WORKING MEMORY IN INDIVIDUALS WITH APHASIA

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CERTIFICATE

This is to certify that this dissertation entitled **"Working memory in individuals with Aphasia"** is a bonafide work submitted in part fulfilment for the degree of Master of Science (Speech-Language Pathology) of the student Registration No: 15SLP010. This has been carried out the under guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any diploma or degree.

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DECLARATION

This is to certify that this Master's dissertation entitled ***"Working memory in individuals with Aphasia"*** is the result of my own study under the guidance of Dr. Hema. N, Lecturer of Speech Sciences, Department of Speech-Language Sciences, All India Institute of Speech and Hearing, Mysuru and has not been submitted in any other University for the award of any Diploma or Degree.

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DEDICATED TO

DAD, MOM AND

TO MY GUIDE

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Hare Krishna, hare Krishna, Krishna Krishna hare hare

Hare rama, hare rama, rama rama hare hare

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CHAPTER 1

INTRODUCTION

Aphasia is generally defined as the loss or impairment of language caused by brain damage (Benson & Ardila, 1996). There are different subtypes of aphasia which includes Broca's aphasia, Wernicke's aphasia, Conduction aphasia, Transcortical aphasia, amnesic aphasia, etc. Aphasia can impact spoken languages via expression and/or comprehension as well as reading, gesture, and writing. Adults with aphasia often display deficits in word retrieval, syntax, auditory attention span, processing ability and memory (Caspari et al., 1998).

The extent and location of the brain damage will typically dictate the specific language characteristics affected by the aphasia (Darley, 1982; Davis, 2007; Ardila & Hough, 2013). Thus, aphasia impairs the ability to comprehend and/or produce language and varies in severity across individuals. Cognitive processes such as retrieval, processing, maintaining, and interpreting information or representations are necessary to comprehend and functionally use language (Martin & Reilly, 2012). One cognitive system believed to be involved with language processing in aphasia includes working memory (WM). Working memory capacity has been conceptualized as a single "resource" pool for attention, linguistic, and other executive processing (Just & Carpenter, 1992).

The working memory refers to a system that is used temporarily for storing and managing information which is necessary to perform complex cognitive tasks according to Baddeley (2003). WM is a cognitive system that maintains selected information and activates Thus serve as a goal-directed behaviour. To add on, according to Conway et al. (2005), it is also broadly defined as “a multi-component system responsible for active maintenance of information in the face of ongoing processing and/or distraction”. Thus, WM is involved in the selection, initiation, and termination of information processing functions such as encoding, storing, and retrieving data (Medterms, 2013).

WM capacity has been found to be related to various cognitive tasks, such as verbal reasoning skills, learning abilities, math skills, and processing linguistic features (Just & Carpenter, 1992; Conway & Engle, 1996; Cowan, 1999; Engle, Tuholski, Laughlin, & Conway, 1999; Baddeley, 2003; Conway et al., 2005) since 40 years. In typical cognitive functioning, these processes operate with other abilities including rehearsal, executive functions, and attention to preserve the activation of words in short term memory (Martin & Reilly, 2012). Compared to short-term memory (STM) (defined as a capacity for temporary storage of presented information) the concept of WM places a stronger emphasis on the notion of active manipulation of information instead of passive maintenance.

These subjective complaints of cognitive skills which are not captured by most aphasia batteries are recognized and appreciated by experienced speech-language pathologists. However, few researches are required to characterize the difficulties few individuals report. There are very less procedures which are clinically feasible in identifying the underlying impairments or objectively validating the complaints of individuals with aphasia for example (Frankel, Penn, & Ormund-Brown, 2010). Majority of aphasia research typically focuses on more severe and easily identified aphasia presentations like receptive and expressive language abilities. In contrast, evidence-based evaluative resources for different types of aphasia resulting from particular sites of damage affecting specific components of the language processing system as well as impacting working memory is limited (Gutbrod, Cohen, Maier, & Meier, 1987; Caramazza, 1988; Caspari, et al., 1998; Ardila, 2003; Baddeley, 2003; Friedmann & Gvion, 2003).

Ardila (2003) studied on WM on crucial role in learning L2 /second language. He found that L2 had more processing information thus WM is less efficient due to decrease efficiency in phonological system and its semantic subsystem. Thus, he suggested that even semantic system should be included in WM model.

Friedman (2003) studies a relation between WM limitation and sentences with different types of aphasia and found that type of reactivating the sentence and memory overload is important to determine the effect on sentence comprehension due to WM limitation.

For example to certain clinicians with less experience, the treatment challenges for the identified clients with aphasia are likely to be present when the severity of aphasia is mild and limited evidence are available from which to derive treatment methods (Armstrong, Fox, & Wilkinson, 2013). Hence, there is a need to improve identification of persisting language difficulties in individuals with brain injury by developing sensitive assessment tools related to working memory. Following this, the research directing towards treatment outcome measurement for various types of aphasia is also in need (Kemper, McDowd, Pohl, Herman & Jackson, 2006; Frankel, Penn, & Ormund Brown 2007). There are studies showing the persisting language difficulties in individuals with aphasia have reduce working memory capacity when compared with the neuro-typical individuals (Wright & Shishler 2005). Few studies have assessed working memory capacity in fluent versus non-fluent aphasia. For example, working memory (WM) assessments may be a practical means for identifying high-level aphasia.

Working memory can be assessed in both ways either using simple span task or complex span tasks. Forward digit, backward digit, ascending and descending digit and visual, spatial spans can be used as simple span. Reading span, operational tasks, rhyme judgement; visual letter monitoring and n-back task can be used as complex span tasks.

Forward digit is a task which requires registration of verbal or visual information and remembers passively of that information to repeat it immediately at the end of the stimulus presentation .For example, one has to observe series of numbers for brief interval of seconds and has to recall orally in order wise as they appeared on the screen.

Backward digit task is also similar task like forward digit after registration, the information has to be manipulated actively and formulate a response immediately at the end of the stimulus presentation. For example: one has to observe series of numbers for brief interval of seconds, then remember the numbers and has to manipulate actively (backwards) after presentation.

Reading span: In this task, a series of unconnected sentences are read aloud and individual has to recall the final word of each sentences being presented and there will be increased increment until the errors made by an individual.

Operational task: In this task, participant will be asked to check the correct mathematical equation and read out the words in between along with recall of those numbers verified after the stimulus presented.

Rhyme judgement task: Pair of real words and pseudo-words is presented and subject has to verify whether pair of stimuli rhymes with one another.

Visual attention task: Subject has to identify the stimulus by pressing the button when the stimulus being presented along with distracters simultaneously

***n*-back task**: In this task, subject is presented with stimulus one at a time and has to recognize and recall the items that appeared "*n*" items at the end of its sequence.

Research in aphasia suggests that aphasia is frequently accompanied by working memory deficits (Caspari et al., 1998). On comparison with neuro-typical individual the patients with left hemisphere lesions have performed significantly poorer on verbal memory and spatial memory tasks (Burgio & Basso, 1996; Caspari et al. 1998). Other previous research also suggests that WM contributes to language impairments in aphasia (Caspari et al., 1998; Friedman & Gvion, 2012).

In Friedmann and Gvion (2003) study, they found variations in memory and language parameters in individuals with aphasia (Conduction versus Broca's aphasia). Limited working memory capacity in individuals with aphasia contributes to language deficits. Thus, in complex span task where the subject will be presented with stimuli and asked to identify the item along with additional cognitive task in between the stimulus presented. And these individuals performed poor due to comprehension and/or verbal demands (Murray et al., 2001; Murray, 2004; Wright & Shisler, 2005; Wright & Fergadio (Murraytis, 2012; Wright & Shisler, 2005). Therefore individual's performance in working memory has influence by language abilities and one should consider what extent of language processes influence the cognitive ability in individuals with aphasia (Sung et al, 2009; Martin, Kohen, Kalinyak-Fliszar, Soveri & Laine, 2011; Lang & Quitz, 2012; Mayer & Murray 2012).

But, generally the studies considering neuro-typical individuals involved verbal production and usually using digit or letters, both of these might be susceptible to errors when it is implemented on individuals with aphasia. Thus, it is not easy to demark WM deficits from general language deficits in people with aphasia. Therefore the tasks used to measure WM in individuals with aphasia include non-linguistic tasks such as block span (Lang & Quitz, 2010), n-back tasks and pointing tasks (Christensen & Wright, 2010). Where block span refers to sequence of blocks which should be identified by an individual and has to arrange the pattern of sequence in either forward or backward order, *n*-back is a task where stimulus is presented one at a time and subject has to recognize and recall the item observed '*n*' times at the end of the sequence and in pointing tasks items have to be identified by pointing or by pressing the cursor button to select the target /stimulus. The results of such studies showing the differences in working memory capacity between individuals with aphasia and neuro-typical individuals using tasks like forward and backward digit span, word span, the n-back task, judgement task with respect to semantic and synonymy and listening/reading span tasks are also available in the review (Wright & Shishler, 2005; Martin et al., 2011; Mayer & Murray 2012).

Mayer and Murray (2012) reported that n-back scores were similar across normal and aphasic group with accurate WM for nameable and non-nameable stimuli. Thus when WM load is increased, it affects the performance of the individual with aphasia.

In spite of this comprehensive literature base study on WM in individual with aphasia, there is limitation in terms of rapid and reliable usage of WM test and also in interpreting the results of assessment done to guide towards treatment procedures for individuals with aphasia. To explain in brief, first from the literature review, it is known that the WM is studied separately for different type of aphasia. For example, different types of aphasia research have assessed short-term WM buffer capacity (Example: Baddeley's "phonological loop") tasks used are digit, word, non-word, and spatial span (Beeson, Bayles, & Kaszniak, 1993; Friedmann & Gvion, 2003; Baldo & Dronkers, 2006). Overall, their research studies address that in individuals with frontal lesions have articulatory rehearsal deficits and with posterior lesions (example temporoparietal) have phonological storage deficits.

The other emphasis is the WM deficit in terms of executive type (Gutbrod, Cohen, Mager, & Meier, 1989; Baldo & Dronkers, 1999; Martin & Allen, 2008), the process of inhibiting irrelevant information and updating the content of WM is the process used to identify the difficulties of adults with aphasia according to Miyake et al (2000). From this observation, it is noticed that there are large number of dissimilar tasks for choice and used by the clinicians to assess WM in adults with aphasia.

Second point is that, WM research more focused on neuro-typical individuals rather than clinical population specifically exploring the validity, clinical feasibility and reliability of WM tasks on neuro-typical individuals (Waters & Caplan, 1996; Salthouse, Atkinson, & Berish, 2003; Hockey & Geffen, 2004) but is very important for clinical population too (Tseng, McNeil, & Milenkovic, 1993). The third point is, even though the amount of information one can retain is related to the speed at which one can process information (Daneman & Carpenter, 1980; Just & Carpenter, 1992; Kail & Salthouse, 1994; Miyake, Carpenter, & Just, 1994, 1995; Hockey & Geffen, 2004). For age related cognitive decline this processing speed act as a major factor (Salthouse, 1996). In a number of studies related to WM in adults with aphasia, this processing speed has not been considered (Tompkins, Bloise, Timko, & Baumgaertner, 1994; Christensen & Wright, 2010). Finally, since a variety of aphasia researchers have assessed limitations in particular verbal WM which affects phonological or syntactical and semantic processing (Miyake et al.,1995; Caplan & Waters, 1999; Friedmann & Gvion, 2003; Martin & Ayala, 2004) or the recall of strictly verbal information (Wright, Downey, Gravier, Love, & Shapiro, 2007; Sung et al., 2009).

Therefore on observation it is difficult to separate out and interpret any proposed WM deficits, since there is an existing resultant link of language skills with WM capacity. Hence there is a need to conduct an extended research on WM in adults with aphasia using the present technology or software with the paradigm to assess the link between the language skill and WM capacity. Thus, the need of the present study was to validate the software by using *n*-back task and forward and backward visual span paradigm for measuring WM abilities in individuals with aphasia (IWA) and compare the same with neuro-typical individuals (NTI). Measurements included the basic psychometric properties as well as its utility for providing insight into the nature of WM deficits in individuals with aphasia.

CHAPTER 2

REVIEW OF LITERATURE

For better social communication, listener and /or speaker should understand what speaker or listener engages in the conversation. But in a condition called Aphasia, an individual is not able to comprehend and/or express language and these difficulties vary with severity across individuals. Cognitive process which involves attention, processing, interpreting, maintaining and retrieving the information are very much important in understanding as well as in functionally using the language in society for better communication. One among the primary processes in cognitive system is working memory which helps to store temporary and information are managed with respect to complex cognitive tasks in particular language. Earlier days “Working memory” was known as the concept of short term memory (STM). STM refers to storage of message for short duration of time which is relatively contrast to working memory (WM).WM plays important role in reading comprehension, reasoning skills, calculations, problem solving and academic skills (Madruga et al., 1997; Conwayet al, 2003; Deschuyteneer ,2006; Passolunghi 2006; Alloway et, 2010). Individuals with aphasia have limitation with verbal/gestural mode of communication or exhibit difficulty in responding to any stimulus. Due to these deficits they perform poor in all complex tasks during assessment procedure. Hence it is very much important to evaluate the simple initial stages of cognition i.e., from attention and working memory tasks and then comparing with NTD, thus deficits can be easily assessed and work on deficits quickly to overcome it.

2.1 Working memory

According to Baddeley &Hitch (1974), working memory model was earlier referred as verbal model. To be specific and with reference to Figure 1, "an articulatory loop" is the first component in the model. This is believed to be associated with sub-vocal rehearsal. But, later it was termed as "phonological loop" which emphasize on storing the information rather than rehearsal, which is considered as second component. There is head among all these components known as "Central executive" (CE) which controls all the activities. The third component considered was Visuo-spatial sketchpad which constitutes visual, spatial or combination of both. In original WM model, as there was limited capacities in phonological and visuo-spatial sketchpad subsystem the model failed to explain the results of various experiments. Baddeley (2000) added a fourth component called "episodic buffer" which acts as a backup storage and thus interacts with short term memory, long term memory and working memory.

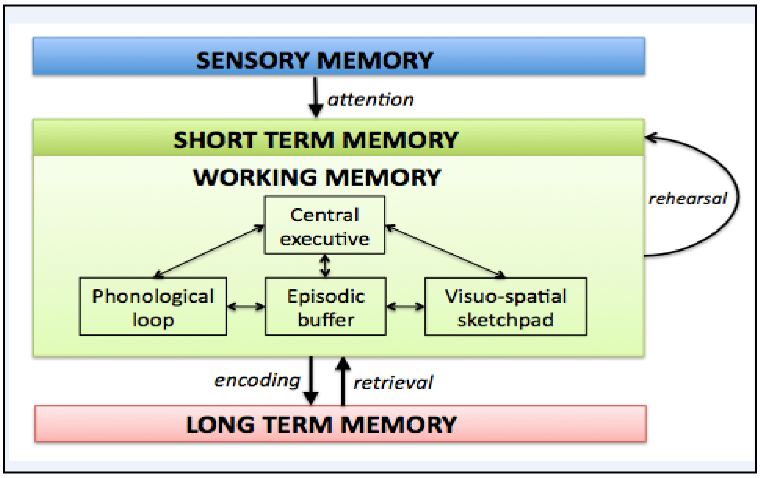


Figure1: Schematic representation of Working Memory Model

In individuals with aphasia, there are many unresolved concerns regarding the WM tasks which are observed. Therefore, the measures must be considered to be more valid and reliable to study working memory tasks in individuals with aphasia.Since the key limitations of the existing research are that: (1) WM tasks have been modified in different ways, making the comparison or aggregation of data across studies problematic (Connor, MacKay, & White, 2000; Murray et al., 2001; Ivanova & Hallowell, 2012) (2) WM tasks used with people who have aphasia are often not designed to take into account potentially confounding factors associated with task requirements and measurement validity (Ivanova & Hallowell, 2012; see Wright & Fergadiotis, 2012 for a related argument); and (3) stimulus design and procedures are often not described in sufficient detail, making it difficult to understand specific task requirements, interpret results, and compare findings with those of other studies. In addition to these methodological limitations, previous studies on WM and aphasia have included heterogeneous aphasia groups and the observed effects were interpreted as if they applied to the whole sample.

2.2 Assessing Working Memory in Aphasia

2.2.1 Simple Span Task

Simple span performance was assessed in individuals with aphasia and neuro-typical individuals to measure on Digit forward span and digit backward span in the group with aphasia (left hemisphere stroke and right hemisphere ,but no aphasia .They were presented upto maximum of eight digits and list of one to nine digits were also given to them to identify the stimulus. Participants are asked to point correct order of numbers presented. Results suggested that there was difference in digit backward span than digit forward span which concludes that it is due to attentional capacity observed in IwA where deficient seen in phonological loop.

2.2.3 Complex Span Task

With reference to complex span task, the independent performance done by individual has differences in domains like general processing efficiency and specific storage capacity According to Wright et al.,(2003), they checked in their study whether there was difference in WM performance in individuals with aphasia (fluent ,nonfluent and nerurotypical individuals) using listening span task and also had good comprehension ability with mild to moderate severity. And found that poorer scores were performed by individuals with aphasia than neurotypical individuals. Performance on WM was measured and correlated with oral language ability along with WAB AQ scores and found that significant correlation in WAB which contains information of both linguistic and cognition (Caspari et al., (1998).

There is also an attempt made to find out the relation between working memory and reading comprehension in aphasia. For example, Isabelle et al, (1998) considered 22 aphasic individuals and their task was to recall the end words of each sentence for subsequent recognition. Working memory capacity was measured using modified version of Daneman and Carpenter's (1980) Reading Span Task. Maximum number of words recalled by an individual was termed as index of working memory capacity. Depending on the individual’s ability there were two versions of task introduced i.e listening and reading. Results suggested that there were high correlations seen between working memory capacity, language function and also in reading comprehension.

Wright and Fergadiotis (2012) conducted a study to review on current WM and its theoretical frameworks, tasks to measure WM and also to relationship between WM and language processing in aphasia. They found various results for different theoretical framework which was less susceptible hence recommended for further investigations to be done in order to see the contributions of WM in language processing in aphasia group. Hence there is a need to choose specific paradigm to assess WM in individuals with aphasia.

2.2.3 Forward span and backward span task

Individuals with aphasia have deficits in cognition processes especially storing information as well as in manipulating it. In Forward span task, it helps in assessing the stored information temporarily and also maintaining the information. Whereas, the backward span task helps not only in assessing the stored information temporarily and maintaining it. But also accompanies with manipulation of information observed during the task (Wilde, Strauss, & Tulsky, 2004; Baddeley, 2007) Hence these tests can be preferred to assess their WM abilities by using simple tasks during assessment and /or intervention before focusing on language therapy. One of the study by Leung et al. (2015) investigated the current study on auditory *n*-back auditory WM test during rehabilitation with two stroke participants and session was carried out for six week for total of 20 hours. Before and after training neural activity on auditory and visual mode was observed. By using n-back task improvement was seen in both modalities (visual and auditory) and also found majorly there was activation in cerebellum. Thus, results showed there was better performance in aphasic participants due to cross model activation. Remarkable improvements in the linguistic features in individuals with aphasia has been observed using WM rehabilitation during intervention (Kalinyak-Fliszar et al., 2011; KoenigBruhin & Studer-Eichenberger, 2007; Majerus et al., 2005).

An experiment conducted by Laures-Gore, Marshall, & Verner, (2011) to measure digit forward and backward span test and compared with different types of aphasia [Broca’s, Anomic Aphasia& Right brain damage (RBD)], but no aphasia based on WAB test scores of age range 40-74 years were included. These participants were asked to indicate the correct order digits on written note card or orally repeat the numbers. Researchers found that individuals with aphasia (IWA) performed lower digit span scores than RBD individuals. In Digit backward span tests both groups performed poor than digit forward span test. Thus study states that decreases attentional capacity in IWA was observed which showed deficient in phonological loop.

2.2.4 *n*-back task

This task was developed by Kirchner (1958), which is a continuous performance task and helps in assessing a part of working memory and its capacity. Also as working memory requires storage and manipulation of information at the same time, in n-back tasks similar procedure is carried out. Therefore, to assess WM capacity in individuals with aphasia *n*-back task with different types of stimulus either linguistic or non-linguistic may be suitable and suitably used one. For example, ten native English speakers with various types of aphasia (Broca's, Conduction, Anomic and individuals with Apraxia) diagnosed based on Western Battery Aphasia (WAB) or Boston Diagnostic Aphasia Examination (BDAE) with 6 months post onset and no other neurological conditions were considered for the study. The participants had to perform on *n*-back task (fruit task) and memory span task in both modalities (visual and auditory) (Downey et al., 2004). Thus, the assessment of WM deficits is in relation with the language difficulty exhibited for longer or more complex sentences and discourse. They also found responses in visual presentation mode being faster than auditory presentation mode in all levels.

Apart from the modality, a study conducted by Christensen and Wright (2010) on verbal and non-verbal working memory in aphasia using three *n*-back task. The aim was to check the effects of varying linguistic processing demands with reference to the context for participants with and without aphasia. Three different *n*-back tasks for example; Higher linguistic –fruits, semi-linguistic–fribble and non-linguistic–blocks were considered. They compared differences within and across individuals with aphasia and also with neurologically intact matched peers and each completed two levels of difficulty (1-back and 2-back test). All aphasia participants performed better in 1 back task than 2-back WM task. To be specific individuals with aphasia performed poorer compared to neuro-typical individuals. Therefore, results suggest that there was a significant influence on performance on working memory tasks by linguistic components and should be considered when discussing cognitive deficits in aphasia. From the above study it is observed that the individuals with aphasia have deficits in cognition system (for example: Working Memory) which will affect their language sources in them which are not noticed often and concentrate more on assessment and/or intervention on language components than with cognitive processes.

Working memory deficits in aphasia with a history of unilateral left-hemisphere lesion with the post morbid duration of at least three months were considered in another study by Mayer and Murray (2012). The aim was to check the feasibility, reliability and internal consistency of n-back task and thus evaluate WM in aphasia. Participants considered were 14 adults with aphasia and the neuro-typical individuals with age and education matched were 12 in number. All the participants completed *n* -back task with varying stimulus type for example, high frequency, low frequency and non-nameable stimuli and also in WM load (0, 1, 2-back test). Accuracy and reaction time (RT) was analyzed in among these experimental tasks, standardized performance task and also calculated effect size. Aphasia and aged matched controls results showed similarly across stimulus types with significantly greater WM accuracy for nameable versus non-nameable stimuli. Compared to the controls, adults with aphasia were significantly more affected by increasing WM load. RT effects generally paralleled accuracy data, whereas age effects were inconsistent across tasks. Hence, *n*-back task holds well in measuring WM for adults with aphasia and can quantify to clinical population.

In the recent study by Ivanova, et al., (2015), an attempt has been made to compare the two WM tasks such as *n*-back task and complex span and also between fluent and non-fluent groups. The task used was a modified listening span task (Ivanova & Hallowell, 2014), an auditory verbal 2-back task and a standardised Russian language comprehension test. The participants considered were 44 individuals with aphasia of non fluent, fluent and mixed type. The results suggested that two tasks indicated primarily different cognitive mechanisms. The correlation between listening span test and language comprehension was good with non fluent aphasia than fluent aphasia. Researchers also claimed that two tasks cannot be substituted for one another and further investigations have to be made for details.

To summarize, some researchers have observed that there is nominal differences between adults with aphasia and healthy controls using the *n* -back task (Friedmann & Gvion, 2003), others have identified that there is deficits in the performance in IWA secondary to to parietal, but not frontal lesions (Baldo & Dronkers, 2006) and still others are investigating impaired performance for those with aphasia across the board (Christensen & Wright, 2010). Due to the variations in the stimuli when using n-back task protocol (e.g., using auditory [Friedmann & Gvion, 2003] or visual stimuli [Baldo & Dronkers, 2006; Christensen & Wright, 2010]), and in recruiting subjects (e.g., testing only those with conduction or Broca's aphasia [Friedmann & Gvion, 2003]) mixed results are obtained .Thus there are differences iobserved in all kind of task with reference to *n*-Back of working memory test.

From all the above observation, it is noted that only few studies are related to *n*-back task that discuss about WM capacity and also its influence in language processing. Hence, future investigations are required to determine performance both in neuro-typical individuals and also in individuals with aphasia. Few researchers found low performance as *n* -back level increases in neuro-typical individuals after using n-back task to assess WM and which implies similar performance with reference to both the group at higher levels. However *n* -back task has strong validity in determining the WM abilities provided the study is replicated with larger number of participants and on different types of aphasia.

2.3 Need for the study

In recent studies, many researchers have stated that *n* -back task has a capability to assess and index WM in individual with aphasia (Friedmann & Gvion, 2003; Baldo & Dronkers, 2006; Christensen & Wright, 2010; Connor & Fucetola, 2011; Wright & Fergadiotis, 2012). As *n* -back is a parametric task , which helps in judging whether a current stimulus matches with previous stimulus sequentially which comes in '*n*' place . It is thus considered to have strong idea which helps in validity and its structure is parallel to the definition of WM, i.e., requiring temporary storage and manipulation of information while continuously updating WM contents (Cohen et al., 1997; Salthouse et al., 2003; Wright & Fergadiotis, 2012). Functional neuroimaging studies of healthy adults performing *n* -back tasks report activation of frontal and other cortical areas implicated in the WM network consistently (Cohen et al., 1997), and both imaging and evoked potential investigations also shown evidence that this task is responsible for the central executive component of WM (Smith, Jonides, Marshuetz, & Koeppe, 1998).

The *n* -back task is advantageous for measuring working memory (WM) in aphasia for several reasons.

- For individuals with auditory comprehension deficits, this task contains simple instructions.
- Lang (1989) suggests that this task's response is mainly involves recognition rather than recall response. Thus, it helps individuals with expressive language and motor speech deficits.
- In this task Reaction Time (RT) can be automatically measured and can easily interpret the results and identify the subtle impairments in cognition (Crerar, 2004).
- With various types of stimulus (shapes, objects or spatial locations), this task can be easily carried out (Wright et al., 2007; Christensen & Wright, 2010).

Measuring WM in aphasia is critical, when not considering language from a complex cognitive test: that is, instead of attempting to eliminate linguistic content, the *n* -back allows researchers and clinicians simply vary with their complexity of the particular information in the task which helps to recognize WM from language domain, and thus can explains about the relation between language (i.e., type of stimulus) and attention(Engle, 2002),without removing language domain. The ability of the *n* -back task in multiple conditions within a single task is also ideal for measuring and interpreting differences in reaction time across individuals and groups (Salthouse & Hedden, 2002).

Individuals with aphasia are often having limitations in responding verbally and/or through gestures which are due to deficits in motor speech and limb motor and thus help them to perform poor in complex span tasks during testing/assessment. Therefore, it is very much important to evaluate every stage of working memory tests and their necessary requirements, and also to challenge directly by comparing individuals with and without aphasia in all tasks where deficits can be assessed easily. Hence, by pointing or through gestures responses can be considered as alternative to spoken language although rarely this is done because of delay in verbal recall in most of the complex span tasks. However there are many unresolved concerns regarding the WM tasks, but the measures should be most valid and reliable for use with individuals with aphasia. Limited attempts have been made to validate the versions of working memory tests. Presently there is a great need for research to establish methodological, theoretical, and psychometrical measures of working memory in individuals with aphasia. Therefore the assessment of WM using 'Cognitive Module' (software) has enabled more thorough and valid investigation of the role of WM in aphasia.

CHAPTER 3

METHOD

Aim of the study

The aim of the present study was to investigate and compare the working memory abilities of individuals with and without aphasia.

Objectives of the study

1. To investigate the working memory in individuals with and without aphasia using forward and backward span task (visual) and *n*-back task.
2. To compare the working memory threshold of individuals with and without aphasia.

Hypothesis

Null Hypothesis

There will be no significant difference in the working memory abilities of individuals with and without aphasia using forward and backward span task (visual) and *n* -back task.

There will be no significant difference in the working memory threshold of individuals with and without aphasia.

Research Design

The present study was a standard group comparison with two groups- clinical group (individual with aphasia) and control group (neuro-typical individuals).

3.1 Participants

The participants chosen for the study were twenty neuro-typical individuals constituted as Group 1 and ten individual with aphasia constituted as Group 2, both within the age range of 20-60 years. In total, thirty participants who were native speakers of Kannada language were considered as participants for the present study. The neuro-typical individuals would constitute the control group and individuals with aphasia would constitute the clinical group. The participants from this Group 1 and Group 2 had to undergo their hearing screening at 500 Hz, 1 KHz, 2 KHz and 4 KHz obtained a hearing acuity at 40 dBHL.

3.1.1 Participant Selection

All the participants from the clinical group were chosen from the All India Institute of Speech and Hearing, Mysuru, Karnataka, India. The participants from the control group were drawn from the work/residential place in and around Mysuru, Karnataka, India.

Participants were included in the study only on fulfilling certain specific criteria. The criteria were different for the clinical and the control groups, with a few common criteria for the two groups.

Inclusion criteria for the control group

The additional inclusionary criteria for the neuro-typical individuals were: (1). no history of speech, language and hearing impairment; (2). No reported history of neurological/psychological impairment confirmed through the administration of General Health Questionnaire. (3). Performance on Mini-Mental Status Examination (Folstein, Folstein, & McHugh, 1975) within the normal range. (4) These individuals should have minimum 10 years of formal education. Twenty neuro-typical individuals were considered as normal participants.

Inclusion criteria for the clinical group

The additional inclusionary criteria for individuals with aphasia were: (1). Individuals with the provisional diagnosis of aphasia as a result of cerebrovascular accident as indicated from a neurologist with the confirmation via neuroimaging data or a speech-language pathologist on administration of Western Aphasia Battery (Ravikumar & Shyamala, 2008) (2). No reported history of cognitive or speech and language impairment prior to aphasia onset (3). Post onset duration of at least two- six months.

Twenty participants with aphasia were considered for the present study and underwent Western Aphasia Battery (WAB) to characterize the nature and severity of language deficits. These participants with aphasia were administered the Aphasia Quotient (AQ) component of WAB (AQ lesser than 93.8 were only selected). From a speech language pathologist, they received a confirmation regarding the presence of aphasia component. And to be specific, participants with the diagnosis of Broca's Aphasia were only considered for the present study. Aphasia in the present study is defined as ‘‘an acquired communication disorder caused by brain damage, characterized by an impairment of language modalities: speaking, listening, reading, and writing; it is not the result of a sensory deficit, a general intellectual deficit, or a psychiatric disorder’’ according to Hallowell and Chappey (2008). Only participants who had aphasia due to cerebro-vascular accident were considered.

3.1.2 Demographic details of the participants.

The demographic and diagnostic details of the participants in the clinical group are shown in Table 1. Table 2 shows the mean age of clinical and control group and the mean of individuals with aphasia of clinical group. The control group was matched with the clinical group for age and education level. Mean age of the participants (N=30) was 40.1 years and IWA has mean post morbid duration was 4.65 months was noted.

Table 1

Demographic details of clinical participants.

Sl no.	Age/sex	Language known	Education level	Type of Aphasia
1.	22/M	K, E	G	Broca’s Aphasia
2.	31/M	K, E	G	Broca’s Aphasia
3.	33/M	K, E	PG	Broca’s Aphasia
4	38/M	K, E	G	Broca’s Aphasia
5.	38/F	K, E	G	Broca’s Aphasia with right hemiplegia
6.	39/M	K, E	G	Broca’s Aphasia
7.	45/M	K, E	G	Broca’s Aphasia
8.	48/M	K, E	G	Broca’s Aphasia
9.	58/M	K, E	PG	Broca’s Aphasia
10.	60/M	K, E	G	Broca’s Aphasia

Note: M- Male, F- Female, K- Kannada, E- English, G- Graduation, PG- Post Graduation.

3.2 Assessment Procedure

3.2.1 Data collection phase

Informed consent form

Informed consent proposed by AIISH (All India Institute of Speech and Hearing) Ethical committee (2009) was used to obtain consent from each of the participants. The informed consent form consisted of two parts: the verbal information sheet and the consent form (Appendix A).

Verbal information sheet

The information sheet included information on the title and objective of the study being undertaken along with the type and number of participants. They were highlighted about risk/benefits for human research subjects willing to participate in the study. Assurance was provided to the participants that they would be clarified of any doubts at anytime during the data collection/study. Emphasize is made on the privacy-confidentiality-anonymity of participating human subjects. Information sheet also consisted of a clear appreciation and understanding about introduction to the study, procedures and protocol, duration, confidentiality, sharing the results, right to refuse or withdraw, and whom to contact.

The consent form**:** The certificate of consent consisted of written statement in first person, in bold. The consent form was signed by all the participants in the group with neuro-typical adults (NTI) and individuals with aphasia/guardian of the same.

General information sheet: General history included name, age/sex, address and contact, languages known, handedness, education, occupation, information about hearing and vision, history of neurological/psychological illness, presenting illness, and address and contact number. Detailed medical history (if any) which included presenting symptoms, details of medical and non-medical treatments, and information about tests which they had undergone was obtained from the participants. (The General Health Questionnaire (GHQ) (Appendix B) was also administrated for all the participants. All the participants were interviewed individually and the general history was taken. The participants were made to sit in front of the examiner. Interviews were in the form of interactive sessions with questions and answers. General history included the demographic details of the participants, education history, language history, medical history, present health status and any other associated problems.

Mini Mental Status Examination (MMSE)

The mini-mental state examination (MMSE) or Folstein's test is a brief 30-point questionnaire test that is used to screen for cognitive impairment. It was introduced by Folstein, Folstein, and McHugh (1975) (Appendix C). It is commonly used to screen for cognitive impairment. It is also used to estimate the severity of cognitive impairment at a given point in time and to follow the course of cognitive changes in an individual over time. It is an effective way to document an individual's response to treatment. In a time span of about 10 minutes, MMSE samples various functions including arithmetic. The MMSE test includes simple questions and problems in several areas: the time and place of the test, repeating lists of words, arithmetic such as the serial sevens, language use and comprehension, and basic motor skills. For example, a question is asked to copy a drawing of two pentagons. Any score greater than, or equal to 25 points (out of 30) is effectively normal (intact). Below this, scores can show severity like severe (≤9 points), moderate (10-20 points) or mild (21-24 points). Low to very low scores correlate closely with the presence of cognitive impairment, although other mental disorders can also lead to abnormal findings on MMSE testing.

MMSE was administered in Kannada to the participants in both clinical and control groups. Table 4 shows the scores obtained on MMSE for all the Aphasia participants. The participants score <25 indicating mild to moderate in the range between 17-23 points cognitive impairment.

Table 2

Scores obtained on MMSE for all the IWA participants.

Aphasia participants (*n* = 10)	**Parameters of MMSE**					
	Orientation (10)	**Registration (3)**	**Attention & Calculation (5)**	**Recall (3)**	**Language & Praxis (9)**	**Total**
1.	6	2	1	2	6	17
2.	8	3	2	2	5	20
3.	9	2	2	2	7	22
4.	8	3	1	2	6	20
5.	8	3	2	2	6	21
6.	9	3	1	3	7	23
7.	6	3	2	2	6	19
8.	7	3	1	2	6	19
9.	8	3	2	2	7	22
10.	6	3	1	2	6	18

Note. n- Number of participants.

Western Aphasia Battery (WAB)

This is a standard test initially given by Kertesz and Poole (1974, 1979, and 1982) to assess the language ability and classify the participants into different types of aphasia. The test consists of different tasks to check spontaneous speech, auditory verbal comprehension, repetition and naming abilities. In the present study the Kannada version of WAB developed by Shyamala and Ravikumar (2008) (Appendix D) was used to rule out the presence/absence of aphasia component in the individuals with aphasia. Only the participants with presence of aphasia component were considered for the study. WAB was administered in Kannada to the participants in clinical group. Table 5 shows the scores obtained on WAB for all the participants in clinical group

Table 3
Scores obtained on WAB for all the Aphasia participants.

Aphasia Participants (*n* - 10)	**Parameters in WAB**				
	Spontaneous speech (20) Fluency (10=AQ)	**Auditory Verbal Comprehension (200/20=AQ)**	**Repetition (100/10=AQ)**	**Naming (100/10=AQ)**	**Presence/ Absence of Aphasia component**
1	1	6	1	0.1	Broca's Aphasia
2	1	5.7	1	0.1	Broca's Aphasia
3	2	6	2	0.2	Broca's Aphasia
4	1	8.5	1	0.1	Broca's Aphasia
5	1	7	2	0.1	Broca's Aphasia with right hemiplegia
6	2	7.2	1	0.1	Broca's Aphasia
7	1	5.8	1	0.1	Broca's Aphasia
8	2	8.4	1	0.1	Broca's Aphasia
9	1	6.9	2	0.1	Broca's Aphasia
10	2	5.3	1	0.1	Broca's Aphasia

Note. *n*- Number of participants.

3.2.2 Assessment of Working Memory

The Software used in the study was 'Cognitive Module' (Kumar & Sandeep, 2012) to assess WM in individuals with and without aphasia. Three subtests such as forward span, backward span and *n*-back test performed according to the instructions given with respect to each subtest.

3.2.2.1 n-back task recording: In n-back task, current stimulus is judged whether it was matched with one that presented '*n*' places previously in a sequence. All participants were asked to complete the task, for example three *n* -back tasks: which has 3 levels of WM load (0, 1, and 2) and having linguistic complexity of high-frequency words per load.

Figure 2. Schematic representation of the *n*-back tasks at 0-, 1-, and 2-back levels.

For example in the 0-back condition, the target was considered as any stimulus that has to be matched with a pre-specified stimulus. In the 1-back condition, the target was any stimulus that has to be matched with one stimulus which was preceded immediately (i.e., one trial back). In the

2-back condition, the target might be of any stimulus and the individual has to identify the stimulus presented two trials back (Figure 2). Prior to the experimental n-back tasks, all participants had to complete training trials for 0-, 1-, and 2-back conditions initially in order to ensure that instructions are comprehensible to the individuals and also to make them to perform easily in the actual task. For every subtests, participant's user ID was created in a .note file format and training trials was carried out as many times as possible for the participants until they were able to complete each trial with 100% accuracy. Task instructions emphasized both accuracy and speed, and included both pictured examples and demonstration was given to minimize the possible effects of auditory comprehension deficits in participants with aphasia group as depicted in Figure 3.

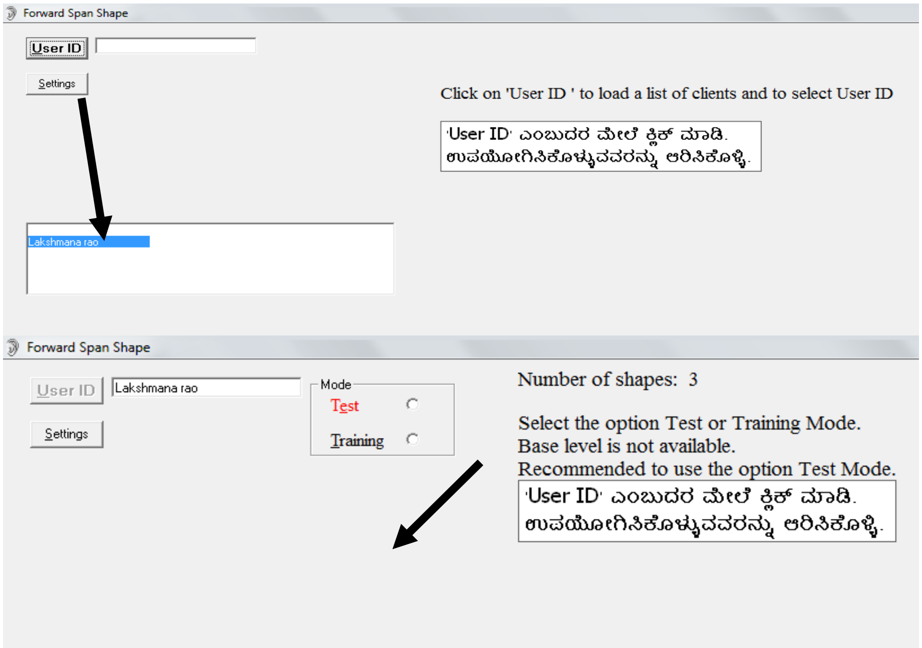


Figure 3. User ID created for a participant to undergo test or training following the instructions.

The n-back task was presented on a laptop computer using "Cognitive Module" developed as part of the projects under AIISH (All India Institute of speech and Hearing) Research Fund, Mysore by Kumar and Sandeep (2012). The subsection called *n* -back task was selected from this software (Figure. 3.3) and each stimulus in the *n* -back task was displayed for 900 ms and an inter-stimulus interval of 1600ms. This relatively rapid presentation rate was chosen to discourage attempts to covertly verbalize the linguistic stimuli (note that it was expected that participants would covertly verbalize the nameable stimuli). Participants were made to seat at a comfortable distance from the screen with their unaffected or dominant hand resting on the keyboard and press a left click on the mouse whenever they see a target stimulus.

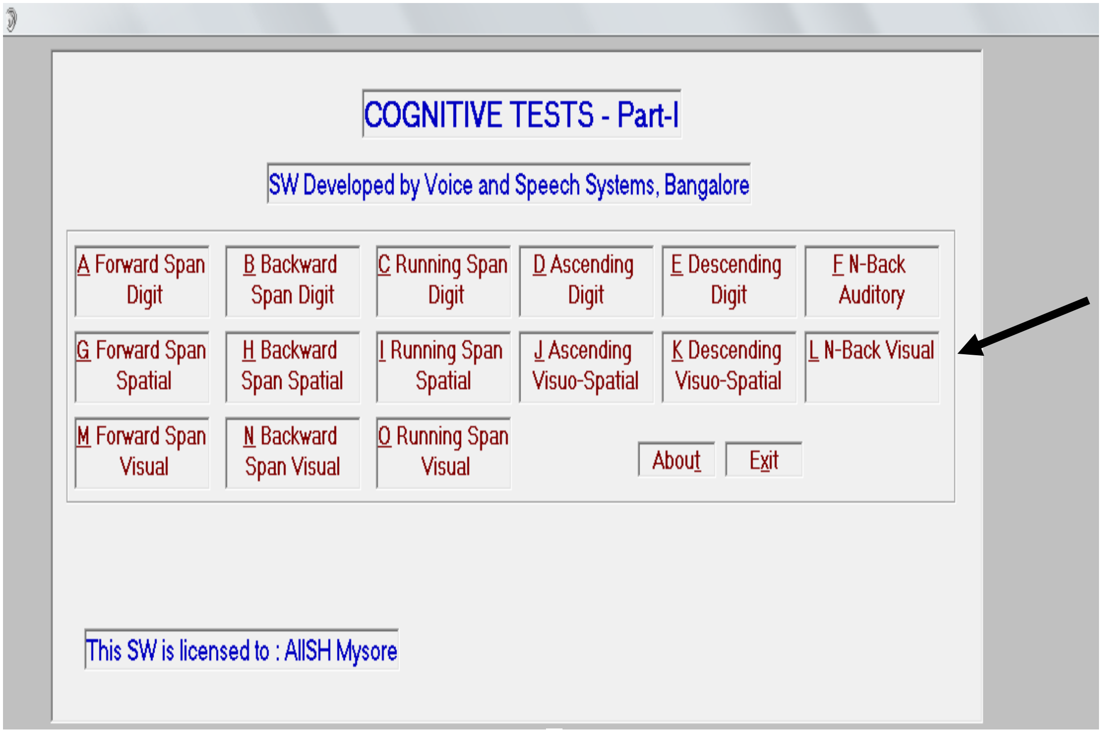


Figure 4. Selection of subsection called *n* -back task, forward span and backward span from the "Cognitive Module software".

The length of each *n* -back sequence was varied automatically by the software according to WM load, there was '*n*' of trials specified and when individuals performs well in the task, level of stimulus presented was increased (one example from the software is shown in Figure 4). For the 0-back tasks and 1-back tasks, participant had to match with a pre-specified target when shown and for the 2-back tasks some target stimuli was repeated. Across *n*-back tasks, non-target stimuli were contributing simultaneously and were distributed across the set of stimulus by same number of times in similar manner. For every attempt of the task the software provided a feedback.

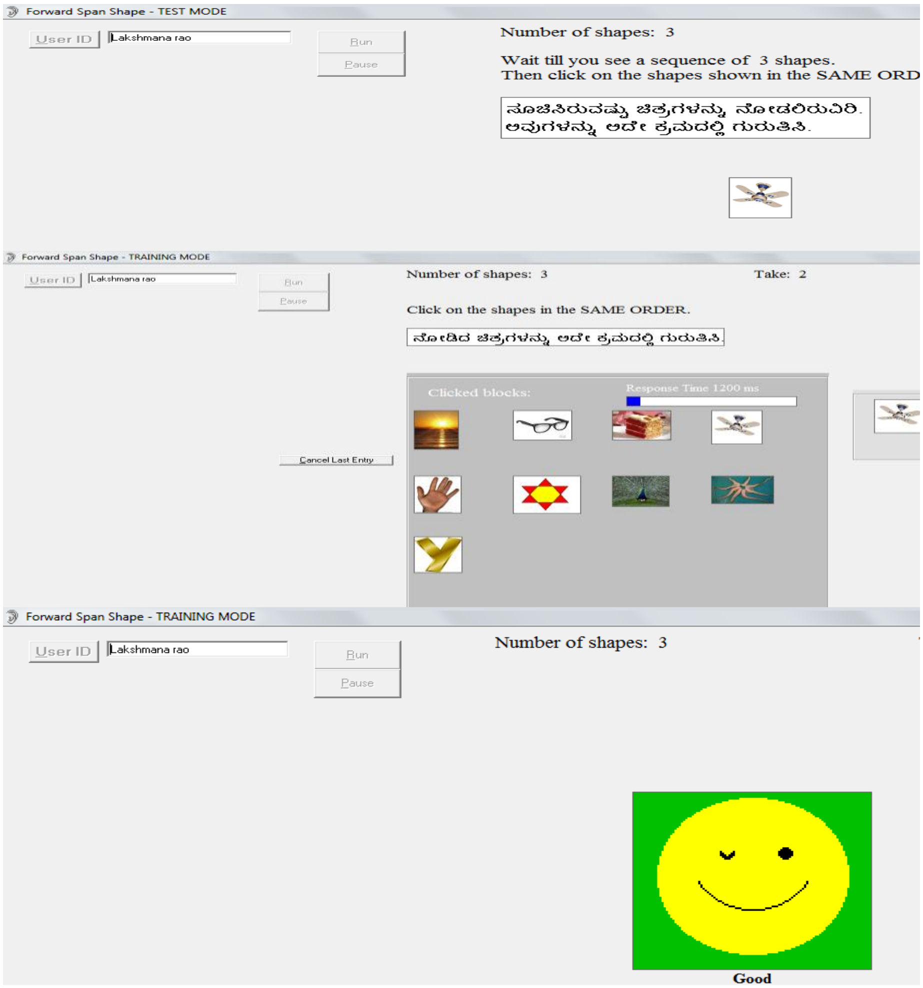


Figure 5. Depiction of the stimulus presentation and matching response.

n-back tasks was administered in a partially fixed order to reduce confusion within set of stimulus. That is, participants would complete all three 0-back tasks before completing the 1-back and then the 2-back tasks, respectively. For every trial, the order of tasks along with the complexity (within high-frequency stimuli) was considered as randomized and a break was given after every set of stimulus as preferred by the participants with aphasia. Most of them might complete the 0- and 1-back tasks (approximately 20 and 25 min per task, respectively), aphasia tests and this experimental n- back task was completed in 90 minutes of one session or two separate sessions if required and the 2-back tasks (approximately 25 min each), in addition to any incomplete tasks, participants was assessed in a second session (60 mins) approximately/one week after the first session.

Instruction: *On desktop screen, you will be seeing a sequence of picture (1, 2, 3), please judge whether the current stimulus matches with previous stimulus sequentially which comes in 'n^{th}' place (n=0, n=1, n=2etc). Positive response (happy face) and negative response (sad face) was shown as feedback after every response.*

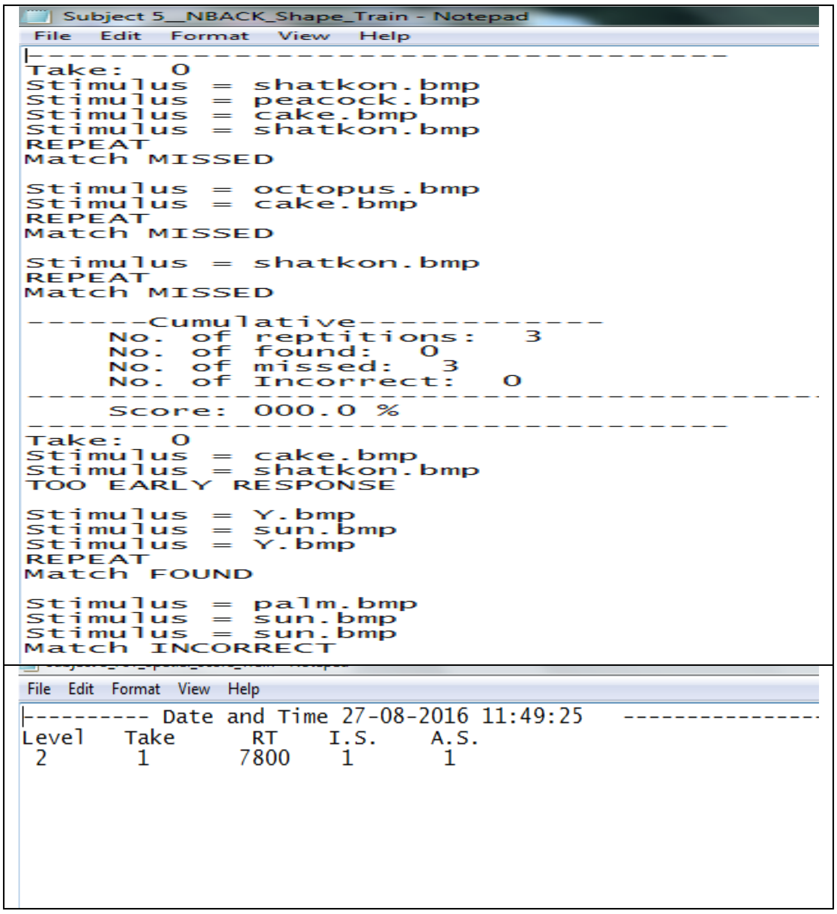
3.2. 2. 2. The forward and backward span visual task recording: This was a visual (forward and backward) span task which is used most often in this form. Participants with and without aphasia had to view the visual stimulus (pictures) presented on the computer screen, remember this set of separately presented pictures and then had to recall the individual pictures after each set of pictures. The visual stimulus was nine in number and which was presented nonlinearly. Pictures to be remembered were concrete and phonologically simple words. All these visual stimuli were presented only visually without any auditory cues. The task was to recall by selecting the three target visual stimuli presented in the specific sequence (forward and backward) amongst the given choice of nine pictures (multiple-choice arrays). Items recalled after the time limit was scored as incorrect responses. The storage score (accuracy and reaction time) was considered as an index of WM capacity.

Pictures used for the multiple-choice arrays was colored images created by a professional artist with extensive experience in developing visual stimuli specifically designed to minimize the influence of visual image characteristics on allocation of attention.

Instruction*: You will be seeing a sequence of target pictures (1, 2, 3) which will be presented, please recognize the sequence (forward or backward) of pictures presented amongst the multiple-choice array. Positive response (happy face) and negative response (sad face) was shown as feedback after every response.*

3.3 Scoring and analysis of n-back task and forward and backward visual span task

The results were saved in the .notepad file within the software as shown in Figure 6. The data of each participant was then examined manually to record the reaction times (RT) associated with correct and wrong responses, so that the mean RT and accuracy of one participant representing correct responses was considered for comparison amongst the other participants.



```
Subject 5__NBACK_Shape_Train - Notepad
File  Edit  Format  View  Help
|------------------------------------
Take:   0
Stimulus  =  shatkon.bmp
Stimulus  =  peacock.bmp
Stimulus  =  cake.bmp
Stimulus  =  shatkon.bmp
REPEAT
Match MISSED

Stimulus  =  octopus.bmp
Stimulus  =  cake.bmp
REPEAT
Match MISSED

Stimulus  =  shatkon.bmp
REPEAT
Match MISSED

------Cumulative-------------
     No. of reptitions:   3
     No. of found:   0
     No. of missed:   3
     No. of Incorrect:   0
--------------------------------------
     Score:  000.0 %
------------------------------------
Take:   0
Stimulus  =  cake.bmp
Stimulus  =  shatkon.bmp
TOO EARLY RESPONSE

Stimulus  =  Y.bmp
Stimulus  =  sun.bmp
Stimulus  =  Y.bmp
REPEAT
Match FOUND

Stimulus  =  palm.bmp
Stimulus  =  sun.bmp
Stimulus  =  sun.bmp
Match INCORRECT
```

```
File  Edit  Format  View  Help
|--------- Date and Time 27-08-2016 11:49:25   ----------------
Level   Take      RT    I.S.    A.S.
 2        1      7800    1       1
```

Figure 6: Results saved in .notepad file for *n* back task and forward and backward span visual task

Thus, the results obtained from the study were analyzed using appropriate statistical measures in Statistical Package for the Social Sciences (SPSS) software package (Version 20.0). The accuracy scores were obtained in module of *n*-back, forward and backward span tasks along with reaction time were also recorded and a threshold/level was established for the considered IWA and NTI. Task was compared between control group (NTI) and clinical group (IWA) using Mixed ANOVA and Mann Whitney-U-test. Test reliability measures were obtained using paired sample-t test and Wilcoxon's signed rank test.

CHAPTER 4

RESULTS

The aim of the present study was to investigate the working memory in individuals with aphasia (IWA) and neuro-typical individuals (NTI).

Objectives of the study

1. To investigate the working memory in individuals with and without aphasia using forward and backward span task (visual) and *n*-back task.
2. To compare the working memory threshold of individuals with and without aphasia.

The performance of individuals with aphasia and neuro-typical individuals is explained under two aspects like reaction time and level/threshold/accuracy for working memory test. The statistical analysis was carried out using SPSS (PASW) Version 20. The statistical tests were carried out in the following steps. Step I to Step V corresponds to reaction time aspects of working memory tests (Forward Span Task, Backward Span Task and n-back) and Step VI corresponds to the level/threshold/accuracy of only n-back test.

In *Step I:* Test of Normality**-** The data was subjected to test of normality by using Shapiro Willis test and it was observed that the data was showing properties of normal distribution ($p > 0.05$) and found no outliers in the data. Hence further parametric tests were carried out to compare between individual with aphasia especially Broca's Aphasia (IWA) group and neuro-typical individuals (NTI).

4.1 Descriptive Statistics

In *Step II*: The mean and standard deviation of reaction time and threshold/level for Forward Span Task (FST) and Backward Span Task (BST) of individuals with Aphasia (IWA) and neuro-typical individuals (NTI) was calculated using descriptive statistics.

The mean and standard deviation of forward span and backward span reaction time of individuals with Aphasia (IWA) and neuro-typical individuals (NTI) was calculated using descriptive statistics and the results are shown in Table 4. From the table it is observed that the mean reaction time (in terms of milliseconds) or the time taken to execute forward span task by IWA was greater compared to NTI. Similarly the mean reaction time or the time taken to execute backward span task by the IWA was greater compared to NTI. Apart from the above statistical analysis with reference to the level/threshold/accuracy of executing the FST and BST (raw score), IWA group had a similar level of '2' for FST and level of '1' for BST among the total 10 individuals. Whereas, among the NTI group, 12 individuals had a level of '2' and 8 individuals had a level of '3' for FST. For BST, 3 individuals had a level of '1'and 10 individuals had a level of '2'and 7 individuals had a level of '3'. Therefore the majority of NTI group had level '2' for FST and level '2' for BST.

Table 4.

Results of descriptive statistics for Forward Span Task and Backward Span Task of individuals with Aphasia (IWA) and neuro-typical individuals (NTI).

Working Memory Tests	Group	N	Mean	S.D
Forward Span Task Reaction Time (FSTRT)	Normal	20	8775.50	2545.14
	Aphasic	10	14255.00	1982.45
	Total	30	10602.00	3516.53
Backward Span Task Reaction Time (BSTRT)	Normal	20	8817.50	3234.28
	Aphasic	10	13215.00	2234.08
	Total	30	10283.33	3584.40

From the Figure 7, with reference to the mean score or the reaction time to execute forward span task and backward span task of Working memory tests with irrespective of the levels, the neuro-typical individuals did not show any differences. Whereas, the individuals with aphasia group could perform better with less reaction time for the backward span task compared to forward span task. However the reaction time taken by the individuals with aphasia group was higher compared to the neuro-typical individuals.

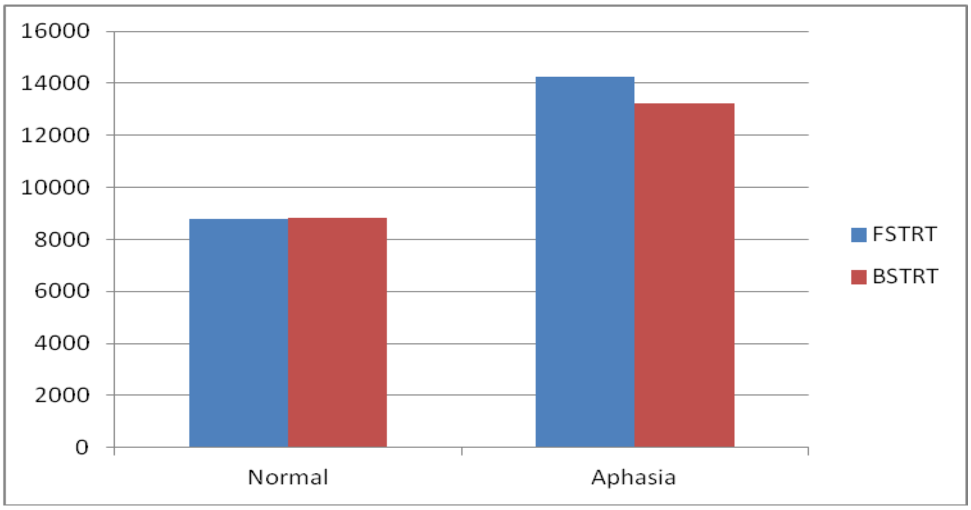


Figure 7. Mean scores for reaction time for Forward Span Task Reaction Time and Backward Span Task Reaction Time of Neuro-typical Individuals and Individual with Aphasia.

4.2 Comparison of Forward Span Task, Backward Span Task and *n*-back between Individual with Aphasia and Neurotypical Individuals.

In *Step II*: Mixed ANOVA, Repeated measure ANOVA to study the main and interaction effects of group (IWA & NTI) and parameters (RT) irrespective of the task (FST and BST).

Following the descriptive statistics, mixed ANOVA was administered to check the main and interaction effects of groups (IWA vs NTI) and reaction time (FSTRT vs BSTRT) and groups over the reaction time of working memory task. Table 5, shows the results of mixed ANOVA.

Table 5

Results of Mixed ANOVA to study the main and interaction effects of groups and reaction time

Source	**F (1,28)**	***p* value**
Groups	27.673	0.000 **
Reaction time (RT)	1.272	0.269
Groups * Reaction Time	1.495	0.232

Note. ** p <0.001

Initially for between group comparisons the results of the statistical analysis showed a significant main effect of groups. This implies a significant difference between the individuals with aphasia group and group with neuro-typical individuals. There was no interaction between the groups and the reaction time. Later, on comparison between FSTRT and BSTRT there was no significant main effect of reaction time. Since there was no significant main effect for reaction time, there was no difference between the FST and BST between the groups. To check the difference between the groups individually for FST and BST, the Mann-Whitney test was administered.

In *Step III*- Mann-Whiney test to study the comparison between individuals with aphasia group and group with neuro-typical individuals on working memory task

Mann-Whitney U test was administered to examine the difference in working memory test like forward span task (FST), backward span task (BST) and n-back task between the individuals with aphasia group and group with neuro-typical individuals. From Table 6, there was a significant difference between the groups for the FST, BST and n-back task of working memory tests.

Table 6
Results of Mann-Whitney Test for the Forward span Task, Backward span Task, n-back

Working memory test	***/Z/***	***p value (2-tailed)***
Forward Span Task	2.296	0.022*
Backward Span Task	4.009	0.000**
n-back	4.633	0.000**

Note. * p < .05. ** p <.001

4.3. Comparison of FST, BST and n back of working memory test within Individuals with Aphasia (IWA) & Neurotypical individuals (NTI).

In *Step IV*- Paired t-test to study the comparison within the individuals with aphasia group and group with neuro-typical individuals for reaction time.

Paired t-test was administered to study the effect of Forward Span Task (FST) and Backward Span Task (BST) over the dependent variable (Reaction time) of working memory test within individual with aphasia group (IWA) and group with neuro-typical individuals (NTI). In Group I (IWA), there was no significant difference with reference to the reaction time of FST versus BST. For the Group II (NTI) also there was no significant difference with reference to the reaction time of FST versus BST as shown in Table 7.

Table 7.

Results of Paired t-test to study the effect of reaction time within each group.

Groups	**Tasks**	**t (9)**	***p* value**
Individual with Aphasia Group	FSTRT vs BSTRT	1.151	0.280
Neuro-typical Individuals	FSTRT vs BSTRT	0.096	0.924

Note: FSTRT: Forward span task reaction time, BSTRT: Backward span task reaction time.

In *Step V*- Wilcoxon's signed rank test to study the comparison within the individuals with aphasia group and group with neuro-typical individuals for level/threshold/accuracy.

Wilcoxon's Signed Rank test results showed significant difference between the FST, BST and *n* -back of working memory test within individuals with aphasia group. With reference to the neuro-typical individuals there was no significant difference between the FST, BST and *n* -back of working memory test. The same is represented in Table 8.

Table 8

Results of Wilcoxon's Signed Rank test for levels of working memory tests within IWA and NTI

Groups	**Levels of working memory tests**	**/Z/**	***p* value**
IWA	**BST level and FST level**	3.162	0.002**
NTI		1.414	0.157

Note. * p < .05. ** p <.001

In *Step VI*- Frequency distribution of level/threshold/accuracy of *n*-back working memory test was compared with IWA & NTI. Working memory test includes FST, BST and n-back task. The FST and BST corresponded with the reaction time measurement and the levels/threshold/accuracy. In the present study, the *n*-back task corresponded only with the levels/threshold/accuracy of individuals' (Aphasia and neuro-typicals) response to working memory capacity. Thus, in the present section, the performance of the two groups (IWA & NTI) on *n*-back task is depicted graphically to show the level/accuracy/threshold of working memory. From the Figure 8, in the IWA group all the participants (100%) had a common level '1' for n-back task and for the group with neuro-typical individual's 55% had level '3', 35% had level '2', 5% had level '4' and 5% had level '5'.

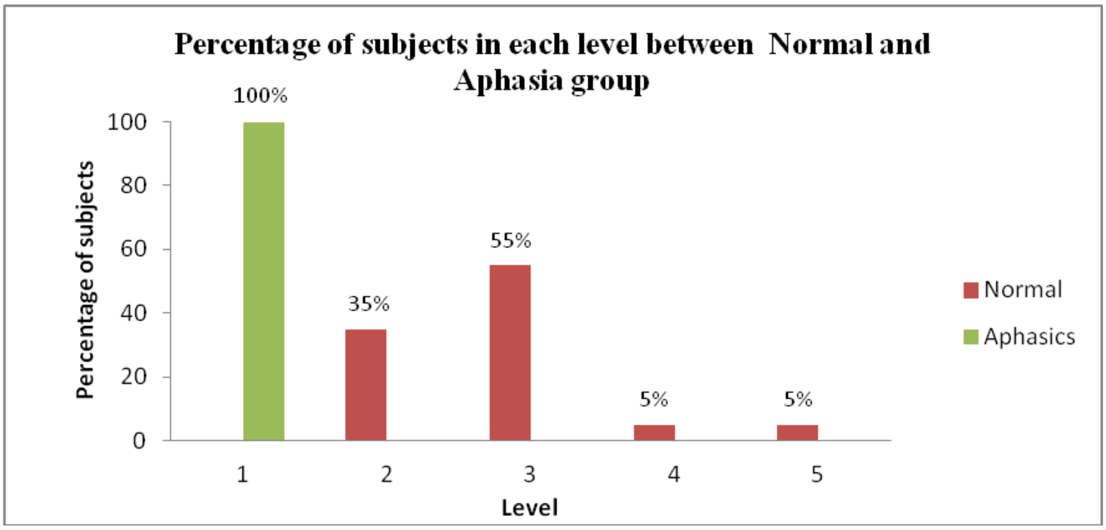


Figure 8. Difference in level/accuracy/threshold of working memory of IWA and NTI.

Summary

The findings suggested that there was significant difference in working memory abilities between NTD and IWA group on FST, BST and *n*-back task with reference to threshold/level/accuracy scores. IWA took more reaction time for both in FST, BST than NTD group. On measuring Levels/threshold/Accuracy score on FST, BST and *n*-back task there was significant difference was observed between groups but within group there was not much difference noted in IwA group.

Hence, there is significant difference in the working memory abilities of individuals with and without aphasia using n-back task. Even though NTD performed faster in all working memory tests, there is not much differences in the working memory threshold of individuals with and without aphasia (Broca’s). Therefore, cognition is approximately equivalent in both NTD and IwA group (Broca’s).

CHAPTER 6

DISCUSSION

The results of the present study are discussed with reference to the assessment of working memory capacity of individuals with aphasia (IWA Group) and neuro-typical individuals (NTI Group). And also the comparison between these groups with reference to reaction time and level/threshold/accuracy of working memory tests.

5.1 Between group comparisons

5.2 Within group comparisons

5.1 Between group comparisons

The reaction time taken to executive forward span task (FST) and backward span task (BST) of working memory test was higher for IWA group compared to NTI group. From this present study an attempt has been made to determine if working memory tasks can differentiate people with aphasia and neuro-typical individuals. Though the sample size for the clinical group is restricted to limited number, as a conclusion we have obtained a level/threshold/accuracy for the FST, BST and n-back task of working memory test.

First with reference to the mean value of the working memory assessment test, within the NTI group there was no difference in the reaction time for FST verses BST and the participants in IWA group had lesser reaction time for BST compared to FST. The contributing reason for this could be the similar performance by all the participants in the NTI group. Where, they could carry out

FST and BST at a common highest level/threshold/accuracy of ‘3’. Among the IWA group, all the participants could carry out FST and BST at one common level/threshold/accuracy of ‘2’ and ‘1’ respectively. Overall, the NTI group had better threshold with lesser reaction time compared to IWA group performing at lower threshold with greater reaction time. Thus, there was an overlap between the FST and BST for NTI group whereas there was no overlap between FST and BST for IWA group. They were an apparent difference in performance on the FST with reference to level/threshold/accuracy. The contributing reason could be the phonological storage or articulatory rehearsal being sensitive to impairment in an individual with aphasia or could be the poor performance due to their reduced attentional capabilities. To support the same, Martin et al (2012) have predicted differences in participants with mild aphasia on short-term memory span tasks and also extending to few individuals with high level of aphasia. In the present study the level/threshold/accuracy of working memory test for example FST, BST and n-back correspond to the difference in the visual span between IWA and NTI. This reduced score in IWA suggest that this reduced working memory capacity is likely to have central executive and attentional component in addition to impairments in the phonological loop.

In other studies, on comparison with neuro-typical individual, the patients with left hemisphere lesions have performed significantly poorer on verbal memory and spatial memory tasks (Burgio & Basso, 1996; Caspari et al. 1998). Similar results which supports the differences in working memory capacity between individuals with aphasia and neuro-typical individuals using tasks like forward and backward digit span, word span, the n-back task and judgement task is also reported (Mayer & Murray 2012; Wright & Shishler, 2005).

The other contributing reason could be the various factors related to the individual participants. The differences in the strategy used by the NTI and IWA participants. Some participants appeared to orally rehearse the name of the visual image and keep a count of the same in the correct sequence. Thus, some could organise the responses in reverse order or could not organize responses by order at all. The participants from the NTI group were able to quickly determine an effective strategy which is likely have an advantage over those participants from the IWA group not able to find effective strategies and needed some assistance. Hence training period was also included for both IWA group and NTI group.

When any one of the processing tasks is simple, when tapping on WM resources, there may be changes between processing and stored information observed. This is considered in attentional theories which infer WM capacity to a domain where attention are divided between relevant information and possible ongoing interference (Cowan, 1999; Engle, Kane, et al., 1999; Engle, Tuholski, et al., 1999; Kane, Bleckley, Conway, & Engle, 2001; Kane et al., 2004; Turner & Engle, 1989) or in competing stimulus there is rapidly switching attention is observed (Barrouillet et al., 2007; Unsworth & Engle, 2008).

There was a statistically significant difference between the NTI and IWA groups for the FST, BST and n-back task of working memory tests. To support this significant finding of difference between NTI and IWA group, an earlier investigation on aphasia has failed to explain the relationship between the measures of language comprehension and performance on n-back (Christensen &

Wright, 2010; Wright et al, 2007). In contrary, the different adapted and simplified versions of the complex span task have demonstrated consistent relationship. In the present study the NTI group did not have any language deficit in comparison with the IWA group. The language impairment in the IWA group is specific to the deficit in the phonological loop and hence performed poor on the FST and BST.

The past research has demonstrated that IWA exhibit deficit in the phonological loop (Heilman et al., 1976; Martin, 1987; Rothi & Hutchinson, 1981). This phonological deficit is related to the comprehension deficits (Caramazza, Basili, Koller, & Berndt, 1981; Ostrin & Schwartz, 1986; Saffran & Martin, 1975; Vallar & Baddeley, 1984). This phonological loop is the first component of WM system. Thus, the language learning and performance of IWA is affected due to their decreased working memory capacity (Baddeley, 2003; Murray, 2004). But, in the present study and previous studies it is unclear that poor performance by IWA is indeed because of deficient phonological loop or rather there could be another possibility of the paradigm used to assess working memory. Hence the visual span forward and backward task was used in the present study. The significance of using visual stimuli to assess working memory capacity is individuals with aphasia and neuro-typical individuals are clearly discussed in the following section of within group comparisons.

5.2 Within group comparisons

5.2.1 With reference to reaction time:

Even though the IWA performed with increased reaction time compared to NTI performance with reduced reaction time on the working memory task in total (FST plus BST). In within group comparison, for Group I (IWA) and Group II (NTI) there was no significant difference with reference to the reaction time of FST verses BST. This is because the working memory task was free from the linguistic aspect or there was no influence of affected linguistic variable on the performance of working memory task in participants with aphasia. Since the stimuli used was a visual representation of the common objects for the present study. Thus, this working memory paradigm (FST & BST) to assess working memory capacity is very effective in assessing the cognitive aspects alone and is not influenced by the impaired linguistic aspects of any individuals with aphasia for example. Hence, this can be used to differentiate clinical verse normal group during diagnosis and as well as in therapy for clinical population.

In the present study with reference to mean score within IWA group, they could perform better in BST compared to FST even though the level of BST was poorer compared FST. With reference to the level/threshold/accuracy the FST was better compared to BST. This particular result of the present study is in support with the Lezak (1995) study on working memory. Where it is reported that patient with brain dysfunction performed better in digit forward task than digit backward task which infer that digit forward task stores information in short term memory whereas digit backward task has highest demands on working memory where manipulation is required to identify the information.

To list few studies in support to the findings of perform better in BST compared to FST, study by Laures-Gore J. et al (2011) compared the performance of the individual with aphasia (left hemisphere stroke) and the group with right brain damage, no aphasia performed worse in digit backward span task than digit forward span task and concluded that scores were poorer because of decreased attention capacity in individuals with aphasia group when compared to individuals with right brain damage. According to Bonini and Radanovic (2015) study, they also reported that aphasic patients performed poorer in the digit span task, visual memory task (cognitive tasks) than non-aphasics which suggests that they have deficits in attention, working memory and mental control.

5.2.2 With reference to the level/accuracy/threshold:

The results showed significant difference between the FST, BST and n-back of working memory test for or within individuals with aphasia group. With reference to the group with neuro-typical individuals there was no significant difference between the FST, BST and n-back of working memory test. This is because of the relationship which exists between the tasks of working memory tests. In certain studies, they have observed a significant relationship between two tasks of working memory which theoretically manifest the different aspects of WM or executive abilities.

This is by the fact that any brain injury rarely affects only one cognitive system. It is very apparent that the neural network which contributes for the different aspects of executive functions will be damaged synchronously, specifically the case of middle cerebral artery stroke. The same was assessed using the functional neuroimaging studies, where they failed to depict the overlapping regions of activation during the execution of n-back task and complex span task (Chatham et al.,2011; Chein et al., 2011; Owen, McMillan, Laird, & Bullmore, 2005; Rottschy et al., 2012). In comparison with the neuro-typical individual's the two processes of cue-dependent search and recognition (or switching versus updating) could combine and dissociate very easily. Whereas, in persons with aphasia these processes (while still separable) could often be damaged concurrently, resulting in detectable relationship between the tasks that index these sub mechanisms. To imply the same in the clinical situation, there is a need for future lesion studies that would help to further clarify the neural underpinnings of the cognitive processes involved in execution of these working memory tasks.

In general working memory test includes FST, BST and n-back task. The FST and BST corresponded with the reaction time measurement and the levels/threshold/accuracy. In the present study, the n-back task corresponded only with the levels/threshold/accuracy of individuals' (Aphasia and neuro-typical) response to working memory capacity. Study done by Downey et al., (2004) found that presentation of stimulus was faster in visual mode than auditory mode and also claimed that n-back task helps in identifying working memory deficits. Thus, in the final section of results, the performance of the two groups (IWA & NTI) on n-back task is depicted graphically to show the level/accuracy/threshold of working memory. The IWA group all the participants had a common level '1' for n-back task and for the group with neuro-typical individual's hierarchy of level was '5', '4', '3', '2', and '1'.

From the results of the present study to support the findings of the IWA group, Christensen and Wright (2010) have concluded that aphasia participants in their study performed significantly better with the stimuli that carried a higher linguistic load (i.e., the fruit), than with the fribbles (semi-linguistic) and blocks (non-linguistic). But IWA participants performed significantly better on the 1-back than the 2-back working memory task. And IWA performed equally poorly with the fribbles and the blocks in the 2-back task which is a non-linguistic content. Thus, in the current study also IWA group could perform well with a level of 1 for *n*-back task and also with a level of '2' for FST and level of '1' for BST task.

The participants' performances with reference to level/threshold/accuracy worsen when the n-back levels increased. They performed better in semantic back task than phonological and syntactic back task which infer that working memory influences different type of linguistic information differently. Benson and Ardila (2010) suggestion of individuals with non-fluent aphasia having difficulty in arranging information in terms of syllable, word or syntactic level supports this statement.

Even though NTI group performed faster in all working memory tests, there were no evident differences in the working memory threshold of individuals with and without aphasia (Broca's). Therefore, cognition is approximately equivalent in both NTI and IWA group (Broca's). There are only few studies that relate to *n*-back task and discuss about working memory capacity and also its influence in language processing. As a future implication further studies has to be done to construct validity and reliability and thus obtain the threshold of an individual using different working memory tests.

CHAPTER 6

SUMMARY AND CONCLUSION

The aim of the present study was aimed to investigate the working memory in individuals with aphasia and neuro-typical individuals using forward span task, backward span task and *n*-back task. There were certain objectives considered for the present study.

Objectives of the study

1. To investigate the working memory in individuals with and without aphasia using forward and backward span task (visual) and *n*-back task.
2. To compare the working memory threshold of individuals with and without aphasia.

The performance of individuals with aphasia and neuro-typical individuals is explained under two aspects like reaction time and level/threshold/accuracy for working memory tests. Working memory (WM) is defined as a multi-component system for temporarily string and managing information required in performing complex cognitive tasks. Limited WM capacity in individual with aphasia also has language deficits. Few researchers suggest that WM capacity is a single “resource” pool for attention, linguistic, and other executive processing.

In the current study, Broca’s aphasia is considered participants in IWA group. As these individual are more susceptible to errors in verbal production tasks the non-linguistic tasks with visual stimuli was considered in the study. Non-linguistic tasks such as forward visual span, backward visual span and *n*-back task was used to measure WM in individuals with aphasia. In recent studies, researchers advocated that n-back is a parametric task which kelps in assessing WM in aphasia. The *n*-back task can be used easily, as it contains simple instructions and, moreover it is a recognition response than recall response. Hence, it can be easily executed by individuals who have deficits in linguistic expression and speech motor deficits. And also *n*-back task can employ various types of stimulus such as objects, shapes and spatial locations (Wright et al., 2007; Christensen & Wright, 2010).

A standard group comparison was made by considering individuals with aphasia (IWA) and neuro-typical individuals (NTI) (20-60 years) as participants. A total of 30 individuals participated in the study. Among them, 20 participants were formed as control group (NTI) and other 10 participants as clinical group (IWA). All the participants were native speakers of Kannada language and the clinical and control group were separated based on a set of criteria. General history with the demographic details was taken from all the participants along with the consent for agreeing to participants in the study.

The data collection involved the execution of forward span task, backward span task and *n*-back task of working memory tests using “Cognitive Module” developed by Kumar and Sandeep (2012) as part of All India Institute of Speech and Hearing Research Fund Project (ARF). In this software, subsections like forward visual span (FST), backward visual span (BST) and *n*-back task were only considered for the present study. Participants were made to sit comfortably in a quiet room and had to follow specific instructions to carry out the each task as training and testing part. Only the scores (reaction time and the level/threshold/accuracy) of testing part was only considered as the participants scores for all the working memory tests. Compare to FST and BST, majorly n-back task would assess WM index. Based on the participants performance, for example if there was better ‘n’ of trials the software would automatically increase and decrease the level of complexity with reference to FST, BST and *n*-back. Reaction time and the level/threshold/accuracy of performance by an individual were automatically saved in the software. Feedback was provided for every positive response in each task. This objective score working memory test was tabulated for further statistical analysis.

The major findings of the present study is discussed under two sections, the between group comparison and within group comparison. The reaction time taken to executive forward span task (FST) and backward span task (BST) of working memory test was found to be higher for IWA group compared to NTI group. From this present study an attempt has been made to determine if working memory tasks can differentiate people with aphasia and neuro-typical individuals. Though the sample size for the clinical group is restricted to limited number, as a conclusion we have obtained a level/threshold/accuracy for the FST, BST and n-back task of working memory test.

Within the NTI group there was no difference in the reaction time for FST verses BST and the participants in IWA group had lesser reaction time for BST compared to FST. Thus, there was an overlap between the FST and BST for NTI group whereas there was no overlap between FST and BST for IWA group. The contributing reason could be the phonological storage or articulatory rehearsal being sensitive to impairment in an individual with aphasia or could be the poor performance due to their reduced attentional capabilities. The other possible reason could be the differences in the strategy used by the NTI and IWA participants. Some participants appeared to orally rehearse the name of the visual image and keep a count of the same in the correct sequence.

But there was a statistically significant difference between the NTI and IWA groups for the FST, BST and n-back task of working memory tests. This is because the language learning and performance of IWA is affected due to their decreased working memory capacity (Baddeley, 2003; Murray, 2004). The other possibility is the paradigm (verbal stimuli) used to assess working memory. Hence the visual span forward and backward task was used in the present study.

Within group comparison, for Group I (IWA) and Group II (NTI) there was no significant difference with reference to the reaction time of FST verses BST. Since the working memory paradigm (FST & BST) to assess working memory capacity is very effective in assessing the cognitive aspects alone and is not influenced by the impaired linguistic aspects of any individuals with aphasia for example. With reference to the level/threshold/accuracy the FST was better compared to BST. This particular result of the present study is in support with the Lezak (1995) study on working memory.

The results showed significant difference between the FST, BST and *n*-back of working memory test for or within individuals with aphasia group. With reference to the group with neuro-typical individuals there was no significant difference between the FST, BST and *n*-back of working memory test. This is in support with the fact that any brain injury rarely affects only one cognitive system. It is very apparent that the neural network which contributes for the different aspects of executive functions will be damaged synchronously, specifically the case of middle cerebral artery stroke. In comparison with the neuro-typical individual's the two processes of cue-dependent search and recognition (or switching versus updating) could combine and dissociate very easily. This imply the same in the clinical situation, hence there is a need for future lesion studies that would help to further clarify the neural underpinnings of the cognitive processes involved in execution of these working memory tasks.

The IWA group all the participants had a common level '1' for *n*-back task and for the group with neuro-typical individual's hierarchy of level was '5', '4', '3', '2', and '1'. The participants' performances with reference to level/threshold/accuracy worsen when the n-back levels increased. They performed better in semantic back task than phonological and syntactic back task which infer that working memory influences different type of linguistic information differently. To conclude, the cognition is approximately equivalent in both NTI and IWA group (Broca's). There are only few studies that relate to *n*-back task and discuss about working memory capacity and also its influence in language processing. As a future implication further studies have to be done to construct validity and reliability and thus obtain working memory abilities of an individual using different working memory tests.

Implication

The present study made an attempt to estimate the clinical feasibility and basic psychomotor properties for adults with aphasia of one instantiation of the forward visual span task, backward visual span task and *n*-back task. This study took advantage of n-back flexibility and forward and backward visual span in terms of stimulus and response type to the designed task which is appropriate for aphasia. The score of n-back task served to highlight the complexity of attempting to separate language and cognitive skill of working memory capacity. Thus, assessment of working memory in aphasia is very important, since the decreased working memory capacity interacts negatively with linguistic and functional outcome of adults with aphasia. There is also a need for future studies to continue to explore the potential utility of the *n*-back task.

Limitations and future directions:

The present study addressed to investigate WM abilities in Broca's aphasia (Non-fluent aphasia) using forward visual span task, backward visual span task and *n*-back task only. The other paradigm of complex span task in combination of visual and verbal stimuli may contribute in different findings.

The study was limited to a smaller group of individuals with aphasia which probably restricts the generalization of the findings. WM has to be assessed in other types of aphasia with different level of severity, especially the mild form aphasia which are eliminated or missed out in traditional standardized test batteries.

There is also a need for future studies to continue to explore the potential utility of the forward, backward visual span task and the *n*-back task to do so in association with the neuro-imaging studies.

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APPENDIX-A

CONSENT FORM

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

Dissertation on

WORKING MEMORY IN INDIVIDUALS WITH APHASIA

Information to the participants

I, Ms. Chayashree P.D., II M Sc student at All India Institute of Speech and Hearing (AIISH) undertake the dissertation work titled- "**Working Memory in individuals with Aphasia**" under the guidance of Dr. Hema. N., Lecturer, Department of Speech – Language Sciences, AIISH, Mysore – 6. The aim of the research is to investigate working memory in individuals with Aphasia in Kannada language. I need to collect data from 20 neuro-typical individuals and 10 individuals with Aphasia in the age range of 20-60 years. Data will be collected with the help of software named "Cognitive Module" for the overall duration of 90 minutes each under one/two recording sessions. I assure you that this data will be kept confidential. There is no influence or pressure of any kind by us or the investigating institute to your participation and the research procedure is different from routine medical or therapeutic care activities. There is no risk involved to the participants, but your cooperation in the study will go a long way in helping us in understanding Working Memory in Individuals with Aphasia in more detail manner and which will be helpful in identifying mild impairments in aphasia also.

Informed Consent

I have been informed about the aims, objectives and the procedure of the study. I understand that I have a right to refuse participation as participant or withdraw my consent at any time. I have the freedom to write to Chairman, AEC in case of any risk associated with the study.

I, ____, the undersigned, give my consent to be participant of this investigation/study/program.

Signature of participant/caretaker   Signature of investigator

(Name and Address)   Date

____

____

____

APPENDIX- B

General Health Questionnaire-12

(Golderberg &Williams, 1988)

7. been able to concentrate on whatever you’re doing?	Better than usual	Same as usual	Worse than usual	Much worse than usual
14. Lost much sleep over worry?	Not at all	No more than usual	Rather more than usual	Much more than usual
35. Felt that you are playing a useful part in things?	More so than usual	Same as usual	Less useful than usual	Much less useful
36. Felt capable of making decisions about things	More so than usual	Same as usual	Less useful than usual	Much less useful
39. Felt constantly under strain?	Not at all	No more than usual	Rather more than usual	Much more than usual
40. Felt you couldn’t overcome your difficulties?	Not at all	No more than usual	Rather more than usual	Much more than usual
42. been able to enjoy your normal day-to-day activities?	More so than usual	Same as usual	Less useful than usual	Much less useful
46. been able to face up to your problems?	More so than usual	Same as usual	Less useful than usual	Much less useful
49. Been feeling unhappy and depressed?	Not at all	No more than usual	Rather more than usual	Much more than usual
50. Been losing confidence in yourself?	Not at all	No more than usual	Rather more than usual	Much more than usual
51. Been thinking of yourself as a worthless person?	Not at all	No more than usual	Rather more than usual	Much more than usual
54. Been feeling reasonably happy, all things considered?	More so than usual	Same as usual	Less useful than usual	Much less useful

APPENDIX- C

Mini-Mental State Exam

(Folstein, Folstein & McHugh, 1975)

Patient________________________ Age/Sex ___________
Date____________

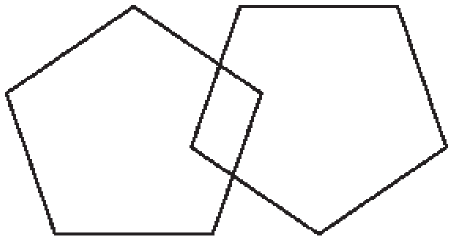
Maximum	*Score*	
		Orientation
5	( )	What is the (year) (season) (date) (day) (month)?
5	( )	Where are we (state) (country) (town) (hospital) (floor)?
		Registration
3	( )	Name 3 objects: 1 second to say each. Then ask the patient all 3 after you have said them. Give 1 point for each correct answer. Then repeat them until he/she learns all 3. Count trials and record. Trials ___________
		Attention and Calculation
5	( )	Serial 7's. 1 point for each correct answer. Stop after 5 answers. Alternatively spell "world" backward.
		Recall
3	( )	Ask for the 3 objects repeated above. Give 1 point for each correct answer.
		Language
2	( )	Name a pencil and watch.
1	( )	Repeat the following "No ifs, ands, or buts"
3	( )	Follow a 3-stage command: "Take a paper in your hand, fold it in half, and put it on the

floor."

1 ( ) Read and obey the following: CLOSE YOUR EYES

1 ( ) Write a sentence.

1 ( ) Copy the design shown.



_____ **Total Score**

ASSESS level of consciousness along a continuum

____

Alert ***Drowsy*** ***Stupor***

Coma

APPENDIX- D

Western Aphasia Battery

(Shyamala & Ravikumar, 2008)

I. Spontaneous Speech
1. How are you today?
2. Have you been here before?
3. What is your name?
4. What is your address?
5. What is your occupation?
6. Tell me a little about why you are here? Or what seems to be the trouble?
7. Description of picture.

II. Auditory Verbal Comprehension

A. Yes/No Questions

		Verbal	Gestural	Eye Blink
1.	Is your name Kuppa swampy? ("no" should be correct)			
2.	Is your name Rama Krishna? ("no" should be correct)			
3.	Is your name________________?			
4.	Do you live in Bangalore? ("no" should be correct)			
5.	Do you live in__________________?			
6.	Do you live in Calcutta? ("no" should be correct)			
7.	Are you a man/woman? ("yes" should be correct)			
8.	Are you a Doctor? ("no" should be correct)			
9.	Am I a man/women? ("yes" should be correct)			
10.	Are the lights on in this room? ("yes" should be correct)			
11.	Is the door closed? ("yes" should be correct)			
12.	Is this a hotel?			

13. Is this ____________?
14. Are you wearing red dhoti? ("no" should be correct)
15. Will paper burn in fire?
16. Does March come before June?
17. Do you eat a banana before you peel it?
18. Does it rain in July?
19. Is a horse larger than a dog?
20. Do you cut the grass with an axe?

B. Auditory Word Recognition

Real objects	Drawn objects	Forms	Letters	Numbers
Cup	Matches	Square	J	5
Matches	Cup	Triangle	P	61
Pencil	Comb	Circle	B	500
Flower	Knife	Arrow	K	1867
Comb	Pencil	Cross	M	32
Knife	Flower	Half Moon	D	5000

Colors	Furniture	Body parts	Fingers	Right-Left
Blue	Window	Ear	Thumb	Right shoulder
Brown	Chair	Nose	Ring Finger	Left knee
Red	Desk	Eye	Index Finger	Left ankle
Green	Light	Chest	Little Finger	Right thigh
Yellow	Door	Neck	Middle Finger	Left Elbow
Black	Ceiling	Fore head	Right Ear	Right cheek

Sequential Command

	Score
1. Raise your hand.	2
2. Shut your eyes.	2
3. Point to the chair.	2
4. Point to the window, then to the door.	4
5. Point to the pen and the book.	4
6. Point to the pen with the book.	8
7. Point to the comb with the pen.	8
8. With the book point to the comb.	8
9. Put the pen on top of the book the give it to me.	14

10. Put the comb on the other side of the pen and turn over the book.	20

III. Repetition

		Maximum score
1.	Hand	2
2.	Nose	2
3.	Bed	2
4.	Window	2
5.	Banana	2
6.	Rain bow	4
7.	Forty five	4
8.	Ninety-five percent	6
9.	Sixty-two and a half.	10
10.	The farmer is ploughing.	8
11.	He is not coming back.	10
12.	All that glitters is not gold.	10
13.	First Indian Field Army.	8
14.	No ifs, ands or buts.	10
15.	Load my cart with five dozen bags of white wheat.	20

IV. Naming

A. Object naming

	Stimulus	Response	Tactile cues	Phonemic cue	Score
Paise					
Ball					
Knife					
Cup					
Safety pin					
Mirror					
Tooth brush					
Book					
Lock					
Pencil					
Scissors					
Key					
Needle					
Bangle					
Comb					

Watch
Spoon
Flower
Plate
Matches

B. Word Fluency

Ask the patient to name as many animals as he or she can in 1 minute. The patient may be helped if hesitant; "Think of a domestic animal, like the horse, or a wild animal, like the tiger". The patient may be prompted at 30 seconds. Score 1 point for each animal named (except for those in the example), even if distorted by literal paraphasia.

C. Sentence Completion

1. The grass is ___________ (green)
2. Sugar is ______________ (sweet or white)
3. Roses are red, Jasmines are_______________ (White)
4. They fought like cats and_______________ (dogs)
5. Indian Independence day is in the month of _____________ (August)

D. Responsive Speech

1. What do you write with? (pen, pencil)
2. What colour is Milk? (white)
3. How many days are in a week? (seven)
4. Where do doctors work? (hospital)
5. Where can you get stamps? (post office, variety store)

Level: 2
Take: 1
Stimulus: Response
Y.bmp   Y.bmp
sun.bmp   sun.bmp
cake.bmp   cake.bmp
Item Score: 1
Acc. Score: 1

Level: 3
Take: 1
Stimulus: Response
glasses.bmp   glasses.bmp
octopus.bmp   sun.bmp
sun.bmp   octopus.bmp
fan.bmp   fan.bmp
Item Score: 1
Acc. Score: 0

Level: 2
Take: 1
Stimulus: Response
shatkon.bmp   shatkon.bmp
Level: 2
Take: 1
Stimulus: Response
shatkon.bmp   shatkon.bmp
cake.bmp   sun.bmp
glasses.bmp   cake.bmp
Item Score: 0
Acc. Score: 0

Level: 1
Take: 1
Stimulus: Response
shatkon.bmp   Y.bmp
sun.bmp   sun.bmp
Item Score: 0
Acc. Score: 0

----

* Summary of FST of working memory test

Level	Item score	Accuracy Score
2	1	1
3	1	0
2	0	0
1	1	1

APPENDIX

mahadev 31yrs Broca's aphasia_BST_Shape_Hist_Test

08-03-2017 12:14:52
User ID: mahadev 31yrs Broca's aphasia
------- TESTING ---------
Level: 3
Take: 1
Stimulus: Response
sun.bmp glasses.bmp
peacock.bmp glasses.bmp
fan.bmp glasses.bmp
glasses.bmp peacock.bmp
Item Score: 0
Acc. Score: 0

Level: 2
Take: 1
Stimulus: Response
octopus.bmp octopus.bmp
shatkon.bmp fan.bmp
fan.bmp peacock.bmp
Item Score: 0
Acc. Score: 0

Level: 1
Take: 1
Stimulus: Response
fan.bmp fan.bmp
octopus.bmp octopus.bmp
Item Score: 1
Acc. Score: 1

Level: 2
Take: 1
Stimulus: Response
fan.bmp fan.bmp
sun.bmp peacock.bmp
peacock.bmp sun.bmp
Item Score: 1
Acc. Score: 0

Level: 1

mahadev 31yrs Broca's aphasia_BST_Shape_Hist_Test

Take: 1

Stimulus: Response

shatkon.bmp shatkon.bmp

peacock.bmp peacock.bmp

Item Score: 1

Acc. Score: 1

Summary of FST of Working memory test

Level	Item score (I.S)	Accuracy Score (A.S)
3	0	0
2	0	0
1	1	1
2	1	0

mahadev 31yrs Broca's aphasia__NBACK_Shape_Train

Take: 0
Stimulus = octopus.bmp
Stimulus = cake.bmp
Stimulus = sun.bmp
Stimulus = palm.bmp
Stimulus = sun.bmp
Stimulus = shatkon.bmp
Match INCORRECT

Stimulus = sun.bmp
Stimulus = sun.bmp
REPEAT
Match FOUND

Stimulus = palm.bmp
Stimulus = peacock.bmp
Stimulus = sun.bmp
REPEAT
Match FOUND

Stimulus = palm.bmp
REPEAT
Match MISSED

------Cumulative------------
No. of reptitions: 3
No. of found: 2
No. of missed: 1
No. of Incorrect: 1

Score: 033.3 %

Level	Accuracy Score (A.S)
3	0
3	1
3	1
3	0

Take: 0
Stimulus = sun.bmp
Stimulus = fan.bmp
Stimulus = fan.bmp
Stimulus = sun.bmp
REPEAT
Match FOUND

Stimulus = Y.bmp
Stimulus = palm.bmp
Stimulus = octopus.bmp
Stimulus = Y.bmp

Level	A.S
3	1
3	0
3	1

REPEAT
Match MISSED

Stimulus = fan.bmp
Stimulus = octopus.bmp
REPEAT
Match FOUND

------Cumulative------------
No. of reptitions: 3
No. of found: 2
No. of missed: 1
No. of Incorrect: 0

Score: 066.7 %

Take: 0
Stimulus = shatkon.bmp
Stimulus = glasses.bmp
Stimulus = palm.bmp
Stimulus = glasses.bmp
Stimulus = peacock.bmp
Stimulus = palm.bmp
REPEAT
Match FOUND

Level	A.S
3	1
3	0
3	1

Stimulus = glasses.bmp
REPEAT
Match MISSED

Stimulus = palm.bmp
Stimulus = palm.bmp
REPEAT
Match FOUND

------Cumulative------------
No. of reptitions: 3
No. of found: 2
No. of missed: 1
No. of Incorrect: 0

Score: 066.7 %

Take: 0
Stimulus = peacock.bmp

Stimulus = sun.bmp
Stimulus = sun.bmp
Stimulus = palm.bmp
Stimulus = cake.bmp
Stimulus = sun.bmp
REPEAT
Match FOUND

Level	A.S
3	1
3	0
3	0

Stimulus = glasses.bmp
Stimulus = cake.bmp
REPEAT
Match MISSED

Stimulus = glasses.bmp
Stimulus = Y.bmp
Stimulus = glasses.bmp
Stimulus = glasses.bmp
REPEAT
Match MISSED

------Cumulative------------
No. of reptitions: 3
No. of found: 1
No. of missed: 2
No. of Incorrect: 0

Score: 033.3 %

Take: 0
Stimulus = shatkon.bmp
Stimulus = sun.bmp
Stimulus = cake.bmp
Stimulus = shatkon.bmp
REPEAT
Match FOUND

Level	A.S
3	1
3	0
3	0

Stimulus = palm.bmp
Stimulus = glasses.bmp
Stimulus = cake.bmp
Stimulus = octopus.bmp
Stimulus = cake.bmp
Match INCORRECT

Stimulus = cake.bmp
REPEAT

Match MISSED

Stimulus = sun.bmp
Stimulus = cake.bmp
REPEAT
Match MISSED

------Cumulative------------
No. of reptitions: 3
No. of found: 1
No. of missed: 2
No. of Incorrect: 1

Score: 000.0 %

Take: 0
Stimulus = octopus.bmp
Stimulus = sun.bmp
Stimulus = cake.bmp
Stimulus = sun.bmp
REPEAT
Match FOUND

Level	A.S
2	1
2	1
2	0

Stimulus = octopus.bmp
Stimulus = sun.bmp
REPEAT
Match MISSED

Stimulus = octopus.bmp
REPEAT
Match MISSED

------Cumulative------------
No. of reptitions: 3
No. of found: 1
No. of missed: 2
No. of Incorrect: 0

Score: 033.3 %

Take: 0
Stimulus = glasses.bmp
Stimulus = octopus.bmp
Stimulus = octopus.bmp
Match INCORRECT

Stimulus = octopus.bmp
REPEAT
Match MISSED

Level	A · S
2	0
2	0

Stimulus = shatkon.bmp
Stimulus = sun.bmp
Match INCORRECT

------Cumulative------------
No. of reptitions: 1
No. of found: 0
No. of missed: 1
No. of Incorrect: 2

Score: 000.0 %

Take: 0
Stimulus = Y.bmp
Stimulus = Y.bmp
REPEAT
Match FOUND

Level	A · S
1	1
1	1
1	1

Stimulus = octopus.bmp
Stimulus = Y.bmp
Stimulus = Y.bmp
REPEAT
Match FOUND

Stimulus = Y.bmp
REPEAT
Match MISSED

------Cumulative------------
No. of reptitions: 3
No. of found: 2
No. of missed: 1
No. of Incorrect: 0

Score: 066.7 %

Take: 0
Stimulus = glasses.bmp
Stimulus = glasses.bmp
REPEAT

Match MISSED

Stimulus = glasses.bmp
REPEAT
Match FOUND

Stimulus = fan.bmp
Stimulus = fan.bmp
REPEAT
Match FOUND

Level	A.S
1	0
1	1
1	1

------Cumulative------------
No. of reptitions: 3
No. of found: 2
No. of missed: 1
No. of Incorrect: 0

Score: 066.7 %

Take: 0
Stimulus = palm.bmp
Stimulus = palm.bmp
REPEAT
Match FOUND

Level	A.S
1	1
1	1
1	0

Stimulus = palm.bmp
REPEAT
Match FOUND

Stimulus = palm.bmp
REPEAT
Match MISSED

------Cumulative------------
No. of reptitions: 3
No. of found: 2
No. of missed: 1
No. of Incorrect: 0

Score: 066.7 %

Take: 0
Stimulus = sun.bmp
Stimulus = sun.bmp
REPEAT

Match FOUND

Stimulus = sun.bmp
REPEAT
Match FOUND

Stimulus = sun.bmp
REPEAT
Match FOUND

------Cumulative------------
No. of reptitions: 3
No. of found: 3
No. of missed: 0
No. of Incorrect: 0

Level	A.S
1	1
1	1

Score: 100.0 %

Take: 0
Stimulus = fan.bmp
Stimulus = shatkon.bmp
Stimulus = cake.bmp
Stimulus = peacock.bmp
Stimulus = shatkon.bmp
Match INCORRECT

Stimulus = peacock.bmp
REPEAT
Match MISSED

Stimulus = shatkon.bmp
REPEAT
Match MISSED

------Cumulative------------
No. of reptitions: 2
No. of found: 0
No. of missed: 2
No. of Incorrect: 1

Level	A.S
2	0
2	0

Score: 000.0 %

Take: 0
Stimulus = octopus.bmp
Stimulus = Y.bmp

Stimulus = palm.bmp
Stimulus = fan.bmp
Stimulus = cake.bmp
Stimulus = fan.bmp
Match INCORRECT

Stimulus = octopus.bmp
Stimulus = fan.bmp
Stimulus = fan.bmp
REPEAT
Match MISSED

Stimulus = fan.bmp
REPEAT
Match FOUND

Stimulus = glasses.bmp
Stimulus = fan.bmp
Stimulus = palm.bmp
Stimulus = fan.bmp
Match INCORRECT

Stimulus = fan.bmp
REPEAT
Match FOUND

------Cumulative------------
No. of reptitions: 3
No. of found: 2
No. of missed: 1
No. of Incorrect: 2

Score: 000.0 %

→

Level	A.S
2	0
2	0
2	1
2	0
2	1

Take: 0
Stimulus = peacock.bmp
Stimulus = cake.bmp
Stimulus = Y.bmp
Stimulus = Y.bmp
REPEAT
Match FOUND

Stimulus = octopus.bmp
Stimulus = octopus.bmp
REPEAT

Match FOUND

Stimulus = sun.bmp
Stimulus = sun.bmp
REPEAT
Match FOUND

------Cumulative------------
No. of reptitions: 3
No. of found: 3
No. of missed: 0
No. of Incorrect: 0

Score: 100.0 %

Level	A.S
1	1
1	1
1	1

∴ Participant accuracy score is level of '1'

Appendix — (n)

nikitha 24yrs normals_BST_Shape_Hist_Test

24-11-2016 18:51:10

User ID: nikitha 24yrs normals

------- TESTING ---------

Level: 3

Take: 1

Stimulus: Response

sun.bmp	sun.bmp
octopus.bmp	octopus.bmp
glasses.bmp	glasses.bmp
sun.bmp	sun.bmp

Item Score: 1

Acc. Score: 1

Level: 4

Take: 1

Stimulus: Response

Y.bmp	Y.bmp
fan.bmp	fan.bmp
shatkon.bmp	shatkon.bmp
palm.bmp	palm.bmp
glasses.bmp	glasses.bmp

Item Score: 1

Acc. Score: 1

Level: 5

Take: 1

Stimulus: Response

glasses.bmp	glasses.bmp
octopus.bmp	peacock.bmp
peacock.bmp	octopus.bmp
sun.bmp	palm.bmp
fan.bmp	Y.bmp
palm.bmp	sun.bmp

Item Score: 0

Acc. Score: 0

Level: 4

Take: 1

Stimulus: Response

peacock.bmp	peacock.bmp
cake.bmp	cake.bmp

sun.bmp sun.bmp
Y.bmp Y.bmp
octopus.bmp shatkon.bmp
Item Score: 0
Acc. Score: 0

Level: 3
Take: 1
Stimulus: Response
sun.bmp sun.bmp
shatkon.bmp shatkon.bmp
octopus.bmp octopus.bmp
sun.bmp sun.bmp
Item Score: 1
Acc. Score: 1

Level: 4
Take: 1
Stimulus: Response
shatkon.bmp shatkon.bmp
Y.bmp palm.bmp
palm.bmp Y.bmp
Y.bmp fan.bmp
fan.bmp palm.bmp
Item Score: 0
Acc. Score: 0

Summary of BST task of the participant

Level	Item score	Acc. score
3	1	1
4	1	1
5	0	0
4	0	0
3	1	1
4	0	0

Level: 2
Take: 1
Stimulus: Response

sun.bmp	sun.bmp
Y.bmp	Y.bmp
sun.bmp	sun.bmp

Item Score: 1
Acc. Score: 1

Level: 3
Take: 1
Stimulus: Response

cake.bmp	cake.bmp
palm.bmp	palm.bmp
Y.bmp	Y.bmp
sun.bmp	sun.bmp

Item Score: 1
Acc. Score: 1

Level: 4
Take: 1
Stimulus: Response

cake.bmp	cake.bmp
palm.bmp	palm.bmp
fan.bmp	fan.bmp
Y.bmp	Y.bmp
cake.bmp	cake.bmp

Item Score: 1
Acc. Score: 1

Level: 5
Take: 1
Stimulus: Response

peacock.bmp	peacock.bmp
sun.bmp	sun.bmp
palm.bmp	palm.bmp
fan.bmp	fan.bmp
glasses.bmp	glasses.bmp
octopus.bmp	octopus.bmp

Item Score: 1
Acc. Score: 1

Level: 6
Take: 1
Stimulus: Response

palm.bmp	palm.bmp
shatkon.bmp	shatkon.bmp
cake.bmp	cake.bmp
glasses.bmp	glasses.bmp
cake.bmp	Y.bmp
Y.bmp	octopus.bmp
sun.bmp	sun.bmp

Item Score: 0
Acc. Score: 0

Level: 5
Take: 1
Stimulus: Response

peacock.bmp	peacock.bmp
sun.bmp	palm.bmp
palm.bmp	shatkon.bmp
octopus.bmp	octopus.bmp
shatkon.bmp	cake.bmp
cake.bmp	sun.bmp

Item Score: 1
Acc. Score: 0

Level: 4
Take: 1
Stimulus: Response

sun.bmp	sun.bmp
glasses.bmp	glasses.bmp
shatkon.bmp	shatkon.bmp
sun.bmp	sun.bmp
glasses.bmp	glasses.bmp

Item Score: 1
Acc. Score: 1

Level: 5
Take: 1
Stimulus: Response

shatkon.bmp	shatkon.bmp
octopus.bmp	octopus.bmp

glasses.bmp glasses.bmp
palm.bmp palm.bmp
glasses.bmp glasses.bmp
sun.bmp sun.bmp
Item Score: 1
Acc. Score: 1

Level: 6
Take: 1
Stimulus: Response
palm.bmp palm.bmp
Y.bmp Y.bmp
fan.bmp fan.bmp
sun.bmp sun.bmp
fan.bmp glasses.bmp
sun.bmp sun.bmp

Level	Item score	Acc. score
2	1	1
3	1	1
4	1	1
5	1	1
6	0	0
4	1	1
5	1	1

Take: 0
Stimulus = octopus.bmp
Stimulus = peacock.bmp
Stimulus = octopus.bmp
Stimulus = octopus.bmp
REPEAT
Match FOUND

Stimulus = shatkon.bmp
Stimulus = octopus.bmp
REPEAT
Match MISSED

Stimulus = Y.bmp
Stimulus = Y.bmp
Stimulus = sun.bmp
Stimulus = cake.bmp
Stimulus = sun.bmp
Stimulus = peacock.bmp
Match INCORRECT

Stimulus = octopus.bmp
Stimulus = fan.bmp
Stimulus = palm.bmp
Stimulus = fan.bmp
Stimulus = fan.bmp
REPEAT
Match FOUND

------Cumulative------------

	Level	A·S
No. of reptitions: 3	3	1
No. of found: 2	3	0
No. of missed: 1	3	1
No. of Incorrect: 1		

Score: 033.3 %

Take: 0
Stimulus = Y.bmp
Stimulus = sun.bmp
Stimulus = sun.bmp
Stimulus = Y.bmp
REPEAT
Match FOUND

Stimulus = octopus.bmp
Stimulus = sun.bmp
REPEAT
Match MISSED

Stimulus = sun.bmp
Stimulus = peacock.bmp
Stimulus = palm.bmp
Stimulus = sun.bmp
REPEAT
Match FOUND

Take: 0
Stimulus = glasses.bmp
Stimulus = shatkon.bmp
Stimulus = palm.bmp
Stimulus = peacock.bmp
Stimulus = palm.bmp
Stimulus = shatkon.bmp
Stimulus = sun.bmp
Stimulus = glasses.bmp
Stimulus = cake.bmp
Stimulus = sun.bmp
REPEAT
Match FOUND

Stimulus = palm.bmp
Stimulus = cake.bmp
REPEAT
Match MISSED

Stimulus = sun.bmp
REPEAT
Match FOUND

------Cumulative------------
No. of reptitions: 3
No. of found: 2
No. of missed: 1
No. of Incorrect: 0

Score: 066.7 %

Level	Accuracy Score
3	1
3	0
3	1

Take: 0
Stimulus = cake.bmp
Stimulus = peacock.bmp
Stimulus = glasses.bmp
Stimulus = cake.bmp
REPEAT
Match FOUND

Stimulus = cake.bmp
Stimulus = glasses.bmp
REPEAT
Match MISSED

Stimulus = peacock.bmp
Stimulus = octopus.bmp
Stimulus = glasses.bmp
REPEAT
Match FOUND

------Cumulative------------ Level A·S
No. of reptitions: 3 3 1
No. of found: 2 3 0
No. of missed: 1 3 1
No. of Incorrect: 0

Score: 066.7 %

Take: 0
Stimulus = sun.bmp
Stimulus = peacock.bmp
Stimulus = cake.bmp
Stimulus = fan.bmp
Stimulus = shatkon.bmp
Stimulus = cake.bmp
REPEAT
Match FOUND

Stimulus = fan.bmp
REPEAT
Match FOUND

Stimulus = Y.bmp
Stimulus = glasses.bmp
Stimulus = sun.bmp
Stimulus = octopus.bmp

Stimulus = fan.bmp
Match INCORRECT

Stimulus = sun.bmp
REPEAT
Match FOUND

Level	A.S.
3	1
3	1
3	0
3	1

------Cumulative------------
No. of reptitions: 3
No. of found: 3
No. of missed: 0
No. of Incorrect: 1

Score: 066.7 %

Take: 0
Stimulus = fan.bmp
Stimulus = sun.bmp
Stimulus = sun.bmp
Stimulus = fan.bmp
REPEAT
Match FOUND

Stimulus = sun.bmp
REPEAT
Match FOUND

Stimulus = peacock.bmp
Stimulus = cake.bmp
Stimulus = sun.bmp
REPEAT
Match FOUND

------Cumulative------------
No. of reptitions: 3
No. of found: 3
No. of missed: 0
No. of Incorrect: 0

Score: 100.0 %

Level	A.S
3	1
3	1
3	1

Take: 0
Stimulus = palm.bmp
Stimulus = shatkon.bmp
Stimulus = octopus.bmp

Stimulus = glasses.bmp
Stimulus = octopus.bmp
Stimulus = glasses.bmp
Stimulus = fan.bmp
Stimulus = glasses.bmp
REPEAT
Match FOUND

Stimulus = fan.bmp
Stimulus = Y.bmp
Stimulus = fan.bmp
REPEAT
Match FOUND

Stimulus = glasses.bmp
REPEAT
Match FOUND

------Cumulative------------
No. of reptitions: 3
No. of found: 3
No. of missed: 0
No. of Incorrect: 0

Score: 100.0 %

Level	A·S
4	1
4	1
4	1

Take: 0
Stimulus = peacock.bmp
Stimulus = sun.bmp
Stimulus = sun.bmp
Stimulus = octopus.bmp
Stimulus = Y.bmp
Stimulus = octopus.bmp
Stimulus = peacock.bmp
Stimulus = Y.bmp
Stimulus = sun.bmp
Match INCORRECT

Stimulus = Y.bmp
REPEAT
Match FOUND

Stimulus = Y.bmp
Stimulus = shatkon.bmp
Stimulus = fan.bmp

Match INCORRECT

Stimulus = sun.bmp
REPEAT
Match FOUND

Stimulus = Y.bmp
REPEAT
Match FOUND

------Cumulative------------
No. of reptitions: 3
No. of found: 3
No. of missed: 0
No. of Incorrect: 2

Level	A·S
4	0
4	0
4	1

Score: 033.3 %

Take: 0
Stimulus = glasses.bmp
Stimulus = octopus.bmp
Stimulus = sun.bmp
Stimulus = glasses.bmp
Stimulus = fan.bmp
Stimulus = sun.bmp
Stimulus = Y.bmp
Stimulus = sun.bmp
REPEAT
Match FOUND

Stimulus = sun.bmp
Stimulus = palm.bmp
Stimulus = palm.bmp
Stimulus = Y.bmp
REPEAT
Match FOUND

Stimulus = octopus.bmp
Stimulus = octopus.bmp
Stimulus = palm.bmp
REPEAT
Match FOUND

Level	A·S
5	1
5	1
5	1

------Cumulative------------
No. of reptitions: 3

No. of found: 3
No. of missed: 0
No. of Incorrect: 0

Score: 100.0 %

Take: 0
Stimulus = sun.bmp
Stimulus = octopus.bmp
Stimulus = fan.bmp
Stimulus = palm.bmp
Stimulus = palm.bmp
Stimulus = shatkon.bmp
Stimulus = shatkon.bmp
Stimulus = peacock.bmp
Stimulus = fan.bmp
REPEAT
Match FOUND

Stimulus = palm.bmp
REPEAT
Match FOUND

Stimulus = Y.bmp
Stimulus = glasses.bmp
Stimulus = sun.bmp
Stimulus = cake.bmp
Stimulus = sun.bmp
Stimulus = peacock.bmp
Match INCORRECT

Stimulus = Y.bmp
REPEAT
Match FOUND

------Cumulative------------
No. of reptitions: 3
No. of found: 3
No. of missed: 0
No. of Incorrect: 1

Level	A.s
6	1
6	1
6	0

Score: 066.7 %

Take: 0
Stimulus = shatkon.bmp

Stimulus = sun.bmp
Stimulus = palm.bmp
Stimulus = fan.bmp
Stimulus = palm.bmp
Stimulus = peacock.bmp
Stimulus = shatkon.bmp
REPEAT
Match MISSED

Stimulus = peacock.bmp
Stimulus = palm.bmp
REPEAT
Match FOUND

Stimulus = peacock.bmp
Stimulus = palm.bmp
REPEAT
Match FOUND

------Cumulative------------
No. of reptitions: 3
No. of found: 2
No. of missed: 1
No. of Incorrect: 0

Score: 066.7 %

Level	A.S
6	0
6	1
6	1

Take: 0
Stimulus = octopus.bmp
Stimulus = glasses.bmp
Stimulus = shatkon.bmp
Stimulus = octopus.bmp
Stimulus = peacock.bmp
Stimulus = shatkon.bmp
Stimulus = octopus.bmp
REPEAT
Match MISSED

Stimulus = glasses.bmp
REPEAT
Match FOUND

Stimulus = fan.bmp
Stimulus = glasses.bmp
Stimulus = shatkon.bmp

Match INCORRECT

Stimulus = shatkon.bmp
REPEAT
Match MISSED

------Cumulative------------
No. of reptitions: 3
No. of found: 1
No. of missed: 2
No. of Incorrect: 1

Score: 000.0 %
------Cumulative------------
No. of reptitions: 3
No. of found: 2
No. of missed: 1
No. of Incorrect: 0

Score: 066.7 %

Level	A.S
6	0
6	1
6	0

∴ Participant Accuracy / threshold is Level of 5 in n-back WM test (100%)