
| DSB: Mean span score | 4.47 | 6.5 | 6.0 |

In Table 6(xiii), the cross-linguistic differences are apparent, with Malay speakers showing a shorter span in comparison with Mandarin and English speakers. Mandarin speakers showed the highest span scores followed by English speakers. The cross-linguistic performance difference supports the word length effect that single syllable words were linked to faster speech production and better immediate recall than multi-syllable words (Suprenant et al., 2011).

Previous studies have found that digit span is substantially greater for Chinese speakers than other languages (Chen et al., 2009; Chan et al., 2011; Baddeley et al., 2023) which partly lies in the fact that digits in Mandarin are single syllabic. In Malay, digits 1-8 are all disyllabic and 9 is trisyllabic, whereas in Mandarin digits 1-9 are all monosyllabic. In English, all digits are monosyllabic except, 7 which is a two-syllable word.  Thus, the current findings support the hypothesis that features of spoken digits (i.e., number of syllables and syllable duration) contribute to cross-language effects in DS tasks (Tolan & Tehan, 2005). It is important to note that several studies have reported the influence of bilingualism on EF task performance: WM (Ratiu & Azuma, 2015), inhibition (Bialystok et al., 2006; Bialystok & Viswanathan, 2009)and cognitive flexibility (Prior & Gollan, 2011). The extent of ‘bilingual advantage’ in executive functioning tasks will be briefly discussed in Chapter 8.

Furthermore, previous findings confirmed the assumption that there exist differences between cognitive demand between the two-digit span tasks, forward and backward. The nature of DS backward, requiring holding and reordering of information, places more demand on the working memory abilities (Alloway et al., 2006). This is evidenced in numerous studies reporting poorer performance in DS backward in both clinical (Curtiss et al., 2001) and non-clinical samples (Ostrosky‐Solís & Lozano, 2007; Hesterm Kinsella & Ong, 2004). One explanation for the differential in performance in forward and backward task is the argument that forward span relies on automatic processing of the phonological store in WM, akin to immediate serial maintenance and recall without item reorganisation, resulting in minimal demand on the executive functioning. Conversely, backward span necessitates the transformation and manipulation of information alongside storage, making additional demand on the central executive. Furthermore, Baddeley (1996) proposed as the digit load increased, demands on the executive function would also increase, emphasising the interplay between the phonological store and executive functioning in determining maximal verbal memory span.

For DSF and DSB, the correlations within-task (i.e., total number of correct responses and span scores) were high. However, no significant correlation was found between the two conditions: forward and backward. This finding supports previous suggestions that forward and backward recall are different (Alloway et al., 2006; St Clair-Thompson & Allen, 2013). There are several approaches taken to account for the difference in performance between forward and backward recall tasks. One view is that DS forward employs short-term phonological storage whereas DS backward demands attention-demanding transformation of the digit sequence, hence classifying this task as a complex measure of WM (St Clair-Thompson & Allen, 2013).

**Verbal fluency test (VFT)**

The performance difference between the semantic and letter tasks were significant with better performance in the two semantic tasks compared to the letter condition. This finding is consistent with previous literature that on average, a healthy adult can produce, within 1 min, about 16 words corresponding to a semantic category, 4 more items than words beginning with a specific letter (Spreen & Strauss, 1998).  One possible explanation for the task performance differences is that letter fluency was constructed as a more demanding analogue of semantic fluency task due to the demand for orthographic searching of words rather than categorical (Bryan et al., 1997). A similar pattern of performance was observed across different languages in healthy adult samples: Thailand (Muangpaisan et al., 2010); Persian (Ghasemian-Shirvan et al., 2018) and Dutch (Van Der Elst et al., 2006).

Between the two semantic tasks, the mean score for supermarket (20.43) category was equivalent to animal (20.39). These data are consistent with previously published scores for healthy English-speaking adults for the same categories: 19.5 for animals and 22.9 for supermarket items (see Troyer, 2000).

For letter tasks, performance for letter [A] was significantly better than letter [M]. It is important to note that there are numerous published norms on letter [A], commonly with combinations in F, A, S. However, there are limited studies using letter [M] (Garcia et al., 2012; Shao et al., 2014; Rivera et al., 2021). Thus, to explore the difference between the data from the letter tasks in this study with other published norms, the mean scores for letter [A] and [M] were considered separately. Due to the limited number of published norms on performance on individual letter tasks, a recent study on Spanish bilinguals (Olabarrieta-Landa et al., 2019) was used for the purpose of the normative data comparison. For letters [A] and [M], the mean score of the current study’s participants was compared with Spanish bilinguals *(see* ***Table 6(xiv)****).* The mean score for both letters [A] and [M] in the current study’s Malay speakers were lower compared to the mean score obtained in healthy bilingual adult groups, Spanish-Basque and Spanish Catalan (Olabarrieta-Landa et al., 2019).

**Table 6(xiv):** Mean score and standard deviation comparison for letter [A] and [M] with Spanish bilinguals

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Malay-English bilinguals | Spanish-Basque | | Spanish-Catalan | |
| Medium of task language (time to complete task) | Malay (1min) | Spanish  (1min) | Basque  (1min) | Spanish  (1min) | Catalan  (1min) |
| Mean score for letter [A]±SD | 11.10 ±1.87 | 12.11±4.53 | 11.42±4.60 | 12.52 ±4.45 | 10.15±3.80 |
| Mean score for letter [M]±SD | 9.86±1.84 | 14.67±4.69 | 10.53±4.03 | 13.70±4.19 | 12.28±4.09 |

*VFT Spanish bilingual performance data from Olabarrieta-Landa et al., 2019*

Differences in VFT letter performance may be accounted for by the frequency of words starting with the letter in the language (Luo et al., 2010). In Malay dictionaries, there are more entries for words beginning with letter [A] compared to letter [M]. Additionally, the possible differences in performance in this sample may be due to letter [M] being the common first letter for prefix in Malay (e.g., me-, men-, meng- and mem-), which are considered as error responses for the letter fluency task, as only words in its root form are considered as correct for this task. In Malay the prefix me- is typically added to stems beginning with letters ‘l, m, n, ng, ny, r, w or y’ (Tan, 2003). For example, me- + nanti (wait)= ‘menanti’ (to wait), which in this case will not be considered as a correct response for the letter task.

The correlation between the two semantic tasks (animal and supermarket items) was significant and moderately high. Similar findings have been found using different semantic categories (e.g., animals and foods) (Ardila et al., 1994; Delis et al., 2001). The correlation among the two letter tasks [A] and [M] were low, which are not sufficient to establish equivalency among the letter tasks. This may be the result of the particular combination of letter tasks [A] and [M] selected for the M-EF test battery and/or language-specific factors (e.g., vocabulary size for each letter).  Previous studies with English samples often used either combinations of letters [F, A, S] or [C, F, L], which has been reported having high correlations (Troyer, 2000; Strauss et al., 2006). Also, it is important to note that versions of VFT often includes three letter tasks [F, A, S] (Anderson et al., 2001; Olabarrieta-Landa et al., 2015) and [C, F, L] (Schum, Sivan & Benton, 1989; Barr, 2003) compared to only two letter tasks as employed in the M-EF test battery.

**M-HSCT**

Performance in M-HSCT was measured by obtaining two types of scores: number of correct responses and latency scores. The number of correct responses were nearly the same in both automatic and inhibition conditions, mean score 14.63 and 14.75 respectively.

The most significant observation was in the latency scores for both correct and error responses. The average latency for correct responses was faster in the automatic condition compared to the inhibition. This pattern indicated that participants were producing correct responses at a significantly quicker rate in the automatic compared to the inhibition condition. This differential in latency scores between the two conditions further supports findings from previous studies in healthy (Burgess & Shallice, 1997; Belleville et al., 2006; Pérez-Pérez et al., 2016) and atypical populations (Burgess & Shallice, 1996).

A closer look at this pattern aligns with the notion of inhibitory control, where suppression of prepotent responses led to slower response time (Burgess & Shallice, 1996). **Table 6(xv)** below shows the total latency scores, including correct and error responses compared with previous studies with Spanish (Pérez-Pérez et al., 2016) and French speakers (Andrés et al., 2000).

**Table 6(xv):** Mean and standard deviation comparison from healthy young samples for total latency score, including correct and error scores

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Malay-English bilinguals | | Native Spanish speakers (Pérez-Pérez et al., 2016) | | Native French speakers (Andrés et al., 2000) | |
|  | Auto | Inhib | Auto | Inhib | Auto | Inhib |
| Age | 21-29 (n=51) | | 18-99 (n=185) | | 20-30 (n=47) | |
| Mean total latency, including error responses±s.d | 8.93±.243 | 45.48±2.92 | 8.54±.391 | 38.45±2.80 | 10.37±.370 | 39.03±.196 |

*Normative data from Pérez-Pérez et al., 2016 and Andrés et al., 2000*

Based on comparison in **Table 6(xv)**, the present findings confirmed and extended the results reported in previous studies on the effect of inhibition control demonstrated in the inhibition task of HSCT. In the inhibition condition, where correct responses required participants to inhibit the dominant response and finding a semantically incongruent word to complete the task, participants were observed to spend significantly more time to complete the task. Furthermore, in both conditions, the errors made were infrequent, which corresponded to findings from previous adapted HSCT studies: French (Bayard et al., 2017) and Spanish (Pérez-Pérez et al., 2016). In the previous studies, due to low error scores from healthy participants, no further analysis was performed on the raw score which was also the case in previous studies (Bayard et al., 2017).  However, for M-EF, separate correct and error score analyses were conducted for M-HSCT task conditions to ensure robustness of the performance data gathered.

The findings of this study found no other significant correlation between other variables in the M-HSCT, this finding corroborates Burgess and Shallice (1997) report that internal correlations were variable in HSCT performance from healthy adult samples, but are more significant in patients with anterior lesions. This warrants for future research using the M-HSCT developed with atypical populations.

**Spatial Fluency Test (SFT)**

SFT was developed for the online M-EF in place of the more traditional block tapping or Corsi block task (Lezak, 1995). It was the only non-verbal task used, designed as an analogue of the verbal fluency task, and involved drawing as many novel shapes or patterns as possible in one minute. Participants produced more correct drawings in the first task (3 lines) compared to the second condition (4 lines). Due to the novel adaptation of SFT, there was a limited reference to comparable tests.

Hence, for comparing performance scores in healthy samples, Ruff Figural Fluency Test (RFFT) which is scored based on the number of correct drawings generated (Ruff, 1987; 1994) was selected. RFFT was chosen for comparison with SFT due to the shared task components and scoring method. **Table 6(xvi)** below outlines the number of correct responses across both studies.

**Table 6(xvi):** Mean and standard deviation comparison for total correct scores in SFT and RFFT

|  |  |  |  |
| --- | --- | --- | --- |
|  | Malay-English bilinguals | | English monolingual young adults  (Hanks et al., 1996) |
|  | 3 lines  (1 min) | 4 lines  (1 min) | Performance across all five pages (5 mins) |
| Age | 21-29 (n=51) | | 16-34 (n=100) |
| Total correct score  Mean±s.d | 5.29±.986 | 4.65±.868 | 27.00±14.02 |

*Note that the scores include performance in all 5 sections of RFFT (Hanks et al., 1996)*

It is important to note that the performance data from Hanks et al., (1996) included the total correct scores across all five pages of RFFT which takes a total of 5 minutes to complete. However, the SFT only consists of two tasks which take 1 minute each to complete. The average mean drawing per minute for RFFT in Hanks et al., (1996) was 5.4 (total mean correct score/5 min). The number of correct scores across both SFT and RFFT per minute were relatively similar in both samples.

The correlation analysis between the 3 and 4 lines using the number of correct responses found a moderate but non-significant correlation. Only one participant made a repetition error in achieving the total correct drawings, so no error analysis was conducted across the two conditions.

**6.4.2 Correlation between-tasks**

This is, to my knowledge, the first EF assessment in the Malay language that examined the underlying cognitive domains of EF from combinations of task performance. Three underlying EF domains were examined: WM, cognitive flexibility, and inhibition. Task performance associated with the underlying domains of WM and inhibition were observed; however, no associations were found between tasks postulated to share the underlying domain of cognitive flexibility. **Table 6(xvii)** below summarises the correlations found between M-EF tasks postulated to provide an underlying measure of the respective EF domains.

**Table 6(xvii):** Summary of between-tasks correlation observed

|  |  |  |  |
| --- | --- | --- | --- |
| **WM** | | **Inhibition** | |
| VFT animal  (Total correct score) | DS forward  (Span score) | SFT 4 lines  (Total correct score) | M-HSCT inhibition  (Average correct latencies) |

For WM, significant negative correlation between task performance emerged for VFT animal total score and DS forward span score (r=-.383). However, there was no corresponding correlation found between the other tasks postulated for the underlying measure of WM. These results contradict findings from previous studies that found a positive correlation between performance in VFT semantic and digit span in younger adults (Stolwyk et al., 2015), where high performance in digit span significantly predicts better performance in the VFT semantic. For inhibition, negative correlations were observed in SFT 4 lines and M-HSCT inhibition, reflecting that participants who produced more responses in the SFT 4 lines tended to have shorter average correct latencies in the M-HSCT inhibition condition. The correlation analysis indicated the existence of two EF constructs in the M-EF battery that were shared across tasks (WM and inhibition).

Based on Diamond’s EF model, an evidence-based selection of the verbal tasks in M-EF was conducted for: (i) DS for underlying domain of WM, (ii) M-HSCT for underlying domain of inhibition and (iii) VFT for underlying domain of cognitive flexibility, which also include its non-verbal counterpart, SFT.  The between-task correlations shed light on the cross-task relationships as hypothesised in relation to possible shared underlying domains.

Overall, the correlations between different M-EF tasks were weak demonstrating the independence of the tasks. The low correlations between EF tasks performance suggests that the three often postulated EF domains, WM, cognitive flexibility, and inhibition are separable and thus supports previous notion of non-unitary nature of EF (Miyake et al., 2000). Although, in Diamond’s EF model (2013) there was no explicit mention of the fractionated EF system, the three EF domains were discussed separately. Based on this, it can be implied that Diamond’s EF model views the three EF domains as separate domains.

The results of this study have significant implications on the assessment of EF in Malay speakers. Firstly, this study offered the opportunity to develop extensive baseline performance for healthy Malay speakers on a range of M-EF tasks. Secondly, results from this study extend the understanding of the underlying measure of EF domains across the M-EF battery to inform future test administration and scoring procedures.

The following Chapter 7 will explore the performance of healthy older adults in the M-EF battery as part of Study 2. Findings from Study 2 will be compared in the General Discussion of Chapter 8.

**Chapter 7:** **M-EF Assessment: Normative Data from Malay Speaking Healthy Older Adults**

**7.1 Introduction**

This Chapter reports results from healthy older adults in the M-EF battery. The delivery and procedures of assessment is similar to the delivery with the younger group. The findings in this chapter contribute to the normative data for older adults’ populations in the M-EF battery. Additionally, the findings aimed to expand the understanding of EF changes associated with normal ageing (Albert & Kaplan, 1980; Whelihan & Lesler, 1985; Libon et al., 1994; Delayole et al., 2009; Kirova et al., 2015) and to explore whether the age-related decrease is present in the older Malay speaking adults using the novel, M-EF battery.

To achieve this, the EF performance of twenty Malay speaking older adults was evaluated. Analyses of performance and correlations within- and between-tasks were performed to explore the following:

* to examine healthy older Malay speakers’ performance on different domains of EF using the newly developed M-EF test battery.
* to investigate the pattern of correlations in within-task performance for each individual task in the M-EF battery
* to examine the extent to which cross-task correlations reflect common underlying EF domains of WM, cognitive flexibility and inhibition.
* to investigate patterns of performance across EF tasks in Malay speaking older adults with other published norms.
* to investigate whether the effects of ageing affect EF performance in the M-EF battery

**7.2 Method**

**7.2.1 Participants**

A total of 20 healthy participants aged between 50-65 were recruited. Older adult participants were recruited through word-of-mouth, community events and local network referrals. All participants self-reported their language ability by completing the language questionnaire (**Appendix F**). Additionally, participants completed a health questionnaire before participating in the assessment (**Appendix F**).

**7.2.2 Ethics and consent**

The study received ethical approval from the University Research Ethics Committee of the Division of Human Communication and Sciences, Health Sciences School at the University of Sheffield (ethics application no: 039324). Participation in this study was voluntary.

All participants received an information sheet that explained the aims and procedure of the study and the exclusion criteria. Participants who agree to take part in the study completed an online consent form and chose a suitable date and time for the assessment. Following an agreed time and date, a copy of the answer sheet for the spatial fluency task was sent to the participants either via email for printing or via hard copy. A Google Meet link was sent to all participants. During the Google Meet session, participants were asked again for their verbal consent to continue with the study (see **Appendix E**).

**7.2.3 Assessment procedure**

All assessment procedures were similar with the younger group *(see Chapter 6 for details of assessment procedure)*. The same M-EF battery consisted of four EF tasks (M-HSCT, VFT, SFT and DS) were administered. All participants were tested remotely using Google Meet, a video conferencing application which does not require specific apps for devices and allows easy access via laptop, tablet, mobile phone. Participants sat in front of their personal computers or tablets in a quiet room and listened to the researcher’s instructions. All data collection was made through Google Meet. All video recordings were stored in University of Sheffield’s Google Drive. To control for sequencing effect, a counterbalanced Latin square design was employed.

**7.2.4 Data analysis**

The data analysis approach used was similar to the analysis used with the younger group *(see details in Chapter 6)*. For all tasks, overall participants’ performance across the 10 sub-tasks in the M-EF battery was evaluated. Additionally, paired sample t-tests were used to evaluate subtask effects in performance within each of the four M-EF tasks. The associations between task performance and underlying EF domains were evaluated with Pearson’s correlations. This was conducted in two steps, first the within-task followed by the between-task analysis. The within-task analysis was conducted for each subtask (i.e. M-HSCT, VFT semantic, VFT letter and Digit Span) to investigate the correlation between task performance across the M-EF battery.

Furthermore, between-task analysis was conducted to examine the degree of association/disassociation between the tasks. The framework for evaluating the correlations between tasks is based on Table 1(ii) in Chapter 6. Where correlations are high between tasks, it is postulated that the task combination measures the same domain of EF. However, lower/zero correlation between tasks indicates the tasks do not measure the same underpinning EF domain(s).

**7.3 Results**

**7.3.1 Demographic characteristics**

All twenty participants aged between 50-65 were healthy, bilingual Malay-English speakers. The demographic characteristics of the sample are in **Table 7(i)**. All participants reported no underlying neurological and/or psychological illnesses which may impact performance in the M-EF.  Majority of participants in this sample were living in the UK for more than 20 years.

**Table 7(i):** Participants demographic characteristics (n=20)

|  |  |
| --- | --- |
| **Baseline characteristics** | **Frequency (Percentage)** |
| **Gender**  Female  Male | 13(65%)  7(35%) |
| **Highest educational level**  Highschool  Bachelor’s Degree  Masters  PhD | 2 (10%)  11(55%)  5 (25%)  2 (10%) |
| **Number of years in the UK (in years)**  Between 15-20 years  Between 21-26 years  Between 27-32 years  Between 33-38 years | 3 (15%)  5 (25%)   10 (50%)  2 (10%) |
| **Self-reported Malay language fluency**    Spoken Malay fluency.  Very fluent     Understanding Malay language  Very fluent | 20(100%)  20(100%) |
| **Baseline characteristics** | **Central tendency** |
| **Age**  Mean±S.D  Median (min, max) | 56.80±4.697  57.50 (50,65) |
| **Number of years in the UK (in years)**  Mean±S.D  Median | 26.45±5.42  28.50 (16,33) |

**7.3.2 M-EF Performance Score**

Overall, all twenty participants did not show any difficulties completing the M-EF battery remotely. However, the overall time taken to complete each task was longer compared to healthy younger adults, this is substantiated by comparing the length of recordings from both samples. **Table 7(ii)** provides a summary of the twenty older adults' performance across all four M-EF tasks.

**Table 7(ii):** Summary of performance across M-EF tasks (n=20)

|  |  |  |
| --- | --- | --- |
| **M-EF tasks** | **Mean±SD** | **Median (min,max)** |
| **DS - Forward**  Number of correct items  Span score | 9.30±1.081  5.85±.671 | 9 (8,11)  6 (5,7) |
| **DS Backward**  Number of correct items  Span score | 6.30±.923  4.45±.686 | 6 (4,8)  4 (3,6) |
| **SFT - 3 lines** | 5.65±.813 | 6 (4,7) |
| **SFT - 4 lines** | 5.80±.951 | 6 (4,8) |
| **VFT - animal** | 16.75±2.197 | 16 (13,21) |
| **VFT - supermarket** | 17.35±2.134 | 17 (14,21) |
| **VFT - [A]** | 10.60±2.280 | 10 (7,15) |
| **VFT - [M]** | 9.05±.999 | 9 (7,11) |
| **M-HSCT - automatic**  Number of correct items  Total time latency (TL) - *includes correct and error responses* | 14.25±.716  13.03±1.289 | 14 (13,15)  13.6 (10.37, 14.61) |
| **M-HSCT - inhibition**  Number of correct items  Total time latency (TL) - *includes correct and error responses* | 13.2±1.240  64.22±5.324 | 13 (11,15)  62.58(54.59, 73.78) |

For the DS task, the number of correct responses was significantly higher in the forward condition compared to the backward (t=1.338; df=19; p=<.001). Similarly, there was a significant difference in the span score across both conditions (t=7.628; df=19; p=< .001), where the span score was higher in the forward task compared to backward.

For SFT, there was no significant difference found between performance in 3 lines and 4 lines (t=-.679; df=19; p=.505). However, it is interesting to note that in the older group performance in the more difficult task condition (4 lines) was better than 3 lines.

For VFT, the overall performance revealed participants performed significantly better in the semantic tasks (animal and supermarket items) compared to letter tasks (A and M) (t=19.34, df=19, p=< .001). Within each VFT condition, no significant difference was observed across the semantic tasks (t=-.986; df=19; p=.337), which can be accounted for by the nearly identical number of correct items produced across both semantic tasks*.* However, within the letter tasks, a significant difference was observed (t=3.538; df=19; p=.002) between performance in letter [A] and [M], where participants exhibited better performance in producing words starting with the letter [A] compared to the letter [M].

For scoring M-HSCT performance, five scores were obtained in automatic and inhibition conditions: (a) total number of correct items produced, (b) total latency and (c) average latency scores for all responses, including correct and error, (d) average latency for correct responses, and (e) average latency for error responses. Firstly, a significant difference was observed between the total correct responses produced in the automatic and inhibition conditions (t=2.987; df=19; p=.008). Similarly, when comparing total latency scores, which include both correct and error responses, a significant difference was found between the two conditions (t=-49.38; df=19; p=< .001), where participants demonstrated longer response times in the inhibition condition than in the automatic condition.

**Table 7(iii)** below provides the average latency scores for both conditions. For correct responses, the latencies were divided by the number of correct responses produced by each participant; for error responses, the latencies were divided by the number of errors produced by each participant.

**Table 7(iii):** Average time latencies for M-HSCT automatic and inhibition conditions

|  |  |  |
| --- | --- | --- |
|  | **Mean latency±SD** | **Median latency (min,max)** |
| **M-HSCT Automatic condition**  Average all responses (n=20)  Average correct responses (n=20)  Average error responses (n=12) | .868±.0859  .8484±.086  1.269±.323 | .907(0.69, 0.97)  .89(0.66, 0.97)  1.31(0.48, 1.66) |
| **M-HSCT Inhibition condition**  Average all responses (n=20)  Average correct responses (n=20)  Average error responses (n=17) | 4.28±.355  4.722±.362  1.126±.062 | 4.17 (3.64, 4.92)  4.77(4.04, 5.42)  1.14(1.02, 1.23) |

For average correct latencies, there was a significant difference between both conditions (t=-58.404; df=19; p=< .001) where participants demonstrated slower latency scores in the inhibition condition compared to automatic condition.

For error responses, not all participants made error responses across both conditions. In the automatic conditions, 9 participants made 1 error whereas 3 participants made 2 errors. In the inhibition condition, only 3 participants made no errors *(see* ***Table 7(iv)*** *for frequencies of error produced in the inhibition condition)*.

**Table 7(iv):** Frequencies of error produced in the inhibition condition

|  |  |
| --- | --- |
| Total error produced | Number of participants (%) |
| 0  1  2  3  4 | 3 (15%)  6 (30%)  5 (25%)  4 (20%)  2 (10%) |

For the average error latencies, the mean latency scores were slightly higher in the automatic condition compared to the inhibition condition *(see Table 3)*. The average time latencies for error responses in the automatic condition were between 0.48 and 1.66 seconds, whereas in the inhibition condition the average error time latencies were 1.02 and 1.23 seconds.  A Mann-Whitney U test yielded no significant difference between the average error latency across both conditions (U=59.5, z=.063, p=.57).

**7.3.3 Correlations within tasks**

In Study 2 with the younger group, it was found that performance within some of the tasks were correlated *(see Chapter 6 for full details)*. To examine whether a similar pattern of correlations exists in the older group, Pearson correlation analysis was conducted for each of the M-EF tasks.

**(i) Digit span forward and backward**

For DS tasks, correlations among the four subtask variables were conducted *(****Table 7(v)****)*. A significant correlation between the total correct score and span score was found for both forward and backward conditions. However, no significant correlation was observed across the two tasks conditions, suggesting weaker associations between task performance between forward and backward span measures.

**Table 7(v):** Correlations between DS tasks

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measures** | **1** | **2** | **3** | **4** |
| 1. **DSF - total score** | **—** |  |  |  |
| 1. **DSF - span** | .936\* | **—** |  |  |
| 1. **DSB - total score** | .169 | .246 | **—** |  |
| 1. **DSB - span** | .234 | .269 | .855\* | **—** |

\**p* < .05

\*\**p* < .01

**(ii) Verbal fluency test (VFT) semantic and letter**

For VFT, there was no significant correlation found within the two semantic tasks, suggesting performance in the animal task was not associated with performance in supermarket items. However, a significant correlation was observed within the two letter tasks, indicating there was an association between fluency performance in letter [A] and [M]. When comparing performance between the semantic and letter tasks, a significant correlation was observed between task performance in VFT [A] and supermarket items, suggesting that participants that have good performance in VFT [A] tended to perform well for the VFT supermarket items. No other correlations were found between other task conditions.

**Table 7(vi):** Correlations between VFT tasks

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measures** | **1** | **2** | **3** | **4** |
| 1. **VFT animal** | **—** |  |  |  |
| 1. **VFT market** | .210 | **—** |  |  |
| 1. **VFT - [A]** | .252 | .517\* | **—** |  |
| 1. **VFT - [M]** | .150 | .140 | .518\* | **—** |

\**p* < .05

\*\**p* < .01

**(iii) M-HSCT automatic and inhibition**

In the analysis of the M-HSCT, correlations were performed on two performance indicators: the number of correct responses and total latency scores, which encompassed both correct and error responses *(****Table 7(vii)****)*. Within the automatic condition, no significant correlation was identified between the total score and the total latency, indicating that, in this condition, the overall performance score did not have a significant association with the time taken to produce responses. However, within the inhibition condition, a significant correlation was observed between the total score and total latency. This implies that as the number of correct responses increased in the inhibition condition, the time taken to generate each response also increased. Across both automatic and inhibition conditions, a significant positive correlation was found between the total latency scores for both correct and error responses, indicating that increased response time in the automatic condition is associated with longer response time in the inhibition condition.

**Table 7(vii):** Correlations between total correct scores and latency scores in M-HSCT tasks

A screenshot of a table

Description automatically generated\**p* < .05

 \*\**p* < .01

For both conditions, correlations between the average correct and error latencies were also analysed. It is important to note that for error latencies, there was a limited sample size due to not all participants making errors in both conditions *(see* ***Table 7(viii)****).*  As a result, this limits the interpretation obtained from the correlation analysis. For example, in **Table 7(viii)** the number of participants who were selected into the correlation analysis in the automatic condition were 12 whereas there were 18 participants selected in the inhibition condition.

Between the two conditions, a significant correlation was observed between the average correct latency across both tasks. This suggests that participants who demonstrated faster response times in producing correct responses in the automatic condition also tended to demonstrate faster response times in the inhibition condition. However, there was no significant correlation found between other latency scores.

**Table 7(viii)**: Correlations between average correct and error latency scores in M-HSCT tasks

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measures** | **1** | **2** | **3** | **4** |
| 1. **M-HSCT Auto**   Average correct latency (n=20) | **—** |  |  |  |
| 1. **M-HSCT Auto**   Average error latency (n=12) | .301  (n=12) | **—** |  |  |
| 1. **M-HSCT Inhib**   Average correct latency (n=20) | .810\*\*  (n=20) | .313  (n=12) | **—** |  |
| 1. **M-HSCT Inhib**   Average error latency (n=18) | -.073  (n=18) | 0.455  (n=12) | -.015  (n=18) | **—** |

\**p* < .05

 \*\**p* < .01

**(iv) Spatial Fluency Test (3 and 4 lines)**

For SFT, there was a moderate but non-significant positive correlation *(****Table 7(ix)****)* between the performance in both tasks (3 lines and 4 lines).

**Table 7(ix):** Correlations between SFT 3 lines and 4 lines

|  |  |
| --- | --- |
| **SFT - 3 lines** | .381 |
| **SFT - 4 lines** |

**7.3.4 Correlations between-tasks**

Similar to Chapter 6, three sets of analyses were conducted to investigate the association/dissociation between different tasks in M-EF using Pearson’s correlations. Using the same hypotheses *(see Table 6(ii) in Chapter 6 for details)*, the correlation analysis was conducted to investigate the three underlying EF domains across the M-EF tasks: (i) WM, (ii) cognitive flexibility and (iii) inhibition.

**(i) Working memory**

To investigate the common underlying domain of WM between-tasks, the correlations between VFT and DS were conducted *(see* ***Table 7(x)****)* based on: (a) number of correct responses in VFT, (b) number of correct responses in DS and (c) total span score in DS. Two significant positive correlations were observed, firstly between VFT market and DSF correct responses and secondly between VFT [M] and DSF span score. These correlations indicate that as performance in VFT supermarket-related tasks increases, so does the number of correct responses in DSF tasks. A similar trend is observed between performance in VFT letter [M] and DSF span scores; participants with higher scores in VFT letter [M] tended to exhibit higher span scores in DSF. However, no other significant between-task correlations were found.

**Table 7(x):** Correlations between digit span and VFT. The blue squares represent the correlations between-tasks.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Measures** | **1.** | **2.** | **3.** | **4.** | **5.** | **6.** | **7.** | **8.** |
| 1. **VFT animal** | **—** |  |  |  |  |  |  |  |
| 1. **VFT market** | .210 | **—** |  |  |  |  |  |  |
| 1. **VFT - [A]** | .252 | .517\* | **—** |  |  |  |  |  |
| 1. **VFT - [M]** | .150 | .140 | .518\* | **—** |  |  |  |  |
| 1. **DSF - correct** | -.343 | .454\* | .179 | .424 | **—** |  |  |  |
| 1. **DSF - span** | -.348 | .333 | .234 | .562\*\* | .936\* | **—-** |  |  |
| 1. **DSB - correct** | .065 | -.243 | -.190 | .211 | .169 | .246 | **—-** |  |
| 1. **DSB - span** | .113 | -.041 | -.182 | .196 | .234 | .269 | .855\* | **—** |

\**p* < .05

 \*\**p* < .01

**(ii) Cognitive flexibility**

To investigate the underlying EF domain of cognitive flexibility, the correlations analyses were conducted between VFT and SFT based on the total number of correct responses (**Table 7(xi)**). There were no significant correlations observed between the spatial and verbal fluency tasks, this is similar to the findings in the healthy younger adults *(see Chapter 6)*.

**Table 7(xi):** Correlation between SFT and VFT. The blue squares represent the correlations between-tasks.

| **Measures** | **1.** | **2.** | **3.** | **4.** | **5.** | **6.** |
| --- | --- | --- | --- | --- | --- | --- |
| 1. **VFT animal** | **—** |  |  |  |  |  |
| 1. **VFT market** | .210 | **—** |  |  |  |  |
| 1. **VFT - [A]** | .252 | .517\* | **—** |  |  |  |
| 1. **VFT - [M]** | .150 | .140 | .518\* | **—** |  |  |
| 1. **SFT - 3 lines** | -.081 | -.047 | -.051 | -.172 | **—** |  |
| 1. **SFT - 4 lines** | -.025 | -.171 | -.281 | -.487 | .381 | **—** |

\**p* < .05

 \*\**p* < .01

**(iii) Inhibition**

To investigate the underlying domain of inhibition, three tasks were chosen: VFT, SFT and M-HSCT inhibition. No significant between-task correlations were found in this group *(****Table 7(xii))****.* This result was expected as almost all tasks were considered to have inhibition as a secondary or tertiary underlying cognitive domain except for M-HSCT inhibition.

**Table 7(xii):** Correlation between M-HSCT inhibition, SFT and VFT. The blue squares represent the correlations between-tasks.

A screenshot of a table

Description automatically generated

\**p* < .05

 \*\**p* < .01

**7.4 Discussion**

The aim of this Chapter is to explore the performance baseline for healthy older adults in the M-EF battery and provide a standard against which to interpret M-EF scores for persons aged 50 years and older. To achieve this, the performance of 20 older adults were analysed and compared with reported norms from previous studies.

**7.4.1 Individual task performance and correlation within-tasks**

There were some similarities in the pattern of M-EF performance in the older participants with other healthy older adult populations. Within-task correlations yielded significant correlations for some performance measures within DS, VFT and M-HSCT, however only a moderate correlation was observed in SFT. For correlations between the M-EF tasks, task performance associated with the underlying cognitive domains of WM and inhibition were observed, however no correlations were found for cognitive flexibility.

**Digit span (DS)**

Overall, the DS performance has been found to be better in the forward compared to the backward condition. Consistent with these findings, previous studies have found poorer performance in DS backward compared to DS forward in healthy older adult samples: Hindi speakers (Tripathi et al., 2019), Spanish speakers (Inesta et al., 2021) and English speakers (Ryan et al., 1996).

A span score comparison with healthy older participants of English, Hindi and Spanish speakers is presented in **Table 7(xiii)**to explore cross-linguistics differences in DS performance*.* Firstly, it is important to note that the participants recruited in this study are slightly younger than the sample collected in previous studies *(see* ***Table 7(xiii)*** *for details)*. Across the group, the proportion of older adults aged above 65 years was highest in English (Ryan et al., 1996) and Spanish speakers (Inesta et al., 2021).

**Table 7(xiii):** Mean span score comparison with English, Hindi, and Spanish speakers

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Malay-English bilinguals (n=20) | English speakers (n=130) | Hindi speakers (n=258) | Spanish speakers  (n=103) |
| Age | 50-65 | 75-79 | 50-80 | 55-87 |
| DSF: Mean span score | 5.85 | 5.80 | 5.60 | 5.36 |
| DSB: Mean span score | 4.45 | 4.27 | 4.00 | 3.94 |

*Span score from Tripathi et al., 2019, Inesta et al., 2021 and Ryan et al., 1996*

For the DS forward, the mean span scores of Malay-English bilinguals were slightly higher compared to the rest of the group. The percentage difference in DSF mean span score for Malay-English bilinguals compared to other linguistics groups are: English (0.86%), Hindi (4.37%) and Spanish (8.74%). However, for DS backward the difference in span scores was larger: English (4.13%), Hindi (10.65%) and Spanish (12.16%) *(see Table 12)*. Previous findings exploring age-related decrease in forward and backward digit spans have yielded similar results (Babcock & Salthouse, 1990; Hester et al., 2004). A meta-analysis of 14 studies by Babcock and Salthouse (1990), demonstrated age-related decreases for DS backward were greater than those for forward span. In a larger study (n=1030) comparing DS forward and backward, Hester et al., (2004) observed a differential in performance across forward and backward tasks, with poorer performance in backward tasks with increasing age. One explanation for this is the distinction between processing required to complete each task. In DS forward, the expectation of WM required is mere storage, whereas in DS backward it demands both processing and storage (Bob & Verhaeghen, 2005). Several ageing theories predict that the latter yielded larger age-related effects due to the decrease in cognitive resources available for processing as age increases (Belleville et al., 1998). Overall, the present observations in DS performance suggest that patterns of performance in verbal digit span tasks may be generalised to Malay-English bilingual speakers.

For DSF and DSB, the correlation within-task performance (i.e., total number of correct responses and span scores) were high. However, no significant correlation was found between the two conditions: forward and backward. The correlation analyses were similar to results found in the younger Malay speaking adults *(see Chapter 6)*. These findings support previous theories that DS forward and backward both tap partly different cognitive domains (Gignac et al., 2018).

**Verbal fluency test (VFT)**

For VFT, performance in the two semantic tasks was significantly better compared to the letter tasks. Similar patterns of performance were observed across other healthy older adult populations: Dutch (Vogel et al., 2019) and Danish (Stokholm et al., 2013). Further within-task analysis for the current study, found significant differences between the performance in the letter tasks however no significant differences were found between performance in the semantic tasks. Though the letter and semantic tasks are very similar, there are some subtle differences in task demands (Shao et al., 2014), which may influence task performance. The semantic task resembles everyday production tasks, where individuals can use existing links between related concepts, however phonemic searching in the letter task is rarely done in everyday speech. In line with the task demand differences, marked performance differences can be found across the letter task compared to semantic task.

Another plausible explanation for the differences in performance across the letter tasks may stem in part due to vocabulary size (Pino Escobar et al., 2018). The effect of vocabulary size and letter task performance in bilingual participants have been found in several studies (Bialystok et al., 2008; Luo et al., 2010), which will be further discussed in Chapter 8.

Cross-linguistics comparisons for each of the VF subtasks in the M-EF were illustrated in **Table 7(xiv)**. Due to the varying task characteristics and combinations in VFT (e.g., letters and categories used) only the mean score from previous studies using the same VF tasks were included in **Table 7(xiv)**. Overall, Malay speakers' performance in the semantic tasks were poorer compared to Dutch and Danish monolinguals. For the letter task, the mean score for letter [A] were within similar range to Dutch monolinguals, however for letter [M] Spanish speakers performed slightly better compared to Malay speakers.

**Table 7(xiv):** Mean score comparison for letter and semantic fluency tasks

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Malay-English bilinguals | Dutch monolinguals (n=131)  Vogel et al., (2020) | Danish monolinguals (n=100)  Stokholm et al., (2013) | Spanish monolinguals (n=174)  Delgado-Losada et al., (2023) |
| Medium of task language (time to complete task) | Malay (1min) | Dutch (1min) | Danish (1 min) | Spanish (1 min) |
| Age | 50-65 | 60-87 | 60-87 | 60-69 |
| Mean score for animal | 16.75 | 21.27 | 21.3 | - |
| Mean score for supermarket | 17.35 | 24.44 | 23.6 | - |
| Mean score for letter [A] | 10.60 | 10.39 | - | - |
| Mean score for letter [M] | 9.05 | - | - | 11.55 |

*Normative data from previous studies (Vogel et al., 2020; Stokholm et al., 2013; Delgado-Losada et al., 2023)*

The cross-linguistics comparison illustrated in **Table 7(xiv)** to some extent shows how sociodemographic variables (e.g., language, culture, and nationality) may influence performance in VFT. These considerations led to the necessity of different norms adjusted to country, language, and sociodemographic variables, to ensure that VFT performance can be accurately interpreted (Franzen et al., 2020).

Further analysis yielded significant correlations between performance in letter [A] and [M] and letter [A] and supermarket items. These correlations however were not observed in the healthy younger adults *(discussion in Chapter 8)*. There are currently only a small number of studies looking at within-task correlation in VFT, hence there is limited comparable data from previous research particularly for the age group under-study. One recent study exploring performance of young children and teenagers in three VF letter tasks (M, R, P) in nine Latin American countries, also found significant correlation between the total scores in the letter tasks (Rivera et al., 2021) across the age group.

**M-HSCT**

The overall performance in M-HSCT was better in the automatic compared to the inhibition condition, where significant differences were observed in the total scores and total latency across both conditions. In terms of total score, participants produced more correct responses in the automatic condition. Further analysis showed that participants were taking longer to complete a correct response in the inhibition condition. Similar patterns of performance were reported in previous studies across different languages: English (Bielak et al., 2006; Gibson et al., 2019); Italian (Spitoni et al., 2018) and Portuguese (Zimmerman et al. 2017).

To illustrate the pattern of performance across other languages, **Table 7(xv)** included the mean total latency scores, including correct and error responses in different healthy older adults populations.

**Table 7(xv):** Mean total latency, including correct and error responses and standard deviation comparison with Italian and Brazilian Portuguese speakers.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Malay-English bilinguals (n=20) | | Italian speakers  (n=75)  *Spitoni et al., 2018* | | Brazilian Portuguese speakers (n=75)  *Zimmerman et al., 2017* | |
|  | Auto | Inhib | Auto | Inhib | Auto | Inhib |
| Age | 50-65 | | 50-59 | | 60-75 | |
| Mean total latency, including error responses±S.D | 13.03±1.289 | 64.22±5.324 | 9.04±6.82 | 26.91±14.74 | 17.02±4.91 | 49.49±17.36 |

The cross-linguistics comparisons demonstrated that the overall time latency was longer in the inhibition compared to the automatic condition (**Table 7(xv)**). The findings support the notion that there exist differences in the underlying EF domains between the two task conditions (automatic and inhibition). Additionally, the findings confirm the demanding nature of inhibitory control in the inhibition condition of HSCT (Belleville et al., 2006), hence resulting in longer response time. The variance of latency scores *(represented as standard deviations)* among the Malay speakers mirrored patterns reported in previous research. Specifically, these studies noted that older participants showed greater variability in their response time for the inhibition conditions (Spitoni et al., 2018; Zimmerman et al., 2017). Coefficient of variation (CV) was calculated cross-linguistically for the groups in Table 14, where Malay speakers demonstrated lowest variability in both tasks (9.89% in automatic and 8.29% in inhibition). Brazilian Portuguese speakers demonstrated 28.85% variability in the automatic condition and 35.08% in the inhibition condition, indicating higher variability than the Malay group. Italian participants showed the highest variability with 75.44% in the automatic and 54.78% in inhibition, indicating that participants demonstrated a wide range of response latencies. The differences in CV may reflect the underlying differences in cognitive processing involved in the specific language and further reassures the need for normative performance data for different linguistic and cultural groups, in particular in the interpretation of the HSCT scores.

Correlations within M-HSCT demonstrated that in the inhibition condition, participants' response times increased as the number of correct responses increased. This result is in line with previous research which found longer response time for accurate responses in the inhibition condition across different groups: healthy children (Siqueira et al., 2016), healthy older adults (Idowu & Szameitat, 2023) and individuals with frontal lobe lesions (Duncan et al., 1995; Volle et al., 2012). Some theories proposed that older individuals are more susceptible to inhibitory control deficits due to reduced attentional control (Burda et al., 2017). Others suggest the decline in inhibition is due to the structural changes of the frontal lobe observed in normal ageing, resulting in overall EF decline (West, 1996). Furthermore, participants who demonstrated faster correct response time for the automatic condition also showed faster correct response time in the inhibition condition. The results suggest that participants who exhibited good initiation also exhibited good inhibitory control, one possible reason for this is the shared brain region supporting both processes (i.e., frontal lobe) which implies that in healthy individuals with no frontal lobe lesions, performance in initiation task positively correlates with performance in inhibition condition (Robinson et al., 2012).  Interestingly, the latencies scores in the older adult group were longer compared to the younger sample. This pattern of performance has also been reported in several studies in healthy ageing populations (Gibson et al., 2018; Martin et al., 2021) which will be further discussed in Chapter 8.

Future research should explore whether this pattern of performance exists in PWA. Age comparison for the healthy Malay participants in the current study will be presented in Chapter 8.

**SFT**

Overall, participants' performance in the SFT was slightly better in the second task condition (4 lines) compared to the first condition (3 lines), although no significant difference in task performance was observed. The Ruff Figural Fluency Test (RFFT) which is scored based on the number of correct drawings generated (Ruff, 1987; 1994) was selected for comparison with performance in SFT. **Table 7(xvi)** outlined the number of correct responses between SFT and RFFT in older adult samples.

**Table 7(xvi)** Mean correct score comparison in SFT and RFFT across Malay and Dutch speakers

|  |  |  |  |
| --- | --- | --- | --- |
|  | Malay-English bilinguals | | Dutch speakers  (Izaks et al., 2011) |
|  | 3 lines  (1 min) | 4 lines  (1 min) | Performance across all five pages (5 mins) |
| Age | 50-65 (n=20) | | 55-59 (n=164) |
| Mean correct score | 5.65 | 5.80 | 75 |

It is important to note that the performance data from Izaks et al., (2011) included the total correct drawings across all five pages of RFFT which takes a total of 5 minutes to complete. However, the SFT only consists of two tasks which take 1 minute each to complete. The average mean drawing per minute for RFFT in Izaks et al., (2011) was 15 (total mean correct score/5min). The number of correct drawings in RFFT for the Dutch speakers were therefore larger than the Malay speakers' performance in the SFT. Furthermore, Izaks and colleagues reported that RFFT performance in the Dutch sample was lower than in the US reference sample (Izaks et al., 2011). The difference varied between 10-20 numbers of correct responses. Performance in the older group of the present study resembles more of the younger adults’ group *(see Chapter 6)* compared to Izaks et al., 2011, which will be discussed in Chapter 8. The results highlight the importance of establishing performance baseline for various neuropsychological tasks, including those with non-verbal modality across different linguistic and cultural groups.

Further correlation analysis between the two task conditions in SFT found no significant correlation, implying that when conducting the SFT, both 3 lines and 4 lines conditions should be administered for a comprehensive measure of EF.

**7.4.2 Correlation between-tasks**

Correlation analysis between different M-EF tasks were conducted to investigate the three underlying EF domains: WM, cognitive flexibility and inhibition. Overall, between-task correlations associated with underlying cognitive domain of WM were observed; however, correlations associated with underlying common cognitive domain of cognitive flexibility and inhibition were less robust.

For WM, positive associations were observed between performance in letter [M] verbal fluency and the span score in DS forward. Similar findings have also been reported in Ruff et al., (1997) where measures of WM in digit span task were significantly correlated with performance in phonemic fluency task in individuals aged between 16-70. The present findings are also consistent with the predictive value of DS span score in phonemic fluency tasks, as described by Hedden et al., (2005) studies to include 345 individuals aged between 20-92.

Another recent study also observed similar results in adults where forward span scores significantly correlated to letter fluency task performance but not semantic fluency (Kave & Sapir-Yogev., 2020). A plausible explanation for this result might be attributed to the role of the phonological loop in the letter fluency task, as described by Rende et al. (2002). The phonological loop’s ability to temporarily store and manipulate phonological information is crucial for successfully implementing strategy for searching initial-letter words as required in the letter fluency task (Rende et al., 2002). Additionally, the capacity of phonological working memory is often evaluated using digit span scores, a method highlighted by Cabbage et al. (2017). Therefore, the observed positive correlation between digit span scores and performance in the letter fluency task in this study likely reflects the previously established significance of the phonological loop in letter fluency tasks. This correlation suggests that individuals with a greater capacity for phonological working memory might perform better in tasks requiring the retrieval and organisation of phonologically related information.

An alternative, albeit highly speculative explanation for this correlation is the possibility of language-specific lexico-syntactic role in the letter fluency task. The letter-based prefixes in certain languages may influence the ability to activate certain words, which brings a more frontal-based set of EF into play. For example, in the Malay language, the letter [M] is associated with several prefixes, me-, men-, mem- and meng- which when added to a noun/verb will change its form and/or meaning. For the VF letter task in this study, words with prefix [M] are scored as inaccurate responses. However, due to the significant letter [M] association with a number of words in the Malay language, the task-rule constraint may result in increased WM ability to successfully perform the task. The hypothesised relationship between task structure and task rules with lexico-syntactic representation was discussed by (Meteyard & Vigliocco, 2018), however this begs further questions on whether this lexico-syntactic representation is pronounced across other languages.

Another significant correlation was also observed between performance on semantic VFT, supermarket items, and the number of correct responses in DSF. The findings support the alternative notion that WM capacity is important for performance on both phonemic and semantic fluency tasks (Shao et al., 2014, Gordon et al., 2018). Although it is important to note that the DS performance indicator observed in the second correlation is the total number of correct scores in the span task. However, the observation in Shao et al., (2014) and Gordon et al., (2018) employed the span score.

In summary, the current study provides the healthy performance baseline for older Malay speakers aged between 50-65, which can be used to interpret neuropsychological performance results more accurately from this population. The method of administration demonstrated that the M-EF battery is suitable for assessing healthy older populations in remote settings. The summary statistics provided (Table 2) may also be used as an important supplement in clinical practice when assessing EF abilities in this target population. The combination of tasks in the M-EF battery were selected based on evidence-based task performance association to underlying domain of cognitive function: WM, inhibition, and cognitive flexibility *(see Table (6ii) in Chapter 6)*. The between-task correlations shed light on the cross-task relationships hypothesised (Chapter 6) in relation to possible shared underlying domain of WM, however weak correlations were observed for underlying domain of cognitive flexibility and inhibition. One reason for this may be due to task impurity problems (Miyake et al., 2000), where more EF tasks are needed to indicate correlation between-tasks in an EF battery due the shared EF abilities across most EF tasks. Future research should look into developing more EF tasks in the M-EF battery and explore the usage of M-EF with clinical populations (e.g., TBI and PWA).

\*\*\*\*\*\*

The following Chapter 8 will provide a general discussion on the M-EF performance across both younger and older Malay speaking adults in the present study. Age related effects will be further discussed.

**Chapter 8: General discussion**

The result from this study provides a novel adaptation of the Malay EF battery (M-EF) for assessing the geographic and demographic needs of the Malay-speaking population, healthy adults’ performance baseline from two age groups and a detailed test administration and scoring mechanism for M-EF. This work was grounded in Diamond’s theoretical framework of EF to develop a linguistically and culturally relevant EF battery for assessing Malay speakers with aphasia. This thesis represents the exploratory approach to the M-EF development, to firstly establish a performance baseline for healthy adults for the telehealth M-EF battery and secondly to investigate the robustness of the scoring mechanism with other established cross-linguistics norms. The findings from this study confirms some cross-linguistics influence on EF ability and the age-effects on executive functioning in the sample understudy *(see Chapter 6 and 7 for details)*.

Study 1 aimed to gather a rich account of clinical professionals' perceptions on usage of a Malay language EF assessments and to explore the current practice for assessing EF in Malaysia, especially in remote settings. Study 1 established the understanding of existing EF assessment in Malaysia, in the context of medium of assessment and assessment for the target group, PWA. Overall, the preliminary evidence supports the need for the M-EF battery for a linguistically and culturally diverse population in Malaysia.

Study 2 examined the performance of healthy younger and older Malay speakers in the M-EF battery. Participants took part in the M-EF assessment remotely via GoogleMeet. Study 2 aimed to establish the healthy performance baseline for the newly adapted M-EF battery as well as to consider the correlation within and between tasks in the M-EF battery to understand the underlying cognitive domains of EF. The performance baseline from both groups will be useful for comparison with the future target population of post-stroke patients and people with aphasia. Section 8.2 of this chapter discusses these results in light of these aims.

In this chapter, Section 8.1 provides a summary of findings and discussion of results from the questionnaire distributed to clinicians in Malaysia in Study 1, including the clinical needs that may give rise to the need for EF battery in the patient’s first/primary language. Section 8.2 provides a summary of results from healthy younger and older Malay-speaking participants from Study 2, supporting the aims summarised above. Section 8.3 presents the overall performance comparisons between the younger and older participants. Section 8.4 considers the implications arising from this study in clinical and research applications.

**8.1 Discussion of results from PPI questionnaires in Study 1**

Study 1 established clinicians’ input that demonstrated the need for a linguistically and culturally suitable EF battery for the Malay speaking population. The current work represents an important first step in understanding the current neuropsychological assessment procedures in Malaysian clinical settings both in terms of availability of suitable tests and the method of assessment delivery (in-person and remote). The present research employed an adapted questionnaire (Webb et al., 2022) to achieve the objectives mentioned above.

The current work adds to the body of evidence that suggests the scarcity of suitable EF assessment in the Malay language and the need for a standardised, remote EF assessment for assessing PWA. Presently, many EF assessments in Malaysia are conducted in English. The usage of English medium EF assessments was viewed as being more practical because most EF tests were more readily available and validated in English. At the time of this research, there were no EF batteries available in the Malay language for assessing PWA.

Furthermore, the clinicians’ responses emphasised the often-neglected fact that culture and linguistics variables are often overlooked in neuropsychological test development (Ardila, 2007). Study 1 revealed two aspects to consider in developing linguistically suitable neuropsychological assessment for a multilingual population: (i) diversity across the linguistic group, and (ii) linguistic and cultural suitability for different items in neuropsychological test batteries.

The first salient point highlighted from the responses was the aspect of language as a social phenomenon. The findings highlighted an important aspect of the Malay language spoken in multilingual Malaysia, which according to the clinicians’ responses in Study 1, the EF test battery should consider dialectal, multilingual mix and syncretism of form and function as accurate responses in the M-EF battery *(see Chapter 4 for details)*. In Malaysia, there is widespread practice of languaging across the ethnolinguistic divides, whereby language users blend local-knowledge and complex repertoire from other languages spoken in the region creating a form of creative, non-conforming Malay language often termed as ‘Bahasa Rojak’ (Albury, 2017). In a diverse multilingual society, this is an important aspect to consider when conducting verbal assessments, to ensure commonly used linguistic items not available in the ‘standard’ language version are considered when scoring and interpreting performance in neuropsychological assessments.

Secondly, the responses highlighted the need to ensure that the test items administered were culturally suitable for the Malaysian population. Cross-cultural neuropsychological consideration when working with non-Western, mainstream populations have also been suggested in previous studies (Franzen et al., 2022; Nguyen et al., 2023). Franzen and colleagues (2022) suggested that more widely applicable, cross-cultural cognitive tests should be used with diverse populations. For example, unsuitable culture specific items (e.g., snowflake and igloo are items familiar to Inuit communities in Canada but are unfamiliar for Malay speakers residing in tropical country, Malaysia) and school-based skills (e.g.., visuoconstruction) should be avoided in neuropsychological assessments to minimise influence of culture and education on test performance (Franzen et al., 2022). Besides minimising cultural and linguistic bias in neuropsychological assessments, Franzen et al., (2022) also makes recommendations for constructing briefer tools (e.g., Abbreviated Mental Test) which are validated for different linguistic groups.

With regards to administration, this study offers insights into the benefits and limitations of remote cognitive assessments. Presently in Malaysia, EF assessments are conducted in face-to-face settings. To the best of our knowledge, this is the first Malay EF test developed and administered in remote settings. In terms of its telehealth benefits, this study demonstrated the feasibility of assessing participants in their own home using videoconferencing software, GoogleMeet. The test administration guidelines provided in Chapter 5, described in detail the steps to administer and score the M-EF battery, which can be used in both in-person and remote settings.  The findings also offered some important considerations for remote assessment in this population: (i) remote administration may not be feasible for individuals in remote, low resource areas in Malaysia, (ii) some individuals may have limited technological skills, and (iii) unsuitability of testing for individuals with complex impairments (e.g., reduced mobility, hearing). Similar suggestions have also been reported by Nguyen et al., (2023). In the suggestion, it was recommended that these are included in the pre-evaluation stage to ensure the individual is fit for remote cognitive assessment.

**8.2 Summary of findings from Study 2**

This section discusses the overall findings from the fifty-one healthy younger participants in and twenty older participants. A brief summary of the group-level results will be discussed, in line with the first aim of Study 2.

For DS, generally all the younger participants in demonstrated better performance in the forward span task compared to backward. Similarly, this was the case for the older group.  Older participants demonstrated significantly better total score and span score in the forward condition compared to backward. This pattern of performance is expected due to the nature of the DS task. Some studies argue that DS forward acts as an essential ‘warm-up’ task prior to a higher ability task (Raiford et al., 2010), DS backward. Another justification for better performance in DS forward is that because DS forward represents a measure of the capacity of the phonological store (Baddeley, 2000) whereas DS backward primarily evaluates the ability to manipulate information in the working memory (Holdnack, 2019) hence backward tasks are  considered more cognitively taxing.

Group-level analyses for VFT performance in the younger group revealed a significantly better performance in the semantic compared to letter task. Similar pattern of performance was observed in the older group. Similar findings have been reported in cross-linguistic studies of healthy adult groups: Hebrew speakers (Kave, 2005) and Spanish speakers (Cavaco et al., 2013) as well as younger adults with reading difficulties (Kave & Sapir-Yogev, 2023). Although both semantic and letter tasks share some similarities in the voluntary nature of word generation, they require different strategies for the creation and selection of appropriate, novel responses (Baldo et al., 2006). Baldo and colleagues (2006) argued that both fluency tasks depend on partially shared and partially distinct cognitive processes, which may be the reason for differences in performance across tasks. The shared cognitive processes between the semantic and letter tasks include WM and self-monitoring. However, distinct cognitive processes also underlie each task, for the semantic task the retrieval of words requires access to the lexical-semantic networks whereas the letter task relies more heavily on strategic retrieval of word forms, which may influence the differential in task performance. It is also possible that better performance in the semantic task may be due to the task relying predominantly on the temporal cortex whereas the letter task engages more frontal lobe network *(see Baldo et al., 2006 for details)*.  The current work adds to this body of evidence that suggests differences in performance across both tasks, even in cross-linguistics study.

Overall, analyses for M-HSCT in Study 2 indicated that the younger and older participants performed significantly faster in the automatic condition compared to the inhibition, similar to previous studies with healthy adults (Pérez-Pérez et al., 2016; Andres et al., 2000). The group-level analyses in the Malay language sentence completion task further support the notion that automated response can be accomplished with minimal cognitive effort, whereas when task demands require participants to inhibit prepotent responses, the time to respond is longer (England et al., 2021).

For the non-verbal fluency component of the M-EF battery, overall group-level analyses for the younger group demonstrated slightly better performance in the first task condition (3 lines) compared to the second task. It is important to note that both groups showed a distinct pattern of performance within-tasks. In the younger sample, performance in SFT 3 lines was better compared to the 4 lines, however for the older sample performance in the 4 lines were better (*see* ***Table 8(i)*** *below*). Due to the novel adaptation of this task, there was a limited reference to comparable tests. Overall, the results indicated that in the younger group practice effects due to learned strategies were not observable in this sample.

Taken together, the pattern of performance across the verbal component (DS, VFT, M-HSCT) of the M-EF battery showed similar results to previous cross-linguistic studies in healthy adults (see Chapter 6 and 7 for full details).

**8.3 Discussion of results comparing the M-EF performance of younger and older Malay speakers**

This section discusses the comparison of executive function between the younger and older sample in more detail. Section 8.3.1 provides group-level performance comparisons for each M-EF task in the younger (reported in Section 6.3.2) and older group (reported in Section 7.3.2). Section 8.3.2 brings together discussion on the between-task correlation observed across both groups in line with the postulated underlying domains of cognitive functions: WM, inhibition and cognitive flexibility. Some reference to the within-task correlation will be made to support the discussion.

**8.3.1 Discussion of results comparing younger and older participants**

The comparison of performance measures across the younger and older participants in each task in the M-EF battery are summarised in **Table 8(i)**.

**Table 8(i):** Comparison of summary statistics of performance scores between younger and older adults in the M-EF battery

|  |  |  |  |
| --- | --- | --- | --- |
| **Task** | **Young** (n=51)  (Mean +/- SE) | **Older** (n=20)  (Mean +/- SE) | **Independent t-test** |
| **DS - Forward**  Number of correct items  Span score | 9.43±.126  5.96±.074 | 9.30±.242  5.85±.150 | t=-.522, df=69, p=.603  t=-.736, df=69, p=.232 |
| **DS Backward**  Number of correct items  Span score | 6.47±.110  4.47±.081 | 6.30±.206  4.45±.153 | t=-.784, df=69, p=.436  t=-.128, df=69, p=.899 |
| **SFT - 3 lines** | 5.29±.138 | 5.65±.182 | t=1.433, df=69, p=.156 |
| **SFT - 4 lines** | 4.65±.122 | 5.80±.213 | t=4.901, df=69, p=<.001 |
| **VFT - animal** | 20.39±.387 | 16.75±.491 | t=-5.268, df=69, p=<.001 |
| **VFT - supermarket** | 20.43±.350 | 17.35±.477 | t=-4.856, df=69, p=<.001 |
| **VFT - [A]** | 11.10±.262 | 10.60±.510 | t=-.948, df=69, p=.346 |
| **VFT - [M]** | 9.86±.258 | 9.05±.223 | t=-1.861, df=69, p=.067 |
| **M-HSCT - automatic**  Total score (correct responses)    Total latency (correct + error) | 14.63±.074  8.93±.040 | 14.25±.160  13.03±.288 | t=-2.443, df=69, p=.017  t=21.59, df=69, p=<.001 |
| **M-HSCT - inhibition**  Total score (correct responses)  Total latency (correct + error) | 14.75±.062  45.48±.409 | 13.2±.277  64.22±1.19 | t=-7.801, df=69, p=<.001  t=18.983, df=69, p=<.001 |

For both conditions in the DS, overall, the mean performance of the younger group was slightly higher than that of the older group (*see* ***Table 8(i)***). However, the results of the independent t-test suggested that these differences were not significantly different, indicating that the age-related differences in performance on the DS task were minimal in the Malay sample. Our findings are similar to Gregoire & Van der Linden’s (1997) findings across healthy French speakers aged between 16-79 years old. Despite the poorer performance in DS backward compared to forward across the age span, the study reported no significant difference between the performance across both tasks.

Overall, the direction of the total score and span score from the Malay speakers confirms the existence of age-related declines in DS forward and backward tasks (*see* ***Figure 8(i)***). Similar age-related decrease in both DS tasks have also been observed in previous studies (Babcock & Salthouse, 1990; Gregoire & Van der Linden, 1997; Hester et al., 2003). The nature of the age-related differences in the DS tasks may be due to differences in cognitive demand across both task conditions. Several researchers argue that the forward span requires the automatic processing of the slave system in WM, as required in most immediate serial recall tasks which does not require reorganisation of materials. In the backward task, the demand on central executive is expected to be significant, due to the nature of the task requiring transformation and manipulation of information while simultaneously storing the information (Hester et al., 2003).

Another possible explanation for the decline in performance across DS tasks is the assumption that EF skills decline in normal ageing (Van der Linden et al., 1998; Keys & White, 2000). Given that WM is predominantly dependent on the frontal lobe, which is known to diminish in volume with advancing age, the volumetric neuroimaging data provide evidence in support of a corresponding deterioration in WM performance in older individuals (Raz, 2000). However, it is important to note that some researchers argue that EF decline with age cannot be generalised, as some EF skills have been found to be resilient with ageing (Glisky, 2007; Zanto & Gazzeley, 2019).

**Figure 8(i):** Mean and 95% confidence interval for DS tasks between younger and older participants

1. Mean number of correct score comparison

**A graph of different colored bars

Description automatically generated with medium confidence**

1. Mean and 95% confidence interval for span score between older and younger participants

A graph of different colored bars

Description automatically generated with medium confidence

In the SFT tasks, the performance of older adults was higher compared to younger adults, with pronounced differences in the 4-line task compared to 3-line *(see Figure 8(ii) for comparison)*. For the 3-line task, the mean scores for older adults were slightly higher than the younger group; however, the t-test yielded no significant difference between the two groups. The 4-line task showed a more pronounced difference with older adults scoring significantly higher compared to younger adults, as indicated by a significant t-value, suggesting an age-related difference in performance in this task. One possible explanation for this pattern of performance is the older group's fluency and familiarity with the medium of pen-and-paper assessment increased. Thus, this may influence their better performance in the second part of SFT.

**Figure 8(ii):** Mean and 95% confidence interval for SFT 3 lines and 4 lines between younger and older participants

A graph of different colored bars

Description automatically generated with medium confidence

In the VFT, overall performance in the younger group was better compared to the older group across all four fluency tasks *(see* ***Figure 8(iii)*** *below)*. Performance in the semantic tasks showed significant age-related differences with higher correct scores for younger adults. However, no significant differences were observed in the letter tasks across both age groups. Similar patterns of performance have been observed in previous studies exploring VFT performance across healthy age spans (Elgamal et al., 2011; Stolwyk et al., 2015). One plausible reason why semantic tasks may be more sensitive to age effects compared to the letter task is due to the correlation between performance in semantic tasks and processing speed (Elgamal et al., 2011; Shao et al., 2014). Many studies have found the effect of age on declining processing speed (Salthouse, 1996; Nettleback & Burns, 2010).  The possible decline in processing speed in the older Malay participants may be the reason for the significant difference between the younger and older group. Future research should factor in the effect of processing speed in fluency in Malay-speaking populations to confirm this assumption.

**Figure 8(iii):** Mean total correct score and 95% confidence interval for VFT between younger and older participants

a. VFT semantic

A graph of different colored bars

Description automatically generated with medium confidence

1. VFT letter

A graph of different colored bars

Description automatically generated with medium confidence

In the M-HSCT, overall group performance was better in the younger compared to the older group both in terms of total correct score and total latency. Significant differences in response times between both age groups were observed across both automatic and inhibition conditions (*see* ***Table 8(i)***), where older participants demonstrated longer response time compared to the younger group. Similar patterns of longer response latencies in older groups have been reported in previous studies exploring HSCT performance across healthy lifespans (Collete et al., 2009; Gibson et al., 2019; a meta-analysis by Cervera-Crespo & González-Alvarez, 2017).

Poor performance in both HSCT conditions have been found in previous studies (Burgess & Shallice, 1997; Bielak et al., 2006). For the automatic condition, one plausible assumption for longer response time in the older group may be due to the influence of age-related decline in verbal initiation, consistent with findings from previous studies (Keys & White, 2000; Rodríguez-Aranda & Jakobsen, 2011). There are many assumptions on the source of verbal initiation and speech production in older adults, including vocabulary knowledge, psychomotor abilities, and type of verbal tasks (Rodríguez-Aranda & Jakobsen, 2011). Longer response time in the inhibition condition among the older adults is linked to age-related influence on the ability to inhibit prepotent responses, as evidenced in previous studies (Williams et al., 1999; Butler & Zacks, 2006). The inhibitory deficits hypothesis of ageing (Hasher & Zacks 1988; Hasher et al., 1999) provides some explanation for this age-related effect in inhibiting prepotent response. According to this hypothesis, age-related changes in cognitive functions including language comprehension resulted in functional decline inhibitory control. As a result, older adults demonstrated slower and more-error prone performance when conflicting response is possible, for instance in the inhibition condition of the M-HSCT.  Overall, these findings suggest that age plays a role in the Hayling task performance.

**Figure 8(iv):** Mean and 95% confidence interval for M-HSCT between younger and older participants

1. Total correct scores

A graph of a group of people

Description automatically generated with medium confidence

1. Mean and 95% confidence interval for total latency, including correct and error responses

**A graph of a group of people

Description automatically generated**

**8.3.2 Discussion on comparison of correlations between-tasks in the younger and older participants**

The correlation analysis between-tasks in the M-EF battery among younger and older groups demonstrated some correlations between specific performance measures, particularly in working memory (WM) and inhibition, however not for the EF domain of cognitive flexibility. **Table 8(v)** below summarises the between-task correlations found in both younger and older groups, in relation to the postulated common underlying domains of EF: WM, cognitive flexibility and inhibition.

**Table 8(v):** Summary of between-task correlation observed in younger and older group

|  |  |  |
| --- | --- | --- |
|  | **Younger (n=51)** | **Older (n=20)** |
| **WM** | A significant, moderate negative correlation was found between VFT animal category and DS forward condition (r=-.383). No other correlation was observed. | Two significant positive correlations were observed: (i) VFT market and DSF correct responses (r=.454) and (ii) VFT [M] and DSF span score (r=.562). No other correlation was observed. |
| **Cognitive flexibility** | No significant correlations observed | No significant correlations observed |
| **Inhibition** | Significant negative correlation was observed between the number of responses in SFT 4 lines and the average correct latencies in M-HSCT inhibition (r=-.418). No other correlation was observed. | No significant correlation observed |

**(i) Working memory (WM)**

The initial hypothesis was that DS and VFT tasks would be correlated, which would in turn reflect a shared underlying cognitive domain of WM. The results across both age groups were mixed. In the younger group, a moderate negative correlation was found between performance in VFT animal and DS forward condition, implying that as performance in one task increases, there was a corresponding decrease in performance in the other task. Whereas the correlation for the older group, revealed significant positive correlations observed between VFT market and DS forward correct responses, and between VFT [M] and DS forward span score.

Although the majority of younger participants exhibited patterns of performance similar to previous studies in both DS and VFT tasks (Chapter 6), between-task correlations in this group does not provide a strong support for the hypothesis about the shared underlying cognitive domain. However, our results in the older group were more convincing as several task performance measures were found to be significantly correlated.

**(ii) Cognitive Flexibility**

The analysis between VFT and SFT in both the younger and older groups showed no significant correlations to provide insight into the common underlying domain of cognitive flexibility. Two plausible explanations for the lack of significant correlations between-tasks are (i) within-task correlations, and (ii) differences in task modality. Both groups showed correlations of subtasks within VFT and correlations of subtasks within SFT. In the younger group, correlations were observed within the two VF semantic tasks and between SFT 3 lines and 4 lines. Whereas in the older group, correlations were observed between the two letter tasks and between VFT supermarket items and letter [A]. This observation suggests that while each task may internally be consistent in providing a measure of a certain aspect of cognitive flexibility, they do not necessarily do so in a manner that is comparable between the two tasks. Another plausible explanation for the absence of between-tasks correlations is the difference in test modalities. The verbal modality of VFT and the non-verbal nature of SFT may not be directly correlated, hence producing lack of between-tasks correlation. The distinction between verbal and non-verbal processing in the human brain have been established in several neuroimaging studies (Thierry & Price, 2006; Hocking & Price, 2009).

**(iii) Inhibition**

Three tasks were postulated to share a common underlying cognitive domain of inhibition, M-HSCT inhibition, SFT and VFT. However, we expected the correlation to be low for this EF domain because the two fluency tasks were hypothesised to provide only moderate (i.e., secondary) measures of inhibitory control.

In the younger group, significant negative correlations were observed between the number of responses in the SFT 4 lines task and the average correct latencies in the M-HSCT inhibition task. However, no significant correlation was observed in the older group for inhibition tasks, indicating that the relationship between response generation and inhibitory control might differ across age.

**8.4 Implications of the current study**

This section describes three main aspects arising from the findings of this study: (i) novel findings and strengths of this current research, (ii) research limitations and (iii) clinical and research implications.

**8.4.1 Novel findings and Strengths of Research**

Test materials in the current study were selected based on the often-postulated EF domains as identified in Diamond’s EF model (2013). For the M-EF test development, four EF tasks were selected, translated and adapted for assessing bilingual Malay speakers. This follows with assessing healthy younger and older Malay speakers using the newly adapted M-EF battery. The present study addressed two focal points in cross-cultural neuropsychology: (i) the development of new neuropsychological instruments, in different linguistic and cultural contexts, and (ii) the development of healthy performance baseline for the current neuropsychological instrument M-EF appropriate to the target population understudy.

The present study provided referential data for healthy Malay speakers on the novel adaptation of the Malay Executive Function (M-EF) battery which was not hitherto available for Malay speakers. By adapting a series of EF tasks and gathering new normative data relevant in the new context, this study contributes to the development of cross-cultural assessment of EF and understanding of EF performance in Malay speakers. We provided specific performance scores (i.e., mean, standard deviation, median, range) related to four selected EF tasks, which in the future may allow clinicians and researchers to use the M-EF battery in the assessment of PWA and patients with cognitive impairment, as part of a diagnostic workup.

Cultural and linguistic variants were evident from the research findings when compared cross-linguistically with healthy younger and older groups *(see Chapter 6 and 7)*. The influences of language, culture and environment on performance in neuropsychological tests have been discussed in previous studies (Ardila, 1995; Ardila, 2007; Kelkar, 2007). According to Ardila (1995), cognitive abilities measured using various neuropsychological tools are in part influenced by the participant’s culture, learned opportunities and contextual experiences. What is relevant for a Malay speaker, does not necessarily coincide with what is worth learning for an English speaker inhabitant of the UK. The extended cross-cultural analysis *(see Discussion in Chapter 6 and 7)* can be helpful in enhancing our understanding of the relations between language and cognition in different cultural contexts.

This research also adds to the body of literature on remote neuropsychological testing. This study began during the COVID-19 pandemic in November 2020 with research that had been originally designed for face-to-face testing. However, due to lockdown restrictions the delivery of assessments was adapted to remote testing. This study provides an evidence-based remote neuropsychological tool for assessing Malay speakers which offers an alternative to face-to-face testing during the pandemic crisis as well as offering clinicians and patients an alternative model of service delivery (i.e., telehealth). The remote M-EF battery thus provides a highly comparable assessment of EF for the population understudy.

**8.4.2 Research limitations**

Firstly, this is the first study of its kind in this target population.  Although cross-linguistic comparisons have been discussed in Chapter 6 and 7, Malay speaking group performance in the present study cannot be compared to other studies involving Malay speakers, due to the lack of EF assessment available in the Malay language. Hence, there were no other comparisons to be made in terms of similarities and differences in findings within the Malay population.

Secondly, we acknowledge that the number of EF tasks selected were limited and may give rise to the task impurity problem *(see Miyake et al., 2000 for details)*. Between-task correlations in the M-EF battery yielded associations between tasks that tapped into WM and inhibition, however no between-task associations were observed for cognitive flexibility. This may be the result of the single EF tasks with a primary underlying domain of cognitive flexibility. As recommended by Miyake et al., (2000) for EF test development, multiple tasks should ideally be used for each underlying EF domain, to partially reduce this problem. Since EF tasks often have idiosyncratic requirements specific to the task, it is impossible to find a ‘pure’ measure of EF domain (Miyake et al., 2000: 180). Whilst most previously developed EF batteries included multiple EF tasks (e.g., nine EF tests in Delis-Kaplan Executive Function System), future research using the M-EF battery should explore the need to include additional EF tasks for the underlying domain of cognitive flexibility.

Another limitation of this study is the changes made to the original study design intended to study the M-EF assessments with a small sample of Malay speaking PWA. This was not feasible due to the additional time needed to develop an online tool suitable for PWA and the inability to conduct exploratory fieldwork with vulnerable groups during the pandemic.

**8.4.3 Future directions**

This study has created future opportunities to explore executive functioning abilities in Malay speakers and contribute to the understanding of cross-cultural cognition in different samples. This section highlights the two potential directions from this study in relation to research and clinical application.

**8.4.3.1 Research implications**

To date, EF models are built on understanding and cognitive workings from studies in populations of the Global North (Diamond, 2013; Miyake et al., 2000).  The findings from this study adds to the understanding of the EF framework from a Global South perspective, particularly in the Malay speaking population. This study extends the current knowledge on EF, shedding light into possible differences in EF abilities that may exist across diverse cultural and linguistic contexts.

This study also contributes to understanding of EF abilities in bilingual adults, particularly in the target sample. While the analysis did not delve into language variables when evaluating participant performance, it highlights a crucial avenue for future research. Subsequent investigations could explore the impact of language intricacies on EF outcomes in bilingual populations, providing a more nuanced understanding of the interplay between linguistic factors and cognitive functions in a diverse population.

**8.4.3.2 Clinical implications**

The present study introduces the M-EF battery, demonstrating its applicability in remote neuropsychological assessments. Preceding this study, EF assessments in Malaysia were predominantly conducted in face-to-face settings, necessitating the physical presence of both the patient and clinician. The findings herein reveal that healthy participants encountered no significant challenges during the administration of the M-EF assessment, implying the viability of remote testing as a comparable alternative in situations where in-person assessments are unavailable. However, it is important to consider aphasia specific considerations when administering the M-EF battery to PWA in future studies. For instance, impaired speech production is a common symptom presented in Broca’s aphasia, which may influence response latencies in M-HSCT. Also, given that aphasia often occurs post-stroke, the remote testing format of the M-EF battery should consider motor impairments in stroke patients which may impact individual abilities to complete cognitive assessment in remote format.  Future validation studies using M-EF battery may benefit from using larger samples in PWA and in other individuals with neurological impairments requiring EF assessment (e.g., TBI).

Time taken for each response is not the focus of interest in the M-EF battery except for M-HSCT. This deliberate focus mitigates potential issues associated with minor delays and variations in sound precision over internet connections. The implications of these results underscore the feasibility and utility of remote neuropsychological assessments, expanding the scope of EF evaluations in diverse clinical settings.

Existing interventions in PWA in Malaysia predominantly focus on language and communication aspects. This is despite growing evidence of EF deficits in PWA (Ramsberger, 2005; Olsson et al., 2019). The development of the M-EF battery creates an opportunity for a more comprehensive approach to rehabilitation for PWA. While existing therapies predominantly address linguistic deficits, incorporating assessments of EF can provide crucial insights into the cognitive processes underlying speech and communication difficulties in PWA. Thus, enabling clinicians to tailor interventions to address not only language impairments but also the additional cognitive processes that influence functional communication (Olsson et al., 2020) and aspects of daily life (Vaughan & Giovanello, 2010).

**8.5 Conclusion**

The purpose of this study was to develop a linguistically and culturally suitable executive functioning assessment for Malay speakers from Malaysia and to expand its usage in clinical settings with PWA. Using Diamond’s (2013) theoretical framework of EF and commonly used EF tests to measure underlying cognitive domains of WM, inhibition, and cognitive flexibility, we adapted and developed the first Malay Executive Function (M-EF) battery for use in remote settings.

Results from the current study may inform treatment approaches in PWA, particularly in understanding the EF profile of PWA in relation to healthy baseline. This project demonstrated how investigations grounded in the EF framework have the potential to broaden the scope of knowledge about language and communication in aphasia, especially with reference to the multilingual population.

\*\*\*\*\*\*\*\*

**References**

​

Albert, M. S., & Kaplan, E. (2014). Organic implications of neuropsychological deficits in the elderly. In *New Directions in Memory and Aging (PLE: Memory)* (pp. 403-432). Psychology Press.

Albury, N. J. (2017). Mother tongues and languaging in Malaysia: Critical linguistics under critical examination. *Language in Society*, *46*(4), 567–589. <https://doi.org/10.1017/S0047404517000239>

Alexander, M. P., Fischette, M. R., & Fischer, R. S. (1989). Crossed aphasias can be mirror image or anomalous. Case reports, review and hypothesis. *Brain : a journal of neurology*, *112 ( Pt 4)*, 953–973. <https://doi.org/10.1093/brain/112.4.953>

Allen, C. M., Martin, R. C., & Martin, N. (2012). Relations between Short-term Memory Deficits, Semantic Processing, and Executive Function. *Aphasiology*, *26*(3–4), 428–461. https://doi.org/10.1080/02687038.2011.617436

Alloway, T. P., & Alloway, R. G. (2013). Working memory across the lifespan: A cross-sectional approach. *Journal of Cognitive Psychology (Hove, England)*, *25*(1), 84–93. <https://doi.org/10.1080/20445911.2012.748027>

Alloway, T. P., Gathercole, S. E., & Pickering, S. J. (2006). Verbal and Visuospatial Short-Term and Working Memory in Children: Are They Separable? *Child Development*, *77*(6), 1698–1716. https://doi.org/10.1111/j.1467-8624.2006.00968.x

Alvarez, J. A., & Emory, E. (2006). Executive function and the frontal lobes: A meta-analytic review. Neuropsychology Review, 16(1), 17–42. https://doi.org/10.1007/s11065-006-9002-x

Alyahya, R. S., Halai, A. D., Conroy, P., & Ralph, M. A. L. (2018). Noun and verb processing in aphasia: Behavioural profiles and neural correlates. *NeuroImage: Clinical*, *18*, 215-230.

Amunts, J., Camilleri, J. A., Eickhoff, S. B., Patil, K. R., Heim, S., von Polier, G. G., & Weis, S. (2021). Comprehensive verbal fluency features predict executive function performance. Scientific reports, 11(1), 6929.

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. Child neuropsychology, 8(2), 71-82.

Anderson, V. A., Anderson, P., Northam, E., Jacobs, R., & Catroppa, C. (2001). Development of executive functions through late childhood and adolescence in an Australian sample. *Developmental neuropsychology*, *20*(1), 385–406. <https://doi.org/10.1207/S15326942DN2001_5>

Anderson, J. R. (1992). Automaticity and the ACT Theory. The American Journal of Psychology, 105(2), 165–180. https://doi.org/10.2307/1423026

Andrés, P., & Van der Linden, M. (2000). Age-related differences in supervisory attentional system functions. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *55*(6), P373-P380.

Ardila, A. (1995). Directions of research in cross-cultural neuropsychology. *Journal of clinical and experimental neuropsychology*, *17*(1), 143-150.

Ardila, A. (1996). Towards a cross-cultural neuropsychology. Journal of Social and Evolutionary Systems, 19(3), 237-248. https://doi.org/10.1016/S1061-7361(96)90034-X

Ardila, A. (2007) The Impact of Culture on Neuropsychological Test Performance. In Uzzell, B.P., Ponton, M., & Ardila, A. (Eds.). (2007). International Handbook of Cross-Cultural Neuropsychology (1st ed.). Psychology Press. https://doi.org/10.4324/9780203936290

Ardila, A. (2008). On the evolutionary origins of executive functions. Brain and cognition, 68(1), 92-99.

Ardila, A., Bernal, B., & Rosselli, M. (2016). How Localized are Language Brain Areas? A Review of Brodmann Areas Involvement in Oral Language. *Archives of Clinical Neuropsychology*, *31*(1), 112–122. https://doi.org/10.1093/arclin/acv081

Ardila, A., Rosselli, M., & Puente, A. E. (1994). *Neuropsychological evaluation of the Spanish speaker*. Springer Science & Business Media.

Aziz, M. A., Razak, R. & Garraffa, M. (2020). Targeting complex orthography in the treatment of bilingual dysgraphia: a case of a Malay/English speaker with conduction aphasia. Behavioural Science, 10 (7) 109–122.

Aziz, A., Razak, R. & Garraffa, M. (2024). Demographic, Clinical and Language Characteristics of Malaysian Patients with Aphasia: A Retrospective Study. Medicine and Health. 19(1): 82-98.

Babcock, R. L., & Salthouse, T. A. (1990). Effects of Increased Processing Demands on Age Differences in Working Memory. *Psychology and Aging*, *5*(3), 421–428. <https://doi.org/10.1037/0882-7974.5.3.421>

Baddeley, A. (1986). Working Memory. Psychological Medicine, 255(2). https://doi.org/10.1017/s0033291700025228

Baddeley, A. D., Xu, Z., Tung Ho, S., & Hitch, G. J. (2023). On verbal memory span in Chinese speakers: Evidence for employment of an articulation-resistant phonological component. *Journal of Memory and Language*, *129*, 104389. https://doi.org/10.1016/j.jml.2022.104389

Baldo, J. V., & Shimamura, A. P. (1998). Letter and category fluency in patients with frontal lobe lesions. Neuropsychology, 12(2), 259.

Baldo, J. V., Schwartz, S., Wilkins, D., & Dronkers, N. F. (2006). Role of frontal versus temporal cortex in verbal fluency as revealed by voxel-based lesion symptom mapping. *Journal of the International Neuropsychological Society*, *12*(6), 896–900. <https://doi.org/10.1017/S1355617706061078>

Baldo, J. V., Shimamura, A. P., Delis, D. C., Kramer, J., & Kaplan, E. (2001). Verbal and design fluency in patients with frontal lobe lesions. Journal of the international neuropsychological society, 7(5), 586-596.

Banich, M. T. (2009). Executive function: The search for an integrated account. Current directions in psychological science, 18(2), 89-94.

Baron, I. S. (2003). Neuropsychological Evaluation of the Child. Oxford University Press. https://books.google.co.uk/books?id=VzlnDAAAQBAJ

Barr W. B. (2003). Neuropsychological testing of high school athletes. Preliminary norms and test-retest indices. *Archives of clinical neuropsychology : the official journal of the National Academy of Neuropsychologists*, *18*(1), 91–101.

Bastiaanse, R., & Jonkers, R. (1998). Verb retrieval in action naming and spontaneous speech in agrammatic and anomic aphasia. *Aphasiology*, *12*(11), 951–969. https://doi.org/10.1080/02687039808249463

Bates, E., Friederici, A., & Wulfeck, B. (1987). Comprehension in aphasia: A cross-linguistic study. *Brain and language*, *32*(1), 19-67.

Bayard, S., Gély-Nargeot, M. C., Raffard, S., Guerdoux-Ninot, E., Kamara, E., Gros-Balthazard, F., Jacus, J. P., Moroni, C., & Collège des Psychologues Cliniciens spécialisés en Neuropsychologie du Languedoc Roussillon (CPCN-Languedoc Roussillon) (2017). French Version of the Hayling Sentence Completion Test, Part I: Normative Data and Guidelines for Error Scoring. *Archives of clinical neuropsychology : the official journal of the National Academy of Neuropsychologists*, *32*(5), 585–591. <https://doi.org/10.1093/arclin/acx010>

Bayard, S., Gély-Nargeot, M. C., Raffard, S., Guerdoux-Ninot, E., Kamara, E., Gros-Balthazard, F., ... & Collège des Psychologues Cliniciens spécialisés en Neuropsychologie du Languedoc Roussillon (CPCN-Languedoc Roussillon). (2017). French version of the hayling sentence completion test, part I: normative data and guidelines for error scoring. *Archives of Clinical Neuropsychology*, *32*(5), 585-591.

Beaton, D. E., Bombardier, C., Guillemin, F., & Ferraz, M. B. (2000). Guidelines for the process of cross-cultural adaptation of self-report measures. *Spine*, *25*(24), 3186–3191. <https://doi.org/10.1097/00007632-200012150-00014>

Beerten-Duijkers, J. C., VISSERS, C. T., Rinck, M., Barkley, R. A., & Egger, J. I. (2019). Dutch translation and adaptation of the Barkley Deficits in Executive Functioning Scale (BDEFS). *Archives of Clinical Psychiatry (São Paulo)*, *46*, 89-96.

Belleville, S., Rouleau, N., & Caza, N. (1998). Effect of Normal Aging on the Manipulation of Information in Working Memory. *Memory & Cognition*, *26*(3), 572–583. <https://doi.org/10.3758/BF03201163>

Belleville, S., Rouleau, N., & Van der Linden, M. (2006). Use of the Hayling task to measure inhibition of prepotent responses in normal aging and Alzheimer’s disease. *Brain and cognition*, *62*(2), 113-119.

Benson, D. F., & Ardila, A. (1996). *Aphasia: A Clinical Perspective*. Oxford University Press. https://books.google.co.uk/books?id=iZ8PfkgGiOUC

Benson, D. F., & Geschwind, N. (1971). The Aphasia and Related Disturbances. In A. B. Baker, L. Baker, & R. Joynt (Eds.), *Clinical neurology* (3rd ed.). Harper & Row.

Benton, A. L. (1968). Differential behavioral effects in frontal lobe disease. *Neuropsychologia*, *6*(1), 53–60. <https://doi.org/10.1016/0028-3932(68)90038-9>

Benton, A. L. (1991). The prefrontal region: Its early history. Frontal lobe function and dysfunction, 3-32.

Berg, K., Isaksen, J., Wallace, S. J., Cruice, M., Simmons-Mackie, N., & Worrall, L. (2022). Establishing consensus on a definition of aphasia: an e-Delphi study of international aphasia researchers. *Aphasiology*, *36*(4), 385-400.

Best, J. R., Miller, P. H., & Jones, L. L. (2009). Executive Functions after Age 5: Changes and Correlates. Developmental review: DR, 29(3), 180–200. https://doi.org/10.1016/j.dr.2009.05.002

Bialystok, E., & Viswanathan, M. (2009). Components of executive control with advantages for bilingual children in two cultures. *Cognition*, *112*(3), 494–500. https://doi.org/10.1016/j.cognition.2009.06.014

Bialystok, E., Craik, F. I. M., & Luk, G. (2008). Lexical access in bilinguals: Effects of vocabulary size and executive control. *Journal of Neurolinguistics*, *21*(6), 522–538. https://doi.org/10.1016/j.jneuroling.2007.07.001

Bialystok, E., Craik, F. I. M., & Ryan, J. (2006). Executive Control in a Modified Antisaccade Task. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *32*(6), 1341–1354. <https://doi.org/10.1037/0278-7393.32.6.1341>

Bielak, A. A. M., Mansueti, L., Strauss, E., & Dixon, R. A. (2006). Performance on the Hayling and Brixton tests in older adults: Norms and correlates. *Archives of Clinical Neuropsychology*, *21*(2), 141–149. https://doi.org/10.1016/j.acn.2005.08.006

Blumstein, S. E., Milberg, W., & Shrier, R. (1982). Semantic processing in aphasia: evidence from an auditory lexical decision task. *Brain and language*, *17*(2), 301–315. <https://doi.org/10.1016/0093-934x(82)90023-2>

Bonini, M. V., & Radanovic, M. (2015). Cognitive deficits in post-stroke aphasia. *Arquivos de neuro-psiquiatria*, *73*(10), 840–847. https://doi.org/10.1590/0004-282X20150133

Bopp, K. L., & Verhaeghen, P. (2005). Aging and Verbal Memory Span: A Meta-Analysis. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences*, *60*(5), P223–P233. <https://doi.org/10.1093/geronb/60.5.P223>

Bose, A., Wood, R., & Kiran, S. (2017). Semantic fluency in aphasia: clustering and switching in the course of 1 minute: Semantic fluency in aphasia. *International Journal of Language & Communication Disorders*, *52*(3), 334–345. https://doi.org/10.1111/1460-6984.12276

Boye, K., & Harder, P. (2012). A Usage-Based Theory of Grammatical Status And Grammaticalization. *Language*, *88*(1), 1–44. http://www.jstor.org/stable/41348882

Brickner, R. M. (1936). The Intellectual Functions of the Frontal Lobes, Physical Therapy, Volume 17, Issue 6, June 1937, 261, https://doi.org/10.1093/ptj/17.6.261b

Brickner, R.M. (1934). An interpretation of frontal lobe function based upon the study of a case of bilateral frontal lobectomy. In: Orton, S.T., Fulton, J. F., Davis, T. K., (eds). Localization of Function in the Cerebral Cortex. Baltimore: Williams and Wilkins; 1934: 259–351

Broadbent, D. E. (1958). Perception and communication London Pergamon Press, 1958.

Bryan, J., & Luszcz, M. A. (2000). Measurement of Executive Function: Considerations for Detecting Adult Age Differences. *Journal of Clinical and Experimental Neuropsychology*, *22*(1), 40–55. https://doi.org/10.1076/1380-3395(200002)22:1;1-8;FT040

Burda, A. N., Andersen, E., Berryman, M., Heun, M., King, C., & Kise, T. (2017). Performance of young, middle-aged, and older adults on tests of executive function. *Canadian Journal of Speech-Language Pathology and Audiology*, *41*(3), 253–262.

Burgess, P. W., & Shallice, T. (1996). Response suppression, initiation and strategy use following frontal lobe lesions. *Neuropsychologia*, *34*(4), 263–272. <https://doi.org/10.1016/0028-3932(95)00104-2>

Burgess, P. W., & Shallice, T. (1997). *The Hayling and Brixton tests*. Bury St. Edmunds, England: Thames Valley Test Company. [doi:10.1097/NMD.0000000000000366](http://dx.doi.org/10.1097/NMD.0000000000000366).

Butler, K. M., & Zacks, R. T. (2006). Age Deficits in the Control of Prepotent Responses. *Psychology and Aging*, *21*(3), 638–643. https://doi.org/10.1037/0882-7974.21.3.638

Cabbage, K., Brinkley, S., Gray, S., Alt, M., Cowan, N., Green, S., Kuo, T., & Hogan, T. P. (2017). Assessing working memory in children: The comprehensive assessment battery for children-working memory (CABC-WM). *Journal of Visualized Experiments*, *2017*(124). https://doi.org/10.3791/55121

Cahana-Amitay, D., & Jenkins, T. (2018). Working memory and discourse production in people with aphasia. *Journal of Neurolinguistics*, *48*, 90–103. https://doi.org/https://doi.org/10.1016/j.jneuroling.2018.04.007

Caplan, D. (1987). *Neurolinguistics and Linguistic Aphasiology: An Introduction*. Cambridge University Press. https://doi.org/10.1017/CBO9780511620676

Caplan, D., & Waters, G. S. (1990). Short-term memory and language comprehension: A critical review of the neuropsychological literature. In Neuropsychological impairments of short-term memory. (pp. 337–389). Cambridge University Press. https://doi.org/10.1017/CBO9780511665547.019

Caplan, D., Michaud, J., & Hufford, R. (2013). Short-term memory, working memory, and syntactic comprehension in aphasia. *Cognitive Neuropsychology*, *30*(2), 77–109. https://doi.org/10.1080/02643294.2013.803958

Caramazza, A., Basili, A. G., Koller, J. J., & Berndt, R. S. (1981). An investigation of repetition and language processing in a case of conduction aphasia. *Brain and Language*, *14*(2), 235–271. https://doi.org/https://doi.org/10.1016/0093-934X(81)90078-X

Caramazza, A., Berndt, R. S., & Koller, J. J. (1981). Syntactic processing deficits in aphasia. *Cortex*, *17*(3), 333-347.

Carpenter, E., Rao, L., Peñaloza, C., & Kiran, S. (2020). Verbal fluency as a measure of lexical access and cognitive control in bilingual persons with aphasia. *Aphasiology*, *34*(11), 1341-1362.

Cavaco, S., Goncalves, A., Pinto, C., Almeida, E., Gomes, F., Moreira, I., Fernandes, J., & Teixeira-Pinto, A. (2013). Semantic fluency and phonemic fluency: Regression-based norms for the portuguese population. *Archives of Clinical Neuropsychology*, *28*(3), 262–271. <https://doi.org/10.1093/arclin/act001>

Cervera-Crespo, T., & González-Alvarez, J. (2017). Age and semantic inhibition measured by the hayling task: A meta-analysis. *Archives of Clinical Neuropsychology*, *32*(2), 198–214. <https://doi.org/10.1093/arclin/acw088>

Chan, M. E., & Elliott, J. M. (2011). Cross-Linguistic Differences in Digit Memory Span. *Australian Psychologist*, *46*(1), 25–30. https://doi.org/10.1111/j.1742-9544.2010.00007.x

Chen, Z. Y., Cowell, P. E., Varley, R., & Wang, Y. C. (2009). A cross-language study of verbal and visuospatial working memory span. *Journal of Clinical and Experimental Neuropsychology*, *31*(4), 385-391.

Chiou, H. S., & Kennedy, M. R. T. (2009). Switching in adults with aphasia. *Aphasiology*, *23*(7–8), 1065–1075. https://doi.org/10.1080/02687030802642028

Choi, H. J., Lee, D. Y., Seo, E. H., Jo, M. K., Sohn, B. K., Choe, Y. M., Byun, M. S., Kim, J. W., Kim, S. G., Yoon, J. C., Jhoo, J. H., Kim, K. W., & Woo, J. I. (2014). A normative study of the digit span in an educationally diverse elderly population. *Psychiatry investigation*, *11*(1), 39–43. https://doi.org/10.4306/pi.2014.11.1.39

Choi, Y., & Trueswell, J. C. (2010). Children’s (in) ability to recover from garden paths in a verb-final language: Evidence for developing control in sentence processing. Journal of experimental child psychology, 106(1), 41-61.

Choinski, M., Szelag, E., Wolak, T., & Szymaszek, A. (2020). Working Memory in Aphasia: The Role of Temporal Information Processing. *Frontiers in Human Neuroscience*, *14*, 589802–589802. https://doi.org/10.3389/fnhum.2020.589802

Chu, S. Y., Khoong, E. S. Q., Ismail, F. N. M., Altaher, A. M., & Razak, R. A. (2019). Speech-language pathology in Malaysia: Perspectives and challenges. *Perspectives of the ASHA Special Interest Groups*, *4*(5), 1162-1166.

Clark, D. G., & Cummings, J. L. (1999). Cognitive and Behavioral Disorders Chapter 25. *Behavioral Disorders*, 265–275.

Coelho, C., Lê, K., Mozeiko, J., Hamilton, M., Tyler, E., Krueger, F., & Grafman, J. (2013). Characterizing discourse deficits following penetrating head injury: a preliminary model. American journal of speech-language pathology, 22(2), S438–S448. https://doi.org/10.1044/1058-0360(2013/12-0076)

Collette, F., Schmidt, C., Scherrer, C., Adam, S., & Salmon, E. (2009). Specificity of inhibitory deficits in normal aging and Alzheimer's disease. *Neurobiology of Aging*, *30*(6), 875–889. https://doi.org/10.1016/j.neurobiolaging.2007.09.007

Colman, K. S. F., Koerts, J., Stowe, L. A., Leenders, K. L., & Bastiaanse, R. (2011). Sentence Comprehension and Its Association with Executive Functions in Patients with Parkinson’s Disease. *Parkinson's Disease*, *2011*, 213983–15. <https://doi.org/10.4061/2011/213983>

Coppens, P., Hungerford, S., Yamaguchi, S., & Yamadori, A. (2002). Crossed aphasia: an analysis of the symptoms, their frequency, and a comparison with left-hemisphere aphasia symptomatology. *Brain and language*, *83*(3), 425–463. <https://doi.org/10.1016/s0093-934x(02)00510-2>

Crawford, J. R., Bryan, J., Luszcz, M. A., Obonsawin, M. C., & Stewart, L. (2000). The executive decline hypothesis of cognitive aging: Do executive deficits qualify as differential deficits and do they mediate age-related memory decline?. Aging, Neuropsychology, and Cognition, 7(1), 9-31.

Cristofori, I., Cohen-Zimerman, S., & Grafman, J. (2019). Executive functions. In M. D'Esposito & J. H. Grafman (Eds.), Handbook of Clinical Neurology (Vol. 163, pp. 197-219). Elsevier. https://doi.org/10.1016/B978-0-12-804281-6.00011-2

Curtiss, G., Vanderploeg, R. D., Spencer, J. A. N., & Salazar, A. M. (2001). Patterns of verbal learning and memory in traumatic brain injury. *Journal of the International Neuropsychological Society*, *7*(5), 574-585.

Damasio, A. R. (1992). Aphasia. In *The New England Journal of Medicine* (Vol. 326, Issue 8, pp. 531–539). Massachusetts Medical Society. https://doi.org/10.1056/NEJM199202203260806

Damasio, A. R., & Damasio, H. (2000). Aphasia and the Neural Basis of Language. In M. Marsel (Ed.), *Principles of Behavioral and Cognitive Neurology* (pp. 1–25). Oxford University Press.

Danly, M., Cooper, W. E., & Shapiro, B. (1983). Fundamental frequency, language processing, and linguistic structure in Wernicke’s aphasia. *Brain and Language*, *19*(1), 1–24. https://doi.org/https://doi.org/10.1016/0093-934X(83)90052-4

Darcy, I., Mora, J. C., & Daidone, D. (2016). The role of inhibitory control in second language phonological processing. Language Learning, 66(4), 741-773.

Dassanayake, T. L., Hewawasam, C., Baminiwatta, A., & Ariyasinghe, D. I. (2021). Regression-based, demographically adjusted norms for Victoria Stroop Test, Digit Span, and Verbal Fluency for Sri Lankan adults. *Clinical Neuropsychologist*, *35*(S1), S32–S49. https://doi.org/10.1080/13854046.2021.1973109

Delaloye, C., Moy, G., Baudois, S., De Bilbao, F., Dubois Remund, C., Hofer, F., Ragno Paquier, C., Weber, K., Urben, S., & Giannakopoulos, P. (2009). The contribution of aging to the understanding of the dimensionality of executive functions. *Archives of Gerontology and Geriatrics*, *49*(1), e51–e59. <https://doi.org/10.1016/j.archger.2008.08.011>

Delgado-Losada, M. L., Rubio-Valdehita, S., López-Higes, R., Campos-Magdaleno, M., Ávila-Villanueva, M., Frades-Payo, B., & Lojo-Seoane, C. (2023). Phonological fluency norms for Spanish middle-aged and older adults provided by the SCAND initiative (P, M, & R). *Journal of the International Neuropsychological Society*, 1–11. <https://doi.org/10.1017/S1355617723000309>

Delis D.C. , Kaplan E. , & Kramer J.H. . ((2001) ). Delis-Kaplan executive function system (D-KEFS), Psychological Corporation: San Antonio,TX.

Dewarrat, G. M., Annoni, J.-M., Fornari, E., Carota, A., Bogousslavsky, J., & Maeder, P. (2009). Acute aphasia after right hemisphere stroke. *Journal of Neurology*, *256*(9), 1461–1467. https://doi.org/10.1007/s00415-009-5137-z

Diamond A. (2013). Executive functions. *Annual review of psychology*, *64*, 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Dignam, J., Copland, D., O'Brien, K., Burfein, P., Khan, A., & Rodriguez, A. D. (2017). Influence of Cognitive Ability on Therapy Outcomes for Anomia in Adults With Chronic Poststroke Aphasia. *Journal of speech, language, and hearing research : JSLHR*, *60*(2), 406–421. <https://doi.org/10.1044/2016_JSLHR-L-15-0384>

Dingwall, K. M., Lindeman, M. A., & Cairney, S. (2014). “You’ve got to make it relevant”: barriers and ways forward for assessing cognition in Aboriginal clients. *BMC Psychology*, *2*(1). https://doi.org/10.1186/2050-7283-2-13

Dronkers, N. F. (2000). The pursuit of brain-language relationships. *Brain and Language*, *71*(1), 59–61. https://doi.org/10.1006/brln.1999.2212

Dronkers, N. F., Wilkins, D. P., Van Valin, R. D., Redfern, B. B., & Jaeger, J. J. (2004). Lesion analysis of the brain areas involved in language comprehension. *Cognition*, *92*(1), 145–177. https://doi.org/https://doi.org/10.1016/j.cognition.2003.11.002

Dronkers, N., & Ogar, J. (2004). Brain areas involved in speech production. *Brain*, *127*(7), 1461–1462. https://doi.org/10.1093/brain/awh233

Dronkers, N., Redfern, B. B., & Knight, R. (2000). The Neural Architecture of Language. In M. Gazzaniga (Ed.), *New Cognitive Neurosciences* (2nd ed., pp. 949–958). MIT Press.

Dubois, B., & Pillon, B. (1997). Cognitive deficits in Parkinson's disease. Journal of neurology, 244(1), 2–8. https://doi.org/10.1007/pl00007725

Duncan, J., Burgess, P., & Emslie, H. (1995). Fluid intelligence after frontal lobe lesions. *Neuropsychologia*, *33*(3), 261–268. https://doi.org/10.1016/0028-3932(94)00124-8

El Hachioui, H., Visch-Brink, E. G., Lingsma, H. F., van de Sandt-Koenderman, M. W., Dippel, D. W., Koudstaal, P. J., & Middelkoop, H. A. (2014). Nonlinguistic cognitive impairment in poststroke aphasia: a prospective study. *Neurorehabilitation and neural repair*, *28*(3), 273–281. <https://doi.org/10.1177/1545968313508467>

Elgamal, S. A., Roy, E. A., & Sharratt, M. T. (2011). Age and verbal fluency: The mediating effect of speed of processing. *Canadian Geriatrics Journal CGJ*, *14*(3), 66–72. https://doi.org/10.5770/cgj.v14i3.17

Ellis Weismer, S., Kaushanskaya, M., Larson, C., Mathée, J., & Bolt, D. (2018). Executive Function Skills in School-Age Children With Autism Spectrum Disorder: Association With Language Abilities. Journal of speech, language, and hearing research : JSLHR, 61(11), 2641–2658. https://doi.org/10.1044/2018\_JSLHR-L-RSAUT-18-0026

Ellis, N. C., & Hennelly, R. A. (1980). A bilingual word-length effect: Implications for intelligence testing and the relative ease of mental calculation in Welsh and English. *The British Journal of Psychology*, *71*(1), 43–51. https://doi.org/10.1111/j.2044-8295.1980.tb02728.x

England, D., Ruddy, K. L., Dakin, C. J., Schwartz, S. E., Butler, B., & Bolton, D. A. E. (2021). Relationship between speed of response inhibition and ability to suppress a step in midlife and older adults. *Brain Sciences*, *11*(5), 643. https://doi.org/10.3390/brainsci11050643

Erickson, J. M., Quinn, D. K., & Shorter, E. (2016). Moria revisited: translation of Moritz Jastrowitz’s description of pathologic giddiness. The Journal of neuropsychiatry and clinical neurosciences, 28(2), 74-76.

Fisk, J. E., & Sharp, C. A. (2010). Age-Related Impairment in Executive Functioning: Updating, Inhibition, Shifting, and Access. Https://Doi.Org/10.1080/13803390490510680, 26(7), 874–890. https://doi.org/10.1080/13803390490510680

Fonseca, J., Raposo, A., & Martins, I. P. (2019). Cognitive functioning in chronic post-stroke aphasia. *Applied neuropsychology. Adult*, *26*(4), 355–364. <https://doi.org/10.1080/23279095.2018.1429442>

Frankel, T., Penn, C., & Ormond‐Brown, D. (2007). Executive dysfunction as an explanatory basis for conversation symptoms of aphasia: A pilot study. *Aphasiology*, *21*(6–8), 814–828. https://doi.org/10.1080/02687030701192448

Franzen, S., European Consortium on Cross-Cultural Neuropsychology (ECCroN), Watermeyer, T. J., Pomati, S., Papma, J. M., Nielsen, T. R., Narme, P., Mukadam, N., Lozano-Ruiz, Á., Ibanez-Casas, I., Goudsmit, M., Fasfous, A., Daugherty, J. C., Canevelli, M., Calia, C., van den Berg, E., & Bekkhus-Wetterberg, P. (2022). Cross-cultural neuropsychological assessment in Europe: Position statement of the European Consortium on Cross-Cultural Neuropsychology (ECCroN). *The Clinical neuropsychologist*, *36*(3), 546–557. https://doi.org/10.1080/13854046.2021.1981456

Franzen, S., van den Berg, E., Goudsmit, M., Jurgens, C. K., Van De Wiel, L., Kalkisim, Y., ... & Papma, J. M. (2020). A systematic review of neuropsychological tests for the assessment of dementia in non-western, low-educated or illiterate populations. *Journal of the International Neuropsychological Society*, *26*(3), 331-351.

Franzen, S., Watermeyer, T. J., Pomati, S., Papma, J. M., Nielsen, T. R., Narme, P., Mukadam, N., Lozano-Ruiz, Álvaro, Ibanez-Casas, I., Goudsmit, M., Fasfous, A., Daugherty, J. C., Canevelli, M., Calia, C., van den Berg, E., & Bekkhus-Wetterberg, P. (2022). Cross-cultural neuropsychological assessment in Europe: Position statement of the European Consortium on Cross-Cultural Neuropsychology (ECCroN). *Clinical Neuropsychologist*, *36*(3), 546–557. <https://doi.org/10.1080/13854046.2021.1981456>

Fridriksson, J., Nettles, C., Davis, M., Morrow, L., & Montgomery, A. (2006). Functional communication and executive function in aphasia. *Clinical Linguistics & Phonetics*, *20*(6), 401–410. https://doi.org/10.1080/02699200500075781

Fridriksson, J., Yourganov, G., Bonilha, L., Basilakos, A., Den Ouden, D.-B., & Rorden, C. (2016). Revealing the dual streams of speech processing. *Proceedings of the National Academy of Sciences of the United States of America*, *113*(52), 15108–15113. https://doi.org/10.1073/pnas.1614038114

Friederici, A. D. (2011). The brain basis of language processing: From structure to function. Physiological Reviews, 91(4), 1357-1392.

Friederici, A. D., & Singer, W. (2015). Grounding language processing on basic neurophysiological principles. Trends in Cognitive Sciences, 19(6), 329-338. https://doi.org/10.1016/j.tics.2015.03.012

Friederici, A. D., Steinhauer, K., Mecklinger, A., & Meyer, M. (1998). Working memory constraints on syntactic ambiguity resolution as revealed by electrical brain responses. Biological psychology, 47(3), 193–221. https://doi.org/10.1016/s0301-0511(97)00033-1

Friedman, N. P., Miyake, A., Young, S. E., DeFries, J. C., Corley, R. P., & Hewitt, J. K. (2008). Individual Differences in Executive Functions Are Almost Entirely Genetic in Origin. Journal of Experimental Psychology. General, 137(2), 201. https://doi.org/10.1037/0096-3445.137.2.201

Fucetola, R., Connor, L. T., Strube, M. J., & Corbetta, M. (2009). Unravelling nonverbal cognitive performance in acquired aphasia. *Aphasiology*, *23*(12), 1418-1426.

Funahashi, S. (2001). Neuronal mechanisms of executive control by the prefrontal cortex. Neuroscience Research, 39(2), 147–165. https://doi.org/10.1016/S0168-0102(00)00224-8

Fuster, J. (1997). The Prefrontal Cortex Anatomy, Physiology and Neuropsychology of the Frontal Lobe. In V. Clinical studies. https://www.researchgate.net/publication/274384343\_The\_Prefrontal\_Cortex\_Anatomy\_Physiology\_and\_Neuropsychology\_of\_the\_Frontal\_Lobe

Fyndanis, V., Arcara, G., Christidou, P., & Caplan, D. (2018). Morphosyntactic Production and Verbal Working Memory: Evidence From Greek Aphasia  and Healthy Aging. *Journal of Speech, Language, and Hearing Research : JSLHR*, *61*(5), 1171–1187. https://doi.org/10.1044/2018\_JSLHR-L-17-0103

Garcia E., Rodriguez C., Martin R., Jimenez J. E., Hernandez S., Dıaz A. (2012). Test de fluidez verbal: Datos normativos y desarrollo evolutivo en el alumnado de primaria [Verbal Fluency Test: normative data and evolutionary development in elementary students]. *European Journal of Education and Psychology*, 5, 53-64.

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: a review using an integrative framework. Psychological Bulletin, 134(1), 31–60. https://doi.org/10.1037/0033-2909.134.1.31

Garraffa, M., & Fyndanis, V. (2020). Linguistic theory and aphasia: An overview. *Aphasiology*, *34*(8), 905-926.

Ghasemian-Shirvan, E., Shirazi, S. M., Aminikhoo, M., Zareaan, M., & Ekhtiari, H. (2018). Preliminary normative data of Persian phonemic and semantic verbal fluency test. *Iranian Journal of Psychiatry*, *13*(4), 288–295.

Gibson, E. C., Barker, M. S., Martin, A. K., & Robinson, G. A. (2019). Initiation, Inhibition and Strategy Generation Across the Healthy Adult Lifespan. *Archives of Clinical Neuropsychology*, *34*(4), 511–523. <https://doi.org/10.1093/arclin/acy057>

Gibson, E. C., Barker, M. S., Martin, A. K., & Robinson, G. A. (2019). Initiation, Inhibition and Strategy Generation across the Healthy Adult Lifespan. *Archives of Clinical Neuropsychology*, *34*(4), 511–523. https://doi.org/10.1093/arclin/acy057

Gignac, G. E., Kovacs, K., & Reynolds, M. R. (2018). Backward and forward serial recall across modalities: An individual differences perspective. *Personality and Individual Differences*, *121*, 147–151. <https://doi.org/10.1016/j.paid.2017.09.033>

Gilbert, S. J., & Burgess, P. W. (2008). Executive function. Current biology : CB, 18(3), R110–R114. https://doi.org/10.1016/j.cub.2007.12.014

Gilmore, N., Meier, E. L., Johnson, J. P., & Kiran, S. (2019). Nonlinguistic Cognitive Factors Predict Treatment-Induced Recovery in Chronic Poststroke Aphasia. Archives of physical medicine and rehabilitation, 100(7), 1251–1258. https://doi.org/10.1016/j.apmr.2018.12.024

Gioia, G. A., Isquith, P. K., Guy, S. C., Kenworthy, L., & Baron, I. S. (2010). TEST REVIEW Behavior Rating Inventory of Executive Function. Child Neuropsychology, 6(3), 235–238. https://doi.org/10.1076/CHIN.6.3.235.3152

Glisky E. L. (2007). “Changes in cognitive function in human aging” In *Brain Aging: Models, Methods, and Mechanisms*. ed. Riddle D. R. (Boca Raton (FL): CRC Press/Taylor & Francis)

Glisky, E. L. (2007). Changes in cognitive function in human aging. Brain aging: Models, methods, and mechanisms, 1, 3-20.

Glosser, G., & Goodglass, H. (1990). Disorders in executive control functions among aphasic and other brain-damaged patients. *Journal of Clinical and Experimental Neuropsychology*, *12*(4), 485–501. https://doi.org/10.1080/01688639008400995

Godefroy, O. (2003). Frontal syndrome and disorders of executive functions. Journal of neurology, 250, 1-6.

Goldstein, K. (1944). The mental changes due to frontal lobe damage. The Journal of Psychology, 17(2), 187-208.

Goldstein, K., & Scheerer, M. (1941). Abstract and concrete behavior an experimental study with special tests. Psychological monographs, 53(2), i.

Goldstein, S., Naglieri, J. A., Princiotta, D., & Otero, T. M. (2014). Introduction: A history of executive functioning as a theoretical and clinical construct. In Handbook of executive functioning. (pp. 3–12). Springer Science + Business Media. https://doi.org/10.1007/978-1-4614-8106-5\_1

Gonçalves, A. P. B., Mello, C., Pereira, A. H., Ferré, P., Fonseca, R. P., & Joanette, Y. (2018). Executive functions assessment in patients with language impairment A systematic review. Dementia & neuropsychologia, 12(3), 272–283. https://doi.org/10.1590/1980-57642018dn12-030008

Gonçalves, H. A., Cargnin, C., Jacobsen, G. M., Kochhann, R., Joanette, Y., & Fonseca, R. P. (2017). Clustering and switching in unconstrained, phonemic and semantic verbal fluency: the role of age and school type. *Journal of Cognitive Psychology*, *29*(6), 670-690.

Goodglass, H., & Wingfield, A. (1997). *Anomia: Neuroanatomical and cognitive correlates*. Academic Press.

Goodglass, H., Gleason, J. B., Bernholtz, N. A., & Hyde, M. R. (1972). Some linguistic structures in the speech of a Broca’s aphasic. In *Cortex: A Journal Devoted to the Study of the Nervous System and Behavior* (Vol. 8, Issue 2, pp. 191–212). Masson Italia. https://doi.org/10.1016/S0010-9452(72)80018-2

Goral, M., Clark-Cotton, M., Spiro, A., 3rd, Obler, L. K., Verkuilen, J., & Albert, M. L. (2011). The contribution of set switching and working memory to sentence processing in older adults. Experimental aging research, 37(5), 516–538. https://doi.org/10.1080/0361073X.2011.619858

Gordon, J. K., Young, M., & Garcia, C. (2018). Why do older adults have difficulty with semantic fluency?. *Neuropsychology, development, and cognition. Section B, Aging, neuropsychology and cognition*, *25*(6), 803–828. <https://doi.org/10.1080/13825585.2017.1374328>

Grant, D. A., & Berg, E. (1948). A behavioral analysis of degree of reinforcement and ease of shifting to new responses in a Weigl-type card-sorting problem. Journal of experimental psychology, 38(4), 404.

Grégoire, J., & Van der Linden, M. (1997). Effect of age on forward and backward digit spans. *Aging, neuropsychology, and cognition*, *4*(2), 140-149.

Grossman, M., Carvell, S., Gollomp, S., Stern, M. B., Vernon, G., & Hurtig, H. I. (1991). Sentence comprehension and praxis deficits in Parkinson's disease. Neurology, 41(10), 1620–1626. https://doi.org/10.1212/wnl.41.10.1620

Hagoort, P. (1993). Impairments of lexical-semantic processing in aphasia: Evidence from the processing of lexical ambiguities. *Brain and Language*, *45*(2), 189–232.

Halstead, W. C. (1940). Preliminary analysis of grouping behavior in patients with cerebral injury by the method of equivalent and non-equivalent stimuli. American Journal of Psychiatry, 96(6), 1263-1294.

Hanks, R. A., Allen, J. B., Ricker, J. H., & Deshpande, S. A. (1996). Normative data on a measure of design fluency: The Make a Figure Test. *Assessment*, *3*(4), 459-466.

Harpaz, Y., Levkovitz, Y., & Lavidor, M. (2009). Lexical ambiguity resolution in Wernicke’s area and its right homologue. *Cortex; a Journal Devoted to the Study of the Nervous System and Behavior*, *45*(9), 1097–1103. https://doi.org/10.1016/j.cortex.2009.01.002

Hartwigsen, G., & Siebner, H. R. (2012). Probing the involvement of the right hemisphere in language processing with online transcranial magnetic stimulation in healthy volunteers. *Aphasiology*, *26*(9), 1131–1152. https://doi.org/10.1080/02687038.2011.590573

Hartwigsen, G., Baumgaertner, A., Price, C. J., Koehnke, M., Ulmer, S., & Siebner, H. R. (2010). Phonological decisions require both the left and right supramarginal gyri. *Proceedings of the National Academy of Sciences*, *107*(38), 16494 LP – 16499. https://doi.org/10.1073/pnas.1008121107

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. *Psychology of learning and motivation*, *22*, 193-225.

Hasher, L., Zacks, R. T., & May, C. P. (1999). Inhibitory control, circadian arousal, and age. In D. Gopher & A. Koriat (Eds.), *Attention and performance XVII: Cognitive regulation of performance: Interaction of theory and application* (pp. 653–675). The MIT Press.

Hassan, M., Lee, G.Z.H., Razak, R.A., Aziz, M.A., Singh, S.J. (2023). The management of multilingual adults with aphasia in Malaysia: Current practices, needs, and challenges. Aphasiology 2023: 1-23.

Heaton, R. K. (1981). Wisconsin card sorting test manual. Psychological assessment resources.

Hedden, T., Lautenschlager, G., & Park, D. C. (2005). Contributions of processing ability and knowledge to verbal memory tasks across the adult life-span. *The Quarterly Journal of Experimental Psychology Section A*, *58*(1), 169-190.

Hedden, T., Park, D. C., Nisbett, R., Ji, L.-J., Jing, Q., & Jiao, S. (2002). Cultural Variation in Verbal Versus Spatial Neuropsychological Function Across the Life Span. *Neuropsychology*, *16*(1), 65–73. https://doi.org/10.1037/0894-4105.16.1.65

Henry, J. D., & Crawford, J. R. (2004). A meta-analytic review of verbal fluency performance in patients with traumatic brain injury. *Neuropsychology*, *18*(4), 621.

Henry, J. D., Crawford, J. R., & Phillips, L. H. (2004). Verbal fluency performance in dementia of the Alzheimer’s type: a meta-analysis. *Neuropsychologia*, *42*(9), 1212–1222. https://doi.org/10.1016/j.neuropsychologia.2004.02.001

Henry, L. A., Messer, D. J., & Nash, G. (2012). Executive functioning in children with specific language impairment. Journal of child psychology and psychiatry, and allied disciplines, 53(1), 37–45. <https://doi.org/10.1111/j.1469-7610.2011.02430.x>

Hester, R. L., Kinsella, G. J., & Ong, B. (2004). Effect of age on forward and backward span tasks. *Journal of the International Neuropsychological Society*, *10*(4), 475–481. https://doi.org/10.1017/S1355617704104037

Hickok, G., & Poeppel, D. (2007). The cortical organization of speech processing. *Nature Reviews. Neuroscience*, *8*(5), 393–402. https://doi.org/10.1038/nrn2113

Higby, E., Cahana-Amitay, D., Vogel-Eyny, A., Spiro III, A., Albert, M. L., & Obler, L. K. (2019). The role of executive functions in object-and action-naming among older adults. Experimental aging research, 45(4), 306-330.

Hochstadt, J., Nakano, H., Lieberman, P., & Friedman, J. (2006). The roles of sequencing and verbal working memory in sentence comprehension deficits in Parkinson’s disease. Brain and language, 97(3), 243-257.

Hocking, J., & Price, C. J. (2009). Dissociating verbal and nonverbal audiovisual object processing. *Brain and Language*, *108*(2), 89–96. https://doi.org/10.1016/j.bandl.2008.10.005

Holdnack, J. A. (2019). The development, expansion, and future of the WAIS-IV as a cornerstone in comprehensive cognitive assessments. In G. Goldstein, D. N. Allen, & J. DeLuca (Eds.), *Handbook of psychological assessment* (pp. 103–139). Elsevier Academic Press. [https://doi.org/10.1016/B978-0-12-802203-0.00004-3](https://psycnet.apa.org/doi/10.1016/B978-0-12-802203-0.00004-3)

Hughes, C., Graham, A. and Grayson, A., 2004. Executive functions in childhood: development and disorder. In: Oates, J. M., and Grayson, A. eds., Cognitive and language development in children. Milton Keynes; Oxford: Open University; Blackwell, pp. 205-230.

Hula, W. D., & McNeil, M. R. (2008). Models of attention and dual-task performance as explanatory constructs in aphasia. *Seminars in Speech and Language*, *29*(3), 164–169. https://doi.org/10.1055/s-0028-1082882

Hunter, S., & Sparrow, E. (2012). Executive function and dysfunction. Cambridge, UK: Cambridge University Press.

Hurks, P. P. M., Schrans, D., Meijs, C., Wassenberg, R., Feron, F. J. M., & Jolles, J. (2010). Developmental Changes in Semantic Verbal Fluency: Analyses of Word Productivity as a Function of Time, Clustering, and Switching. *Child Neuropsychology*, *16*(4), 366–387. https://doi.org/10.1080/09297041003671184

Hurtado-Pomares, M., Valera-Gran, D., Sánchez-Pérez, A., Peral-Gómez, P., Navarrete-Muñoz, E. M., & Terol-Cantero, M. C. (2021). Adaptation of the Spanish version of the Frontal Assessment Battery for detection of executive dysfunction. *Medicina Clínica*, *156*(5), 229-232.

Idowu, M. I., & Szameitat, A. J. (2023). Executive function abilities in cognitively healthy young and older adults—A cross-sectional study. *Frontiers in Aging Neuroscience*, *15*, 976915–976915. https://doi.org/10.3389/fnagi.2023.976915

Ikanga, J., Braggs, P., Howard, C., & Stringer, A. (2019). African Enculturation and Performance on the African Neuropsychological Battery. *Archives of Clinical Neuropsychology*, *34*(6), 858–858. https://doi.org/10.1093/arclin/acz035.26

Im‐Bolter, N., Johnson, J., & Pascual‐Leone, J. (2006). Processing limitations in children with specific language impairment: The role of executive function. Child development, 77(6), 1822-1841.

Iñesta, C., Oltra-Cucarella, J., Bonete-López, B., Calderón-Rubio, E., & Sitges-Maciá, E. (2021). Regression-Based Normative Data for Independent and Cognitively Active Spanish Older Adults: Digit Span, Letters and Numbers, Trail Making Test and Symbol Digit Modalities Test. *International Journal of Environmental Research and Public Health*, *18*(19), 9958. <https://doi.org/10.3390/ijerph18199958>

Izaks, G. J., Joosten, H., Koerts, J., Gansevoort, R. T., & Slaets, J. P. (2011). Reference data for the ruff figural fluency test stratified by age and educational level. *PloS One*, *6*(2), e17045–e17045. <https://doi.org/10.1371/journal.pone.0017045>

Jennekens-Schinkel, A. (1988). Aphasia: FC Rose, R. Whurr and MA Wyke (eds.); Whurr Publishers, London, Jersey City, 1988,£49.95, US $79.95. ISBN 1 870332 00 8. *Journal of the Neurological Sciences*, *87*(1), 139.

Johansson, M. B., Carlsson, M., & Sonnander, K. (2012). Communication difficulties and the use of communication strategies: from the perspective of individuals with aphasia. International journal of language & communication disorders, 47(2), 144–155. https://doi.org/10.1111/j.1460-6984.2011.00089.x

Johansson, M. B., Carlsson, M., & Sonnander, K. (2012). Communication difficulties and the use of communication strategies: from the perspective of individuals with aphasia. *International journal of language & communication disorders*, *47*(2), 144–155. <https://doi.org/10.1111/j.1460-6984.2011.00089.x>

Joseph, R. M., McGrath, L. M., & Tager-Flusberg, H. (2005). Executive dysfunction and its relation to language ability in verbal school-age children with autism. Developmental neuropsychology, 27(3), 361-378.

Kalbe, E., Reinhold, N., Brand, M., Markowitsch, H. J., & Kessler, J. (2005). A new test battery to assess aphasic disturbances and associated cognitive dysfunctions—German normative data on the aphasia check list. Journal of clinical and experimental neuropsychology, 27(7), 779-794.

Kang, E. K., Sohn, H. M., Han, M.-K., & Paik, N.-J. (2017). Subcortical Aphasia After Stroke. *Annals of Rehabilitation Medicine*, *41*(5), 725–733. https://doi.org/10.5535/arm.2017.41.5.725

Kaplan, E. (1991). *WAIS-R as a Neuropsychological Instrument (WAIS-R NI)*. Psychological Corporation.

Karbach, J., & Kray, J. (2016). Executive functions. In T. Strobach & J. Karbach (Eds.), Cognitive training: An overview of features and applications (pp. 93–103). Springer International Publishing AG. https://doi.org/10.1007/978-3-319-42662-4\_9

Kaushanskaya, M., Park, J. S., Gangopadhyay, I., Davidson, M. M., & Weismer, S. E. (2017). The Relationship Between Executive Functions and Language Abilities in Children: A Latent Variables Approach. Journal of speech, language, and hearing research : JSLHR, 60(4), 912–923. https://doi.org/10.1044/2016\_JSLHR-L-15-0310

Kave, G. (2005). Phonemic Fluency, Semantic Fluency, and Difference Scores: Normative Data for Adult Hebrew Speakers. *Journal of Clinical and Experimental Neuropsychology*, *27*(6), 690–699. https://doi.org/10.1080/13803390490918499

Kave, G., & Sapir-Yogev, S. (2020). Associations between memory and verbal fluency tasks. *Journal of Communication Disorders*, *83*, 105968–105968. https://doi.org/10.1016/j.jcomdis.2019.105968

Kave, G., & Sapir-Yogev, S. (2023). Differences Between Semantic and Phonemic Verbal Fluency in Adolescents With Reading Disorders. *Archives of Clinical Neuropsychology*, *38*(1), 126–130. <https://doi.org/10.1093/arclin/acac062>

Kean, M. L. (1977). The linguistic interpretation of aphasic syndromes: Agrammatism in Broca’s aphasia, an example. *Cognition*, *5*(1), 9–46. https://doi.org/10.1016/0010-0277(77)90015-4

Keil, K., & Kaszniak, A. W. (2002). Examining executive function in individuals with brain injury: A review. *Aphasiology*, *16*(3), 305–335. https://doi.org/10.1080/02687030143000654

Kelkar, A. S., Hough, M. S., & Fang, X. (2013). Do we think alike? A cross-cultural study of executive functioning. *Culture and Brain*, *1*(2-4), 118–137. <https://doi.org/10.1007/s40167-013-0010-4>

Kelly, M. A., & Reitter, D. (2018). How Language Processing can Shape a Common Model of Cognition. Procedia Computer Science, 145, 724-729. https://doi.org/10.1016/j.procs.2018.11.047

Kendrick, L. T., Robson, H., & Meteyard, L. (2019). Executive control in frontal lesion aphasia: Does verbal load matter? *Neuropsychologia*, *133*, 107178–107178. <https://doi.org/10.1016/j.neuropsychologia.2019.107178>

Keys, B. A., & White, D. A. (2000). Exploring the relationship between age, executive abilities, and psychomotor speed. *Journal of the International Neuropsychological Society*, *6*(1), 76–82. https://doi.org/10.1017/S1355617700611098

Kirova, A.-M., Bays, R. B., & Lagalwar, S. (2015). Working Memory and Executive Function Decline across Normal Aging, Mild Cognitive Impairment, and Alzheimer’s Disease. *BioMed Research International*, *2015*, 748212–748219. <https://doi.org/10.1155/2015/748212>

Kohen, F., Martin, N., Kalinyak-Fliszar, M., Bunta, F., & Dimarco, L. (2007). Effects of memory load on two measures of semantic knowledge. *Brain and Language*, *1*(103), 187–188.

Kohn, S. E. (1984). The nature of the phonological disorder in conduction aphasia. *Brain and Language*, *23*(1), 97–115. https://doi.org/https://doi.org/10.1016/0093-934X(84)90009-9

Kohn, S. E. (1988). Phonological production deficits in aphasia. In Phonological processes and brain mechanisms (pp. 93–117). Springer.

Kokubo, K., Suzuki, K., Hattori, N., Miyai, I., & Mori, E. (2015). Executive Dysfunction in Patients with Putaminal Hemorrhage. *Journal of stroke and cerebrovascular diseases : the official journal of National Stroke Association*, *24*(9), 1978–1985. <https://doi.org/10.1016/j.jstrokecerebrovasdis.2015.04.047>

Kolb, B., & Whishaw, I. Q. (2009). *Fundamentals of Human Neuropsychology*. Worth Publishers. https://books.google.co.uk/books?id=z0DThNQqdL4C

Lacey, E. H., Skipper-Kallal, L. M., Xing, S., Fama, M. E., & Turkeltaub, P. E. (2017). Mapping Common Aphasia Assessments to Underlying Cognitive Processes and Their Neural Substrates. *Neurorehabilitation and neural repair*, *31*(5), 442–450. <https://doi.org/10.1177/1545968316688797>

Laures-Gore, J., Marshall, R. S., & Verner, E. (2011). Performance of Individuals with Left-Hemisphere Stroke and Aphasia and Individuals with Right Brain Damage on Forward and Backward Digit Span Tasks. *Aphasiology*, *25*(1), 43–56. https://doi.org/10.1080/02687031003714426

Law, B., Young, B., Pinsker, D., & Robinson, G. A. (2015). Propositional speech in unselected stroke: The effect of genre and external support. *Neuropsychological rehabilitation*, *25*(3), 374–401. <https://doi.org/10.1080/09602011.2014.937443>

LeBlanc, J., Seresova, A., Laberge-Poirier, A., Tabet, S., Correa, J. A., Alturki, A. Y., ... & de Guise, E. (2020). Cognitive-communication skills and acute outcome following mild traumatic brain injury. Brain Injury, 34(11), 1472-1479.

Lee, C., Grossman, M., Morris, J., Stern, M. B., & Hurtig, H. I. (2003). Attentional resource and processing speed limitations during sentence processing in Parkinson’s disease. *Brain and Language*, *85*(3), 347–356. https://doi.org/10.1016/S0093-934X(03)00063-4

Lee, L.W., Low, H.M., & Mohamed, A.R. (2013). A Comparative Analysis of Word Structures in Malay and English Children's Stories.

Lezak, M. D. (1995). Neuropsychological Assessment (3rd ed.). New York: Oxford University Press.

Li, S.-C., & Lewandowsky, S. (1995). Forward and Backward Recall: Different Retrieval Processes. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *21*(4), 837–847. https://doi.org/10.1037/0278-7393.21.4.837

Libon, D. J., Glosser, G., Malamut, B. L., Kaplan, E., Goldberg, E., Swenson, R., & Prouty Sands, L. (1994). Age, Executive Functions, and Visuospatial Functioning in Healthy Older Adults. *Neuropsychology*, *8*(1), 38–43. https://doi.org/10.1037/0894-4105.8.1.38

Lichtheim, L. (1885). On aphasia. *Brain*, *7*, 433–484.

Lin, H., Chan, R. C., Zheng, L., Yang, T., & Wang, Y. (2007). Executive functioning in healthy elderly Chinese people. Archives of Clinical Neuropsychology, 22(4), 501-511.

Linck, J. A., Hoshino, N., & Kroll, J. F. (2008). Cross-language lexical processes and inhibitory control. The mental lexicon, 3(3), 349–374. https://doi.org/10.1075/ml.3.3.06lin

Logan, G. D. (1980). Attention and automaticity in Stroop and priming tasks: Theory and data. Cognitive psychology, 12(4), 523-553.

Logiudice, D., Vrantsidis, F., Rayner, V., Dow, B., O'Connor, D., & Runci, S. (2012). A review of translated cognitive assessment tools to assess culturally and linguistically diverse (CALD) older people. *Alzheimer's & Dementia*, *8*(4), P540–P540. <https://doi.org/10.1016/j.jalz.2012.05.1452>

López, E., Steiner, A. J., Hardy, D. J., IsHak, W. W., & Anderson, W. B. (2016). Discrepancies between bilinguals' performance on the Spanish and English versions of the WAIS Digit Span task: Cross-cultural implications. *Applied Neuropsychology. Adult*, *23*(5), 343–352. <https://doi.org/10.1080/23279095.2015.1074577>

Lorenzen, B., & Murray, L. L. (2008). Bilingual aphasia: a theoretical and clinical review. *American journal of speech-language pathology*, *17*(3), 299–317. https://doi.org/10.1044/1058-0360(2008/026)

Luo, L., Luk, G., & Bialystok, E. (2010). Effect of language proficiency and executive control on verbal fluency performance in bilinguals. *Cognition*, *114*(1), 29–41. <https://doi.org/10.1016/j.cognition.2009.08.014>

Luria, A. (1966). *Human brain and psychological processes*. Harper & Row.

Luria, A. R. (1969). Frontal Lobe Syndromes. In P. Vinken & G. Bruyn, (2012.), Handbook of Clinical Neurology (pp. 2–725). North Holland

Luria, A. R. (1976). *Basic Problems of Neurolinguistics*. De Gruyter Mouton. https://doi.org/doi:10.1515/9783110800159

Mancuso, M., Demeyere, N., Abbruzzese, L., Damora, A., Varalta, V., Pirrotta, F., Antonucci, G., Matano, A., Caputo, M., Caruso, M. G., Pontiggia, G. T., Coccia, M., Ciancarelli, I., Zoccolotti, P., & Italian OCS Group (2018). Using the Oxford Cognitive Screen to Detect Cognitive Impairment in Stroke Patients: A Comparison with the Mini-Mental State Examination. *Frontiers in neurology*, *9*, 101. <https://doi.org/10.3389/fneur.2018.00101>

Martin, A. K., Barker, M. S., Gibson, E. C., & Robinson, G. A. (2021). Response initiation and inhibition and the relationship with fluid intelligence across the adult lifespan. *Archives of Clinical Neuropsychology*, *36*(2), 231–242. <https://doi.org/10.1093/arclin/acz044>

Martin, N., Kohen, F., & Kalinyak-Fliszar, M. (2010). *A processing approach to the assessment of language and verbal short-term memory in aphasia*.

Martin, N., Kohen, F., Kalinyak-Fliszar, M., Soveri, A., & Laine, M. (2012). Effects of working memory load on processing of sounds and meanings of words in aphasia. *Aphasiology*, *26*(3–4), 462–493.

Martin, N., Roach, A., Brecher, A., & Lowery, J. (1998). Lexical retrieval mechanisms underlying whole-word perseveration errors in anomic aphasia. *Aphasiology*, *12*(4–5), 319–333. https://doi.org/10.1080/02687039808249536

Martinez-Ferreiro, S., Ishkhanyan, B., Rosell-Clari, V., & Boye, K. (2019). Prepositions and pronouns in connected discourse of individuals with aphasia. *Clinical Linguistics & Phonetics*, *33*(6), 497-517. <https://doi.org/10.1080/02699206.2018.1551935>

Mayer, J. F., Mitchinson, S. I., & Murray, L. L. (2017). Addressing concomitant executive dysfunction and aphasia: previous approaches and the new brain budget protocol. *Aphasiology*, *31*(7), 837–860. https://doi.org/10.1080/02687038.2016.1249333

Mazuka, R., Jincho, N., & Oishi, H. (2009). Development of executive control and language processing. Language and Linguistics Compass, 3(1), 59-89.

McCloskey, G., & Perkins, L. A. (2012). Essentials of executive functions assessment (Vol. 68). John Wiley & Sons.

Mccloskey, G., Perkins, L., & Diviner, B. (2008). Assessment and Intervention for Executive Function Difficulties. Assessment and Intervention for Executive Function Difficulties, 1–362. https://doi.org/10.4324/9780203893753

McDonald, S., & Pearce, S. (1998). Requests That Overcome Listener Reluctance: Impairment Associated with Executive Dysfunction in Brain Injury. *Brain and Language*, *61*(1), 88–104. <https://doi.org/10.1006/brln.1997.1846>

Mega, M. S., & Alexander, M. P. (1994). Subcortical aphasia: the core profile of capsulostriatal infarction. *Neurology*, *44*(10), 1824–1829. https://doi.org/10.1212/wnl.44.10.1824

Meier, E. L., Lo, M., & Kiran, S. (2016). Understanding semantic and phonological processing deficits in adults with aphasia: effects of category and typicality. *Aphasiology*, *30*(6), 719–749. https://doi.org/10.1080/02687038.2015.1081137

Meteyard, L., & Vigliocco, G. (2018). Lexico-Semantics. In Gaskell, M. G. (2018). *The Oxford handbook of psycholinguistics* (pp. 71-95). Oxford University Press. 9780191090424

Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. Annual review of neuroscience, 24(1), 167-202.

Milner, B. (1963). Effects of different brain lesions on card sorting: The role of the frontal lobes. Archives of neurology, 9(1), 90-100.

Milner, B. (1964). Some effects of frontal lobectomy in man. The frontal granular cortex and behavior., 313-334.

Minkina, I., Martin, N., Spencer, K. A., & Kendall, D. L. (2018). Links Between Short-Term Memory and Word Retrieval in Aphasia. *American Journal of Speech-Language Pathology*, *27*(1S), 379–391. <https://doi.org/10.1044/2017_AJSLP-16-0194>

Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: Four general conclusions. Current Directions in Psychological Science, 21(1), 8–14. https://doi.org/10.1177/0963721411429458

Miyake, A., Emerson, M. J., & Friedman, N. P. (2000). Assessment of executive functions in clinical settings: Problems and recommendations. *Seminars in Speech and Language*, *21*(02), 169–183.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The Unity and Diversity of Executive Functions and Their Contributions to Complex “Frontal Lobe” Tasks: A Latent Variable Analysis. *Cognitive Psychology*, *41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

Mohapatra, B., & Marshall, R. S. (2020). Performance differences between aphasia and healthy aging on an executive function test battery. International journal of speech-language pathology, 22(4), 487-497.

Mohd Natar, A. K., Nagappan, R., Ainuddin, H. A., Masuri, G., & Thanapalan, C. K. K. (2015). Psychometric Properties of the Malay Version of the Loewenstein Occupational Therapy Cognitive Assessment for Geriatrics (M-LOTCA-G) Among the Malaysian Elderly Population. *Educational Gerontology*, *41*(1), 27–40. https://doi.org/10.1080/03601277.2014.896542

Mohr, J. P., Watters, W. C., & Duncan, G. W. (1975). Thalamic hemorrhage and aphasia. *Brain and Language*, *2*(1), 3–17. https://doi.org/10.1016/s0093-934x(75)80050-2

Monaco, M., Costa, A., Caltagirone, C., & Carlesimo, G. A. (2015). Erratum to: Forward and backward span for verbal and visuo-spatial data: standardization and normative data from an Italian adult population. *Neurological Sciences*, *36*(2), 345–347. https://doi.org/10.1007/s10072-014-2019-7

Moser, D. C., Fridriksson, J., & Healy, E. W. (2007). Sentence comprehension and general working memory. Clinical linguistics & phonetics, 21(2), 147–156. https://doi.org/10.1080/02699200600782526

Muangpaisan, W., Intalapaporn, S., & Assantachai, P. (2010). Digit span and verbal fluency tests in patients with mild cognitive impairment and normal subjects in Thai-community. *Journal of the Medical Association of Thailand = Chotmaihet thangphaet*, *93*(2), 224–230.

Muniz, J., Elosua, P., & Hambleton, R. K. (2013). International Test Commission Guidelines for test translation and adaptation. *Psicothema*, *25*(2), 151-157.

Murray, L. (2017). Focusing attention on executive functioning in aphasia. Aphasiology, 31(7), 721-724.

Murray, L. L. (2000). The Effects of Varying Attentional Demands on the Word Retrieval Skills of Adults with Aphasia, Right Hemisphere Brain Damage, or No Brain Damage. *Brain and Language*, *72*(1), 40–72. https://doi.org/https://doi.org/10.1006/brln.1999.2281

Murray, L. L. (2012). Attention and other cognitive deficits in aphasia: presence and relation to language  and communication measures. *American Journal of Speech-Language Pathology*, *21*(2), S51-64. https://doi.org/10.1044/1058-0360(2012/11-0067)

Murray, L. L. (2017). Design fluency subsequent to onset of aphasia: a distinct pattern of executive function difficulties? *Aphasiology*, *31*(7), 793–818. https://doi.org/10.1080/02687038.2016.1261248

Nettelbeck, T., & Burns, N. R. (2010). Processing speed, working memory and reasoning ability from childhood to old age. *Personality and Individual Differences*, *48*(4), 379–384. https://doi.org/10.1016/j.paid.2009.10.032

Newcombe, F. (1969). Missile wounds of the brain: A study of psychological deficits. Oxford: Oxford University Press.

Nguyen, C. M., Tan, A., Nguyen, A., Lee, G. J., Qi, W., Thaler, N. S., & Fujii, D. (2023). Cross-cultural considerations for teleneuropsychology with Asian patients. *Clinical Neuropsychologist*, *37*(5), 896–910. <https://doi.org/10.1080/13854046.2021.1948104>

Nicholas, M., Sinotte, M. P., & Helm-Estabrooks, N. (2011). C-Speak Aphasia alternative communication program for people with severe aphasia:  importance of executive functioning and semantic knowledge. *Neuropsychological Rehabilitation*, *21*(3), 322–366. https://doi.org/10.1080/09602011.2011.559051

Niemi, J., & Laine, M. (1997). Syntax and inflectional morphology in Aphasia: Quantitative aspects of Wernicke speakers’ narratives. *Journal of Quantitative Linguistics*, *4*(1–3), 181–189. https://doi.org/10.1080/09296179708590094

Niessen, E., Ant, J. M., Bode, S., Saliger, J., Karbe, H., Fink, G. R., Stahl, J., & Weiss, P. H. (2020). Preserved performance monitoring and error detection in left hemisphere stroke. *NeuroImage Clinical*, *27*, 102307–102307. https://doi.org/10.1016/j.nicl.2020.102307

Norman, D. A., & Shallice, T. (1986). Attention to action. In Consciousness and self-regulation (pp. 1-18). Springer, Boston, MA.

O'Driscoll, K., & Leach, J. P. (1998). “No longer Gage”: an iron bar through the head: Early observations of personality change after injury to the prefrontal cortex. BMJ, 317(7174), 1673-1674.

Ojemann, G. A. (1975). Language and the thalamus: Object naming and recall during and after thalamic stimulation. *Brain and Language*, *2*, 101–120. https://doi.org/https://doi.org/10.1016/S0093-934X(75)80057-5

Olabarrieta-Landa, L., Rivera, D., Galarza-Del-Angel, J., Garza, M. T., Saracho, C. P., Rodríguez, W., Chávez-Oliveros, M., Rábago, B., Leibach, G., Schebela, S., Martínez, C., Luna, M., Longoni, M., Ocampo-Barba, N., Rodríguez, G., Aliaga, A., Esenarro, L., García de la Cadena, C., Perrin, B. P., & Arango-Lasprilla, J. C. (2015). Verbal fluency tests: Normative data for the Latin American Spanish speaking adult population. *NeuroRehabilitation*, *37*(4), 515–561. <https://doi.org/10.3233/NRE-151279>

Olsson, C., Arvidsson, P., & Blom Johansson, M. (2019). Relations between executive function, language, and functional communication in severe aphasia. *Aphasiology*, *33*(7), 821–845. https://doi.org/10.1080/02687038.2019.1602813

Olsson, C., Arvidsson, P., & Blom Johansson, M. (2020). Measuring executive function in people with severe aphasia: Comparing neuropsychological tests and informant ratings. *NeuroRehabilitation*, *46*(3), 299-310.

Ostrosky‐Solís, F., & Lozano, A. (2006). Digit span: Effect of education and culture. *International Journal of Psychology*, *41*(5), 333-341.

Owen, A. M., Downes, J. J., Sahakian, B. J., Polkey, C. E., & Robbins, T. W. (1990). Planning and spatial working memory following frontal lobe lesions in man. Neuropsychologia, 28(10), 1021-1034.

Paap, K. R., Myuz, H. A., Anders, R. T., Bockelman, M. F., Mikulinsky, R., & Sawi, O. M. (2017). No compelling evidence for a bilingual advantage in switching or that frequent language switching reduces switch cost. Journal of Cognitive Psychology (Hove, England), 29(2), 89–112. https://doi.org/10.1080/20445911.2016.1248436

Pakhomov, S. V. S., Eberly, L. E., & Knopman, D. S. (2018). Recurrent perseverations on semantic verbal fluency tasks as an early marker of cognitive impairment. Journal of Clinical and Experimental Neuropsychology, 40(8), 832–840. https://doi.org/10.1080/13803395.2018.1438372Papathanasiou, I., Coppens, P., & Davidson, B. (2017). Aphasia and related neurogenic communication disorders: basic concepts, management, and efficacy. *Aphasia and related neurogenic communication disorders*, *2*, 3-12.

Park, D. C., & Payer, D. (2006). Working Memory Across the Adult Lifespan. In E. Bialystok & F. I. M. Craik (Eds.), *Lifespan cognition: Mechanisms of change* (pp. 128–142). Oxford University Press. [https://doi.org/10.1093/acprof:oso/9780195169539.003.0009](https://psycnet.apa.org/doi/10.1093/acprof:oso/9780195169539.003.0009)

Patra, A., Bose, A., & Marinis, T. (2020). Performance difference in verbal fluency in bilingual and monolingual speakers. *Bilingualism* (Cambridge, England), 23(1), 204–218. <https://doi.org/10.1017/S1366728918001098>

Penn, C., Barber, N., & Fridjhon, P. (2017). Early recovery profiles of language and executive functions after left hemisphere stroke in bilingualism. Aphasiology, 31(7), 741-764.

Penn, C., Frankel, T., Watermeyer, J., & Russell, N. (2010). Executive function and conversational strategies in bilingual aphasia. *Aphasiology*, *24*(2), 288–308. https://doi.org/10.1080/02687030902958399

Pérez-Pérez, A., Matias-Guiu, J. A., Cáceres-Guillén, I., Rognoni, T., Valles-Salgado, M., Fernández-Matarrubia, M., ... & Matías-Guiu, J. (2016). The hayling test: development and normalization of the Spanish version. *Archives of Clinical Neuropsychology*, *31*(5), 411-419.

Peristeri, E., Tsimpli, I. M., Dardiotis, E., & Tsapkini, K. (2020). Effects of executive attention on sentence processing in aphasia. *Aphasiology*, *34*(8), 943–969. https://doi.org/10.1080/02687038.2019.1622647

Perret, E. (1974). The left frontal lobe of man and the suppression of habitual responses in verbal categorical behaviour. *Neuropsychologia*, *12*(3), 323-330.

Peters R. (2006). Ageing and the brain. Postgraduate medical journal, 82(964), 84–88. https://doi.org/10.1136/pgmj.2005.036665

Pino Escobar, G., Kalashnikova, M., & Escudero, P. (2018). Vocabulary matters! The relationship between verbal fluency and measures of inhibitory control in monolingual and bilingual children. *Journal of Experimental Child Psychology*, *170*, 177–189. <https://doi.org/10.1016/j.jecp.2018.01.012>

Poirier, J., & Shapiro, L. P. (2012). Linguistic and psycholinguistic foundations. In R. K. Peach & L. P. Shapiro (Eds.), Cognition and Acquired Language Disorders (pp. 121-146). Mosby. https://doi.org/10.1016/B978-0-323-07201-4.00015-5

Polsinelli, A. J., Moseley, S. A., Grilli, M. D., Glisky, E. L., & Mehl, M. R. (2020). Natural, everyday language use provides a window into the integrity of older adults’ executive functioning. The Journals of Gerontology: Series B, 75(9), e215-e220.

Porteus, S. D. (1950). The Porteus Maze Test and intelligence.

Posner, M., & Snyder, C. (1975). Attention and cognitive control. In D. Balota & E. Marsh (2004), Cognitive Psychology: Key Readings (pp. 205-223). Psychology Press.

Pribram, K. H. (1973). The primate frontal cortex–executive of the brain. In Psychophysiology of the frontal lobes, 293-314. Academic Press.

Princiotta, D., DeVries, M., & Goldstein, S. (2013). Executive functioning as a mediator of age-related cognitive decline in adults. In Handbook of executive functioning (pp. 143-155). New York, NY: Springer New York.

Prins, R., & Bastiaanse, R. (2006). The early history of aphasiology: From the Egyptian surgeons (c. 1700 bc) to Broca. *Aphasiology*, *20*(8), 762-791.

Prior, A., & Gollan, T. H. (2011). Good Language-Switchers are Good Task-Switchers: Evidence from Spanish–English and Mandarin–English Bilinguals. *Journal of the International Neuropsychological Society*, *17*(4), 682–691. <https://doi.org/10.1017/S1355617711000580>

Pulsipher, D. T., Stricker, N. H., Sadek, J. R., & Haaland, K. Y. (2013). Clinical utility of the Neuropsychological Assessment Battery (NAB) after unilateral stroke. *The Clinical neuropsychologist*, *27*(6), 924–945. <https://doi.org/10.1080/13854046.2013.799714>

Purdy, M. (2002). Executive function ability in persons with aphasia. *Aphasiology*, *16*(4–6), 549–557. https://doi.org/10.1080/02687030244000176

Raiford, S. E., Coalson, D. L., Saklofske, D. H., & Weiss, L. G. (2010). Practical issues in WAIS-IV administration and scoring. *WAIS-IV Clinical Use and Interpretation*, 25–59. https://doi.org/10.1016/b978-0-12-375035-8.10002-3

Ramsberger, G. (2005). Achieving conversational success in aphasia by focusing on non-linguistic cognitive skills: A potentially promising new approach. *Aphasiology*, *19*(10-11), 1066–1073. <https://doi.org/10.1080/02687030544000254>

Ratiu, I., & Azuma, T. (2015). Working memory capacity: Is there a bilingual advantage? *Journal of Cognitive Psychology (Hove, England)*, *27*(1), 1–11. https://doi.org/10.1080/20445911.2014.976226

Raymer, A. (2011). Anomic Aphasia. In J. S. Kreutzer, J. DeLuca, & B. Caplan (Eds.), *Encyclopedia of Clinical Neuropsychology* (pp. 172–173). Springer New York. <https://doi.org/10.1007/978-0-387-79948-3_856>

Raz, N. (2000). Aging of the brain and its impact on cognitive performance: Integration of structural and functional findings. In F. I. M. Craik & T. A. Salthouse (Eds.), *The handbook of aging and cognition* (pp. 1–90). Lawrence Erlbaum Associates Publishers.

Reitan, R. M. (1971). Trail Making Test Results for Normal and Brain-Damaged Children. Perceptual and Motor Skills, 33(2), 575-581. https://doi.org/10.2466/pms.1971.33.2.575

Rende, B., Ramsberger, G., & Miyake, A. (2002). Commonalities and Differences in the Working Memory Components Underlying Letter and Category Fluency Tasks. *Neuropsychology*, *16*(3), 309–321. https://doi.org/10.1037/0894-4105.16.3.309

Rivera, D., Olabarrieta-Landa, L., Van der Elst, W., Gonzalez, I., Ferrer-Cascales, R., Peñalver Guia, A. I., Rodriguez-Lorenzana, A., Galarza-del-Angel, J., Irías Escher, M. J., & Arango-Lasprilla, J. C. (2021). Regression-Based Normative Data for Children From Latin America: Phonological Verbal Fluency Letters M, R, and P. *Assessment (Odessa, Fla.)*, *28*(1), 264–276. <https://doi.org/10.1177/1073191119897122>

Roberts, R. J., & Pennington, B. F. (2009). An interactive framework for examining prefrontal cognitive processes. Https://Doi.Org/10.1080/87565649609540642, 12(1), 105–126. https://doi.org/10.1080/87565649609540642

Robinson, G., Shallice, T., Bozzali, M., & Cipolotti, L. (2012). The differing roles of the frontal cortex in fluency tests. *Brain (London, England : 1878)*, *135*(7), 2202–2214. https://doi.org/10.1093/brain/aws142

Roca, M., Parr, A., Thompson, R., Woolgar, A., Torralva, T., Antoun, N., Manes, F., & Duncan, J. (2010). Executive function and fluid intelligence after frontal lobe lesions. Brain (London, England : 1878), 133(1), 234–247. <https://doi.org/10.1093/brain/awp269>

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

Rock, D., & Price, I. R. (2019). Identifying culturally acceptable cognitive tests for use in remote northern Australia. *BMC Psychology*, *7*(1), 62–62. https://doi.org/10.1186/s40359-019-0335-7

Rodrigues, J. C., Machado, W. L., da Fontoura, D. R., Almeida, A. G., Brondani, R., Martins, S. O., Ruschel Bandeira, D., & Salles, J. F. (2019). What neuropsychological functions best discriminate performance in adults post-stroke?. *Applied neuropsychology. Adult*, *26*(5), 452–464. <https://doi.org/10.1080/23279095.2018.1442334>

Rodríguez-Aranda, C., & Jakobsen, M. (2011). Differential Contribution of Cognitive and Psychomotor Functions to the Age-Related Slowing of Speech Production. *Journal of the International Neuropsychological Society*, *17*(5), 807–821. https://doi.org/10.1017/S1355617711000828

Rohrer, J. D., Knight, W. D., Warren, J. E., Fox, N. C., Rossor, M. N., & Warren, J. D. (2008). Word-finding difficulty: a clinical analysis of the progressive aphasias. *Brain : a journal of neurology*, *131*(Pt 1), 8–38. <https://doi.org/10.1093/brain/awm251>

Ross, T. P., O'Connor, S., Holmes, G., Fuller, B., & Henrich, M. (2019). The Reliability and Validity of the Action Fluency Test in Healthy College Students. *Archives of Clinical Neuropsychology*, *34*(7), 1175–1191. https://doi.org/10.1093/arclin/acz016

Rousseaux, M., Vérigneaux, C., & Kozlowski, O. (2010). An analysis of communication in conversation after severe traumatic brain injury. European Journal of Neurology, 17(7), 922-929.

Ruff, R. M., Allen, C. C., Farrow, C. E., Niemann, H., & Wylie, T. (1994). Figural fluency: differential impairment in patients with left versus right frontal lobe lesions. *Archives of Clinical Neuropsychology*, *9*(1), 41-55.

Ruff, R. M., Light, R. H., & Evans, R. W. (1987). The Ruff Figural Fluency Test: a normative study with adults. *Developmental neuropsychology*, *3*(1), 37-51.

Ruff, R. M., Light, R. H., Parker, S. B., & Levin, H. S. (1997). The Psychological Construct of Word Fluency. *Brain and Language*, *57*(3), 394–405. https://doi.org/10.1006/brln.1997.1755

Ryan, J. J., Lopez, S. J., & Paolo, A. M. (1996). Digit Span Performance of Persons 75-96 Years of Age. *Psychological Assessment*, *8*(3), 324–327. <https://doi.org/10.1037/1040-3590.8.3.324>

Salis, C., & Edwards, S. (2004). Adaptation theory and non-fluent aphasia in English. \*Aphasiology, 18\*(12), 1103-1120. <https://doi.org/10.1080/02687030444000552>

Salthouse, T. A. (1996). The Processing-Speed Theory of Adult Age Differences in Cognition. *Psychological Review*, *103*(3), 403–428. https://doi.org/10.1037/0033-295X.103.3.403

Salthouse, T. A. (2005). Relations between cognitive abilities and measures of executive functioning. Neuropsychology, 19(4), 532–545. https://doi.org/10.1037/0894-4105.19.4.532

Schum R.L. , Sivan A.B. , & Benton A. (1989). Multilingual aphasia examination: Norms for children. The Clinical Neuropsychologist, 3: (4), 375– 383.

Schumacher, R., Halai, A. D., & Lambon Ralph, M. A. (2019). Assessing and mapping language, attention and executive multidimensional deficits in stroke aphasia. Brain, 142(10), 3202-3216.

Shao, Z., Janse, E., Visser, K., & Meyer, A. S. (2014). What do verbal fluency tasks measure? Predictors of verbal fluency performance in older adults. *Frontiers in Psychology*, *5*, 772–772. https://doi.org/10.3389/fpsyg.2014.00772

Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending and a general theory. Psychological review, 84(2), 127.

Simmons-Mackie, N., & Kagan, A. (2007). Application of the ICF in aphasia. Seminars in speech and language, 28(4), 244–253. <https://doi.org/10.1055/s-2007-986521>

Siqueira, L. de S., Gonçalves, H. A., Hübner, L. C., & Fonseca, R. P. (2016). Development of the Brazilian version of the Child Hayling Test. *Trends in Psychiatry and Psychotherapy*, *38*(3), 164–174. https://doi.org/10.1590/2237-6089-2016-0019

Sira, C. S., & Mateer, C. A. (2014). Executive function. In M. J. Aminoff & R. B. Daroff (Eds.), Encyclopedia of the Neurological Sciences (Second Edition, pp. 239-242). Academic Press. https://doi.org/10.1016/B978-0-12-385157-4.01147-7

Slevc, L. R. (2011). Saying what's on your mind: working memory effects on sentence production. Journal of experimental psychology: Learning, memory, and cognition, 37(6), 1503.

Small, J. A., Kemper, S., & Lyons, K. (2000). Sentence repetition and processing resources in Alzheimer's disease. Brain and language, 75(2), 232–258. https://doi.org/10.1006/brln.2000.2355

Spitoni, G. F., Bevacqua, S., Cerini, C., Ciurli, P., Piccardi, L., Guariglia, P., Pezzuti, L., & Antonucci, G. (2018). Normative Data for the Hayling and Brixton Tests in an Italian Population. *Archives of Clinical Neuropsychology*, *33*(4), 466–476. https://doi.org/10.1093/arclin/acx072

Spitzer, L., Binkofski, F., Willmes, K., & Bruehl, S. (2020). Executive functions in aphasia: A novel aphasia screening for cognitive flexibility  in everyday communication. *Neuropsychological Rehabilitation*, *30*(9), 1701–1719. https://doi.org/10.1080/09602011.2019.1601572

Spreen, O., & Strauss E. (1998). A compendium of neuropsychological tests (2nd ed.). New York: Oxford University Press.

St Clair-Thompson, H. L., & Allen, R. J. (2013). Are forward and backward recall the same? A dual-task study of digit recall. *Memory & Cognition*, *41*(4), 519–532. <https://doi.org/10.3758/s13421-012-0277-2>

Stark, H. K., & Stark, J. A. (1990). Syllable Structure in Wernicke’s Aphasia. In J. Nespoulous & P. Villiard (Eds.), *Morphology, Phonology, and Aphasia* (pp. 213–234). Springer. https://doi.org/10.1007/978-1-4613-8969-9\_13

Stelzer, F., Mazzoni, C. C., & Cervigni, M. A. (2014). Modelos cognitivos del desarrollo de las funciones ejecutivas: limitaciones metodológicas y desafíos teóricos. anales de psicología, 30(1), 329-336.

Stokholm, J., Jørgensen, K., & Vogel, A. (2013). Performances on five verbal fluency tests in a healthy, elderly Danish sample. *Aging, Neuropsychology, and Cognition*, *20*(1), 22-33.

Stolwyk, R., Bannirchelvam, B., Kraan, C., & Simpson, K. (2015). The cognitive abilities associated with verbal fluency task performance differ across fluency variants and age groups in healthy young and old adults. *Journal of Clinical and Experimental Neuropsychology*, *37*(1), 70–83. https://doi.org/10.1080/13803395.2014.988125

Stolwyk, R., Bannirchelvam, B., Kraan, C., & Simpson, K. (2015). The cognitive abilities associated with verbal fluency task performance differ across fluency variants and age groups in healthy young and old adults. *Journal of Clinical and Experimental Neuropsychology*, *37*(1), 70–83. <https://doi.org/10.1080/13803395.2014.988125>

Strauss, E., Sherman, E. M. S., Spreen, O. (2006). A Compendium of Neuropsychological Tests: Administration, Norms, and Commentary. Spain: Oxford University Press.

Stuss, D. T. (1992). Biological and psychological development of executive functions. Brain and Cognition, 20(1), 8–23. https://doi.org/10.1016/0278-2626(92)90059-U

Stuss, D. T., & Benson, D. F. (1984). Neuropsychological studies of the frontal lobes. Psychological Bulletin, 95(1), 3–28. https://doi.org/10.1037/0033-2909.95.1.3

Surprenant, A. M., Brown, M. A., Jalbert, A., Neath, I., Bireta, T. J., & Tehan, G. (2011). Backward Recall and the Word Length Effect. *The American Journal of Psychology*, *124*(1), 75–86. <https://doi.org/10.5406/amerjpsyc.124.1.0075>

Tan, K. S., & Venketasubramanian, N. (2022). Stroke Burden in Malaysia. *Cerebrovascular diseases extra*, *12*(2), 58–62. https://doi.org/10.1159/000524271

Tan, Y. L. (2003). A minimally-supervised Malay affix learner. In *Proceedings of the Class of 2003 Senior Conference, Computer Science Department, Swarthmore College*.

Taylor, K. I., & Regard, M. (2003). Language in the Right Cerebral Hemisphere: Contributions from Reading Studies. *Physiology*, *18*(6), 257–261. https://doi.org/10.1152/nips.01454.2003

Teuber H. L. (1972). Unity and diversity of frontal lobe functions. Acta neurobiologiae experimentalis, 32(2), 615–656.

Thiele, K., Quinting, J. M., & Stenneken, P. (2016). New ways to analyze word generation performance in brain injury: A systematic review and meta-analysis of additional performance measures. *Journal of Clinical and Experimental Neuropsychology*, *38*(7), 764–781. <https://doi.org/10.1080/13803395.2016.1163327>

Thierry, G., & Price, C. J. (2006). Dissociating Verbal and Nonverbal Conceptual Processing in the Human Brain. *Journal of Cognitive Neuroscience*, *18*(6), 1018–1028. https://doi.org/10.1162/jocn.2006.18.6.1018

Thothathiri, M., & Mauro, K. L. (2018). The relationship between short-term memory, conflict resolution, and sentence comprehension impairments in aphasia. *Aphasiology*, *32*(3), 264–289. https://doi.org/10.1080/02687038.2017.1350630

Tourville, J. A., & Guenther, F. H. (2011). The DIVA model: A neural theory of speech acquisition and production. *Language and Cognitive Processes*, *26*(7), 952–981. https://doi.org/10.1080/01690960903498424

Tremblay, T., Monetta, L., & Joanette, Y. (2004). Phonological processing of words in right- and left-handers. In *Brain and Cognition* (Vol. 55, Issue 3, pp. 427–432). Elsevier Science. https://doi.org/10.1016/j.bandc.2004.02.068

Tripathi, R., Kumar, K., Balachandar, R., Marimuthu, P., Varghese, M., & Bharath, S. (2015). Neuropsychological markers of mild cognitive impairment: A clinic-based study from urban India. *Annals of Indian Academy of Neurology*, *18*(2), 177.

Tripathi, R., Kumar, K., Bharath, S., P, M., Rawat, V. S., & Varghese, M. (2019). Indian older adults and the digit span A preliminary report. *Dementia & Neuropsychologia*, *13*(1), 111–115. <https://doi.org/10.1590/1980-57642018dn13-010013>

Troyer, A. K., Moscovitch, M., & Winocur, G. (1997). Clustering and switching as two components of verbal fluency: evidence from younger and older healthy adults. *Neuropsychology*, *11*(1), 138–146. https://doi.org/10.1037//0894-4105.11.1.138

Troyer, A. K., Moscovitch, M., Winocur, G., Leach, L., & Freedman, and M. (1998). Clustering and switching on verbal fluency tests in Alzheimer’s and Parkinson’s disease. *Journal of the International Neuropsychological Society*, *4*(2), 137–143. doi:10.1017/S1355617798001374

Tseng, C. H., McNeil, M. R., & Milenkovic, P. (1993). An investigation of attention allocation deficits in aphasia. *Brain and Language*, *45*(2), 276–296. https://doi.org/10.1006/brln.1993.1046

Van Der Elst, W., Van Boxtel, M. P. J., Van Breukelen, G. J. P., & Jolles, J. (2006). Normative data for the Animal, Profession and Letter M Naming verbal fluency tests for Dutch speaking participants and the effects of age, education, and sex. *Journal of the International Neuropsychological Society*, *12*(1), 80–89. https://doi.org/10.1017/S1355617706060115

Van der Linden, M., Brédart, S., & Beerten, A. (1994). Age-related differences in updating working memory. *The British Journal of Psychology*, *85*(1), 145–152. <https://doi.org/10.1111/j.2044-8295.1994.tb02514.x>

Vaughan, L., & Giovanello, K. (2010). Executive function in daily life: Age-related influences of executive processes on instrumental activities of daily living. *Psychology and aging*, *25*(2), 343.

Villard, S., & Kiran, S. (2017). To what extent does attention underlie language in aphasia? *Aphasiology*, *31*(10), 1226–1245. https://doi.org/10.1080/02687038.2016.1242711

Vogel, A., Stokholm, J., & Jørgensen, K. (2020). Normative data for eight verbal fluency measures in older Danish adults. *Aging, Neuropsychology, and Cognition*, *27*(1), 114-124.

Wagner, D. D., & Heatherton, T. F. (2017). The cognitive neuroscience of self-regulatory failure. Handbook of self-regulation: Research, theory, and applications, 111.

Webb, S. S., Kontou, E., & Demeyere, N. (2022). The COVID-19 pandemic altered the modality, but not the frequency, of formal cognitive assessment. *Disability and rehabilitation*, *44*(21), 6365–6373. <https://doi.org/10.1080/09638288.2021.1963855>

Wechsler, D. (1981). Wechsler adult intelligence scale--. *Frontiers in Psychology*.

Wecker, N. S., Kramer, J. H., Wisniewski, A., Delis, D. C., & Kaplan, E. (2000). Age effects on executive ability. Neuropsychology, 14(3), 409.

Weigl, E. (1927). Zur Psychologie sogenannter Abstraktionsprozesse. I. Untersuchungen über das" Ordnen". Zeitschrift für Psychologie und Physiologie der Sinnesorgane. Abt. 1. Zeitschrift für Psychologie.

Wernicke, C. (1874). *Der aphasische Symptomencomplex: eine psychologische Studie auf anatomischer Basis*. Cohn.

Wernicke, C. (1874). The aphasic symptom complex (Der aphasiche Symptomenkomplex). Kohn and Weigart, Breslau. Reprinted in translation in RS Cohen and W. Warofsky. *Boston Studies in the Philosophy of Science*, *4*.

West, R. L. (1996). An Application of Prefrontal Cortex Function Theory to Cognitive Aging. *Psychological Bulletin*, *120*(2), 272–292. https://doi.org/10.1037/0033-2909.120.2.272

Whiteside, D. M., Kealey, T., Semla, M., Luu, H., Rice, L., Basso, M. R., & Roper, B. (2016). Verbal Fluency: Language or Executive Function Measure?. *Applied neuropsychology. Adult*, *23*(1), 29–34. <https://doi.org/10.1080/23279095.2015.1004574>

Wild, D., Grove, A., Martin, M., Eremenco, S., McElroy, S., Verjee-Lorenz, A., & Erikson, P. (2005). Principles of Good Practice for the Translation and Cultural Adaptation Process for Patient-Reported Outcomes (PRO) Measures: Report of the ISPOR Task Force for Translation and Cultural Adaptation. *Value in Health*, *8*(2), 94–104. https://doi.org/10.1111/j.1524-4733.2005.04054.x

Wilde, N. J., Strauss, E., & Tulsky, D. S. (2004). Memory span on the Wechsler scales. *Journal of clinical and experimental neuropsychology*, *26*(4), 539-549.

Wilkins, A., Shallice, T., & McCarthy, R. (1987). Frontal lesions and sustained attention. Neuropsychologia, 25(2), 359-365.

Williams, B. R., Ponesse, J. S., Schachar, R. J., Logan, G. D., & Tannock, R. (1999). Development of Inhibitory Control Across the Life Span. *Developmental Psychology*, *35*(1), 205–213. https://doi.org/10.1037/0012-1649.35.1.205

Woodard, K., Pozzan, L., & Trueswell, J. C. (2016). Taking your own path: Individual differences in executive function and language processing skills in child learners. Journal of experimental child psychology, 141, 187–209. https://doi.org/10.1016/j.jecp.2015.08.005

Ye, Z., & Zhou, X. (2009). Executive control in language processing. *Neuroscience & Biobehavioral Reviews*, *33*(8), 1168-1177.

Yeung, O., & Law, S. P. (2010). Executive functions and aphasia treatment outcomes: Data from an ortho-phonological cueing therapy for anomia in Chinese. International Journal of Speech-Language Pathology, 12(6), 529-544.

Zanini, G. A. V., Miranda, M. C., Cogo-Moreira, H., Nouri, A., Fernández, A. L., & Pompéia, S. (2021). An Adaptable, Open-Access Test Battery to Study the Fractionation of Executive-Functions in Diverse Populations. *Frontiers in psychology*, *12*, 627219. <https://doi.org/10.3389/fpsyg.2021.627219>

Zanto, T. P., & Gazzaley, A. (2019). Aging of the frontal lobe. *Handbook of clinical neurology*, *163*, 369-389.

Zimmermann, N., Gindri, G., de Oliveira, C. R., & Fonseca, R. P. (2011). Pragmatic and executive functions in traumatic brain injury and right brain damage: An exploratory comparative study. *Dementia & Neuropsychologia*, *5*(4), 337–345. <https://doi.org/10.1590/S1980-57642011DN05040013>

Zinn, S., Bosworth, H. B., Hoenig, H. M., & Swartzwelder, H. S. (2007). Executive Function Deficits in Acute Stroke. *Archives of Physical Medicine and Rehabilitation*, *88*(2), 173–180. <https://doi.org/10.1016/j.apmr.2006.11.015>

**Appendix**

**Appendix A**

This appendix contains the ethics documents relating to Study 1, including the project approval letter, information sheets for participants, and consent forms for participants.

**A paper with text on it

Description automatically generated**



**Participant Information Sheet**

1. **Research Project Title**

Questionnaire Consultation for the Development of Executive Function Test for Malay Speakers with Aphasia

**2. Research invitation**

You are being invited to take part in a research project. This project is being carried out by Zhamayne F. Fakharuzi, as part of her PhD, under the supervision of Professor Patricia Cowell and Dr Ozge Ozturk at the University of Sheffield, UK.  Before you decide whether or not you would like to take part, it is important for you to understand why the research is conducted and what it will involve. Please take time to read the following information and take time to decide whether or not you wish to take part. If there is anything that is not clear or if you would like more information please feel free to ask us. Thank you for reading this.

**3. What is the purpose of the project?**

This study is designed to explore different factors for developing an online method to test specific cognitive skills of Malay speakers with communication difficulties after stroke. The cognitive abilities being investigated are executive functions and the communication difficulties being studied are those seen in aphasia. The study will involve completing an online questionnaire that asks about your professional experience and opinions on executive function assessment for individuals with aphasia.

**4. Why have I been chosen?**

The study is recruiting speech-language therapists, cognitive therapists, occupational therapists, neurologists, neuropsychologists, psychologists or any other rehabilitation personnel who are involved in supporting individuals’ post-stroke across Malaysia. You have been approached to take part because you work in this field.

**5. Do I have to take part?**

It is up to you to decide whether or not to take part. This is an entirely voluntary project. If you do decide to participate, you will be asked to answer some initial questions to make sure you work in the area of focus for this study. You will then complete and sign an online consent form. Following those initial steps, you will be sent a link to an online questionnaire to complete.

All information you provide will be anonymised and kept strictly confidential. Even if you give consent, you will still be free to withdraw without giving a reason, before the start and during the study, but not two weeks after completing the questionnaire. If you wish to withdraw from the research, please contact the researcher (see bottom of page 4 for contact information).

**6. What will happen to me if I take part? What do I have to do?**

If you decide to participate in the study, first a link to a screening survey will be provided via email. The screening survey consists of two yes/no questions related to your work with individuals with aphasia. The screening survey will ensure you meet the target specification for the questionnaire. Following the screening survey, a consent form will be provided for you to complete and sign.

Next, a link will be provided where you can fill out an online and anonymised questionnaire. The questionnaire is available in English or Bahasa Malaysia, and you can state your language preference in the screening survey. The questionnaire consists of 26 questions on executive function assessment which will help inform future research for the development of executive function tests. It is expected that you will need between 30 - 40 minutes to complete the questionnaire.

**7. What are the possible disadvantages and risks of taking part?**

There are no foreseeable risks or harms expected from taking part in this study.

**8. What are the possible benefits of taking part?**

Whilst there are no immediate benefits for those participating in the project, it is hoped that this project will help us understand your experience and opinions in our development of executive function tests for individuals with aphasia in the Malaysian clinical setting.

**9. Will my taking part in this project be kept confidential?**

Yes. All the information that we collect from you during the research will be kept strictly confidential, anonymised and will only be accessible to members of the research team. The only personal information that will be obtained from participants is participants’ names and email addresses. This information will only be used for communication purposes between the researcher and participant *(i.e. email link to the consent form and questionnaire)*. This personal information will be securely stored and disposed of carefully upon completion of the researcher’s PhD. To ensure confidentiality, each participant will be assigned an ID number. This will be the only form of identification that will be on any database used in this study. You will not be able to be identified in any reports or publications of this study. As the questionnaire responses are anonymous, you will not receive a copy of your answers or feedback from the researcher.

**10. What is the legal basis for processing my personal data?**

We will not be processing any personal data defined in the legislation as sensitive information. However, we need to let you know that all information that will be collected from the questionnaire will be anonymised. You will not be identifiable in any case. According to data protection legislation, we are required to inform you that the legal basis we are applying to process your personal data is that ‘processing is necessary for the performance of a task carried out in the public interest’ (Article 6(1)(e)). Further information can be found in the University’s Privacy Notice https://www.sheffield.ac.uk/govern/data-protection/privacy/general

**11. What will happen to the data collected, and the results of the research project?** All data will be stored on an electronic database on the University of Sheffield’s secure Google drive. The anonymised data from the questionnaire will be accessible to the researcher and academic supervisors. The resulting data will be used for developing a remote executive function assessment, the researcher’s PhD dissertation and for publication in a peer-reviewed journal, but no individuals will be identifiable from this data.

**12. Who is organising and funding the research?**

The project received no financial support for the research, authorship, and/or publication of this article.

**13. Who is the Data Controller?**

The University of Sheffield will act as the controller. This means that the University is responsible for looking after your information and using it properly.

**14. Who has ethically reviewed the project?**

The project has been reviewed via the University of Sheffield’s ethics review procedure, as administered by the Health Sciences School.

**15. What if something goes wrong and I wish to complain about the research or report a concern or incident?**

If you are dissatisfied with any aspect of the research and wish to make a complaint, please contact the researcher or the supervisory team in the first instance. You may find their contact details in the section below.

If the complaint relates to how your personal data has been handled, you can find information about how to raise a complaint in the University’s Privacy Notice: https://www.sheffield.ac.uk/govern/data-protection/privacy/general.

If you wish to make a report of concern or incident relating to potential exploitation, abuse or harm resulting from your involvement in this project, please contact the project’s Designated Safeguarding Contact, Professor Patricia Cowell; p.e.cowell@sheffield.ac.uk. If the concern or incident relates to the Designated Safeguarding Contact, or if you feel a report you have made to this Contact has not been handled satisfactorily, please contact the University’s Research Ethics & Integrity Manager, Lindsay Unwin; l.v.unwin@sheffield.ac.uk.

**Contact for further information**

|  |  |
| --- | --- |
| **Researcher:**  Zhamayne F. Fakharuzi  zfbintiahmadfakharuzi1@sheffield.ac.uk  Division of Human Communication Sciences  Health Sciences School  University of Sheffield  362 Mushroom Lane, Sheffield S10 2TS  United Kingdom | |
| **Supervisors:**   Professor Patricia Cowell  [p.e.cowell@sheffield.ac.uk](mailto:p.e.cowell@sheffield.ac.uk)    Division of Human Communication  Sciences  Health Sciences School  University of Sheffield  362 Mushroom Lane, Sheffield S10 2TS United Kingdom | Dr Ozge Ozturk  [o.ozturk@sheffield.ac.uk](mailto:o.ozturk@sheffield.ac.uk)    Division of Human Communication  Sciences  Health Sciences School  University of Sheffield  362 Mushroom Lane, Sheffield S10 2TS United Kingdom |
| **Dean of Health Sciences School**  Professor Tracey Moore  [tracey.moore@sheffield.ac.uk](mailto:tracey.moore@sheffield.ac.uk)  Division of Nursing and Midwifery  Health Sciences School  Barber House Annexe  3 Clarkehouse Road  Sheffield S10 2HQ |  |

**A form with text and a checklist

Description automatically generated with medium confidence**

**Appendix B**

This appendix contains the items in the pre-survey Study 1 questionnaire.

**A questionnaire with a box and a box with text

Description automatically generated with medium confidence**

**Appendix C**

This appendix contains Study 1 questionnaire

**Part 1**

Part 1 of this questionnaire consists of two sections: (a) professional background and (b) executive function assessment.

Section 1a: Professional background contains 3 multiple-choice questions and 1 free text question aimed to establish an understanding of the participant’s professional role and the frequency and type of interaction with clients with aphasia.

Section 1b: Executive function assessment consists of twelve questions of which 3 are short answer questions, 5 yes/no questions and 4 multiple-choice questions. The questions in Part 2 will provide information on participant’s previous experience administering executive function tests and their opinion on a Malay version executive function test.

|  |  |  |
| --- | --- | --- |
| **Section 1a: Professional background** | | |
| **No.** | **Questions** | **Answer keys** |
| 1 | In what setting do you work the majority of the time? | 1. Neurology Rehabilitation Unit 2. Psychological Clinical Unit 3. Occupational Therapy Unit 4. Speech Therapy Unit 5. Geriatric Rehabilitation Department 6. Neurosurgery Rehabilitation Department 7. Other, please specify |
| 2 | What role do you have? | 1. Occupational therapist 2. Neuropsychologist 3. Clinical Psychologist 4. Assistant psychologist 5. Speech and language therapist 6. Neurologist 7. Other, please specify |
| 3 | How many times in a month do you interact (e.g., assessment, screening, therapy) with individuals with aphasia in your current job? | Free text |
| 4 | In your current job, what kind of services do you provide for your patients with aphasia? | 1. Speech, language, and/or cognitive assessment only 2. Speech, language and/or cognitive treatment only 3. Both assessment and treatment of speech, language and/or cognitive deficits 4. Other, please specify |
| **Section 1b: Executive Function Assessment** | | |
| **No.** | **Questions** | **Answer keys** |
| **Terminology**  The term executive function refers to a set of cognitive abilities that are necessary for guiding behaviour towards a goal and is required in non-routine situations (Banich, 2009)  Banich, M. T. (2009). Executive function: The search for an integrated account. *Current directions in psychological science*, *18*(2), 89-94. | | |
| 1 | From your professional perspective, describe executive function? | Free text |
| 2 | From your professional experience, what are some of the signs that a patient may have an executive function impairment?  *(You may choose more than one symptom)* | 1. Difficulty regulating emotions 2. Short attention span 3. Difficulty in problem-solving 4. Difficulty switching between tasks 5. Difficulty in organising and planning 6. Other, please specify |
| 3 | Have you previously completed any executive function assessment with your patients? | Yes/No  *(If the answer is ‘No’ for Q3, participant will be directed to Q8)* |
| 4 | If Yes for (3): Which executive function tasks/assessments have you used with your patients?  *(You may choose more than one answer)* | 1. Behavioural Assessment of Dysexecutive Syndrome (BADS) 2. Cambridge Neuropsychological Test Automated Battery (CANTAB) - Executive Function Domain 3. Delis-Kaplan Executive Function System (D-KEFS) 4. Eriksen Flanker Task 5. Brixton Spatial Anticipation Test 6. Stroop Color and Word Test 7. Wisconsin Card Sorting Test (WCST) 8. Trail Making Test 9. Corsi Block Tapping Test 10. Digit Span Forward and Backward 11. Semantic Verbal Fluency Test 12. Letter Verbal Fluency Test 13. Hayling Sentence Completion Test 14. Raven’s Coloured Progressive Matrices 15. Tower of London 16. Tower of Hanoi 17. Other, please specify |
| 5 | In the last year, for how many clients with aphasia have you completed measures of executive functioning? | Numeric answers |
| 6 | Have you previously completed any EF measures in languages other than English? (e.g., Bahasa Malaysia, Tamil, Mandarin or Cantonese) | Yes/No  *(If the answer is ‘No’ for Q6, participant will be directed to Q8)* |
| 7 | If Yes for (6), name the executive function test(s) that you have administered in languages other than English. | Free text |
| 8 | Do you think there is a need for executive function tests in the main languages spoken in Malaysia? (i.e. Bahasa Malaysia, Tamil, Mandarin or Cantonese) | Yes/No |
| 9 | If there are executive function tests available in Bahasa Malaysia, would you use the test to evaluate executive functioning of Malay speaking clients with aphasia? | Yes/No |
| 10 | What do you think are the potential benefits of standardised Bahasa Malaysia EF assessments for Malay speakers with aphasia?  *(You may choose more than one option)* | 1. Ease of usage for clinicians without the need for translating during assessment/screening 2. Ease of usage for patients in terms of understanding task instructions and task stimuli 3. Increase patient’s willingness to participate during screening/assessment 4. Reduce participants lack of interest in assessment/screening 5. Reduce time of assessment for Malay patients 6. Other, please specify |
| 11 | In your opinion, if an executive function test is developed for Malay speakers with aphasia, what aspects should be considered for the test development? | 1. Suitability for Malay speakers (language use, instruction, familiarity, suitable context) 2. Consideration for Malay culture (e.g., avoid using offensive/culturally inappropriate words/images) 3. Consideration for cultural relevant task stimuli (e.g., avoid using image of plants that are not native to Malaysia i.e. strawberry plant) 4. Other, please specify |
| 12 | For future research, do you think EF assessments should be available in different varieties of Bahasa Malaysia? (e.g. Melayu utara, Melayu Sarawak, Melayu pantai timur) | Yes/No |

**Part 2**

The second part of the questionnaire consists of 10 questions on remote executive function assessment. There are 4 yes/no questions and 6 multiple-choice questions with the option for short answers.

|  |
| --- |
| **Definition and terminology**  What is telehealth?  **Telehealth** is the delivery of health care services, where patients and healthcare professionals are separated by distance. Telehealth is delivered using information and communication technologies (ICT) for various non-emergency and routine care where face-to-face interactions are not required, such as providing psychological assessment (Monaghesh & Hajizadeh, 2020)  What is remote executive function (EF) assessment?  **Remote EF assessment in this questionnaire** refers to the delivery of EF assessment, where patients and therapists/clinicians are not in the same location. It is delivered via telephone calls or video conferencing app such as Skype, Google Meet, Zoom or other applications that support the delivery of online EF assessment.  Monaghesh, E., & Hajizadeh, A. (2020). The role of telehealth during COVID-19 outbreak: a systematic review based on current evidence. *BMC Public Health*, *20*(1), 1-9. |

|  |  |  |
| --- | --- | --- |
| **Remote EF Assessment** | | |
| **No.** | **Questions** | **Answer keys** |
| 1 | Have you provided your client with aphasia with telehealth services (e.g., screening, rehabilitative therapy)? | Yes/No  *(If the answer is ‘No’ for Q1, participant will be directed to Q6)* |
| 2 | If Yes for (1): How do you provide the telehealth service(s)?  *(You may choose more than one answer)* | 1. By telephone call 2. By phone app (Facetime/Whatsapp) 3. By video 4. By email 5. Other, please specify |
| 3 | Have you previously completed any executive function assessments/screening remotely (telephone, video conferencing)? | Yes/No  *(If the answer is ‘No’ for Q3, participant will be directed to Q6)* |
| 4 | If Yes for (3): Which executive function tests were used to evaluate your patients with aphasia remotely?  *(You may choose more than one answer)* | 1. Behavioural Assessment of Dysexecutive Syndrome (BADS) 2. Cambridge Neuropsychological Test Automated Battery (CANTAB) - Executive Function Domain 3. Delis-Kaplan Executive Function System (D-KEFS) 4. Eriksen Flanker Task 5. Brixton Spatial Anticipation Test 6. Stroop Color and Word Test 7. Wisconsin Card Sorting Test (WCST) 8. Trail Making Test 9. Corsi Block Tapping Test 10. Digit Span Forward and Backward 11. Semantic Verbal Fluency Test 12. Letter Verbal Fluency Test 13. Hayling Sentence Completion Test 14. Raven’s Coloured Progressive Matrices 15. Tower of London 16. Tower of Hanoi 17. Other, please specify |
| 5 | Why do you think your setting/organisation uses remote assessment for measuring executive function in individuals with aphasia? | 1. To continue care services provided by therapists to individuals at home 2. Reduce the risk of COVID-19 transmission 3. Reach a wider population of individuals who may have restricted mobility or live long distances from the clinic 4. Reduce the use of resources in health centres 5. Other, please specify |
| 6 | If No for (1 and/or 3): Why do you think your setting/organisation does not use remote assessment for measuring executive function in individuals with aphasia?  *(You may choose more than one answer)* | 1. Lack of standardised EF tests for online usage 2. Poor internet connectivity on patient’s end 3. Poor internet connectivity on clinician/therapist’s end 4. Lack of suitable devices to conduct online assessment/therapy (e.g., computer, laptop, webcam) 5. Lack of appropriate training for delivery of telehealth 6. Concerns on clinical quality of medical services provided 7. Telehealth services are not covered by healthcare insurance 8. Other, please specify |
| 7 | If a remote EF assessment is developed for Malay speakers, would you use it for post-stroke patients? | Yes/No |
| 8 | What do you think are the potential benefits of remote assessment of executive function?  *(You may choose more than one answer)* | 1. Reduce travel time and/or cost for patients to visit hospital/clinic 2. Increase accessibility for assessment/screening for patients living far from hospital/clinic 3. Increase the number of patients to receive assessment/screening daily 4. Flexibility of appointment time 5. Economic, time and environmental cost savings 6. Other, please specify |
| 9 | What do you think are the potential challenges or disadvantages of remote assessment of executive function?  *(You may choose more than one answer)* | 1. Lack of technological expertise among patients 2. Lack of technological expertise among therapists/clinicians 3. Difficulty controlling distractions in patient’s surroundings (e.g., noise, help from family members) 4. Limited technological equipment in patient’s home (e.g., laptop/desktop with a webcam, internet) 5. Limited technological equipment in clinician’s setting/workplace 6. Difficulty assessing patients with reduced mobility due to injuries or stroke 7. Other, please specify |
| 10 | Based on your experience working with patients with aphasia, do you think remote assessment/screening/therapy will benefit people with aphasia in Malaysia? | 1. Yes 2. No 3. Optional, give reason(s) |

**Appendix D**

This Appendix contains the PPI Questionnaire Flowchart for Study 1 of the study.

A diagram of a question

Description automatically generated

A diagram of a flowchart

Description automatically generated

**Appendix E**

This Appendix contains the ethics documents relating to Study 2, including the project approval letter; information sheets for participants; and consent forms for participants.

**A paper with text and blue text

Description automatically generated**

**Participant Information Sheet**

**Assessment of Executive Functions for Healthy Malay Speakers**

Dear potential participant,

You are being invited to take part in a research project ‘Assessment of Executive Functions for Healthy Malay Speakers’. Before you decide whether or not to participate, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Thank you for taking the time to read this.

1. **What is the project’s purpose?**

The project is aimed to develop an assessment tool to measure cognitive functions of Malay speakers with communication difficulties post-stroke. The cognitive abilities being measured are executive functions and the communication difficulties being studied are those seen in aphasia. Executive functions refer to a set of skills that allow us to plan, focus attention, remember instructions and juggle multiple tasks. Aphasia is when a person has difficulty with their speech usually caused by damage to the left side of the brain. The study will involve completing an online assessment with the researcher that consists of four simple tasks. The assessment will be conducted via Google Meet and should take no more than 50 minutes to complete.

1. **Why have I been chosen?**

You have been approached to take part because we are seeking healthy, bilingual/multilingual Malay speakers aged between 20-35 and 60-75, who have no serious psychological or medical illnesses.

1. **Do I have to take part?**

It is up to you to decide whether to take part. If you do decide to take part, you will be able to keep a copy of this information sheet and consent form confirmed by you. You can withdraw at any time before the completion of the assessment or two weeks after the completion of the assessment, and you do not need to give a reason for withdrawing. If you wish to withdraw from the study, please contact the researcher (contact details can be found on the last page of this document).

Also, it is important to inform you that participating in this research will not create a legally binding agreement and will not create an employment relationship between you and the University of Sheffield.

1. **What will happen to me if I take part? What do I have to do?**

After reading this Participant Information Sheet, you can sign up for the study by completing the online Consent Form in the email you received. Once this is completed you will receive a ‘Study Pack’ via postal mail within 5-7 working days. The ‘Study Pack’ will contain an answer sheet for one of the four tasks. Upon receiving the answer sheet, you can select a suitable time and date for the online session via a link which will be emailed to you.

During the online assessment, you will first be asked to answer some language background and health questionnaires by the researcher. Then, you will be given three verbal and one non-verbal task  to complete, and you will do this via one online session with the researcher. The tasks will involve saying words, repeating words, completing sentences, and  drawing simple patterns. To complete the pattern drawing task, use the answer sheet given in the ‘Study Pack’ which will be sent  to your postal address.

It is estimated that the session will last no more than 50 minutes. The researcher will collect audio-video recordings to measure the speech and accuracy of your performance. It is advised that you complete the assessment alone in a quiet environment and away from distractions, whenever possible.

Because of the concern on COVID-19 transmission, the research will be conducted through an online meeting via Google Meet. You will receive a link to the session via the email confirming the date and time of your participation.

1. **What are the possible disadvantages and risks of taking part?**

It is anticipated that participation in this research will not cause any physical or mental discomfort, disadvantages or risks because the tasks  are based on skills and abilities that people use in daily life. It is possible that some tasks may feel challenging. If any  aspect of the study poses discomfort or fatigue, you may pause for a break, or discontinue the study.

It is also possible that if someone is present in your surroundings during the meeting, s/he could see or hear something about your background information, speech or cognitive skills. Although it is not anticipated that this experience would physically harm you or this person, you should conduct the meeting in a private setting, whenever possible. If at any time during the session, you feel uncomfortable or at risk, this should be immediately brought to the attention of the researcher.

1. **What are the possible benefits of taking part?**

Whilst there are no immediate benefits for those people participating in the project, it is hoped that this work will bring new understanding about the effect of executive functions on rehabilitation therapy of people with aphasia. Also, it is hoped that this study will provide the information necessary to design a standardised Malay language executive function test to assess people with aphasia in Malaysia.

1. **Will my taking part in this project be kept confidential?**

All the information collected about you during the course of the research will be kept strictly confidential, and only researchers of this project will be able to access it. You will not be identified in any reports or publications.

You may optionally agree to us sharing the information collected from you with other researchers. If you opt into this as part of your consent, the shared data will be anonymised, and your personal details will not be included. You can say “no” to this part of the consent and still take part in the study.

1. **What is the legal basis for processing my personal data?**

According to data protection legislation, we are required to inform you that the legal basis we are applying to process your personal data is that "processing is necessary for the performance of a task carried out in the public interest” (Article 6(1)(e)). Further information can be found in the University’s Privacy Notice:

<https://www.sheffield.ac.uk/govern/data-protection/privacy/general>.

As we will be collecting some data that is defined in the legislation as more sensitive (some information about your medical history), we also need to let you know that we are applying the following condition in law: that the use of your data is "necessary for archiving purposes in the public interest, scientific or historical research purposes or statistical purposes" (9(2)(j)).

1. **What will happen to the data collected, and the results of the research project?**

Collected data and the results of this project will be used as part of a dissertation study for the researcher’s PhD at the University of Sheffield. Data will be accessible by only the researcher and the academic supervisors of this project. The results of the research may be published as part of a scientific conference or paper. Your personal information will not be disclosed in any dissertation, report, or publication.

After each data collection session, the video recordings will be automatically transferred and stored on an encrypted University's Google Drive folder which is only accessible by the researcher and supervisory team. All identifiable data such as name and email, collected from you during the online assessment will be anonymised. Any identifiable data of the participants will not be shared with anyone outside the research project. Participants’ information will remain anonymous in analyses and interpretation of the data.

Data collected from participants will be stored for 5 or 10 years depending on their type and then carefully destroyed. Identifiable personal data such as name, contact information and postal address will be destroyed immediately after completion of the PhD which will end by 20/10/2024. Video recordings will be stored for 5 years while anonymised data will be stored for 10 years.

Due to the nature of this research, other researchers may think that the anonymised data collected from you is useful in answering future research questions. In addition to your consent for this study, we will also ask for your permission for the anonymised data to be shared in the consent form. This additional consent is optional, and you do not have to agree to this to complete the study. If you consent to sharing your data with other researchers, the data shared will be completely anonymised and no identifying information will be disclosed.

1. **Will I be recorded, how will the recorded media be used?**

The online session will be recorded and then used only for analysing your speech and the patterns drawn. If you wish and if it is possible to arrange the position of your camera, your face will not be recorded, and only your speech and the drawn patterns will be recorded. No one outside the research will be allowed access to the original recordings. These records will be stored on secure University's Google Drive. The researcher will also use a password-protected computer during the online session.

1. **Who is organising and funding the research?**

The research is conducted by Zhamayne Fakharuzi who is a PhD student in the Division of Human Communication Sciences at The University of Sheffield. The research is supervised by Professor Patricia E. Cowell and Dr. Ozge Ozturk, from the Division of Human Communication Sciences, Health Sciences School, University of Sheffield.

1. **Who is the Data Controller?**

The University of Sheffield will act as the Data Controller for this study. This means that the University is responsible for looking after your information and using it properly.

1. **Who has ethically reviewed the project?**

This project has been ethically approved via the University of Sheffield’s Research Ethics Review Procedure, as administered by the Health Sciences School. The University’s Research Ethics Committee monitors the application and delivery of the Ethics Review Procedure across the University.

1. **What if something goes wrong and I wish to complain about the research or report a concern or incident?**

If you are dissatisfied with any parts of the research and wish to make a complaint about the project in the first instance you can contact Professor Patricia E Cowell [p.e.cowell@sheffield.ac.uk]. If you feel your complaint has not been handled to your satisfaction, you can contact Professor Tracey Moore, Dean, Health Sciences School [tracey.moore@sheffield.ac.uk].

If the complaint relates to how the personal data of the participants has been handled, you can find information about how to raise a complaint in the University’s Privacy Notice: https://www.sheffield.ac.uk/govern/data-protection/privacy/general

If you wish to make a report of any concern or incident relating to potential exploitation, abuse or harm resulting from your involvement in this project, please contact the project’s Designated Safeguarding Contact [Dr Jenny Thomson, j.m.thomson@sheffield.ac.uk]. If the concern or incident relates to the Designated Safeguarding Contact, or if you feel a report you have made to this Contact has not been handled in a satisfactory way, please contact the University’s Research Ethics & Integrity Manager [Lindsay Unwin; l.v.unwin@sheffield.ac.uk].

**16.**               **Contact for further information**

If you have any questions or wish to obtain further information about the project, you may contact:

|  |  |
| --- | --- |
| **Researcher:**  Zhamayne F. Fakharuzi  zfbintiahmadfakharuzi1@sheffield.ac.uk  Division of Human Communication Sciences  Health Sciences School  University of Sheffield  362 Mushroom Lane, Sheffield S10 2TS | |
| **Supervisors:**  Professor Patricia Cowell  p.e.cowell@sheffield.ac.uk  Division of Human Communication Sciences  Health Sciences School  University of Sheffield  362 Mushroom Lane, Sheffield S10 2TS | Dr Ozge Ozturk  o.ozturk@sheffield.ac.uk  Division of Human Communication Sciences  Health Sciences School  University of Sheffield  362 Mushroom Lane, Sheffield S10 2TS |

**Thank you for taking the time to participate in this research**

**A checklist with text on it

Description automatically generated**

**Appendix F**

This Appendix contains the Malay Executive Function (M-EF) battery protocol including translation of the task instructions.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Groups** | **EF tasks sequence** | | | |
| **1st** | **2nd** | **3rd** | **4th** |
| **A** | VFT | SFT | HSCT | DST |
| **B** | SFT | HSCT | DST | VFT |
| **C** | HSCT | DST | VFT | SFT |
| **D** | DST | VFT | SFT | HSCT |

*EF tasks abbreviation*

1. *Verbal Fluency Test (VFT)*
2. *Spatial Fluency Test (SFT)*
3. *Hayling Sentence Completion Test (HSCT)*
4. *Digit Span Test (DST)*

**Assessment checklist**

|  |  |
| --- | --- |
| 1. Introduction   *Self-introduction, the project, brief overview of the session and start recording when ready*  “Today we will start by checking your consent, then if ok, spend a few minutes on background questions about you and your health. We will then go through the language and picture tasks which will take no more than 40 minutes”. |  |
| 1. Consent form and participant information sheet |  |
| 1. Health and Language Background questionnaire   Explain why these questions are asked:  “This health and language questionnaire is important to confirm the healthy status of participants in order to make meaningful comparisons later on when we compare with people who had strokes” |  |
| 1. Verbal Fluency Test    1. Semantic - Animal    2. Semantic - Supermarket items    3. Phonemic - [A]    4. Phonemic - [M] |  |
| 1. Spatial fluency test    1. Draw using 3 lines    2. Draw using 4 lines    3. Check drawing immediately after the task and one more time before the end of the session |  |
| 1. Hayling Sentence Completion Test    1. Automatic condition (15 sentences)    2. Inhibition condition (15 sentences) |  |
| 1. Digit span    1. Span forward (8 levels; two items in each level)    2. Span backward (8 levels; two items in each level) |  |
| 1. Conclude assessment    1. Extend thanks    2. Ask if participant have any questions/comments regarding the study |  |

**Introduction**

1. **Introduce self and study**

Things to mention in introduction:

1. What is the study about? What does their voluntary participation entail?
2. How participating in the study can help?

**Thank you for participating in this study. This research study cognitive abilities in healthy adults to lay groundwork for people with language impairment after stroke. Your participation in this study is voluntary and you may opt out of the study anytime during the study period and two weeks after the assessment has taken place.**

**Today we will start by checking your consent, then if ok, spend a few minutes on background questions about you and your health. We will then go through the language and picture tasks which will take no more than 40 minutes**

1. Explain what we are going to do today, explanation to include:
   1. Briefly go through participant information sheet and verbal consent

Read the consent form to participants again and ask if the participant has any questions before proceeding with the study.  Participants are reminded that they may stop or withdraw at any time during the study and may take a short break if needed.

1. Ask participant if they agree to be recorded.

**Consent form statement below** (you may reread this statement to the participant)

|  |  |  |
| --- | --- | --- |
| ***Please tick the appropriate boxes*** | **Yes** | **No** |
| **Taking Part in the Project** | | |
| I have read and understood the participant information sheet. I have been given the opportunity to ask questions about the project.  *(If you will answer ‘No’ to this question please do not proceed with this consent form until you are fully aware of what your participation in the project will mean.)* |  |  |
| I agree to take part in the project. I understand that taking part in the project will involve completing three verbal and one non-verbal tasks. Verbal tasks will involve saying words, repeating words and completing sentences. The non-verbal task will involve drawing simple patterns on paper. |  |  |
| I agree that whilst I am participating in this online meeting, video recordings will be made. I agree to be video recorded and for these anonymised video recordings to be used in the research. |  |  |
| I understand that my taking part is voluntary and that I can withdraw from the study anytime before the completion of the assessment or two weeks after completion of the assessment; I do not have to give any reasons for why I no longer want to take part and there will be no adverse consequences if I choose to withdraw. |  |  |
| **How my information will be used during and after the project** | | |
| I understand my personal details such as name, age, gender, email address and postal address will not be revealed to people outside the project and will be anonymised. All identifiable data will be destroyed after the project is completed. |  |  |
| I understand and agree that my performance data may be quoted in publications, reports, web pages, and other research outputs. I understand that I will not be named in these outputs unless I specifically request this. |  |  |
| I give permission for my performance in the verbal and non-verbal tasks to be deposited in the University of Sheffield’s Google Drive which can only be assessed by the research team, so it can be used for future research and learning. |  |  |
| **So that the information you provide can be used legally by the researchers** | | |
| I agree to assign the copyright I hold in any materials generated as part of this project to The University of Sheffield. |  |  |
| **Additional use of information after the project. These are optional, you can say NO to them and still take part in the study.** | | |
| I understand that other authorised researchers may think that the data collected from me is useful in answering future research questions. I agree that my anonymised data can be shared with them only if they agree to protect the confidentiality of the information as described in this consent form. |  |  |
| I understand and agree that other authorised researchers may use my data in publications, reports, web pages, and other research outputs, only if they agree to preserve the confidentiality of the information as requested in this form. |  |  |

1. **Health and Language questionnaire**

**Language and Health Background Questionnaire**

1. **Age | Umur**

|  |
| --- |
|  |

1. **Gender | Jantina**

|  |  |
| --- | --- |
| a | Male | Lelaki |
| b | Female | Perempuan |
| c | Non-binary |
| d | Prefer not to say | Tidak berkenaan |

1. **Highest level of education level | Peringkat pendidikan tertinggi**

|  |  |
| --- | --- |
| a | Primary education | Sekolah rendah |
| b | Secondary education | Sekolah menengah |
| c | College | Kolej (i.e., diploma, asasi, matrikulasi, A-level) |
| d | Bachelor’s degree | Ijazah sarjana muda |
| e | Masters degree | Ijazah sarjana |
| f | Doctoral degree | Doktor falsafah |
| g | Religious education | Maahad/Pondok/Tahfiz |
| h | No formal education | Tiada pendidikan formal |

1. **Do you have, or have you had, any of the following conditions, if yes since when?**

|  |  |  |
| --- | --- | --- |
| **I’ll ask you a few questions regarding your health condition, which may affect your performance in the task today. Firstly, do you have any of the following conditions:** | | |
| Visual impairment  Corrected with glasses/surgery/contact lens | Yes [ ]  No [    ]  Yes [ ]   No [    ] | Since: |
| Hearing impairment  Corrected with hearing aid | Yes [ ]   No [    ]  Yes [ ]   No [    ] | Since: |
| **Have you had any major illnesses or conditions needing medical treatment for example cancer or heart disease?** | | |
| Heart Disease | Yes [ ]   No [    ] | Since: |
| Stroke | Yes [ ]   No [    ] | Since: |
| Cancer | Yes [ ]   No [    ] | Since: |
| Diabetes | Yes [ ]   No [    ] | Since: |
| Asthma | Yes [ ]   No [    ] | Since: |
| High blood pressure | Yes [ ]   No [    ] | Since: |
| **Have you had any major illnesses or injuries affecting your brain or your thinking which needed medical treatment for example, epilepsy?** | | |
| Epilepsy | Yes [ ]   No [    ] | Since: |
| Mobility issues (i.e,. hand movement, movement of your face or mouth for speaking) | Yes [ ]   No [    ] | Since: |

1. **Were you born in Malaysia?**
2. **How long have you lived in Malaysia?**

1. **How long have you lived in the UK/countries outside of Malaysia?**

1. **Which language(s) can you speak?**

|  |  |
| --- | --- |
| a | Malay |
| b | English |
| c | Mandarin |
| d | Tamil |
| e | Others, please specify | Lain-lain sila nyatakan |

1. **How fluent would you say you are in speaking Malay?**

**Bagaimanakah kefasihan anda bertutur dalam Bahasa Malaysia?**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Not fluent |**  **Tidak fasih** | **Limited fluency |**  **Kurang memuaskan** | **Somewhat fluent | Memuaskan** | **Quite fluent | Baik** | **Very fluent | Sangat baik** |
| Little speaking ability | Some ability; can say short, simple sentences  e.g. answer the phone, or greet a neighbour | Good speaking; can express yourself on many topics  e.g. explain what you want; give  instructions | Can use the language adequately for most situations | Very comfortable expressing him/herself in the language in all situations |

1. **How competent would you say you are in understanding Malay?**

**Bagaimanakah kebolehan anda memahami Bahasa Malaysia?**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Not competent |**  **Tidak fasih** | **Limited competence |**  **Kurang memuaskan** | **Somewhat competent | Memuaskan** | **Quite competent | Baik** | **Very competent | Sangat baik** |
| Little understanding ability | Some understanding; can understand simple conversations. | Good understanding | Can understand the language adequately for most situations  e.g. follow films or TV shows | Understands almost everything. |

(cited from Katsos et al., 2021)

**Verbal fluency test (VFT)**

VFT sequence of tasks are as follow:

i. VFT - Animal

ii. VFT - supermarket items

iii. VFT - letter [A]

iv. VFT - letter [M]

**Reminder:**

Each task is done for 60 seconds, participants can only start when you say ‘start’ and should stop when you say ‘stop’.

|  |
| --- |
| Task instruction semantic VFT (animal & supermarket items)  Dalam 60 saat, anda perlu berikan sebanyak mungkin perkataan dalam Bahasa Malaysia yang terdiri daripada kategori (i) haiwan; (ii) barangan yang boleh dibeli di supermarket. Anda boleh menyebut apa apa perkataan seperti kucing, cicak, durian, bayam dan sebagainya. Anda boleh mula apabila saya sebut ‘mula’ dan berhenti apabila saya sebut ‘tamat’. Adakah anda mempunyai apa apa soalan sebelum kita mulakan tugasan ini?  English translation  In 60 seconds, list all the animals/supermarket items you can think of. You can mention any words like cat, lizard, durian and spinach. You can start when you hear me say ‘start’ and stop the task when you hear ‘stop’. Do you have any questions before we start the task? |

|  |
| --- |
| Task instruction phonemic VFT [A] and [M]  Dalam 60 saat, saya mahu anda berikan sebanyak mungkin perkataan dalam Bahasa Malaysia yang bermula dengan huruf \_. Anda boleh menyebut apa-apa perkataan dalam bentuk kata dasar, seperti **ayam** untuk huruf A and **manggis** untuk huruf M. Selain itu, anda tidak boleh memberikan perkataan bagi nama orang dan nama tempat, seperti Ali dan Ampang untuk huruf A atau Malaysia untuk huruf M. Bagi tugasan ini, anda harus menggunakan perkataan yang berbeza dan bukannya perkataan yang sama dengan menambahkan imbuhan. Jika anda berikan kata kerja, seperti ‘angkat’ anda tidak  boleh memberikan perkataan yang sama dengan menambahkan imbuhan contohnya, ‘angkatkan’.  English translation  In 60 seconds, list as many words as you can that begin with the letter A/M. You can say any word in its root form like **chicken** for the letter A and **mangosteen** for the letter M. For this task, you cannot provide proper nouns such as name of people and places such as Ali and Ampang for A, or Malaysia for M. Also, for this task you should provide the root word for the given letter/alphabet and do not use the same words with different suffix. For example, if you say the verb ‘lift’ do not provide the same word with the prefix ‘to-lift’ |

**Spatial fluency test (SFT)**

**Task instruction**

Bagi tugasan ini, anda memerlukan kertas template ujian yang diberikan dan pen/pencil. Tugasan ini memerlukan anda untuk melukis apa-apa lukisan menggunakan tiga garis. Anda boleh lukis apa apa bentuk atau paten tetapi, anda harus menggunakan hanya tiga garis. Setiap lukisan yang anda lukis, hendaklah menjadi lukisan yang baru. Anda akan diberikan 60 saat untuk melengkapkan ujian ini. Lukis setiap lukisan baru di dalam kotak baru yang disediakan. Adakah anda mempunyai apa apa soalan sebelum kita bermula?

Untuk tugasan kedua, anda ditugaskan untuk melukis apa apa bentuk atau paten di dalam kotak yang disediakan menggunakan empat garisan. Anda ada 60 saat untuk menyiapkan tugasan ini.

English translation

For this task, you will need the following items: pen or pencil and the answer template provided to you. This task will require you to draw first by using three lines. You can draw any shapes or patterns; however, you must only use three lines. Each drawing should be a new combination of three lines. You are given 60 seconds to complete the task. Use the template to draw the shapes/patterns. Put each new drawing in a separate square of the template. Do you have any questions before we begin?

For this second task, you are given four lines to draw any patterns or shapes. Similar to before, you have 60 seconds to complete the task.

**\*\*\*Remember to check the drawing immediately after the task ends and one time before the end of the session.**

**Hayling Sentence Completion Test (HSCT)**

There are two test conditions for HSCT. In total there are 30 sentences to complete 15 in automatic condition and another half in inhibition condition. Participants will start with (i) automatic condition.

|  |
| --- |
| **Task instruction**  Untuk tugasan berikutnya, saya akan bacakan beberapa ayat dan apabila saya selesai membaca, anda perlu berikan satu perkataan yang sesuai bagi mengisi tempat kosong di akhir ayat tersebut dengan secepat mungkin.  Sebagai contoh, bagi ayat ini ‘Murid murid sedang beratur untuk membeli makanan di \_\_’. jawapan yang sesuai ialah ‘kantin’. Adakah anda faham apa yang anda perlu lakukan?  Sebelum kita mulakan tugasan ini, kita akan mula dengan beberapa ayat praktis. Adakah anda bersedia?  **Ayat praktis/practice sentences**   1. Sebelum keluar rumah, jangan lupa kunci \_\_ (pintu)   ENG: Before leaving the house, don’t forget to lock the \_\_ (door)   1. Pesawah itu sedang menanam \_\_ (padi)   ENG: The rice farmer is planting the \_\_ (paddy)  Sebelum kita mulakan tugasan ini, adakah anda mempunyai soalan bagi tugasan ini. Adakah anda bersedia untuk mulakan tugasan ini?  **English translation**  Now, I will begin with the sentence task. This task contains two parts. For the first part, before we start, listen carefully to each sentence. When I finish reading, your task is to give me a word that is relevant or that makes sense to fill the blank at the end of each sentence.  For example, for this sentence ‘The students are queuing up to buy food in the \_\_’. An example of a suitable answer for this is ‘canteen’. Does it make sense what you have to do for this task?  Before we start this task, we will start with some practice. Are you ready?  **Ayat praktis/practice sentences**   1. Sebelum keluar rumah, jangan lupa kunci \_\_ (pintu)   ENG: Before leaving the house, don’t forget to lock the \_\_ (door)   1. Pesawah itu sedang menanam \_\_ (padi)   ENG: The rice farmer is planting the \_\_ (paddy)  Now are you ready for the task? |

**Automatic conditions**

1. Seorang posman digigit oleh seekor \_\_
2. Bomba sedang memadam \_\_
3. Saya memasukkan adunan kek itu kedalam \_\_
4. Monyet-monyet itu gemar memakan \_\_
5. Sebelum makan, jangan lupa basuh \_\_
6. Dia melawat ibunya yang tenat di \_\_
7. Mereka pergi ke sekolah menaiki \_\_
8. Untuk mengait buah cempedak, ayah menggunakan \_\_
9. Penternak lembu itu sedang memerah\_\_
10. Untuk mencegah kaviti, kita perlu gosok \_\_
11. Lebah menghasilkan \_\_
12. Untuk menenangkan perasaannya, dia mendengar \_\_
13. Hujan lebat pada musim tengkujuh mengakibatkan \_\_
14. Sebelum melintas jalan, pandang kiri dan \_\_
15. Angin kencang menumbangkan beberapa batang \_\_

|  |
| --- |
| **Task instruction**  Sekarang kita akan mulakan tugasan yang kedua. Seperti sebelum ini, dengar dengan teliti ayat yang saya akan bacakan. Kali ini, apabila saya habis membaca, tugasan anda adalah untuk mengisi tempat kosong di hujung ayat yang saya bacakan dengan perkataan yang tidak sesuai untuk maksud ayat tersebut.  Sebagai contoh, bagi ayat ini ‘Ibu sedang menyiram \_\_’. Jawapan yang sesuai bagi ayat ini ialah apa apa perkataan selain ‘pokok’ atau ‘bunga’. Adakah anda faham apa yang anda perlu lakukan?  Sekarang, kita akan mulakan dengan dua ayat praktis. Adakah anda bersedia?  **Ayat praktis/practice sentences**   1. Sebelum keluar rumah, jangan lupa kunci \_\_ (bukan pintu)   ENG: Before leaving the house, don’t forget to lock the \_\_ ( not equal to door)   1. Pesawah itu sedang menanam \_\_ (bukan padi)   ENG: The rice farmer is planting the \_\_ (not equal to paddy)  Sebelum kita mula, adakah anda mempunyai apa-apa soalan mengenai tugasan ini?  **English translation**  Now we will start the second part of the task. As before, listen carefully to each sentence. This time, when I finish reading, your task is to give me a word that is irrelevant or does not make sense at all. The words you provide must be irrelevant to the sentence being read.  For example, for this sentence ‘Mother is watering the \_\_’. An example of a  suitable answer for this sentence is any word besides ‘plant/flower’. Does it make sense what you have to do for the task?  Before we start this task, we will start with some practice. Are you ready?  Now are you ready for the task? |

**Inhibition conditions**

1. Apabila ibu mendengar berita buruk itu dia \_\_
2. Nenek sedang membancuh kopi di \_\_\_
3. Dia mengirim surat tanpa menampal \_\_
4. Untuk mengelakkan dirinya dibasahi hujan, dia membawa \_\_
5. Kebiasaannya, anak-anak penyu menetas di waktu \_\_
6. Tukang masak itu menyiang ikan menggunakan \_\_
7. Untuk membantu penglihatannya, dia memakai \_\_
8. Setelah seharian bekerja, dia pulang  ke\_\_
9. Angkasawan itu selamat kembali ke \_\_
10. Kita disarankan untuk makan tiga kali \_\_
11. Kucing itu sedang mengejar seekor \_\_
12. Sebelum tidur, saya akan menutup \_\_\_
13. Terdapat banyak buku di \_\_
14. Kami mendeposit duit simpanan di \_\_\_
15. Nelayan itu turun ke laut membawa \_\_

**Digit span**

**This test consists of two test conditions (i) forward and (ii) backward. We will first start with the digit span forward.**

|  |
| --- |
| **Digit forward task instruction**  **Arahan:** Bagi ujian ini, anda perlu mendengar dengan teliti nombor siri yang akan saya bacakan kepada anda. Anda akan diminta untuk mengulangi nombor siri tersebut dalam susunan yang sama seperti yang saya bacakan. Kita akan mulakan dengan dua nombor siri, kemudian tiga, empat dan berikutnya.  Sebelum kita mulakan ujian ini, saya akan mulakan dengan beberapa praktis latihan. Adakah anda bersedia?  **English translation**  For this task, you will listen carefully to the sequence of numbers which I will read aloud. Your task is to repeat the sequence of numbers in the same order that I read them. We will begin with sequences of two numbers, then three, four and so on.  Before we start this task, we will start with some practice. Are you ready?  Praktis 1: 387  Praktis 2: 96354  Sekarang saya akan memulakan ujian yang sebenar, adakah anda mempunyai apa-apa pertanyaan tentang ujian ini, sebelum kita bermula?  Now I will begin with the real task, before we start this do you have any question? |

|  |  |
| --- | --- |
| **Digit Span Forward** | |
| Level 2 | 53, 94 |
| Level 3 | 762, 238 |
| Level 4 | 6837, 5916 |
| Level 5 | 16357, 84621 |
| Level 6 | 458213, 971384 |
| Level 7 | 3795148, 7261584 |
| Level 8 | 68174523, 35184692 |

|  |
| --- |
| **Digit backward task instruction**  Arahan: Untuk ujian berikutnya, anda akan mendengar nombor siri seperti ujian sebelum ini. Tetapi kali ini, anda perlu mengulangi nombor siri tersebut dalam susunan terbalik dengan apa yang disebutkan. Kita akan mulakan dengan dua nombor siri, kemudian tiga, empat dan berikutnya. Seperti sebelum ini, kita akan mulakan dengan beberapa praktis latihan.  For this task, you have to listen carefully to the sequence of numbers which I will read aloud. You will be asked to repeat the sequence of numbers in reverse order of the sequence I read them.We will begin with sequences of two numbers, then three, four and so on. Before we start this task, we will start with some practice. Are you ready?  Praktis 1: 5239  Praktis 2: 27481  Adakah anda mempunyai apa-apa pertanyaan mengenai ujian ini? Sekarang saya akan memulakan ujian berikutnya. |

|  |  |
| --- | --- |
| **Digit Span Backward** | |
| Level 2 | 24, 38 |
| Level 3 | 456, 943 |
| Level 4 | 9837, 5264 |
| Level 5 | 68742, 76425 |
| Level 6 | 179365, 468719 |
| Level 7 | 2374659, 8235746 |
| Level 8 | 31427685, 57486129 |

**Appendix G**

This Appendix contains the inter-rater scoring instruction

You will be scoring responses for **three** executive function tasks. For each task you will be given a separate document which details the instructions and test items used on how to complete the score. You will be scoring the anonymised transcriptions of responses for 10 participants. These transcribed responses have been stored in excel or word files (i.e., there is one file for each task which includes the data for the 10 participants).

**Task 1:** Sentence completion task

**How to score the responses**

For part (a), if participants produce the target response, give a score of 1. Target responses have been detailed in the spreadsheet *(Column C-F)*.

For any inaccurate response, score ‘0’.

For part (b), if participants produce any word other than the ones provided in the spreadsheet *(Column H)* give a score of 1.

For any response which is stated in the spreadsheet *(Column I-J)* ‘error words’ give a score of 0.

**Task 2:** Verbal fluency task

**How to score the responses**

For part (a) and (b), give a score of 1 for each word/response which is correct according to the category mentioned.

Give a score of ‘0’ for repetition and errors due to naming an item which does not belong to the category

Give a score of ‘0’ for words which are not used or commonly used in the Malay language

**Task 3:**  Spatial drawing

**How to score the responses**

**Part a - three lines drawing**

Score each new/novel pattern or shapes as 1

For any inaccurate drawing:

More than 3 lines

Less than 3 lines

Repetitive or identical in form  to shapes/pattern already drawn

Any of the above, score 0

**Part b- four lines drawing**

Score each new/novel pattern or shapes as 1

For any inaccurate drawing:

More than 4 lines

Less than 4 lines

Repetitive or identical in form o shapes/pattern already drawn

Any of the above, score 0