SYMBOLIC LANGUAGE ABILITIES FOR AIDED COMMUNICATION IN PERSONS WITH APHASIA

A DOCTORAL THESIS

Submitted to the University of Mysore for the degree of

Doctor of Philosophy in Speech Language Pathology

Candidate

VINEETHA SARA PHILIP

All India Institute of Speech and Hearing

Mysuru-570006.

Guide

Dr. S. P. GOSWAMI

Professor of Speech Pathology,

Department of Speech-Language Pathology

All India Institute of Speech and Hearing

Mysuru-570006

All India Institute of Speech and Hearing,

Manasagangothri, Mysuru-570006

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DECLARATION

I declare that the thesis entitled **'Symbolic Language Abilities for Aided Communication in Persons with Aphasia'** which is submitted herewith for the award of degree of Doctor of Philosophy (Speech Language Pathology) to the University of Mysore, Mysuru, is the result of my own study under the guidance of Dr. S. P Goswami, Professor of Speech Pathology, All India Institute of Speech and Hearing, Mysuru. I further, declare that this has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Place: Mysuru

Date:

Candidate

Ms. Vineetha Sara Philip

CERTIFICATE

This is to certify that the thesis entitled **'Symbolic Language Abilities for Aided Communication in Persons with Aphasia'** submitted by Ms. Vineetha Sara Philip**,** for the degree of Doctor of Philosophy (Speech Language Pathology) to the University of Mysore, Mysuru, has been prepared by her under my guidance. It is also certified that this has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Place: Mysuru

Date:

Dr S. P Goswami
Professor of Speech Pathology
Department of Speech-Language Pathology
All India Institute of Speech &
Hearing, Mysuru-570006

CERTIFICATE

This is to state that the thesis entitled **'Symbolic Language Abilities for Aided Communication in Persons with Aphasia'** submitted by Ms. Vineetha Sara Philip for the degree of Doctor of Philosophy (Speech-Language Pathology) to the University of Mysore, Mysuru, was carried out at the All India Institute of Speech and Hearing, Mysuru.

Place: Mysuru

Date:

Dr. M Pushpavathi
Director
All India Institute of Speech & Hearing,
Mysuru-570006

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Ms. Swathi Geetha, Senior Lecturer, Department of Audiology and Speech Language Pathology, NISH, Trivandrum

Ms. Arya S.S, Senior Lecturer, Department of Audiology and Speech Language Pathology, NISH, Trivandrum

Ms. Preethi Susan Reni, Lecturer, Department of Audiology and Speech Language Pathology, NISH, Trivandrum

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PWA	Persons with Aphasia
AAC	Augmentative and Alternative Communication
WAB	Western Aphasia Battery
AQ	Aphasia Quotient
CQ	Cortical Quotient
PCS	Picture Communication Symbols
BCC-K	Battery of Cognitive Communicative disorder-Kannada
SPQ	Symbol Performance Quotient
SGD	Speech Generating Device

ABSTRACT

Aphasia is an impairment in the capacity to formulate and interpret symbolic language functions caused by focal brain damage. The compensatory approach to aphasia rehabilitation usually takes the form of augmentative and alternative communication (AAC) which provides communication strategies for supplementing, scaffolding, replacing or restoring natural speech. AAC for persons with aphasia (PWA) ranges from vocalizations, signs, or gestures (unaided communication), to writing, communication books, and speech-generating devices that utilize picture or graphic symbols (aided communication). In recent years, aided AAC that utilizes graphic symbols have been trialled in PWA and reports of their ability to combine single meaning symbols to form simple phrases and sentences to convey message has been on the high rise.

Despite these positive outcomes, PWA poses several challenges towards learning and acquisition of AAC due to their inherent linguistic and cognitive impairments that affect the linguistic, operational, social and strategic competence required to use an AAC. An adequate understanding of strengths and resources available to PWA becomes important in planning AAC intervention. However, there is an insufficient number of researches involving AAC in PWA to enable our understanding of how symbolic language skills required to use a visual-based alternative communication system is affected by each type and severity of aphasia. Also, the intervention studies that gave evidence towards the ability of PWA to identify, categorize and sequence symbols to use aided AAC, often failed to show generalization of abilities. The lack of ability of PWA to use an AAC system for independent communication demands researchers to re-explore the skills required to these systems. Furthermore, there is a need to conduct such studies in India due to the large disparity

between the country's small number of research done to guide clinicians to implement evidence-based AAC intervention and the large number of PWA who are potential candidates for AAC; given that India has the world's second-largest number of PWA. Thus, the present study investigated the symbolic language abilities required to use aided AAC in PWA.

The symbolic language abilities studied included the ability to identify, categorize, and sequence symbols which was tapped using seven behavioural tasks designed using picture communication symbols (PCS). The study also explored the relationship between these symbolic language abilities and verbal language skills as well as non-verbal cognitive skills which were obtained from aphasia quotient and cortical quotient measures of test of aphasia in Malayalam. The study included 20 PWA (inclusive of 10 anomic aphasia and 10 Broca's aphasia which formed subgroups of aphasia) and 20 age, gender, education-matched neurotypical adults as participants for the study. The comparison of performance between participant groups as well as within and across groups on the behavioural tasks, and the correlation between measures were performed using descriptive and inferential statistical analyses.

The results of the study revealed that the performance of PWA and its subgroups were poorer than neurotypical adults. The study findings revealed that even persons with severe aphasia can identify, categorize symbols as well as sequence symbols to construct simple phrases and sentences to convey information. Supplementary analyses of the obtained data from the behavioural tasks showed that (a) grid size of the AAC display and grammatical category of referents have an effect on symbol identification in PWA, (b) performance on auditory categorization is better than visual categorization in PWA, and (c) the syntactic structure and semantic informativeness of sentences constructed using symbols by Broca's aphasia was significantly less than anomic

aphasia and neurotypical adults. It was observed that symbols facilitated word retrieval, improved verbal utterances and rectified phonemic paraphasias in PWA. In addition, a strong positive correlation was found between symbolic language abilities and verbal language abilities, as well as between symbolic language abilities and non-verbal cognitive abilities. The implications, limitations, and future directions of the study are discussed in detail.

CHAPTER I

INTRODUCTION

All human languages are symbolic systems in which symbols are used to transmit information. A symbol is anything that "performs a referential function such as denoting, representing, or exemplifying an element, object, or concept" (Gardner, 1974a, p. 141). Any purposeful communication that uses "learned, socially shared signal systems to transfer propositional knowledge via symbols" is known as symbolic communication (Buck & VanLeer, 2002, p. 522). Even though the verbal language is a symbolic form of communication, symbolic communication encompasses not only verbal symbols but also non-verbal symbols. Verbal communication, which makes use of words (spoken and written) to communicate is thought to fall into the symbolic realm because of the arbitrary link between the word (both written and spoken) and the concept. On the other hand, nonverbal symbolic communication makes use of icons, indices, or graphic symbols, instead of words to communicate the meaning of a concept.

Focal damage to the cortical and subcortical structures of the brain hemisphere(s) dominant for symbolic manipulations, can cause an impairment of the capacity for interpretation and formulation of language symbols (i.e., a reduction in efficiency of the ability to decode and encode conventional meaningful linguistic elements such as morphemes and larger syntactic units), resulting in a condition known as aphasia (McNeil, 1984; McNeil & Kimelman, 2001). Aphasia, thus being a symbolic processing weakness may limit the ability to process all types of symbolic information (Hallowell & Chapey, 2008). This view popularly known as the central symbolic deficit theory considers aphasia as an impairment to a central cognitive-symbolic process that manifests itself in parallel dysfunctions of both verbal and nonverbal communication (Bay, 1964; Duffy et al., 1984). However, there is a robust second view known as the theory of multiple symbolic capacities in aphasia which suggests that verbal and non-verbal types of communication are affected differentially by the presence of aphasia (Thorburn et al., 1995). Considering that aphasia is not a central-symbolic disorder, persons with aphasia (PWA) can be trained to circumvent their communicative difficulties by learning to use alternative non-verbal systems (Buck & VanLeer, 2002). This latter view is supported by clinical evidence that PWA can compensate for their verbal impairment using nonverbal modes which they tend to generate spontaneously or as a result of treatment (Coelho & Duffy, 1987; Daniloff et al., 1986; Moody, 1982).

1.1. Evolution of AAC as a Compensatory Approach to Aphasia Rehabilitation

The birth and development of the compensatory approaches coincide with a period in time when aphasiologists became increasingly aware that approximately half of PWA treated using traditional restorative approaches continued to have restricted ability to communicate in everyday conversational exchanges (Porch, 1981). This awareness triggered a shift of focus from traditionally used restorative approaches to compensatory approaches in aphasia rehabilitation (Nicholas & Helm-Estabrooks, 1990). The compensatory approaches based on the premise that language function is lost after brain damage aim to increase the level of function of PWA despite their deficit (i.e., establish functional communication) by adapting to the needs of the individual with language impairment (Beukelman et al., 2017; Russo et al., 2017). This is in contrast to the restorative approach that utilizes specific techniques to recover skills that are impaired due to brain damage such as strategies to retrain naming, recalling words, and executive functions (Russo et al., 2017).

Compensatory approaches for aphasia usually take the form of augmentative and alternative communication or AAC (Russo et al., 2017). According to Beukelman and Mirenda (2013), “AAC refers to any communication strategy that is used to replace or supplement spoken expression, auditory comprehension, written expression, or reading comprehension to facilitate communicative participation for persons with complex communication needs" (Taylor et al., 2019, p. 465). In other words, methods that enable individuals to convey their intentions either along with spoken language or instead of it is collectively termed as AAC. The AAC intervention usually establishes a combination of aided and unaided communication methods to convey information. Unaided communication relies solely on the body or ability of the user (such as vocalizations, speech, gestures, body language) to convey a message. Aided communication, on the other hand, is when the communicator relies on a physical form outside of themselves to express an intended message.

The aided AAC strategies more appropriately known as communication supports in the field of aphasia (Beukelman et al., 2015) include materials (alphabets, words, pictures, or symbols) and strategies to facilitate communicative competence and linguistic skills. The aided AAC systems that use alphabets, pictures, or symbols as a means of language representation can be broadly classified into non-technology based and technology-based AAC approaches (Koul & Corwin, 2011). The non-technology based strategies involve the use of communication books, cue cards, or memory books that do not produce speech output when messages are selected. "Dedicated speech generating devices, software programs, and applications that transform computers or hand-held electronic devices into communication devices that produce digitized or synthesized voice output upon selection of messages" are examples of technology-based strategies (Koul & Corwin, 2011, p. 2). The exploration of AAC in the rehabilitation of PWA started with the underlying expectation that the use of nonstandard linguistic forms in persons with severe aphasia would serve as replacements for spoken language skills or at least restore the person to functional communication levels (Kraat, 1990).

The first description of the benefits of using an iconographic system to improve grammaticality and phrase length for a person with expressive aphasia was provided by Luria in 1947 (Steele, 2010). Even though the use of AAC was first suggested several decades ago, further literature on the use of aided AAC in PWA did not appear until the report by Gardner and Zurif (1976). They used a visual-based symbol system and showed modest but distinctive communication benefits even for persons with global aphasia. Later, Garrett et al. (1989) documented the use of a multimodal augmentative communication system in a 74-year-old man with Broca's aphasia. Their system consisted of an alphabet card, writing paper, and a thematic dictionary which was consolidated into a portable notebook. They found greater efficiency while transferring information using the augmented system than in unaugmented conditions. Since these reports, several documentations of the use of non-technology based aided AAC systems in PWA can be found in the literature. These included writing, drawing, communication books, pictures, and topic setters (tangible remnants or souvenirs).

Kraat (1990), in her discussion of the evolution of the field of AAC and its intersection with aphasia rehabilitation, states that the field of AAC started growing at a steady pace in the late 1970s and early 1980s. This was mainly due to the following three reasons. First, pieces of evidence in the 1960s and 1970s based on single-case designs pointed at the possibility of using alternate means of communication, such as signs, gestures and writing to facilitate improvement in spoken language. Second, a shift in the traditional treatment focuses on improving phonology, syntax, and semantics to a new direction of pragmatics or social use of language in context. This new orientation changed the narrow "oral approach" to a much broader holistic view of communication thus letting AAC be viewed as an appropriate treatment tool. Third, the rapid development of technologies that allowed communication through synthetic speech or printed symbols.

Even with the proliferation of technologies in the 1980s, Sandt-Koenderman (2004) opined that the use of computer technology to support communication (technology-based aided AAC) in aphasia had been developing at a slow pace. He thought this to be due to a lack of cooperation between technologists and aphasiologists. He pointed out that the early computerized systems designed to improve communication in PWA focused on developing prostheses for specific linguistic issues (such as word-finding or sentence generation), and it had only been in the late 1990s and early 2000 that devices supporting communication started being developed. The devices that aided word-finding (Colby et al., 1982; Bruce & Howard, 1987) used phonological and semantic information to identify a target word when the user offers clues about the target word, to deliver a list of most probable words.

Computer-aided Visual Communication (C-VIC) system (Steele et al., 1989; Weinrich 1991; Steele et al., 1992) was a device designed specifically for PWA around their residual cognitive strengths and relieve them from the demands of real-time processing, morpho-syntactic processing, and phonetic processing. Icons representing natural language lexical items (nouns, verbs, prepositions) were used to compose messages; wherein word-finding assistance was provided through icons during sentence construction. Later, a commercial version of C-VIC, called Lingraphica (Aftonomous et al., 1997) was developed using interactive multimodal materials for PWA. A picture-based software program that was conceptually based on C-VIC was known as C-Speak Aphasia (Nicholas et al., 2005) and a computer-assisted system that operated similar to Lingraphica was Talking Screen (Koul & Harding, 1998). Both C-Speak Aphasia and Talking Screen offer graphic symbols along with synthesized speech output and allow PWA to select icons and put them together to form statements, commands, and questions. In 2000, Linebarger and her colleagues described a processing prosthesis known as SentenceShaper, which allowed the production of longer utterances without aiding word finding. It was later developed into a portable computer software version known as “SentenceShaper To Go” (Bartlett et al., 2007; Linebarger et al., 2008). Several studies documented the use of these technology-based AAC systems resulting in an improvement in language functions but showed variation in the ability of PWA to learn the system.

The devices that aided conversation in PWA included Talksbac (Waller et al., 1998) and TouchSpeak® (Sandt-Koenderman et al., 2005). Talksbac provided ready-made utterances in conversations and utilized written language modality to address vocabulary, on the other hand, TouchSpeak used digitized and synthesized speech along with written words, photos, drawings and pictographs to communicate which allowed PWA to decide which messages they need (Sandt-Koenderman, 2004). The Easy Speaker, a desktop computer software (Rostron et al., 1996) was also designed for PWA with very limited reading ability. It consisted of approximately 800 vocabularies represented as icons with speech output and also a range of topics that allowed the PWA to ask questions, or suggest an area of conversation.

An increased reporting of the use of high-tech speech-generating devices (SGD) for PWA have been increasingly found in the mid-2000s, even though most of them focused on supporting specific communication tasks such as answering the telephone, calling for help, giving speeches, and ordering in restaurants (Garrett & Lasker, 2005). To support communication interactions dealing with a wide range of topics, narratives, and experiences, an effort to develop an AAC device prototype was undertaken in 2006, known as the visual scene display project (Beukelman et al., 2007).

Traditionally, most of the high tech AAC devices have grid displays, where the vocabulary is represented by graphic symbols and/or written words displayed in rows and columns, and these isolated symbols were combined to formulate messages. High-tech AAC devices with visual scene displays (VSD) utilize personally relevant, high-context photographs that are designed to complement residual cognitive and linguistic abilities of PWA by utilizing their intact episodic memory (Dietz et al., 2006; Thiessen et al., 2014), thus creating conversational support between the PWA and their communication partner (Beukelman et al., 2007; Brock et al., 2019; Taylor et al., 2019). DynaVox (McKelvey et al., 2007) and DynaVox VMax (Griffith et al., 2014; Dietz et al., 2014) are dedicated AAC devices that utilize visual scene displays to help PWA communicate. Research on VSDs is slowly gaining momentum due to the presence of contextualized pictures allowing for more communication exchanges and fewer communication breakdowns in PWA. VSDs focuses on manipulating the user interface of technology and fails to consider the language representation methods (i.e., use of single meaning symbols, multi-meaning icons or alphabets), high-frequency (core) vocabulary, and low frequency (extended) vocabulary, and availability of spontaneous novel utterance generation (Shin, 2017).

The earliest research in aphasia and AAC attempted to develop alternative symbol communication systems for people with aphasia having extremely limited verbal language, while most of the later studies focused on how PWA was taught to use AAC (Garrett & Kimmelman, 2000). Recently, AAC intervention is currently receiving greater emphasis in aphasia rehabilitation because (a) a high percentage of stroke survivors having aphasia often experience persistent communication impairment even with an intensive speech-language intervention which limits their independence, social relations, education and employment, and (b) as the goal of aphasia intervention emphasize on maximizing communication function for social interaction (Russo et al., 2017). While revisiting the role of AAC in aphasia rehabilitation, Dietz et al (2020), pointed out that AAC intervention is usually multimodal, and needs to be implemented alongside traditional restorative interventions. While the restorative approach allows the PWA to recover as much language as possible, thereby decreasing the overall aphasia severity, the AAC approach provides support for PWA during inevitable anomic events during interactions. They further stated that the AAC had been frequently applied with an emphasis on compensatory function; however, it can be viewed as a dual-purpose tool that can simultaneously drive inter-systemic reorganization (i.e., a weak system being restored or strengthened during intervention when it is paired with a stronger or intact system, Luria, 1972) with the potential to support language function while compensating during communication breakdowns.

1.2 Factors Influencing AAC use in PWA

Light (1989) stated that to achieve communicative competence using AAC requires the individual to have knowledge, judgement, and skills in four interrelated domains which are linguistic, operational, social, and strategic. Linguistic competence involves an adequate level of mastery of the linguistic code (i.e., developing skills in the native language spoken by the family and community as well as mastering the language code of the AAC system). While operational competence refers to the skills required to operate any AAC system, social competence involves understanding the social rules (pragmatics) of communication (i.e. both socio-linguistic and socio-relational). Last but not the least, strategic competence involves the use of appropriate compensatory strategies to bypass limitations in linguistic, operational, and/or social skills.

Despite the positive results on using AAC, some persons with severe aphasia lack communicative competence or in other words, show difficulty in retrieval, construction, and utilization of messages from symbol-based aided AAC systems while others do not. Garrett and Kimelman (2000) hypothesized that accessing AAC systems independently may tax their cognitive and linguistic resources. These resources include memory, symbol recognition and association, semantic retrieval, syntactic encoding, pragmatic skills, and auditory and visual comprehension, resulting in variability of performance among PWA (Garrett & Lasker, 1997).

Lasker (2008) has used an example of a communication partner asking a simple personal question to a PWA having an AAC device to help in understanding of the various linguistic and cognitive demands of a relatively simple conversational task. To communicate effectively, PWA must understand the question asked, identify an expressive modality of their choice (residual speech or AAC device), and attend to the symbols in the AAC system to recognize them accurately. They must utilize semantic mapping skills to know the content of the message represented by the symbol in the AAC system, remember the location to access the appropriate message symbol to deliver the message, use pragmatic knowledge to determine if their communication partner has understood them and decide if or not to revise the message. Finally, they must combine symbols to form a new message if they would like to continue the conversation. The example in itself is self-explanatory on why some PWA may have difficulty in consistently and effectively using AAC in real-life situations.

Many linguistic impairments experienced by PWA can affect all types of symbolic communication, including the ability to recognize or categorize symbols within an AAC system (Taylor et al., 2019). For example, syntactic encoding difficulties affect the ability of PWA to combine symbols or to encode complex messages, or word retrieval/ semantic breakdowns affect the ability to comprehend and associate meanings to alternate symbol forms (Garrett & Kimelman, 2000). This warrants individualized language assessment to determine the impaired and preserved residual linguistic skills and match them with the language requirements of each AAC system under consideration before its recommendation (Lasker, 2008) to ensure that a PWA is linguistically competent to use the AAC.

Furthermore, cognitive skills such as attention, executive function, concept knowledge, and memory are important for constructing and retrieving language as the broad network of connected brain regions that support language also supports other processes such as working memory and cognitive control (Vallila-Rohter and Kiran, 2013). Hence, it is only logical that impairments of attention, memory, executive functions, visual perceptual and visual cognitive processing may adversely affect the operational and strategic competencies required to use AAC. According to Purdy and Dietz (2010), PWA often have difficulty in maintaining fundamental levels of alertness and attention due to which they demonstrate reduced linguistic accuracy and efficiency during focused and divided attention conditions as the level of distraction increases. The resource allocation theory of aphasia (McNeil, 1983; McNeil et al., 1991) postulates that aphasia has an impaired resource capacity, impaired resource allocation abilities, or both. When the cognitive system in PWA tries to process information with fewer resources or incorrectly allocated resources, communication gets compromised. Impairments in verbal and non-verbal working memory in PWA might affect their ability to search multiple levels of messages, retain ideas, and persevere until the message is communicated or interfere with the ability to recall operational procedures for a system (thus affecting strategic competency). Impairments in executive functioning might affect their ability to initiate the use of an alternative strategy (i.e., the ability to switch to another modality such as gesturing or using an AAC device to repair the failed verbal attempts).

In sum, while language impairment in PWA can influence learning and use of symbols resulting in extensive training periods, cognitive limitations result in poor generalization to untrained items, reduced ability to initiate the use of an alternative strategy. Personal factors that may influence the use of technology-based AAC include age and individual expectations. While younger PWA may struggle to accept their disability and AAC, older PWA may have less technology experience, necessitating basic level training. Unrealistic expectations might lead to disappointment and abandonment of AAC in PWA. Environmental factors such as social support, beliefs, and perspectives of SLPs, and duration as well as the intensity of SLP services might also influence the use of AAC in PWA. Social support is required for maintenance of the AAC device, to provide opportunities to use the device in real-life contexts, co-construction of messages and to act as an external monitor of the effectiveness of their communication attempts. The introduction of AAC primarily in chronic stages due to lack of awareness among SLPs might influence their usage. Low-intensity therapy input and therapy without generalization training is unlikely to facilitate meaningful success with AAC (Taylor et al. 2019).

1.3. Need for the Study

The need for conducting the present study is justified in line with the research gaps identified from critical analyses of literature reviewed in the field of AAC and aphasia. The need for the study in terms of the population, the research site, and the field of study are discussed in the below sections.

1.3.a Need for Integrated Research in Aphasiology and AAC

McNaughton and Light (2015) reviewed and summarized 30 years of research in the field of AAC from 1985 to 2014, revealing that 83% of research was done in individuals with developmental disabilities, and only 17% of research accounted for acquired disabilities. A manual search of AAC research published from the year 2015 to 2022 was done using the same method as the above study to understand if the pattern found in McNaughton and Light's (2015) study on the percentage of population under investigation has changed in recent years. The obtained data as depicted in Figure 1.1 shows that the number of AAC researches in PWA is quite limited.

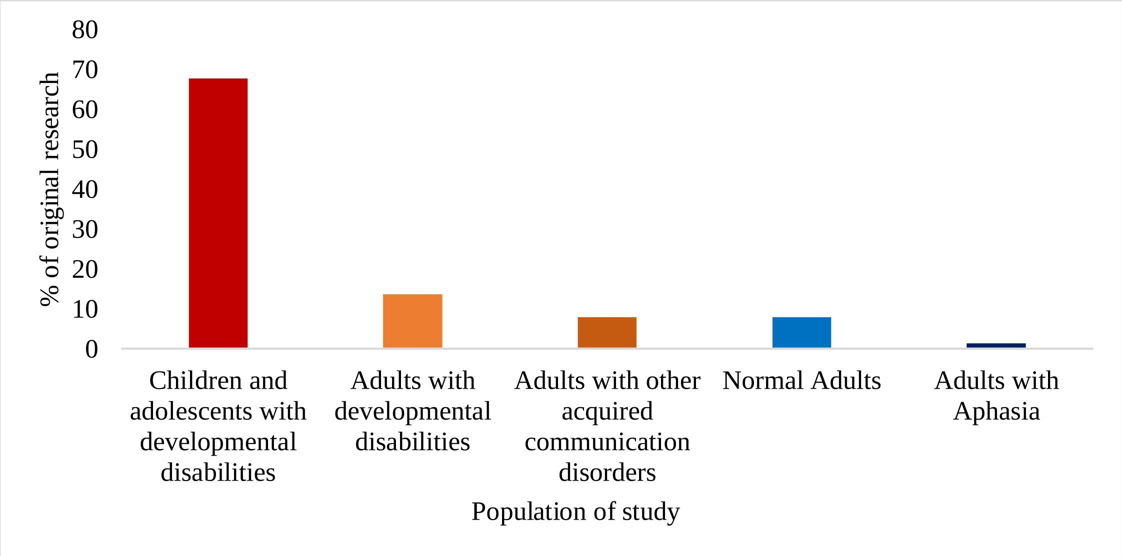

Figure 1.1: Percentage of original research papers published between 2015 and 2022

The global estimates of post-stroke aphasia frequency range between 18% to 38% of stroke survivors (Ellis et al., 2018) and reports of the communication challenges in these populations being unmet or require support using compensatory strategies or alternatives to speech are on the high rise (LaPointe, 2005 and Laska et al., 2001). A dearth of research studies on AAC in this population as evident from the literature review can create challenges for AAC interventionists (SLPs) providing services to PWA. The major challenge is being unable to integrate AAC into all aspects of aphasia intervention. The task of providing a PWA with an efficient communication system differs from those with motor impairments (such as ALS) since the individual's communication system has been impaired as a result of inherent language disorder as opposed to poor motor control (Beukelman & Garrett, 1988). PWA often have an intense desire to communicate (Beukelman & Garrett, 1988), but must learn new or familiar communication tools in different ways and accept different outcomes from daily exchanges (Fried-Oken et al., 2011) which tend to disrupt the automaticity of a previously habitual process (Lasker, 2008). This indicates that before a brain injury, adults depended almost unconsciously on the brain's ability to search, formulate, and create messages; but, after incurring aphasia, these individuals are required to shift from a familiar internal mechanism to external support for communication- a highly challenging task.

To address these clinical challenges, researchers are entrusted to provide evidence to professionals to enable them to introduce AAC effectively to maximize successful communication exchanges in PWA. Considering the importance of evidence-based practice in aphasia rehabilitation and the imbalance between the required evidence on AAC in PWA to enable clinical decision making and the actual number of researches done to date, justifies the need for additional research that allows integrating evidence from aphasiology, neuroscience and AAC.

1.3.b. Need for study in India

In India, the earliest reports published on post-stroke aphasia frequency shows that approximately 50% of the sample they studied from South India were affected (*n* =94 in Karanth & Rangamani, 1988; *n* = 78 in Nair and Viramani, 1973). Later, Panicker et al. (2003) pointed out that approximately 25% (*n* =26) of individuals with ischemic stroke in their study (*n* =105) exhibited aphasia. Tiwari and Krishnan (2011) underscored the lack of community-based, large-scale published prevalence data on aphasia in India. They speculated that the prevalence of aphasia in India could be remarkably high considering the disability statistics (which state that 11.65% of the total Indian population has a disability; NSSO, 2002) and the available prevalence data on stroke which ranged from 143 to 220 per million people (Razdan et al., 1989; Dalal, 1997). In 2015, Bohra et al. found that the frequency of post-stroke aphasia from North India in subjects having mixed etiology was 28%. In 2019, Dietz estimated the prevalence of aphasia in India to be greater than 5.2 million considering its population of 1.38 billion, making the country the second-highest in having the most number of individuals having aphasia following China which is closer to 5.5 million.

An expert meeting on aphasia in India brought out the necessity of having a hospital-based data bank on the prevalence of aphasia from stroke registries across the country because of inadequate data available (Pauranik et al., 2019). A recent study among Bengali speakers (North-eastern India) reported a 40.39% incidence of post-stroke aphasia from a total of 515 samples screened (Lahiri et al., 2020). Chazikhat (2012) projected that 22,000 people in Kerala (a southern Indian state) have aphasia out of a total population of 34.8 million (Directorate of Census Operations in Kerala, 2011), based on the National Aphasia Association's (2012) estimate that 40% of stroke survivors have aphasia. Since it is estimated that 50% of PWA may never recover linguistic skills sufficient for functional communication (Purdy & Dietz, 2010), there is an urgent need to implement AAC intervention among this population in the country.

Even though an exhaustive literature search can rarely be complete, considering the geographical origin of the reviewed literature on AAC and aphasia, a disproportionately large number of studies are generated from the USA followed by Europe (Figure 1.2).

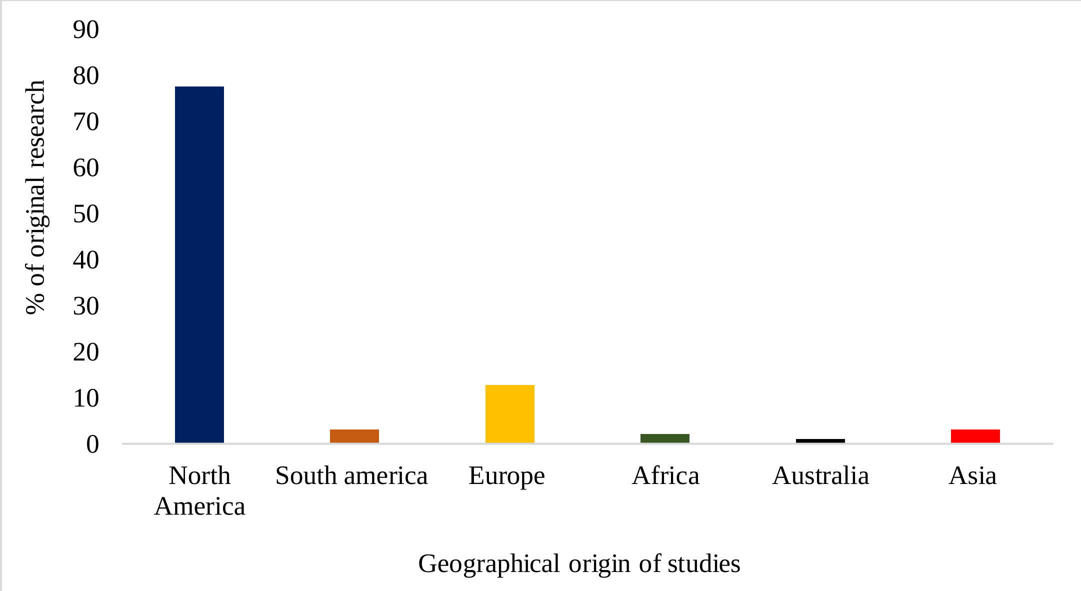

Figure 1.2. Geographical origin of research studies on AAC in PWA

In India, even though the advocacy for using AAC in various communication disorders is gaining strength, published research studies are focused more on children with developmental disabilities (Ramani & Sankar, 2016; Sreekumar, 2014; Sreekumar et al., 2018; Sreekumar et al., 2019; Srinivasan et al., 2017; Veena et al., 2017). The only two published studies on AAC among PWA in the country were on investigating (a) the efficacy of using a communication board among PWA in hospital/ acute care settings (Sarkar, 2017), and (b) the efficacy of an AAC app as an adjunct to stimulation therapy in improving language and quality of life in PWA (Alam et al., 2021). The practice of AAC intervention for adults with acquired communication disorders is slowly gaining momentum in India, especially for use with progressive motor neuron diseases (Mukherjee et al., 2015); however, it is still not a popular choice for those having aphasia (Pauranik et al., 2019; Tiwari & Krishnan, 2011). This could be due to the presence of cognitive and linguistic limitations in using traditional AAC technologies that use grid displays with decontextualized symbols in PWA (Light et al., 2019). Similarly, from a caregiver's perspective, a lack of awareness of AAC use among PWA could affect their decision to support AAC intervention. Moreover, from the AAC interventionist perspective, the lack of adequate clinical research demonstrating the efficacy of one type of symbol or one type of aid or technology or AAC strategy over the other makes the clinical decision more challenging. This could be one of the reasons for the lack of its recommendation for clinical use, among other factors such as lack of expertise in providing AAC services. The lack of adequate training to implement AAC in PWA among professionals can also be assumed to contribute to its limited use clinically.

Anecdotal reports from SLPs on the implementation and use of AAC in the country suggested that factors such as economic constraints imposed on the family, implementation barriers associated with technical skills of PWA and caregivers, as well as a dearth of AAC devices and apps that support the regional language of each state, limits the clinical recommendation and popularity of AAC in PWA. Moreover, the critical gaps in knowledge and everyday practice on AAC intervention in the country impede the clinical decision of whether to implement AAC in aphasia rehabilitation among practicing clinicians. This gap between research and everyday practice has been documented as one of the major challenges in the field of AAC (Light et al., 2019). Given the possibility that graphic symbols, which form the basis of any aided AAC system, are perceived differently by individuals from various cultural and ethnic backgrounds (Nigam, 2003, 2006), and that cognitive-linguistic deficits inherent in PWA make the task of using AAC challenging, it is difficult to answer questions raised by PWA caregivers without sufficient research studies within the country (e.g., whether the PWA will be able to recognize symbols, understand that they represent language, and combine them to produce sentences?). This opens up a wide range of research opportunities to bridge knowledge gaps and make recommendations on AAC intervention for PWA based on linguistically and culturally appropriate evidences.

1.3.c. Need to study symbolic language abilities for aided communication

Having established the need to conduct additional AAC research in PWA globally as well in India, it was necessary to perform a comprehensive review of advances in AAC for aphasia to identify the critical gaps in the literature to initiate research that would enhance clinical practice. The literature review on AAC in PWA pointed out that the flow of research is only in certain directions. A significant portion of original research done with respect to AAC in this population since the 1980s includes interventional studies aimed at exploring and understanding the appropriateness and effectiveness of the use of alternative nonverbal communication systems using symbols. This is followed by experimental research that manipulated different components or features of the AAC system (such as symbol display; visual scene display v/s traditional grid display, number of graphic symbols and levels of symbols, message organization) to study the effect of these variables on the ability of PWA to identify and use AAC (McKelvey et al., 2007; Dietz et al., 2014; Petroi et al., 2014; Brock et al., 2017). Research studies that explored cognitive and linguistic factors that affect the ability of PWA to communicate expressively using an AAC system are also found to some extent (Nicholas et al., 2011; Petroi 2011).

The interventional studies that looked at the ability of PWA to learn alternative communication systems used different types of AAC ranging from unaided AACs (i.e., manual gestures) to graphic symbol based-high technology AAC devices. Several original research as well as reviews on understanding the efficacy of AAC intervention in PWA since the 1990s have been successful in providing evidence that PWA can learn to use nonverbal symbol systems to a degree significantly greater than spoken language in controlled environments while using both non-technology based as well as technology-based AAC approaches (for example, Beukelman & Garrett, 1988; Dietz et al., 2020; Fried-Oken et al., 2011; Jacobs et al., 2004; Koul & Corwin, 2011; Koul et al., 2012; Russo et al., 2017). The use of AAC not only resulted in improvement in language but also cognitive skills and communicative independence (Hough & Johnson, 2009; Johnson et al., 2008). They were conclusive that PWA has multiple symbolic capacities, and cognitive factors that remain intact can be detrimental in learning these artificial languages.

Despite the contribution of these research studies to understanding the effectiveness of using AAC in PWA, most of them had methodological limitations. Most early initiatives to provide alternate communication for PWAs relied on existing communication methods that were not designed to accommodate the disabilities and residual cognitive strengths of these individuals (Weinrich, 1991). The interventional studies that investigated the ability of PWA to use graphic symbol systems in the early years were just a detailed description of their work and did not employ an experimental design to establish the causality for the phenomenon reported or to determine principles for symbol design, or to document generalization (Steele et al., 1989). This observation led to the use of single-subject designs and experimental group designs in AAC intervention studies in PWA. Even with the use of subject control variables, most of these studies posed a threat to internal validity due to the small sample size chosen for their research. Koul et al. (2010) after systematically reviewing single-subject experimental and group designs to investigate the effectiveness of AAC intervention using SGDs and software programs using symbols or text for PWA, stated that "the variability of results within single-subject design studies indicates that predictions about the effectiveness of AAC interventions using SGDs for PWA cannot be made yet" (p. 158).

It is worth noting that the majority of these interventional studies indicated that some PWA performed better than others, but even those with better performance failed to generalize their skills to use AAC in everyday settings. This can be speculated to be caused due to failure to adequately control a myriad of factors affecting the communicative success for aided communication. One such factor could be a lack of matching the language demands of an AAC system to the skills and strengths of PWA (a process known as feature matching), before its recommendation and use. This may often lead to problems at the level of interaction during AAC use (Lasker, 2008). A lack of reporting of feature matching (i.e., matching strengths and skills of the user of AAC to the features of an AAC system) before intervention is evident in most of the intervention studies.

In accordance, Goodenough-Trepagnier's (1995) statement that "poor rate of success in using AAC in aphasia is due to the unavailability of means of obtaining an accurate characterization of the abilities preserved in the presence of severe aphasia" (p. 338) is particularly noteworthy. Considering that aphasia is primarily characterized by deficits in language, and deficits in cognitive-linguistic domains, determining the extent of cognitive and linguistic strengths and weaknesses that influences the ability to comprehend and produce various augmented messages should be considered while planning AAC interventions (Beck & Fritz, 1998). Thus, if the ability for symbolic representation is found to be relatively spared despite profound language impairment, it will allow in choosing and developing appropriate AAC for PWA to conform to and build on preserved abilities (Goodenough-Trepagnier, 1995).

Among the experimental research studies in PWA that manipulated AAC system features, only a few studies utilized grid displays (Brock et al., 2017; Petroi, 2011) while most of them focused on using visual scene displays (Beukelman et al., 2015; Dietz et al., 2014; Mckelvey et al., 2007; Steele et al., 2007). Due to the inherent linguistic and cognitive impairments, PWA often have difficulty learning and using AAC systems that utilize grid displays with decontextualized symbols (Brock et al., 2017). However, since most of the aided AAC systems available uses grid displays, it becomes necessary to evaluate and determine factors related to symbols, such as the type of symbols, their organization in a grid display that reduces cognitive load and facilitates the easy acquisition and use of the AAC system in PWA. Since the graphic symbols in the grid displays help to visualize concepts, relationships, and the structural aspects of language (Arvidson et al., 1999), knowledge of the degree to which a PWA can assign meaning to various types of symbols and which elements would facilitate appropriate activation of their semantic form is important (Beck & Fritz, 1998). Furthermore, Glennon and DeCoste (1997) stated that communicating with an aided AAC system at a symbolic level requires any individual to understand and use an object, tactile or picture symbols, or written language. They further explain the several symbolic skills that are necessary to successfully use any aided AAC system based on pictures or graphic symbols. At the preliminary level, the individual requires to understand that the act of pointing to a picture or symbol is a communicative act. At the next level, they are required to discriminate between multiple symbol choices followed by the ability to sequence symbols together to communicate messages. At higher levels, the individual needs to learn to categorize and associate words or phrases into logical semantic and syntactic groupings.

The linguistic and cognitive processing patterns unique to aphasia may prevent the use of AAC strategies learned during the intervention program. Among, the limited number of studies that investigated residual strengths of PWA to use aided AAC, the focus is found to be more on cognitive skills such as resource allocation, and working memory (Nicholas et al., 2011; Petroi, 2011) than linguistic skills. However, according to Garrett and Lasker (2005), “the language limitations in (a) symbolizing meaning using printed messages or icons (representation), (b) combining words or sequencing icons into messages (formulation), (c) locating information in a book or electronic devices (navigation)”, often restricts the ability of PWA to use AAC systems (Beukelman et al., 2007, p. 236). Thus, similar to individuals with developmental disabilities, communication in PWA using aided AAC can become laborious without the ability to identify/ recognize, navigate, locate, and sequence symbols.

To summarize, even though the use of alternative visual symbols has sufficient evidence for it to go beyond the level of research and into clinical application in PWA, numerous documentation of its eventual dismissal necessitates the need for understanding the “why” behind it. While we have some understanding of factors influencing AAC use in PWA, what aspects of symbolic language abilities for aided communication are available to the individual after brain damage and whether there exists any relationship with the residual verbal language and non-verbal cognitive skills remains the critical questions to be addressed to effectively employ AAC in aphasia rehabilitation. Knowledge of how persons with different types of aphasia vary in these abilities can have significant implications for aphasia rehabilitation; however, research studies that attempt to understand how PWA performs on various tasks to tap their symbolic language abilities for aided communication is very scanty and is a potential area of research.

1.4. Aim of the Study

The current study aimed to understand the symbolic language abilities for aided communication and its relationship with verbal language and non-verbal cognitive abilities among PWA who are natives of Kerala using a series of behavioural tasks that involved picture communication symbols (PCS).

1.5. Objectives of the Study

The symbolic language abilities for aided communication investigated in the present study includes symbol identification, categorization and sequencing abilities. To investigate symbol identification abilities, three behavioural tasks were designed which required the participants to identify symbols from a grid display. Symbol categorization abilities were tapped using two categorization tasks involving auditory and visual stimuli. Two tasks were designed to tap symbol sequencing abilities in terms of the ability to imitate symbol sequences and spontaneously produce symbol sequences in a grid display. The study derived accuracy, efficiency, and response time measures from the performance of PWA, subgroups of PWA (i.e., anomic aphasia and Broca's aphasia), and their age, gender and education matched neurotypical adults while identifying, categorizing and sequencing PCS symbols in a traditional grid display. Furthermore, the accuracy score obtained from all tasks of identification, categorization, and sequencing of symbols was used to represent overall symbolic language abilities. All of these measures obtained across tasks were compared between PWA and neurotypical adults as well as within PWA and across neurotypical adults. The relationship between symbolic language abilities for aided communication with verbal language abilities and non-verbal & verbal cognitive abilities was also investigated in PWA and subgroups of PWA.

Specifically, the objectives and sub-objectives of the study were to:

1. Compare the symbol identification abilities in terms of accuracy, efficiency, and response time obtained on all three identification tasks combined (task 1, task 2, and task 3)

    (i) between PWA and neurotypical adults

    (ii) across sub groups of PWA and neurotypical adults

2. Compare the symbol categorization abilities in terms of accuracy, efficiency and response time obtained on both categorization tasks combined (auditory categorization or task 4 and visual categorization or task 5)

   (i) between PWA and neurotypical adults

   (ii) across sub groups of PWA and neurotypical adults

   2.a) Compare the symbol categorization abilities in terms of accuracy, efficiency, and response time obtained on auditory categorization Task (task 4)

   (i) between PWA and neurotypical adults

   (ii) across sub groups of PWA and neurotypical adults

   2. b) Compare the symbol categorization abilities in terms of accuracy, efficiency, and response time obtained on visual categorization task (task 5)

   (i) between PWA and neurotypical adults

   (ii) across sub groups of PWA and neurotypical adults

3. Compare the symbol sequencing abilities in terms of accuracy of response obtained on both sequencing tasks combined (task 6 and task 7)

   (i) between PWA and neurotypical adults

   (ii) across sub groups of PWA and neurotypical adults

   3. a) To compare the symbol sequencing abilities in terms of accuracy, efficiency, and response time obtained on symbol sequence imitation task (task 6)

   (i) between PWA and neurotypical adults

   (ii) across sub groups of PWA and neurotypical adults

3. b) To compare the symbol sequencing abilities in terms of accuracy of response obtained on symbol sequence production task (task 7)

(i) between PWA and neurotypical adults

(ii) across sub groups of PWA and neurotypical adults

4. Compare symbolic language abilities in terms of accuracy of response obtained on all tasks of identification, categorization, and sequencing combined

   (i) between PWA and neurotypical adults

   (ii) across sub groups of PWA and neurotypical adults

5. Determine the relationship between the symbolic language abilities and verbal language abilities in PWA and subgroups of PWA.
6. Determine the relationship between symbolic language abilities and nonverbal &verbal cognitive abilities in PWA and subgroups of PWA.

1.6. Hypotheses of the study

Based on the above objectives and sub-objectives, the following were the hypotheses and sub-hypotheses of the study:

1. There is no statistically significant difference in the symbol identification abilities in terms of accuracy, efficiency, and response time taken to perform on all three identification tasks combined (task 1, task 2, and task 3)

   (i) between PWA and neurotypical adults

   (ii) across sub groups of PWA and neurotypical adults

2. There is no statistically significant difference in the symbol categorization abilities in terms of accuracy, efficiency, and response time taken to perform on both categorization tasks combined (auditory categorization or task 4 and visual categorization or task 5)

(i) between PWA and neurotypical adults

(ii) across sub groups of PWA and neurotypical adults

2. a) There is no statistically significant difference in the symbol categorization abilities in terms of accuracy, efficiency, and response time taken to perform on auditory categorization task (task 4)

(i) between PWA and neurotypical adults

(ii) across sub groups of PWA and neurotypical adults

2. b) There is no statistically significant difference in the symbol categorization abilities in terms of accuracy, efficiency, and response time taken to perform on visual categorization task (task 5)

(i) between PWA and neurotypical adults

(ii) across sub groups of PWA and neurotypical adults

3. There is no statistically significant difference in the symbol sequencing abilities in terms of accuracy of response to perform on both sequencing tasks combined (task 6 and task 7)

(i) between PWA and neurotypical adults

(ii) across sub groups of PWA and neurotypical adults

a) There is no statistically significant difference in the symbol sequencing abilities in terms of accuracy, efficiency, and response time taken to perform on symbol sequence imitation task (task 6)

(i) between PWA and neurotypical adults

(ii) across sub groups of PWA and neurotypical adults

b) There is no statistically significant difference in the symbol sequencing abilities in terms of accuracy of response to perform on symbol sequence production task (task 7)

(i) between PWA and neurotypical adults

(ii) across sub groups of PWA and neurotypical adults

4. There is no statistically significant difference in symbolic language abilities in terms of accuracy of response while performing all tasks of identification, categorization, and sequencing combined

    (i) between PWA and neurotypical adults

    (ii) across sub groups of PWA and neurotypical adults

5. There is no statistically significant correlation between symbolic language abilities and verbal language abilities in PWA and subgroups of PWA
6. There is no statistically significant correlation between symbolic language abilities and nonverbal & verbal cognitive abilities in PWA and subgroups of PWA.

CHAPTER II

REVIEW OF LITERATURE

Aphasia, as defined by most of the established aphasiologists, is an acquired neuro-communication disorder characterized by impairment in understanding and formulating language (Hallowell, 2017). Aphasia results in impairment of symbolic processing of spoken and written language, as well as signs, pictures, graphic symbols, and gestures. This impairment may leave many PWA little or no functional speech making them rely on alternative or artificial language systems that supplement or replace natural or verbal language. Thus, considering that aphasia is a language disorder, and more precisely a symbol processing disorder, it is necessary to examine deficits associated with communication that extends beyond the use of natural language (Petroi, 2011).

The most critical question of whether individuals who were unable to use the dominant language hemisphere due to brain damage can effectively communicate using an artificial language system was first addressed in the early 1970s. This was enabled through graphic symbol-based interventional studies whose primary aim was to determine the extent to which cognitive or conceptual functions specific to normal verbal communication may be preserved in severe cases of aphasia (Baker et al., 1975; Gardner et al., 1976; Glass et al., 1973). The primary element of Glass et al.'s (1973) artificial language system was symbols of varying shape and colour which were functionally equivalent to words. On the other hand, Baker et al (1975) and Gardener et al (1976) devised an artificial system known as a visual communication system (VIC) which also consisted of arbitrary, ideographic or representational graphic symbols denoting single words. This symbol system had an advantage over gesture/sign language in that it circumvented the visual memory deficits and motor coordination problems that are common in aphasia.

Glass et al. (1973) opined that, despite aphasia being an impairment of symbolization, the capacity for using symbols is not entirely abolished, even in persons with global aphasia. Moreover, persons with severe aphasia could use a system of visual symbols to respond to commands, answer questions, and describe actions in a real-time context and some may even use them to establish new communication (Baker et al., 1975; Gardner et al., 1976). Both Gardner et al. (1976) and Glass et al. (1973) suggested the promise of mastering the vocabulary, syntax, and pragmatics of a visually based alternative communication system in PWA. They also proved that this visual-based communication system showcase superior performance over spoken language. But, these claims that logographic shapes and symbols were superior to spoken words in acting as a communicative medium for PWA was questioned by Funnell and Allport (1989). They found that symbols are processed by the same processes that underlie their residual natural language function for isolated spoken and written English words. Also, performance with symbols was identical to their known processing of the word classes to which the symbols were matched making them no superior to written or spoken language.

It can be noted that these early intervention studies were successful in proving that PWA can learn an alternative symbol-based system to communicate. However, having a partially impaired natural language as seen in PWA might interfere in the acquisition of an alternative symbol system unlike in individuals who possess intact natural language (Gardner et al., 1976). The extent and degree of success that can be achieved by a PWA in using a symbol system were always questioned partly because of the simplicity of the alternate communication system (i.e., limited lexicon mostly corresponding to familiar objects and actions as well as syntax consisting of the simple ordering of elements left to right) and partly because of the impaired verbal language. However, the notion that relatively intact visual and cognitive capabilities in PWA can improve impaired communication even in the absence of usable natural language is supported by these early researches.

Even when pieces of evidence weighed more towards proving that the use of non-verbal treatment approach using visual symbol system might be effectively used to communicate in PWA, it is noteworthy that a failure to functionally use mastered symbols during communicative interactions was evident in certain PWA in almost all research. This failure could be due to demands placed by different features of the visual graphic symbol (Bertoni et al., 1991) or due to the differential residual abilities of PWA (Avent et al., 1995). Hence, on the foundation built by earlier research that PWA can learn an artificial language system based out on visual symbols, later researches focused more on studying the efficacy of AAC intervention using different aided AAC systems and the effect of different features of AAC system on the ease of learning and acquisition of AAC use in PWA.

From the above observations, an extensive review was conducted to gather relevant literature on (a) language abilities required to use aided communication in PWA, and (b) the effect of different aspects of the AAC system on the abilities of PWA to use AAC, and to subject them to critical analysis to find research gaps and identify the potential research areas.

2.1. Symbolic language abilities for aided communication

The ability to use an aided AAC for communication requires an individual to be able to locate/discriminate/identify single symbols, categorize, and sequence symbols to form meaningful utterances (Glennen & Decoste, 1997). The existing literature on each of these abilities in PWA are reviewed in the below sections:

2.1.1 The Ability of PWA to identify/recognize and locate Graphic Symbols

Gardner (1974a) investigated the ability to recognize symbols in 15 fluent, 15 non-fluent and 10 individuals with global aphasia and compared their performance with 10 neurotypical adults, 15 individuals with brain damage having no language defects, and six individuals having alexia. The author included individuals with alexia to investigate if they would only have difficulty with verbal symbols. Approximately 200 symbols from 11 categories (such as letters, animals, numbers, faces, objects, signs, and printed words) were used as stimuli. Recognition of symbol was investigated either by asking them to name the symbol or else identify it among multiple choices. PWA performed worse in comparison to individuals with no brain damage. Individuals with fluent aphasia had more difficulty recognizing symbols than those with non-fluent aphasia. The average number of recognition errors were small, indicating that most subjects recognized most symbols. Individuals with non-fluent aphasia and individuals with brain damage having no language defects had the same number of errors in recognizing symbols; however, when scores from the facial recognition were controlled for, nonfluent aphasia had more errors. Neurotypical adults and brain-damaged controls only produced errors in the recognition and naming of rare and specialized signs. They found that recognition of symbols is differentially affected in PWA with symbols of objects being least affected suggesting that familiar, and easy to decode symbols are identified better. Participants with alexia had difficulty recognizing symbols from all categories suggesting that decoding of verbal symbols shares properties with decoding of other symbolic materials.

It was found that a person with severe non-verbal aphasia could be trained to select Blissymbol nouns to identify photographed objects with 100% accuracy (Sawyer-Woods, 1987). Similarly, Bellaire et al. (1991) stated that PWA could be taught to identify and point to pictured symbols to enable communication, even though not all of them may perform similarly. Thorburn et al. (1995) examined the ability of PWA to perform on iconographic symbol recognition test that they had developed. The test required the participants to watch a videotape of 21 rebus symbols and select the target symbol from a series of four pictures (which had a target, a semantic, perceptual and unrelated picture foils) after each presentation. The results showed that PWA demonstrated iconographic symbol understanding comparable to that of controls.

Koul and Lloyd (1998) compared the performance of ten PWA, eight individuals with right hemisphere damage (RHD), and ten healthy individuals on recognition of graphic symbols across time. They also tried to determine the variables that affect symbol comprehension and use. Neurotypical adults and those with aphasia were found to have little difference in their ability to recognize, learn, and recall graphic symbols. PWA showed superior performance in comparison to individuals with RHD. They found translucency to be a potential factor that affects the ability of PWA to recognize or identify a visual symbol. Gardner (1974b, 1974a) and Koul and Lloyd (1998) emphasized the ability of PWA to recognize, learn, and retain graphic symbols. They discussed variations in performance among PWA and the potential contributions of symbol iconicity and grammatical category on these differential performances. Oetzel (2001) found that all three participants with chronic severe Broca's aphasia who participated in her study were able to identify all 119-core vocabulary symbols on a dedicated communication device (DynaMyte 3100) with 100% accuracy after training.

The number of studies that focused only on the symbol recognition ability of PWA was quite a few, and all of them yielded positive results on the ability of PWA to identify symbols with training and found that their performance was on par with neurotypical adults. However, the understanding of symbol recognition in PWA without intervention is very limited. Thorburn et al. (1995) was the only study that included a tool to assess the ability of PWA to visually analyze written language, pantomime, and iconographs. The study emphasized the importance of identifying factors that hinder or facilitate the ability to recognize visual symbols in PWA. Hence, research that focused on understanding the effect of different symbol systems/sets, as well as other AAC system features on symbol identification abilities in PWA are reviewed in the below sections:

2.1.1a. Effect of different Visual Graphic Symbol sets. Blissymbols were among the first alternative visual languages used for enabling communication in PWA because of its vocabulary for abstract concepts and its potential to combine symbols to express new and complex meanings (Johannsen-Horbach et al., 1985; Lane & Samples, 1981; O'Donnell et al., 2010; Ross, 1979; Sawyer-Woods, 1987). Blissymbols not only improved communication but also facilitated spontaneous verbal language and writing in PWA despite any emphasis given to treatment on writing (Lane & Samples, 1981). However, Blissymbols required modification for it to be used for PWA (O'Donnell et al., 2010) and had to be integrated with other means of communication available (Ross, 1979). According to Lane and Samples (1981), PWA requires better auditory comprehension, visual perceptual skills, and motivation to be able to learn this visual language. Furthermore, the long time required to learn these symbols, the lower degree of symbol translucency, and the lack of superiority to the written medium of communication eventually reduced the use of Blissymbols in PWA research.

Contrary to Blissymbols which served as an alternative communication, other picture-based symbol systems were mostly designed for augmentative communication. Glass et al. (1973) used graphic symbols of different colour sizes and shapes which were functionally equivalent to words, and they were cut out from coloured paper.

Gardner et al. (1976) used index cards on which simple, arbitrary (geometric) and representational (ideographic) forms denoting a meaningful unit was drawn in their visual communication (VIC) system that they developed. Gardner et al. (1976) and Glass et al. (1973) chose to use visual graphic symbols as opposed to visual- manual symbols (i.e., gestures) to circumvent the visual memory deficits and motor coordination difficulties in aphasia. For PWA, iconographs, which are made of two-dimensional, visually processed symbolic elements, were easier to understand than written words made of visually processed linguistic elements, and pantomime made of three-dimensional visually sequenced ongoing elements (Thorburn et al., 1995). Written text is mostly used to complement other means of communication (such as graphic symbols or spoken utterances) to improve its quality and efficiency in PWA (Lasker et al., 1997).

The demands imposed by the abstractness of symbols such as Blissymbols or index cards used in VIC systems may frequently result in PWA failing to functionally use mastered symbols during daily communicative interactions. Hence, pictographs were developed which were more simplified pictorial representations of objects associated with tasks of daily living, under the assumption that their concrete rather than arbitrary graphic entries allow them to be easily comprehensible. Bertoni et al. (1991) found that pictographs were more amenable to intervention than gestures or VIC or Blissymbols in PWA because their referential meaning can be inferred easily, allowing attention to be drawn more effectively on components of information that must be indicated for the desired message to come over.

Based on the representational hierarchy of symbols which states that more iconic symbols are easier to recognize without any prior learning, it can be assumed that photographs are easier to recognize than pictographs (Porter & Burkhart, 2010).

Thus, photographs viewed more as a supplemental material than a symbol type is increasingly used during elicitation of expressive language in PWA. Their increased usage can be accounted for their ability to provide visual referents for keywords thus helping them express ideas more efficiently (Beukelman et al., 2015). Thus, investigations using photographs in PWA focused more on the overall ability to express their ideas rather than specifically looking at their ability in identifying or locate specific referents within the pictures.

Ho et al., (2005) compared the effectiveness of remnants and pictographic symbols during initiating and maintaining social interactions in PWA with familiar communication partners. Remnants include an actual object or photograph depicting recent or past events. Both types of communication symbols, remnants, and pictographs, successfully facilitated the interactions of PWA and their conversational partner. Even though there was no significant difference between the use of remnants and pictographs; the authors suggested that remnants might be more effective than pictographs because of less cognitive processing, augmentation of retention of the message due to the static representation to support the recall of events and, activation of emotional associations that may stimulate motivation and linguistic abilities of PWA.

Highly contextualized and personally relevant photographs were found to be superior to personally irrelevant photographs when presented as visual supports during narration in PWA (Beukelman et al., 2015; Dietz, Weissling et al., 2014; Griffith et al., 2014). The use of self-captured photographs in PWA increased the amount and specificity of content conveyed while decreasing reliance on the verbal modality (Ulmer et al., 2017). The efficacy of using digital photographs has been documented (Mahmud et al., 2013) given the increased use of speech-generating devices for the rehabilitation of PWA. Lin and Chen (2017) found that their participants with aphasia preferred photographs for representing nouns (represented human relations and objects), while line drawing was preferred for verbs and adjectives. They also found that animated (dynamic) symbols were preferred more by PWA than static symbols with auxiliary lines or only static symbols even though they thought for some vocabulary the qualities were better represented by the latter two types of symbols.

To summarize, the literature reveals that among representational symbols, the most easily identified and used graphic symbols by PWA are personally relevant real or digitized photographs and highly translucent/transparent graphic symbols. Among graphic symbols, picture communication symbols (PCS) are being chosen for investigations in PWA due to their higher iconicity which makes them easily recognizable (Franco et al., 2015; Petroi et al., 2014). Since the perception of symbols may vary across various ethnic and cultural backgrounds (Nigam, 2003), the above statement on the ability of PWA to comprehend various visual stimuli should be interpreted with caution.

2.1.1b. Effect of Symbol Display and Symbol Organization

2.1.1b.(i) Effect of Symbol display. Symbol displays are classified as static/fixed displays (as in picture communication boards/ books) and dynamic displays (as in speech generating devices). Fixed displays are limited by the number and size of symbols they can contain, depending on the size of the screen, and cannot contain many vocabularies. On the other hand, in a dynamic display, the pictorial symbols can be placed over various pages, and each page can be composed of related symbols (Shin, 2017). Lin & Chen (2017) opined that fixed displays are better for representing symbols for nouns in PWA while dynamic display enables ease of identification for verbs and adjectives.

Symbol displays are also classified into traditional grid display, visual scene display (VSD), and hybrid display. Traditionally, most AAC systems used grids of symbols, pictures, or icons that occupied individual spaces at regular intervals. The individual square or grid isolates each symbol which requires PWA to process them individually and then combines them to formulate messages (Beukelman et al., 2007). Among grid displays, the taxonomic message organization strategy, in which symbols are represented in grids across multiple pages of a book or multiple screens (dynamic) of a device in a logical sequence, is commonly used (Petroi et al., 2014). This type of display puts additional cognitive demands such as that of working memory, and attention allocation on PWA to navigate, select, and combine graphic symbols (Petroi, 2011; Petroi et al., 2014, Purdy & Dietz, 2010). With respect to locating symbols on the AAC system, PWA tends to locate graphic symbols on a taxonomic grid easily and with shorter latency, if the number of symbols is lesser on the screen. This is because as the number of symbols on a screen increases, the PWA requires more cognitive processing time to accurately identify those symbols. The level of location of the graphic symbol also decides how well a PWA will be able to locate it and use it to produce messages in an aided AAC system. For PWA, symbol identification tends to also be dependent on the iconicity of symbols. Moreover, navigating across screens to select symbols may be a more challenging task for PWA than the number of symbols displayed on the screen (Petroi et al., 2014).

Unlike grid displays, a visual scene is generally a picture, photograph, or virtual environment that depicts and represents a situation, place, or experience. It gives PWA the visual contextual support to facilitate navigation of a dynamic display and successful communication of messages (Dietz et al., 2006). A highlighting difference between grid display and VSD is that in the grid display vocabulary is represented through graphic symbols while in VSD, vocabulary is embedded within contextually relevant photographs or scenes. The superiority of VSDs over grid display for organizing messages for construction of multi-symbol messages due to reduction in the working memory demands (Thistle & Wilkinson, 2013) led to a more extensive exploration of visual scene displays in PWA (Beukelman et al., 2015; Dietz et al., 2006; McKelvey et al., 2007; Seale et al., 2007). Persons with aphasia tend to take shorter conversation time, more conversational turns and increased levels of conceptual complexity while using VSD in comparison to grid displays (Brock et al., 2017). The overall semantic organization of symbols, the greater number of symbols per page, higher number of subordinate categories, increased requirement for allocation of attentional resources and working memory in grid displays might affect the conversation time and the number of conversational turns taken by PWA (Brock et al., 2017; Petroi, 2011).

Hybrid displays usually include features of both grid displays as well as VSDs. These displays usually place high demands semantically and syntactically, thus requiring high levels of working memory and attention in PWA (Dietz, 2019).

2.1.1b.(ii) Effect of Symbol organization. While designing an AAC device, the symbols featured in the array must be organized either by a structural dimension such as colour or shape or by a grammatical organization such as parts of speech (Thistle & Wilkinson, 2009). The other ways to organize an AAC system would be based on the topic, episode, or communicative context or based on semantic category (Balandin & Johnson, 2001). An aided symbol display that is organized to match the internal cognitive and lexical organizational strategies of the AAC user usually helps to maximize functional use (Wilkinson et al., 2006). A display that maps to or violates basic principles of visual processing tends to influence functional outcomes such as symbol discrimination, identification, and recall.

During the visual search for symbols, often perceptual cues such as colour help in narrowing down the search to facilitate response and is often known as guided search (Carlin et al., 2002). If colour serves as a powerful cue in AAC, as it does in visual cognitive science and neuroscience, it could be used as a facilitative cue to avoid unintentional barriers to AAC use. Several studies in the past two decades have thus investigated the effect of colour cueing (symbol-internal colour cues and symbol background colour cues) on locating symbols in an array.

Symbol-Internal colour cueing. Wilkinson et al. (2006) observed that colour is considered as a primary element in many perceptual and cognitive tasks as it has a direct effect on responses or visual search. Colour has been found to play a role in the perceptual processes of stimulus location, recognition, and encoding, as well as in the cognitive processes of short-term memory, long-term memory, object classification, and picture recognition. Even when colour is commonly used in many aided AAC systems, they found that no research had been conducted to date on how colour affects symbol identification, recognition, recall, or use in AAC. Hence, they conducted the first study that aimed at understanding the speed of locating symbols under different colour conditions among 16 typically developing pre-school children. They found that grouping symbols having the same internal colour improved the speed and accuracy of locating symbols. Alant et al. (2010) further elaborated Wilkinson et al.'s (2006) work to understand if sequential exposure to different types of colour conditions had an impact on the accuracy and response time of locating target symbols in 60 preschool children. The results of the study pointed out that using same-colour condition as the first exposure in a sequence could potentially benefit participants in orienting more to the symbol detail that could eventually enhance the accuracy of performance.

Stephenson (2007) studied the influence of symbol internal colour on matching performance in children with severe intellectual disabilities and poor spoken language comprehension who were beginning picture users. She found that they performed best when the internal colour of the symbol matched with that of their referent, then when the colours were mismatched or when it was black and white; suggesting that colour may facilitate recognition of symbols. Wilkinson and colleagues (2008) found that typically developing children as well as children with Down's syndrome (DS) was faster and more accurate in locating symbols when symbols that shared internal colours were clustered together, irrespective of the type or complexity of the symbol. Wilkinson and Mcllvane (2013) replicated these findings with another sample of DS and found that a matched group of children having autism spectrum disorders (ASD) also performed similarly to children with DS. Even though, the influence of display design was consistent across two participant groups to suggest a potential universality of processing of these basic features; the fact that children with ASD outperformed children with DS in the visual search task, gives additional insights into universal vs etiologically linked aspect of visual processing. Studies exploring the similar effect on adults with no disability or adults with an acquired communication disorder have not been found and it still appears to be a grey area of research.

Background colour cueing. Providing colour cues in the symbol background is an alternative to manipulating the internal colour to provide perceptual cues as they can guide users to find related sets of symbols, or signal word-class categories (Thistle & Wilkinson, 2009; Wilkinson & Snell, 2011). Guidelines recommending the use of specific background colours to denote different parts of speech have been available since the 1990s. The first empirical study published on background colour coding found that among adults with severe intellectual disabilities, colour can be utilized to draw attention to an object and focus visual attention on it (Bailey & Downing, 1994). Later in 2009, Thistle and Wilkinson examined the role of background colour presented either together or isolated from internal colour cues on the speed of locating symbols in younger and older typically developing children. They found that background colour coding does not affect the response time as long as the line drawings have foreground colour in both younger and older children. Further exploration of background colour cueing when the internal symbol colour cannot be manipulated, changed or clustered together found that the addition of background colour cueing did not aid typically developing pre-school children in locating symbols (Wilkinson & Coombs, 2010). The authors of both studies on typically developing children implied that dependence of physical characteristics of the display may be decreased with maturation/ experience (i.e., the control required over physical features of aided AAC displays for young children might not be required for older or more advanced communicators).

Wilkinson and Snell (2011) argued that the report of background colour cueing having no facilitative effect on locating target symbols in typically developing children only indicates that role of background colour cueing is less straightforward than that of internal colour cueing. With this proposition, they examined the influence of background colour cues and spatial organization of symbols on the accuracy and speed of locating symbols representing emotions in 30 typically developing children. Spatial organization of symbols based on positive and negative emotions was found to enable rapid location of targets; however, colour cue did not enhance either accuracy or speed of responding when it was provided alone or along with the spatial cue. Wilkinson et al. (2014) tested the hypothesis that spatial arrangement provides additional guidance for coloured-guided search for symbols using eye-tracking measures in school children without disabilities. They found that clustering symbols based on their internal colour represent a narrowing of visual attention away from irrelevant distractors who do not share a target's colour. Their findings appear relevant while designing displays for several individuals who have difficulty inhibiting attention such as children with autism spectrum disorders or even adults with aphasia.

All of the above studies on the role of background colour cueing required locating a single symbol and the colour cueing reflected semantic properties. As a result, the findings of studies in which colour is used as a semantic cue may not apply to searches for multiple symbols belonging to different syntactic word classes. To test the above assumption, Thistle and Wilkinson (2017) studied the effect of symbol arrangement and background colour cues on multi-symbol message constructions using symbols representing different word class categories in typically developing children. Their results did not support the initial assumption as only symbol arrangement influenced the construction of multi-symbol messages.

In summary, none of the previous studies that explored the role of background colour cueing in typically developing children and children with intellectual and developmental disabilities found any systematic effect of background colour cueing either on accuracy or response time of locating a single symbol or constructing multiple symbol messages. A single investigation on the effect of symbol background on the speed of constructing a three sequence symbol message in adults without disabilities also reciprocated the above findings (Thistle, 2019). However, this particular study has been successful in pointing out the distinct advantage of background colour cueing on the performance of the participants while locating symbols in a 60-symbol array as opposed to a 16-symbol array. She suggested that AAC displays that use background colour coding to highlight parts of speech of symbols can prove beneficial for adults, especially when the complexity of display increases.

From the literature reviewed on background colour coding, the following critical points are underscored, (a) background colour may reduce the visual-cognitive processing demands as they draw users' attention to specific symbols, (b) background colour cue highlighting the syntactic cueing would facilitate ease of producing multi-symbol messages, and (c) clinicians tend to use background colour cueing more often than symbol internal cues while designing AAC displays. Most of the empirical evidence that emerged from typically developing children or children with intellectual and developmental disabilities found no facilitative effect of colour cues, and there was insufficient evidence from adults with and without communication disorders to argue for or against what is already known. Wilkinson and Mcllvane (2013) suspected that individuals with different etiological profiles might show different sensitivities to the perceptual features of the AAC display. Hence, it is critical to expand these studies and evaluate the visual cognitive processing of AAC displays in PWA as it becomes essential to understand how these variables influence the performance of individuals who have inherent cognitive and linguistic processing deficits. An understanding of visual processing abilities in individuals with disabilities and optimizing design based on such information can reduce barriers that unintentionally deter individuals from using AAC effectively (Wilkinson & Mcllvane, 2013).

2.1.1c. Effect of the grammatical category of Graphic Symbols. The single-meaning symbols in any AAC system are usually categorized into symbols representing nouns, verbs and other word classes. Noun symbols distinguish the external characteristics of concrete items and hence they can be easily identified and tends to exhibit relatively higher iconicity than verbs and adjectives (Mizuko, 1987; Mizuko & Riechle, 1989; Worah et al., 2015). Since symbols representing verbs and word classes other than nouns are more abstract, they take more time to get processed even in typical adults. Weinrich (1991) reported the use of a modified C-VIC system (C-VIC 2.0) which included animated representations to indicate verbs and found that their participant with global aphasia learned animated verbs more quickly than static symbols for verbs. Lin and Chen (2017) found that adjectives that represented abstract or comparative concepts that required substantial details to prevent cognitive burden among neurotypical adults were better characterized by static symbols; whereas animated symbols were found more appropriate for representing approving and positive concepts (such as human emotions). Brock and Hung (2021) found no effect of symbol format (i.e., photograph vs video) on the identification of verbs in PWA which they assumed could be due to the relative simplicity of the task which only required them to use recognition memory and due to their relatively intact receptive semantics.

Blissymbols representing open word class such as names of useful items and topics of interest were mostly highly translucent or transparent and were learned and used more meaningfully in PWA than closed class or nonspecific words such as pronouns, spatial prepositions, conjunctions, verbs of general reference with low imageability and concreteness, and interrogatives that were less translucent or opaque (Funnell & Allport, 1989).

Symbols that had shared visual features were more difficult for PWA to learn initially than those which were not. Persons with severe aphasia take a longer duration to learn symbols representing verbs than nouns (Gardner et al., 1976). The concrete representation of verbs was learned slightly more quickly than abstract representation in persons with agrammatic aphasia (Weinrich et al., 1989b). Moreover, PWA finds it difficult to extend the use of symbols related to verbs into new contexts when compared to nouns and prepositions. Their inability to generalize could be due to difficulty in spontaneously accessing the semantic field that corresponds to the meaning of that symbol, and it is already established that semantic fields of PWA are largely intact for nouns than verbs (Weinrich et al., 1989b). To enhance transparency and preference of symbols in PWA, nouns may be represented using real photographs while verbs and adjectives can be characterized using line drawings (Lin & Chen, 2017).

Thus, even though PWA can learn to use visual graphic symbols to communicate, the symbol set used, the grammatical category of the symbols, their design, and representation affect the ease with which they learn to use a particular system. Moreover, the interface/ organizational layout can also substantially affect the efficiency and accuracy with which PWA locate symbols (Wallace &Hux, 2014).

2.1.2 The Ability of PWA to Categorize Graphic Symbols

Categorization is defined as the ability to assign objects or other stimulus patterns to categories to gain access to information and make predictions (Schlosser, 1997). Categorization, also known as semantic classification or semantic organization is thus thought to be a cognitive process whereby items are grouped by their similarity thus facilitating storage and retrieval of words (Balandin & Johnson, 2001). This process is important in the formation of concepts, where concepts refer to all of an individual's knowledge about a class of objects or events. (Hough, 1993). The ability to categorize is thought to enable humans to cope with a multitude of stimuli encountered every day and reportedly follows a developmental process (Bruner, 1970). Young children organize semantic concepts schematically (i.e., organize items related to scenes or events based on their function in that scene. For example, the words teacher, book, and singing might be grouped as they are related to each other in a preschool event).

As children mature, they start learning to associate semantic concepts based on their shared functions within events; they shift from schematic organization to categorical or taxonomical organization structures. The taxonomical organization "refers to a hierarchical system of categories that are related to one another by means of class inclusion and within taxonomy, a superordinate term includes subordinate concepts" (Fallon et al., 2003, p. 75). The superordinate category is more abstract and perceived to be least semantically related as they tend to have few perceptual features in common and lack distinct perceptual representation (for example, vehicles and tools). The subordinate items share attributes and hence has the most semantic inter-relatedness among members (for example, types of chairs) (Schlosser, 1997). Nelson (1977) suggested that superordinate-subordinate categorization is the dominant word organization strategy for neurologically healthy adolescents and adults.

Several reports of PWA having an altered semantic organization have been documented by investigations that tapped their categorization abilities. Goodglass and Baker (1976) found that adults with nonfluent aphasia (with high comprehension scores) had little difficulty in recognizing superordinate (e.g., the relation between car and vehicle) and same word associations (e.g., the relation between car and car), but had more difficulty identifying function (e.g., the relation between car and drive) and attribute associations (e.g., the relation between car and fast) and the greatest errors were for recognizing same class associations (e.g., the relation between car and truck). On the other hand, fluent aphasia (low comprehension scores) had severe difficulty in appreciating function associations than superordinate associations. Thus, a disproportionate increase in the difficulty of recognizing function associates (verbs) and a marked increase in the difficulty for the associative category of functional context in fluent aphasia is suggestive of a qualitative change in the semantic organization. Since the stimulus used in this study was auditory, it is possible that the auditory signals representing information at the periphery of the semantic fields (i.e., functionally related verbs) were not able to arouse associations in an intact semantic system. Baker and his colleagues (1981) through their later works suggested that functional information lies at the core of some concepts rather than periphery and their results could have been as a result of testing procedure artifact (Nicholas, 1998; McCleary & Hirst, 1986).

Adults with posterior (fluent) aphasia had difficulty in classifying atypical members and related non-members in a category verification task (Grober et al., 1980). On the other hand, nonfluent aphasia tends to produce exemplars from central or highly representative portions of the semantic field while fluent aphasia produced out-of-set responses demonstrating only a superficial appreciation of the central part of the semantic field (Grossman, 1978, 1981). It was argued that adults with nonfluent aphasia may use implicit knowledge of the structure of the semantic field, that some items are more central than others to make reference and hence may perform better for superordinate categories. Grossman and Wilson (1987) who explored the ability of nonfluent aphasia to categorize object picture stimuli found that PWA has a general-purpose categorizing ability. Kudo (1987) investigated the mental representative structure of hierarchically ordered semantic categories by asking the participants with aphasia to judge if a given picture was a member of a given category named by the examiner. They found that the category boundaries may be preserved in aphasia at least partially except for in fluent aphasia in which there is a profound disruption of category boundaries.

McCleary and Hirst (1986) examined the appreciation of three semantic associations (i.e., items of same basic level category, items of same superordinate category, and items related by function) in fluent aphasia using a classification task. They used stimuli that were not dependent on auditory comprehension as they assumed the nature of the stimuli affected the outcome of Goodglass and Baker's (1976) study on the semantic organization in PWA. They found that in comparison to nonfluent aphasia, adults with fluent aphasia had significantly more difficulty classifying semantically related items whether the items to be classified were basic, superordinate or function related items. Adults with nonfluent aphasia made few errors on basic and superordinate levels and more on function related items. This differential performance could be suggestive of a change in the structure of the semantic organization in fluent aphasia has changed while it is relatively preserved in nonfluent aphasia. While some opined that the structure of the semantic organization changes after aphasia has incurred (Goodglass & Baker, 1976), others suggested that the semantic organization may be intact but the ease with which they are accessed can be altered (McCleary & Hirst, 1986).

More recently, Lice and Palmovic (2017) attempted to determine the semantic categorization of animate and inanimate objects in PWA having language comprehension difficulties using event-related potentials. They concluded that PWA has difficulty in both phases of lexical-semantic processing (i.e., lexical retrieval or recognition phase as well as categorization phase). The absence of difference in processing animate and inanimate objects was consistent with the connectionist model of semantic processing which claims that concepts are represented in a single distributed conceptual system and the same semantic system is active no matter which category is being processed.

Despite the difference in opinion on the semantic organization or categorization of concepts in PWA, developers of the AAC system have reasoned that even though one of the fundamental forms of symbolization (i.e., verbal language) may no longer be available, the ability to conceptualize the world symbolically may be intact in severe aphasia. It is assumed that the central core of conceptual information is intact and this core can be accessed via alternate modalities if the language is no longer a viable route (Nicholas, 1998) and hence PWA should be able to use a semantically organized AAC system.

Simpson et al (1996) pointed out that the AAC systems used by PWA often all use semantic strategies to organize selection sets (i.e., individual symbols are grouped according to superordinate categories. For example, symbols representing objects of daily living are represented under “things” category). Intact semantic knowledge is thought to be necessary to utilize such an AAC system and those PWA who were successful in using such a system would have retained substantial semantic knowledge despite severe aphasia (Hux et al., 1993). Thus, dependence on this type of organizational strategy presumes that the user has a semantic organization system that is similar to neurotypical adults in their culture. Since most individuals with severe aphasia have difficulty in comprehending and using semantic information, the above assumption might be incorrect. Hence, Simpson and his colleagues used a two-item comparison task to evaluate the semantic organization and found that at least some PWA does not retain the commonly used strategy of organizing semantic information based on superordinate-subordinate categorization as neurotypical adults do.

Nicholas (1998) investigated the ability to make category selection in adults with nonfluent aphasia using two experimental tasks. The first task required the participants to choose among the basic categories of people, actions, and objects in response to a category item spoken aloud by the examiner. The second task asked the participants to choose among subcategories of objects and then select an exemplar match in response to a picture and spoken word stimuli. They found that even participants with severe aphasia can make many category decisions that are required by most of the available picture-based AAC systems. They had particular difficulty in categorizing action concepts and making decisions among semantically related categories. Her results pointed out that the conceptual-semantic knowledge required to select correct categories or subcategories may not be fully available in severe aphasia.

Van de Sandt-Koenderman et al. (2007) emphasized the importance of intact semantic abilities for using the AAC system (Touch Speak) in PWA. All of their aphasia participants who were found to be extensive and independent Touch Speak users had normal or near-normal visual semantic association abilities as measured during baseline assessment using a task in which the participants had to choose the semantically closest picture to the target picture from a set of four pictures. They stated that since the Touch Speak vocabulary has to be organized following semantic principles, it is possible that the ability to use the system for communication would rely heavily on semantic processes such as identifying central features, appreciating semantic relation between items sharing the same features, and discriminating between items that are closely related. Future research into the central role of visual semantics in nonverbal communication or AAC use is recommended, as it is of clinical and theoretical relevance. Clinically, it seems important because semantic deficits are very common in aphasia and it may have no relation with severity or type of aphasia, hence there is a need to investigate the value of semantic processing for AAC success. Theoretically, it is necessary to find more evidence for the hypothesis that visual semantic processing may be closely related to the central process of non-linguistic concept formation and is needed for all non-verbal communication.

In contrast, to the above study, Nicholas et al. (2011) found executive functions appeared to be more relevant than semantic categorization abilities or auditory comprehension for successful use of the C-Speak Aphasia system among their participants. However, they used the tasks used in Nicholas's (1998) study to investigate if pictorial semantic abilities are preserved in PWA. The performance of their participants with severe aphasia indicated that basic semantic categories and the ability to make a reasonable guess about where a particular item might be located in a pictorial semantic hierarchical system were relatively intact.

To sum, many of the currently available AAC systems rely on the capacity to categorize conceptual units into three basic categories (people, actions, and objects) and hence requires the user to have a high level of semantic organizational ability. Understanding the semantic organization or categorization ability of adults who would use AAC as their primary mode of communication is of prime importance while considering language intervention and layout of communication systems (Balandin & Johnson, 2001); however, upon review of literature, there is a clear scarcity of studies investigating the ability of PWA to categorize symbols in an AAC system. An intact semantic organization is thought to be essential for word retrieval and sentence formation and hence it becomes critical to understand how PWA who are augmented communicators classify or categorize concepts as it may have an effect not only on their sentence structure but also on the rate of production of the message.

2.1.3. The Ability of PWA to combine and produce sentences using Graphic Symbols

The ability of PWA to combine and produce sentences using graphic symbols were first evidenced when the participants with aphasia in Glass et al.'s (1973) study demonstrated that they could learn to convey information through simple constructions using symbols. Two of their subjects, in particular, showed considerable improvement and were able to comprehend and express simple declarative statements. Even though these sentences were simple, composed of subject-predicate-object, they involved the syntactic use of symbols. Ross (1979) found that her participant with aphasia could effectively express herself using Blissymbols on a communication board with intervention. The participant could initiate conversation, ask questions and express opinions. The communication improved in terms of the use of longer and more complex sentence structure as well as with respect to increased speed and less effort.

Lane and Samples (1981) investigated the ability of PWA to combine Blissymbols for communication. They noticed that when the PWA began to combine symbols, the number of symbols was not a significant factor because a string of two or three was combined with the same ease; rather, familiarity with symbols was found to have a significant contribution for producing symbol sequences. Three out of four participants tend to use necessary grammatical markers; however, the use of articles and conjunctions was more sporadic (i.e., they would omit articles and conjunctions and then immediately repeat the sequence with them).

Based on these positive findings, Johannsen-Horbach et al. (1985) investigated the ability of PWA to acquire a basic lexicon involving nouns, verbs, adjectives, and adverbs and learn to understand and produce simple sentences using graphic symbols. Their results were not only in line with those of Glass et al. (1973), but they also found that three of their subjects who otherwise only produced automatisms could simultaneously articulate correct sentences while pointing to the symbols.

With the rapid growth in technology, visual symbols started getting generated using computer software and communication devices. Technology allowed these symbols to be used along with synthesized speech which started being used in research that aimed at investigating the ability of PWA to understand and produce graphic symbols. Also, the evolution of linguistic and psycholinguistic research allowed solving issues fundamental to the construction of alternative communication systems.

Furthermore, elaboration and refinement of single-subject experimental designs allowed investigations to overcome limitations of early research which were only descriptive accounts of work without an experimental control. Tapping into the above advancements, Weinrich et al. (1989a) designed a computer-aided visual communication system (C-VIC) around residual cognitive strengths of PWA that relieves them of the processing demands of natural language such as real-time processing, morpho-syntactic processing and phonetic processing. They trained a person with global aphasia for two weeks and found that he could produce syntax without word order errors analogous to reversible prepositional phrases in verbal language using the C-VIC system. Subsequently, Steele et al. (1989) used C-VIC and successfully trained five PWA to access, manipulate symbols, and combine them into valid communications on screen and to use them appropriately in communication transactions.

Participants with severe aphasia were found to produce locative prepositional phrases using C-VIC at greater than 90% accuracy with training (Weinrich et al., 1993). Weinrich et al. (1995) documented improvements in verbal and graphic symbol productions of prepositional phrases and S-V-O sentences with C-VIC training was in two persons with severe chronic Broca's aphasia similar to findings of Johannsen-Horbach et al. (1985) and Weinrich et al. (1993). They reasoned that the ability of PWA to build accurate C-VIC structures shows that their functional level representations, at least the component carrying semantic information are intact. Evidence was on the rise regarding the ability of PWA to comprehend and produce sentences of varying syntactic structures and complexity using these symbols in the C-VIC system with intervention (Goodenough-Trepagnier, 1995; McCall et al., 2000; Shelton et al., 1996; Weinrich et al., 2001; Weinrich et al., 1996; Weinrich et al., 1997a) even though the performance varied with respect to the severity of aphasia (Naeser et al., 1998).

Rostron et al. (1996) documented the ability of an individual with severe expressive aphasia and apraxia to identify symbols and construct sentences using a flexible icon-based communication aid (Easy Speaker for Windows). They noted that the time taken to construct sentences was slow (3.5 to 4 words per minute), and the accuracy of responses while improved, varied across sessions. They also reported that the PWA was unable to use the system independently for communication.

Koul (1997) and Koul and Harding (1998), attempted to replicate the results of studies that claimed using computer-generated picture symbols that persons with severe chronic aphasia could access, manipulate, and combine graphic symbols. The PWA was trained to construct S-V and S-V-O sentences using symbols (PCS) in response to a picture stimulus using software called Talking Screen. In both studies, PWA performed better for symbol identification tasks than symbol production and the percentage of nouns learned for subjects was more than verbs. The faster rate of learning of nouns could probably be because they tend to be iconic and concrete and they are acquired easily. Their results supported the "multiple symbolic capacities" theory of aphasia as PWA could acquire graphic symbols and could not develop spoken language even with treatment. They provide evidence against the central symbolic deficit theory that aphasia might be a central symbolic defect in which there is a decrease in competence across a range of symbol systems (from nonverbal pictures to purely linguistic symbols). They further discuss that recognition memory, vocabulary organization, and absence of articulatory and phonetic processing has an important role to play in the enhanced learning of computer-based graphic symbols in PWA.

Communication devices that had pre-stored messages allowed its users to identify and use them with more efficiency and speed. They are installed with the feature of iconic encoding which is a technique that allows the user to select and combine icons or pictures in order to communicate pre-stored messages on communication devices. An example is for the stimulus "I want to go to bed," the iconic code will be "bed." Beck and Fritz, (1998) studied the effect of different types of aphasia on their ability to learn iconic encoding and the effect of the message type (abstract vs. concrete) on the ability of PWA to learn and retain iconic codes. Since, iconic codes typically use sequences of one, two, or three icons, their focus of research also encompassed finding if, there is an effect of these lengths on the ability of persons with various types of aphasia to learn and retain iconic codes. They also attempted to investigate the type of AAC that will be most beneficial to persons with various types of aphasia.

All participants with aphasia as well as neurotypical adults in Beck and Fritz's (1998) study learned and retained more iconic codes for concrete messages than for abstract messages. They suggested that similar performance between PWA and controls indicated that PWA understood the basic task of iconic encoding and auditorily and/or visually comprehended the messages they had to reproduce. PWA having high comprehension skills learned abstract messages as well but at a slower pace than concrete messages. They speculated that factors such as differences in cognitive skills (e.g., visual processing, memory deficits, attentional inefficiencies) or variations in underlying language processes could account for the disparity in abstract message performance between groups. It was observed that the acquisition of messages decreased for all participant groups as the length of iconic codes increased from one to two to three icons. Even though the performance of PWA and controls were similar at the level of one icon, the performance of PWA at the level of two and three icon lengths was markedly poor than controls which were attributed to the deficit in short-term memory and difficulty in allocating attentional resources. They concluded that a person with anterior (nonfluent) aphasia with good comprehension skills could acquire iconic codes for concrete messages represented with one or two icons and for abstract messages represented with one icon. On the other hand, a person with a posterior type of aphasia and poor comprehension skills might be able to learn and retain concrete messages represented by a single icon.

Linebarger et al. (1998) and Linebarger et al. (2000) provided evidence that PWA (chronic severe nonfluent agrammatic aphasia) could produce longer and more structured utterances when provided with a communication system (sentence synthesizer or sentence shaper; SS) designed for PWA. This allowed PWA to maintain sentence elements long enough to assemble them into larger structures after observing that PWA cannot maintain lexical items long enough to produce single sentences using graphic symbols. To be specific, the median utterance length ranged between 4 to 5 using SS in comparison to 2 to 3 without SS; the % words in sentences ranged between 70% to 86% using SS in comparison to 11% to 49% without SS; the % well-formed sentences ranged between 45% to 67% in comparison to 20% to 54% without SS; the mean sentence length ranged between 4.78 to 6.5 with SS compared to 3.4 to 4.87 without SS.

Oetzel (2001) examined the ability of three individuals with chronic severe Broca's aphasia to produce sentences of increasing complexity as a result of AAC intervention using DynaMyte 3100 dedicated communication device. The syntactic complexity of experimental sentences was adapted from the "suggested hierarchy of difficulty for syntactic constructions by persons with aphasia" (Chapey, 1994). Level I consisted of two-word constructions (action + object), Level II had two-word combinations + morphological inflections [plural (-s)], Level III included a combination of noun phrases and verb phrases (agent+ action+ object), Level IV consisted of transformed sentences (e.g., question transformations) and Level V had a combination of two or more constructions to make one sentences. In comparison to earlier reports that persons with severe aphasia can acquire S-V, S-V-O sentences, and simple sentences with prepositions (Weinrich et al., 1995; Koul and Harding, 1997), Oetzel's result provided evidence that PWA could produce substantially more complex sentences that included morphological markers and transformations using the AAC system. She also reported that performance on sentence production tasks varied across the three subjects, which precludes any prediction of the performance of individuals with Broca's aphasia on computer-based AAC systems.

Weinrich et al. (2001) trained two individuals with chronic agrammatic aphasia on the production of passive sentences in English using the C-VIC system. They found that both participants produced passive sentences, even though they showed variability in performance despite having similar syntactic deficits. In a second experiment, they tested the production of sentences involving conjoined subjects and objects without providing any training to the participants in the same. Both participants produced correct C-VIC constructions with conjoined subjects and objects. They concluded that semantic representations involving tenses and passive constructions with conjoined subjects and objects are intact in PWA.

Koul et al. (2005) and Koul et al. (2008) examined the ability of individuals with severe Broca's aphasia or global aphasia to produce graphic symbol sentences of varying syntactical complexity using the speech-generating device. They also aimed to investigate if the production of sentences using graphic symbols will be affected by the underlying deficits that cause morphological and syntactical impairments in the spoken language of individuals with severe Broca's aphasia or global aphasia. The sentences used in both studies ranged in complexity from simple two-word phrases to those with morphological inflections, transformations, and relative clauses. Eight out of the nine participants with aphasia (Koul et al., 2005) and all the three participants (Koul et al., 2008) produced sentences using graphic symbols with varying degrees of success. However, it was noted that their performance on the generalization probes was more deficient than their performance on the training probes. Participants with global aphasia were unable to demonstrate any generalization. The most common type of sentences produced by PWA included noun +verb combinations. They opined that underlying linguistic impairment observed in individuals with aphasia might also affect their ability to produce grammatically complex sentences using graphic symbols.

Johnson et al. (2008) adapted the treatment protocol from Koul et al. (2005) and tailored it for each of their three participants with chronic non-fluent aphasia to examine the quality and effectiveness of communication with AAC devices (Dialect with Speaking Dynamically Pro). The participants were effectively trained to identify symbols, navigate, and sequence two to three symbols to produce sentences and later use them for role-play sessions. The results were again replicated on a 56-year-old individual with severe non-fluent aphasia and apraxia of speech (Hough & Johnson, 2009). A report from Brazil stated that PWA was able to combine several symbols (graphical or pictorial) effectively for communication and that AAC intervention improved the quality of communication (Franco et al., 2015).

The therapeutic advantage to producing sentences using graphic symbols from any graphic symbol set in PWA is that they are usually free of dysarthria, paraphasias, and grammatical flaws in comparison to verbal language (Goodenough-Trepagnier, 1995). The added advantage is that it remains visually present for the communication partner to decipher at any point in time. To fully exploit the use of visual graphic symbols in PWA during the intervention, a clear idea of the presence and amount of extension of lexical deficits to a nonverbal system is required. However, this is still a matter of debate. Moreover, since PWA does not represent a homogeneous group, it becomes necessary to determine whether the use of symbols or pictorial materials is appropriate for all PWA (Stead, 2007; Stead et al., 2011). Thus the need to identify the relative integrity of the nonverbal system after aphasia has incurred, but before intervention becomes essential. This need appears to have been less addressed by researchers over the years as their focus was more on intervention-based studies and hence is a potential area of research.

2.2. Non-Verbal Symbolic Language and its Relationship with Verbal Language, and Cognition in PWA

2.2a. Relationship between Non-Verbal Symbolic Language and Verbal Language

The relationship between non-verbal symbolic language and verbal language was first studied by Thorburn et al. (1995) who found no strong relationship between reading comprehension, pantomime recognition and iconographic comprehension in PWA. They also analyzed the relationship between each type of visual stimuli and aphasia severity as measured by Western Aphasia Battery-Aphasia Quotient (WAB-AQ) and found no significant relationship between any stimuli and aphasia severity. The possible lack of association between the variables was attributed to relatively small sample size and the participant group being homogenous in terms of type and degree of aphasia.

Later, the relationship between natural language (verbal language) ability and symbol-based language (aided language) ability was addressed by Steele and his colleagues (1989) while investigating the ability of PWA to use a computerized visual communication (C-VIC) system. They noted that the use of the C-VIC system did not affect the natural language abilities as it remained impaired across all modalities before and after the intervention. However, they suggested that the natural language and C-VIC both had the symbolic ability to provide a communicative advantage in a variety of human contexts, and some of the rules of the person's natural language have been adopted into the C-VIC system (for example, left to right presentation of symbols similar to the word order in written language). C-VIC is not a natural language, though it may use common symbolic communication abilities and associated extra-linguistic cognitive structures. Thus, they opined that the alternative communication system is considered as an independent entity with rules which can be compared and contrasted with natural language through further research.

Weinrich et al. (1993) discussed the relationship between natural language processing and comprehension and production of C-VIC. They explained different stages of natural language production using Levelt's (1992) and Garrett's (1992) model; and the processes involved in C-VIC comprehension and production using Marr's (1982) approach to analyzing processing in the visual system. For natural language production, a pre-linguistic message is formed by a conceptualizer. The message is then encoded into linguistic form by a formulator which is involved in a two-stage process of lexical retrieval, first at the level of lemmas (linked to semantic and syntactic representations) and second at the level of word forms (linked to phonological and morphological representations). Finally, the encoded message is converted to speech by the articulators. On the other hand, for producing a message in C-VIC, the individual must select the symbols to represent objects of interest, select the symbols to represent the propositional relationship between objects and order them to express thematic roles the objects play in the proposition. Weinrich and his colleagues (1993) identified important differences between C-VIC and natural language processing: (a) C-VIC production lacks phonological encoding and articulation while auditory processing is absent from C-VIC comprehension, (b) the surface structure and grammatical encoding of C-VIC is simpler than natural language and is not similar to it.

Naeser et al. (1998) examined the relationship between the scores obtained on the Boston assessment of severe aphasia (BASA) before and after C-VIC training. The overall BASA scores and BASA auditory comprehension scores of PWA in the best response group were significantly higher than those in the moderate response group. The overall BASA score before C-VIC treatment also showed significance in predicting C-VIC outcome as the median cut off for BASA scores for the best response group was 38 and PWA in the moderate group had a score less than 38.

Linebarger and Schwartz (2005) noticed that all their participants with aphasia who did not show consistent treatment effects using AAC had their WAB AQs outside the range of those who responded well for the treatment, thus linking the ability to effectively use an AAC system to the severity of language impairment in PWA. Johnson et al. (2008) used WAB AQ and WAB CQ (WAB- Cortical Quotient) scores to measure treatment outcomes using AAC devices in three individuals with chronic severe non-fluent aphasia. While AQ scores significantly improved with treatment for one participant, they did not change for another and declined for the third participant. The improvement in AQ scores was noted as a result of increased scores for naming and auditory comprehension subtests of WAB. The CQ scores increased for a single participant with treatment, the scores showed limited but meaningful improvement for another and minimal changes for the third participant. The changes in CQ were due to improved reading scores, as well as writing and drawing scores. These improvements in AQ and CQ were attributed to the overall improvement of symbolic language processing. Hough and Johnson (2009) who replicated Johnson and his colleagues'

(2008) study on a single participant with aphasia also reported continuous improvement in WAB AQ and WAB CQ during AAC intervention with most improvements were noted in auditory and visual comprehension skills. Similarly, Steele (2010) reported improvements in auditory comprehension and naming subtests of WAB along with AQ scores after AAC intervention using an SGD in 20 persons with global aphasia.

2.2b. Relationship between Non-Verbal Symbolic Language and Cognition

Traditionally, it was assumed that PWA's poor communication abilities were solely due to their language impairment; however, more and more scientific evidence suggests that non-linguistic cognitive deficits could have contributed to the same. These cognitive impairments are presumed to be the reason for the inability of these individuals to spontaneously compensate for their language deficits and to functionally apply skills acquired in the intervention program (Nicholas et al., 2017). The same has been held accountable for a large variation in response to AAC (Nicholas et al., 2005), poor generalization of the use of AAC in everyday settings (Van de Sandt-Koenderman et al., 2007; Purdy & Dietz, 2010) and reduced inability to initiate use of an alternative strategy (Nicholas et al., 2011).

Glass et al. (1973) examined the conceptual functions and capacity of symbolization in global aphasics under the assumption that damage to language processes causing aphasia may leave the pre-linguistic cognitive functions intact. They conducted an assessment of the natural language and perceptual-cognitive capacity of their participants with global aphasia before artificial language training. The language tests that tapped into the semantic and syntactic knowledge, as well as word-non word recognition, revealed functional deficits in natural language. The cognitive assessment involved sorting picture cards of various objects, animals, plants, people and scenes. During the perceptual-cognitive picture sorting task, they found that their participants made sophisticated conceptual judgements such as identifying key aspects of the discrimination, elucidating the underlying concept, and applying it to replicate the pictorial sort. They were also able to collapse and expand categories as the level of super-ordination changed. With intervention, all the participants showed an ability to learn artificial language systems despite gross deficits in natural language. Based on all of these observations, the authors concluded that (a) the cognitive impairments may not be in direct proportion to their language impairment, (b) and that individuals who have lost their ability to communicate due to a massive stroke may still retain some capacity for abstraction and conceptual thought as well as primitive linguistic functions.

Baker et al. (1975) pointed out that understanding whether cognitive functions are preserved in the absence of language has both theoretical and practical importance in PWA. This is because, in the absence of natural language, effective communication may depend on their ability to master an alternative communication system that captures relevant cognitive properties of natural language. The ability of PWA to use arbitrarily designed symbols to represent elements of experience, encode meaningful relationships in terms of configurational properties or syntax of the symbol sequence, and encode such relationships in alternative syntactic forms is a critical test of the hypothesized dissociation between natural language and its cognitive pre-requisites. The preservation of cognitive concomitants of natural language in PWA was verified with alternative communication system training (Baker 1975; Gardner et al., 1976). Thus, these early descriptive reports on PWA using visual symbols were useful in understanding that PWA could master the fundamentals of alternative symbol systems and that some cognitive operations involved in natural language persist despite severe aphasia.

Funnell and Allport (1989) criticized the claims of Baker et al. (1975), Gardner et al. (1976), and Glass et al. (1973) that symbol systems tap into cognitive processes that are no longer available to surface forms of natural language. They argued that symbols successfully learned and used in communication by PWA are those which map onto preserved cognitive processes that are also available to familiar alphabetic forms of written language. Since symbols were taught entirely in relation to words, symbols behaved like their equivalent written words thus suggesting that they are processed based on the same processes that underlie their residual language function for isolated spoken and written words. Another evidence that the processing of a non-verbal symbol system is mediated by the same processing mechanisms subserving language is obtained from Coelho and Duffy's (1987) investigation that trained PWA with manual signs. They found that the number of manual signs in Amerind acquired on a training level tend to decrease as the severity of aphasia increases (as measured by overall PICA scores).

Gardner et al. (1976) correlated the ability of PWA to answer questions and describe events using a visual communication system (VIC) involving symbols with that of analogous scores obtained on the Boston Examination of Aphasia Severity. The participants were required to name objects in English and answer questions involving names in VIC. Results showed that PWA answered questions better in VIC than in English. An inverse correlation was found between these two measures suggesting that the better the natural language of the individual, the poorer his use of VIC in answering questions requiring names. This underlined the patient's superior communication effectiveness using the new symbol system. They could not conclude if there were systemic differences in the cognitive status of those who failed to learn VIC at all in comparison to those who were successfully trained due to the small number of participants in the study and suggested the importance of determining cognitive features that helps to differentiate those who can complete the training from those who cannot. Weinrich et al. (1993) found that even when non-verbal tests of cognitive function demonstrate that PWA retains some level of abstract reasoning and semantic organization, deficits in non-verbal tasks do not predict their performance in interpreting C-VIC symbol order.

Johanssen-Horbach et al. (1985) observed that while one of their participant with aphasia recovered expressive speech via the use of symbols, another one could produce correct expressive speech with symbols, while two others could not draw many benefits. The authors assumed that the slow progress in two of their participants with aphasia might indicate that residual language capacities are necessary to benefit from symbol-based communication systems. Sawyer-Woods (1987) assumed that high scores on Raven's test and Illinois test of psycholinguistic ability in his participant with severe aphasia could be one of the reasons for his ability to identify and sequence symbols successfully with training.

The use of AAC strategies requires several cognitive skills which led some investigators to look into the role of specific cognitive processes in using AAC systems in PWA. Cognitive impairments in terms of challenges in attention, perceptual processing, memory and executive functions in PWA may interfere with their ability to learn AAC strategies (Garrett & Kimelman, 2000). Even after being successfully trained to use alternate communication modes such as gesturing, drawing or using communication boards, PWA having an impairment of executive function (cognitive flexibility) were found to have difficulty in shifting to these alternate communication modes spontaneously (Purdy, 2002; Purdy & Koch, 2006; Yoshihata et al., 1998). To further elaborate, they were found to be less independent at using alternative communication systems to communicate in real-life tasks (Bellaire et al., 1991; Nicholas et al., 2011; Purdy et al., 1994; Rostron et al., 1996; Yoshitata et al., 1998). Memory impairments (both short-term and long-term) in PWA tend to affect their ability to search multiple levels for messages, ability to retain ideas and persevere until the message is communicated, ability to recall operational procedures for an AAC system (Garrett & Kimelman, 2000). Moreover, they may have a limited amount of processing resources available or decreased ability to allocate resources to perform tasks involving graphic symbols (Petroi, 2011; Petroi et al., 2014).

In the field of aphasiology, the relationship between verbal language and non-linguistic cognitive abilities has long been a source of debate (Nicholas et al., 2017). This is because while some aphasiologists thought that non-linguistic cognitive deficits co-occur with language disturbances, others thought of it as part of the language disorder itself. Moreover, the presence of language impairment makes it difficult to evaluate non-verbal cognitive skills such as working memory and executive functions; and when language influence was controlled for, the relationship between aphasia severity and non-linguistic deficits were not uniform across patients (Nicholas et al., 2017). The literature on non-verbal cognitive deficits shows that they tend to affect the course of treatment using AAC systems in PWA. Studies that examined the relationship between residual verbal language, non-verbal language and non-verbal cognitive skills prior to training were scarce; but is considered important to predict the performance of PWA on alternate communication treatments.

To summarize, over the years, the compensatory based approach in aphasia rehabilitation has evolved from strategies that utilized gestures, drawing, and writing or pictures in the past to strategies that use a wide range of visual graphic symbol systems aided with and without technology to circumvent the verbal deficits in PWA.

Owing to the wide variety of symbols, and AAC systems available for communication intervention in PWA, clinicians often turn to evidence-based research for guidance to initiate intervention. Contrary to aphasia restoration intervention with well over 80 years of evidence to guide clinicians in planning rehabilitation (Beukelman et al., 2008), the relative novelty in implementation of AAC strategies in PWA makes it difficult to find enough evidence to support evidence-based practices.

The PWA has become a target population for most of the original AAC research only in recent years, and hence the number of published literature is way behind the statistics documented for AAC research in children and adolescents with various communication disorders. The majority of the existing research has focused on understanding the effectiveness of using AAC to enable communication in PWA using intervention based studies. Various AAC symbol sets (such as Blissymbols, Dynasyms, PCS), and various types of aided AAC systems (no technology, low technology, and speech-generating devices) have been subjected to research in this population. The factors affecting AAC use in PWA also has been explored to some extent.

Literature on aphasia and symbolic language abilities using various AAC systems raises several concerns. One is the inability of PWA to use a symbol-based AAC system effectively for independent communication. Second, clinicians and researchers have less knowledge about how basic skills required to use an AAC system for communication (i.e., navigating, locating, identifying, and combining symbols to generate messages) are affected by each type of aphasia, making it difficult to predict how well they will use them with training. Third, most of the intervention studies that gave evidence towards the ability of aphasia to identify, categorize and sequence measured their abilities only using the accuracy of response. None of the reports used detailed measures of response time or the number of attempts taken to respond, as difficulty in both of these measures would equate to inefficient processing. Fourth, the relationship between verbal language and non-verbal cognitive skills is complex and has been found to interfere with the acquisition of alternate communication forms such as AAC. However, understanding the type and strength of the relationship of verbal language, non-verbal language, and non-verbal cognitive skills have received less attention. Fifth, the majority of the reviewed studies are from the Western, which raises concerns about the generalizability of the obtained results to the Indian population with over 22 regional languages. Thus, there exists a considerable need to research symbolic language abilities in PWA to guide SLPs in India for better clinical decision making and application of AAC intervention.

CHAPTER III

METHODS

The linguistic demands for individuals who require AAC involve knowledge, judgment, and skills in linguistic codes of their native spoken language as well as the linguistic representation of the AAC system. Thus, in addition to receptive and expressive skills in spoken language, the individual must learn how to use AAC symbols to represent meaning, and how to combine symbols to express more complex ideas (Garrett & Kimelman, 2000; Light, 2003). These skills namely symbol identification, categorization, and sequencing collectively form symbolic language abilities for aided communication. Symbol identification is the receptive understanding of graphic symbols (i.e., the individual's ability to discriminate between graphic symbols), while symbol categorization is the ability of an individual to understand semantic, syntactic, and functional vocabulary categories as they relate to graphic symbols. Symbol combination or sequencing is the ability of an individual to combine two or more graphic symbols to communicate a message. The present study examines these three symbolic language abilities required to use any aided AAC system in persons with aphasia using a series of behavioural tasks. It also attempts to investigate the relationship between symbolic language abilities, verbal language abilities and non-verbal cognitive abilities. The participant details, nature of stimuli, the procedure for administration of tasks, and scoring/analyses of data obtained are explained in this chapter.

3.1 Study Design

The study employed a quasi-experimental research design and a correlational design to meet the study objectives. The quasi-experimental research design (non-equivalent control group design) was utilized to compare the performance of persons with aphasia and its subgroups (clinical group) and neurotypical adults (control group) on behavioural tasks involving graphic symbols that tap symbolic language abilities. Since the research design is quasi-experimental, it did not involve randomization or random assignment of participants; however, participants were matched on assigned variables to improve the comparability of experimental and comparison groups. The independent variables included the participant groups and subgroups (assigned independent variable) and the behavioural tasks (active independent variable). The dependent variables were the accuracy, efficiency, and response time taken to perform each behavioural task. The dependent variables also included semantic and syntactic measures specifically for the sequence production task. The semantic measures were the total number of symbols, the total number of correct information units for symbols (CIU-S), and the percentage of correct information units for symbols (%CIU-S). The syntactic measures included the percentage of complete sentences, and the percentage of correct number of verbs.

A correlational design was used to determine the relationship between symbolic language abilities and verbal language abilities as well as between symbolic language abilities and non-verbal & verbal cognitive abilities. The variables used for correlation design included symbol performance quotient score (measured from behavioural tasks), aphasia quotient score and cortical quotient score (as measured from the test of aphasia in Malayalam).

3.1.1 Sample size and Sampling

The sample size was calculated using G*power 3.1 software utilizing the mean and standard deviation obtained from the pilot study at the significance level (α) of 0.05 and power of the test ($1-\beta$) at 0.80. The analysis prescribed a sample size ranging from 5 to 10. A total of 40 participants were recruited for the present study consisting of 20

PWA and 20 neurotypical adults. A purposive sampling method was employed to collect samples for the present study.

3.2 Participants

Two groups of individuals having Malayalam (an Indo-Dravidian language spoken by natives of Kerala, a south-western state in India) as their native language were selected as participants for the study. The age of the participants ranged between 20 to 80 years. Participants in both groups were visually and auditorily screened using case-history information along with the use of screening tools. Visual screening for the participants did not involve direct visual acuity testing, instead, language-free tasks of sustained and selective attention under the cognitive domain of the battery of cognitive-communication disorder—Kannada[1] (BCC-K; Goswami et al., 2020) was used. These tasks allowed to ensure that the participants could attend to visual information presented in the study. They were auditorily screened using Ling's six sound test (Ling, 1989). All participants had the ability to use single finger-pointing as the responses for the tasks were recorded in the motor form.

3.2.1 Persons with Aphasia

The first group of participants (clinical group) included 20 individuals (males = 16, females = 4) who incurred aphasia due to damage to the dominant cerebral hemisphere primarily as a result of stroke, traumatic brain injury or tumour as confirmed by neurological examination and computerized tomography (CT) scan or magnetic resonance imaging (MRI) but not limited to these aetiologies. They were recruited from various hospitals, speech and hearing private clinics, and institutes from the two major cities of Ernakulam and Trivandrum in the state of Kerala, India.

[1] BCC-K is a clinical assessment tool to diagnose cognitive and linguistic deficits in Kannada (an Indo-Dravidian language) speaking adults with acquired neurological disorders.

They were diagnosed as having aphasia based on the results of the test of aphasia in Malayalam (Jenny, 1992). Similar to Western Aphasia Battery or WAB (Kertesz, 1982), the test of aphasia in Malayalam consists of four language subtests (i.e., spontaneous speech, auditory comprehension, naming, and repetition) and three performance subtests (i.e., reading and writing, arithmetic, and praxis). The test was developed such that the stimuli used in the test were translated from WAB in English and modified to suit the linguistic principles of Malayalam and the Indian cultural context. The number of stimuli in each subtest, as well as the administration, scoring, and interpretation of the results, are all comparable to WAB. The test was validated by administering it alongside the WAB in English to five Malayalam-English bilingual neurotypical adults. In the current study, the type of aphasia and severity of language impairment in adults with aphasia was determined based on the test of aphasia in Malayalam.

Those individuals who obtained a score of greater than five in auditory comprehension (out of a maximum score of 10) on the test of aphasia in Malayalam were selected for the study to ensure that the participants would understand the task instructions provided to them. The persons with aphasia included in the study were classified into two major types — Broca's aphasia (non-fluent aphasia, n =10) and anomic aphasia (fluent aphasia, n =10). These two types of aphasia were labelled as the subgroups of aphasia in the study. Thus, throughout the study PWA group indicate a combined group of persons with anomic aphasia and Broca’s aphasia. All participants in this group were right-handed as confirmed by Edinburgh Handedness Inventory-Short Form (Veale, 2014).

The demographic details of the participants with aphasia in terms of age, gender, education, time post-onset of stroke in months, aphasia quotient (AQ) scores, cortical quotient (CQ) scores, the severity, and type of aphasia are provided in Table 3.1.

Table 3.1

Clinical and behavioural characteristics of persons with aphasia

#	Age (yrs)/ Gender	Education (yrs)	TPO (mth)	AQ	CQ	Clinical Diagnosis/Site of Lesion	Severity and type of Aphasia
1	50/M	14	18	83	79.6	Left MCA infarct	Mild/Anomic Aphasia
2	70/M	17	36	86	80.5	Recurrent Left MCA infarct	Mild/Anomic Aphasia
3	67/M	21	5	82.8	70.5	Status post road traffic accident; left fronto-temporal-parietal lesion	Mild/Anomic Aphasia
4	65/M	19	5	84.7	85.8	Acute dense infarct in left temporo-parietal lobe(left MCA territory); chronic lacunar infarcts in bilateral lentiform nucleus	Mild/Anomic Aphasia
5	62/M	10	24	79.1	69.4	Left MCA infarct	Mild/Anomic Aphasia
6	59/M	17	51	85.3	87.7	Left MCA infarct	Mild/Anomic Aphasia
7	51/F	19	11	85.8	87	Left MCA territory subacute infarcts (left fronto-temporal-parietal lobes)	Mild/Anomic Aphasia
8	36/M	12	2	79.2	80.1	Left MCA infarct	Mild/Anomic Aphasia
9	69/F	17	5	66.8	61.3	Left MCA infarct	Moderate/ Anomic Aphasia
10	74/F	12	3	73.4	77.9	Temporal evolution with an acute infarct in left frontal and parietal area	Moderate/ Anomic Aphasia
11	35/M	18	60	51.6	57	Left MCA infarct with right hemiparesis	Moderate/ Broca's Aphasia
12	64/M	17	2	17.3	34.3	Left MCA ischemic stroke with severe right hemiparesis	Very Severe/ Broca's Aphasia

#	Age (yrs)/ Gender	Education (yrs)	TPO (mth)	AQ	CQ	Clinical Diagnosis/Site of Lesion	Severity and type of Aphasia
13	53/M	14	12	21.4	32.9	Left MCA infarct	Very severe/ Broca's Aphasia
14	67/M	21	108	69.7	71.9	Recurrent left MCA infarct; left internal carotid artery occlusion	Moderate/ Broca's Aphasia
15	52/F	12	19	66.2	62.6	Left MCA infarct	Moderate/ Broca's Aphasia
16	47/M	15	312	58.2	52.1	Status post road traffic accident; left fronto-temporal lesion with right hemiparesis	Moderate/ Broca's Aphasia
17	56/M	17	7	42.6	49.8	Left MCA infarct with right hemiparesis	Severe/ Broca's Aphasia
18	51/M	18	48	39.1	40.1	Status post tumour removal	Severe/ Broca's Aphasia
19	21/M	14	24	38	45.4	Status post road traffic accident; left fronto-parietal lesion	Severe/ Broca's Aphasia
20	74/M	14	120	21.7	24.7	Left MCA infarct with right hemiparesis	Very Severe/ Broca's Aphasia

***Note*.** #= Participant number, TPO= Time post-onset, yrs= years, mth= months, M= Males, F= Females, AQ= Aphasia Quotient, CQ = Cortical Quotient, MCA= Middle cerebral artery

3.2.2 Neurotypical Adults

Twenty neurotypical adults (Males = 16, Females = 4) with no reported history of neurologic, linguistic, motor, sensory, or cognitive problems were also recruited for the study as the control group. Montreal Cognitive Assessment- Malayalam (MoCA-M, Krishnan et al., 2015; Radhamani, 2015) was used to screen these participants for cognitive impairments. This group of individuals were included in the study to understand symbol identification, categorization, and sequencing abilities without the confounding variables of the linguistic, perceptual, and cognitive impairments.

Neurotypical adults were matched to the age, gender, and education level of the adults with aphasia.

Table 3.2 summarizes the group characteristics of persons with aphasia and neurotypical adults who participated in the study.

Table 3.2

Characteristics of Participant Groups and subgroups

Group	Age (years)	Education (years)	Time post-onset (months)	Aphasia Quotient Scores	Cortical Quotient Scores
Persons with aphasia[a]					
Mean	56.15	15.85	43.60	61.59	62.53
SD	13.96	3.06	71.61	23.79	19.65
Range	21 to 74	10 to 21	2 to 312	17.3 to 86.0	24.7 to 87.7
Anomic aphasia[b]					
Mean	60.30	15.80	16.00	80.61	77.98
SD	11.60	3.61	16.48	6.26	8.55
Range	36 to 74	10 to 21	2 to 51	66.8 to 86.8	61.3 to 87.7
Broca's aphasia[b]					
Mean	52.00	16.00	71.20	42.58	47.07
SD	15.44	2.67	94.13	18.78	14.55
Range	21 to 74	12 to 21	2 to 312	17.3 to 69.7	24.7 to 71.9
Neurotypical adults[a]					
Mean	55.80	15.70			
SD	14.19	3.09			
Range	20 to 75	10 to 21			

Note. [a] *n*= 20 for each group, [b]*n*= 10 for each group SD= Standard deviation

3.3 Ethical consideration

The present study was approved by the Ethical Committee for bio-behavioural research involving human subjects at the All India Institute of Speech and Hearing (AIISH), Mysuru, India (WF-180/2018-2019, Appendix-A). The participants were recruited for the study only after obtaining their written consent (refer to Appendix B for informed consent form) as per the ethical guidelines for bio-behavioural research involving human subjects of the All India Institute of Speech and Hearing (Basavaraj & Venkatesan, 2009). All the participants with aphasia, their caregivers, and participants in the control group (i.e., neurotypical adults) were explained the need, procedure, and approximate duration of the tasks. They were assured of safety during testing and confidentiality regarding their personal details.

3.4 Materials

Materials included graphic symbols, two stimuli booklets with one containing symbols and the other having real-photographs to elicit and record responses, and rating scales. The graphic symbols from the Picture Communication Symbol set (PCS; Johnson, 1981) was used to investigate the ability of the participants to identify, categorize, and sequence graphic symbols. The primary reason for selecting PCS symbols in the current study was because it is the most transparent symbol set used widely across the globe (Beukelman & Mirenda, 2013). The other reasons are, (a) these symbols have alternatives that are more or less concrete depending on the needs of the AAC communicator, and they are available through computer software which allows customization of symbols, (b) PCS symbols have been evaluated for cultural appropriateness and more than 90% of PCS lexical items (i.e. approximately 2,235 symbols) were considered to have at least some value to individuals from Asian-Indian culture (Nigam, 2006), (c) the only other commercially available symbol set in India is Indian Picture Symbols for Communication (IPSC) developed at Indian Institute of Cerebral Palsy, Kolkata, India and these symbols have not been subjected to any formal investigations on iconicity or socio-cultural validation for different states in the country, and (d) stimulate the clinical material that is already in use thus maintaining some ecological validity of materials under study (Wilkinson et al., 2014).

To select the target PCS lexical items required for each of the behavioural tasks, the following steps were followed: First, a master list of lexical items was obtained from the English word list provided in the manual for Indian picture symbols for communication (Chakraborthy et al., 2007), Indian adaptations of Action Naming Test (Girish & Shyamala, 2015) in Kannada-English bilinguals, and Boston Naming Test (Shyamala et al., 2010) in Kannada-English and Telugu-English bilinguals. Second, the master list that encompassed 526 nouns, 180 verbs, 54 adjectives, and 12 prepositions were translated from English to the Malayalam language.

The translated referents (words) were rated by five speech-language pathologists (SLPs) and five lay-persons who were native speakers of Malayalam language. Speech-language pathologists with a minimum of three years of clinical experience were recruited for rating. The lay-persons recruited included three females and two males belonging to different age groups, with different educational and professional backgrounds as provided in Table 3.3.

Table 3.3

Demographic details of lay-persons recruited for rating stimuli

#	Age	Gender	Education	Profession
1	28	Female	Post graduate	Career Advisor
2	35	Male	Post-graduate	Human Resource Executive
3	59	Female	Graduate	Teacher
4	67	Male	Diploma holder	Civil Draftsman
5	60	Female	Graduate	Home-maker

A 3-point scale was used to rate the target words in Malayalam for their appropriateness, frequency of occurrence in daily usage, and familiarity. Appropriateness of the word was rated in terms of the correctness of the translated Malayalam word corresponding to its English counterpart (highly appropriate -2, fairly appropriate-1, not appropriate-0). The rater's perception of the frequency with which the target Malayalam word is used in daily conversation was used to rate the frequency of occurrence of words (frequent use-2, occasional use-1, no frequent use-0). Familiarity of the word was rated in terms of how well known is a target Malayalam word to the rater (highly familiar-2, less familiar-1, not familiar-0).

Third, the PCS symbols for all the words that were rated high on the frequency of occurrence and familiarity were obtained from Boardmaker speaking dynamically pro software, Version 6[2]. When searching for symbols from the Boardmaker software, the first symbol that appeared for the target word from the generated word list was selected based on the following criteria: (a) search for exact label or keyword reserved for the symbol and/or a different form of the same label, and (b) exact match for word class. The selected PCS symbols were again rated by the same set of five SLPs and five lay-persons. The symbols were rated on appropriateness, cultural relevance, simplicity, and iconicity using a 3-point scale (Goswami et al., 2011).

The appropriateness was rated in terms of consistency of the meaning of the selected symbol with the meaning of the target word in Malayalam (highly appropriate -2, fairly appropriate-1, not appropriate-0). Cultural relevance was rated as the acceptability of the symbols culturally and ethnically (highly relevant-2, fairly relevant-1, not relevant-0). The comprehensibility of symbols was evaluated with simplicity (highly comprehensible-2, fairly comprehensible-1, not comprehensible-0). With respect to iconicity, a symbol was given a score of 2, if it can be understood in the absence of a referent; a score of 1 if it can only be understood if referent was provided and a score of 0 if it cannot be understood even if the referent was provided. Thus, a

[2] Boardmaker software and PCS are trademarks of Tobii Dynavox LLC, USA and was used in the present study with permission.

final list of PCS symbols corresponding to nouns, verbs, adjectives, and prepositions that were rated high by all raters across all the parameters was obtained using the above method. The final PCS corpus consisted of 351 nouns, 94 verbs, 30 adjectives, and 10 prepositions.

Fourth, target symbols required for each behavioural task were randomly selected from the final corpus and foil symbols or distractor items were randomly selected from lexical items excluded from the final corpus to construct stimuli plates in a traditional grid display. The distractor items were selected such that their physical shapes were as dissimilar as possible to minimize their influence on the performance. The target symbols and foils were arranged in separate grids and the size of the grid was dependent on the number of symbols displayed per page. The stimuli plates were printed on A4 size sheets to obtain the final stimuli booklet with symbols arranged in varying grid sizes (i.e., four, eight, twelve, and sixteen) as per the requirement of each task involved in the study. Thus, the presentation of stimuli was in the form of a non-technology based AAC system. Appendix for the same is not provided as the stimuli is copyrighted.

Along with the symbol stimuli booklet, an additional real-photograph stimuli booklet consisting of single action pictures was also constructed as required by the final task in the study. The second booklet aimed to include coloured real-photographs to elicit single sentence descriptions using symbols from the participants. The setting, agent, object, and action used in the real photograph stimuli of the Test of Aided Symbol Communication Performance (TASP[3]; Bruno, 2010) was used to create 17 similar real photographs with regional/ country-specific characteristics. Five

[3] TASP is copyrighted to Dr. Joan Bruno, and the symbols are copyrighted to Mayer-Johnson. The permission to adapt the test material for the present study was obtained from both the author and Mayer-Johnson.

neurologically healthy lay-persons were asked to describe the main event of the picture in a complete sentence in Malayalam to obtain a list of target sentences corresponding to each stimulus. A total of 13 stimuli that were rated high by five speech-language pathologists and five non-professionals (same raters who rated symbols) were included in the study. A 3-point scale was used to rate the stimuli in terms of their appropriateness (highly appropriate -2, fairly appropriate-1, not appropriate-0), stimulability (highly stimulable -2, fairly stimulable-1, not stimulable-0), and relevancy (highly relevant-2, fairly relevant-1, not relevant-0). The appropriateness of the stimulus was rated in terms of its relevance to the target sentence, stimulability was rated in terms of the ability of the stimuli to elicit an appropriate response, and relevancy was rated with respect to the acceptability of the stimuli culturally and ethnically (Goswami et al., 2011).

A 12-point rating scale (refer to Appendix C) was developed to score the accuracy of responses obtained from the symbol sequence production task in the participant groups and subgroups. The scale allowed accounting for syntactic appropriateness, syntactic complexity, and semantic aspects of the response into the accuracy scoring. The content validity of the scale was carried out by five SLPs and the final rating scale was developed.

A set of target sentences for the symbol sequence imitation task (task 6) was adapted from the syntactic performance subsection of the TASP (Bruno, 2010) through the following steps. First, the target sentences in English were subjected to forward translation to Malayalam language by two laypersons proficient in both languages. The necessary changes required to preserve the meaning of the target sentences in English as well as to maintain the different level of syntactic complexity was made to the stimuli. Second, any discrepancies between the two individuals' translations were resolved in order to obtain a list of Malayalam target sentences. Third, the translated sentences underwent backward translation by another two bilingual laypersons proficient in English and Malayalam. The forward and backward translations were reviewed and necessary modifications were made. These sentences were rated by five SLPs in terms of equivalence of sentence length (highly equivalent-2, fairly equivalent-1, not equivalent-0), syntactic appropriateness (highly appropriate -2, fairly appropriate-1, not appropriate-0), and semantic appropriateness (highly appropriate -2, fairly appropriate-1, not appropriate-0). A total of 18 target sentences in Malayalam rated high were included for the final study.

3.5 Pilot study

A pilot study was conducted on five neurotypical adults and three persons with aphasia (who were not included in the main study) to determine and verify the stimuli, tasks and presentation related parameters to be used in the study. The number of stimuli used for each task, the target and foil stimuli used for each task, order of presentation of the stimulus (stimulus-related parameters), mode of presentation of tasks, order of presentation of tasks, number of grid sizes to be used for various tasks (task-related parameters), number of attempts to be provided and response duration (presentation related parameters) was noted during the pilot study. The performance of neurotypical adults provided support for the manner in which stimuli and tasks were developed for the study. All of the parameters were kept unchanged for the main study except for response duration and number of attempts.

During the pilot study, each participant was given 15 seconds to respond correctly to a particular test item in each task. The neurotypical adults were able to complete all of the behavioural tasks in an average of 2 hours per participant, with an average time of less than 15 seconds per test item. Persons with aphasia often took more than 15 seconds per test item, with those having severe aphasia performing only with an increase in time allotted (range 10-50 sec). Considering the observations from the pilot study and a previous investigation on the identification of single symbol and subject-verb-object (S-V-O) sentences which provided a time of 60 sec for persons with moderate to severe Broca's aphasia to respond (Petroi et al., 2014), a time duration of 60 sec was chosen for the original study. The decision to make the final task to be untimed was taken after the pilot study as time constraints were found to affect the performance of persons with aphasia.

The number of attempts given to the participant to produce a correct response was three during the pilot study. With an increase in the time provided to respond to 60 sec, it was logical to increase the number of attempts beyond three. Hence, for the main study, the participants were provided with five attempts to produce a correct response.

3.6 Procedure

All participants who were recruited as per the subject selection criteria underwent familiarization tasks before administration of each of the behavioural tasks after obtaining a written consent. All sessions were carried out in a quiet room, free from distractions, and the responses of all the participants were video and audio recorded for later analyses.

Neurotypical adults took a maximum of two sessions to complete all the tasks. The time taken by PWA to complete the tasks varied and an average of five sessions were required. The participants were provided brief periods of rest whenever required or at the end of one task. The administration of tasks was terminated if the participant (especially PWA) reported fatigue or they had difficulty in attending to them and was continued in the next session. A summary of the study procedure is provided in Figure 3.1.

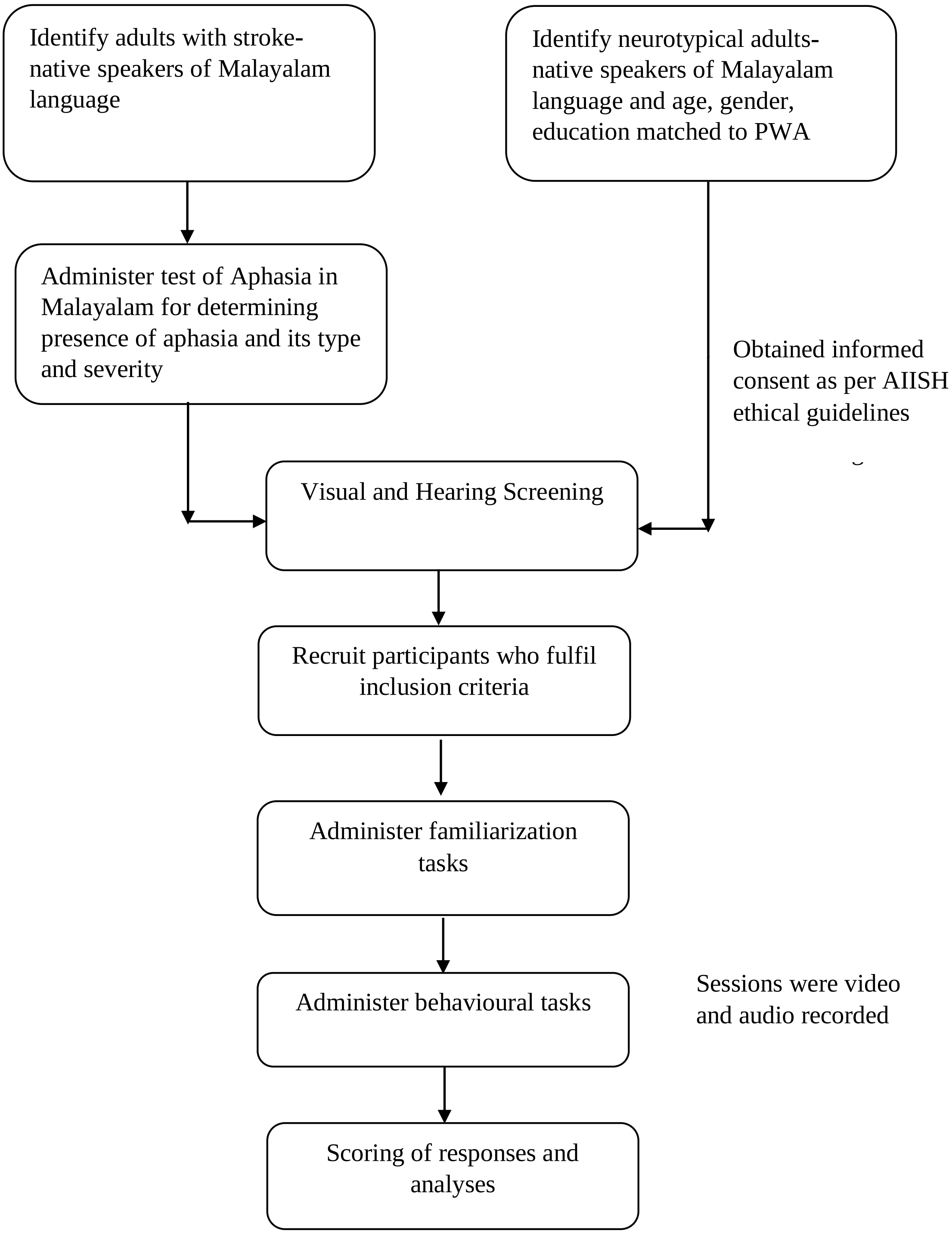

Figure 3.1. Flowchart depicting summary of data collection procedure in the study

3.6.1 Familiarization Task

Since none of the participants had any prior exposure or experience using AAC or symbols, familiarization trials were conducted before each behavioural task. This allowed each of the participants to familiarize themselves with the tasks before the investigation began. Five practice items were provided prior to each of the seven behavioural tasks. The symbols and target sentences used for the practice trials were different from the ones used in the original study. The instructions used for practice items were the same as those used for the original test stimuli. Correct responses provided by the participant were acknowledged and incorrect responses were corrected.

3.6.2 Behavioural Tasks

A total of seven behavioural tasks (refer Figure 3.2) were constructed to explore the performance of participants to identify, categorize, and sequence symbols to meet the objectives of the study. The seven tasks consisted of three identification tasks, two categorization and two symbol sequencing tasks. The description of each task along with the stimuli used and its administration are described in detail in the below sections. The order of the tasks was made random during administration and care was taken not to administer tasks of similar nature consecutively to avoid practice effect on the performance of participant groups.

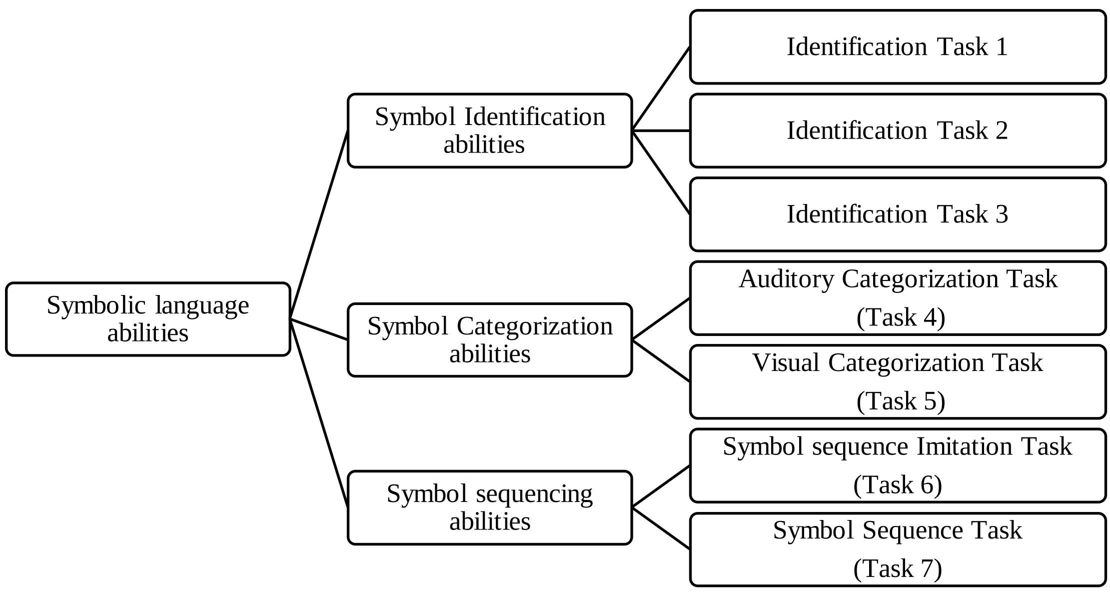

Figure 3.2. Behavioural tasks designed to meet objectives of the study

Symbol Identification Tasks. Identification of single symbols consisted of participants identifying target symbols from a set of symbols and foils to evaluate their ability to recognize symbols. The instructions to the participants for identification tasks were provided in Malayalam language and the English version of the instruction was, *You will be given a set of picture symbols. Look carefully at all the picture symbols and point to the one that I say*. The participants were given a total of 60 seconds to respond to a particular test item. If they were unable to produce a correct response in 60 seconds, they were provided with the next test item. If they pointed or selected an incorrect symbol within 60 seconds, they were given four more attempts to point to the correct test item. A total of three tasks were designed to measure symbol identification abilities. In addition to tapping the symbol identification abilities, each of the tasks was designed for gathering additional relevant information on the performance of the participants. The tasks are described in detail below:

Identification Task 1. The first identification task required the participants to identify symbols in varying grid sizes. Apart from tapping the symbol identification ability it also allowed to determine the effect of the number of symbols per display (i.e., grid size) on the identification of the target PCS symbol and the effect of cognitive taxing on recognition of the target PCS symbol. The stimuli for this task included four PCS symbols representing concrete nouns to avoid the influence of different levels of concreteness associated with word classes if any (such as verbs, adjectives, and prepositions) on symbol identification. Thus, any difficulty in identifying symbols can be attributed to the grid size and not to the iconicity of symbols or concreteness of the referent. The same set of four nouns was arranged at different grid levels (i.e., four, eight, twelve, and sixteen) along with foil symbols. All the test items were presented randomly to each participant. The participants were expected to point to the target PCS symbols (nouns) across four grid levels (i.e., four, eight, twelve, and sixteen symbols per display) as shown in Figure 3.3.

Figure 3.3. Sample template for Identification task 1 showing grid sizes (a) four, (b) eight, (c) twelve, and (d) sixteen

Identification Task 2. This task required the participants to identify PCS symbols across two symbol organizations and background colour cue conditions as shown in Figure 3.4. The task also allowed investigation of the effect of symbol background colour cues and symbol arrangement on the identification of symbols.

In the first condition, PCS symbols were arranged in a taxonomic grid display with each semantic category colour based on the modified Fitzgerald key (Thistle, 2019). The word class category and the corresponding colour coding were— people (yellow), verbs (green), adjectives (blue), and things (orange). The second condition involved randomly arranging the same set of PCS symbols without any categorization or colour coding in a grid display. The participants were expected to point to seven target symbols under these two conditions across four grid sizes (i.e., 4, 8, 12, and 16 grid sizes). The two conditions were counterbalanced across each grid size and target items were randomly presented to the participant.

(a) Condition 1 (b) Condition 2

Figure 3.4. Sample template for identification task 2 showing PCS symbols between two symbol organizations and background colour cue conditions.

Identification Task 3. This task involved the identification of PCSs belonging to different grammatical categories such as verbs, nouns, adjectives, and prepositions (refer Figure 3.5). The task allowed determining the effect of the grammatical category on the identification of target symbols.

The participants were expected to identify a total of 60 target PCS belonging to different grammatical categories (Nouns=18, Verbs =17, Adjectives =15, prepositions=10) in each of the four grid sizes.

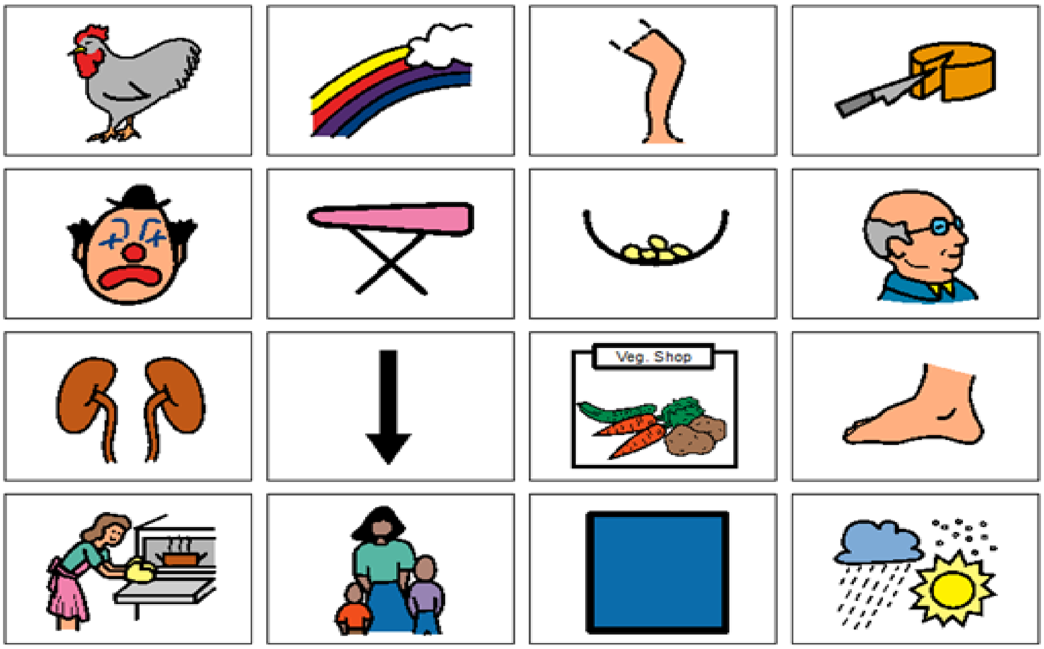

Figure 3.5. Sample template for identification task 3 showing PCS symbols belonging to different grammatical categories along with foil symbols (for example, Hen =noun, cutting=verb, few =adjective, and down = preposition)

Symbol Categorization Tasks. The symbol categorization abilities were investigated using two tasks which studied the auditory categorization and visual categorization of PCS symbols. In other words, these tasks aimed at investigating the participants' ability to visually and auditorily categorize symbols to gain (a) insight into their understanding of how vocabulary can be associated and categorized using graphic symbols, and (b) determine if categorization ability was modality bound (auditory vs. visual). The participants were expected to categorize a total of 30 target symbols into four semantic categories (i.e., animals, food, action verbs, and things). The sample stimulus plate for these tasks is provided in Figure 3.6. The participants were given 60 seconds to correctly categorize the test items. If they were unable to correctly categorize a symbol in 60 seconds, they were provided with the next test item. If they incorrectly categorized a symbol within 60 seconds, they were given four more attempts to produce a correct response.

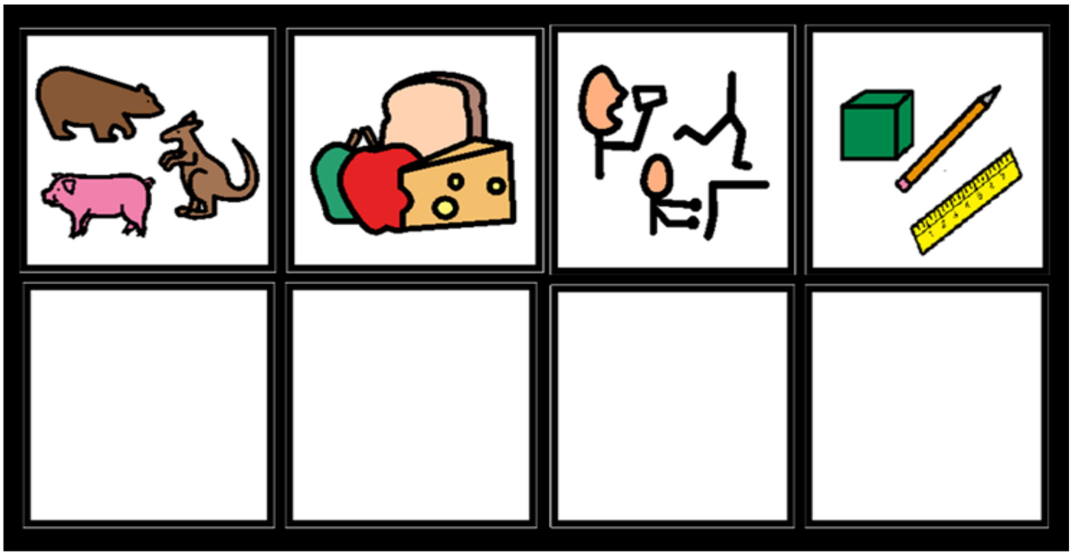

Figure 3.6. Sample template for symbol categorization task where PCS symbols representing four categories (animals, food, action verbs, and things)

Auditory Categorization Task (Task 4). In the auditory categorization task, each participant was expected to point to the appropriate category denoted by PCS in response to the spoken target word. The instruction to the participants for the task was provided in Malayalam language and the English version of the instruction was, *I will say a word, point to the category to which the word belongs*.

Visual Categorization Task (Task 5). The target symbols for this task were printed out on 3 cm x 3 cm cards and the participants were expected to place these PCS symbol cards into the appropriate semantic category denoted by PCS, one by one. The cards were mixed randomly and given to each participant to sort. The instruction to the participants for the task was provided in Malayalam language and the English version of the instruction was, *You will be given a picture symbol card. Look at the card carefully and place the card in the correct category to which it belongs*.

Symbol Sequencing Tasks. The symbol sequencing abilities or in other words, the ability to combine symbols in a sequence were explored using two tasks, symbol sequence imitation task and symbol sequence production task, both of which are described in detail below.

Symbol Sequence Imitation Task (Task 6). In this task, the participant was expected to sequence symbols after the researcher pointed and said the designated sequence. This task determined if the participants can imitate symbol sequences of varying syntactic complexity (i.e., from two symbol sequences to four or five symbol sequences). The PCS symbols required for each sentence along with foil symbols were arranged in a taxonomic grid display with each semantic category colour coded with Fitzgerald key (refer to Figure 3.7). Only three grid sizes (i.e., eight, twelve and sixteen) were used for this particular task as sequencing of symbols is difficult on a 2 x 2 array or grid size containing only 4 symbols.

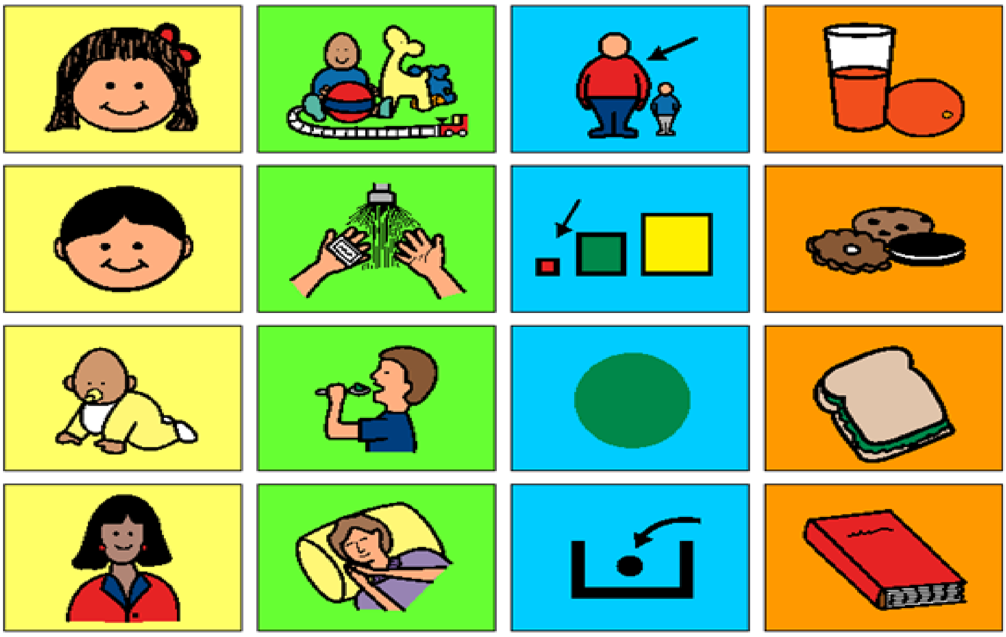

Figure 3.7. Sample template for symbol sequence imitation task

The instruction to the participants for the task was provided in Malayalam language and the English version of the instruction was, *I will say and point to certain symbol sequences corresponding to a sentence in Malayalam. You have to point to the same sequence of symbols as I have shown*. The participants were given 60 seconds to correctly imitate each of the symbol sequences. If they were unable to correctly imitate a symbol sequence within 60 seconds, they were provided with the next test item. If they incorrectly sequenced symbols or omitted symbols in a target sequence within 60 seconds, they were given four more attempts to produce a correct response.

***Symbol Sequence Production Task (Task 7)*.** The task aimed to determine the ability to sequence symbols to form messages to convey meaning. A picture description task involving 13 real coloured photographs containing action pictures were used to assess the performance of the participants. The participants were expected to construct simple sentences using symbol combinations in response to each of the real coloured photographs. The target symbols corresponding to each sentence along with foil symbols were arranged in a 4x4 taxonomic grid display (containing 16 symbols) with each semantic category colour coded with Fitzgerald key (refer to Figure 3.8).

Figure 3.8. Sample template for symbol sequence production task

The instruction to the participants for the task was provided in Malayalam language and the English version of the instruction was, *You will be shown a few real photographs one by one. Describe the photographs using the symbols provided as practiced before*. This particular task was untimed; however, they were provided with a minimum of three attempts to produce the target sentence using symbol sequences. The next target stimuli were provided when the participant produced a correct response or when they indicated that they are ready for the next stimuli. The best of all the attempts which contained the maximum number of correct target symbols were taken for further analyses.

3.7 Response Scoring

Both the correct and error responses for each task were measured and scored from the obtained video samples. The procedure for scoring of responses and calculation of data for statistical analyses is described below:

3.7.1 Correct Responses

The correct responses were measured in terms of accuracy, efficiency, and response time for all tasks except the symbol sequence production task (task 7). In task 7, only accuracy was measured as this task was untimed and the participants were given any number of attempts till they produced a response or indicated that they are ready for the next test stimuli. For all tasks except for task 7, the correct response was scored as "1" and incorrect response or no response was scored as "0" for each test item to calculate the accuracy of responses. For calculating the accuracy score for the symbol sequence production task, a 12-point scale was developed (refer to Appendix C). The symbol production accuracy scale measured the combined accuracy of semantic and syntactic aspects of simple sentences constructed using symbols. To enable statistical analyses, accuracy was calculated in percentage as per the following method- the total number of correct responses divided by the maximum possible correct targets (Thistle & Wilkinson, 2017) multiplied by 100. A symbol performance quotient (SPQ) score was calculated by dividing the accuracy scores of correct responses from all the seven tasks by the maximum attainable accuracy score, multiplied by 100. This quotient was used to correlate the symbolic language abilities with the verbal language abilities (as measured using aphasia quotient) and non-verbal language abilities (as measured using cortical quotient) in persons with aphasia. The illustration of the same is given below:

$$\text{Symbol Performance Quotient} = \frac{\text{Accuracy scores of correct responses from all seven tasks}}{\text{Maximum attainable accuracy score}} \times 100$$

The number of attempts to produce an accurate response was noted to calculate the efficiency using a reverse scoring method. If the participant could produce a correct response in the first attempt, they would receive an efficiency score of "4" for that particular test item. If the participant could only produce a correct response in the second or third attempt, they received a score of "3" and "2" respectively. Any attempts beyond three received a score of "1" and if the participants did not attempt to respond to a particular test item, they were given a score of "0". Efficiency was also calculated in percentage for statistical analyses using the following equation- the total efficiency score of correct responses divided by the maximum attainable score multiplied by 100. Thus, more attempts to produce a correct response resulted in a reduced efficiency score. The response time of correct responses was measured in terms of the time duration in seconds from the onset of presentation of a stimulus to the beginning of the correct response for each task provided (Petroi et al., 2014). A freely downloadable video analyzing software, Wondershare Filmora 9 was used to extract response time in seconds. The response time was averaged for further statistical analyses.

3.7.2 Error Responses

The errors made while identifying, categorizing and sequencing target symbols in PWA were documented. A descriptive analysis of errors was employed to understand the nature of errors. For identification tasks, the non-target PCS selection or error responses were recorded in terms of (a) errors due to perceptual indistinctiveness, where target PCS shares visual features with a different PCS that can make them look similar, (b) errors due to semantic indistinctiveness where the symbols do not look similar visually but may represent the same meaning as that of a different PCS used in the study, (c) errors due to both perceptual and semantic indistinctiveness, where symbols both look similar and have the potential to represent the same meaning (Dada et al., 2013), (d) unrelated error as a result of a random selection of a symbol which was not as a result of perceptual or semantic indistinctiveness, and (e) no response or "I do not know" response. A total frequency of non-target PCS selection or percentage of a total error response for all three identification tasks combined was calculated as the total number of non-target selections divided by the total response (correct and error), multiplied by 100. For each type of error response in identification, a percentage of error response was calculated in terms of the total error produced.

The frequency of categorization errors was recorded for both symbol categorization tasks. For symbol sequencing tasks, errors were recorded in terms of selection errors and sequencing errors. The selection errors were further analyzed in terms of (a) omission errors of predicates and arguments, and (b) substitution of predicates and arguments. The omission and substitution errors were calculated as the proportion of symbols omitted and substituted from a participant's response calculated across each component of the sentence respectively (Weinrich et al., 1997). The sequencing errors were reported in terms of word-order errors. The word order was considered correct if the sentences constructed using symbols were syntactically correct (i.e., follows the subject-object-verb order of Malayalam language) even if the symbols did not match the target. Sequencing errors were only considered for productions involving a combination of two or more symbols.

Only the errors on the participants' final attempt for each target item was taken for error analysis (Binger et al., 2019) and the attempts were considered final when the participant indicated that they are ready to move on to the next item either verbally or gesturally. For the symbol production task (task 7), the errors on their best attempt (i.e., response having the maximum target responses) were considered for descriptive analysis.

3.8 Statistical Analyses

Descriptive data for each task was tabulated for each participant. The obtained data were analyzed using IBM Statistical Package for Social Sciences (SPSS) Version 26. Descriptive analyses in terms of mean, standard deviation, median and inter-quartile range were estimated for the data for each objective. Non-parametric tests were done mostly across the study because (a) the data followed non-normal distribution, as evidenced in the Shapiro-Wilk test of normality, and (b) other assumptions of parametric tests were not met. In instances where data followed a normal distribution, parametric tests were also applied. For all tests, statistical significance was considered at $p<.05$. Whenever multiple tests were performed on the data set, Bonferroni corrections were applied. Bonferroni corrections allowed adjusting the significance value to reduce the possibility of making Type I error when performing multiple statistical comparisons (Armstrong, 2014). The statistical analyses in the present study involved main analyses and additional analyses which are described in the sections below.

3.8.1 Main Analyses

The main analyses included statistical analyses that were done to meet the objectives of the study. The calculation of all dependent variables (i.e., accuracy, efficiency, and response time) in each task for statistical analyses are described below along with a summary of the statistical tests done.

Symbol Identification Tasks. For identification task 1, the accuracy, efficiency, and response time of correctly identified symbols were calculated for each grid size (i.e., four, eight, twelve, and sixteen). For identification task 2, which involved symbol identification between two symbol organization and background colour cue conditions, the average accuracy, efficiency, and response time was calculated for correctly identified symbols for each condition in four grid sizes. For identification task 3, which involved the identification of symbols belonging to different grammatical categories, the accuracy, efficiency, and response time was calculated for each category (i.e., nouns, verbs, adjectives, and prepositions). The average accuracy (%), efficiency (%), and response time (sec) for all correctly identified symbols in all three identification tasks combined were calculated to meet the study objectives 1. (i) and 1. (ii).

Symbol Categorization Tasks. Behavioural tasks 4 and 5 involved visual and auditory categorization of PCS belonging to different semantic categories. For both tasks, accuracy was calculated in terms of the total number of PCS correctly categorized, and efficiency was calculated as the total number of attempts required to correctly categorize a symbol in a semantic category. The response time was calculated as the time measured from the period of onset of presentation of the stimulus (in terms of stimulus card or spoken stimulus) to the time that the participant correctly categorized the target symbol. The percentage of accurately categorized symbols, efficiency in terms of percentage of correctly categorized symbols, and response time of the symbols correctly categorized was averaged for all the stimuli from both tasks and the data was analyzed to meet the study objective 2. (i) and 2. (ii). The averaged data from each task of categorization was analyzed to meet the sub-objectives 2.a.(i), 2.a.(ii), 2.b(i) and 2.b.(ii) of the study.

Symbol Sequencing Tasks. For the symbol sequence imitation task (task 6), accuracy was calculated as the total number of correctly imitated sequences; efficiency was the total number of attempts required to imitate the symbol sequences correctly and response time was the time measured as the period of onset of presentation of a stimulus to the time that the participant correctly imitated the symbol sequence. The accuracy, efficiency, and response time for all correctly produced targets in each grid size were calculated separately and later averaged to determine the performance of participant groups and subgroups on symbol sequence imitation. For the symbol sequence production task (task 7), only the accuracy of responses was calculated and a 12-point scale was used (refer to Appendix C). The accuracy for each sentence constructed using the symbol was calculated separately and total accuracy in percentage was calculated using the equation mentioned earlier for all other tasks. The average accuracy in percentage obtained for both sequencing tasks combined was used to meet the study objectives 3. (i) and 3. (ii), and the averaged data from both tasks were analyzed separately to meet the sub-objectives 3.a.(i), 3.a.(ii), 3. b(i) and 3.b.(ii) of the study

Overall Performance. The performance from all behavioural tasks in terms of percentage of average accuracy (or symbol performance quotient) was used to meet the study objectives 4. (i) and 4. (ii).

Correlation between Symbolic Language Abilities, Verbal Language Abilities, and Non-Verbal & Verbal Cognitive Abilities. The symbol performance quotient derived from accuracy scores obtained from all seven behavioural tasks, aphasia quotient and cortical quotient derived from the test of aphasia in Malayalam was used to meet objectives 5 and 6 of the study. A summary of statistical analyses done to meet the objectives of the study are illustrated in Figure 3.9.

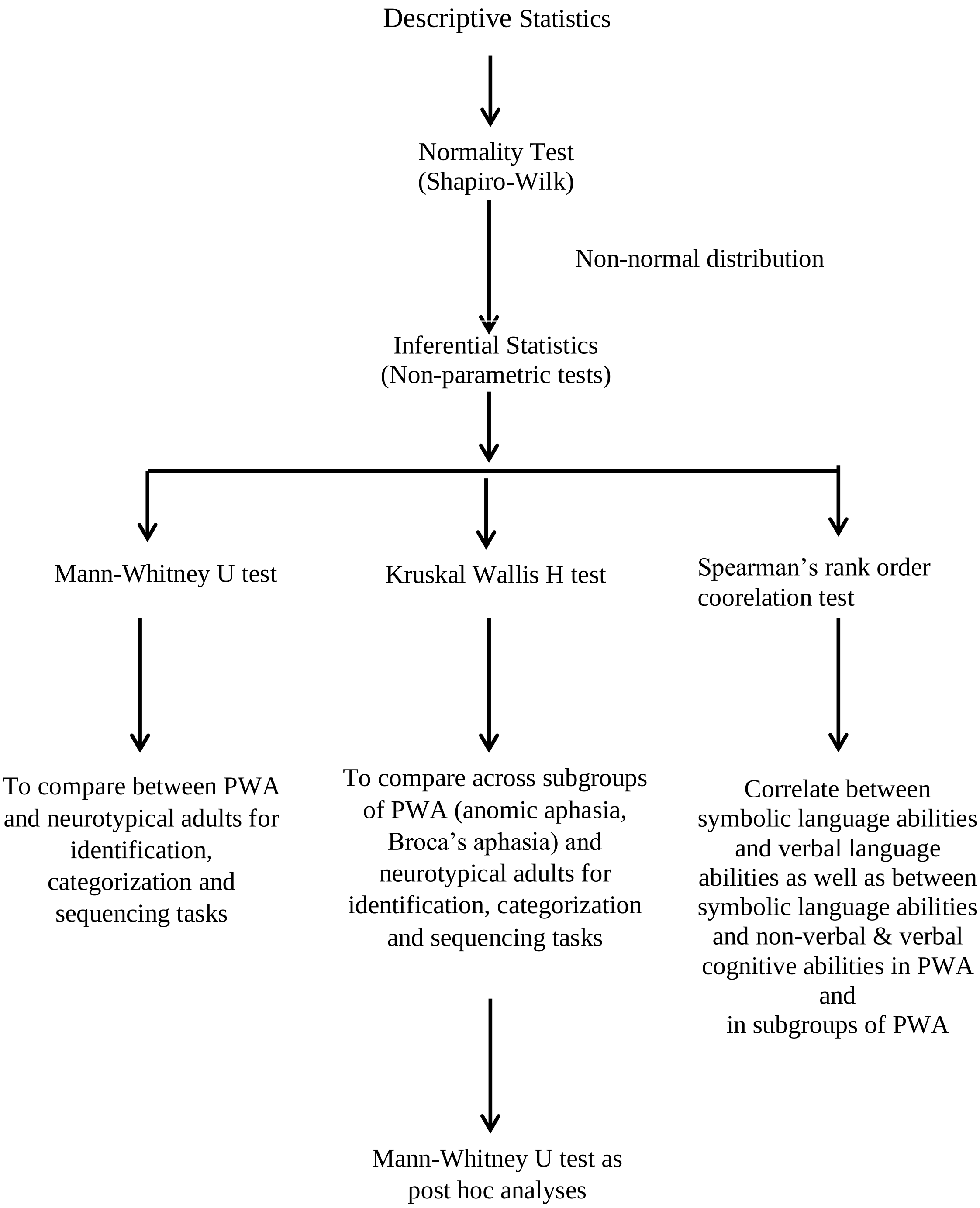

Figure 3.9. Flowchart of statistical analyses performed to meet objectives of the study

3.8.2 Additional Analyses

The data was further analysed over and above the objectives of the study to explore the available data to gain more insights on the performance of participants. Hence, this set of data analyses was labelled as additional analyses in the present study and is described below.

Symbol Identification Tasks. From the data obtained on each of the identification tasks, an additional analysis was done to determine the effect of (i) grid size, (ii) symbol organization and background colour coding, and (iii) grammatical category of referents on the identification of symbols in each participant group and subgroups. To investigate the effect of grid size on symbol identification, the average accuracy, efficiency and response time obtained from each of the four grid sizes (i.e., 4, 8, 12 and 16) in Identification task 1 was compared. The average accuracy, efficiency, and response time obtained from two symbol organization conditions in identification task 2 were compared to explore the effect of symbol organization and background colour coding on symbol identification. In task 3, the average accuracy, efficiency and response time obtained for identifying symbols in each grammatical category (i.e., nouns, verbs, adjectives and verbs) was compared to determine the effect of the grammatical category of referent on the identification of symbols.

A descriptive error response analyses was also performed in each subgroup of aphasia in terms of the percentage of error responses for different types of symbol identification errors.

Symbol Categorization Tasks. A comparison of performance between auditory and visual categorization was performed using the data obtained from each task of categorization in the participant groups and subgroups. An error response analyses was also performed descriptively in each subgroup of aphasia in terms of the percentage of auditory and visual categorization errors.

Symbol Sequencing Tasks. Additional linguistic analyses along semantic and syntactic measures were performed on the sentences produced using symbols in the symbol sequence production task. In the semantic domain, the correct information unit

(CIU) analyses (Nicholas & Brookshire, 1993) were used for measuring the quantity of information and efficiency with which information in the connected speech was adapted to be used for analyzing aided sentences produced by the participants. Thus, the semantic measures included the total number of symbols, the total number of correct information units for symbols, and the percentage of correct information units for symbols (CIU-S). The total number of symbols included any symbol chosen from the communication board despite it being relevant to the stimulus shown. The total number of CIU-S included those symbols that were relevant to the target picture even though incorrectly sequenced. The percentage CIU-S (% CIU-S) was obtained by dividing the total CIU-S by the total number of symbols multiplied by 100. Each of these measures was averaged for all 13 stimuli and taken up for final analyses.

The syntactic measures included (a) percentage of complete sentences (Marini et al., 2011), and (b) the percentage of the correct number of verbs (Weinrich et al., 1997). A percentage of complete sentences were calculated by dividing the number of grammatically correct sentences (i.e., a sentence with all required syntactic information in the S-O-V word order of Malayalam) with the number of utterances and then multiplying by 100. The correct number of verbs for each stimulus was calculated even if the production was syntactically incorrect and despite containing an incorrect subject or object (Weinrich et al., 1997). The percentage of the correct number of verbs was calculated by dividing the total number of correct verbs by the expected number of verbs, multiplied by 100.

Error responses for sequencing tasks were analyzed descriptively in each subgroup of aphasia in terms of percentage of symbol selection errors and symbol sequencing errors.

A flowchart of the statistical tests performed for additional analyses of the data is provided in Figure 3.10.

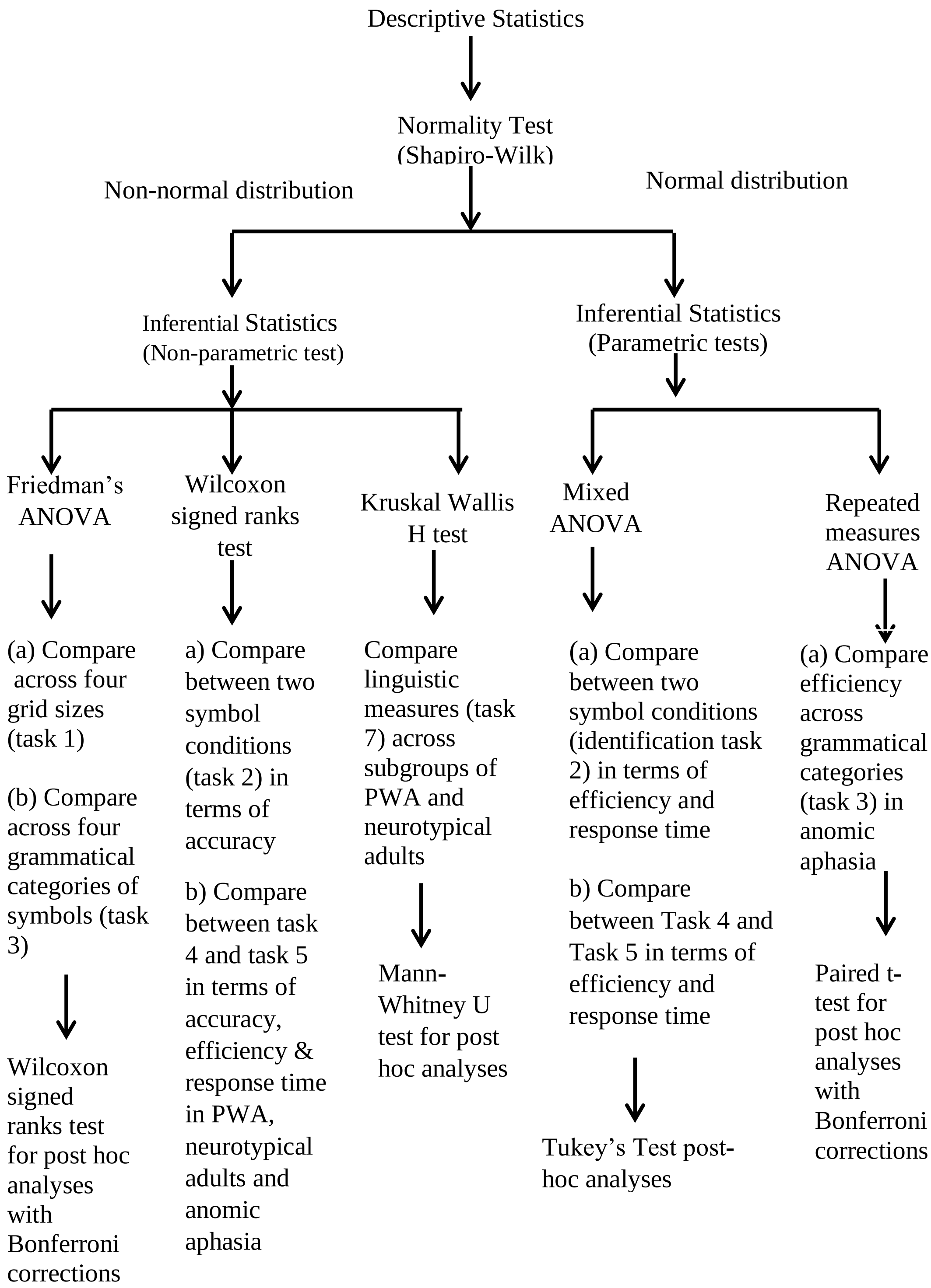

Figure 3.10. Flowchart summarizing statistical tests performed as additional analyses

3.9 Reliability of dependent variables

The inter-rater reliability of dependent variables (accuracy, efficiency and response time) were measured by analyzing the video-recorded samples of eight randomly selected participants (i.e., 20% of the participants) by a clinically practising speech-language pathologist familiar with the terms used in the study.

The rater was explained all the operational definitions laid for this study and was given the training to use the video-editing software before the data analysis was initiated. The rater independently analyzed the video recorded samples to obtain accuracy, efficiency, and response time for each behavioural task for all eight participants. The data provided by the rater was compared with the data entered by the primary researcher using Cronbach's alpha (α) to estimate the internal consistency of the outcome measures used in the study.

The results of inter-rater reliability are provided in Table 3.4. The Cronbach's correlation coefficient (α) value of greater than 0.9 is considered as excellent inter-rater reliability, a value between 0.9 and 0.7 is considered good, between 0.6 and 0.7 is considered acceptable, between 0.6 and 0.5 is poor and any value less 0.5 is considered unacceptable (Kline, 1999). From the table, it is evident that all the outcome measures had excellent inter-rater reliability. Whenever the inter-rater values were constant, Cronbach's alpha couldn't be determined; however, a 100% agreement was seen between both the raters.

Table 3.4

Results of Inter-Judge Reliability of the Dependent Variables Measured for Each Task Analyzed Using Cronbach's Alpha (α)

Tasks	Subtasks	Dependent Variables	Cronbach's alpha
Identification	Task 1	Accuracy	*
		Response Time	.979
		Efficiency	*
	Task 2	Accuracy	1.000
		Response Time	.991
		Efficiency	1.000
	Task 3	Accuracy	1.000
		Response Time	.979
		Efficiency	.997
	Overall	Accuracy	1.000
		Response Time	.999
		Efficiency	.999
Categorization	Task 4	Accuracy	*
		Response Time	.998
		Efficiency	.994
	Task 5	Accuracy	1.000
		Response Time	.998
		Efficiency	.995
	Overall	Accuracy	1.000
		Response Time	.999
		Efficiency	.998
Sequencing	Task 6	Accuracy	*
		Response Time	.983
		Efficiency	.969
	Task 7	Accuracy	1.000
	Overall	Accuracy	1.000
Total performance on all seven tasks		Accuracy	1.000

Note. * means that the inter-rater values were a constant and hence reliability co-efficient could not be determined; however 100% agreement was seen between both the raters.

CHAPTER IV

RESULTS

The present study aimed to investigate the symbolic language abilities for aided communication in PWA. The symbolic language abilities explored in this study included the ability to identify, categorize, and sequence AAC symbols. These abilities were tapped by measuring the accuracy (%), efficiency (%), and response time (sec) taken (dependent variables) to perform tasks involving identification, categorization, and sequencing of symbols. In the present study, a total of seven experimental tasks were designed which included three tasks involving identification, two tasks involving categorization, and two tasks involving sequencing of AAC symbols. The performance of PWA was compared with age, gender, and education-matched neurotypical adults. Furthermore, the relationship between symbolic language abilities and verbal language abilities as well as between symbolic language abilities and non-verbal & verbal cognitive abilities in PWA were also analyzed. The verbal language abilities and non-verbal & verbal cognitive abilities were measured using aphasia quotient scores and cortical quotient scores respectively which obtained from the test of aphasia in Malayalam (Jenny, 1992).

The data obtained from 20 PWA and 20 neurotypical adults who participated in the study were taken for analysis. Among 20 PWA, 10 participants had anomic aphasia and 10 participants had Broca's aphasia (which formed the subgroups of aphasia). Those participants in both groups who were found as outliers were not excluded from the final data analysis as the findings did not substantially change with and without the outliers. Analyses of performance were done to meet the study objectives and sub-objectives which were as follows:

1. To compare the symbol identification abilities in terms of accuracy, efficiency, and response time obtained on all three identification tasks combined (task 1, task 2 and task 3)

    (i) between PWA and neurotypical adults

    (ii) across subgroups of PWA and neurotypical adults

2. To compare the symbol categorization abilities in terms of accuracy, efficiency and response time obtained on both categorization tasks combined (auditory categorization or task 4 and visual categorization or task 5)

    (i) between PWA and neurotypical adults

    (ii) across subgroups of PWA and neurotypical adults

    2. a) To compare the symbol categorization abilities in terms of accuracy, efficiency, and response time obtained on auditory categorization task (task 4)

    (i) between PWA and neurotypical adults

    (ii) across subgroups of PWA and neurotypical adults

    2. b) To compare the symbol categorization abilities in terms of accuracy, efficiency, and response time obtained on visual categorization task (task 5)

    (i) between PWA and neurotypical adults

    (ii) across subgroups of PWA and neurotypical adults

3. To compare the symbol sequencing abilities in terms of accuracy of response obtained on both sequencing tasks combined (task 6 and task 7)

    (i) between PWA and neurotypical adults

    (ii) across subgroups of PWA and neurotypical adults

3. a) To compare the symbol sequencing abilities in terms of accuracy, efficiency, and response time obtained on symbol sequence imitation task (task 6)

(i) between PWA and neurotypical adults

(ii) across subgroups of PWA and neurotypical adults

3. b) To compare the symbol sequencing abilities in terms of accuracy of response obtained from symbol sequence production Task (Task 7)

(i) between PWA and neurotypical adults

(ii) across subgroups of PWA and neurotypical adults

4. To compare symbolic language abilities in terms of accuracy of response obtained on all tasks of identification, categorization and sequencing combined

   (i) between PWA and neurotypical adults

   (ii) across subgroups of PWA and neurotypical adults

5. Determine the relationship between the symbolic language abilities and verbal language abilities in PWA and subgroups of PWA.
6. Determine the relationship between symbolic language abilities and nonverbal & verbal cognitive abilities in PWA and subgroups of PWA.

The statistical analyses done in the present study includes main analyses done to meet the objectives of the study and additional analyses on the obtained data to gain more insight into the performance of the participants. In the main analyses, the statistical tests employed on the dependent variables derived from the tasks (i.e., accuracy, efficiency, and response time) are provided in Table 4.1.

Table 4.1

List of statistical tests employed to meet the objectives in the present study

Statistical Test	Comparison/ Correlation
Objective 1.(i)	
Descriptive Statistics	Mean, SD, Median and inter-quartile range of the average accuracy (%), efficiency (%), and response time (sec) obtained from all three identification tasks in PWA (i.e., combined group of anomic aphasia and Broca's aphasia) and neurotypical adults
Mann-Whitney U test*	To compare the performance between PWA and neurotypical adults on all three identification tasks combined
Objective 1.(ii)	
Descriptive Statistics	Mean, SD, Median and inter-quartile range of the average accuracy (%), efficiency (%), and response time (sec) obtained from all three identification tasks in each subgroup of PWA (i.e., anomic aphasia and Broca's aphasia) and neurotypical adults
Kruskal-Wallis H test	To compare the performance across subgroups of PWA and neurotypical adults on all three identification tasks combined
Mann-Whitney U test*	To determine the pairwise comparison of performance between participant groups
Objective 2.(i)	
Descriptive Statistics	Mean, SD, Median and inter-quartile range of the average accuracy (%), efficiency (%), and response time (sec) obtained from both categorization tasks in PWA (i.e., combined group of anomic aphasia and Broca's aphasia) and neurotypical adults
Mann-Whitney U test*	To compare the performance between PWA and neurotypical adults on both categorization tasks combined

Statistical Test	Comparison/ Correlation
Objective 2.(ii)	
Descriptive Statistics	Mean, SD, Median and inter-quartile range of the average accuracy (%), efficiency (%), and response time (sec) obtained from both categorization tasks in each subgroup of PWA (i.e., anomic aphasia and Broca's aphasia) and neurotypical adults
Kruskal-Wallis H test	To compare the performance across subgroups of PWA and neurotypical adults on from both categorization tasks
Mann-Whitney U test*	To determine the pairwise comparison of performance between participant groups
Objective 2.a.(i)	
Descriptive Statistics	Mean, SD, Median and inter-quartile range of the average accuracy (%), efficiency (%), and response time (sec) obtained from auditory categorization tasks in PWA (i.e., combined group of anomic aphasia and Broca's aphasia) and neurotypical adults
Mann-Whitney U test*	To compare the performance between PWA and neurotypical adults on the auditory categorization task
Objective 2.a.(ii)	
Descriptive Statistics	Mean, SD, Median and inter-quartile range of the average accuracy (%), efficiency (%), and response time (sec) obtained from auditory categorization task in each subgroup of PWA (i.e., anomic aphasia and Broca's aphasia) and neurotypical adults
Kruskal-Wallis H test	To compare the performance across subgroups of PWA and neurotypical adults on from auditory categorization task
Mann-Whitney U test*	To determine the pairwise comparison of performance between participant groups

Statistical Test	Comparison/ Correlation
Objective 2.b.(i)	
Descriptive Statistics	Mean, SD, Median and inter-quartile range of the average accuracy (%), efficiency (%), and response time (sec) obtained from visual categorization tasks in PWA (i.e., combined group of anomic aphasia and Broca's aphasia) and neurotypical adults
Mann-Whitney U test*	To compare the performance between PWA and neurotypical adults on the visual categorization task
Objective 2.b.(ii)	
Descriptive Statistics	Mean, SD, Median and inter-quartile range of the average accuracy (%), efficiency (%), and response time (sec) obtained from visual categorization task in each subgroup of PWA (i.e., anomic aphasia and Broca's aphasia) and neurotypical adults
Kruskal-Wallis H test	To compare the performance across subgroups of PWA and neurotypical adults on from visual categorization task
Mann-Whitney U test*	To determine the pairwise comparison of performance between participant groups
Objective 3.(i)	
Descriptive Statistics	Mean, SD, Median and inter-quartile range of the average accuracy (%) obtained from both sequencing tasks in PWA (i.e., combined group of anomic aphasia and Broca's aphasia) and neurotypical adults
Mann-Whitney U test*	To compare the performance between PWA and neurotypical adults on both sequencing tasks combined

Statistical Test	Comparison/ Correlation
Objective 3.(ii)	
Descriptive Statistics	Mean, SD, Median and inter-quartile range of the average accuracy (%) obtained from both sequencing tasks in each subgroup of PWA (i.e., anomic aphasia and Broca's aphasia) and neurotypical adults
Kruskal-Wallis H test	To compare the performance across subgroups of PWA and neurotypical adults on from both sequencing tasks combined
Mann-Whitney U test*	To determine the pairwise comparison of performance between participant groups
Objective 3.a(i)	
Descriptive Statistics	Mean, SD, Median and inter-quartile range of the average accuracy (%), efficiency (%), and response time (sec) obtained from symbol sequence imitation task in PWA (i.e., combined group of anomic aphasia and Broca's aphasia) and neurotypical adults
Mann-Whitney U test*	To compare the performance between PWA and neurotypical adults on symbol sequence imitation task
Objective 3.a(ii)	
Descriptive Statistics	Mean, SD, Median and inter-quartile range of the average accuracy (%), efficiency (%), and response time (sec) obtained from symbol sequence imitation task in each subgroup of PWA (i.e., anomic aphasia and Broca's aphasia) and neurotypical adults
Kruskal-Wallis H test	To compare the performance across subgroups of PWA and neurotypical adults on from symbol sequence imitation task
Mann-Whitney U test*	To determine the pairwise comparison of performance between participant groups

Statistical Test	Comparison/ Correlation
Objective 3.b(i)	
Descriptive Statistics	Mean, SD, Median and inter-quartile range of the average accuracy (%) obtained from symbol sequence production task in PWA (i.e., combined group of anomic aphasia and Broca's aphasia) and neurotypical adults
Mann-Whitney U test*	To compare the performance between PWA and neurotypical adults on symbol sequence production task
Objective 3.b(ii)	
Descriptive Statistics	Mean, SD, Median and inter-quartile range of the average accuracy (%) obtained from symbol sequence production task in each subgroup of PWA (i.e., anomic aphasia and Broca's aphasia) and neurotypical adults
Kruskal-Wallis H test	To compare the performance across subgroups of PWA and neurotypical adults on symbol sequence production task
Mann-Whitney U test*	To determine the pairwise comparison of performance between participant groups
Objective 4.(i)	
Descriptive Statistics	Mean, SD, Median and inter-quartile range of the average accuracy (%) obtained from all seven behavioural tasks combined (symbol performance quotient) in PWA (i.e., combined group of anomic aphasia and Broca's aphasia) and neurotypical adults
Mann-Whitney U test*	To compare the performance between PWA and neurotypical adults on all seven behavioural tasks combined
Objective 4.(i)	
Descriptive Statistics	Mean, SD, Median and inter-quartile range of the average accuracy (%) obtained from all

Statistical Test	Comparison/ Correlation
	seven behavioural tasks combined (symbol performance quotient) in each subgroup of PWA (i.e., anomic aphasia and Broca's aphasia) and neurotypical adults
Kruskal-Wallis H test	To compare the performance across subgroups of PWA and neurotypical adults on all seven behavioural tasks combined
Mann-Whitney U test*	To determine the pairwise comparison of performance between participant groups
Objective 5	
Spearman's rank-order correlation test**	To determine the correlation between symbol performance quotient and aphasia quotient score in PWA
Objective 6	
Spearman's rank-order correlation test**	To determine the correlation between symbol performance quotient and cortical quotient score in PWA

Note. PWA= Persons with aphasia (i.e., combined group of persons with anomic aphasia and Broca's aphasia)

* The effect sizes for the Mann-Whitney U test were computed using the formula, $r_e = |z| / \sqrt{N}$ (Rosenthal, 1991); where N is the total number of participants in the study. An effect size of 0.3 was considered as low, a r_e-value of 0.3 to 0.5 was considered as medium effect size and any value greater than 0.5 was considered as high effect size (Field, 2009).

**The Spearman coefficient (ρ) of greater than .70 is indicative of a very strong relationship, ρ-value between 0.69 and 0.40 is indicative of a strong relationship, a ρ-value value between 0.39 and 0.30 is indicative of a moderate relationship, a ρ-value value between 0.29 and 0.20 is indicative of weak relationship and a ρ-value value between 0.19 and 0.01 is indicative of no or negligible relationship (Dancey & Reidey, 2004).

The statistical tests employed for additional analyses are provided in Table 4.2.

Table 4.2

List of statistical tests employed for additional analyses in the present study

Statistical Test	Comparison
	Analysis 1
Descriptive Statistics	Mean, SD, Median and inter-quartile range of the average accuracy (%), efficiency (%), and response time (sec) obtained from each of the four grid sizes in PWA, subgroups of PWA (i.e., anomic aphasia and Broca's aphasia) and neurotypical adults
Friedman's ANOVA	To determine the effect of grid size on symbol identification in participant groups and subgroups by comparing average accuracy (%), efficiency (%), and response time (sec) obtained across four grid sizes in identification task 1
Wilcoxon signed ranks test with Bonferroni correction for post hoc analyses	Pairwise comparison of performance between grid sizes in each participant group and subgroups
	Analysis 2
Descriptive Statistics	Mean, SD, Median and inter-quartile range of the average accuracy (%), efficiency (%), and response time (sec) obtained from two symbol conditions in PWA, subgroups of PWA (i.e., anomic aphasia and Broca's aphasia) and neurotypical adults
Wilcoxon signed ranks test	To determine the effect of symbol organization and background colour cueing on symbol identification in participant groups and subgroups in terms of accuracy by comparing the average accuracy (%) obtained between two symbol conditions in identification task 2
Mixed ANOVA test *	To determine the effect of symbol organization and background colour cueing on symbol identification in participant groups and subgroups in terms of efficiency and response time by comparing average efficiency (%), and response time (sec) obtained between two symbol conditions in identification task 2

Statistical Test	Comparison
Tukey's test as post hoc analysis of Mixed ANOVA	To determine individual means those are significantly different from a set of means.
Analysis 3	
Descriptive Statistics	Mean, SD, Median and inter-quartile range of the average accuracy (%), efficiency (%), and response time (sec) obtained from each of the four grammatical categories in PWA, subgroups of PWA (i.e., anomic aphasia and Broca's aphasia) and neurotypical adults
Friedman's ANOVA test	To determine the effect of the grammatical category of referents on symbol identification in participant groups and Broca's aphasia subgroup in terms of accuracy by comparing average accuracy (%) obtained across four grammatical categories in identification task 3
Wilcoxon signed ranks test with Bonferroni correction for post hoc analyses	Pairwise comparison of performance between grammatical categories in each participant group and Broca's aphasia subgroup
Repeated measures ANOVA test	To determine the effect of the grammatical category of referents on symbol identification in anomic aphasia subgroup in terms of efficiency and response time by comparing average efficiency (%), and response time (sec) obtained across four grammatical categories in identification task 3
Paired t-test with Bonferroni corrections as post hoc analyses of repeated measures ANOVA test	Pairwise comparison of performance between grammatical categories in anomic aphasia subgroup
Analysis 4	
Descriptive Statistics	Mean, SD, Median and inter-quartile range of the average accuracy (%), efficiency (%), and response time (sec) obtained from both tasks of categorization task in PWA, subgroups of PWA (i.e., anomic aphasia and Broca's aphasia) and neurotypical adults.
Wilcoxon signed ranks test	To determine the effect of presentation modality on symbol categorization in terms of accuracy, efficiency and response time in PWA and neurotypical adults by comparing average

Statistical Test	Comparison
	accuracy (%), efficiency (%), and response time (sec) obtained from auditory categorization and visual categorization tasks
Wilcoxon signed ranks test	To determine the effect of presentation modality on symbol categorization in terms of accuracy in subgroups of aphasia by comparing average accuracy (%) obtained from auditory categorization and visual categorization tasks
Mixed ANOVA test*	To determine the effect of presentation modality on symbol categorization in terms of efficiency and response time by comparing average efficiency (%) and response time (%) obtained in both subgroups of aphasia from auditory and visual categorization tasks.
Tukey's test as post hoc analysis of Mixed ANOVA	To determine individual means those are significantly different from a set of means.
Analysis 5	
Kruskal-Wallis H test	Compare linguistic (semantic and syntactic) measures obtained from symbol sequence production task within subgroups of aphasia and neurotypical adults
Wilcoxon signed ranks test with Bonferroni correction for post hoc analyses	Pairwise comparison of performance in semantic measures and syntactic measures between subgroups of aphasia and neurotypical adults
Analysis 6	
Descriptive Statistics	Determine the percentage of symbol identification errors, symbol categorization errors and symbol sequencing errors in subgroups of aphasia

Note. PWA= Persons with aphasia (i.e., combined group of persons with anomic aphasia and Broca's aphasia).

* The effect size for mixed ANOVA was calculated using partial eta square (η^2). A η^2 value between 0.01 and <0.06 was considered as a small effect size, while a η^2 value of >0.06 and <0.14 was considered as medium effect size and a η^2 value of >0.14 is considered as large effect size (Cohen, 2013).

A summary of all the analyses performed in the current study is provided in Figure 4.1.

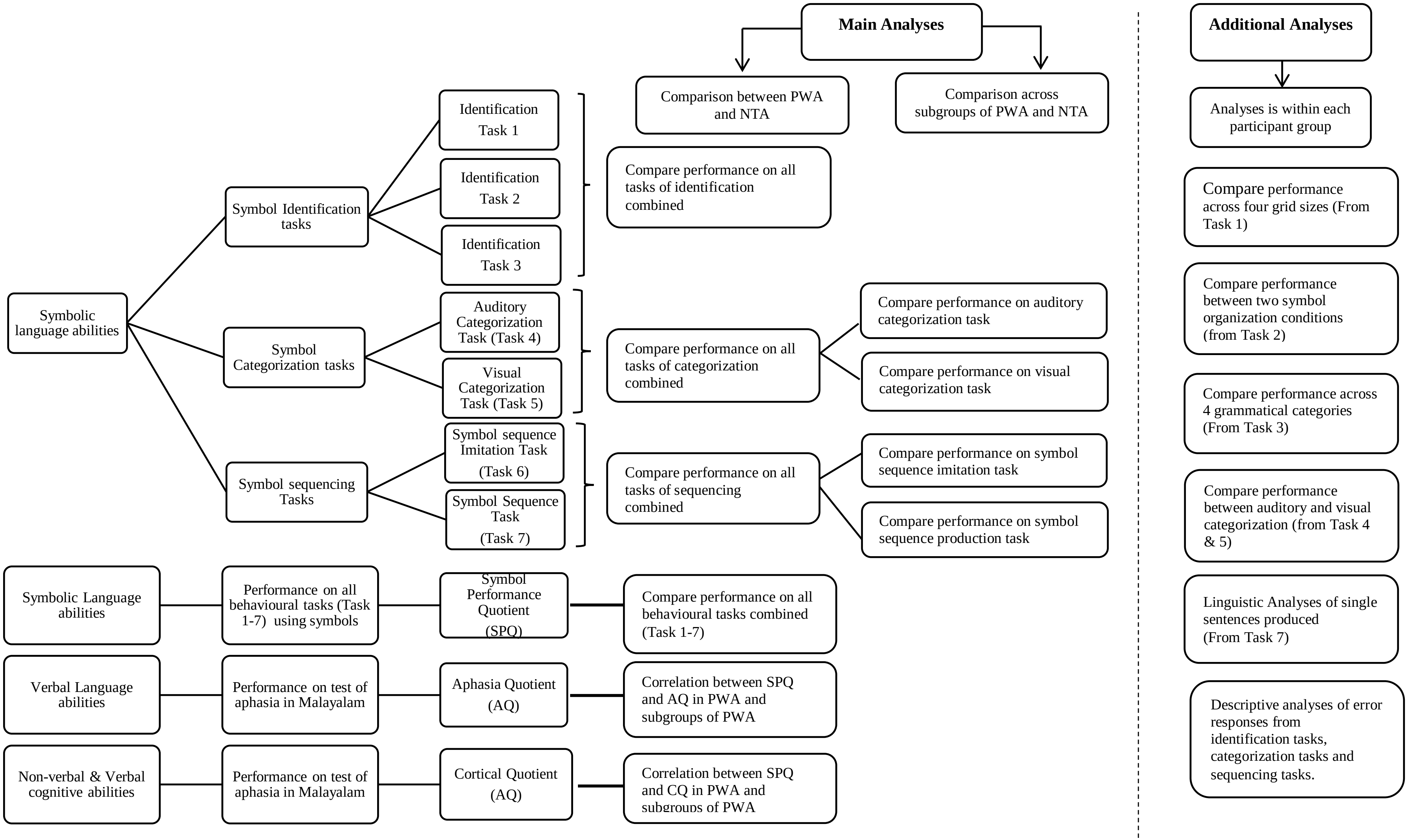

Figure 4.1. Summary of analyses of data in the current study

The findings of the present study based on the above statistical analyses are reported in detail in this chapter under the following headings:

4.1 Symbolic Language abilities for aided communication

4.1.1 Performance on Symbol Identification Tasks

4.1.1a Additional Analyses

4.1.1a (i) Effect of grid size on identification of symbols

4.1.1a (ii) Effect of symbol arrangement and background colour coding on identification of symbols

4.1.2a (iii) Effect of grammatical category of referent on identification of symbols

4.1.2a (iv) Error response analyses in Identification tasks

4.1.2 Performance on Symbol Categorization Tasks

4.1.2a Performance on auditory categorization Task (task 4)

4.1.2b Performance on visual categorization task (task 5)

4.1.2c Additional Analyses

4.1.2c (i) Performance between Auditory and Visual Categorization Task

4.1.2c (ii) Error Response Analyses in Categorization Tasks

4.1.3 Performance on Symbol Sequencing Tasks

4.1.3a Performance on Symbol Sequence Imitation Task (task6)

4.1.3b Performance on Symbol Sequence Production Task (task 7)

4.1.3c Additional Analyses

4.1.3c (i) Linguistic Analyses of Single sentence production using symbols

4.1.3c (ii) Error Response Analyses in Sequencing Tasks

4.1.4 Overall Performance on all Behavioural Tasks

4.2 Correlation between Symbolic Language Abilities and Verbal Language Abilities

4.3 Correlation between Symbolic Language Abilities and Non-verbal & Verbal Cognitive Abilities

4.1 Symbolic Language Abilities for Aided Communication

This section addresses the results of objective 1, objective 2, objective 3, and objective 4 and their sub-objectives which were to investigate the symbolic language abilities for aided communication using behavioural tasks involving PCS symbols.

4.1.1 Performance on Symbol Identification Tasks

The ability to identify symbols was determined from the average accuracy (%), average efficiency (%), and average response time (sec) taken by each participant group for all three identification tasks combined. The results of the performance on all three identification tasks combined between PWA and neurotypical adults [objective 1(i)], as well as across subgroups of PWA and neurotypical adults [objective 1. (ii)], are described below. This section also addresses additional analyses done on data obtained from identification task 1, task 2, and task 3 of the present study.

Performance between PWA and Neurotypical Adults. The results of descriptive statistics on the performance of PWA and neurotypical adults are provided in Table 4.3. A Mann-Whitney U test was used to compare the performance between

PWA (n=20) and neurotypical adults (n=20) to meet the study's objective 1. (i). The results revealed that the two groups significantly differed (p <.05) in terms of accuracy, efficiency and response time (refer Table 4.3) with a large effect size. The PWA was significantly less accurate and efficient than neurotypical adults in their ability to identify symbols and took a significantly longer response time to perform the task.

Table 4.3

Mean, Standard deviation, Median and Inter-Quartile Range Values for Accuracy, Efficiency, and Response Time Taken by PWA and Neurotypical Adults for all Three Identification Tasks Combined Along with the Result of Mann-Whitney U Test Used to Compare the two Groups.

	Participant Groups	*n*	Mean	SD	Median	IQR	|z|	*p*	r_e
Accuracy	PWA	20	86.75	14.17	91.50	19.55	5.407	<.001	.85
	NTA	20	99.76	0.35	100.00	0.33			
Efficiency	PWA	20	73.44	19.53	78.48	28.49	5.383	<.001	.85
	NTA	20	97.96	1.57	96.71	2.06			
Response Time	PWA	20	6.12	2.90	5.74	4.23	5.275	<.001	.83
	NTA	20	1.89	0.60	1.90	1.01			

Note. PWA= Persons with Aphasia, NTA= Neurotypical adults, n= sample size, SD= Standard deviation, IQR= Interquartile range, |z|= standardized test statistic, p= significance value, r_e = effect size. PWA is a combined group of persons with anomic aphasia and Broca's aphasia.

Performance across Subgroups of PWA and Neurotypical Adults. Since the performance between PWA and neurotypical adults showed a significant difference, a further three-group analysis (wherein each of these subgroups was further compared with neurotypical adults individually) was performed. This was expected to shed more information on the performances when the participant groups were made more homogeneous. The results of the descriptive statistics are provided in Table 4.4.

Table 4.4

Mean, Standard Deviation, Median and Inter-Quartile Range Values for Accuracy, Efficiency and Response Time Taken by Anomic Aphasia, Broca's Aphasia and Neurotypical Adults for all Three Identification Tasks combined and Result of Kruskal Wallis H Test to Compare the three Groups.

Dependent Variables	Participant Groups	*n*	Mean	SD	Median	IQR	$\chi^2(2)$	*p*
Accuracy	Anomic Aphasia	10	94.93	5.12	96.63	6.73	31.492	<.001
	Broca's Aphasia	10	78.56	15.78	80.66	20.92		
	NTA	20	99.76	0.35	100.00	0.33		
Efficiency	Anomic Aphasia	10	85.37	10.02	88.58	15.43	31.266	<.001
	Broca's Aphasia	10	61.51	19.71	62.69	31.83		
	NTA	20	97.96	1.57	96.71	2.06		
Response Time	Anomic Aphasia	10	4.40	1.66	3.59	3.31	30.106	<.001
	Broca's Aphasia	10	7.83	2.92	7.48	5.26		
	NTA	20	1.89	0.60	1.90	1.01		

Note. NTA= Neurotypical adults, *n*= sample size, SD= Standard deviation, IQR= Interquartile range. PWA is a combined group of persons with anomic aphasia and Broca's aphasia.

Each dependent variable was compared across three groups (i.e., anomic aphasia, Broca's aphasia and neurotypical adults) using the Kruskal-Wallis H test to meet the sub-objective 1. (ii) of the study. The test revealed that the accuracy, efficiency and response time taken differed significantly across the groups, $p < .05$ (refer Table 4.4). Pairwise comparison of groups using the Mann-Whitney U test was performed to follow up on the above findings (refer Table 4.5). For accuracy, even though the performance of anomic aphasia was numerically superior to Broca's aphasia, the score between the groups did not differ significantly (p>.05). On the other hand, the scores obtained by neurotypical adults was significantly higher than both anomic aphasia and Broca's aphasia (p<.05). Similarly for efficiency, there was no significant difference between anomic aphasia and Broca's aphasia (p>.05); however, the difference was found to be significant between anomic aphasia and neurotypical adults (p<.05), and between Broca's aphasia and neurotypical adults (p<.05). For response time, a significant difference was found between anomic aphasia and Broca's aphasia (p<.05), between anomic aphasia and neurotypical adults (p<.05), and between Broca's aphasia and neurotypical adults (p<.05).

Table 4.5

Result of Mann-Whitney U test between groups for Identification Tasks

Dependent Variables	Pair wise comparison [Objective 1.(ii)]		
	BA Vs. AA	BA Vs. NTA	AA Vs.NTA
Accuracy	BA < AA	BA < NTA (*)	AA < NTA(*)
Efficiency	BA < AA	BA < NTA (*)	AA < NTA(*)
Response Time	BA < AA (*)	BA < NTA (*)	AA < NTA(*)

Note. NTA= Neurotypical adults, BA= Broca's aphasia, AA= Anomic aphasia.

* Difference was significant at p< .05 with high effect size (r_e =.51 to 0.96)

4.1.1a Additional Analyses. A between group analyses of the performance of participants (i.e., between PWA and neurotypical adults, and across subgroups of PWA and neurotypical adults) were performed separately for each identification task (i.e., task 1, task 2 and task 3). The findings of this analysis were similar to the above stated findings (i.e., PWA performed poorer than neurotypical adults in terms of accuracy, efficiency, and response time taken to identify symbols in task 1, task 2 and task 3. Similarly, among subgroups of aphasia, Broca's aphasia performed poorer than anomic aphasia and neurotypical adults, and anomic aphasia performed poorer than neurotypical adults in terms of accuracy, efficiency and response time obtained from identification task 1, task 2 and task 3). The results of comparison of performance between participants in each task of identification are not individually illustrated in this section to avoid redundancy and as it was not an objective of the study. However, the data was additionally analysed to obtain certain additional information from a research point of view which is provided below.

The data obtained individually from identification task 1, task 2, and task 3 was used to study the effect of (i) grid size, (ii) symbol organization and background colour coding, and (iii) grammatical category of referents on symbol identification within each of the participant group and sub-groups. The error responses obtained from the participants while performing on identification tasks were also analyzed. The results of all the additional analyses of data obtained from symbol identification tasks are reported below:

4.1.1a(i). Effect of Grid Size on Identification of Symbols. From descriptive statistics provided in Table 4.6, it is evident that the average accuracy of single symbol identification declined as the grid size increased from 4 to 16 in PWA. In PWA, Broca's aphasia showed a similar pattern; however, no such decline in accuracy could be observed in anomic aphasia or neurotypical adults. While efficiency also declined with an increase in grid size in PWA and both its subgroups; neurotypical adults did not show a decrease in efficiency. On the other hand, the response time taken to identify symbols increased with an increase in grid size in PWA, its subgroups and neurotypical adults.

The design of the task allowed exploring the effect of grid size in each participant group and subgroups using Friedman's ANOVA test. In PWA, results revealed a significant difference in the accuracy scores, χ^2 (3) = 11.562, p <.05, and efficiency scores, χ^2 (3) = 16.676, p <.001 obtained across grid sizes. Response time across the grid sizes did not show any significant difference. A pairwise comparison using Wilcoxon signed ranks test revealed that the accuracy scores significantly differed (p <.05) between grid 4 and grid 16, between 4 and 12, and between 8 and 12 after applying Bonferroni correction, with medium effect size (r_e =0.30-0.50). On the other hand, after applying Bonferroni correction to pairwise comparisons using Wilcoxon signed ranks test on the efficiency scores, a significant difference was found only between grid 4 and 12 (p<.05) and the difference was significant with low effect size (r_e < 0.30).

Considering subgroups of PWA, the accuracy scores across the four grid sizes were found to be significantly different only for Broca's aphasia, χ^2 (3) = 11.563, p <.05. Further testing using Wilcoxon signed-rank test after Bonferroni correction showed a significant difference of accuracy scores between grid size 4 and 12, grid size 4 and 16, and grid size 8 and 12 (p<.05) with high effect size (r_e. = 0.64-0.65). The efficiency scores across the four grid sizes were also found to be significantly different only for Broca's aphasia, χ^2 (3) = 12.181, p<.05. Wilcoxon signed-rank test, after applying Bonferroni correction, showed a significant difference of efficiency scores between grid size 4 and 12, grid size 4 and 16, and grid size 8 and 12 (p < .05) with high effect size (r_e. = 0.74-0.77). The response times to accurately identify symbols across four grid sizes were found to be significant neither in anomic aphasia nor in Broca's aphasia (p > .05).

Table 4.6

The Mean and Standard Deviation of Accuracy, Efficiency, and Response Time Measured for Identification Task 1 for Each Participant Group

Variable	Grid size	Anomic Aphasia (*n*=10)				Broca's Aphasia (*n*=10)				Persons with Aphasia (*n*=20)				Neurotypical Adults (*n*=20)			
		Mean	SD	Median	IQR	Mean	SD	Median	IQR	Mean	SD	Median	IQR	Mean	SD	Median	IQR
Accuracy	G4	100.00	0.00	100.00	0.00	100.00	0.00	100.00	0.00	100.0	0.00	100.0	0.00	100.00	0.00	100.00	0.00
	G8	100.00	0.00	100.0	0.00	97.50	7.91	100.0	0.00	98.75	5.59	100.0	0.00	100.00	0.00	100.00	0.00
	G12	100.00	0.00	100.0	0.00	80.00	22.97	87.50	50.0	90.00	18.48	100.0	19.0	100.00	0.00	100.00	0.00
	G16	100.00	0.00	100.0	0.00	78.50	27.49	90.00	50.0	89.00	22.04	100.00	15.0	100.00	0.00	100.00	0.00
Efficiency	G4	100.00	0.00	100.00	0.00	90.63	12.58	96.87	18.75	95.32	9.91	100.0	4.69	100.00	0.00	100.0	0.00
	G8	99.37	1.97	100.0	0.00	84.37	14.80	84.37	25.56	91.88	12.84	100.0	17.19	100.00	0.00	100.0	0.00
	G12	96.87	7.93	100.0	1.56	65.00	27.35	71.87	42.19	80.94	25.53	93.75	29.69	100.00	0.00	100.00	0.00
	G16	96.87	6.75	100.0	3.13	65.00	27.35	71.87	46.88	83.12	23.57	96.87	32.81	100.00	0.00	100.00	0.00
Response Time	G4	1.42	0.57	1.45	0.68	4.27	3.19	2.98	5.81	2.84	2.67	1.65	1.81	0.88	0.67	0.77	0.42
	G8	1.45	0.77	1.44	1.06	4.39	2.32	4.28	3.31	3.86	3.61	2.25	5.39	0.54	0.16	0.54	0.21
	G12	1.99	1.85	1.27	2.29	6.26	3.74	6.32	7.67	5.71	7.88	2.92	4.70	0.67	0.28	0.56	0.45
	G16	2.75	3.77	1.38	1.87	9.41	9.85	3.84	13.13	3.57	3.16	2.41	4.30	0.98	0.45	0.99	0.73

Note. G4= Grid size 4, G8= Grid size 8, G12= Grid size 12, G16= Grid size 16, SD= Standard deviation, IQR= Interquartile range, *n*= sample size. PWA is combined group of persons with anomic aphasia and Broca's aphasia

In neurotypical adults, there was no difference in the accuracy or efficiency scores across the grid sizes; however, the response time showed a significant difference across grid sizes on Friedman's ANOVA test, χ^2 (3) = 17.593, p <.001. A follow-up analysis using Wilcoxon signed ranks test for pairwise comparisons showed a significant difference in response time to identify symbols only between grid 4 and 8 and between grid 8 and 16 (p<.05). The difference was significant with high effect size (r_e > 0.50). A summary of the results are provided in Table 4.7.

Table 4.7

Summary of Performance across Grid Sizes in PWA, Subgroups of PWA and Neurotypical Adults

Dependent Variables	Performance across grid sizes			
	Persons with Aphasia	Broca's Aphasia	Anomic Aphasia	Neurotypical Adults
Accuracy	declined with an increase in grid size G4>G8>G12>G16*	declined with an increase in grid size G4>G8>G12>G16*	remained the same across grid sizes	remained the same across grid sizes
Efficiency	declined with an increase in grid size G4>G8>G12>G16*	declined with an increase in grid size G4>G8>G12>G16*	declined with an increase in grid size G4>G8>G12>G16	remained the same across grid sizes
Response Time	increased with an increase in grid size G4< G8<G16<G12	increased with an increase in grid size G4<G8<G16<G12	increased with an increase in grid size G4<G8<G16<G12	increased with an increase in grid size G4<G8<G16< G12*

Note. G4= Grid size 4, G8= Grid size 8, G12=Grid size 12, G16= Grid size 16.

Persons with aphasia is a combined group of anomic aphasia and Broca's aphasia

*Difference was significant at p<.05 with medium to high effect size (r_e= 0.45- 0.77)

4.1.1a(ii) Effect of symbol organization and background colour coding on the identification of symbols. Identification task 2 required the participants to identify PCS symbols in two symbol organization and background colour cue conditions. The first condition (C1) had the symbols arranged in a taxonomic grid display with each semantic colour category in a different colour, while the second condition (C2) had symbols randomly placed in a grid without any categorization or colour coding. Thus, design of the task allowed determining the effect of symbol organization and background colour coding on symbol identification in each participant group and subgroup. The descriptive statistical analyses performed on average accuracy, efficiency, and response time taken to identify symbols in each condition from all grid sizes combined are provided in Table 4.8. The accuracy and efficiency measured in the two symbol conditions (i.e., C1 and C2) were compared in each participant group and subgroups of PWA using the Wilcoxon-signed rank test. On the Wilcoxon-signed ranks test, the average accuracy, and efficiency between the two symbol conditions in PWA did not show any significant difference (p >.05). Neither anomic aphasia nor Broca's aphasia showed a significant difference in the accuracy or efficiency in identifying symbols between the two symbol conditions (p >.05). Neurotypical adults showed a significant difference with high effect size between the two conditions only in terms of efficiency, $|z| = 2.558$, $p<.05$, $r_e= 0.57$.

A mixed ANOVA was done to study the main and interaction effect of the two symbol conditions (i.e., C1 and C2) and two participant groups (PWA and neurotypical adults) in terms of response time. The difference in response time between C1 and C2 as within-subject groups was statistically significant with medium to high effect size, F (1, 38) = 6.455, p <.05, η^2= 0.145. Thus, the main effect for symbol condition was significant for response time. The response time taken between participant groups, irrespective of symbol conditions, were also found to be significantly different with a high effect size, F (1, 38) = 33.723, p <.001, η^2 =0.470. There was no interaction effect between symbol condition and participant group.

Table 4.8

The Mean, Standard Deviation, Median, and Inter-quartile range of Accuracy, Efficiency, and Response Time Measured for Identification Task 2 for Each Participant Group and subgroups

Variable	Conditions	Anomic Aphasia (*n*=10)				Broca's aphasia (*n*=10)				Persons with Aphasia (*n*=20)				Neurotypical adults (*n*=20)			
		Mean	SD	Median	IQR	Mean	SD	Median	IQR	Mean	SD	Median	IQR	Mean	SD	Median	IQR
Accuracy	C1	93.56	4.99	94.63	4.46	79.28	16.73	78.57	26.78	86.42	14.07	92.85	19.64	99.64	1.10	100.0	0.0
	C2	92.49	8.15	94.63	13.40	78.57	18.82	83.92	29.46	85.53	15.82	91.06	17.85	99.82	0.80	100.0	0.0
Efficiency	C1	84.28	10.41	88.39	19.76	63.30	19.70	63.39	33.47	73.79	18.73	80.35	28.13	94.95	3.69	95.53	5.14
	C2	85.08	12.59	90.17	16.06	65.18	20.97	65.63	34.62	75.13	19.69	82.58	29.02	97.00	2.53	96.87	3.58
Response Time	C1	4.94	3.99	3.99	4.44	7.23	2.43	6.60	4.42	6.09	2.67	5.43	5.18	2.75	1.37	2.64	2.25
	C2	4.84	2.76	3.81	3.56	6.31	2.11	6.19	2.79	5.57	2.51	5.64	4.39	2.07	0.85	1.99	0.89

Note. C1= Condition 1 of symbol organization and colour coding, C2= Condition 2 of symbol organization and colour coding, n= sample size, SD= standard deviation, IQR= Inter Quartile range. PWA is a combined group of persons with anomic aphasia and Broca's aphasia

Similarly, mixed ANOVA was conducted for response time measures with symbol conditions as within-subject factors and participant groups as between-subject factors. The results showed a significant difference between the two conditions, F (1, 37) = 5.417, p <.05, η^2= .128 irrespective of group. The participant groups were also found to be significantly different in terms of their response time in identifying symbols, irrespective of symbol conditions, F (2, 37) = 21.898, p < .001, η^2= .542. No significant interaction effect was found between conditions and participant groups. As a follow up for mixed ANOVA, Tukey's test was conducted to allow pairwise comparisons of groups to determine which two groups significantly differed in terms of response time. According to Tukey's test, anomic aphasia, Broca's aphasia, and neurotypical adults significantly differed with high effect size (p > 0.5) in the response time taken for identifying symbols (p <.05). A summary of the results are provided in Table 4.9.

Table 4.9

Summary of Performance between two Symbol Organization and Colour cue Conditions in PWA, Subgroups of PWA and Neurotypical Adults

Dependent Variables	Performance between two symbol organization and colour cue conditions			
	PWA	Broca's Aphasia	Anomic Aphasia	NTA
Accuracy	C1>C2	C1>C2	C1>C2	No difference
Efficiency	C1>C2	C1>C2	C1>C2	C1>C2
Response Time	C1<C2 (*)	C1< C2 (*)	C1< C2 (*)	C1<C2 (*)

Note. PWA= Persons with aphasia (combined group of persons with anomic aphasia and Broca's aphasia), NTA= Neurotypical adults, C1= semantically arranged with colour coding, C2= with no colour and categorization.

* Difference significant at p< .05

4.1.1a(iii). Effect of Grammatical Category of Referents on Symbol Identification. The third and final task under identification required the participants to identify symbols belonging to different grammatical categories (i.e., nouns, verbs, adjectives, and prepositions) which allowed to determine the effect of the grammatical category of referents on symbol identification. The average accuracy, efficiency, and response time taken to identify symbols representing nouns, verbs, adjectives, and prepositions in each participant group were subjected to descriptive statistical analyses and the results are tabulated in Table 4.10.

Table 4.10

The Mean, Standard Deviation, Median, and Inter-quartile range of Accuracy, Efficiency, and Response Time Measured for Identification Task 3 for each Participant Group

Variable	Grammatical Category	Anomic Aphasia (*n*=10)				Broca's aphasia (*n*=10)				Persons with Aphasia (*n*=20)				Neurotypical adults (*n*=20)			
		Mean	SD	Median	IQR	Mean	SD	Median	IQR	Mean	SD	Median	IQR	Mean	SD	Median	IQR
Accuracy	Nouns	99.17	1.49	100.0	1.74	88.17	13.65	93.67	14.24	93.67	11.00	97.22	6.64	100.0	0.00	100.0	0.00
	Verbs	96.47	5.68	98.53	5.15	83.38	17.02	88.97	20.22	89.92	14.06	95.51	14.71	100.0	0.00	100.0	0.00
	Adjectives	93.67	7.36	95.00	10.00	71.83	21.39	75.83	29.58	82.75	19.18	89.17	22.08	99.58	1.19	100.0	0.00
	Prepositions	87.75	9.61	90.00	13.75	59.25	20.45	57.50	28.75	73.50	21.34	80.00	34.38	99.12	1.67	100.0	1.88
Efficiency	Nouns	92.86	4.24	94.38	6.86	71.35	20.95	81.42	35.07	82.11	18.39	87.14	14.58	98.42	1.54	98.78	1.31
	Verbs	87.12	9.17	89.70	27.35	65.87	20.78	66.35	31.71	76.49	19.06	83.27	24.64	97.58	1.98	97.79	3.04
	Adjectives	80.69	12.91	84.36	49.37	52.63	22.12	49.37	31.77	66.66	22.76	65.83	37.19	96.52	2.73	96.87	4.48
	Prepositions	76.54	15.00	81.25	22.08	41.23	23.87	34.68	30.16	58.88	26.54	65.22	50.31	94.99	2.94	94.37	4.22
Response Time	Nouns	3.31	1.00	3.01	1.84	6.99	3.75	6.18	4.65	5.15	3.27	4.23	3.59	1.41	0.37	1.39	0.61
	Verbs	4.40	1.86	4.08	3.63	7.81	3.26	6.78	6.32	6.10	3.12	5.81	3.07	1.93	0.85	1.85	1.27
	Adjectives	5.67	2.51	4.67	4.24	9.95	4.37	9.04	5.33	7.81	4.10	7.45	5.41	1.93	0.66	2.02	1.22
	Prepositions	5.93	3.09	5.24	2.96	11.24	4.57	8.97	7.78	8.58	4.67	7.28	7.47	2.31	0.92	2.09	1.04

Note. n= sample size**,** SD= standard deviation, IQR= Inter Quartile range. Persons with aphasia is a combined group of persons with anomic aphasia and Broca's aphasia.

A comparison of the performance of each participant group and subgroups to identify symbols across grammatical categories (i.e., nouns, verbs, adjectives and prepositions) was done using Friedman's ANOVA test (refer Table 4.11).

Table 4.11

Result of Friedman's ANOVA to Compare Accuracy, Efficiency, and Response Time across Grammatical Categories in Each Grid Size in Persons with Aphasia and Neurotypical Adults.

Variable	Participant Group	*n*	χ^2 (df =3)	*p*
Accuracy	Persons with Aphasia	20	41.96	<.001
	Anomic aphasia	10	23.46	<.001
	Broca's aphasia	10	20.64	<.001
	Neurotypical adults	20	10.20	<.05
Efficiency*	Persons with Aphasia	20	40.02	<.001
	Broca's aphasia	10	21.00	<.001
	Neurotypical adults	20	21.57	<.001
Response Time *	Persons with Aphasia	20	34.56	<.001
	Broca's aphasia	10	18.36	<.001
	Neurotypical adults	20	29.76	<.001

Note. * The efficiency scores and response time in anomic aphasia followed normal distribution due to which Friedman's ANOVA was not performed. Persons with aphasia is a combined group of persons with anomic aphasia and Broca's aphasia.

From the above Table 4.11, it is evident that a significant difference across grammatical categories was found in the accuracy, efficiency, and response time measures in PWA, Broca's aphasia and neurotypical adults; and in terms of accuracy in anomic aphasia. The post-hoc analyses for Friedman's ANOVA carried out using the Mann-Whitney U test after Bonferroni correction in each participant group and subgroup is reported below. Since efficiency scores and response time in anomic aphasia followed a normal distribution, repeated measures ANOVA was performed which is also reported below along with its post hoc analyses using paired t-test.

In PWA, pairwise comparison using the Mann-Whitney U test showed a significant difference ($p<.05$) in accuracy was between nouns and adjectives, between nouns and prepositions, and between verbs and prepositions with medium to high effect size (r_e = 0.73- 1.25). Pairwise comparison of efficiency scores in PWA showed a significant difference ($p<.05$) between noun and adjectives, noun and prepositions, verbs and prepositions as well as verb and adjectives with high effect size (r_e = 0.87-1.23). Pairwise comparison of response time after Bonferroni correction showed a significant difference between all word classes ($p <.05$) with small to medium effect size (r_e = 0.26-0.44), except between nouns and verbs and between adjectives and prepositions ($p <.05$) in PWA.

In anomic aphasia, post hoc analyses of Friedman's ANOVA for accuracy scores showed significant difference ($p <.05$) with high effect size between noun and preposition (r_e = 1.31) and between verb and preposition (r_e = 0.93). The efficiency scores in anomic aphasia followed a normal distribution and hence a repeated-measures ANOVA was done to compare the average efficiency taken to identify symbols across grammatical categories. The results showed a significant effect of grammatical category on efficiency, F (3, 27) = 13.091, $p <.05$, with a large effect size as shown from partial eta square (η^2) of .59. Pairwise comparisons after Bonferroni correction, showed a significant difference ($p<.05$) in the efficiency score between noun and adjectives, noun and preposition and between verbs and prepositions. Similarly, response time data in anomic aphasia was analyzed using repeated measures ANOVA which showed a significant effect of grammatical category on response time, F (3, 27) = 6.999, $p <.05$, with a medium effect size (η^2=0 .43). Pairwise comparison showed a significant difference in response time between nouns and verbs, nouns and adjectives and verbs and adjectives ($p<.05$).

For Broca's aphasia, post-hoc analysis of Friedman's ANOVA showed that the accuracy scores had significant differences between noun and adjectives, noun and prepositions and between verbs and prepositions ($p < .05$) with high effect size (r_e = 0.87-1.20). The efficiency scores showed a significant difference ($p < .05$) between nouns and adjectives, nouns and prepositions and between verbs and prepositions with high effect size (r_e = 0.93-1.25). The response time taken significantly differed ($p < .05$) between nouns and adjectives, nouns and prepositions and between verbs and prepositions with high effect size (r_e = 0.66- 1.09).

In the case of neurotypical adults, post hoc analyses showed no significant difference in accuracy score between any grammatical categories ($p > .05$). A pairwise comparison after Bonferroni correction of efficiency scores showed a significant difference between noun and adjectives, noun and prepositions, as well as between verbs and prepositions ($p < .05$) with high effect size (r_e = 0.67- 0.91). The response time in neurotypical adults showed a significant difference between nouns and verbs, nouns and adjectives and between nouns and prepositions ($p < .05$) with high effect size (r_e = 0.65-1.21). Table 4.12 provides a summary of performance participant group and subgroup across grammatical categories.

Table 4.12

Summary of Performance across Grammatical Categories in PWA, Subgroups of PWA and Neurotypical Adults

Dependent Variable	Performance across grammatical categories			
	PWA	Broca's Aphasia	Anomic Aphasia	NTA
Accuracy	N>V>A>P (*)	N>V>A>P (*)	N>V>A>P (*)	N>V>A>P (*)
Efficiency	N>V>A>P (*)	N>V>A>P (*)	N>V>A>P (*)	N>V>A>P (*)
Response Time	N<V<A<P (*)	N<V<A<P (*)	N<V<A<P (*)	N<V<A<P (*)

Note. PWA = Persons with aphasia (which is a combined group of persons with anomic aphasia and Broca's aphasia), NTA= Neurotypical adults, N= Nouns, V= Verbs, A= Adjectives, P = Prepositions.
* Difference significant at $p < .05$

4.1.1a.(iv). Error Response Analyses. An error analysis was conducted on incorrect responses during symbol identification in both subgroups of PWA. The mean percentage of each type of error response for identification tasks in each subgroup of PWA (i.e., anomic aphasia and Broca's aphasia) is provided in Figure 4.2 and in Figure 4.3.

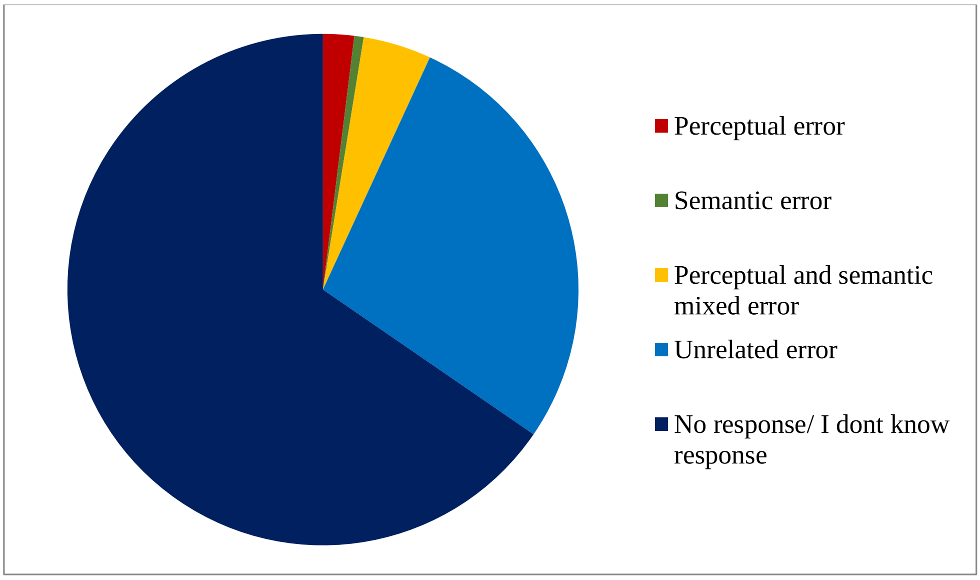

Figure 4.2. Mean of percentage of error responses in anomic aphasia

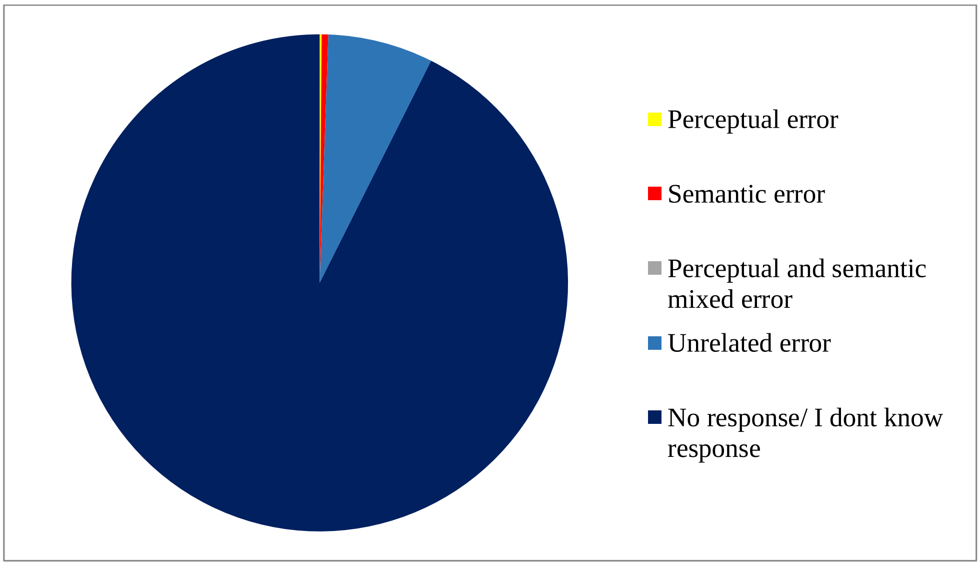

Figure 4.3. Mean of Percentage of error responses in Broca's aphasia

Persons with anomic aphasia had a total of 5.09% error responses while Broca's aphasia had a total of 21.63% error responses in identification tasks. Among all the error types, the highest percentage of errors consisted of no response errors which was evident in both subgroups of PWA. A visual inspection of the data reveals that the percentage of no response/ "I don't know" errors is numerically superior to other error types in Broca's aphasia. On the other hand, anomic aphasia had a relatively higher percentage of unrelated errors. It was also observed that symbols representing nouns had the least number of error responses, while error responses were highest for symbols representing prepositions and adjectives.

4.1.2 Performance on Symbol Categorization Tasks

The overall ability to categorize symbols was determined from the accuracy, efficiency, and response time taken by each participant group for the two tasks of categorization (i.e., auditory and visual categorization). The results of the performance between PWA and neurotypical adults [objectives 2. (i)] as well as across subgroups of PWA and neurotypical adults [objective 2. (ii)] on both categorization tasks combined are described below:

Performance between PWA and Neurotypical Adults. The obtained accuracy, efficiency scores and response time taken to categorize symbols from both categorization tasks combined was subjected to descriptive statistical analyses and the results are tabulated in Table 4.13.

The performance in terms of the three dependent variables was compared between PWA and neurotypical adults using the Mann-Whitney U test to meet objective 2. (i). The test revealed that the two groups significantly differed (p<.05) with a high effect size in terms of accuracy, efficiency and response time (refer Table 4.13).

Table 4.13

Mean, Standard deviation, Median, and Inter-Quartile Range Values for Accuracy, Efficiency, and Response Time by PWA and Neurotypical Adults for the Two Categorization Tasks and the Result of Mann-Whitney U Test to Compare the Two Groups.

Dependent Variables	Groups	*n*	Mean	SD	Median	IQR	|*z*|	*p*	r_e
Accuracy	PWA	20	88.58	16.98	96.65	17.08	3.283	<.05	0.51
	NTA	20	99.83	0.51	100.0	0.00			
Efficiency	PWA	20	68.45	21.18	72.08	26.76	5.128	<.001	0.81
	NTA	20	94.98	4.03	96.04	5.31			
Response Time	PWA	20	8.33	3.80	7.51	5.45	5.032	<.001	0.79
	NTA	20	2.72	1.19	2.45	2.00			

Note. PWA= Persons with aphasia (is a combined group of persons with anomic aphasia and Broca's aphasia), NTA= Neurotypical adults, *n*= sample size, SD= Standard deviation, IQR= Interquartile range, |*z*|= standardized test statistic, *p*= significance value, r_e = effect size.

Performance across Subgroups of PWA and Neurotypical Adults. The results of descriptive statistics for accuracy, efficiency, and response time measures from both categorization tasks is provided in Table 4.14.

The performance for the task was compared across anomic aphasia, Broca's aphasia, and neurotypical adults using the Kruskal Wallis H test to meet objective 2. (ii). The results revealed that the three groups differed significantly in terms of accuracy, efficiency and response time taken to categorize symbols (refer Table 4.14).

Table 4.14

Mean, Standard deviation, Median and Inter-Quartile Range Values for Accuracy, Efficiency, and Response Time Taken by Anomic Aphasia, Broca's Aphasia, and Neurotypical Adults for the Two Categorization Tasks and Result of Kruskal Wallis Test to Comparison of Three Groups.

	Participant Groups	*n*	Mean	SD	Median	IQR	χ^2 *(2)*	*p*
Accuracy	Anomic aphasia	10	98.33	3.33	100.0	2.53	18.902	<.001
	Broca's aphasia	10	78.83	19.65	84.16	33.75		
	Neurotypical adults	20	99.83	0.51	100.0	0.00		
Efficiency	Anomic aphasia	10	79.90	9.31	80.35	14.16	27.772	<.001
	Broca's aphasia	10	56.99	23.86	61.66	36.67		
	Neurotypical adults	20	94.97	4.03	96.04	5.31		
Response Time	Anomic aphasia	10	6.79	2.22	6.85	3.87	26.195	<.001
	Broca's aphasia	10	9.86	4.51	9.82	9.21		
	Neurotypical adults	20	2.71	1.19	2.44	2.00		

A Mann-Whitney U test was performed to follow up on the above finding (refer Table 4.15). The results showed that the accuracy scores obtained by Broca's aphasia were found to be significantly lower than neurotypical adults (p<.05) with high effect size (r_e = 0.78), and significantly lower than anomic aphasia (p<.05) with high effect size (r_e = 0.63). On the other hand, the accuracy scores of anomic aphasia did not significantly differ from those obtained by neurotypical adults (p>.05). The efficiency scores were found to significantly differ between anomic aphasia and neurotypical adults (p<.05) with large effect size (r_e = 0.63), and between Broca's aphasia and neurotypical adults (p <.001) with high effect size (r_e = 0.89). Similarly, for response time, a significant difference was found between anomic aphasia and neurotypical adults (p < .001) with high effect size (r_e = 0.76), and between Broca's aphasia and neurotypical adults (p <.001) with high effect size (r_e = 0.63).

Table 4.15

Result of Mann-Whitney U test to compare Performance between Groups for Categorization Tasks

Dependent Variable	Pair-wise comparison [Objective 2.(ii)]		
	BA vs AA	BA vs NTA	AA vs NTA
Accuracy	BA < AA (*)	BA < NTA (*)	AA < NTA
Efficiency	BA < AA	BA < NTA (*)	AA < NTA(*)
Response Time	BA < AA	BA < NTA (*)	AA < NTA(*)

Note. NTA= Neurotypical adults, BA= Broca's aphasia, AA= Anomic aphasia

* Difference significant at p< .05

The performance on each task of categorization was also subjected to comparison to meet the sub-objectives 2.a.(i),2.a.(ii), 2.b (i), 2.b.(ii).The results are discussed below under each categorization task.

4.1.2a. Auditory Categorization Task (Task 4). The auditory categorization task required the participants to accurately categorize spoken words by pointing to the appropriate category denoted by PCS symbols to which the word belongs. The results of the comparison between PWA and neurotypical adults [objective 2.a.(i)] and across subgroups of PWA and neurotypical adults [objective 2.a.(ii)] on auditory categorization task is reported below:

Performance between PWA and Neurotypical Adults. The accuracy, efficiency, and response time taken to correctly categorize auditory stimuli were subjected to descriptive statistical analyses and the results are provided in Table 4.16. The performance was compared between the two participant groups using the Mann-Whitney U test to meet sub-objective 2.a.(i). The results showed a significant difference (p <.05) with moderate to high effect size between the two groups in their ability to auditorily categorize AAC symbols in terms of accuracy, efficiency and response time (refer Table 4.16).

Table 4.16

Mean, Standard Deviation, Median, and Inter-Quartile Range Values for Accuracy, Efficiency, and Response Time Taken by PWA and Neurotypical Adults for Auditory Categorization Task and the Result of Mann-Whitney U Test to compare the two Groups

	Participant Groups	*n*	Mean	SD	Median	IQR	|z|	*p*	r_e
Accuracy	PWA	20	88.17	18.08	100.0	23.34	2.989	<.05	0.47
	NTA	20	99.83	0.74	100.0	0.00			
Efficiency	PWA	20	71.98	21.92	73.75	24.58	5.162	<.001	0.81
	NTA	20	98.29	3.44	100.0	1.67			
Response Time	PWA	20	6.96	3.65	5.42	4.93	5.004	<.001	0.79
	NTA	20	1.66	1.21	1.24	1.23			

Note. PWA= Persons with Aphasia (is a combined group of persons with anomic aphasia and Broca's aphasia), NTA= Neurotypical adults, SD= Standard deviation, IQR= Interquartile range, $|z|$= standardized test statistic, p= significance value, r_e = effect size

Performance across Subgroups of PWA and Neurotypical Adults. The accuracy, efficiency, and response time taken to accurately categorize symbols in response to spoken words were measured in anomic aphasia, Broca's aphasia, and neurotypical adults. The descriptive statistics for the same are provided in Table 4.17.

The performance between the three participant groups was compared using the Kruskal-Wallis H test to meet objective 2.a.(ii). The results showed a significant difference (p<.05) across the participant group in their ability to auditorily categorize in terms of accuracy, efficiency and response time (refer Table 4.17).

Table 4.17

Mean, Standard deviation, Median and Inter-Quartile Range Values for Accuracy, Efficiency, and Response Time Taken by Anomic Aphasia, Broca's Aphasia, and Neurotypical Adults for Auditory Categorization Task and Result of Kruskal Wallis H Test to Compare the Three Groups

	Participant Groups	*n*	Mean	SD	Median	IQR	$\chi^2(2)$	*p*
Accuracy	Anomic aphasia	10	99.00	2.25	100.0	0.83	17.59	<.001
	Broca's aphasia	10	77.33	20.59	80.0	41.67		
	Neurotypical adults	20	99.83	0.74	100.0	0.00		
Efficiency	Anomic aphasia	10	84.81	10.67	86.57	19.17	28.92	<.001
	Broca's aphasia	10	59.17	23.14	65.83	38.75		
	Neurotypical adults	20	98.29	3.44	100.0	1.67		
Response Time	Anomic aphasia	10	5.45	1.02	1.89	2.00	25.92	<.001
	Broca's aphasia	10	8.48	4.18	8.41	8.06		
	Neurotypical adults	20	1.65	1.21	1.23	1.23		

Note. *n* = sample size, SD= Standard deviation, IQR= Interquartile range.

A follow-up test using Mann-Whitney U was performed for pairwise comparisons. Comparison of anomic and Broca's aphasia showed that they significantly differed in terms of only accuracy (p <.05) with high effect size (r_e = 0.65). On the other hand, Broca's aphasia and neurotypical adults significantly differed in terms of accuracy, efficiency, and response time (p<.05) with high effect size (r_e= 0.75-0.92). Anomic aphasia and neurotypical adults showed a significant difference only in terms of efficiency (p<.05) with high effect size (r_e =0.61) and response time (p <.05) with high effect size (r_e =0.64).

Table 4.18 provides a summary of the pairwise comparison of the performance of participant groups.

Table 4.18

Result of Mann-Whitney U test to compare Performance between Groups for Auditory Categorization Task

Dependent Variable	Pair-wise comparison [Objective 2.(ii)]		
	BA vs AA	BA vs NTA	AA vs NTA
Accuracy	BA < AA (*)	BA < NTA (*)	AA < NTA
Efficiency	BA < AA	BA < NTA (*)	AA < NTA(*)
Response Time	BA < AA	BA < NTA (*)	AA < NTA

Note. NTA= Neurotypical adults, BA= Broca's aphasia, AA= Anomic aphasia

* Difference significant at $p < .05$

4.1.2b. Visual Categorization Task (Task 5). The visual categorization task required the participants to accurately categorize symbols printed on 3x3 cm cards by sorting them into the appropriate category. The results of analyses done to meet the study sub-objective 2.b.(i) which was to compare the performance between PWA and neurotypical adults on visual categorization task is provided below. Also, the result of comparison of performance across subgroups of PWA and neurotypical adults on the task [sub-objective 2.b.(ii)] is reported below:

Performance between PWA and Neurotypical Adults. The accuracy, efficiency, and response time taken by each participant group to visually categorize symbols were measured and subjected to descriptive statistical analyses. The results of the same are tabulated in Table 4.19. The performance between PWA and neurotypical adults for this task was compared using the Mann-Whitney U test to meet sub-objective 2.b.(i). The results showed a significant difference (p<.05) between the two groups in their ability to visually categorize AAC symbols in terms of accuracy, efficiency and response time, with a high effect size (refer Table 4.19).

Table 4.19

Mean, Standard deviation, Median, and Inter-Quartile Range Values for Accuracy, Efficiency, and Response Time Taken by PWA and Neurotypical Adults for Visual Categorization Task and Result of Mann-Whitney U Test to Compare the Two Groups

	Participant Groups	*n*	Mean	SD	Median	IQR	$\|z\|$	*p*	r_e
Accuracy	PWA	20	88.99	17.10	96.63	13.33	3.504	<.001	0.55
	NTA	20	99.83	0.744	100.00	0.00			
Efficiency	PWA	20	64.92	21.43	67.91	24.38	4.642	<.001	0.73
	NTA	20	91.66	6.08	93.75	9.58			
Response Time	PWA	20	9.68	4.63	8.62	5.95	4.463	<.001	0.71
	NTA	20	3.76	1.68	3.35	3.08			

Note. PWA= Persons with Aphasia (combined group of persons with anomic aphasia and Broca’s aphasia), NTA= Neurotypical adults, SD= Standard deviation, IQR= Interquartile range, $|z|$= standardized test statistic, *p*= significance value, r_e = effect size

Performance across Subgroups of PWA and Neurotypical adults. The accuracy, efficiency, and response time taken by anomic aphasia, Broca’s aphasia, and neurotypical adults to visually categorize symbols were measured. The results of descriptive statistical analyses are provided in Table 4.20

The performance across subgroups of PWA and neurotypical adults were compared using the Kruskal-Wallis H test to meet objective 2.b.(ii). The results showed a significant difference in accuracy, efficiency and response time taken to visually categorize across the participant groups (refer Table 4.20).

Table 4.20

Mean, Standard deviation, Median, and Inter-Quartile Range Values for Accuracy, Efficiency, and Response time taken by Anomic aphasia, Broca's aphasia, and Neurotypical adults for Visual Categorization task and Result of Kruskal Wallis H test to compare the three Groups

	Participant Groups	*n*	Mean	SD	Median	IQR	χ^2 *(2)*	*p*
Accuracy	Anomic aphasia	10	97.66	4.45	100.0	4.22	19.64	<.001
	Broca's aphasia	10	80.33	20.75	88.33	38.33		
	Neurotypical adults	20	99.83	0.744	100.0	0.0		
Efficiency	Anomic aphasia	10	74.99	9.77	74.14	11.25	22.71	<.001
	Broca's aphasia	10	54.83	25.38	56.67	35.83		
	Neurotypical adults	20	91.66	6.08	93.75	9.58		
Response Time	Anomic aphasia	10	8.13	2.70	8.19	3.93	20.27	<.001
	Broca's aphasia	10	11.24	5.71	11.12	11.81		
	Neurotypical adults	20	3.76	1.68	3.35	3.08		

Note. *n* = sample size, SD= Standard deviation, IQR= Interquartile range.

A follow-up test using Mann-Whitney U was performed for pairwise comparisons. Comparison of anomic aphasia and Broca's aphasia showed a significant difference only in the accuracy to visually categorize symbols ($p < .05$) with high effect size (r_e =0.61). Between anomic aphasia and neurotypical adults, a significant difference was found in efficiency ($p<.05$) with high effect size (r_e =0.57) and response time taken to visually categorize symbols ($p < .05$) with high effect size (r_e =0.60). Considering Broca's aphasia and neurotypical adults, the groups differed in terms of accuracy, efficiency, and response time taken to visually categorize ($p < .05$) with high effect size (r_e =0.72-0.80). A summary of the pairwise comparison of the performance of subgroups of aphasia and neurotypical adults are provided in Table 4.21

Table 4.21

Result of Mann-Whitney U test to compare Performance between Groups in Visual Categorization Task

Dependent Variable	Pair-wise comparison [Objective 2.(ii)]		
	BA vs AA	BA vs NTA	AA vs NTA
Accuracy	BA < AA (*)	BA < NTA (*)	AA < NTA
Efficiency	BA < AA	BA < NTA (*)	AA < NTA(*)
Response Time	BA < AA	BA < NTA (*)	AA < NTA(*)

Note. NTA= Neurotypical adults, BA= Broca's aphasia, AA= Anomic aphasia

* Difference is significant at $p < .05$

4.1.2c. Additional Analyses. This section reports the results of the additional analyses done to compare the performance between auditory categorization and visual categorization in each of the participant groups. The results of the analyses of error responses obtained from categorization tasks are also reported in this section.

4.2.1c (i) Performance between Auditory Categorization Task (Task 4) and Visual Categorization Task (Task 5). A comparison of the performance of each participant group between their ability to auditorily and visually categorize symbols was performed and the results are reported below.

Performance in PWA and Neurotypical Adults. Results from Wilcoxon signed-rank test showed that the accuracy in auditorily and visually categorizing symbols differed significantly neither in PWA nor in neurotypical adults. However, a significant difference with high effect size was found between the tasks in PWA in terms of efficiency, $|z|= 2.875$, $p<.05$, $r_e =0.64$ and response time, $|z| = 2.987$, $p<.05$, $r_e =0.66$. Similarly, for neurotypical adults, a significant difference was found for efficiency, $|z| = 3.514$, $p <.001$, $r_e =0.78$ and response time, $|z| = 3.435$, $p <.05$, $r_e =0.76$

taken to auditorily and visually categorize symbols.

Performance in Anomic aphasia and Broca's aphasia. No significant difference between auditory and visual categorization of symbols was found in terms of accuracy in anomic aphasia and Broca's aphasia as seen from results of the Wilcoxon signed-rank test (p>.05). A Mixed ANOVA was performed to compare the efficiency and response time between the two categorization tasks with participant groups as within-subject factors, as both data followed a normal distribution. The results showed a significant difference for efficiency, F (1, 37) = 30.939, p < .001, η^2= .455, and response time, F (2, 74) = 44.085, p < .001, η^2= .544, between the tasks. The participant groups were also found to significantly differ in their efficiency, F (2, 37) = 28.746, p < .001, η^2= .608, and response time, F (2, 37) = 34.286, p < .001, η^2= .650, to categorize symbols. Significant interaction effect was noted between tasks and participant groups only in terms of response time, F (2, 74) = 6.168, p < .001, η^2= .250. Tukey's test done as follow up analysis to mixed ANOVA revealed that all three participant groups significantly differed in their efficiency and response time (p < .05). A summary of the results are provided in Table 4.22

Table 4.22

Summary of Performance between Categorization Tasks in PWA, Subgroups of PWA and Neurotypical Adults

Dependent Variable	Performance between auditory and visual categorization			
	PWA	Broca's Aphasia	Anomic Aphasia	NTA
Accuracy	A < V	A < V	A > V	A = V
Efficiency	A > V (*)	A > V (*)	A > V (*)	A > V (*)
Response Time	A<V (*)	A<V (*)	A<V (*)	A<V (*)

Note. PWA= Persons with aphasia (is a combined group of persons with aphasia and Broca's aphasia), NTA= Neurotypical adults, A = Auditory categorization, V= visual categorization

*Difference significant p<.05

***4.1.2c (ii). Error Response Analyses in Categorization Tasks*.** The average visual and auditory categorization errors were calculated for both subgroups of PWA. Broca's aphasia was found to have a higher proportion of errors in comparison to anomic aphasia (refer Figure 4.4). Auditory categorization errors were found to be more frequent than visual categorization errors in both anomic aphasia and Broca's aphasia.

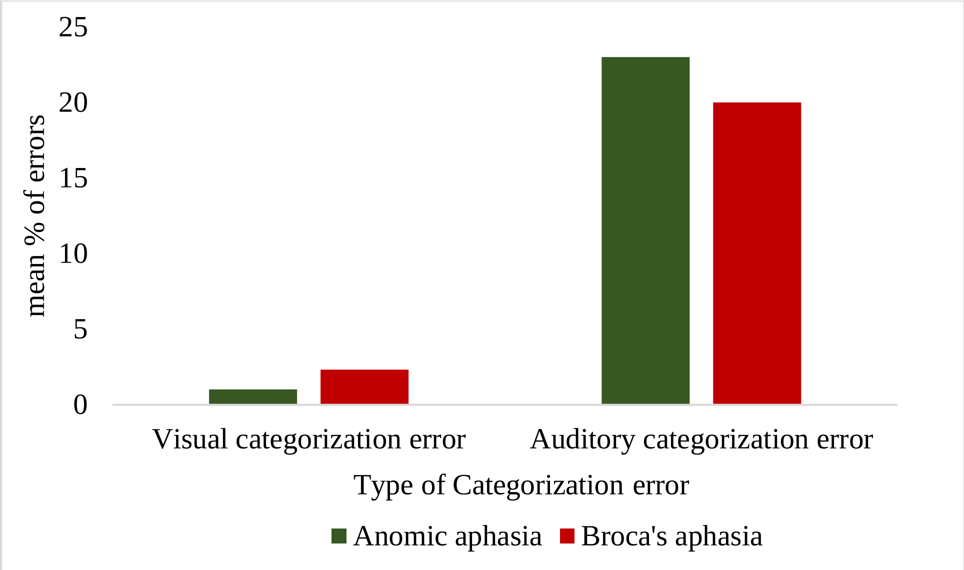

Figure 4.4. Mean percentage of categorization errors in subgroups of PWA

4.1.3. Performance on Symbol Sequencing Tasks

The overall ability to sequence symbols was calculated in percentage only from the accuracy scores of two tasks of sequencing. Investigating the ability to sequence in terms of efficiency and response time was not permissible as the second task of sequencing symbols did not have any restriction in the number of attempts and was untimed. The results of the performance between PWA and neurotypical adults [objective 3. (i)] as well as across subgroups of PWA and neurotypical adults [objective 3. (ii)] on both symbol sequencing tasks combined are described below:

Performance between PWA and Neurotypical Adults. The accuracy score was compared between PWA (M = 83.17, SD = 8.33, Md= 85.41, IQR= 7.71) and neurotypical adults (M = 90.62, SD = 1.72, Md= 90.83, IQR= 1.36) using the Mann-

Whitney U test to meet objective 3.(i). The test revealed that the accuracy scores differed significantly between the two groups with large effect size, $|z| = 4.288$, $p < .001$, $r_e = .67$.

Performance across subgroups of PWA and Neurotypical adults. The obtained accuracy score was compared across three participant groups (anomic aphasia, $M = 87.01$, $SD = 3.77$, $Md = 87.29$, $IQR = 4.92$, Broca's aphasia, $M = 79.33$, $SD = 9.97$, $Md = 82.50$, $IQR = 10.94$ and neurotypical adults, $M = 90.63$, $SD = 1.72$, $Md = 90.83$, $IQR = 1.36$) using the Kruskal Wallis H test. The test done to meet objective 3. (ii) revealed that the scores differed significantly across the groups, $\chi^2 (2) = 21.229$, $p < .001$. A pair-wise comparison of participant groups was done using the Mann-Whitney U test to follow up on the above findings. The scores obtained by anomic aphasia did not differ statistically from that of Broca's aphasia ($p > .05$), but differed with medium effect size when compared with neurotypical adults, $|z| = 2.529$, $p < .05$, $r_e = 0.46$. The accuracy scores of Broca's aphasia also differed from that of neurotypical adults significantly with high effect size, $|z| = 4.474$, $p < .001$, $r_e = 0.81$.

The performance on each task of symbol sequencing was also subjected to comparison to meet sub-objectives 3.a.(i), 3.a.(ii), 3.b.(i) and 3.b.(ii), and the results are discussed below under each task of sequencing.

4.1.3a Symbol Sequence Imitation Task (Task 6). This task required the participants to imitate the symbol sequences by pointing to the correct symbols in the order demonstrated by the researcher. Analyses of data obtained from this task were done to meet the study sub-objectives 3.a. (i) and 3.a.(ii).

Performance between PWA and Neurotypical Adults. The accuracy, efficiency, and response time taken to accurately imitate symbol sequences in each participant group were measured and subjected to descriptive statistical analyses. The results are tabulated in Table 4.23. The performance between PWA and neurotypical adults were compared using the Mann-Whitney U test to meet sub-objective 3.a.(i). Even though there was no significant difference in accuracy to imitate symbol sequences between the two participant groups, they significantly differed (*p* <.05) in terms of efficiency and response time taken to perform the task with a high effect size (refer Table 4.23).

Table 4.23

Mean, Standard deviation, Median, and Inter-Quartile Range Values for Accuracy, Efficiency, and Response Time Taken by PWA and Neurotypical Adults for Symbol Sequence Imitation Task and the Result of Mann-Whitney U Test to Compare the Two Groups

	Participant Groups	*n*	Mean	SD	Median	IQR	|*z*|	*p*	r_e
Accuracy	PWA	20	98.88	3.77	100.0	0.00	1.777	.076	-
	NTA	20	100.0	0.00	100.0	0.00			
Efficiency	PWA	20	86.29	12.10	91.43	18.64	5.430	<.001	0.85
	NTA	20	99.24	0.97	99.54	1.39			
Response Time	PWA	20	2.43	0.96	2.18	1.84	4.896	<.001	0.77
	NTA	20	1.18	0.23	1.16	0.36			

Note. PWA= Persons with aphasia (is a combined group of persons with aphasia and Broca's aphasia), NTA= Neurotypical adults, SD= Standard deviation, IQR= Interquartile range, |*z*|= standardized test statistic, *p*= significance value, r_e = effect size

Performance across Subgroups of PWA and Neurotypical Adults. The accuracy, efficiency, and response time taken to correctly imitate symbol sequences in anomic aphasia, Broca's aphasia, and neurotypical adults were subjected to descriptive analyses and the results are displayed in Table 4.24. The performance across the three participant groups was compared using the Kruskal Wallis H test to meet sub-objective

3.a.(ii). The three groups significantly differed (*p*<.05) in their ability to correctly imitate symbol sequences only in terms of efficiency and response time (refer Table 4.24).

Table 4.24

Mean, Standard Deviation, Median, and Inter-Quartile Range Values for Accuracy, Efficiency, and Response Time Taken by Anomic Aphasia, Broca's Aphasia, and Neurotypical Adults for Symbol Sequence Imitation Task and Result of Kruskal Wallis H Test to Compare the Three Groups

	Participant Groups	*n*	Mean	SD	Median	IQR	χ^2 *(2)*	*p*
Accuracy	Anomic aphasia	10	99.44	1.25	100.0	.46	3.725	>.05
	Broca's aphasia	10	98.33	5.27	100.0	0.0		
	Neurotypical adults	20	100.0	0.0	100.0	0.0		
Efficiency	Anomic aphasia	10	88.05	10.54	93.28	16.44	29.742	<.001
	Broca's aphasia	10	84.53	13.83	90.51	26.51		
	Neurotypical adults	20	99.24	0.97	99.54	1.39		
Response Time	Anomic aphasia	10	2.24	1.02	1.89	2.0	24.782	<.001
	Broca's aphasia	10	2.62	.91	2.44	1.68		
	Neurotypical adults	20	1.18	0.23	1.16	0.36		

Note. *n*= sample size, SD= Standard deviation, IQR= Interquartile range.

Mann-Whitney U test was done to follow up on the above finding by performing pairwise comparisons. The results of the test revealed that anomic aphasia and neurotypical adults significantly differed with high effect size (*p* <.05) in terms of efficiency (r_e = 0.76) and response time (r_e = 0.63). Similar results were obtained while comparing Broca's aphasia and neurotypical adults (p<.05; r_e = 0.86 for efficiency and r_e = 0.82 for response time). There was no difference (*p*>.05) between the performance of Broca's aphasia and anomic aphasia in terms of efficiency or response time. Table 4.25 provides a summary of pairwise comparison of the performance of subgroups of PWA and neurotypical adults.

Table 4.25

Result of Mann-Whitney U test to compare Performance between Groups in Symbol Sequence Imitation Task

Dependent Variable	Three-group comparison [Objective 3.a(ii)]		
	BA vs AA	BA vs NTA	AA vs NTA
Accuracy	BA < AA	BA < NTA	AA < NTA
Efficiency	BA < AA	BA < NTA (*)	AA < NTA(*)
Response Time	BA < AA	BA < NTA (*)	AA < NTA(*)

Note. PWA= Persons with aphasia (is a combined group of persons with aphasia and Broca's aphasia), NTA= Neurotypical adults,

*Difference significant p<.05

4.1.3b Symbol Sequence Production Task (Task 7). This task required the participants to construct simple sentences using symbol sequences or combinations in response to real coloured photograph stimuli presented. The accuracy scores calculated using a 12-point scale for each stimulus was averaged to obtain a score for each participant. This score was subjected to descriptive statistics and the results for each participant group and subgroups are displayed in Table 4.26.

Performance between PWA and Neurotypical Adults. The obtained scores (refer Table 4.26) were compared between PWA and neurotypical adults using the Mann-Whitney U test to meet sub-objective 3.b.(i). The results revealed that the scores obtained by PWA were significantly lower than scores obtained by neurotypical adults with a large effect size, $|z| = 4.572$, $p < .001$, $r_e = 0.72$.

Table 4.26

Mean, Standard Deviation, Median, and Inter-Quartile Range Values for Symbol Sequence Production Score (Accuracy) Obtained by each Participant Group and Subgroups

Participant Groups	*n*	Mean	SD	Median	IQR
Persons with Aphasia	20	75.43	16.16	78.99	17.00
Neurotypical adults	20	92.64	3.30	92.75	3.00
Anomic Aphasia	10	84.57	7.95	86.23	10.00
Broca's Aphasia	10	66.30	17.41	71.74	26.00

Note. n = sample size, SD= Standard deviation, IQR= Interquartile range. Persons with aphasia is inclusive of persons with anomic aphasia and Broca's aphasia

Performance across subgroups of PWA and neurotypical adults. The performance of anomic aphasia, Broca's aphasia and neurotypical adults (refer Table 4.26) were compared using the Kruskal Wallis H test to meet sub-objective 3.b.(ii). The results showed a significant difference across participant groups, χ^2 *(2)* = 24.179, *p* <.001. Pairwise comparison on Mann-Whitney U test revealed a significant difference between Broca's aphasia and neurotypical adults, anomic aphasia and neurotypical adults as well as between Broca's aphasia and anomic aphasia ($p < 0.05$) with medium to high effect size ($r_e = 0.44\text{-}0.82$).

4.1.3c. Additional Analyses. The single sentences constructed using symbols by participants in task 7 were subjected to linguistic analyses and the results are reported in this section along with the analyses of error responses obtained in the symbol sequencing tasks.

4.1.3c.(i) Linguistic Analyses of symbol sequence production. The aided responses obtained by anomic aphasia, Broca's aphasia, and neurotypical adults were subjected to linguistic analyses along semantic and syntactic measures. The semantic measures included the total number of symbols, the total number of correct information units for symbols, and the percentage of correct information units for symbols and syntactic measures included the percentage of complete sentences and the percentage of correct number of verbs. The descriptive analyses of the performance of each participant group and the results of the Kruskal-Wallis H test to compare performance across three groups are provided in Table 4.27

Table 4.27

Mean, Standard Deviation, Median, and Interquartile Range for all Dependent Variable Measures of Aided Responses in anomic aphasia, Broca's aphasia, and Neurotypical Adults and Result of Kruskal Wallis H Test to Compare the Three Groups

Dependent Variables	Anomic Aphasia		Broca's Aphasia		Neurotypical Adults		χ^2 *(2)*	*p*
	Mean	Median	Mean	Median	Mean	Median		
	Semantic Measures							
Total symbols	39.50 (2.59)	40.00 (3.00)	32.90 (10.95)	36.00 (16.00)	39.40 (1.35)	39.00 (2.00)	7.005	.030
CIU-S	35.90 (4.18)	36.50 (5.00)	28.50 (9.78)	33.00 (16.00)	39.15 (1.27)	39.00 (2.00)	21.367	<.001
% CIU-S	90.86 (8.55)	93.75 (8.00)	86.92 (9.63)	89.63 (18.00)	99.38 (1.74)	100.00 (0.00)	27.062	<.001
	Syntactic Measures							
% of complete sentences	60.17 (29.13)	65.60 (37.00)	17.93 (15.13)	15.38 (27.00)	95.23 (4.71)	92.00 (8.00)	35.582	<.001
% of correct verbs	93.84 (7.07)	96.15 (15.00)	85.90 (14.11)	88.47 (31.00)	100.00 (0.00)	100.00 (0.00)	1.042	.307

Note. CIU-S= correct information unit for symbols. Standard deviations are presented in parenthesis along with mean and interquartile ranges are presented in parenthesis along with median.

From the above table 4.27, it is evident that there was a significant difference across the three groups for all semantic measures and one syntactic measure (i.e., % of complete sentences). Mann-Whitney U test was performed as follow-up analyses to determine which two groups showed significant differences on each of these measures (refer table 4.28). Anomic aphasia and Broca's aphasia was found to differ on all semantic measures (p<.05). The same trend was noted between Broca's aphasia and neurotypical adults; however anomic aphasia and neurotypical adults only differed in terms of two measures (i.e., CIU-S and % CIU-S). In syntactic measures, a significant difference was found in terms of % of grammatically complete sentences between anomic aphasia and Broca's aphasia, anomic aphasia and neurotypical adults as well as between Broca's aphasia and neurotypical adults.

Table 4.28

Results of Mann-Whitney U test Between Participant Groups for all Semantic and Syntactic Measures in Symbol Sequence Production Task

Dependent Variable	Pairwise comparison of performance of groups		
	BA vs AA	BA vs NTA	AA vs NTA
	Semantic measures		
Total symbols	BA < AA (*)	BA < NTA (*)	AA < NTA
CIU-S	BA < AA (*)	BA < NTA (*)	AA < NTA(*)
% CIU-S	BA < AA	BA < NTA (*)	AA < NTA(*)
	Syntactic measures		
% of complete sentences	BA < AA (*)	BA < NTA (*)	AA < NTA(*)
% of correct verbs	BA < AA	BA < NTA (*)	AA < NTA(*)

Note. NTA= Neurotypical adults, BA= Broca's aphasia, AA= Anomic aphasia

*Difference is significant at $p< .05$

During this task, it was observed that persons with aphasia had a tendency to produce verbal sentences. Persons with anomic aphasia often attempted to produce verbal sentences while constructing symbol sequences. In instances where they produced phonemic paraphasias, pointing to symbols was observed while attempting to self-correct their utterances. Many participants with Broca's aphasia were found to accurately produce verbal sentences after constructing the same sentences using symbols.

4.3.1c(ii) Error Analyses for Sequencing Tasks. The error analyses for the sequencing task were limited to errors in symbol sequence production tasks as the symbol sequence imitation task had hardly any errors due to the inherent nature of the task itself. The errors in symbol sequence production tasks were classified into selection errors and sequencing errors. For selection errors in Broca's aphasia, the mean percentage of omission of single symbols were found to be more than substitution of target symbols for non-target symbols (refer Figure 4.5).

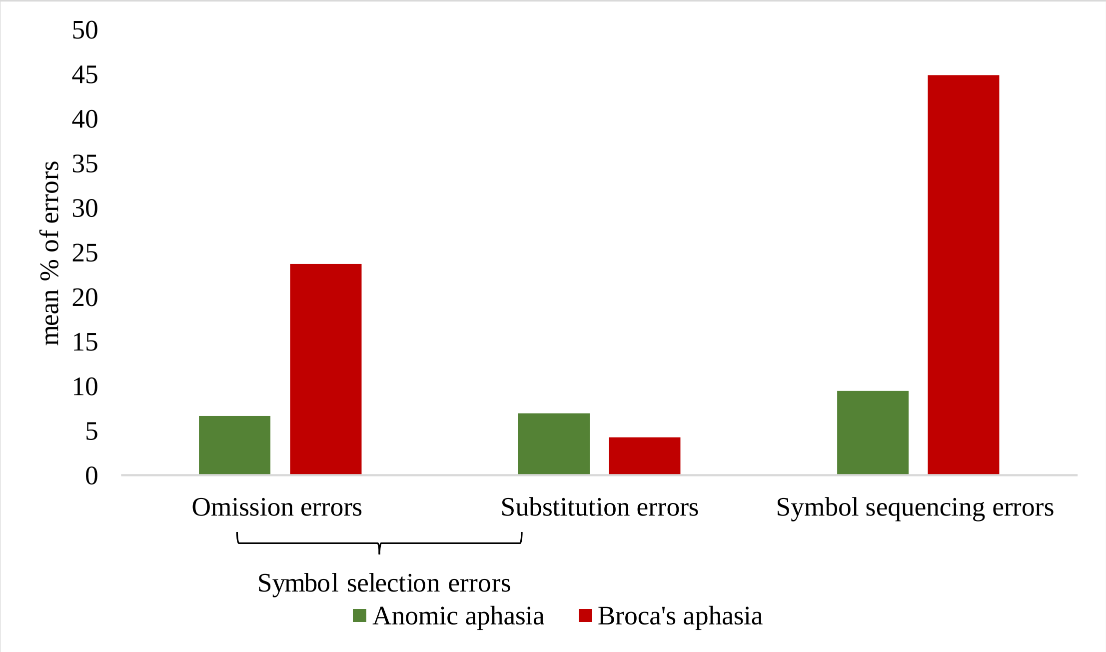

Figure 4.5. Mean percentage of selection errors (omission and substitution errors) and sequencing errors in symbol sequence production task

Among omission errors in Broca's aphasia, the mean percentage of omission of arguments (*M* = 19.70, *SD* = 21.63) were found to be more than the percentage of omission of predicates (*M* = 4.00, *SD* = 3.78). Similarly, the percentage of substituted arguments (*M* = 3.33, *SD* = 3.84) were more than omitted arguments (*M* = 1.00, *SD* = 1.59) in Broca's aphasia. In anomic aphasia, the percentage of substitution errors were relatively higher than the percentage of omission errors (refer Figure 4.3). The percentage of omission (*M* = 4.99, *SD* = 4.77) and substitution (*M* = 5.33, *SD* = 3.22) of arguments was found to be more than the percentage of omission (*M* = 1.65, *SD* = 1.73) and substitution (*M* = 1.65, *SD* = 1.73) of predicates in anomic aphasia. The percentage of sequencing (word order) errors were found to be more in Broca's aphasia (*M* =44.94, *SD* = 27.39) than for anomic aphasia (M= 9.5, *SD* = 17.07).

4.1.4 Overall Performance on Symbol Tasks

The symbolic language abilities for aided communication as represented using the symbol performance quotient (SPQ) score was calculated in percentage from the accuracy scores of symbol identification, categorization, and sequencing tasks to meet study objectives 4. (i) and 4. (ii). The results are reported below:

Performance between PWA and Neurotypical Adults. The obtained SPQ score was compared between PWA and neurotypical adults to meet objective 4. (i). The SPQ score obtained by PWA (*M* = 83.74, *SD* = 12.49; *Md* = 87.82, *IQR* = 15.62) was found to be lower than those obtained by neurotypical adults (*M* = 95.89, *SD* = 0.44; *Md* = 95.97, *IQR* = .55). The SPQ score in both participant groups is illustrated in figure 4.8. The difference in the scores was found to be statistically significant with a high effect size on the Mann-Whitney U test, $|z| = 5.425$, $p < .001$, r_e=.85.

Performance within PWA and across neurotypical adults. The SPQ score in three participant groups (i.e., anomic aphasia, *M* = 91.05, *SD* = 4.22, *Md* = 92.67, *IQR* = 5.50, Broca's aphasia, *M* = 76.42, *SD* = 13.88, *Md* = 79.66, *IQR* = 19.83, and neurotypical adults, *M* = 95.89, *SD* = .44, *Md* = 95.97, *IQR*= 0.55) are illustrated in figure 4.6. The scores were compared using the Kruskal-Wallis H test to meet objective 4. (ii). The results revealed that the scores significantly differed across the participant groups, χ^2 (2) =31.550, p <.001. A follow-up test conducted using the Mann-Whitney

U test to compare each group of participants revealed that neurotypical adults obtained a significantly higher overall symbol performance quotient score than anomic aphasia, $|z| = 3.588$, $p < .001$, $r_e = 0.65$ and Broca's aphasia, $|z| = 5.271$, $p < .001$, $r_e = 0.96$. On the other hand, even though the performance of anomic aphasia was numerically superior to Broca's aphasia, the score between the groups did not differ significantly ($p > .05$).

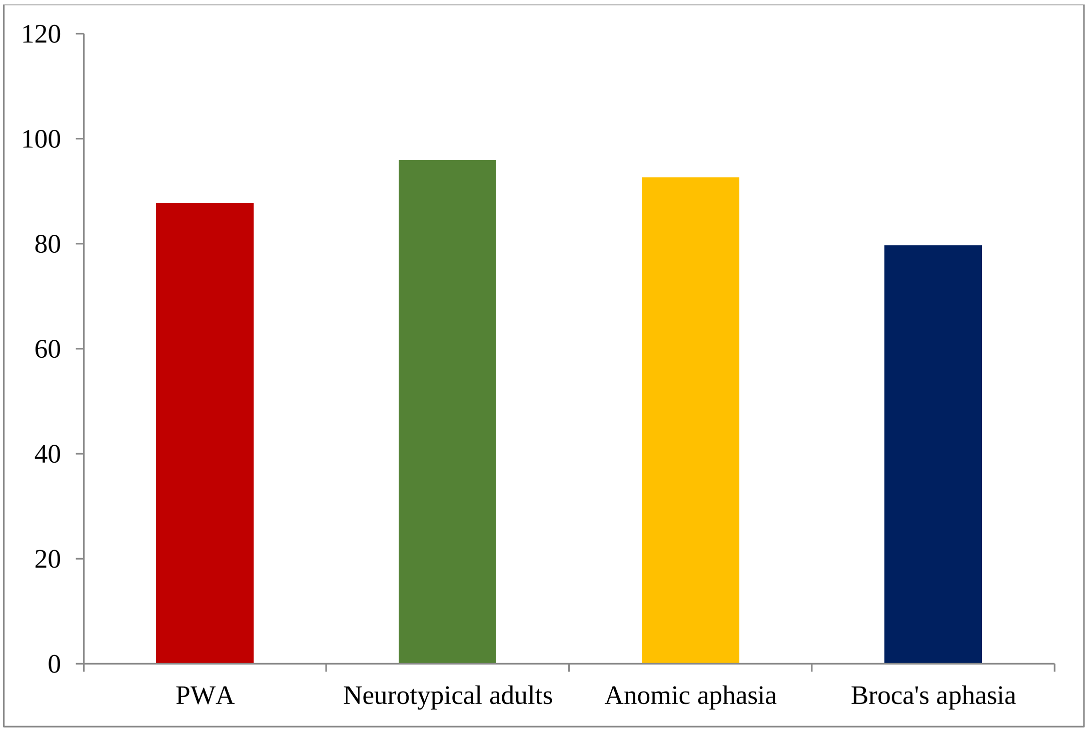

Figure 4.6. Bar graph representing median SPQ scores in PWA, subgroups of PWA and neurotypical adults.

4.2 Correlation between Symbolic language abilities and verbal language abilities

The correlation between verbal language abilities (obtained from the aphasia quotient score of test of aphasia in Malayalam) and the symbolic language abilities (obtained from the accuracy scores of all tasks of identification, categorization, and sequencing combined represented as SPQ), in PWA, was tested using Spearman's rank-order correlation to meet objective 5. The correlation was found to be significant, ρ =

.808, p <.001 in PWA (n = 20). The spearman's ρ-value of .808 indicates a very strong positive relationship between the two variables (Dancy & Reidy, 2004). The relationship between SPQ and AQ is represented in a scatter plot in Figure 4.7.

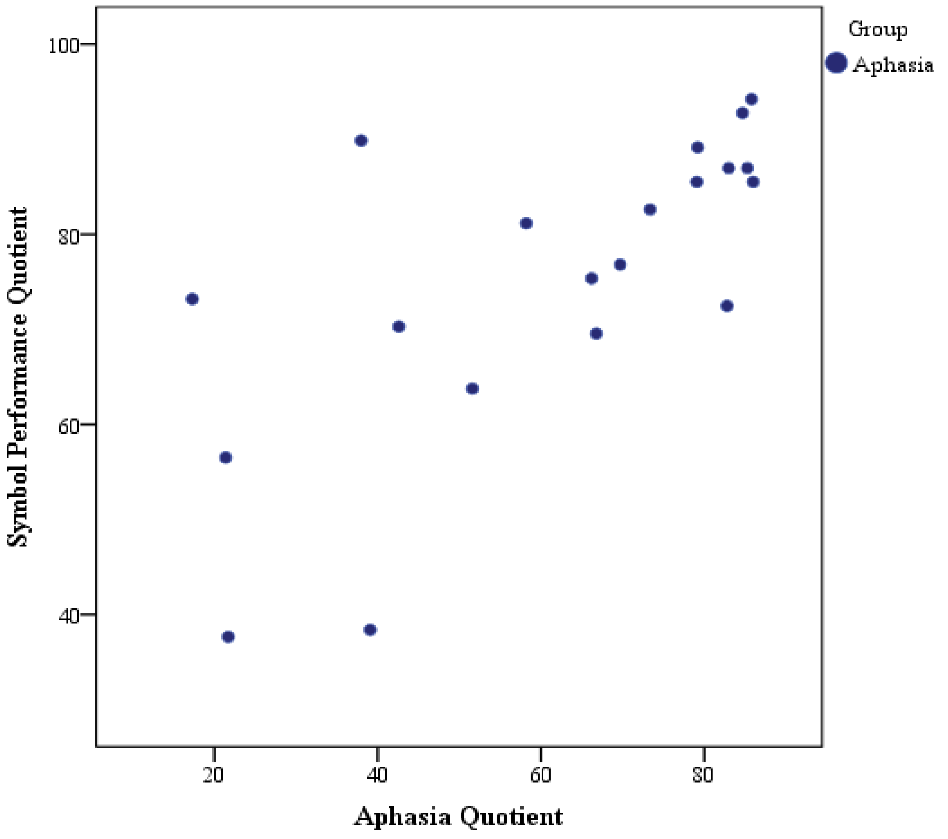

Figure 4.7. Scatter plot showing the relationship between symbol performance quotient (SPQ) and aphasia quotient (AQ) in PWA (combined group of persons with anomic aphasia and Broca's aphasia).

Considering each subgroup of aphasia, anomic aphasia did not show a significant correlation between symbolic language abilities and verbal language abilities (p > .05), while Broca's aphasia showed a significant correlation, ρ = .733, p <.05. The relationship appears to be positive and very strong in Broca's aphasia based on Spearman's rho value. The relationship between SPQ and AQ in anomic aphasia and Broca's aphasia are represented in a scatter plot in figure 4.8.

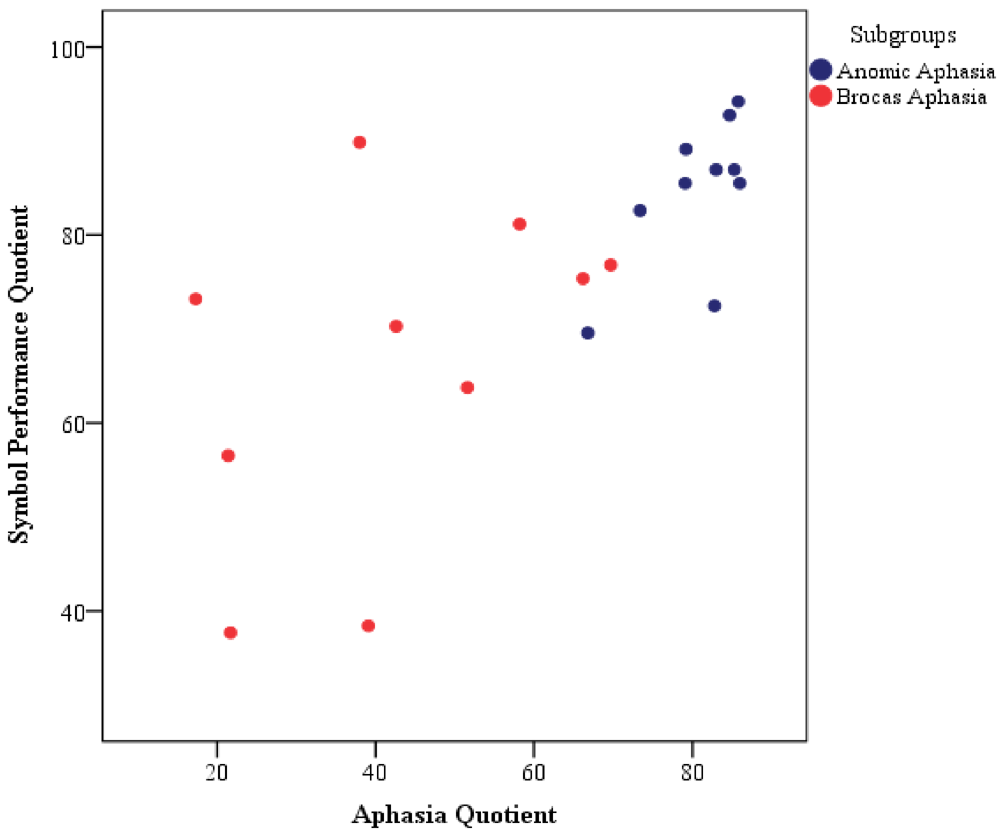

Figure 4.8. Scatter plot showing the relationship between symbol performance quotient (SPQ) and aphasia quotient (AQ) in anomic aphasia and Broca's aphasia.

4.3 Correlation Between Symbolic Language Abilities and Non-Verbal & Verbal Cognitive Abilities

The correlation between non-verbal & verbal cognitive abilities in PWA obtained from the cortical quotient (CQ) of test of aphasia in Malayalam and the symbolic language abilities obtained from the accuracy scores of all tasks of identification, categorization and sequencing combined (SPQ), was tested using Spearman's rank-order correlation to meet study objective 6. The correlation was found to be significant, ρ = .904, p <.001 n PWA (n = 20). The spearman's rho value of .904 indicates a very strong positive relationship between the two variables (Dancy & Reidy, 2004). Figure 4.9 shows the scatter plot depicting the relationship between SPQ and CQ in PWA.

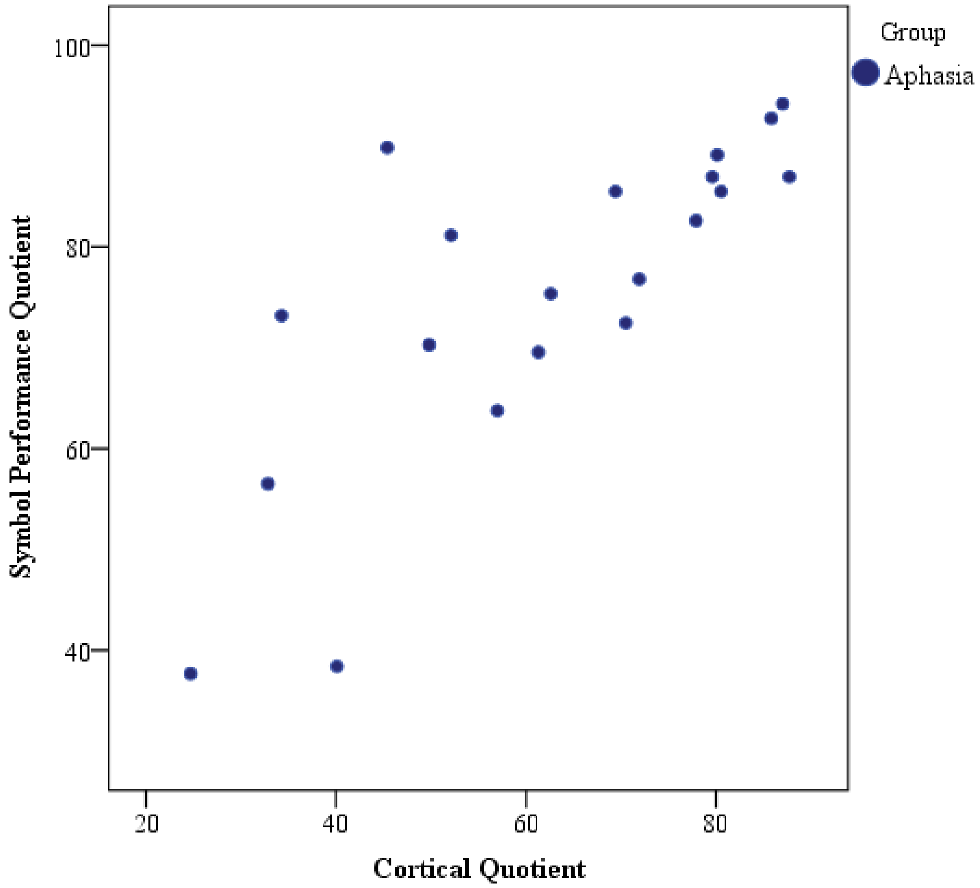

Figure 4.9. Scatter plot showing the relationship between symbol performance quotient (SPQ) and cortical quotient (CQ) in PWA (a combined group of persons with aphasia and Broca's aphasia)

Considering each subgroup of aphasia, a significant correlation between symbolic language abilities and verbal language abilities was found in both anomic aphasia, ρ= .770, p <.05, and Broca's aphasia, ρ= .842, p <.05. The relationship between the two variables appears to be positive and very strong in both anomic aphasia and Broca's aphasia based on Spearman's rho value. This relationship is represented in a scatter plot in figure 4.10

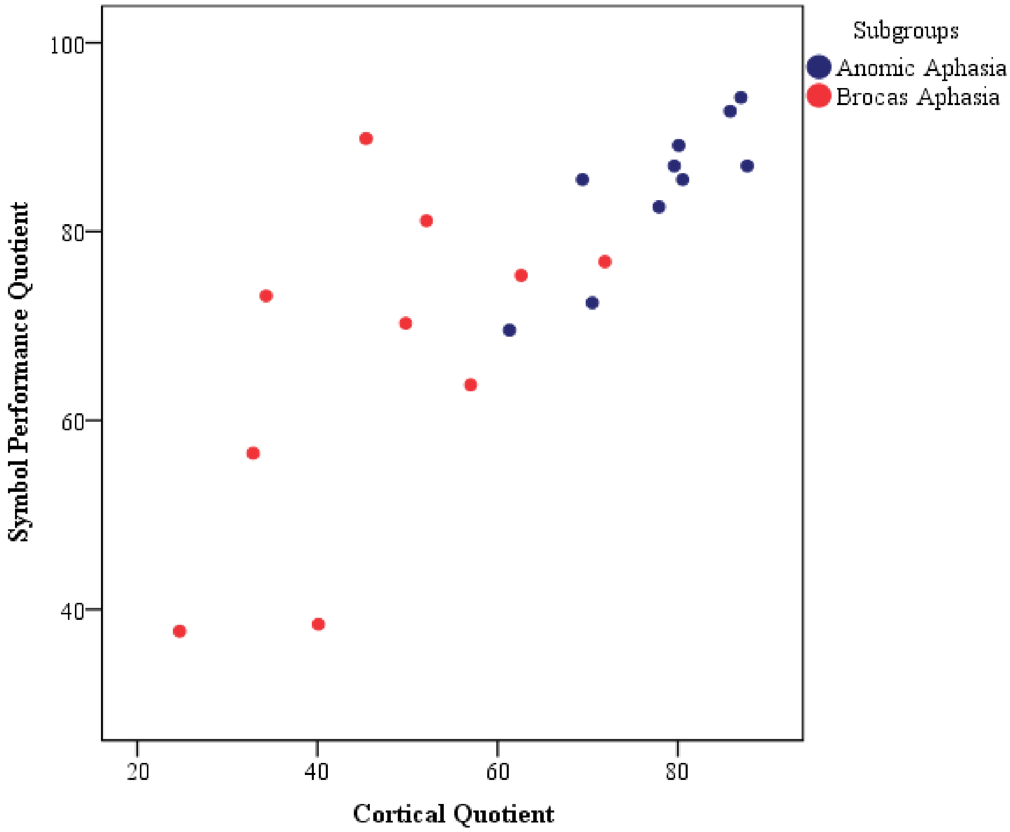

Figure 4.10. Scatter plot showing the relationship between symbol performance quotient (SPQ) and cortical quotient (CQ) in anomic aphasia and Broca's aphasia.

CHAPTER V

DISCUSSION

Linguistic competency to use an AAC necessitates that an individual has sufficient knowledge, judgment, and abilities in the linguistic code of the spoken and written language in their family and social community, as well as the language code of the AAC system they may use (Light, 1989). Learning the language code of the AAC system can be challenging because most of them are semantic systems that offer sets of symbols to represent concepts but have no inherent grammar or morphology (Light & McNaughton, 2014). These systems rely on the individual's cognitive skills (Purdy & Dietz, 2010) as well as language formulation and navigation skills (Thiessen et al., 2014), as most of the semantic concepts are organized in a grid pattern with rows and columns of compartmentalized icons or isolated images. Hence, to use these systems to produce meaningful utterances, an individual must be able to visually search multiple arrays, discriminate between symbols, identify the target symbol, retrieve them from categories defined by symbols, and arrange them in a linear sequence.

Persons with aphasia, due to their inherent language and cognitive impairment present unique challenges to AAC use, unlike other acquired communication disorders. Even then, the ability of PWA to use different AAC systems to communicate in experimental and clinical context have been evidenced from numerous treatment studies conducted since the 1980s (Koul et al., 2005; Koul et al., 2008; Koul & Harding, 1998; McCall et al., 2000; Weinrich et al., 2001; Weinrich et al., 1997). Given the scarcity of reports of functional or independent AAC use among PWA, we must re-investigate and understand the linguistic abilities required to use such a system. Moreover, to date, there are no published literature on the performance of these individuals on tasks involving symbolic language abilities without providing intervention. Furthermore, there are no data available in India that have investigated the symbolic language abilities required for using an aided AAC system in PWA. The current study provides insights into the performance of persons with aphasia on a series of behavioural tasks that tap into the linguistic abilities required to use aided communication in comparison to neurotypical adults. These language abilities included the ability to identify, categorize, and sequence symbols. This study also investigates the relationship between symbolic language abilities, verbal language abilities and non-verbal & verbal cognitive abilities in PWA. The current study's objectives and hypotheses were evaluated using the data collected from all participants, and the findings have been detailed in Chapter IV. These findings are discussed in detail in this chapter under the following heads:

5.1 Symbolic Language Abilities for aided communication

5.1.1 Performance on Symbol Identification tasks

5.1.1a Effect of grid size on identification of symbols

5.1.1b Effect of symbol organization and background colour coding on identification of symbols

5.1.1c Effect of grammatical category of referents on identification of symbols

5.1.2 Performance on Symbol categorization tasks

5.1.2a. Effect of presentation modality on categorization

5.1.3 Performance on Symbol sequencing tasks

5.1.3a Symbol sequence imitation

5.1.3b Symbol sequence production

5.1.4 Overall Performance on symbol-based tasks

5.2 Relationship between symbolic language abilities, verbal language abilities, and non-verbal & verbal cognitive abilities

5.3 Summary of outcome of the hypotheses stated in the study

5.1 Symbolic Language Abilities for Aided Communication

This section is intended towards understanding how and to what extent aphasia affects each of the levels of linguistic processing that the AAC system requires by addressing objectives 1, 2, 3, and 4 of the study. Objective 1 investigated the symbol identification abilities in terms of accuracy, efficiency, and response time in PWA by comparing their performance with that of neurotypical adults as well as comparing performance across subgroups of aphasia (anomic aphasia, Broca's aphasia) and neurotypical adults. Similar comparisons were done to investigate symbol categorization abilities as per objective 2, symbol sequencing abilities as per objective 3. Objective 4 investigated the symbolic language abilities by comparing the overall performance on all seven behavioural tasks in terms of accuracy between PWA and neurotypical adults and across subgroups of PWA and neurotypical adults.

Among the numerous behavioural outcome that can be measured, the current study selected and studied three specific behaviours: accuracy, response time, and efficiency with which the adult participants' identified, categorized and sequenced symbols. Accuracy and response time measures are considered fundamental components of successful aided communication (Wilkinson et al., 2006; 2008; Wilkinson & Coombs, 2010; Wilkinson & Snell, 2011). The accuracy of response is critical because errors can lead to frustrating communication breakdowns. The speed or time taken (response time) for message construction (which involves symbol identification, categorization, and sequencing) is also important. This is because an extremely low rate of message construction (Beukelman & Mirenda, 2013) is one of the most significant barriers faced by AAC users (Wilkinson & Mcllvane, 2013).

Previous literature has discussed the efficiency of response in terms of speed and accuracy of response (Brown et al., 2015). The current study; however, has considered efficiency as the number of attempts required for producing an accurate response. Even though the efficiency measure is closely related to response time, it is an entirely different measure as it provides information on the functional aspect of response which is just as much as clinically relevant as the other two variables studied.

5.1.1 Performance on Symbol Identification tasks

An important aspect in AAC concerns the ability of the user to locate an aided visual symbol on a communication display to facilitate meaningful interaction with communication partners (Alant et al., 2010). Locating a symbol requires visual search and symbol identification. Symbol identification is the receptive understanding of graphic symbols or the individual's ability to discriminate between graphic symbols. The ability to identify symbols in the current study was investigated using three behavioural tasks that involved visual search. Visual search tasks have been used as the most common experimental approach to study basic visual processing and its relation to AAC; wherein the participant is asked to locate a target stimuli and the response time taken to do so is measured (Wilkinson et al., 2006).

To better understand the performance of different participant groups on symbol identification tasks, it would be beneficial to first examine the following data obtained from all three tasks of symbol identification. The neurotypical adults showed 100% accuracy and 97% efficiency in identifying symbols. On the other hand, the performance was slightly reduced for anomic aphasia, wherein they were 97% accurate and 89% efficient in the identification of symbols. Broca's aphasia showed even poorer performance with 81% accuracy and 63% efficiency in identifying symbols. The time taken to identify symbols was shortest for neurotypical adults (1.9 sec), followed by anomic aphasia (3.59 sec) and Broca's aphasia (7.48 sec). The data from all three identification tasks when subjected to analysis revealed that PWA was able to identify symbols; however, they were significantly less accurate, less efficient and took significantly longer response time to identify symbols in comparison with neurotypical adults. These findings are in consensus with previous research which mostly utilized only accuracy measures (Gardner et al., 1974a). Several studies that found the performance of PWA to be comparable to that of neurotypical adults (Koul & Lloyd, 1998; Sawyer-Woods, 1987) used training, whereas the current study did not. Among PWA, the performance between Broca's aphasia and anomic aphasia differed only in terms of response time and not in terms of accuracy or efficiency of response. Koul (1994) and Koul and Lloyd (1998) reported no difference between their subjects with moderate aphasia and global aphasia in terms of the mean number of symbols recognized and suggested that recognition of single graphic symbols may be independent of type and severity of aphasia. Hence, from the present study findings, it is suggested that the identification of single graphic symbols measured in terms of accuracy might be independent of type and severity of aphasia, but the type and severity of aphasia may influence the efficiency and response time taken to identify symbols.

The two subgroups of aphasia in the current study also did not differ in terms of the proportion of errors produced while attempting to identify symbols. The lack of difference could be because of the relatively preserved recognition abilities in Broca's aphasia and the relatively milder language impairment in anomic aphasia resulting in a fewer and similar proportion of errors. Gardner (1974a) reported that non-fluent aphasia produced lesser errors while recognizing symbols in comparison to fluent aphasia. Considering the type of error produced, both anomic and Broca's aphasia produced relatively large proportions of no responses followed by responses that had no direct relation to the stimuli (unrelated errors). No response errors can be assumed to result from a lack of semantic concepts or inability to extract features of the symbols or due to the lack of concreteness of the symbols representing the concepts. They exhibited a relatively small proportion of perceptual, semantic, and perceptual-semantic mixed errors. Thorburn et al. (1995) observed perceptual errors (e.g., brush instead of toothbrush) and semantic errors (e.g., glasses for eyes) among two of their participants with aphasia while investigating their ability to identify a target rebus symbols from a group of semantic, perceptual and unrelated foil. The current investigation differs from Thorburn's study in that the foils were not specifically designed to be semantically or perceptually related to the target. However, such an attempt would have provided better insights into understanding what aspects of symbols facilitated or presented difficulty to PWA, and differentiating from processing difficulty of images in PWA from inherent representational limitations of symbols.

Locating symbols in an AAC system requires PWA to translate the symbols which are much more novel than natural speech. They must understand the meanings and internal representations of unfamiliar symbols. When multiple symbols are used, they must search an array, or multiple arrays or levels to identify a symbol. Most PWA even with good comprehension would have difficulty in carrying out these tasks (Garrett & Kimmelman, 2000). To further elaborate, Carlin et al. (1995) explain that typically top-down processing of visual arrays involves parallel and serial processing. Parallel processing occurs in the early stage of processing and operates parallel across the visual array to extract basic image characteristics (such as colour and orientation) which allow in rapid detection of targets. This is often followed by serial processing which allows for a more focused or localized processing of the visual array where target stimuli are identified as per their multiple or conspicuous defining features. Hence, longer target detection time (or response time) as the number of symbols increases in an array is considered as evidence of serial or attentive processing. Also, when there is no increase in the response time with an increase in array size is suggested to be due to parallel processing of stimuli. Thus, a processing system with capacity limitations affects the pre-attentive (i.e., parallel) and/ or serial stage of visual processing and would be expected to require more time to process an array in the parallel stage and an item in the serial stage of processing.

The speed and accuracy of retrieving symbols can also be influenced by the location of the symbol within AAC devices and the cognitive abilities of an individual such as sustained attention and cognitive flexibility (Perrin et al., 2017). Sustained attention is the ability to maintain a conscious effort during a task while simultaneously inhibiting all other interferences or distractions within the task or in the surrounding environment, while the ability to activate and modify the way we perceive and react to changes during a task is known as cognitive flexibility. Thus, the relatively reduced accuracy, efficiency, and response time in identifying symbols can be attributed to the inherent linguistic impairment, visual processing difficulty, and also to the difficulty in attention and cognitive flexibility.

The efficiency with which an individual can access lexical items in an AAC system is also linked to the efficiency of the AAC system (Fallon et al., 2003). Thistle and Wilkinson (2009) pointed out that various perceptual characteristics of a display might be exploited to enhance the user's ability to perceive and understand the visual aided AAC displays. These characteristics include grid versus schematic scene design, symbol colour, location, and symmetry. Such display characteristics interact with individual characteristics of the user (such as their language, cognition, sensory and motor abilities) and the task demands to influence functional communication outcomes of symbol discrimination and identification. Thus, organizing symbols on AAC devices such as symbol location, size, and colour may be very important for increasing the efficiency and effectiveness of communication (Wilkinson & Jagaroo, 2004).

In the current study, three secondary exploratory questions were enabled by the nature of the behavioural tasks involving the identification of symbols that would facilitate clinicians in clinical decision making on AAC display designs. However, these questions were not directly targeted in the research objective (which was to understand the ability of participants to identify symbols) but seemed of interest to investigate given the ability of the individual to interact with the display designs and symbol features used. The three questions are as follows:

a) What is the effect of grid size on the accuracy, efficiency, and response time taken for the identification of symbols in PWA, subgroups of PWA, and neurotypical adults?
b) What is the effect of grammatical organization and background colour coding on the accuracy, efficiency, and response time taken for the identification of symbols in PWA, subgroups of PWA and neurotypical adults?
c) What is the effect of the grammatical category of referents on the accuracy, efficiency, and response time taken for the identification of symbols in PWA, subgroups of PWA and neurotypical adults?

The above questions are discussed in the following subsections:

5.1.1a Effect of grid size on identification of symbols. The effect of grid size on the identification of symbols in PWA and neurotypical adults was measured using accuracy, efficiency, and response time taken to identify single symbols on a grid display with 4, 8, 12, and 16 symbols from the identification task 1. The results revealed that the neurotypical adults performed significantly better than PWA in terms of accuracy, efficiency, and response time taken to identify symbols. Both groups identified symbols more accurately, efficiently, and with shorter response time on displays having four symbols followed by 8, 12, and 16. Thus, the gradual decline of performance with an increase in grid size was evident in both groups. However, it is worth noting that the rate of decline was different in each participant group.

In PWA, while the mean accuracy of identifying symbols dropped from 100% at grid size 4 to 89% at grid size 16, neurotypical adults showed no such decline in accuracy scores with an increase in grid size. Similarly, while the mean efficiency dropped from 95% at grid size 4 to 83% at grid size 16 in PWA, in neurotypical adults, the mean efficiency remained the same across all grid sizes. The average response time taken to identify symbols increased from 2.74 sec to 3.57 sec as grid size increased from 4 to 16 in PWA; while in the case of neurotypical adults, the increase was from 0.77 sec to 0.99 sec. Thus, at grid size 4, the accuracy and efficiency of performance of PWA were at par with neurotypical adults. Similar results were obtained by Thorburn et al. (1995) during their investigation on the ability of PWA to identify target rebus symbols from a set of four choices.

The performance of subgroups of PWA (i.e., anomic aphasia and Broca's aphasia) also showed a similar trend. Persons with anomic aphasia identified symbols more accurately, efficiently and with less response time than persons with Broca's aphasia. In the case of Broca's aphasia, the mean accuracy and efficiency declined from 100% and 91% respectively at grid size 4 to 79% and 65% at grid size 16, and the average response time increased from 4.27 sec at grid size 4 to 9.41 sec at grid size 16. On the other hand, the mean accuracy did not decline across grid sizes in anomic aphasia as found in neurotypical adults. However, the mean efficiency reduced from

100% at grid size 4 to 97% at grid size 16, unlike neurotypical adults which remained the same for all grid sizes. The average response time increased from 1.42 sec to 2.75 sec as grid size increased from 4 to 16 symbols per display in anomic aphasia, which was slower than neurotypical adults, but faster than Broca's aphasia. Thus, the results of the current study show that there is an effect of grid size on the accuracy, efficiency, and response time taken to identify symbols in PWA, and subgroups of PWA. While the effect of grid size on symbol identification is evident in terms of response time in neurotypical adults.

The results of the present study are consistent with the findings of Petroi et al. (2014), who found that PWA had shorter response latency and higher response accuracy when they located target symbols from among 4 symbols than 16 symbols per display. They attributed this finding to the fact that as the number of symbols on a screen increases, the longer cognitive processing time is required by the persons with aphasia (PWA) to identify those symbols accurately.

In a grid display, placing each symbol in a separate cell separated by boundaries created by lines or spacing minimizes the association of one symbol with other symbols, requiring a minimum degree of localized attention from an individual to each symbol. Each stimulus in the grid is also subjected to object-centred processing, which involves extraction of the object's main axes and perception of form, configuration, boundaries, and contrasts within the object (Wilkinson & Jagaroo, 2004). Thus, determining the target symbol in a grid display may demand more cognitive resources. Further, with an increase in the grid size, the demand again rises, affecting the performance in both neurotypical adults and PWA as found in the current study. Since PWA have impairments of attention, visual perceptual and visual cognitive processing (Purdy & Dietz, 2010), their performance on higher grid sizes considerably declines in comparison to neurotypical adults. The decline in performance of neurotypical adults with increase in grid size is consistent with the findings of Frisch (2020) who reported that their neurologically healthy participants had difficulty in performing when the number of symbols on a screen increased.

5.1.1b Effect of symbol organization and background colour coding on identification of symbols. The processing of stimuli location, recognition, and recall is thought to be aided by colour as it contributes to perceptual attention (Gegenfurtner & Rieger, 2000). Since colour helps to draw attention to certain symbols, they can be used for organizational and coding reasons to make the target locations easily distinguishable and useful to the user so that communication accuracy is increased (Bailey & Downing, 1994). Thus, colour can be utilized to reduce the cognitive demands of AAC related tasks. For example, the use of colour-coded background has been recommended as a method of easing visual processing demands through the utilization of colour-coded display designs such as modified Fitzgerald key (Beukelman & Mirenda, 2005; Goossens et al., 1999). The Fitzgerald key, originally developed to provide visual support to deaf children, was colour coded and applied to AAC displays to group targets together based on semantic-syntactic categories to improve visual access and provide the user with a reference to help locate symbols more easily (Thistle & Wilkinson, 2009).

The current study also utilized the Fitzgerald key for symbol grouping and colour coding to study its effects on the identification of symbols (identification task 2) in each participant group and subgroups. Based on previous studies, it was assumed that colours would reduce the need to visually review each symbol allowing them to restrict the visual search to just symbols with assigned colour according to the symbols part of speech. The current study found that symbol grouping based on word class category and background colour coding cues had no effect on the accuracy, efficiency, and response time required for symbol identification in both PWA and neurotypical adults. Similar results were found for anomic aphasia and Broca's aphasia as well.

To date, studies that have investigated the role of symbol arrangement and background colour cues have been mostly conducted on children, and they have found that background colour does not have an effect on the accuracy and response time for single symbol identification or multi-symbol message construction (Thistle & Wilkinson, 2009; Wilkinson & Coombs, 2010; Wilkinson & Snell, 2011; Thistle & Wilkinson, 2017). However, symbol grouping (in terms of internal symbol colour or implicit cue) was found to have an influence on the accuracy and efficiency of symbol identification in typically developing children. Thistle (2019) who investigated the effect of symbol background colour on the speed of locating symbols in neurotypical adults found no effect of background colour on neurotypical adults' response time. This result is similar to the findings of the current study and previous literature on children. They also found that for adults, background colour cues provided a distinct advantage for a larger array (such as a 60-symbol array) than a 16-symbol array. Thus, the background colour provided grouping that reduced the complexity of the display. It was suggested therefore that for adults, AAC displays may utilize colour coding to highlight parts of speech of symbol. Since the current study did not utilize a symbol array more complex than 16-symbols, it is difficult to arrive at a similar conclusion and hence needs to be further explored.

5.1.1c Effect of grammatical category of referents on identification of symbols. The current study utilized PCS symbols representing nouns, verbs, adjectives, and prepositions to investigate the effect of the grammatical category of referents on the identification of symbols. The results from the study show that both PWA and neurotypical adults identified nouns most accurately and efficiently with shorter response time followed by verbs, adjectives and prepositions. Thus, the order of difficulty in identifying symbols of the various grammatical categories was similar in PWA and neurotypical adults which was also reported in Gardner's (1974a) study that investigated recognition of symbols in PWA.

The largest difference in accuracy scores was evident between nouns and prepositions followed by between verbs and adjectives and between adjectives and prepositions in PWA and in the subgroups of aphasia. The identification accuracy dropped from 94% for nouns to 74% for prepositions in PWA (99% for nouns to 87% for prepositions in anomic aphasia, and 88% for nouns to 59% for prepositions in Broca's aphasia). In other words, PWA made more errors while attempting to identify symbols representing adjectives and prepositions than nouns or verbs. However, for neurotypical adults, there was relatively less difference in the mean identification accuracy for nouns (100%) in comparison to verbs (100%), adjectives (99%), and prepositions (99%).

The findings of the current study are in accordance with previous research that reported nouns were identified more accurately than other word classes such as verbs and modifiers in neurotypical adults (Bloomberg et al., 1990) and PWA (Lin & Chen., 2017). This could be attributed to the concreteness of the referent (i.e., the ease with which stimulus evokes an image of an object or objects) that permit relatively iconic representations of nouns graphically (Schlosser et al., 2014). In other words, the graphic representation of nouns allows preservation of most of the referent's unique features, thus allowing a direct visual-perceptual association with the referent or rendering it highly iconic (Bloomberg et al., 1990). Those symbols which are more familiar and require less specialized knowledge, and those symbols for which well-established routines of decoding exist are easier to identify (Gardner, 1974a). The study findings are in contrast with the results of Shin et al. (2017) who found no difference in the accuracy with which neurotypical adults in Korea identified Korean-based Ewha-AAC symbols representing different word categories (nouns, verbs, and adverbs). It can be assumed that the differences in the transparency of symbols within each symbol set (i.e., Ewha-AAC symbols and PCS) would have resulted in contrasting results.

Verbs, on the other hand, are difficult to represent graphically as it often requires an object which is part of the activity to be depicted in the icons (Kozleski, 1991). A functionally useful representation of verbs depicts enough detail to evoke a clear connotation (Weinrich et al., 1989b). Since different cues such as convention cues (i.e., frozen postures, arrows, and dots) and postural cues (i.e., body postures that deviate from a neutral position) are used to depict action in a fixed or static position (Friedman & Stevenson, 1975; Bloomberg et al., 1990), the perception of iconicity of verbs might differ across individuals even for the same symbol.

Adjectives and prepositions are considered less concrete than nouns and verbs, and hence it is more difficult to represent them graphically. The relative relationship between the referents aids in the identification of modifiers. Prepositions, especially spatial prepositions, often require a representation of a location relative to a reference point (Schlosser et al., 2011). Static representations of prepositions in PCS usually involves the use of a black coloured bar, or two bars or a schematic open box as a reference point along with a ball positioned in relation to a reference point. Sometimes, they also include arrows to serve as movement cues (Schlosser et al., 2014). This very abstract nature of the symbols might account for reduced performance in neurotypical adults. Furthermore, in PWA, accurately identifying symbols from different grammatical categories requires them to rely on the various direct perceptual features as well as indirect conceptual cues which might be difficult given their impairment in visual perceptual and visual cognitive processing.

Similarly, the mean efficiency also showed a decline from 82% for nouns to 58% for prepositions in PWA. While in anomic aphasia, the decrease in efficiency ranged from 92% for nouns to 76% for prepositions, Broca's aphasia showed an efficiency range from 71% for nouns to 41% for prepositions. Neurotypical adults showed a decline in efficiency scores from 98% for nouns to 95% for prepositions. It is noteworthy that even neurotypical adults did not achieve 100% efficiency in accurately identifying nouns. This in turn calls our attention to other factors that might play a role in symbol recognition, such as an individual's cultural background and word knowledge.

The average response time for identifying nouns was the shortest, while prepositions took the longest in both neurotypical adults (1.41 sec - 2.09 sec) and PWA (5.15 sec - 8.58 sec). Among PWA, Broca's aphasia had the longest response time for identifying symbols belonging to all grammatical categories (range: 6.18 sec – 8.97 sec), while for anomic aphasia, it ranged from 3.01 sec to 5.93 sec. The findings in neurotypical adults are consistent with the findings reported by Shin et al. (2017), who stated that among neurotypical adults, the response time required to identify a symbol corresponding to a noun was significantly shorter than an adverb or verb. They also found no significant difference between response time taken to identify adverbs and verbs. The current study findings along with previous literature suggest that the difference in iconicity of symbols affects the performance of even neurotypical adults as evident from the difference in response time taken to recognize and process symbols belonging to different word classes. Similarly, the current study's findings also imply that PWA takes additional cognitive processing time to analyse the properties of the symbol and correlate them with their referents due to their inherent cognitive and language impairments.

5.1.2 Performance on Symbol Categorization Tasks

Categorization or semantic organization reflect how lexical items are organized in an internal lexicon (mental representations) or an external AAC display (Wilkinson et al., 2006). Since most of the picture-based AAC systems depend on non-verbal semantic category selection, it is not enough that PWA have retained their ability to identify symbols for functional use of these systems. They may still experience difficulty in locating symbols if they do not have retained semantic categorization abilities or in other words, have intact semantic knowledge. The ability of PWA to categorize symbols was investigated in the current study using an auditory and a visual categorization task and their performance was compared with that of neurotypical adults.

Before delving into the study's findings, it is important to understand how concepts are semantically organized in a healthy brain and what happens to it after aphasia has incurred. Often, concepts in neurotypical adults appear to be organized hierarchically, from subordinate to basic level to superordinate concepts forming a semantic field or network (Goodglass & Baker, 1976; Kudo, 1987; Marques et al., 2013). To further elaborate, the semantic field has an inner circle that consists of the label of an item/ object, its superordinate association, the most common descriptive adjective (Attribute), and terms related to the object by function (Functional Context). Towards the outskirts of the field are other objects of the same category (contrast coordinates), and verbs denoting actions carried out by the particular object (Function associates). These semantic representations or concepts are constructed from lifelong multimodal verbal and non-verbal experiences, and these information are encoded in modality-specific cortices distributed across the brain (Martin, 2016). As opposed to earlier theories which assumed that concepts arise through direct connections among modality-specific regions, the controlled semantic cognition theory (Ralph et al., 2017) in common with classic neurological models and contemporary theories (Martin, 2016) proposes that semantic representations are activated by cross-modal interactions which are mediated at least in part by a single transmodal hub situated bilaterally in the anterior temporal lobes (semantic control system).

Aphasia is thought to impair a person's ability to categorize, and the reason for this is largely explained by two opposing schools of thought: semantic deficit hypothesis (Caramazza et al., 1982) and conceptual preservation hypothesis (Nicholas, 1998). The semantic deficit hypothesis reasons that underlying semantic representations are impaired in severe aphasia which affects both expressive and receptive processing. The conceptual preservation hypothesis, on the other hand, divides semantic information into conceptual-semantic information (i.e., real-world knowledge about concepts) and lexical-semantic information (i.e., linguistic knowledge) and states that conceptual-semantic information is relatively preserved in severe aphasia and the lexical-semantic information is mostly impaired. Thus, even if a PWA may not be able to point to a chair after hearing the word because of an impairment in the lexical-semantic system, they will still be able to group it with other furniture because of the preservation of the conceptual-semantic system. Numerous empirical evidence support that PWA has relatively intact central semantic representations, and the issue lies with the process by which those representations are activated making it a semantic access disorder than a semantic storage disorder (Crutch & Warrington, 2008; McCleary & Hirst, 1986; Nicholas et al., 2011; Ralph et al., 2017; Van de Sandt-Koenderman et al., 2007).

The current study utilized both auditory and visual stimuli for categorization tasks under the assumption that auditory access is not the only route to semantic knowledge. For example, the concept "apple" can be accessed by either looking at the picture of an apple, reading the word apple or by hearing the word apple. Separate semantic organizations may exist for each of these access systems, each geared to make access easier (McCleary & Hirst, 1986). It was hypothesized in the previous literature on the semantic organization in PWA, that if PWA performs differently when given spoken words versus pictures symbols, then the degree to which their semantic structure remains intact is dependent on the mode of access used.

Participants in this study were asked to choose which of the four superordinate categories (i.e., animal, food, actions, and object) best represented the target picture symbol or a spoken word. Their performance on categorization using both stimuli was measured in terms of accuracy, efficiency, and response time and was averaged. Taking a closer look at the performance data across each of the three dependent measures would seem beneficial in understanding their ability to categorize symbols. PWA (i.e., combined group of persons with anomic aphasia and Broca's aphasia) obtained a median accuracy score of 96.65%, while the score was 100% for neurotypical adults. Considering each subgroup of aphasia separately, anomic aphasia obtained an accuracy score of 98.33%, while an accuracy score of 78.3% was obtained by adults with Broca's aphasia. Similar to accuracy scores, the median efficiency score for PWA was significantly less (72.08%) than those obtained by neurotypical adults (96.04%). Anomic aphasia obtained a 79.9% efficiency score, while the efficiency scores significantly reduced to 56.9% in Broca's aphasia. The response time taken by PWA was significantly longer (7.51 sec) than neurotypical adults (2.45 sec). Anomic aphasia took 6.85 sec, Broca's aphasia took 9.82 sec to perform the categorization tasks, both of which were considerably longer than the response time taken by neurotypical adults. Thus, while anomic aphasia performed at par with neurotypical adults in terms of accuracy, they demonstrated lower efficiency and increased response time in comparison to neurotypical adults. Broca's aphasia, on the other hand, performed poorer than anomic aphasia and neurotypical adults in terms of accuracy, efficiency, and response time.

The current study results are in line with reports of Weinrich et al. (1993) who also had found that all of their participants with severe aphasia (three global aphasia and three Broca's aphasia) could accurately categorize pictures during their baseline measures prior to intervention. The ability to abstract features common to a set of items and then use this information to identify another item from the same set is required for the categorization task. Thus, a successful performance is determined by the individual's knowledge of the items, the associations the items evoke for the individual, and the relationships recognized among these associations (McCleary & Hirst, 1986). Since the participants in the current study with severe aphasia showed some ability to make category selections that are required to use AAC systems, it can be assumed that their semantic-conceptual system is preserved to some extent. Weinrich and his colleagues (1993) had also opined that the ability to categorize pictures or symbols correctly by their participants with aphasia was suggestive of the presence of a functionally intact abstract semantic memory.

Persons with aphasia have been found to be superior in processing subordinate items when compared to more general superordinate categories or basic level items (Crutch & Warrington, 2008). This does not mean that there is a loss of knowledge at the superordinate level and considering the relatively better accuracy scores, we can exclude the possibility that category information was not available in the semantic network. A relatively reduced efficiency score and longer response time would point towards less efficient access to the system. Longer response time in both nonfluent and fluent aphasia for a category verification task using auditory stimuli was reported by Hough (1993). The author suggested that it may be indicative of reduced integration of auditory stimuli, slower accessing of the semantic system and increased initiation time. It was further pointed out by the author that longer latencies are indicative of different organization of lexicon as per semantic memory research with normal adults; however, cautions us to interpret the same without analyzing the entire pattern of performance. Lice and Palmovic (2017) also noted that PWA has a longer response time and lower accuracy scores than neurotypical adults on behavioural categorization tasks (i.e., participants had to judge if the auditory presented words belonged to the category of animate or inanimate objects). However, their observation along with results from event-related potentials studied (N400 and LPC components) made them conclude that PWA has difficulty in both categorization and lexical retrieval.

5.1.2a Effect of Presentation Modality on Categorization. In the current study, collapsing data across the two tasks (i.e., auditory categorization and visual categorization) in each participant group was done to gain an insight into whether the degree to which their semantic structure remains intact is dependent on the mode of access used. Neurotypical adults were 100% accurate in both auditory and visual categorization. PWA (i.e., combined group of anomic and Broca's aphasia) had a median accuracy of 100% for auditory categorization and 96.63% for visual categorization, though the difference was not significant. However, both groups were able to efficiently categorize auditory stimuli (100% in neurotypical adults and 73.75% in PWA) than visual stimuli (93.75% in neurotypical adults and 67.91% in PWA). Both groups took significantly longer response time for visual categorization (3.35 – 8.62

sec) than auditory categorization (1.24 sec- 5.42 sec). The subgroups of PWA also showed a similar trend, wherein the performance of anomic aphasia and Broca's aphasia did not differ significantly between auditory and visual categorization in terms of accuracy, but it did differ in terms of efficiency and response time. While adults with anomic aphasia had an 86.6% efficiency score for auditory categorization, the score was reduced to 74.1% for visual categorization. In the case of Broca's aphasia, a reverse trend was noted wherein the efficiency for auditory and visual categorization was 56.7% and 65.83% respectively. Also, response time taken visually categorize symbols was longer (8.19 sec in anomic aphasia and 11.12 sec in Broca's aphasia) than the time taken to auditorily categorize symbols (5.45 sec in anomic aphasia and 8.41 sec in Broca's aphasia).

Thus, the presentation modality of stimulus did not affect the performance of the participants in terms of accuracy in the present study (i.e., they were equally able to or unable to select appropriate categories when the stimuli were picture symbols or spoken words). In terms of efficiency, the opposite trend in performance of anomic aphasia and Broca's aphasia is suggestive of using a relatively stronger modality to access the semantic system when either of the two access pathways is affected. In other words, the relatively impaired auditory system would have been responsible for poorer efficiency scores for auditory categorization in Broca's aphasia and the use of their relatively intact visual system allowed for increased efficiency for visual categorization. On the other hand, anomic aphasia was able to use their relatively intact auditory modality to access the semantic system similar to neurotypical adults leading to increased efficiency scores for auditory categorization than visual. Considering only visual categorization, difficulty in attending to visual stimuli (presence of picture symbols of categories might have been distracting) or novelty of picture symbols as opposed to auditory stimuli could have also contributed to poorer efficiency scores in all participant groups and subgroups.

The increased response time for visual categorization than auditory categorization in the present study also may support the idea that modality may have an effect on accessing the relatively preserved semantic representations. If this is true, then it might account for the slow rate of message construction on the AAC system in PWA. However, the inherent nature of the visual categorization task may also have contributed to an increase in response time (i.e., the time taken to view the picture symbol, scan the superordinate categories, and initiate the motor activity of placing the symbol card in the appropriate place in the response sheet).

The lack of modality effect on the accuracy of performance was also reported by Nicholas (1998) on adults with nonfluent aphasia. They considered that the lack of effect of presentation modality is due to better performance in categorizing auditory stimuli than expected and poorer performance in categorizing visual stimuli than expected. The author further pointed out that it would be premature to conclude that the impaired performance is due to the deterioration of underlying semantic representations (semantic deficit hypothesis). This is because if semantic representations for a particular concept is impaired, then there will be difficulty making semantic decisions about that concept no matter the stimuli is presented auditorily or visually. They observed that categorization errors in both presentation modalities were only for $1/4^{th}$ of the stimulus items and the rest of the items, errors were made more only for one presentation modality which does not support the semantic-deficit hypothesis. In the present study, the target word which could not be categorized auditorily could be categorized visually and vice-versa. Also, the presence of more proportion of auditory categorization errors than visual categorization errors in both anomic aphasia and

Broca's aphasia supports the idea that the underlying semantic representations might be intact in PWA, but access modality might be impaired.

The observation that even the participant with the least AQ score in the study had an accuracy rate of 40% for categorizing symbols, further supports the above statement of at least partially preserved semantic organization in PWA. Another observation was that between the two participants with poor AQ scores, while one obtained an accuracy score above 80%, the other only obtained a score of 40%. This individual variation in accuracy scores shows that the integrity of semantic organization following aphasia considerably differs from person to person (Simpson et al., 1996) and may not be directly related to the severity of language impairment. The observation of Van de Sandt-Koenderman (2007) that semantic deficits have no relation with severity of language impairment in aphasia is supported from the above observation. However, it needs to be interpreted with caution as a direct correlation analysis of the two data were not done as part of this study. Even then, it brings out the importance of evaluating semantic organization abilities in PWA who are potential candidates for AAC. This argument is supported by Weinrich et al. (1993) who opined that the ability to sort pictures into appropriate categories may be predictive of success in mastering the mechanics of an alternative symbol-based communication system as two of their participants who were unable to categorize were unable to complete AAC intervention successfully.

5.1.3 Performance on Symbol Sequencing Tasks

In a symbol/ picture-based AAC system, symbols that represent a word or concept are often combined to produce meaningful phrases or sentences. Investigations on symbol sequencing in the AAC system has focused more on symbol sequence production and to some extent symbol sequence interpretation (e.g., Sutton et al., 2000;

Sutton et al., 2004; Poupart et al., 2013; Trudeau et al., 2010;) mostly among children, neurotypical adults and individuals with cerebral palsy. The current study investigated symbol sequencing ability using an imitation and a production task between the participant groups. The PWA performed poorer than neurotypical adults in their overall ability to accurately sequence symbols. The performance based on each of the sequencing tasks has been discussed below:

5.1.3a Symbol Sequence Imitation. The current study investigated the ability of participants to produce symbol sequences upon imitation. The purpose of including the symbol sequence imitation task (task 6) was twofold. First, the task resembled the repetition task on the Western Aphasia Battery test and was thought to provide information on visual-motor skills required to use the AAC system unlike the auditory-motor skills used for the production of spoken utterances. Second, it would provide an opportunity for the participants to practice pointing to symbol sequences in the AAC display prior to the symbol sequence production task (Sutton et al., 2000). The results from the study showed that PWA (combined group of anomic aphasia and Broca's aphasia together) and the subgroups of PWA could accurately perform the task similar to neurotypical adults; however, they exhibited decreased efficiency and increased response time. The performance between anomic aphasia and Broca's aphasia did not differ significantly in terms of accuracy, efficiency, or response time. Thus, all the participants exhibited spatial picture or visual memory that is required to sequence symbols in an AAC system. Similar results were also reported by Weinrich et al. (1993) where four out of their six participants with aphasia were found to imitate the symbol sequence involving 3 icons during baseline measures prior to intervention.

5.1.3b Symbol Sequence Production. In order to use an AAC system with graphic symbols (no-tech/ low-tech or high-tech), it is not enough that one can identify individual symbols, but one should be able to combine them into sequences forming utterances (Poupart et al., 2013). The current study utilized a structured picture description task to investigate single sentence productions using symbols arranged in a grid display. The accuracy of single sentence aided productions was compared between PWA and neurotypical adults which revealed that they performed poorer than neurotypical adults. Among the subgroups of aphasia, the performance of anomic aphasia was found to be almost at par with neurotypical adults probably because the severity of language impairment was mild. The subgroup of Broca's aphasia consisted of individuals with moderate to very severe language impairment which justifies their performance being poorer than anomic aphasia and neurotypical adults. Even though the performance of PWA was poorer than neurotypical adults, their accuracy scores show that they benefit in language production when augmented with symbols.

Linguistic analyses of sentences produced along semantic and syntactic domains allowed for a deeper understanding of how the use of symbols augment single sentence productions in PWA. The semantic measures included a total number of symbols, the total number of correct information units for symbols (CIU-S) and percentage of CIU-S. While the total number of symbols included all symbols selected irrespective of their relevance to the target picture stimuli, the total number of CIU-S included only those symbols that were relevant to the target stimuli. The percentage of CIU-S was calculated as the ratio of CIU-S and the total number of symbols multiplied by 100. The total number of symbols selected by anomic aphasia and neurotypical adults were almost the same; however, the total number of CIU-S and % CIU-S were significantly lower than neurotypical adults. This could be viewed as a result of the language impairment in anomic aphasia or due to the abstractness of the symbols representing verbs, adjectives, and prepositions or because of the influence of modality of expression. Smith (1996) had similar assumptions on the tendency to omit words in a picture based communication system and thought it could be due to an underlying linguistic deficit of the user or a communication process for effective communication, or due to modality-specific influences.

It was observed that even neurotypical adults in the present study often failed to select symbols representing adjectives and prepositions while constructing sentences. Previous literature on neurotypical English speaking adults (Sutton et al., 2000; Nakamura et al., 1998) and Japanese speaking adults also reports that constituents tend to get omitted while constructing sentences using graphic symbols. Sutton et al. (2000) suggested that these omissions in neurotypical adults were more than random and could be because of the influence of modality of expression (visual-graphic symbols) which is also supported by the current study findings given these individuals did not possess any language impairment.

Broca's aphasia selected fewer symbols in comparison to anomic aphasia and neurotypical adults and the total relevant symbols as observed from the total number of CIU-S was also significantly lower than the other participant groups. However, considering the total symbols, total CIU-S and %CIU-S, even though Broca's aphasia selected fewer symbols, most of the selected symbols were relevant to the target stimuli. It was observed that despite the limited verbal utterances, the selection of relevant target stimuli in Broca's aphasia resulted in approximately 86% of efficiency in information transfer (as evidenced from %CIU-S), which was found to be 93% in anomic aphasia and 100% in neurotypical adults.

The syntactic measures used in the present study included the percentage of grammatically complete sentences and the percentage of correct verbs. The percentage of grammatically complete sentences using symbols was significantly lower in both anomic aphasia and Broca's aphasia when compared to neurotypical adults. Broca's aphasia had a significantly low percentage of complete sentences in comparison to anomic aphasia as well. The lack of ability to produce grammatically complete sentences in aphasia can be explained based on (a) percentage of the correct number of verbs and (b) error responses.

Verbs have a strong relation with sentence production as they contain the semantic and syntactic information necessary for their generation (Webster & Whitworth, 2012). Persons with aphasia have been shown to have difficulty producing verbs when compared to other word classes as verbs have low imageability, impose additional syntactic and semantic constraints on phrases, and may take on different argument structures increasing the syntactic complexity of sentences (Brock & Hung, 2021). Those adults with aphasia who found it difficult to produce verbs had fewer and simpler sentences than those who were better at retrieving verbs (Berndt et al., 1997), which probably explains why Broca's aphasia had a low percentage of grammatically complete sentences.

On a positive note, Broca's aphasia produced an average of 85% correct verbs, which did not differ significantly from anomic aphasia whose average % of correct verbs was 94%. Weinrich et al. (1997) reported similar findings where all three of their participants with non-fluent aphasia produced verbs using a computerized visual communication system (C-VIC) with 85% accuracy. Thus, despite the greater degree of language impairment demonstrated by individuals having Broca's aphasia, they were able to identify and select symbols representing verbs appropriate to the target picture similar to that of anomic aphasia. In the case of spoken sentences, it is assumed that an impairment in accessing the lexical-syntactic information (argument-predicate structure) generally results in increased verb errors, thus affecting their production.

However, the use of symbols in the current study would have helped alleviate the problem, as the symbols acted as visual cues that enabled easy retrieval of lexicons from recognition memory (Weinrich et al., 1997; Koul et al., 2005). This could have increased the number of accurately selected verbs and grammatically complete sentences, especially in Broca's aphasia.

The description of a static picture requires abstraction and identification of actions (verbs), identification of objects and actors (agent), and assignment of appropriate thematic roles to the actors (Weinrich et al., 1997). In the present study, even with correct verb retrieval, the number of grammatically complete sentences did not increase considerably for adults with aphasia in comparison to neurotypical adults, which allows us to shift our focus on the errors in their production. The error responses were classified into symbol selection errors and symbol sequencing or word-order errors. The symbol selection errors were further classified into omission errors involving predicate and arguments, and lexical errors in terms of substitution of predicate and arguments. The proportion of symbol selection errors was higher in Broca's aphasia when compared to anomic aphasia and neurotypical adults. While Broca's aphasia showed more omission errors, anomic aphasia showed more substitution errors while selecting symbols. Among omission errors, Broca's aphasia and anomic aphasia had a higher proportion of omission of arguments (verbs) than predicates (nouns). The omission errors could be attributed to the lack of concreteness of the symbol which might be making it difficult for PWA to locate them. It is known that nouns are easier to locate as they are concrete and easy to represent in comparison to verbs which is relatively less concrete and difficult to represent using static symbols. Moreover, the ability to allocate attentional resources could be more severely affected in Broca's aphasia than anomic aphasia which affects their visual search task leading to more number of omission errors.

In the present study, the argument errors made by PWA were more agent (subject) errors than instrument (object) errors. McCall et al. (2000) found that their participant produced more noun errors than verbs when asked to locate more than two nouns on the AAC system. The ability of an individual to construct messages on a communication system that is organized based on semantic principles relies heavily on semantic processes such as (a) identification of central feature, (b) appreciation of the semantic relationship between items sharing the same features and (c) discrimination between items that are closely related (Van de Sandt-Koenderman et al., 2007). As a result, it is possible that PWA's difficulties identifying symbols representing agents, which were all more semantically related and perceptually similar than objects, contributed to the higher frequency of agent-related errors. However, this assumption should be interpreted with caution because they had not received any formal training on these symbols, and a lack of training could be a factor in increased errors on agent symbols.

The number of lexical errors (i.e., substitution of arguments and predicates) made by participants of the study was relatively less in comparison to other errors, even in PWA, probably because they only had to choose lexicon only from a limited vocabulary set. Moreover, the vocabulary in the communication display provides stable representations that do not require continuous refreshment while other parts of the sentences are constructed (Weinrich et al., 1997). This improves lexical retrieval, which is otherwise difficult in verbal utterances. Substitution errors might also demonstrate the participants' clear intention to select and use relevant vocabulary to produce messages (Binger et al., 2019) which can be held true for participants with anomic aphasia.

Word order errors (or sequencing errors) were found to be more than other syntactic errors in aphasia in this study. A possible explanation for this can be contemplated with respect to how symbols were arranged on the communication display in the study. The symbols were semantically organized but were not arranged in the syntactic order of the participants' native language (i.e., Malayalam). Instead, the English language word order was (subject-verb-object) used to prevent the participants from drawing cues on the correct semantic-grammatical category for typical components of a message in Malayalam. The influence of arranging symbols as per the English constituent word order on the accurate production of non-semantically reversible sentences was earlier documented in an investigation using C-VIC (McCall et al., 2000).

In the current study, while some participants with aphasia retained the correct word order of Malayalam (i.e., subject-object-verb) for all 13 stimuli, many did not. At this point, it is noteworthy that Malayalam has a flexible word order in which any arrangement of the subject, verb, and object is grammatically licensed and independent of syntactic function, even though it follows the S-O-V order in general (Perera & Srivastava, 2016). Given that all neurotypical adults maintained the S-O-V order despite their knowledge of flexible word order points out to an assumption that word order deficits do exist and it may be due to the lack of knowledge of PWA on the functional role of each component of the message plays in a sentence. Comparing anomic aphasia and Broca's aphasia, the latter showed more word order errors or sequencing errors. This could be because Broca's aphasia is characterized by impairment in the syntactic organization which is manifested as impaired linguistic sequencing (Ardila, 2010) unlike anomic aphasia, and this underlying syntactic impairment can also be found while sequencing symbols to construct sentences (Koul, 2005). Funnell and Allport (1989) also reported errors of word order even in highly practiced sequences during sentence construction tasks using symbols among their participants with aphasia.

Having discussed the performance of aphasia in symbol sequence production, to understand underlying processing deficits for sentence production in aphasia and to specify the processes shared by verbal and aided language, it is essential to review a model of natural (verbal) language production. Garrett's model of sentence production (Garrett, 1984) which was widely used to interpret the ability of PWA to learn to use symbols to construct sentences with intervention (Weinrich et al., 1995; Weinrich et al., 1997; Marshall et al., 1998) was also adopted by the current study for the above purpose. According to this model, sentence production is a five-stage process. In the first stage or the message level, the speaker conceptualizes the utterance. In the second stage or functional level, the semantic relationship between the verb and the arguments are defined. In the current study, the ability of the PWA to retrieve words (especially verbs) relevant to the target stimuli using symbols excludes the possibility that they were unable to process the event depicted in the picture stimuli and shows the integrity of semantic verb formation. Furthermore, the symbols enable PWA to access recognition memory, eliminating the need to generate and retrieve lexical representations, which is required in spoken language (Weinrich et al., 1997). The third stage or positional level is responsible for inserting retrieved words into the syntactic frame and laying out the word order of the sentence. This stage appears to be affected in PWA as evidenced by their syntactic errors in single sentence productions using symbols. The last two stages (i.e., phonetic and articulatory level) of the model responsible for phonological processing and articulation of speech seems irrelevant to aided productions. Thus using symbols allows PWA to bypass the last two stages of sentence productions thus providing an advantage over spoken utterances.

The present study required production of only simple sentences and the participants were provided with all the necessary symbols except for the grammatical markers. The observation that neurotypical adults maintained the same word order for graphic symbol sequences as that of spoken language (Malayalam) supports the findings of Nakamura et al. (1998) that neurotypical adults tend to use their fully mature metalinguistic skills in a situation where all symbols are present and chose to adhere to spoken word sequences of their native language. In situations where AAC systems do not display all the necessary symbols, they would still use their metalinguistic ability to compensate for the lack of grammatical markers (Sutton et al., 2004). The findings in neurotypical adults support the view that graphic symbols are first constructed in a spoken representation and later transferred to graphic symbols (Trudeau et al., 2007). Further, the construction of graphic symbol sequences in PWA showed errors similar to that made in verbal utterances providing further evidence to the above transposition hypothesis of graphic symbol production. Inherent in this view is the need for metalinguistic skills in constructing graphic symbol utterances (i.e., intentional control over various aspects of language such as semantics, morphosyntax, and pragmatics). The presence of errors in graphic symbol production especially in Broca's aphasia can be assumed to be due to the lack of metalinguistic ability in PWA in addition to linguistic impairments.

5.1.4 Overall Performance on Behavioural Tasks

In the current study, PWA could accurately identify approximately 78%-94% of symbols, categorize 78%-98% of symbols, and combine symbol sequences to produce simple two to three-word sentences without training. Horner and Lapointe's (1979) states that the use of picture stimuli minimizes memory load due to its inherent static character, modifies impulsivity and concomitant noise build-up through increased visual scanning and analysis time and provides increased opportunity for PWA to respond independently. This holds true for the participants with aphasia in the current study. The overall performance of PWA on all tasks involving graphic symbols has been discussed in terms of the following:

Symbolic Processing Theories in Aphasia: Multi-symbolic Capacities Theory vs Central Symbolic Deficit Theory. What happens to an individual's ability to process symbols after brain damage is of clinical significance as such an understanding would help to enhance communication with PWA. There are essentially two schools of thought. The first one suggests that aphasia is a central symbolic disorder (Duffy & Duffy, 1981; Duffy et al., 1975; Duffy et al., 1984; Cicone et al., 1979) which results in an overall reduction in the ability to process (i.e., express and comprehend) symbols in any modality. The second school of thought is the "pluralistic" position that suggests verbal and non-verbal communication are differentially affected (Daniloff et al., 1982). Thus, PWA have varying levels of symbolic impairment or in other words, they have multiple profiles of symbolic capacities. While some evidence supports each of the above two hypotheses, there are others who could not fully support either (Thorburn et al., 1995). This, thus leaves the issue open to debate because there are numerous ways to understand the processing of symbols and it is possible that different types of symbols are coded and manipulated differently (Stead, 2007; Stead et al., 2011).

Graphic symbol-based AAC studies in PWA has provided several pieces of evidence in favour of the multiple symbolic capacity theory. For example, previous researches on pantomime interpretation (for example, Varney, 1982; Thorburn et al., 1982; Wang & Goodglass, 1992), disconnection syndromes, sign and gesture dissociations, recognition of graphic symbols (for example, Gainotti et al., 1989; Glass et al., 1973), learning and acquisition of graphic symbols and symbol sequences (for example, Koul, 1994; Koul et al., 2005) points to the fact that PWA performs better in graphic or gestural symbolic systems despite deficits in verbal language or sign language.

The present study findings that PWA, especially those with moderate to severe aphasia can identify, categorize, and sequence non-verbal graphic symbols without intervention provide support to the theory of multiple profiles of symbolic capacities in aphasia. The variability of performances among PWA in all the tasks in the current study depending on the severity of aphasia also supports the aforementioned theory, which predicts that different profiles of symbolic capacities exist depending on the severity of aphasia, site of lesion and other variables. Furthermore, an extension of the current study that compared aided single sentence productions with verbal single sentence productions among the same participants with aphasia found that even those with severe aphasia performed significantly better in the task of sentence production using symbols than verbally, lending support to the multiple symbolic capacities theory (Philip & Goswami, 2021).

The ability of PWA to recognize, categorize, and sequence symbols without training is also supportive of dual coding theory (Paivio, 1991) which is similar to the "pluralistic" position. According to this theory, there exists two functionally independent but interconnected systems, one that specializes in linguistic material (verbal system), and the other that specializes in non-linguistic stimuli (imaginal system). Thus, non-verbal symbols are most likely to be dually coded which would arouse a visual code and hence would be easily available to PWA even if access to the verbal system is damaged (Koul, 1994). The following observations from the present study are supportive of dual coding theory (i.e., graphic symbols arouse both verbal and imagery codes): (a) ability of PWA to identify symbols representing less concrete concepts such as adjectives and prepositions, (b) less number of visual categorization errors than auditory categorization errors, (c) the ability of Broca’s aphasia to verbally produce simple sentences after constructing them using symbols, and (d) the ability of anomic aphasia retrieve words and to correct phonemic paraphasias after pointing to the graphic symbols.

Since graphic symbols form the basic unit of the study, it is necessary to address right hemisphere involvement in the processing of symbolic language which is discussed in the section below:

Right hemisphere involvement in processing of symbols. Linguistic processing has long been assumed to be left-hemisphere-dependent, while non-linguistic processing is right-hemisphere-dependent. Persons with aphasia with little or no ability to communicate using spoken language have been successfully taught to use visual communication systems. These findings support the hypothesis that certain groups of PWA become more dependent on the visuospatial processing strategy of the right hemisphere for communication. Since the current study did not utilize individuals with right hemisphere damage as a comparison group, it is difficult to conclude the role of the right hemisphere processing of symbols. However, it is assumed that the participants with aphasia in the current study would have utilized right hemisphere resources while identifying, categorizing, and sequencing symbols as the study employed graphic symbols or non-verbal linguistic stimuli for all the tasks and the right hemisphere is known to be able to process stimuli of high imagery value.

Further evidence obtained from comparing verbal and aided sentence production in the participants with aphasia from the current study also supports the role of the right hemisphere as sentences produced using graphic symbols were semantically and syntactically superior to verbal utterances (Philip & Goswami, 2020). Similar results have been demonstrated by Weinrich et al. (1989a) whose participants with aphasia demonstrated the ability to perform syntactic like operations with a symbol communication system despite having no useful natural language. They suggested that the anterior language area of the brain for syntactic like cognitive operations may be necessary for natural language and that alternative representations may be able to access analogous operations in other cortical areas. Recent evidence suggests that syntax is neurologically segregated and its components are housed in several distinct cerebral locations. Grodzinsky and Friederici (2006) found portions of the right cerebral hemisphere in the brain map for syntax. Moreover, Haverkort (2005) emphasizes that persons with Broca's aphasia have limitations in the use of grammar, but their grammatical knowledge is still available and they select simpler syntactic structures as it imposes less burden on working memory. This view is supported by the current study results. Thus, understanding the involvement of the right hemisphere in non-linguistic information processing in contrast to the left hemisphere should enable the use of the spared right hemisphere in the rehabilitation of aphasia (Kaczmarek, 1991).

Language competence vs performance theory in Aphasia. The task of differentiating competence from performance in the study of language disorders in PWA is a constant issue (Linebarger, 1998). The competency theory indicates that the basic units of language in the repertoire of PWA are lost due to the destruction of neural tissue; while the performance theory suggests that aphasia cannot be considered as a primary loss of language, but inefficiency in performing various linguistic and cognitive operations (McNeil, 1984; Linebarger & Schwartz, 2005). Linebarger et al. (1998) defined competence as the "range of linguistic operations that the patient is capable of performing under 'ideal' circumstances.

Several evidences supporting performance deficit theory in aphasia were drawn from studies involving AAC. Linebarger (1998) and Linebarger et al. (2000) found that the sentence production ability of PWA improved when they were provided with a computer-based communication system that minimized the processing load for sentence construction. Since the communication system allowed PWA to keep utterances in their working memory and provided no linguistic assistance (i.e., word-finding assistance), the more structured sentences are suggestive of linguistic production competence being relatively preserved in aphasia.

In the current study, the following two observations (a) persons with anomic aphasia could self-correct the phonemic paraphasias in verbal productions via the use of symbols, and (b) persons with Broca's aphasia could produce complete sentences verbally after constructing the sentences using symbols, support the theory that linguistic knowledge is preserved to some extent in PWA. Johannsen-Horbach et al. (1985) thought that the presence of simoultaneous articulation of correct German sentences after training on Blissymbols whose syntax does not reflect German flection endings could support the theory that language competence remains largely undisturbed by aphasia. They assumed that simple sentences as those articulated simoultaneously have premorbidly been called up only in a grammatical form. The authors also assumed that a phonemic-motor store that is subordinate to a lexical content generator has stereotyped phrases, highly overlearned sequences, and frequently occurring flection morphemes. According to them, the intact production of highly overlearned sequences in persons with global aphasia suggests that there should be non-semantic access to the phonemic-motor store which is possibly activated with the mediation of symbol language.

Linebarger & Schwartz (2005) suggested that performance theories have more implications for use of AAC in PWA. They argued that if aphasia is viewed as a performance deficit (i.e., difficulty in accessing, retaining and selecting linguistic information), then the goal of AAC would be to provide indirect support. In which case, the device would help the PWA to utilize preserved language abilities rather than attempting to compensate for the deficits. AAC systems that allow the icons selected to be visible while the sentence construction is being completed, helps retain more elements to integrate them into sentences. This also allows the PWA to fully exploit lexical associations which otherwise is difficult for them. The ability of the AAC system to bypass spoken utterances is also considered as indirect support to PWA. On the other hand, if aphasia is believed to be due to a deficit in linguistic knowledge or ability, AAC may act as direct support (i.e., provide linguistic information in terms of words, phrases or sentences which the PWA might require). Since most of the AAC systems employ graphic symbols or printed text to enable PWA to construct sentences, they tend to provide direct support; but the sentence tab which displays all the icons selected tends to provide indirect support as well. Understanding such AAC system features and selecting them based on clinical and theoretical basis should enhance AAC use in PWA.

5.2 Relationship between Symbolic Language Abilities, Verbal Language Abilities, and Non-Verbal & Verbal Cognitive Abilities

In this section, objectives 5 and 6 of the study are addressed. Objective 5 was to investigate the relationship between symbolic language abilities and verbal language abilities, while objective 6 investigated the relationship between symbolic language abilities and non-verbal & verbal cognitive abilities. Symbolic language abilities were derived from the symbol performance quotient (SPQ) obtained from averaging the accuracy of responses from identification, categorization, and sequencing tasks. The verbal language abilities in PWA was represented by the aphasia quotient (AQ) obtained on the test of aphasia in Malayalam (Malayalam adaptation of Western Aphasia Battery; Jenny, 1992). Aphasia Quotient is thought to be a functional measure of the severity of the spoken language deficit in aphasia (Shewan & Kertesz, 1980). The AQ is inclusive of scores from subtests measuring spontaneous speech, auditory comprehension of language, repetition and naming ability. Since three out of the four subtests rely on speech production, AQ is heavily weighted for speech production (Fridriksson et al., 2018). The cortical quotient (CQ) obtained on the test of aphasia in Malayalam reflects a broad measurement of cognitive behaviours or higher cortical functioning (Shewan & Kertesz, 1980), and was used to represent non-verbal and verbal cognitive abilities in PWA in the current study. The CQ is inclusive of scores from subtests of reading, writing, calculation, drawing, block design test, and Raven's Coloured Progressive Matrices along with weighted scores of remaining subtests used to calculate AQ.

The results of the current study showed a very strong positive relationship between symbolic language abilities and verbal language abilities (as measured using AQ) as well as between symbolic language abilities and non-verbal & verbal cognitive abilities (as measured using CQ). Thus, those individuals with better verbal language and non-verbal & verbal cognitive skills tend to perform better for graphic symbol related tasks. Petroi (2011) also reported a weak but positive correlation between WAB-AQ values and accuracy of single symbol identification and a moderately strong positive relationship between WAB-AQ values and accuracy of S-V-O sentence identification. Their results implied that PWA who had higher AQ values had a greater number of accurate responses and that participants who had lower AQ values had a fewer number of accurate responses while identifying single symbols and constructing S-V-O sentences in English.

Similar findings were reported by Trudeau et al. (2010) who found that their participants with cerebral palsy having better receptive language skills and cognitive level showed more stable patterns while constructing sequences of symbols lending support to the idea that these two factors may facilitate the use of graphic symbol communication. Lane and Samples (1981) observed that those PWA with better auditory comprehension abilities performed better with Blissymbols. PWA who were rapid learners of VIC were found to have less severe aphasia than those who were slower and unsuccessful learners (Steele et al., 1992). Previous literature which has utilized WAB-AQ and WAB-CQ scores to measure outcomes of AAC intervention has been successful in showing improvements in both aided and verbal language skills suggesting an overall improvement in symbolic language processing in PWA with the use of a symbol-based AAC system (Johnson et al., 2008; Hough and Johnson, 2009; Steele et al., 2010).

An inverse relationship between natural language and the use of alternative communication systems (i.e., poorer the natural language, better the use of symbol system) in PWA was reported by Gardner and his colleagues (1976). They believed that the presence of residual, ineffective natural language may cause more difficulty in mastering the visual communication system than having a total lack of natural language. Funnell & Allport (1989) found that the use of symbols failed to provide a channel of communication independent of natural language processes (i.e., whenever a symbol could be learned and used, so could an equivalent written word sharing the same conceptual base).

5.3 Summary of outcome of the hypotheses stated in the study

A summary of the outcomes of the hypotheses in the present study provided in Table 5.1 and Table 5.2.

Table 5.1

Summary and Status of Null Hypothesis 1, 2, 3 and 4 after Statistical Comparisons

Hypotheses	Comparison groups	Dependent Variable measured	Results obtained through statistical comparisons	Null Hypothesis accepted/ rejected
Hypothesis 1. There is no statistically significant difference in the symbol identification abilities in terms of accuracy, efficiency, and response time taken to perform on all three identification tasks combined (Task 1, Task 2 and Task 3): (i) between PWA and neurotypical adults (ii) across subgroups of PWA and neurotypical adults	(i)PWA and neurotypical adults	Accuracy, Efficiency, Response Time	The accuracy and efficiency of identifying symbols in PWA were significantly lower than neurotypical adults. PWA took a significantly longer response time to identify symbols than neurotypical adults	Hypothesis 1. (i) rejected in terms of accuracy, efficiency and response time
	(ii) Anomic aphasia, Broca's aphasia and neurotypical adults	Accuracy	Performance of Broca's aphasia was significantly lower than anomic aphasia and neurotypical adults; Performance of anomic aphasia and Broca's aphasia did not differ	Hypothesis 1. (ii) partially rejected in terms of accuracy
		Efficiency	Efficiency in identifying symbols did not significantly differ between anomic aphasia and Broca's aphasia; Performance efficiency of Broca's aphasia and anomic aphasia was significantly lower than neurotypical adults	Hypothesis 1. (ii) partially rejected in terms of efficiency

Hypotheses	Comparison groups	Dependent Variable measured	Results obtained through statistical comparisons	Null Hypothesis accepted/ rejected
		Response Time	The response time taken to identify symbols did not significantly differ between anomic aphasia and Broca's aphasia; Response time taken by Broca's aphasia and anomic aphasia was significantly longer than neurotypical adults	Hypothesis 1. (ii) rejected in terms of response time
Hypothesis 2. There is no statistically significant difference in the symbol categorization abilities in terms of accuracy, efficiency and response time taken to perform on both categorization tasks combined (Task 4 and Task 5) (i) between PWA and neurotypical adults (ii) across subgroups of PWA and neurotypical adults	(i) PWA and neurotypical adults	Accuracy, Efficiency and Response Time	Performance of PWA was significantly lower than neurotypical adults in terms of accuracy and efficiency. PWA took a significantly longer response time to categorize symbols than neurotypical adults	Hypothesis 2. (i) rejected in terms of accuracy, efficiency and response time
	(ii) anomic aphasia, Broca's aphasia and neurotypical adults	Accuracy	Performance of Broca's aphasia was found to be significantly lower than anomic aphasia and neurotypical adults; Performance of anomic aphasia and neurotypical adults did not differ	Hypothesis 2. (ii) partially rejected in terms of accuracy
		Efficiency	Efficiency in categorizing symbols did not significantly differ between anomic aphasia and Broca's aphasia; Performance efficiency of Broca's aphasia and anomic aphasia was significantly lower than neurotypical adults	Hypothesis 2. (ii) partially rejected in terms of efficiency
		Response time	The response time taken to categorize symbols did not significantly differ between anomic aphasia and Broca's	Hypothesis 2. (ii) partially rejected in terms of

Hypotheses	Comparison groups	Dependent Variable measured	Results obtained through statistical comparisons	Null Hypothesis accepted/ rejected
			aphasia; Response time taken by Broca's aphasia and anomic aphasia was significantly longer than neurotypical adults	response time
Hypothesis 2. a. There is no statistically significant difference in the symbol categorization abilities in terms of accuracy, efficiency, and response time taken to perform on auditory categorization Task (Task 4) (i) between PWA and neurotypical adults (ii) across subgroups of PWA and neurotypical adults	(i) PWA and neurotypical adults	Accuracy, Efficiency, Response Time	The accuracy and efficiency in auditory categorization were significantly lower in PWA than in neurotypical adults. PWA took a significantly longer response time for auditory categorization.	Hypothesis 2.a.(i) is rejected in terms of accuracy, efficiency and response time.
	(ii) anomic aphasia, Broca's aphasia and neurotypical adults	Accuracy	Anomic aphasia had significantly higher accuracy in auditory categorization than Broca's aphasia. While Broca's aphasia had significantly lower accuracy than neurotypical adults, anomic aphasia and neurotypical adults did not significantly differ in their accuracy for auditory categorization	Hypothesis 2.a.(i) is partially rejected in terms of accuracy
		Efficiency	Anomic aphasia and Broca's aphasia did not significantly differ in their efficiency for auditory categorization. Broca's aphasia and anomic aphasia had significantly lower efficiency than neurotypical adults.	Hypothesis 2.a.(ii) is partially rejected in terms of efficiency
		Response Time	A significantly longer response time for auditory categorization	Hypothesis 2.a.(ii) is partially

Hypotheses	Comparison groups	Dependent Variable measured	Results obtained through statistical comparisons	Null Hypothesis accepted/ rejected
			was found only for Broca's aphasia when compared with neurotypical adults. Neither anomic aphasia and Broca's aphasia significantly differed, nor did anomic aphasia and neurotypical adults	rejected in terms of response time
Hypothesis 2. b. There is no statistically significant difference in the symbol categorization abilities in terms of accuracy, efficiency, and response time taken to perform on visual categorization Task (Task 5) (i) between PWA and neurotypical adults (ii) across subgroups of PWA and neurotypical adults	(i) PWA and neurotypical adults	Accuracy, Efficiency, Response Time	The accuracy and efficiency in visual categorization were significantly lower in PWA than in neurotypical adults. PWA took a significantly longer response time for visual categorization.	Hypothesis 2. b (i) is rejected in terms of accuracy, efficiency, and response time.
	(ii) anomic aphasia, Broca's aphasia and neurotypical adults	Accuracy	Anomic aphasia had significantly higher accuracy scores than Broca's aphasia in visual categorization. While Broca's aphasia showed significantly lower accuracy scores when compared with neurotypical adults, anomic aphasia did not differ in terms of accuracy scores when compared with neurotypical adults	Hypothesis 2.b.(ii) partially rejected in terms of accuracy
		Efficiency	Anomic aphasia and Broca's aphasia did not differ in their efficiency for visual categorization. Anomic aphasia and Broca's aphasia had significantly lower efficiency when	Hypothesis 2.b.(ii) partially rejected in terms of efficiency

Hypotheses	Comparison groups	Dependent Variable measured	Results obtained through statistical comparisons	Null Hypothesis accepted/ rejected
			compared to neurotypical adults	
		Response Time	The response time taken by anomic aphasia and Broca's aphasia for visual categorization did not significantly differ. However, the response time was found to be significantly lower for anomic aphasia and Broca's aphasia in comparison to neurotypical adults	Hypothesis 2.b.(ii) partially rejected in terms of response time
Hypothesis 3. There is no statistically significant difference in the symbol sequencing abilities in terms of accuracy of response to perform on both sequencing tasks combined (Task 6 and Task 7) (i) between PWA and neurotypical adults (ii) across subgroups of PWA and neurotypical adults	(i) PWA and neurotypical adults	Accuracy	Accuracy in symbol sequencing in PWA was significantly lower than neurotypical adults	Hypothesis 3. (i) is rejected
	(ii) anomic aphasia, Broca's aphasia and neurotypical adults	Accuracy	Performance of Broca's aphasia and anomic aphasia was found to be significantly lower neurotypical adults; Performance of anomic aphasia and Broca's aphasia did not differ	Hypothesis 3. (ii) is partially rejected
Hypothesis 3.a. There is no statistically significant difference in the symbol sequencing abilities in terms of accuracy, efficiency, and	(i) PWA and neurotypical adults	Accuracy Efficiency Response Time	PWA had significantly lower efficiency and significantly longer response time than neurotypical adults	Hypothesis 3.a.(i) rejected only in terms of efficiency and response time

Hypotheses	Comparison groups	Dependent Variable measured	Results obtained through statistical comparisons	Null Hypothesis accepted/ rejected
response time taken to perform on symbol sequence imitation Task (Task 6) (i) between PWA and neurotypical adults & (ii) across subgroups of PWA and neurotypical adults	(ii) anomic aphasia, Broca's aphasia and neurotypical adults	Accuracy	Anomic aphasia and Broca's aphasia did not differ in terms of accuracy of symbol sequence imitation. Similar findings were obtained when anomic aphasia and neurotypical adults were compared and when Broca's aphasia and neurotypical adults were compared	Hypothesis 3.a.(ii) was accepted in terms of accuracy
		Efficiency	Anomic aphasia and Broca's aphasia did not significantly differ in their efficiency for symbol sequence imitation. Anomic aphasia and Broca's aphasia had significantly lower efficiency when compared with neurotypical adults	Hypothesis 3.a.(ii) is partially rejected in terms of efficiency
		Response Time	The response time obtained by anomic aphasia and Broca's aphasia did not significantly differ; however, both subgroups of aphasia had significantly longer response time when compared to neurotypical adults while performing on symbol sequence imitation task	Hypothesis 3.a.(ii) is partially rejected in terms of response time
Hypothesis 3. b. There is no statistically significant difference in the symbol sequencing	(i) PWA and neurotypical adults	Accuracy	PWA had significantly lower accuracy for symbol sequence production tasks when compared to neurotypical adults	Hypothesis 3.b.(i) was rejected.

Hypotheses	Comparison groups	Dependent Variable measured	Results obtained through statistical comparisons	Null Hypothesis accepted/ rejected
abilities in terms of accuracy of response to perform on symbol sequence production Task (Task 7) (i) between PWA and neurotypical adults (ii) across subgroups of PWA and neurotypical adults	(ii) anomic aphasia, Broca's aphasia and neurotypical adults		Anomic aphasia had significantly higher accuracy than Broca's aphasia, but significantly lower than neurotypical adults. Broca's aphasia also had significantly lower accuracy scores than neurotypical adults	Hypothesis 3.b.(ii) is rejected
Hypothesis 4. There is no statistically significant difference in the symbolic language abilities in terms of accuracy of response while performing all tasks of identification, categorization and sequencing combined (i) between PWA and neurotypical adult (ii) across subgroups of PWA and neurotypical adults	(i) PWA and neurotypical adults	Accuracy	The PWA had significantly lower accuracy than neurotypical adults	Hypothesis 4. (i) is rejected.
	(ii) anomic aphasia, Broca's aphasia and neurotypical adults	Accuracy	Anomic aphasia and Broca's aphasia did not significantly differ in terms of accuracy. Anomic aphasia and Broca's aphasia had significantly lower accuracy scores when compared with neurotypical adults	Hypothesis 4. (ii) is partially rejected.

Table 5.2

Summary and Status of Null Hypothesis 5 and 6 after Statistical Analyses

Hypothesis	Variables	Result from statistical analyses	Status of null hypothesis
Hypothesis 5. There is no significant correlation between symbolic language abilities and verbal language abilities	Symbol performance quotient (SPQ) and aphasia quotient (AQ)	A very strong positive correlation was found between symbolic language abilities and verbal language abilities in PWA	Hypothesis 5 is rejected
Hypothesis 6. There is no significant correlation between symbolic language abilities and non-verbal & verbal cognitive abilities	Symbol performance quotient (SPQ) and cortical quotient (CQ)	A very strong positive correlation was found between symbolic language abilities and non-verbal & verbal cognitive abilities in PWA	Hypothesis 6 is rejected

CHAPTER VI

SUMMARY AND CONCLUSIONS

"Aphasia is a communication disability due to an acquired impairment of language modalities caused by focal brain damage" (Berg et al., 2020, p.7). It is estimated that more than 50% of persons having aphasia do not recover enough language skills that enable independent communication (Purdy & Dietz, 2010), which makes them potential candidates for AAC intervention. AAC intervention includes any communication strategy used to supplement or replace spoken language, auditory comprehension, written expression, or reading comprehension (Beukelman & Mirenda, 2012). The use of AAC in PWA to improve communication have been trialled only since the 1980s. Even though the literature on AAC in PWA is limited (McNaughton & Light, 2015; Russo et al., 2017), there are several documentation of positive outcomes for its use in this population. Despite these encouraging reports, implementing AAC for PWA presents unique challenges due to their inherent language and cognitive impairments.

The linguistic impairments (such as semantic processing, grammar, and syntax deficits) that are experienced by PWA can affect all types of symbolic communication including the ability to understand or categorize icons that represent concepts within an AAC system (Vallila-Rohter & Kiran, 2013a, 2013b). The cognitive impairments in PWA (such as executive functioning, attention and memory impairments) affect their ability to initiate the use of AAC, poor generalization to untrained items and large variation of response (Taylor et al., 2019). Determining residual linguistic and cognitive capacities in PWA is often difficult; however, effective non-verbal rehabilitation needs to evaluate how they understand and use non-verbal concepts (Stead, 2007).

The reviewed literature on understanding symbolic language abilities for using aided AAC in PWA highlights several research gaps. The first one is the presence of an insufficient number of researches involving AAC in PWA to enable our understanding of how symbolic language skills required to use a visual-based alternative communication system is affected by each type and severity of aphasia. Second, the intervention studies that gave evidence towards the ability of PWA to identify, categorize and sequence symbols to use aided AAC, often failed to show generalization of abilities. The lack of ability of PWA to use an AAC system for independent communication demands researchers to re-explore the skills required to these systems. Third, the outcome measure used in most of the intervention studies on AAC in PWA used accuracy of response as their only dependent variable; even though the use of response time and efficiency of response would better quantify inefficient processing of non-verbal linguistic stimuli. Fourth, the relationship between verbal language, non-verbal language, and non-verbal cognitive skills is complex and thought to interfere with the learning and acquisition of AAC in PWA; however, this area of research has received less attention in comparison to the understanding influence of language impairments on use of AAC in PWA. Last, but not least, only a single study was found on the Indian population that explored the use of AAC in PWA which shows the huge imbalance between the number of evidence generated and the proportion of evidence required for implementing AAC, given India has the second-largest number of PWA in the world (Dietz, 2019).

In light of the above research gaps, the present study was designed to determine the symbolic language abilities for aided communication in PWA using a quasi-experimental research design. Specifically, one independent variable (behavioural tasks to identify, categorize, and sequence AAC symbols) was systematically manipulated to observe changes in three dependent variables (i.e., accuracy, efficiency and response time) in PWA and their subgroups (clinical group) as well as neurotypical adults (control group). A total of 20 PWA (inclusive of subgroups of PWA, i.e., 10 persons with anomic aphasia and 10 persons with Broca's aphasia) and 20 neurotypical adults participated in the study. The obtained data were subjected to descriptive and inferential statistical analyses to enable between-group and within-group comparisons of performance on behavioural tasks. The data was also used to determine the relationship between symbolic language abilities, verbal language abilities and non-verbal cognitive abilities. The verbal language abilities and non-verbal & verbal cognitive abilities were obtained from aphasia quotient and cortical quotient measures respectively on the test of aphasia in Malayalam. Several supplementary analyses were also done with the obtained data to gain a better understanding of the performance of the participant groups on the behavioural tasks.

The results from the present research provide evidence that PWA can identify, categorize and sequence graphic symbols at varying levels and hence can be employed in treatment to enhance communication. To further elaborate, the salient findings of the study are provided below:

- A significant difference between PWA and neurotypical adults was observed in terms of accuracy, efficiency, and response time taken to identify symbols from all three tasks of symbol identification. The performance of Broca's aphasia and anomic aphasia on symbol identification tasks did not significantly differ in terms of accuracy, efficiency, but differed in terms of response time. Anomic aphasia and Broca's aphasia had significantly lower accuracy and efficiency with a longer response time for identifying symbols in comparison to neurotypical adults.

- A significant effect of grid size on the identification of symbols was found in PWA, their subgroups and neurotypical adults. It was found that accuracy and efficiency lowered and response time increased with an increase in the number of symbols per display (grid size) from 4 to 16. At gird size 4, the performance of PWA was the same as that of neurotypical adults.
- A significant effect of the grammatical category of referents on the identification of symbols was observed among participant groups and subgroups. Among the grammatical category of referents, nouns were identified with the most accuracy, efficiency, and shorter response time followed by verbs, adjectives, and prepositions in PWA, their subgroups and neurotypical adults.
- Considering all tasks of symbol categorization, the performance of PWA was significantly lower than neurotypical adults in terms of accuracy, efficiency, and response time. Anomic aphasia and Broca's aphasia did not significantly differ in terms of accuracy, efficiency, and response time taken to categorize symbols. The performance of anomic aphasia and Broca's aphasia was significantly lower than neurotypical adults in terms of accuracy, efficiency, and response time.
- Persons with aphasia performed significantly poorer than neurotypical adults on auditory categorization tasks in terms of accuracy, efficiency, and response time. Anomic aphasia and Broca's aphasia was found to significantly differ in their ability to auditorily categorize only in terms of accuracy. While Broca's aphasia significantly differed from neurotypical adults in terms of accuracy, efficiency and response time taken to auditorily categorize; anomic aphasia differed from neurotypical adults only in terms of efficiency.

- The performance of PWA on visual categorization was significantly poorer than neurotypical adults in terms of accuracy, efficiency, and response time. Broca's aphasia and anomic aphasia significantly differed in their ability to visually categorize only in terms of accuracy. Anomic aphasia differed from neurotypical adults in terms of efficiency and response time; while Broca's aphasia differed from neurotypical adults in terms of all three dependent variables.
- Considering the performance between auditory and visual categorization, the performance significantly differed only in terms of efficiency and response time in PWA and neurotypical adults. In anomic aphasia and Broca's aphasia, a significant difference between auditory and visual categorization was found in terms of efficiency and response time.
- The performance of PWA on symbol sequencing tasks was significantly reduced than neurotypical adults in terms of accuracy. Performance of anomic aphasia and Broca's aphasia did not differ; however, their performance was significantly lower than neurotypical adults.
- A significant difference was observed between PWA and neurotypical adults for symbol sequence imitation in terms of efficiency and response time. Both anomic aphasia and Broca's aphasia performed significantly poorer than neurotypical adults in terms of efficiency and response time taken for symbol sequence imitation task; however, there was no difference in the performance of Broca's aphasia and anomic aphasia in terms of any of the dependent variable measured.
- For the symbol sequence production task, the PWA obtained a significantly lower accuracy score than neurotypical adults. The same was observed for both

Broca's aphasia and anomic aphasia in comparison with neurotypical adults. Among the subgroups of aphasia, Broca's aphasia performed significantly poorer than anomic aphasia in terms of accuracy.

- Linguistic analyses of single sentences constructed using PWA was done in terms of semantic and syntactic measures between anomic aphasia, Broca's aphasia, and neurotypical adults. Anomic aphasia and Broca's aphasia, as well as Broca's aphasia and neurotypical adults, differed significantly from each other on all measures of semantics (i.e., the total number of symbols selected, the total number of correct information units for symbols (CIU-S) and % of CIU-S). Anomic aphasia and neurotypical adults differed only in terms of CIU-S and % CIU-S. In syntactic measures, anomic aphasia and Broca's aphasia differed significantly in terms of % of complete sentences, while no difference was found for % of correct verbs. On the other hand, anomic aphasia and neurotypical adults differed in both syntactic measures and so did Broca's aphasia and neurotypical adults.
- The symbolic language score obtained from accuracy scores of all behavioural tasks by PWA and their subgroups were significantly lower than neurotypical adults.
- A very strong positive correlation was found between symbolic language abilities and verbal language abilities as well as between symbolic language abilities and non-verbal & verbal cognitive abilities in PWA.

6.1 Implications of the Study

Demonstration that PWA can identify, categorize, and sequence symbols without intervention is an encouraging finding for the development of AAC systems as well as designing AAC intervention. The communicative performance of such individuals with aphasia can be enhanced by configuring communication systems around their residual abilities. The clinical implications of the findings of the study are discussed in the below sections.

Insights from identification tasks

The present study results showed that PWA has the ability to identify symbols from a grid display and their performance increases when the number of symbols per display is less, and when the symbols were more concrete than abstract. The results contribute to our understanding of symbols and display characteristics that may impact the identification of symbols in a grid display. It is known that locating each symbol on a grid via an explicit visual search for relevant graphic places significant demands on attention and short-term memory (Dukhovny & Zhou, 2016). Since PWA are known to have deficits in attention and short-term memory (Garrett & Kimelman, 2000), it becomes essential that the cognitive load of locating a graphic symbol be reduced to ensure that the message production is not affected. One way to reduce cognitive load would be to decrease the number of symbols per display or start with a smaller grid size (probably with 4 symbols). Even though the present study only investigated the effect of grid size on the identification of symbols, it is necessary to consider two features closely related to grid size (i.e., icon/symbol location and symbol/icon size). These two features allow a grid display to be either location centred design or size-centred grid design. In a size centred design, the icon location changes with a decrease in the size of the icon or as grid size decreases, thus forcing the user to relearn the visuospatial arrangement of the grid. This will require them to conduct explicit visual searches to locate the target icon. On the other hand, the location-centred design introduces an initial AAC grid with several small icons and then progressively add icons on the grid keeping the locations of the previously introduced icons constant. This method is presumed to improve learning and reduce cognitive demands of the device as the user is not required to relearn the visuospatial arrangement of the grid as new icons are introduced (Dukhovny & Zhou, 2016). Thus, maintaining consistent symbol placement may support procedural memory thus significantly reducing the cognitive load of searching for the appropriate symbol. Given the limited resource allocation capacity and reduced perceptual processing in PWA, it can be speculated that their performance on a grid-based AAC system would be enhanced by using a small grid size and a location-sized design. However, future investigations are required to gather scientific evidence for the above hypothesis. Even then, it may be beneficial to include consideration of grid size, size-centred and location-centred design during AAC assessment in PWA. Since sustained attention assists in determining the ease with which he or she would be able to learn symbol locations on a symbol grid (Perrin et al., 2017), the assessment may also include tasks to measure sustained attention.

The finding from the present study that the concreteness of the symbol affects the ease with which they are identified, introducing more concrete symbols such as nouns and transparent verbs for PWA who are first-time users of AAC would seem beneficial. Since grid displays use static symbols and abstract symbols such as opaque verbs, adjectives and prepositions are difficult to represent graphically, additional assistance might be provided to PWA during AAC intervention in guiding them to select those symbols.

Insights from Categorization Tasks

The results from both behavioural tasks involving categorization provide evidence that PWA can make category selections that are required by most of the picture or graphic-symbol based AAC systems, though the extent and ease with which they perform will not be the same as that of neurotypical adults. It can be assumed that the independent use of a visual-graphic based communication system such as that of an AAC requires visual categorization abilities relatively more than auditory categorization; however, both skills are thought to be essential during the training phase given PWA benefits from multimodal stimulation.

Most of the AAC system requires a PWA to select symbols from categories for actions, people, and objects. The present study used objects as well as action categories in the categorization task, and informally it was observed that they made more errors while categorizing actions than objects. The suggestions provided by Baker (1992) and Nicholas (1998) to minimize the number of action icons while introducing AAC, providing extra assistance for training actions category, or organizing action icons along with objects they are most likely to be used with receives support from the above observation in the present study.

Insights from Symbol Sequencing Tasks

The results from symbol sequencing tasks provide encouraging findings that persons with even severe Broca's aphasia have the ability to construct simple S-V-O sentences using symbols despite their difficulty to verbally produce sentences as seen on the test of aphasia in Malayalam. Some of the persons with severe expressive (Broca's) aphasia could verbally produce simple sentences after constructing those using graphic symbols. It was also observed that symbols facilitated word retrieval abilities and alleviated phonemic paraphasic errors in anomic aphasia. All of these findings and observations imply that AAC can be used as a compensatory strategy to convey the desired message despite their linguistic, cognitive, and motor limitations, and they may also contribute to a restorative approach in terms of facilitating word retrieval in those individuals with aphasia having mild language impairment.

In summary, the findings from the present study have important clinical implications as they support the claim that AAC can be used to enhance communicative abilities of PWA and hence should be considered as an active treatment option (Koul et al., 2005) rather than a last resort. The behavioural tasks utilized in the study can be used to develop an AAC assessment tool for PWA to gain insight into all the resources and strengths of PWA while planning AAC intervention for communication. The study also supports Sandt-koenderman's (2004) opinion that determining only the type and severity of aphasia may be insufficient indicators of the success of an aided AAC and hence assessment must go beyond the administration of a standard aphasia battery.

6.2 Strengths of the Study

- The study is the first of its kind to provide evidence on symbolic language abilities required to use aided AAC among PWA in India.
- The study utilized a quasi-experimental group design (non-equivalent comparison group research design). Since randomization of participants is required to meet the requirements of a true experimental design, a non-equivalent comparison group design, which has properties similar to a classic experimental design but without randomization, was utilized to answer the research objectives. The design is considered superior to non-experimental research design as it allows manipulation of the independent variable and hence improves the internal validity of the study.
- Since randomization was difficult, including a comparison group (neurotypical adults) matched based on assigned variables decreased the subject selection bias and provided control of extraneous variables to some extent, thus increasing the internal validity of the study.

- The study utilized an adequately sized sample through sample size calculation taking into consideration the level of significance and power of test values. An adequately sized sample is expected to allow the drawing of precise and accurate conclusions from the data measured.
- The use of accuracy, efficiency, and response time measures as dependent variables provided a better understanding of the processing of symbolic language abilities unlike previous studies in the literature which utilized only accuracy measures.
- The study participants from the experimental group (PWA) could be further grouped into anomic aphasia and Broca's aphasia, thus incorporating persons from two major types of aphasia (i.e., fluent and non-fluent aphasia) into the study. This allowed the formation of a more homogeneous study group which provided better insight into how aphasia of different types and severity perform on the behavioural tasks utilized to tap symbolic language abilities.
- The study utilized picture communication symbols (PCS) which is the most widely used symbol set across the globe both for clinical and research purposes. This allowed comparison of the study results with that of previous literature findings.
- The design of the behavioural tasks and the stimuli used in the present study was such that the behaviours elicited resembled the naturally occurring behaviours while using an aided AAC in real-life situations, thus improving the ecological validity of the study. For example, the study developed the stimuli material similar to that of a no-technology AAC system (such as a communication book) using a commonly used symbol set and utilized single finger pointing to record responses. This resembled real-life/ clinical situations

as observed wherein many PWA tend to use no-tech AAC systems as opposed to high-tech AAC systems due to socio-economic constraints as well as lack of easy availability of technology.

- Along with analyses to meet primary objectives, several supplementary analyses were performed as found necessary to gain more insight into the interaction of various AAC system features on the symbolic language abilities of PWA.
- The evidence from the present study can be utilized for AAC assessment in PWA as well as designing an AAC system when first introduced to a PWA.

6.3 Limitations of the Study

- The study utilized the purposive sampling method and hence the inferential generality (external validity) of results from sample to a population is limited. Subsequent studies with a representative sample will be required to generalize the study findings.
- The study participants were not a representative sample as they were not randomly selected from the population which again limits the validity of the study.
- The study did not include all types of aphasia (such as Wernicke's aphasia or global aphasia) due to the inclusion of criteria of auditory comprehension score of greater than five for the experimental group. According to the participation model of AAC assessment and treatment (Beukelman & Mirenda, 2012), AAC follows no candidacy rule (i.e., any individual with communication needs is an AAC candidate. However, understanding how other types of aphasia perform on tasks of symbolic language abilities would have aided our knowledge in assisting them for further AAC intervention.

- The present study did not employ Indian picture symbols for communication (IPSC) as stimuli for the behavioural tasks despite the symbols being developed for the Indian population as there was no published literature on the iconicity of symbols or socio-cultural validation of symbols for different states in the country.
- The study did not employ an objective method for the presentation of stimuli or measuring of the dependent variables (for example, software such as DMDX or E-Prime)
- The study did not use any existing high-technology AAC device to measure the performance on the tasks even though the tasks were designed such that they could have been customized on an AAC device.

6.4 Future directions

The present study, which is the first of its kind, opens up several opportunities for future research in the field of AAC and aphasia. As an extension of the current study, an investigation that explores the predictive capability of symbolic language performance quotient, aphasia quotient and cortical quotient on the outcomes of AAC intervention in PWA can prove beneficial. Since both linguistic and cognitive capabilities are necessary for achieving communicative competence using AAC in PWA and the current study only investigated linguistic capabilities, future studies can evaluate the effect of cognitive impairments (such as working memory, attention, executive functions) on AAC use among PWA. Further studies along the same lines, can include all types and severity of aphasia, individuals with right hemisphere damage, and also individuals with other focal and diffuse lesions causing linguistic and cognitive disturbances. They may also explore the extent to which the abilities assessed in the task rely on right hemisphere processing.

Each of the tasks designed in the current study can be modified to gain further understanding of the symbolic language abilities. The identification tasks could incorporate higher grid sizes (such as above 16 symbols per display) to understand the effects of cognitive taxing on the performance of the task. It may also help in understanding AAC system features that facilitate the use of AAC in PWA. For example, the effect of symbol organization and colour coding on symbol identification was not found in any grid size less than 16 in the present study and previous studies report the effect to be evident on higher grid sizes. The categorization tasks may involve the "people" category as most of the AAC systems use basic categories such as people, actions and objects, out of which the present study had the latter two. Future studies may also involve exploring the performance of PWA across semantic categories (such as comparison of performance across people, actions and objects) and also the effect of semantic-interrelatedness on categorization abilities in PWA (i.e., comparison of category decision abilities on semantically related categories vs semantically unrelated categories). The symbol sequence imitation task in the present study involved test stimuli ranging from two symbol combinations to four symbol combinations. Future studies may investigate the ability to imitate symbol sequences across the length of the stimuli. The symbol sequence production task in the current study only required the participants to construct simple S-V-O sentences. Future investigations may study the effect of different types of sentences or sentences of varying syntactic complexity on the performance of PWA.

Furthermore, the stimuli used in all the tasks could be replaced with either Indian picture symbols for communication (IPSC) or PCS® In-context symbols, if any attempts of systematic replication of the current study are undertaken in the future. The advantage of IPSC being indigenous and the PCS® In-context symbols being specifically designed for adults to allow for understanding the effect of symbol sets on the performance of PWA on tasks that tap symbolic language abilities. Furthermore, the effect of animated symbols on the performance of tasks, especially identifying and locating action verbs, adverbs, and prepositions can be explored in this population. With respect to AAC system layout, evidence from recent research points towards the use of visual scene displays (VSD) over traditional grid displays for PWA. The basis of message representation and navigation in AAC systems that utilize VSDs with personally relevant contextualized images are autobiographical memory and visual-cognitive abilities than linguistic processing (Dietz et al., 2006). Future research may explore the effect of VSDs over grid displays on communicative competence in PWA.

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APPENDIX-A

ETHICS COMMITTEE APPROVAL CERTIFICATE

All India Institute of Speech and Hearing
(An autonomous Institute under the
Ministry of Health and Family Welfare, Govt. of India)
Center of Excellence - Assessed & accredited by NAAC with 'A' Grade
ISO 9001: 2015 Certified Institute
Manasagangothri, Mysuru - 570 006

ಅಖಿಲ ಭಾರತ ವಾಕ್ ಶ್ರವಣ ಸಂಸ್ಥೆ
ಮಾನಸಗಂಗೋತ್ರಿ, ಮೈಸೂರು - 570 006
अखिल भारतीय वाक् श्रवण संस्थान
मानसगंगोत्री, मैसूरु - 570 006

ETHICS COMMITTEE APPROVAL FOR BIO-BEHAVIORAL RESEARCH PROJECTS INVOLVING HUMAN SUBJECTS AT AIISH

AIISH ETHICS COMMITTEE (AEC)

Title of the thesis	:"Symbolic language abilities for aided communication in persons with Aphasia"
Guide	: Dr. S P Goswami
Candidate	: Ms. Vineetha Sara Philip
Proposed Duration of the Research study	: 3-5 years
Source of Funding	: A!ISH Research Funds
Reference number of the proposal	: WF-180/2018-19
Date on which AEC meeting was held	: ----
Clear statement of decision reached at AEC meeting (in the event of a proposal being not approved, a statement of reasons for the same must be indicated)	: **Provisionally Approved**
Advice & Suggestions (If any)	: Nil

Date: 21.12.2020

Signature & Name of Member Secretary
Dr. Animesh Barman
Professor of Audiology, Department of Audiology
All India Institute of Speech and Hearing, Mysore
Member Secretary
AIISH ETHICS
COMMITEE

Phone : 0821-2502000 / 2502100 Toll Free No. 18004255218 Fax : 0821-2510515,
e-mail : director@aiishmysore.in / directoraiish@gmail.com, web: www.aiishmysore.in

APPENDIX-B

INFORMED CONSENT FORM

**All India Institute of Speech and Hearing (AIISH), Manasagangothri,
Mysore- 570006, Karnataka, India**

<u>Consent to Participate in a Research Study</u>

Title of the study	**Symbolic Language abilities for aided communication in persons with aphasia**
Investigator	**Ms. Vineetha Sara Philip**
Guide	**Dr. S.P.Goswami**

I Ms. Vineetha Sara Philip, Junior Research Fellow at All India Institute of Speech and Hearing (AIISH), Mysore is conducting a study on symbolic language abilities required for using aided communication in persons with Aphasia. During the course of the study, I will be administering certain tasks which involves picture symbols. Audio and video recording of the sessions will be done for later analysis of responses. It is assured that these recordings will be kept confidential. There are no risks or discomforts or involved during the study. Participation in the study is purely voluntary and not compulsory. You may choose to withdraw from the study at any point in time.

Informed Consent

I have been informed about the study and understand its purpose and my/my son's/daughter's/ spouse's participation in it. I understand that there are no risks involved by extending my/ my son's/daughter's/ spouse's participation as a human subject in the study. I understand that I have a right to refuse participation or withdraw my consent at any time. I willingly give my consent for my/ my son's/daughter's/ spouse's participation in this study.

Signature
(Name and Address)

All India Institute of Speech and Hearing (AIISH), Manasagangothri, Mysore- 570006, Karnataka, India

ഗവേഷണത്തില് പങ്കെടുക്കാൻ ഉള്ള സമ്മതപത്രം

പഠനത്തിൻടെ പേര്	സിംബോളിക് ലാംഗ്വേജ് എബിലിറ്റീസ് ഫോർ എയ്ഡഡ് കമ്മ്യൂണിക്കേഷൻ ഇൻ പേഷ്യൻസ് വിത്ത് അഫേസിയ
ഗവേഷക	വിനീത സാറ ഫിലിപ്പ്
നിർദേശകൻ	ഡോ. എസ് പി ഗോസ്വാമി

വിനീത സാറ ഫിലിപ്പ് എന്ന ഞാൻ ഓൾ ഇന്ത്യ ഇൻസ്റ്റിറ്റ്യൂട്ട് ഓഫ് സ്പീച് ആൻഡ് ഹിയറിങ്ങിലെ ജൂനിയർ ഗവേഷക ആണ്. ഞാൻ അഫേസിയ ഉള്ളവരിൽ ചിത്രങ്ങൾ ഉപയോഗിച്ച് ആശയവിനിമയം നടത്തുവാനുള്ള കഴിവുകളെ കുറിച്ചാണ് പഠിക്കുന്നത് . ഈ പഠനത്തിനായി ഞാൻ ചിത്രങ്ങൾ ഉൾപ്പെടുത്തിയിട്ടുള്ള കുറച്ചു പ്രവർത്തികൾ ആണ് ചെയ്യിപ്പിക്കാൻ ഉദ്ദേശിക്കുന്നത് . ഈ പ്രവർത്തികൾ ചെയ്യുന്നതിൻറെ വിഡിയോചിത്രം എടുക്കുന്നതായിരിക്കും. ഈ വിഡിയോചിത്രങ്ങളുടെ സ്വകാര്യത നിലനിർത്തുന്നതായിരിക്കും. ഈ പഠനത്തിൽ നിങ്ങൾ പങ്കുചേരുന്നത് കൊണ്ട് നിങ്ങൾക്ക് യാതൊരുവിധ അപകടമോ, നഷ്ടമോ, ഉണ്ടായിരിക്കുന്നതല്ല. ഈ പഠനത്തിൽ പങ്കുചേരുന്നത് തികച്ചും നിങ്ങളുടെ ഇഷ്ടാനുസരണം ആയിരിക്കും, യാതൊരു വിധത്തിൽ ഉള്ള നിർബന്ധവും ഉണ്ടായിരിക്കുന്നതല്ല . പഠനം തുടങ്ങിയതിനു ശേഷം എപ്പോൾ വേണമെങ്കിലും നിങ്ങക്ക് ഇതിൽ നിന്നും പിന്തിരിയാവുന്നതാണ്.

വിവരങ്ങള് വ്യക്തമാക്കിക്കൊണ്ടുള്ള സമ്മതം

ഈ പഠനത്തെ പറ്റിയും, ഇതിൽ എൻ്റെ, എൻ്റെ മകൻ/മകൾ/ ഭർത്താവ്/ഭാര്യയുടെ പങ്കിനെ കുറിച്ചും എനിക്ക് പറഞ്ഞു തരികയും , അതിനെ പറ്റി ഞാൻ പൂർണമായും മനസിലാക്കുകയും ചെയ്യുന്നു. ഈ പഠനത്തിൽ പങ്ക് ചേരുന്നത് കൊണ്ട് എൻ്റെ മകൻ/മകൾ/ ഭർത്താവ് / ഭാര്യക്ക് യാതൊരു വിധ ഹാനിയും ,സംഭവിക്കുകയില്ല എന്ന് ഞാൻ മനസിലാക്കുന്നു. പഠനവേളയിൽ എപ്പോളെങ്കിലും എൻ്റെ മകൻ/മകൾ/ഭർത്താവ്/ഭാര്യക്ക് എന്തെങ്കിലും അസൗകര്യം ഉണ്ടായാൽ ഏതു സമയത്തും എൻ്റെ വിസമ്മതം അറിയിക്കുകയും പഠനത്തിൽനിന്നും പിന്തിരിയാൻ സാധിക്കുകയും ചെയ്യും എന്ന് ഞാൻ മനസിലാക്കുന്നു. താഴെ പറയുന്ന ഞാൻ ഈ പഠനത്തിൽ പങ്കെടുക്കാനുള്ള എൻ്റെ മകൻ/മകൾ/ഭർത്താവ്/ഭാര്യയുടെ സമ്മതം അറിയിക്കുന്നു.

പേര് ഒപ്പ്

APPENDIX C

SCORING DESCRIPTION FOR ACCURACY OF RESPONSE FOR SYMBOL SEQUENCE PRODUCTION TASK

Score	Description for scoring aided response
0	No symbol selected
1	Single symbol selected but not appropriate for the photograph provided
2	Two symbols selected-not appropriate for the photo provided
3	Three or more symbols selected- not appropriate for the photo provided
4	Single symbol selected, appropriate for the photograph.
5	Two symbols (agent & object) selected- appropriate for the photo, not following word order
6	Two symbols (agent& object) selected- appropriate for the photo, following word order
7	Two symbols (agent& action, or action &object) selected, appropriate for the photo, not following word order
8	Two symbols (agent &action, or action & object) selected- appropriate for the photo, following word order
9	Three symbols (agent, action &object) selected- appropriate for the photo provided, not following S-O-V order
10	Three symbols (agent, action &object) selected- appropriate for the photo provided, following S-O-V order
11	More than three symbols (agent, action, preposition/ adjective &object) selected which is appropriate for the photo provided, not following S-O-V order
12	More than three symbols (agent, action, preposition/ adjective &object) selected which is appropriate for the photo provided, following S-O-V order