INFERENCE REVISION PROCESSING IN INDIVIDUALS WITH APHASIA

Divya Seth

Register No. 13SLP006

Dissertation submitted in part fulfillment for the Degree of

Master of Science (Speech-Language Pathology)

University of Mysore, Mysore.

ALL INDIA INSTITUTE OF SPEECH AND HEARING

MANASAGANGOTHRI

MYSORE- 570 006

May, 2015

CERTIFICATE

This is to certify that this dissertation entitled "**Inference Revision Processing in Individuals with Aphasia"** is a bonafide work in part fulfillment for the degree of Master of Sciences (Speech-Language Pathology) of the student (Registration No. 13SLP006). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore

May, 2015

Dr. S. R. Savithri

Director

All India Institute of Speech and Hearing

Manasagangothri, Mysore- 570 006

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Mysore

May, 2015

Dr. Jayashree C. Shanbal

(Guide)

Reader in Language Pathology

Department of Speech-Language Pathology

All India Institute of Speech and Hearing

Manasagangothri, Mysore- 570 006

DECLARATION

This is to certify that this dissertation entitled "**Inference Revision Processing in Individuals with Aphasia"** is the result of my own study under the guidance of Dr. Jayashree C. Shanbal, Reader in Language Pathology, Department of Speech-Language Pathology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore

Registration No.: 13SLP006

May, 2015

Dedicated to

Bestest Mumma & Papa

& dear Jayashree ma'am ☺

Acknowledgment

I would like to thank God almighty for bestowing his blessings on me in all my endeavors. Thank you my dear Papa and Mumma for all your love, support and encouragement. Papa for being my best teacher and guide and Mumma for being the best friend. I am a blessed child to have you both and I want you to know that you are the best parents ever. Love you infinity ☺ I can never miss to thank my partner in crime, my sweetest brother Ayush. You are my secret keeper and advisor when I have no other way to go. Thank you so much for everything and love you tons ☺. A huge thanks to my grandparents, all my uncles, aunts, cousins and well-wishers for all your blessings and best wishes.

Jayashree ma'am – my guide, my mentor, a role-model and an inspiration. Thank you ma'am for being so patient with me, answering all my stupid questions and helping me at every step. Not just this one year, but you have been a constant support throughout my journey at AIISH. Ma'am you are an epitome of perfection. A big big big.... Thank you for everything ☺

A sincere thanks to Vasanthalakshmi ma'am, Gopishankar sir, Gnanvel sir, Ajith sir and Kavitha ma'am for your timely help and support. A special note of thanks to Nike sir for his 'golden voice' without which this study wouldn't have started.

A very special thank to Yeshoda ma'am, Priya ma'am, Sandeep sir and Sujeet sir. You have been the four strongest pillars of my support system at all times.

I would also like to extend my sincere gratitude to Manjula ma'am, Prema ma'am, Sreedevi ma'am, Animesh sir and Goswami sir for teaching how knowledge turns into wisdom.

I would also like to thank all my teachers at Bethany Convent and Tagore Public School who nurtured and brought me to this level.

I would like to acknowledge all the participants of the study and all those who helped me in preparation of the stimuli.

Spruha and Shreyank, my life is just undone without you both. You are my priceless assets and a boon in my life. Spruha- my sleeping beauty, my secret keeper, my beti, my counselor, my motivator and god knows how many endless relations we share. Through all thick and thin, with the tide of time the bond between us has just become stronger. I hereby proudly declare that you are my bestest buddy and I feel blessed to share this bond with you. Shreyank- in no words can I tell how lucky I am to have you. I know you would kick me for this, but thankyou for all the love and care, for tolerating my temper tantrums and being by my side for all my best and worst times. Thank you for being there always. I love you both a lot ☺.

My priced possession, my friends forever- Richa, Shelly, Ankita, Nooreen, Aditi, Mani, Sonam, Yashu, Amruth, Malu, Rekha & Preeta. Thankyou all for all the support, love and care, memories and wonderful time we had together. Looking forward to make many more such memories.

A big thanks to all my lovely seniors: Priyanka di (my college mother), Mohana akka (sweetest thing ever), Irfana chechi, Indu (simplicity at its best), Supi (Innocence unlimited), Sandhya di (bank of talent), Lakshmi akka (sweetest senior ever), Ansu di, Neetu di, Srushti di, Mitu di, Harshita di, and Rajan – my 'big' elder brother, thank you for being there always.

I can never forget my crazy kids: Veepee, Varsha and Jasi. You make me smile even on the worst days. Thankyou for making me a part of your family ☺ Love you people. My amazing juniors: Preeti, Deepthi, Raveena, Janani (Gundu) and Kristi (Jalebi) – thank you guys for the never ending fun and happiness unlimited ☺

Last but not the least, I would like to thank all my B.Sc and M.Sc batchmates who made this journey a memorable one and added numerous colors to it. Thank you all ☺.

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CHAPTER 1: Introduction

Language processing is a complex process and not just a mere mechanism of relating words to meanings. It refers to the extensive computational mechanism involved in understanding of spoken and written language. Processing of complex linguistic information requires the knowledge of various aspects of language as follows: phonology (knowledge about linguistic sounds), morphology (knowledge of the meaningful components of words), syntax (knowledge of the structural relationships between words), semantics (knowledge of meaning), pragmatics (knowledge of the relationship of meaning to the goals and intentions of the speaker) and discourse (knowledge about linguistic units larger than a single utterance).

A balanced interaction of these aspects of language with other cognitive processes leads to language comprehension and/or production. All individuals use language in different contexts for different purposes and here is when the cognitive processes come to picture. A wide range of cognitive processes ranging from attention and memory to thinking, reasoning and drawing inferences are involved in language processing. Inference generation and revision is one such cognitive process which aids in sentence and discourse comprehension.

Literature reports significant comprehension deficits in individuals with aphasia. These deficits are reported to occur at different levels with varying severities across individuals. Though many individuals do not face difficulty comprehending single words, a processing breakdown at sentence or discourse level is observed in most of the individuals with aphasia (Davis, 2014). A processing breakdown at word level will be an indication of severe aphasia while sentence or discourse comprehension deficits usually indicate mild to moderate impairment. This implies a likelihood of difficulty in inference generation and revision in individuals with aphasia (Harris-Wright & Newhoff, 2004).

Various experiments have been conducted in the past to assess the inference generation abilities of neurotypical individuals and those who suffered from right hemisphere brain damage. The tasks used in these experiments majorly comprised of story narration or sentence pair presentation followed by factual and inference questions (Tompkins, Bloise, Timko, & Baumgaertner, 1994; Wapner, Handy, & Gardner, 1981) to be answered by the subjects.

In a study by Nicholas and Brookshire (1986), comprehension of narrative discourse in terms of understanding the stated and implied meanings were investigated for individuals with aphasia, right hemisphere damage (RHD) and non-brain damaged adults. The findings revealed that both brain-damaged and non-brain damaged groups had better comprehension for explicitly stated information than implied meanings. But, individuals with brain damage exhibited more difficulty in understanding implied meanings when compared to the normal group. Swaab, Brown and Hagoort (1998) explored sentence comprehension in Broca's aphasia and reported that these individuals have delayed integration of lexical information. This delay was attributed to the delay in processing contextual information which in turn affects their sentence comprehension skills. Levey and Goldfarb (2003) studied the response of individuals with fluent aphasia to indirect requests and the findings revealed poor response latencies and accuracy in comparison to the neurologically intact individuals. This implicates that comprehension of indirect request is a complex process which involves understanding the non-literal or speaker meaning.

In relation to these, there have been several studies done to understand the inference skills in individuals with Right Hemisphere Damage (RHD). Wapner, Hamby, and Gardner, (1981), investigated the role of right hemisphere in processing complex linguistic information and found that individuals with RHD exhibited difficulties on story comprehension and arrangement, drawing conclusions about moral of the story and understanding jokes. Findings also revealed that the individuals with aphasia performed poor on tasks of inferring when compared to non-brain damaged group. This indicates that poor comprehension in aphasia can be attributed to inference deficits.

Though inference revision has been studied extensively in RHD population, there are few studies in individuals with aphasia. Tompkins, Bloise, Timko and Baumgaertner (1994), carried out a study to understand the relationship between working memory and inference revision abilities in individuals with and without brain damage. It was reported that individuals with aphasia had greater difficulty in revising the inferences leading to poor comprehension scores. These findings also support the idea that inference generation abilities are critical for sentence comprehension and brain damaged individuals with aphasia often show difficulty in this area of inference generation.

Till, Mross and Kintsch (1988) and Harris-Wright and Newhoff (2002) also carried out studies to investigate inference generation skills in comprehension of sentences focusing on the point of lexical activation. This activation is aided by the phenomenon of priming which in turn is decided by the reaction time. So we observe reaction time to be shorter for related words than that for unrelated words. Swinney with his colleagues conducted several studies on neurologically intact individuals to probe if inference generation can occur automatically (Swinney & Osterhout, 1990; Cutler & Swinney, 1978). Findings revealed that not all types of inferences are generated automatically, which means that a controlled processing is also essential for inference generation as it was found to have occurred after a brief time period. This indicates that majority of inferences require controlled processing. Thus, two types of inferences were proposed: perceptual (automatic) and cognitive (controlled) (Swinney & Osterhout, 1990). Perceptual inferences are automatic or immediate and thus are usually measured through on-line tasks. While cognitive inferences can be measured through on-line task the reaction time would be more as it is a controlled process. Cognitive inferences are highly determined by an individual's knowledge (Swinney & Osterhout, 1990).

Harris-Wright and Newhoff (2002) using these principles conducted a research and studied the differences in inference revision processing across age groups in neurotypical individuals. They used a cross-modal lexical priming paradigm (CMLP) for lexical decision task and questions for inference revision. The participants could generate inferences 750 ms after the sentence presentation. Thus, this study supported the use of priming tasks and proved that sentence comprehension involves cognitive inference and cannot occur automatically. Harris-Wright and Newhoff (2004) conducted another study investigating inference revision in individuals with and without aphasia. The assessment protocol was same as in their study done on neurologically intact individuals (Harris-Wright & Newhoff, 2002). The findings suggested that the individuals with fluent aphasia had more difficulty in inference generation when compared with non-fluent and neurologically intact categories.

The literature on inference generation in aphasia is not as rich as that for inference generation in RHD or neurologically intact individuals. Above mentioned studies and their findings put forth the notion of inference generation being an essential component of sentence comprehension. It is known that individuals with aphasia are found to have predominant comprehension deficits with varied severity. However, it would be interesting to understand whether these comprehension deficits are occurring due to a deficit at the lexical level, or at inference generation or related to inference revisions in sentence comprehension. Thus, the present study aims at understanding inference revision processing in individuals with aphasia.

CHAPTER 2: Review of Literature

An individual's efficiency in producing and understanding discourse forms the basis of his/her successful communication. It requires comprehension at various levels - individual words and sentences and also includes integration across sentences resulting into a coherent understanding of the discourse as a whole. This coherence is attained by a dynamic interaction between mental representations formed with the current sentence, the prior discourse context, and the background (world) knowledge.

Brain damage is one such condition which impairs the comprehension and retention of spoken language to varying degrees. Individuals with aphasia, right hemisphere damage and traumatic brain injury are often found with these comprehension deficits.

In a neurotypical individual sentence comprehension involves two main levels of analysis. First is the analysis of the syntactical (grammatical) structure of each of the sentences referred as parsing. Second, is the analysis of semantics or sentence meaning. The syntactic component may not always have a direct connection with the sentence meaning. In other words the surface and the deep structure do not always have a one-to-one correlation. In such cases where the surface and deep structure have no direct relation, we use other redundant sources of information like the context, background knowledge and draw inferences or predict the upcoming events.

Tracing down the history of sentence comprehension, the earliest models were the *transformational models* inspired majorly by the work of Chomsky (Chomsky, 1968).The basic assumption of this model was that to deduce the meaning of a given sentence, the literal content ("surface structure") of the sentence is subjected through a series of transformations which finally yields the meaning ("deep structure"). The complexity of the sentence and the duration taken to comprehend it were considered to be dependent on the number of transformations which take place. Following Chomsky's work, few researchers proposed the *verification models* (Carpenter & Just, 1975; Clark & Chase, 1972; Trabasso, Rollins, & Shaughnessy, 1971). These models also supported the view that sentence comprehension involves a series of cognitive operations acting linearly and that the entire process requires time. But both of these models failed to explain how one derives meaning out of the sentences in a natural context. Thus, in mid- to late 1970s the focus of research shifted to investigate how the listeners go beyond the literal content and how the linguistic and situational context, general knowledge and intuition helps them to deduce the meanings. Foss (1970) reported that when presented with ambiguous sentences listeners are biased by the linguistic or situational context toward a particular interpretation of the sentence.

According to Clark and Haviland (1977) speakers rarely present all the necessary information to the listeners in order to understand their communicative intent. The speakers' message often consists of informational gaps, which they expect to be filled by the listeners based on the context, general knowledge and intuition. Thus, drawing inference is usually an unconscious process for the listeners which occur spontaneously most of the time. But the directness of the information does have an influence on the listeners' comprehension both in terms of the speed and accuracy (Singer, 1988; Cohen, 1979).

Thus, drawing inference is a common phenomenon which all of us do almost unconsciously during our day to day communication. Studies of inference have also proved that listeners go beyond the literal content of the sentences to deduce meaning. It has been concluded that individuals usually follow the top-down process (use of context, general knowledge, and intuition) to infer meaning from a sentence.

2.1 Inference revision processing

As described by Hayakawa (1991) "*an inference is a statement about the unknown made on the basis of the known"*. Kintsch (1998) defined it as "a controlled, information-generation process that requires deductive reasoning abilities." In simple terms it can be defined as the art of relating sentences and comprehend the meaning. Most of the time we draw inferences while reading a text or listening to someone. Eysenck and Keane (2010) describe three main types of inferences: logical, bridging and elaborative. Logical inferences solely depend on the meaning of the words in a sentence. For example, anyone when referred as a 'widow' we infer that it's a 'female'. Bridging inferences involve establishing a connection between the preceding and the current text/speech unit. These are also referred as *backward inferences*. The third variety is the elaborative inferences where we utilize our background (world) knowledge to add on more information. These are referred to as *forward inferences* also as they involve predicting or anticipating the future events.

Usually reading involves drawing logical or bridging inferences as they are essential for a better understanding. But, drawing elaborative inferences automatically is a matter of controversy. Singer (1994) carried out an experiment to compare the time taken to draw the three types of inferences and draw a conclusion about each of its automaticity. Findings revealed shorter and same verification times for logical and bridging inferences indicating that these are automatic in nature, unlike the elaborative inference with longer verification time. Garrod and Terras (2000) studied the phenomenon of bridging inferences and concluded that it is two-step formation. In the first stage words from the preceding sentence are automatically activated. This is referred to as bonding. The second stage is resolution, where it is assured that the overall interpretation matches with the contextual information. Resolution is influenced by context but bonding is not.

Literature also reveals that for a better understanding of inference skills two approaches or views regarding inference generation were proposed- *Constructionist approach* and *Minimalist hypothesis.* Constructionist approach was proposed by Bransford, Barclay, and Franks (1972) who believed that while reading one forms a complete "mental model" of the events and situation referred to in the text. Thus, they say that many elaborative inferences are formed during the process of reading. Earlier, memory tests were used as an indirect measure for assessing the inferential process. But, the disadvantage is that the inferences formed might be made at the time of testing and not while reading. Instead it represents the reconstructive process during retrieval.

Minimalist hypothesis was proposed by McKoon and Ratcliff (1992) who opposed the Constructionist view and stated that in the absence of specific, goal-directed strategic processes, only two kinds of inferences are constructed: first the ones which establish locally coherent representations of the parts of a text that are processed concurrently and second those that rely on information that is quickly and easily available. The main assumptions put forth were that,

- Inferences are either automatic or strategic (goal directed)
- Some automatic inferences establish local coherence (two or three sentences making sense on their own or in combination with easily available general knowledge). These inferences involve parts of the text in working memory at the same time.
- Other automatic inferences rely on information readily available information because it is explicitly stated in the text.
- Strategic inferences are formed in accordance with the reader's goals; they sometimes help in deducing local coherence.
- Most elaborative inferences are found to be made at recall rather than during reading.

The major difference between the above mentioned two approaches is with reference to the number of automatic inferences formed. The constructionist approach believes in formation of numerous automatic inferences during reading while the minimalist view talks about strong constraints on this number.

Dosher and Corbett (1982) also studied the dichotomy and differences between the automatic and strategic inferences. Their study gave evidence for the formation of strategic inferences and not the automatic ones. Thus, their study favors the minimalist hypothesis. Calvo et al. (2006) also supported these findings. McKoon and Ratcliff (1992) in another experiment proved the presence of automaticity in local inferences but not in global inferences. Murray and Burke (2003) tested predictive inference generation in individuals with high, moderate and low levels of reading skills. The findings of his study indicated the presence of predictive inferences in all the three groups but automatic generation was present only in the group with high reading skills.

As discussed earlier inference making involves establishing a coherent system by linking words and sentences and understanding the meaning. Gernsbacher (1990) found that inference making is accompanied with activation of words in the mental lexicon. She proposed that this does not involve only the enhancement of the activation of referents but also includes suppressing the activation of non-referents. Matlin (2003) proposed few factors that facilitate inferences. He says that naturally we don't always draw inferences while reading. Individual differences do occur across readers and these are important. These include: likelihood of drawing inferences in presence of a large working memory capacity (Carpenter et al., 1995), in presence of excellent meta-comprehension skills like awareness to establish some connections between two seemingly unrelated sentences (Ehrlich, 1998; Graesser et al., 1996), in presence of background information or expertise regarding the topic discussed in the text (Kintsch, 1998). Also it is found that, people with depression are less likely to draw inferences (Ellis et al., 1997). Research has also proved that one often fails to construct inferences when reading any scientific texts (Noordman et al., 1992). Few others believe that inferences are drawn when reading scientific texts only to establish coherence in the text, but the same is not done to predict or anticipate forthcoming events in the text (Millis & Graesser, 1994). Friedman and Gvion (2003) also opined that working memory capacity plays an important role in processing of linguistic information.

Kintsch's (1988) "*Construction-integration model of discourse processing*" also provides an explanation for formation of inferences. Kintsch proposed that inferential process takes place in two phases, the first phase comprising of inference generation and the second phase including integration of the drawn inferences into a coherent text base. The construction phase is said to have four steps. The first step includes a merger of the linguistic input and the general knowledge forming a concept or proposition. In the second step, each concept or proposition leads to activation of the related information. Here the information with maximum activation makes it way to the working memory and finally an inference is formed. In the third step additional inferences or counterexamples are created. Occasionally, formation of the additional inferences increases the demands on the working memory by claiming active concentration on the information present in the working memory. The fourth and the final step is the formation of interconnections between the inferences and general knowledge. In the integration phase, once the activation is stabilized, the text base integrates into a "coherent whole". Thus, Kintsch's model highlights the importance of comprehension of linguistic input, general knowledge and working memory for inference generation.

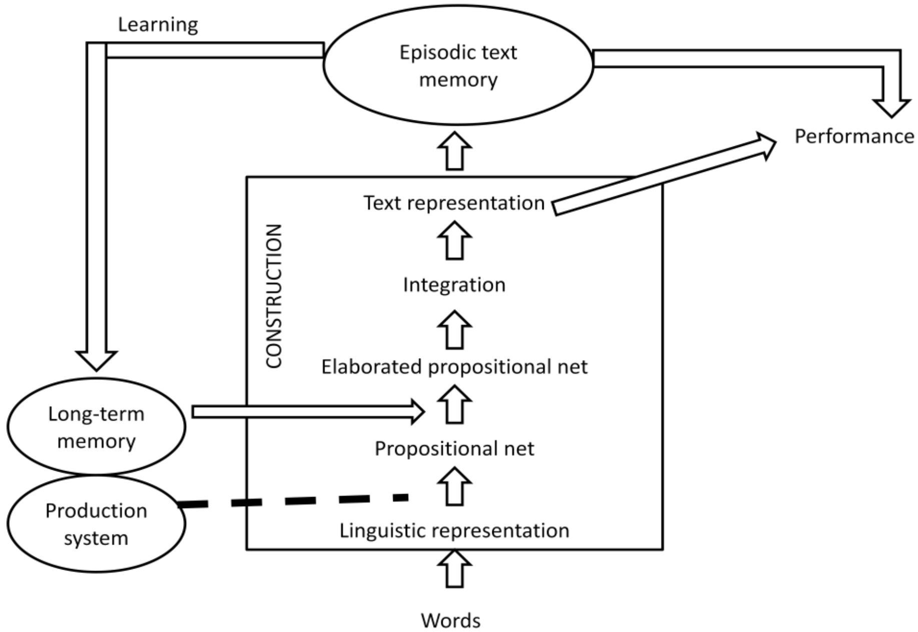

Figure 2.1: The construction-integration model (Kintsch, 1992). (*Source:* Adapted from Eysenck, M. W., & Keane, 2010)

Swinney and Osterhout (1990) classified inference into two categories: perceptual and cognitive. According to their classification, inferences drawn automatically during on-line language processing are referred to as perceptual inferences, while the inferences which are never automatic or mandatory and are under cognitive control are called as non-perceptual or cognitive inferences. Thus, they consider the following two main factors to differentiate between the two kinds of inferences: (i) extent to which it is influenced by world knowledge and; (ii) automaticity during on-line comprehension or processing.

Understanding the complex interaction of the three important components of spoken/written discourse, i.e., comprehension of linguistic input, general world knowledge, and working memory, it is clear that individuals with variety of disabilities will exhibit some deficit in inference generation. Few of the documented literature includes disabilities like traumatic brain injury (Moran & Gillon, 2005), language-learning disabilities (Crais & Chapman, 1987), specific language impairment (SLI; Bishop & Adams, 1992; Ellis Weismer, 1985), nonverbal learning disabilities (Humphries et al., 2004; Worling, Humphries, & Tannock, 1999), and reading disabilities(Snyder & Downey, 1991), specifically, poor reading comprehension (Catts, Adolf, & Weismer, 2006; Nation, Clarke, Marshall, & Durand, 2004; Yuill, Oakhill, & Parkin, 1989).

Out of the several disorders researchers have always shown special interest in individuals with Right Hemisphere Damage (RHD) and their inference skills. It is a known fact that individuals with RHD have relatively preserved phonological and syntactical abilities, but exhibit deficits in understanding humor, sarcasm, indirect requests and/or stories (Bihrle, Brownell, Powelson, & Gardner,1986; Joanette, Goulet, Ska, & Nespoulous, 1984; Brownell, Michel, Powelson, & Gardner, 1983; Gardner, Brownell, Wapner, & Michelow, 1983; Foldi,1982; Myers, 1979; Wapner, Hamby, & Gardner,1981; Wechsler, 1973). Another major difficulty faced by these individuals in day to day conversation is that they follow individual sentences but find it difficult to integrate information across sentences and establish a meaning or inference out of it (Brownell, Potter, Bihrle and Gardner, 1986). In discourse they specially miss out the information which are implied rather than explicitly stated.

With this premise Brownell et al. (1986) conducted a study to investigate the inference deficits seen in individuals with right hemisphere brain damage. They used sentence pairs which implied different meanings in isolation and a different meaning as a pair. The sentences were followed by factual and inference questions. The findings revealed that the overall performance of the RHD group was poor than the controls. Both the groups had more difficulty with the inference questions, RHD individuals exhibiting greater difficulty. The authors attributed this high error rate in the RHD group to memory deficits or abnormal rigidity of interpretation, second reason being more common. The findings also revealed that the position of the ambiguous sentence, significantly influenced the error rate (ambiguous sentence in first position led to higher error rate) in RHD group. Also it was found that the effect of position was more for implicit than explicit information. Thus, they concluded that individuals with RHD have more difficulty with inference when compared to comprehension and retention of any factual information. Also they suggest that they have poor cognitive flexibility during comprehension and usually get fixed to the first interpretation. McDonald and Wales (1986) studied the ability of the right-hemisphere brain damage (RHD) group to process inferences in language. The performance of individuals with RHD was poor when compared to the controls. Thus, the authors concluded that individuals with RHD memorize the material normally, but face difficulty in accurate spontaneous retrieval. This difficulty increases when the stimuli consists of more semantically confusable facts. Thus, the study could not confirm the hypothesis that individuals with RHD have poor inference abilities rather their performance reflects retrieval deficits.

Brookshire and Nicholas (1984b) and Katsuki-Nakamura et al. (1988) studied the effect of directly stated and implied information on comprehension abilities of individuals with aphasia, right-hemisphere-damage (RHD) and no-brain damage (NBD). They reported that directness did not have any significant effect on comprehension of main ideas in a discourse. However, Nicholas and Brookshire (1986) did report that the directness of information stated had an influence on the details but not the main idea. In their study they considered the same three groups (aphasia, RHD, NBD) and investigated their comprehension of stated and implied meanings from a story read out at fast rate (approximately 200 wpm) and at a slow rate (approximately 120 wpm). It was found that the comprehension of main ideas were unaffected by the directness and the speech rate. The NBD group was found to perform better for the stated details questions than the implied detail questions at the fast rate, though no significant difference was found when stories were presented at a slow rate. Unlike NBD group, the other two groups (aphasia and RHD) performed better for the stated detail questions than the implied detail questions regardless of the speech rate.

There are few studies with contrastive findings also. One such study conducted by Stachowiak et al. (1977) revealed that individuals with aphasia and RHD were able to comprehend the non-literal meaning of idiomatic expressions when placed at the end of the short narratives. Authors justified their findings saying that the subjects made use of the preceding contextual information provided in the form of the short narratives. Weylman, Brownell, Roman, and Gardner (1989) supported the findings of Stachowiak et al. (1977). Their study was conducted in two parts. In the first part they compared the performance of the NBD with the RHD group. They found that both the groups made use of the contextual information (preceding narrative) and chose the non-literal choice wherever implied. However, RHD group was more likely to choose the literal endings than the NBD group. In the second part of the study, they compared the RHD with LHD (left hemisphere damage) and found that both the groups were sensitive to the context and make use of it to decide when to choose the non-literal endings.

Thus, we can see there has been an inconsistency in the findings. Study by Tompkins and Mateer (1985) sheds some light on this inconsistency. They investigated the comprehension of factual and inferential information in short narratives of adults with NBD and those with temporal lobe seizures (right or left hemisphere). They found that the group with right-temporal lobe seizures had higher error rate than the NBD group on inferential questions. Thus, they concluded that though these individuals may be capable of going beyond the literal meaning of the non-literal material, they might be very rigid with their interpretations and may face difficulty in revising them.

Harden, Cannito, and Dagenais (1995) investigated the inferential abilities of normal and right-hemisphere damaged adults. Their findings revealed no significant difference in the performance of the two groups. Also it was found that both the groups performed significantly better when the stimulus was presented in the combined condition (Auditory + Orthographic) than when presented in any one modality. Thus, they did not find any difference in the inference abilities of controls and the RHD group. The reasons they put forth for such similarity include- considering all RHD as a homogenous group, the effect of different cerebral areas being affected. They also stated that the type of stimuli also would have influenced the responses. All the narratives were straightforward without any misleading/distracting or ambiguous information, thereby facilitating better comprehension.

Gernsbacher and colleagues (Gernsbacher & Faust, 1991; Gernsbacher et al., 1990) in their series of experiments on young neurotypical individuals have established a link between suppression function and comprehension skill. Authors reported that, those with poor comprehension skills are deficient in suppressing or inhibiting inappropriate information as quickly as those with good comprehension skills, across tasks, modalities and domains (visual and auditory; linguistic and non-linguistic). Based on these findings, Tompkins, Lehman, and Baumgaertner (1999) formed a *'suppression deficit hypothesis'* which includes two factors: first that the suppression would be poor in adults with RHD than the neurotypical adults and the second that the suppression function post RBD can predict the discourse performance of this group. The stimuli comprised of an ambiguous initial stimulus sentence which elicited both the dominant and the non-dominant inference. The second sentence resolved the ambiguity. There were four main tasks administered for each of the participants of the study. The four main tasks were as follows: the suppression task (judge if the probe word fits the entire stimulus meaning or not), the comprehension task (answering yes/no questions: two for factual and inference each), the initial sentence interpretation task (judge if the probe word fits the meaning of the sentence presented. Here the probe words were presented after each sentence) and the inference revision task. Findings revealed there were no significant gender differences across the two groups. It was found that for the short intervals, the control group had significantly shorter RT than the RHD group. However, for long intervals this difference was not significant. Also it was found that for both the groups at two intervals (short and long) suppression ratio was positive (indicating interference from unintended interpretations). However, the overall performance of control group was better than the RHD group which was attributed to better working memory capacity.

Blake and Lesniewicz (2005) investigated the influence of contextual bias on inference processing abilities of older adults with right-hemisphere damage (RHD) and those with no brain damage (NBD).Their findings supported the view that few individuals with RHD are capable of generating predicting inferences with the given contextual information. However, they generated multiple predictions for all the stories regardless of the version. This suggests that though they can use context to guide them, they still exhibit difficulties in suppressing the competing predictions and selecting the appropriate one.

With this overview it is clear that there has been extensive research to explore the inference skills of individuals with RHD and varying degree of deficits at various levels have been reported. Unlike individuals with RHD there has been scarcity of research to assess higher functions like inference skills in individuals with left-hemisphere damage (LHD). Individuals with aphasia are known to have wide range of comprehension deficits depending on the severity, and type of aphasia. (Chapman & Ulatowska, 1989; Samuels & Benson, 1979; Selnes, Knopman, Niccum, Rubens, & Larson, 1983).

Nicholas and Brookshire (1995) conducted a study to explore the comprehension of spoken narrative discourse in adults with aphasia, right-hemisphere brain damage (RHD) and traumatic brain injury (TBI). The subjects were tested on the Discourse Comprehension Test given by Brookshire and Nicholas (1993) which taps on comprehension and retention abilities of an individual for the stated and implied main ideas and details. The findings revealed that all the groups performed better for the main idea questions than the detail questions. Similarly all the groups performed better on the stated information questions than the implied information questions. They also reported that the influence of directness was more for the detail questions than the main idea questions. Among the individuals with the brain damage the performance of the three groups (aphasia, RHD, TBI) was found to be both quantitatively and qualitatively similar.

When compared to those with NBD, individuals with brain damage performed qualitatively similar but quantitatively poor, especially for the detail and implied information. The findings supported the findings of their previous study in 1986. The authors also tried to explain their findings on the basis of the resource allocation models which suggest that the human cognitive activities is dependent on a limited pool of processing resources (Kahneman, 1973) i.e., as the cognitive processing load increases, the demand for the resources also increases. When this demand exceeds the available resources, the cognitive process and the performance is compromised. So according to the resource allocation model, any kind of brain damage limits the available processing resources which in turn affects the performance of those with brain damage on tasks which are cognitively loaded and taxing (Kahneman, 1973). Heuristic processes which are involved in comprehension of main ideas are usually less dependent on these resources while the comprehension of details or implied information is highly reliant on these resources. Thus, the better performance for the main idea is justified. The researchers also suggest that though within the brain damage group, the performance was found to be qualitatively and quantitatively similar, the underlying reasons for these deficits might not be the same. For some it may be due to poor accuracy or speed in decoding lexical or syntactic information, while for others it may be due to reduced or misallocated attentional resources. For few others it may be because of their impaired verbal retention or inferential abilities.

Wapner, Hamby, & Gardner (1981) collated and contrasted the performance of individuals with RHD with those of individuals with aphasia, younger and older adults on a test battery designed to assess comprehension of complex linguistic material(stories featuring different contents, story arrangement task, stories presented through different medias- auditory and visual and choosing punch lines for jokes). The RHD, younger and older adult groups were subjected to entire test battery while for the aphasia group all but humor test was done. Findings revealed intact elementary linguistic functions in RHD. However they exhibited difficulty in integration of elements of story and organization of content. Performance of those with aphasia was at par with RHD. RHD had difficulty in deriving the moral for the story and selecting appropriate punch lines for the jokes as well. Those with aphasia and aging (older adults) performed relatively better.

Tompkins, Bloise, Timko and Baumgaertner (1994) investigated the relation between working memory limitations and difficulty resolving conflicting information during spoken discourse comprehension. They compared performance of individuals with RHD, LHD and neurotypicals. The discourse comprehension task consisted Attitudinal inference (AI) and Linguistic Inference (LI). Findings revealed that under AI task, all the subjects found incongruent stimuli more difficult with individuals with LHD facing the maximum difficulty (LHD > RHD > Controls). Less significant difference in the performance of RHD and Controls was justified based on methodological variations, older age of controls and absence of any neglect or perceptual deficits in the RHD group. Under the LI task all the groups had poorer performance for initial inference questions than the questions about revised inferences. No significant relationship was established between the working memory capacity and task performance for the control group. However, for individuals with brain damage (LHD and RHD) there was association found between the two.

Swaab, Brown and Hagoort (1997) carried out an event-related potential study where they investigated whether the spoken sentence comprehension deficits seen in individuals with Broca's and Wernicke's aphasia is due to difficulties in on-line lexical integration. Their performance was compared with that of age-matched neurotypical individuals. They used N400 as the ERP and found that aphasics with mildly affected comprehension skills had N400 similar to that of non-brain damaged individuals. However, for those who had moderate to severe comprehension deficits a reduction and delay in N400 response was obtained. Thus they made a conclusion attributing comprehension deficits to impaired integration of lexical content into higher order representation of the preceding sentence.

Virtue, Haberman, Clancy, Parrish, and Beeman (2006) studied neural activity during inferences using event related functional magnetic resonance imaging (fMRI) protocol. They assessed neural activity or mechanism for implied and explicit events at two critical points of the stories (when verb in text implied inference and at coherence break). They also considered two groups of people- those with high and low working memory capacity respectively. The findings revealed increased fMRI signal in right superior temporal gyrus for the first condition where the verb in the text implied meaning, while increased signal in left superior temporal gyrus and left inferior frontal gyrus was observed during the coherence break. Also it was found that the activity in left inferior frontal gyrus was found to be a function of the working memory capacity i.e., higher the working memory capacity stronger the fMRI signal. The authors also suggest that right hemisphere STG is involved during early inferential processing, while during later inferential processing left hemisphere STG and IFG take over. Increased neural activity was observed in few other areas though specific areas could not be tracked down as they were active throughout the story. Thus, this study unveils the role of these cortical centers during inference making and ongoing comprehension. So it will not be wrong to assume that damage or insult to these centers will lead to impaired inference skills and poor online comprehension.

2.2 Cross-modal lexical priming in aphasia

The Cross-Modal priming task (CMPT) used in the present study was originally developed by David Swinney. It is an online measure which helps to detect activation of any lexical or syntactic information during sentence comprehension. Before Swinney proposed this method, most of the lexical access experiments followed offline measures like phoneme monitoring task. In these offline measures, subjects had to respond to the lexical or syntactic ambiguities only after the entire sentence has been understood. Swinney believed that the process of resolving the ambiguities is an autonomous, fast and mandatory process and therefore, the time lag between stimulus and response may contaminate the findings. Thus, CMPT was developed to measure lexical access in real time. Since then it has been used extensively in several experiments to assess language comprehension.

Lexical decision and priming paradigms have been very popular to study the level of linguistic functioning in individuals with aphasia. Reaction time (RT) and accuracy measures have helped in predicting the linguistic skills and severity of deficits in these individuals. Both RT and accuracy are considered to be influenced by factors like word frequency and familiarity in neurotypicals (Brysbaert, Lange, & van Wijnendaele, 2000;

Morrison & Ellis, 2000; Gerhand & Barry, 1999; Ferreira, Henderson, Anes, Weeks, & McFarlane, 1996) as well as in individuals with aphasia (Kittredge, Dell, Verkuilen, & Schwartz, 2008; Bose, van Leishout, & Square, 2007; Gerratt & Jones, 1987). Swinney, Zurif and Nicole (1989) examined the effect of preceding semantic context upon lexical access during sentence comprehension for three groups: Broca's aphasia, Wernicke's aphasia and neurologically intact individuals. Simple sentences with lexical ambiguities inclined to one strong interpretation were presented auditorily with a visually presented lexical decision task to be performed. As per the findings, strong priming effect was seen for the neurologically intact group across all the ambiguities irrespective of the context. Priming effect was present for Wernicke's aphasia also. However for the agrammatic group i.e., the Broca's aphasia priming was observed only for most frequent sense of the ambiguous word irrespective of the context. Swinney et al. discussed that language comprehension system is autonomous and contextual constraints are enforced wherever there is competing information. Also, they report that the comprehension limitations arise at various stages or levels across the two types of aphasias (Wernicke's and Broca's).

Swinney, Zurif, Prather, and Love (1996) explored the processing resources underlying language comprehension and their neurological distribution across the types of aphasia. They utilized the cross-modal lexical priming technique. The performance of Wernicke's aphasia was found to be better than the Broca's aphasia for the lexical decision task. This was considered to be so because of the regions involved in the two types of aphasia and their implications and role in lexical processing. Tissues or brain regions of Broca's aphasia were found to be much more implicated in terms of resources available for syntactic comprehension than the Wernicke's aphasia.

Wright and Newhoff (2001, 2002, 2004) carried out series of experiments using CMLP paradigm to uncover the comprehension and inference processes in different populations. In 2001 they assessed the revised inference processing in normal young adults and also studied its relationship with the working memory. They presented revised inference sentence pairs followed by lexical decision tasks (at 750ms and 1000ms ISI) and questions (factual and inference). Reaction time to LDT and accuracy for questions were considered for analysis. To assess the working memory they used Tompkins et al.'s listening span task and found the error rate. Findings revealed shorter reaction times to control words of filler sentence blocks than those of revised inference block. Priming occurred at both the ISI values. It was also found that the error rate was higher for the inference questions than the comprehension questions. They did not establish any significant correlation between the scores of working memory and performance on revised inference questions.

Wright and Newhoff (2002) compared the performance of younger versus older adults. The study aimed to determine the time course of processing inference revision sentence pairs by the two groups. The method was same as the previous study done in 2001 for normal young adults. To assess the working memory capacity they used Tompkins et al.'s listening span task. They also included the lexical decision task following the presentation of sentence pairs. This was followed by factual and inference questions. Performance on listening span task revealed no significant difference across the two groups. However, significant priming effects were observed for both the groups for initial inference and revised inference target words at 750ms ISI. It was also found that the reaction time for target and control words was significantly shorter in younger adults than the older adults. Talking about the accuracy of questions, findings revealed that younger adults missed fewer questions than the older adults. Both the groups missed more questions from the first sentence than the second and inference questions more than the comprehension questions. Also there was a significant relationship between working memory capacity and comprehension of sentence pairs for the older adult group. However, the relationship between working memory and inference questions did not reach significance value. It was expected that the older adults might not be able to inhibit the initial inference within the short time frame, however findings revealed better performance indicating that they were able to inhibit or depress the initial inference activation at 750 ms post revision. The researchers justify good performance on LDT by both the groups based on Shapiro et al.'s (1998) findings where they reported that LDT involves automatic activation of information and is thus not overloading on working memory. In contrast to this, response to inference questions involved complex cognitive functions like making judgments alongwith attention and memory processes involved. This in-turn taxes the working memory.

Wright and Newhoff in their series of experiments conducted another study in 2004 to assess inference revision processing skills in individuals with and without aphasia. The stimuli and task was same as their study done in 2002 (as mentioned above). Findings revealed that the neurologically intact and non-fluent aphasic group performed on similar lines for the LDT. However, it was found that the several participants in the fluent aphasic group could generate initial inference but faced difficulty in revising their inferences. All neurologically intact (NI) and non-fluent aphasics (NFA) (except two) had shorter reaction time for revised inference target word than the initial inference target word. However, no such significant difference was observed for the fluent-aphasic group. This highlights their inability to inhibit or suppress the initial interpretation. Under comprehension, as expected individuals with aphasia missed more questions than the NI group and inference questions were missed more than the factual questions. Though the two aphasic groups performed differently for LDT, performance on questions were similar. They supported their finding by that of Kempler et al. (1998) where he proposed that performance on on-line and off-line tasks involve different linguistic and cognitive functions. As indicated in the findings, aphasic group made more errors on the revised inference questions than the initial inference questions indicating the difficulty in consistently comprehending the intended meaning. However they did not accept the initial inferences also as correct interpretation, showing the awareness of what is not correct.

As discussed earlier individuals with aphasia have been reported to have better comprehension for discourse than for single sentences (Brookshire & Nicholas, 1984) and also the presence of preceding context facilitates better comprehension (Cannito, Hough, Vogel, & Pierce, 1996; Pierce, 1991; Cannito, Jarecki, & Pierce, 1986). With this premise Wright and Newhoff (2004) using a cross modal task investigated the influence of neutral, incorrect and related lexical probes on comprehension of sentence pairs by individuals with aphasia and compared their performance with those with no-brain damage (NBD). They believed that the presentation of the lexical probe like preceding context would facilitate better comprehension and help to deduce the correct meaning. The task and the stimuli were same as used in their previous study in 2001. The findings revealed the performance to be better for the questions when the lexical probe represented the revised or intended interpretation of the sentence pair. Also more questions were missed when the lexical probe represented the initial or incorrect interpretation. The authors attributed this to the poor resource allocation or reduced working memory capacity. Thus, their findings supported the earlier studies which highlight the influence of preceding context on comprehension abilities (in this case the lexical probes acted as cue).

Need for the study

Language comprehension is considered as a complex interaction of several cognitive and linguistic processes. A balanced or healthy interaction of these processes is the key to good comprehension abilities in a neurotypical individual. An insult to the underlying neural structures involved in this complex network of linguistic processing hampers and degrades the ability of an individual to understand and make appropriate interpretations of the linguistic content. The nature of these deficits has been an enigma to the researchers in the field. They have always been inquisitive to explore the language processing deficits in individuals with brain damage and have strived to determine the underlying factors or causes for these language deficits. Comprehension deficits in aphasia have been a common finding in several research reports. These deficits are reported to be occurring at different levels ranging from single words and sentences up to the level of discourse. It is known that with the increase in the complexity of linguistic content, the number of processes involved in comprehension also increase. Drawing inference is considered to one such higher order cognitive-linguistic function which is likely to be affected as a result of brain damage in individuals with aphasia.

The overview of extensive literature available on assessment of inference skills in different populations clearly projects that the processing of inferencing is not restricted to only inference generation. Instead it involves other important parts like maintenance of inferences over time and selection of most appropriate inference suppressing all others. Many studies have reported that these skills of maintenance and revision of initial interpretation are affected in individuals with RHD (Lehman-Blake & Tompkins, 2001; Brownell et al., 1986; Tompkins et al., 1994).

The literature on inference processing skills in aphasia is not as rich as that for inference processing skills in RHD or neurologically intact individuals. Above mentioned studies and their findings put forth the notion of inference generation being an essential component of sentence comprehension. The present study looks forward to determining the level at which there is a processing breakdown in individuals with aphasia, nature of their deficits and possible underlying factors for these deficits in inference skills and auditory comprehension of complex linguistic material.

Aim of the study

The aim of the present study was to understand inference revision processing in individuals with aphasia.

Objectives of the study

- To study inference generation/revision abilities for sentence comprehension in individuals with aphasia.
- To compare inference generation/revision abilities in neurotypicals and individuals with aphasia on sentence comprehension.

CHAPTER 3: Method

The primary aim of the present study was to understand inference revision processing in individuals with aphasia.

Objectives of the study were as follows:

- To study inference generation/revision abilities for sentence comprehension in individuals with aphasia.
- To compare inference generation/revision abilities in neurotypicals and individuals with aphasia on sentence comprehension.

A two group comparison research design was used to compare the clinical group i.e., individuals with aphasia (N=5) and control group i.e., neurotypical individuals (N=15).

3.1 Participants

Participants were divided into two groups- The clinical group and the control group.

Clinical group: A total of five individuals with aphasia (three with Broca's aphasia and two with Anomic aphasia) in the age range of 21-75 years of age participated in the study. The profile each of these individuals is mentioned below.

Control group: Fifteen neurotypical (NT) individuals who were age-, gender- and education-matched to the clinical group were considered. Participants in the clinical group were matched to three participants each in the control group.

Participant selection criteria

All the participants spoke Kannada as their native language and had exposure to English since grade one. Informed consent was taken from all the participants regarding their participation in the study and they were assured about maintenance of confidentiality.

Clinical group: Criteria followed to select participants for the clinical group are as follows:

- A clinical diagnosis by a neurologist stating stroke/trauma confirmed with a CT/MRI scan.
- A diagnosis of Aphasia based on administration of Western Aphasic Battery (WAB) in Kannada (Kertesz, 1982; adapted by Shyamala, Vijayashree & Ravi, 2008).
- Bilingual Aphasia Screening Test (BAT) English version (Guilherm, Gomes, Prod'homme & Köpke, 1989) was administered to assess the auditory verbal comprehension and reading abilities (in English) of the participants.
- Mini Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975) was administered to assess the level of cognitive functioning.
- Normal hearing abilities, normal or corrected vision for reading, adequate comprehension skills to follow the task instructions.
- Stable physical status.

Control group

- Participants selected had normal hearing, normal or corrected vision and no known sensory, neurological, cognitive or speech and language disorder.
- All the participants were screened for any speech-language or hearing disorders using ICF CY questionnaire version 1.B, >13 years given by World Health Organization (WHO) in 2003.

Profiles of the participants

Clinical group

Participant 1 (a1) was a 75 years male, with 68 years of language experience in English. He was a graduate in commerce (B.Com) and a retired bank official. Participant had an attack of stroke due to hypertension. CT/MRI scan reports revealed left middle cerebral artery (MCA) infarct. As reported he had a history of diabetes and hypertension. On administration of Western Aphasia Battery (WAB), he got an Aphasia Quotient (AQ) of 6.8 and was diagnosed as Global Aphasia. He attended speech and language therapy for 7 months and on re-administration of WAB, he received AQ of 31.65 and was finally diagnosed as Anomic Aphasia. He comprehended spoken English and written form as well. BAT-screening (English) revealed a total score of 29/31 for spoken language comprehension and a score of 16/17 for written language comprehension. On administration of Mini Mental State Examination (MMSE), he scored 22. Pre-morbidly the person was right handed and post-morbidly he is ambidextrous.

*Participant 2 (a2)*was a 33 years male, with 27 years of language experience in English. He was a graduate in commerce (B.Com) and dancer by profession (pre-morbid).

Neurological investigations (CT/MRI) revealed acute infarct in left basal ganglia, corona radiate and insular cortex region which affected the middle cerebral artery (MCA) territory. WAB administration on first visit gave an Aphasia Quotient (AQ) of 14.4 and the diagnosis made was (?) Global Aphasia. Client attended speech-language therapy for approximately one year and on re-administration of WAB the AQ obtained was 29.2 leading to a change in diagnosis to Broca's Aphasia. He comprehended both spoken and written English. He scored 28/31 on spoken language comprehension and 16/17 on reading comprehension sections of BAT-English (Screening). The score obtained on MMSE was 26. Pre-morbidly he was right handed and pos-morbidly there has been a change in handedness (shift to left hand).

Participant 3 (a3) was a 43 years male, with language experience of 38 years in English. He was a graduate in Mechanical Engineering and was working as an assistant manager in a private firm. It was reported that the client had a history of spondilitis. CT/MRI reports revealed middle cerebral artery (MCA) infarct majorly affecting the fronto-parietal lobes in the left hemisphere. Language assessment was done using WAB and he got Aphasia Quotient of 62.1, thus was diagnosed as Anomic Aphasia. He attended speech-language therapy for approximately 2 months and on re-evaluation Aphasia Quotient increased to 65.6 but the diagnosis remained the same as Anomic Aphasia. Comprehension of both spoken and written English was present. On BAT-English (Screening) he scored 31/31 on spoken language comprehension and 16/17 on reading comprehension. On MMSE he got a score of 28. He was right-handed and post-morbidly there has been no change in the handedness.

Participant 4 (a4) was a 41 years male, with 35 years of language experience in English. He was a graduate in Arts. He had a history of hypertension. As observed through CT/MRI, he had left middle carotid artery infarct (ischemic stroke). On WAB he got an Aphasia Quotient (AQ) of 14.2 and was diagnosed as Broca's Aphasia. He was attending therapy since 3 months. Spoken and written English comprehension was present. On administering BAT-English (Screening) it was found that he could score 30/31 in spoken language comprehension and 15/17 in reading comprehension sections. In MMSE he obtained a score of 25. Post morbidly there has been a change in handedness in terms of shifting of handedness from right to left.

Participant 5 (a5) was a 21 years female, with 15 years of language experience in English language. She had completed first year of Bachelor of Arts (B.A.). CT/MRI revealed left basal ganglia hemorrhage extending to left side of midbrain and pons and into bilateral lateral ventricles. Also diffuse cerebral and cerebellar atrophy was observed. On administering WAB she got an Aphasia Quotient (AQ) of 52.2 and was diagnosed as Broca's Aphasia. She attended demonstration therapy spaced over a period of three months. She scored 26/31 in spoken language comprehension and 14/17 in reading comprehension sections of BAT-English (Screening). MMSE revealed a score of 22. Post-morbidly there was a change in handedness (shift from right to left hand).

Control group

The control group comprised of fifteen neurotypical individuals acting as controls for the individuals with aphasia (three controls for each aphasic). The details are summarized below in table.

Table 3.1

Details of the participants

Individuals with aphasia (Demographic data)	Age-matched neurotypical	Age/Gender	Education
Participant a1	Participant a1c1	75 years/male	B.Com
75 years/male	Participant a1c2	75 years/male	B.E.
B.Com	Participant a1c3	75 years/male	B.Sc.
Participant a2	Participant a2c1	33 years/male	B.Com
33 years/male	Participant a2c2	33 years/male	B.Com
B.Com	Participant a2c3	33 years/male	B.Sc.
Participant a3	Participant a3c1	43 years/male	B.Com
43 years/male	Participant a3c2	43 years/male	B.Sc.
B.E.	Participant a3c3	43 years/male	B.Sc.
Participant a4	Participant a4c1	41years/male	B.Com
41 years/male	Participant a4c2	41 years/male	B.A.
B.A.	Participant a4c3	41 years/male	B.Sc.
Participant a5	Participant a5c1	21 years/female	All three are B.Sc. students
21 years/female	Participant a5c2	21 years/female	
B.A.	Participant a5c3	21 years/female	

3.2 Stimulus Material

The test material consisted of 32 sentence pairs (2 practice trials and 30 test trials) constructed for inference revision task. The investigator prepared a set of 120 sentences (60 pairs) based on the stimuli made by Harris-Wright and Newhoff (2002) in their study on inference revision processing. The 60 sentence pairs were given to thirty graduate students for validation. The instruction given to them was as follows: "Please read the first sentence and then write one word for each sentence which you think describes/explains it the "best".

For example, in the following sentence

"Jack hurriedly crossed the street but did not see the car coming. Jack caught the bus while his friend drove around looking for him". In the first sentence, one might generate an inference that Jack met with an accident (inference target word = hit), but the second sentence implies that Jack did not meet with an accident and actually caught a bus (revised target word = ride).

Sentences with 75% similar responses (N=40) were selected for next step of validation i.e. rating, where 15 individuals were asked to rate the sentence pairs. The instruction for this step was as follows: "If you think the two sentences in each pair are related, rate them as '2'. If you think the two sentences are not related, rate them as '0'."Sentence pairs rated as '2' by at least 75% (N=34) of the raters were selected. Out of these a total of 32 sentence pairs (2 practice trials + 30 test trials) were taken up as test stimuli for the final task (appendix).

The words given by 30 graduates in the first step of validation formed the target words for the lexical decision task (LDT) (appendix). List of non-words was prepared by the investigator and the control words were selected from the wordlist developed by Prema, Abhishek and Prarthna (2010) for their study titled "Development of a test for assessment of proficiency in bilingual adults through lexical priming". Thus, for each set of sentence pair, there were two LDTs. The first LDT had one target word, one non-word and one control word each. While for the second LDT only two words- a target word and a non-word were presented.

Cross modal lexical priming (CMLP) and LDT comprised the online task. For the offline task, comprehension and inference generation/revision questions were asked. These questions were validated on three graduate students. An example for the questions is given below:

Did Jack hurry across the street? (Y) (Comprehension question for initial sentence)
Did Jack catch a taxi? (N) (Comprehension question for second sentence)
Did a car hit Jack? (N) (Inference question-generation for initial sentence)
Did Jack miss his ride with his friend? (Y) (Inference question-revision for second sentence)"

The entire set of stimuli i.e., the sentence pairs, words for LDT and the questions for the offline task is given in the appendix.

3.3 Instrumentation

The sentence pairs were audio recorded using a condenser microphone connected through Moto software and Adobe Audition version 3.0. The stimuli recorded were saved as wav files with a sampling frequency of 22 kHz and 16 bits quantization.

A 14 inch screen, Lenovo G560 laptop was used to conduct the experiment. DMDX software was used to program the stimuli for cross-modal LDT and stimuli presentation. It is a Windows based software which calculates the reaction time for auditory and visual stimuli and also give the accuracy measures. Participants heard the sentences through speaker whose volume was set at a comfortable level. Letter strings appeared at the center of the monitor in lowercase letters.

3.4 Procedure

Testing was carried out individually in a quiet environment. The participants were seated in a comfortable position at an appropriate distance from the screen. The letter strings were presented in black font on a white background. The stimuli (sentence pairs) presentation across participants was randomized for the CMLP task and the sequence in which questions were presented was also randomized for each sentence pair and across participants. As mentioned earlier the presentation of the stimuli was controlled by DMDX (Forster & Forster, 2003).

For CMLP task, participants were instructed to carefully listen to the sentence pairs presented. They were told to pay attention to the letter strings appearing on the screen and press the specified keys to indicate if the presented letter string was an English word or not. The inter-stimulus interval between a sentence and the LDT was kept as 750 ms based on the study carried out by Harris-Wright and Newhoff (2002).

The LDT was followed by an offline task where the participants were instructed to provide yes or no answer for four questions. Out of the four questions two assessed comprehension and the other two investigated the inference revision abilities. Catch trials were also included to check for the consistency of responses. After every 5 test trials one catch trial was administered.

3.5 Scoring and Analysis

The responses for the LDT (reaction time and accuracy) were computed by the DMDX software. The responses for the offline task were scored manually as 1 (correct) and 0 (incorrect/no response). The data was coded, tabulated and subjected to statistical analysis using Statistical Package for Social Sciences (SPSS), version 17.0.

CHAPTER 4: Results

The primary aim of the present study was to understand inference revision processing in individuals with aphasia (IA). The present study also investigated the performance on lexical decision through cross-modal priming paradigm. The data obtained from both the groups i.e., individuals with aphasia (IA) and neurotypical (NT) individuals was analyzed for reaction time (RT in ms) and accuracy measures.

The data was subjected to statistical analyses to measure accuracy for three types of questions: factual questions (FQ), inference generation questions (IGQ), and inference revision question (IRQ). The scores obtained for accuracy was in terms of whether the individuals answered the questions appropriately or not. Also RT (in ms) and accuracy measures for the following types of words: target words (TW), non-words (NW), and control words (CW) were computed.

As the sample size was small and unequal across the two groups i.e., clinical group (individuals with aphasia) and the control group (neurotypical individuals), and the sample did not follow normal distribution, non-parametric tests were used. The data was analyzed using the following statistical procedures:

- Mann Whitney test was done to compare the performance of individuals with aphasia (IA) and neurotypicals (NT) on inference revision and lexical decision.
- Friedman test was done to determine any statistically significant difference across different types of questions and types of words in the performance of individuals with aphasia (IA) and neurotypicals (NTs)

- The Wilcoxon signed rank test was done to compare the performance of the individuals with aphasia (IA) and neurotypicals (NT) for inference revision and lexical decision.

The results of the present study are discussed under the following headings:

4.1 Performance of individuals with aphasia (IA) on inference revision and lexical decision

4.2 Performance of neurotypicals (NT) individuals on inference revision and lexical decision

4.3 Comparison of performance of individuals with aphasia (IA) and neurotypicals (NTs) individuals on inference revision and lexical decision.

4.1 Performance of individuals with aphasia (IA) on inference revision and lexical decision

The data obtained from IA was analyzed for accuracy measures for different types of questions. The overall mean, median and standard deviation (SD) was calculated for the performance of individuals in the clinical group i.e., IA across different types of questions for exploring inference revision. Table 4.1 shows the performance of IA across different question types such as factual questions (FQ), inference generation questions (IGQ) and inference revision questions (IRQ).

Table 4.1

Performance of individuals with aphasia (IA) across different question types on accuracy measure (n=5)

Individuals with aphasia (IA) (Accuracy in %)			
Type of question	**Mean**	**Median**	**SD**
FQ	65.99	66.66	5.60
IGQ	55.33	56.66	9.00
IRQ	51.99	46.66	21.93

Note: FQ- Factual questions, IGQ- Inference generation questions, IRQ- Inference revision questions

The analysis of results in Table 4.1 showed that the IA had highest accuracy for FQ (Mean=65.99, Median= 66.66, SD= 5.60), followed by IGQ (Mean= 55.33, Median= 56.66, SD= 9.00) and lastly IRQ (Mean= 51.99, Median= 46.66, SD= 21.93). However, Friedman Test revealed that there was no significant difference in accuracy for the three types of questions. The findings of the study indicates that the performance of IA was better for factual questions (FQ) inference generation (IG) and inference revision (IR) (see Figure 4.1 below), though the difference was not found to be statistically significant.

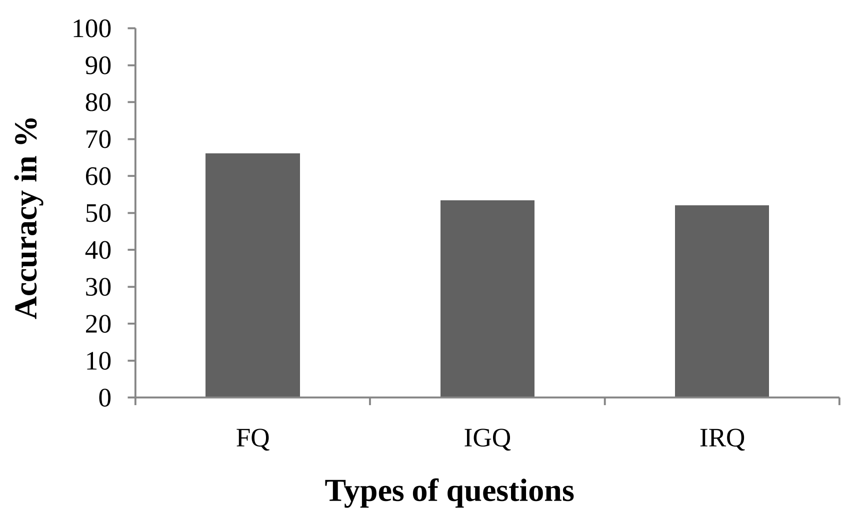

Figure 4.1: Performance of IA across question types on accuracy measures
Note: FQ- Factual questions, IGQ- Inference generation questions, IRQ- Inference revision question

The data obtained from IA on LDT was further analyzed for RT and accuracy measures for different types of words. The overall mean, median and standard deviation (SD) of the reaction time (RT) measure was calculated for the clinical group i.e., individuals with aphasia (IA) across different types of words. Table 4.2 shows the performance of IA across different word types such as TW, NW and CW

Table 4.2

Performance of individuals with aphasia (IA) across different word types on RT measure (n=5)

Individuals with aphasia (RT in ms)			
Type of word	**Mean**	**Median**	**SD**
TW	1509.57	1271.90	440.56
NW	1477.36	1362.65	444.01
CW	1504.79	1310.25	518.09

Note: TW- Target word, NW- Non-word, CW- Control word

The analysis of results in Table 4.2 revealed that the IA showed longest reaction time for TW (Mean= 1509.57, Median = 1271.90, SD = 440.56) followed by control words (Mean= 1504.79, Median = 1504.79, SD = 518.09), while the shortest reaction time was observed for the NW (Mean= 1477.36, Median = 1362.65, SD = 444.01). However, Friedman's test indicated no significant difference in the reaction time of IA for different word types. The findings of the study indicates that the performance of IA was better for NW followed by CW and TW (see Figure 4.2 below), though the difference was not found to be statistically significant.

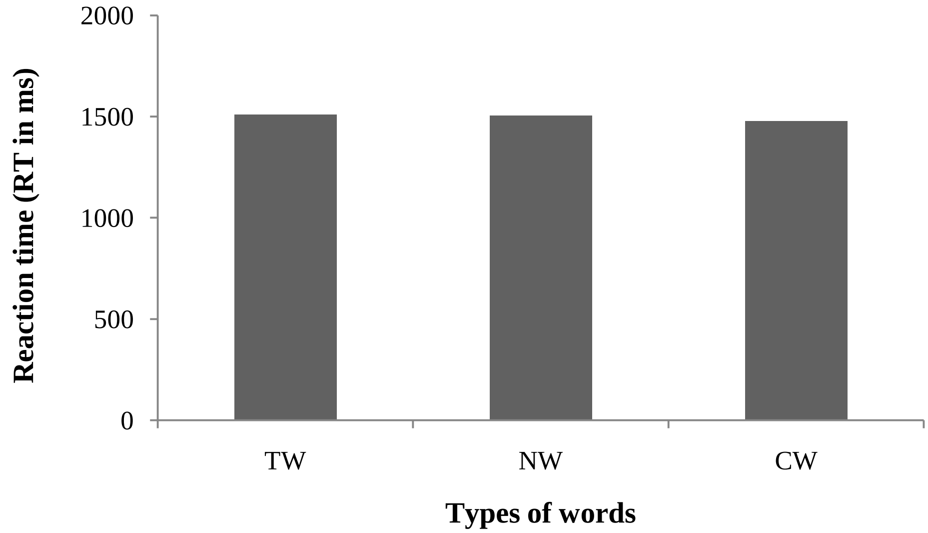

Figure 4.2: Performance of individuals with aphasia across word types on RT measure
Note: TW- Target word, NW- Nonword, CW- Control word

Table 4.3 shows the performance of IA across different type of words such as TW, NW and CW for accuracy measure.

Table 4.3

Performance of individuals with aphasia (IA) across different word types on accuracy measure (n=5)

Individuals with aphasia (accuracy in %)			
Type of word	**Mean**	**Median**	**SD**
TW	83.66	85	7.94
NW	83.66	81.66	11.98
CW	90.66	90	4.34

Note: TW- Target word, NW- Non-word, CW- Control word

Analysis of results in Table 4.3 showed that IA showed higher accuracy measure for CW (Mean= 90.66, Median = 90, SD = 4.34) than the TW (Mean= 83.66, Median=

85, SD= 7.94) and the NW (Mean= 83.66, Median= 81.66, SD= 11.98). Further Friedman test revealed no significant difference in the accuracy scores of three types of words. The findings of the study indicates that the performance of IA was better for CW followed by TW and NW (see Figure 4.3 below), though the difference was not found to be statistically significant.

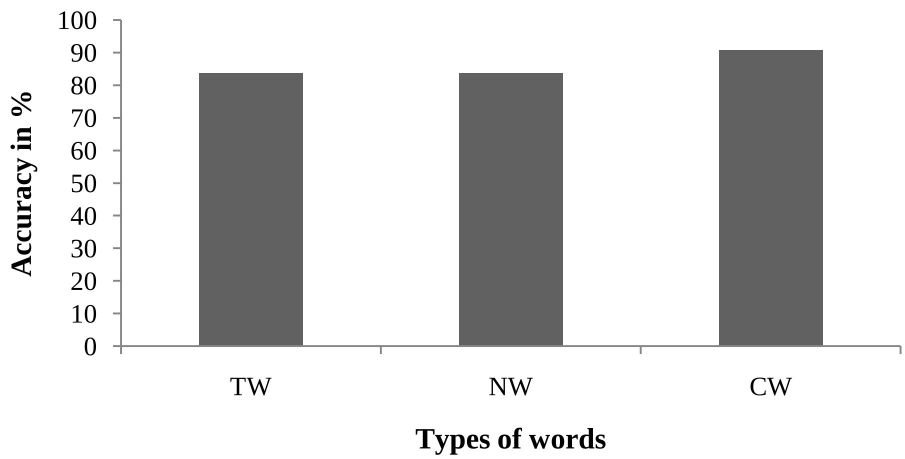

Figure 4.3: Performance of individuals with aphasia (IA) across word types on accuracy measure
Note: TW- Target word, NW- Nonword, CW- Control word

4.2 Performance of NT individuals on inference revision and lexical decision

The data obtained from NT individuals was analyzed for accuracy measures for different types of questions. The overall mean, median and standard deviation (SD) of the accuracy measure was calculated across different types of questions. Table 4.4 shows the performance of NT individuals across different question types such as FQ, IGQ, and IRQ.

Table 4.4

Performance of NT individuals across different question types on accuracy measure (n=15)

NT Individuals (Accuracy in %)			
Type of question	**Mean**	**Median**	**SD**
FQ	85.77	93.33	12.46
IGQ	82.66	87.77	12.21
IRQ	83.33	87.77	10.15

Note: FQ- Factual questions, IGQ- Inference generation questions, IRQ- Inference revision questions

Analysis of results in Table 4.4 showed that the NT individuals had highest accuracy for FQ (Mean= 85.77, Median= 93.33, SD= 12.46), followed by IGQ (Mean= 83.33, Median= 87.77, SD= 10.15) and IRQ (Mean= 82.66, Median= 87.77, SD= 12.21). Further Friedman Test revealed that the there was a significant difference in terms of performance on the three types of questions. Further Wilcoxon Signed Rank Test was done to determine the significant pair-wise difference between FQ, IGQ and IRQ. The results unveiled the presence of significant difference between FQ and IGQ, $|z|= 3.327$, $p<0.05$ and FQ and IRQ, $|z|= 2.785$, $p<0.05$. However, the difference between IGQ and IGR was found to be statistically insignificant. The findings of the study indicate that the performance of NT individuals was significantly better for factual questions (FQ) than inference generation questions (IGQ) and inference revision questions (IRQ) (see Figure 4.4 below). Also it was found that the performance on IGQ was better than IRQ, though no statistically significant difference was found.

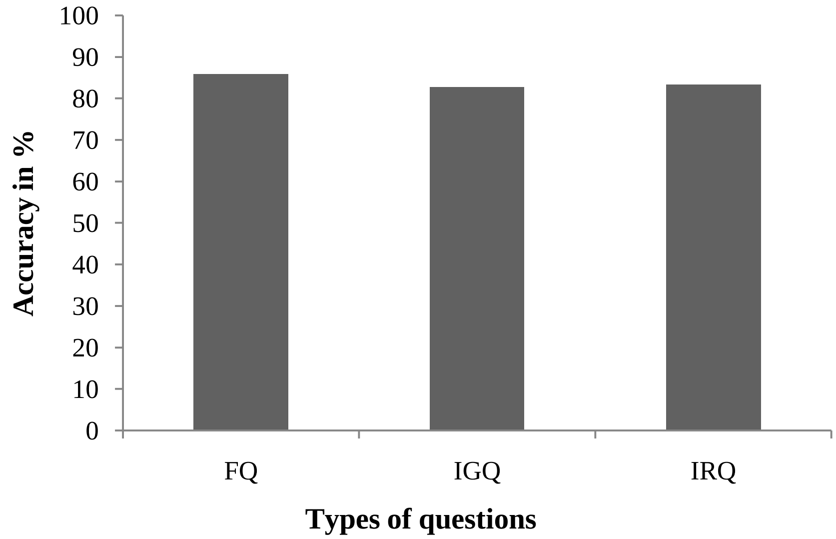

Figure 4.4: Performance of NT across question types on accuracy measures

Note: FQ- Factual questions, IGQ- Inference generation questions, IRQ- Inference revision question

The data obtained from NT individuals on LDT was further analyzed for RT and accuracy measures for different types of words. The overall mean, median and standard deviation (SD) of the RT measure was calculated for the control group and is summarized below in Table 4.5

Table 4.5

Performance of NT individuals across different word types on RT measure (n=15)

NT Individuals (RT in ms)			
Type of word	**Mean**	**Median**	**Standard deviation**
TW	1002.03	981.63	193.32
NW	1060.63	979.10	163.06
CW	1071.53	982.44	252.42

Note: TW- Target word, NW- Non-word, CW- Control word

Analysis of results in Table 4.5 reveal that the NT individuals demonstrated the longest reaction time for CW (Mean= 1071.53, Median = 982.44, SD = 252.42) followed by NW (Mean= 1060.63, Median = 979.10, SD = 163.06), while the shortest reaction time was observed for the TW (Mean= 1002.03, Median = 981.63, SD = 193.32). Further Friedman's test showed that there was no significant difference in reaction time across the three types of words. The findings of the study indicates that the performance of NT individuals was better for TW followed by CW and NW (see Figure 4.5 below), though the difference was not found to be statistically significant.

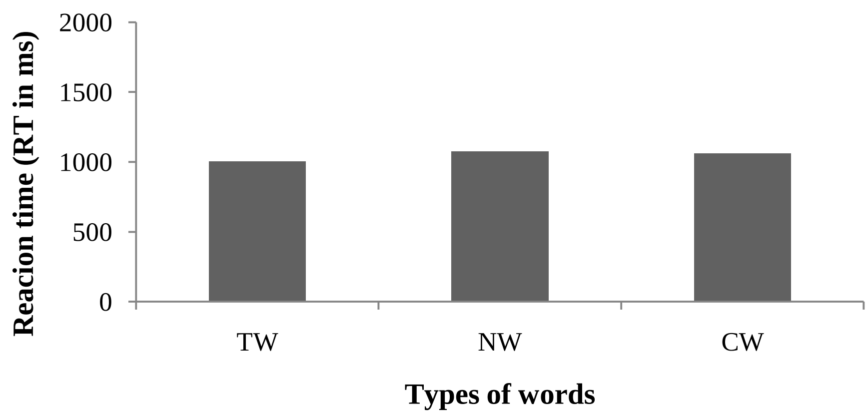

Figure 4.5: Performance of NT individuals across word types on RT measure
Note: TW- Target word, NW- Nonword, CW- Control word

Table 4.6 shows the performance of NT individuals across different types of words such as TW, NW and CW for accuracy measure.

Table 4.6

Performance of individuals with aphasia across different word types on accuracy measure (n=15)

NT Individuals (accuracy in %)			
Type of word	**Mean**	**Median**	**Standard deviation**
TW	95.11	95.55	1.85
NW	95.55	95.55	2.00
CW	96.22	97.77	3.38

Note: TW- Target word, NW- Non-word, CW- Control word

Analysis of results in Table 4.6 showed that the NT individuals showed higher accuracy measure for CW (Mean= 96.22, Median = 97.77, SD = 3.38) than the TW (Mean= 95.11, Median= 95.55, SD= 1.85) and the NW (Mean= 95.55, Median= 95.55, SD= 2.0). Further Friedman test revealed no significant difference in accuracy measures of the three types of words. The findings of the study indicates that the performance of NT individuals was better for CW followed by NW and TW (see Figure 4.6 below), though the difference was not found to be statistically significant.

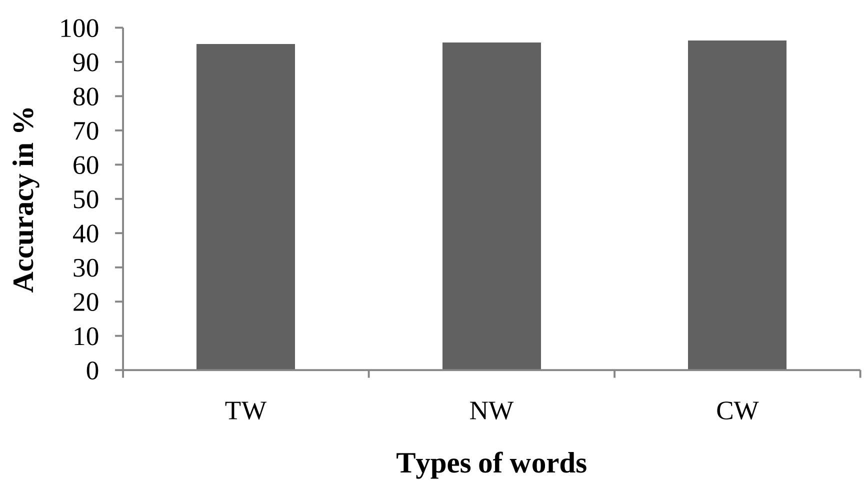

Figure 4.6: Performance of NT individuals across word types on accuracy measure
Note: TW- Target word, NW- Nonword, CW- Control word

4.3 Comparison of performance of individuals with aphasia and NT individuals on inference revision and lexical decision

The performance of the two groups – individuals with aphasia (IA) and neurotypicals (NT) was compared on accuracy measures. An overall analysis of the results showed that IA manifested higher error rates than the NT group across all the types of questions for inference revision. Table 4.7 shows the performance of NTs and IA on accuracy measure for different question types such as FQ, IGQ and IRQ.

Table 4.7

Performance of NT and individuals with aphasia (IA) on accuracy measure (in %)

	Neurotypical Accuracy (in%) (N=15)		**Individuals with aphasiaAccuracy (in %) (N=5)**	
Type of question	**Median**	**SD**	**Median**	**SD**
FQ	93.33	12.46	66.66	5.60
IGQ	87.77	12.21	56.66	9.00
IRQ	87.77	10.15	46.66	21.93

Note: FQ- Factual questions, IGQ- Inference generation questions, IRQ- Inference revision questions

Man Whitney Test was done to compare the performance of NT and IA on inference revision. Analysis of the results revealed that overall for the questions there was a significant difference between the performances of the two groups for accuracy measures. The results of the study with respect to each of the question types are explained in the following sections:

Factual questions (FQ)

Analysis of results as shown in Table 4.7 indicated higher error rates in IA (Mean= 65.99, Median= 66.66, SD= 5.60) when compared to NTs (Mean= 85.77, Median= 93.33, SD=12.46). It was found that there was a significant difference in terms of accuracy of response between IA and NT, $|z|=2.973$, $p<0.05$. Thus, the findings of the study indicate that the performance of IA was significantly poorer when compared to the NTs on factual questions (FQ) (see Figure 4.7 below).

Inference Generation questions (IGQ)

Analysis of results as shown in Table 4.7 indicated that IA had higher error rates (Mean= 55.33, Median= 56.66, SD= 9.00) when compared to the NT (Mean= 82.66, Median= 87.77, SD=12.21). It was found that there was a significant difference in terms of accuracy of response between IA and NT, $|z|=2.910$, $p<0.05$. Thus, the findings of the study indicates that the performance of IA was significantly poorer when compared to the NTs on inference generation questions (IGQ) IA (see Figure 4.7 below).

Inference Revision questions (IRQ)

Analysis of results as shown in Table 4.7 also revealed higher error rates in IA (Mean= 51.99, Median= 46.66, SD= 21.93) when compared to NT (Median= 83.33, SD= 10.15). It was found that there was a significant difference in terms of accuracy of response between IA and NT, $|z|=2.723$, $p<0.05$. Thus, the findings of the study indicated that the performance of IA was significantly poorer when compared to the NTs on inference revision questions (IRQ) (see Figure 4.7 below).

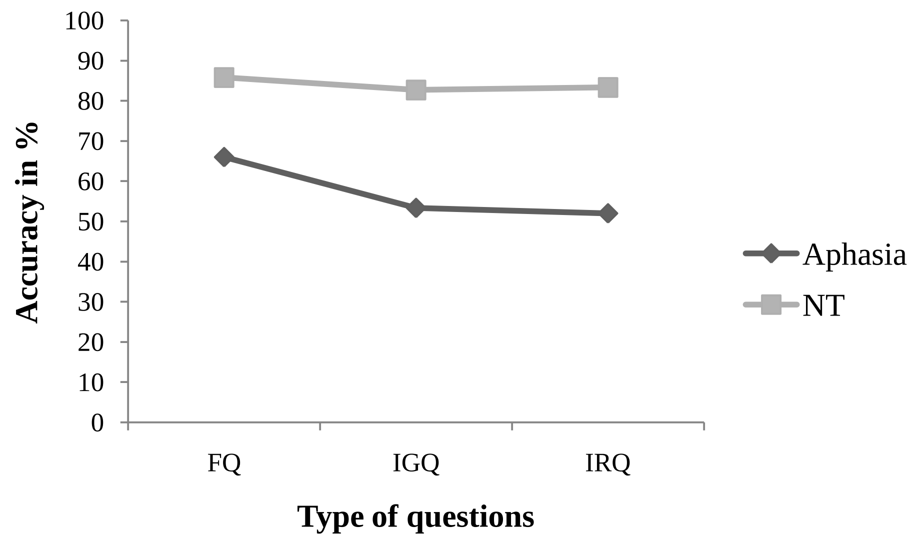

Figure 4.7: Performance of individuals with aphasia and NT across questions on accuracy measures

Note: FQ- Factual questions, IGQ- Inference generation questions, IRQ- Inference revision question

The performance of the two groups – aphasics and neurotypicals was compared on RT and accuracy measures on LDT. An overall analysis of the results showed that IA manifested longer reaction time and higher error rates than the NT group across all the types of words. Table 4.8 shows the performance of IA and NT on RT measure for different word types: TW, NW and CW.

Table 4.8

Performance of NT and individuals with aphasia on RT (in ms) measure

	Neurotypical(RT in ms) (N=15)		**Individuals with aphasia (RT in ms)(N=5)**	
Type of word	**Median**	**SD**	**Median**	**SD**
TW	981.63	193.32	1271.90	440.56
NW	979.10	163.06	1362.65	441.01
CW	982.44	252.42	1310.25	518.09

Note: TW- Target word, NW- Non-word, CW- Control word

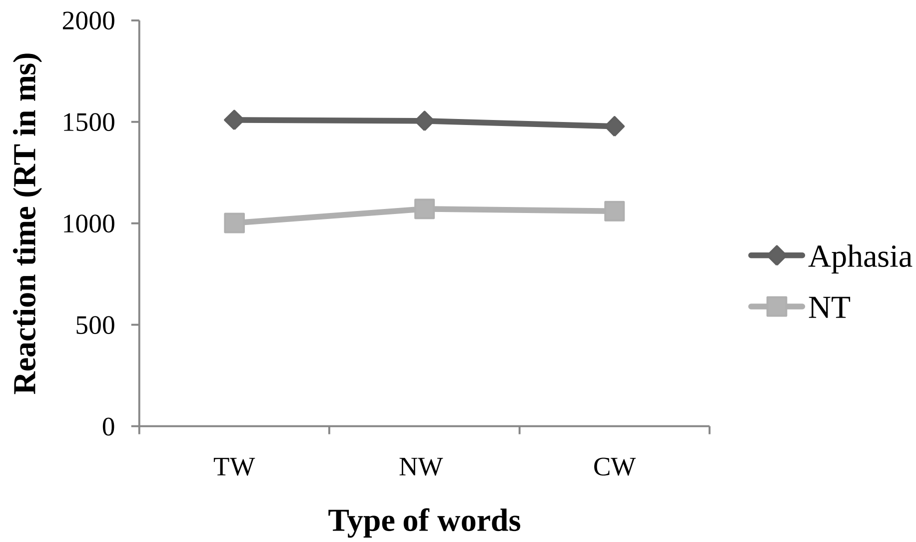

Figure 4.8: Performance of individuals with aphasia and NT across words on RT measures
Note: TW- Target word, NW- Nonword, CW- Control word

Table 4.9 shows the performance on accuracy measure by both the groups across the three types of words i.e., TW, NW and CW.

Table 4.9

Performance of NT and individuals with aphasia on accuracy measure (in %)

	Neurotypical Accuracy (in %) (N=15)		**Individuals with aphasia Accuracy (in %) (N=5)**	
Type of word	**Median**	**SD**	**Median**	**SD**
TW	95.55	1.85	85	7.94
NW	95.55	2.00	81.66	11.98
CW	97.77	3.38	90	4.34

Note: TW- Target word, NW- Non-word, CW- Control word

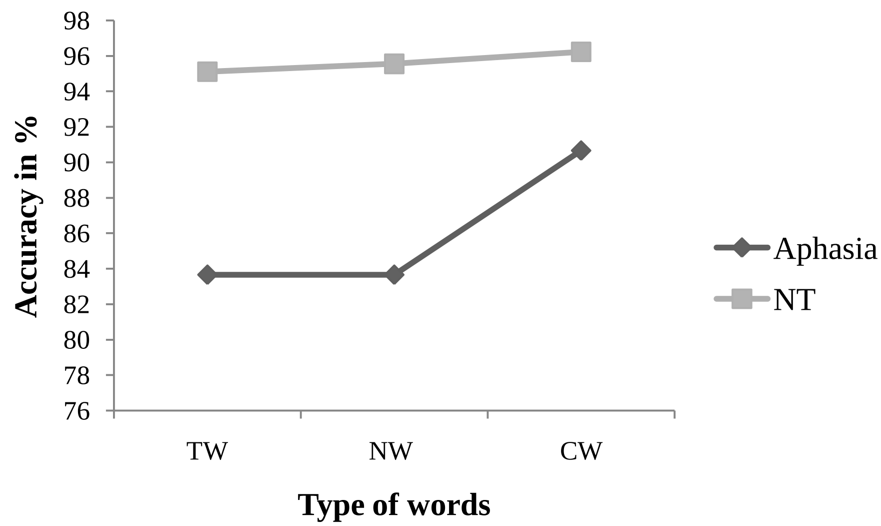

Figure 4.9: Performance of individuals with aphasia and NT across words on accuracy measures
Note: TW- Target word, NW- Nonword, CW- Control word

The Man Whitney Test was administered to compare the performance of NT and IA on lexical decision. Analysis of the results revealed that there was a significant difference between the performances of the two groups for reaction time and accuracy measures. The results of the study with respect to performance on each of the word types are explained in the following sections:

Target words (TW)

Analysis of the results as shown in Table 4.8 revealed that IA (Mean= 1509.97, Median= 1271.90, SD= 440.56) had longer RT measures when compared to the NT (Mean= 1002.03, Median= 981.63, SD= 193.32). There was a significant difference between the RT of IA and NT, $|z|= 2.488$, $p<0.02$. Thus, the findings of the study indicate that the IA had significantly longer RT for the TW when compared to NT individuals (see Figure 4.8 above).

Analysis of results as shown in Table 4.9 also indicated higher error rates in IA (Mean= 83.66, Median= 85, SD= 7.94) when compared to the NT individuals (Mean= 95.11, Median= 95.55, SD=1.85). It was found that there was a significant difference in terms of accuracy of response between IA and NT, $|z|=2.974$, $p<0.02$. Thus, the findings of the study indicate that the IA had significantly poorer accuracy for TW when compared to NT individuals (see Figure 4.9 above).

Non words (NW)

Analysis of the results as shown in Table 4.8 revealed that IA (Mean= 1504.79, Median= 1362.65, SD= 441.01) had longer reaction time measures than the NT (Mean= 1071.53, Median= 979.10, SD= 163.06). There was a significant difference between the reaction time of IA and NT, $|z|= 2.313$, $p<0.05$. Thus, the findings of the study indicate that the IA had significantly longer RT for the NW when compared to NT individuals (see Figure 4.8 above).

Analysis of results as shown in Table 4.9 also indicated higher error rates in IA (Mean= 83.66, Median= 81.66, SD= 11.98) than the NT (Mean= 95.55, Median= 95.55, SD=2.00). It was found that there was a significant difference in terms of accuracy of response between IA and NT, $|z|=1.990$, $p<0.05$. Thus, the findings of the study indicate that the IA had significantly poorer accuracy for NW when compared to NT individuals (see Figure 4.9 above).

Control words (CW)

Analysis of the results as shown in Table 4.8 revealed that IA (Mean= 1060.63, Median= 1310.25, SD= 518.09) had longer reaction time measures than the NT (Mean= 1477.36, Median= 982.44, SD= 252.42). There was a significant difference between the reaction time of IA and NT, $|z|= 2.051$, $p<0.05$. Thus, the findings of the study indicate that the IA had significantly longer RT for the CW when compared to NT individuals (see Figure 4.8 above).

Analysis of results as shown in Table 4.9 also indicated higher error rates in IA (Mean= 90.66, Median= 90, SD= 4.34) than the NT (Mean= 96.22, Median= 97.77, SD= 3.38). There was found that there was a significant difference in terms of accuracy of response between IA and NT, $|z|=2.105$, $p<0.05$. Thus, the findings of the study indicate that the IA had significantly poorer accuracy for CW when compared to NT individuals (see Figure 4.9 above).

Further, a qualitative subjective analysis of the performance of IA compared to age matched controls was done. The observations of the samples are explained in the following sections.

Participant 1: 75 years/male with Anomic aphasia when compared with age, gender and education matched controls had poorer performance for both the off-line questions and the lexical decision task. Accuracy results of performance on off-line questions revealed better performance for FQ (63.33%) than the IGQ (50%) and IRQ (23.33%). It was found that for LDT, RT was shortest for the NW (Mean=1511.80 ms) followed by CW (Mean=1739.38 ms) and TW (Mean=1773.71 ms). While for accuracy measure, the performance was in the following order: CW (90%) > NW (75%) > TW (73.33%). The NT individuals also exhibited similar pattern of better performance on factual than inference questions. On lexical decision task also they performed significantly better than the IA. For e.g., on inference revision, when the stimulus was sentence pair "Girija lay quietly as the bright light and heat beat down on her; The nurse opened the door and turned the scanning machine down", performance on IRQ "Was Girija in hospital for scanning tests?" revealed that participant 1 made error while all the three controls responded appropriately. Similarly it was observed that the RT for TWs 'sunny'= 1473.57 ms and 'scan'= 1033.06 ms for participant 1 whereas for the matched controls it was found to be 1089.58 ms and 782.63 ms respectively. Also in terms of accuracy for TWs 'sunny' and 'scan' participant 1 gave incorrect responses unlike matched controls who responded appropriately.

Participant 2: 33 years/male with Broca's aphasia when compared with age, gender and education matched controls had poorer performance for both the lexical decision task and the off-line questions. Accuracy results of performance on off-line questions revealed better performance for IGQ (66.66%) than the FQ (58.33%) and IRQ (43.33%). It was found that for LDT, RT was shortest for the TW (Mean=1271.90 ms) followed by CW (Mean=1310.25 ms) and NW (Mean=1362.65 ms). While for accuracy measure, the performance was in the following order: CW (93.33%) > TW (88.33%) > NW (81.66%). The NT individuals in the control group had significantly shorter reaction time and higher accuracy scores for the LDT and off-line questions. Though it was observed that the accuracy scores of the two groups were similar for TW and CW, they differed on performance on the NW. For e.g., On inference revision, when the stimulus was sentence pair “Laxmi was in tears when she saw the condition of her kitchen after the party. Laxmi’s husband had spent all night making the kitchen spotless”, performance on IRQ “Did Laxmi’s husband clean the kitchen?” revealed that participant 2 made error while two out of three controls responded appropriately. Similarly it was observed that the RT for TW ‘dirty’= 1370.88 ms and NW ‘cleen’= 1314.60 ms for participant 2 whereas for the matched controls it was found to be 881.43 ms and 943.21 ms respectively. Also in terms of accuracy for TW ‘dirty’ and NW ‘cleen’ participant 2 gave incorrect responses unlike matched controls who responded appropriately.

Participant 3: 43 years/male with Anomic aphasia when compared with age, gender and education matched controls had poorer performance for both the lexical decision task and the off-line questions. Accuracy results of performance on off-line questions revealed better performance for IRQ (80%) than the FQ (73.33%) and IGQ (56.66%). It was found that for LDT, RT was shortest for the CW (Mean=1020.21 ms) followed by TW (Mean=1113.05 ms) and NW (Mean=1190.33 ms). While for accuracy measure, the performance was in the following order: CW (96.66%) > TW (93.33%) = NW (93.33%). The NT individuals in the control group had significantly shorter reaction time and higher accuracy rates for the LDT and off-line questions. It was observed that the performance of individual with aphasia varied significantly in terms of RT on LDT but the accuracy measures for the same were similar to the controls. For e.g., on inference revision, when the stimulus was sentence pair “Jyoti couldn’t believe how the book ended; Jyoti was amazed that she could write such a suspenseful novel”, performance on IRQ “Was Jyoti the author of the book?” revealed that participant 3 made an error while all the three controls responded appropriately. Similarly it was observed that the RT for TW ‘disbelief’= 3500 ms and NW ‘desbelief’= 2108.18 ms for participant 2 whereas for the matched controls it was found to be 1345.68 ms and 1311.05 ms respectively. Also in terms of accuracy for TW ‘disbelief’ and NW ‘desbelief’ participant 3 gave incorrect responses unlike matched controls who responded appropriately.

Participant 4: 41 years/male with Broca’s aphasia when compared with age, gender and education matched controls had poorer performance for both the lexical decision task and the off-line questions. Accuracy results of performance on off-line questions revealed better performance for FQ (68.33%) than the IGQ (60%) and IRQ (66.66%). It was found that for LDT, RT was shortest for the NW (Mean=1102.26 ms) followed by CW (Mean=1158.20 ms) and TW (Mean=1233.93 ms). While for accuracy measure, the performance was in the following order: NW (98.33%) > CW (86.66%) > TW (85%). The NT individuals in the control group had significantly shorter reaction time and higher accuracy rates for the LDT and off-line questions except the accuracy for NW in LDT. For e.g., On inference revision, when the stimulus was sentence pair “Rajesh was burning from head to toe. He had always been jealous of his colleagues”, performance on IRQ “Did Rajesh have good rapport with his colleagues?” revealed that participant 4 made an error while all the three controls responded appropriately. Similarly it was observed that the RT for TW ‘jealousy’= 925.51 ms for participant 4 whereas for the matched controls it was found to be 794.04 ms respectively. Also in terms of accuracy for TW ‘jealousy’ participant 4 gave incorrect response unlike matched controls who responded appropriately.

Participant 5: 21 years/female with Broca’s aphasia when compared with age, gender and education matched controls had poorer performance for both the lexical decision task and the off-line questions. Accuracy results of performance on off-line questions revealed better performance for FQ (66.66%) than the IGQ (43.33%) and IRQ (46.66%). It was found that for LDT, RT was shortest for the TW (Mean=2155.26 ms) followed by NW (Mean=2219.77 ms) and CW (Mean=2295.90 ms). While for accuracy measure, the performance was in the following order: CW (86.66%) > TW (78.33%) > NW (70%). The NT individuals in the control group had significantly shorter reaction time and higher accuracy rates for the LDT and off-line questions. For e.g., on inference revision, when the stimulus was sentence pair "The sirens and bright lights made Rishi's heart pump faster; Rishi made the last basket and handed the prize to his coach", performance on IRQ "Was Rishi playing basketball?" revealed that participant 5 made an error while all the three controls responded appropriately. Similarly it was observed that the RT for TWs 'police'= 1693.88 ms and 'win'= 3203.10 ms for participant 5 whereas for the matched controls it was found to be 1191.97 ms and 823.71 ms respectively. Also in terms of accuracy for TW 'police' and 'win' participant 5 gave incorrect responses unlike matched controls who responded appropriately.

To summarize, findings of the present study based on the quantitative and qualitative analysis of performance on inference revision shows that individuals with aphasia (IA) performed significantly poorer on all the three types of questions i.e., FQ, IGQ, and IRQ and the highest error rate was noted for IRQ followed by IGQ and FQ. Also findings on lexical decision revealed that IA exhibited significantly longer processing time (RT) and higher error rates when compared to the NT individuals. Further the findings of the present study on inference revision also revealed that within the types of aphasias, individuals with Anomic aphasia performed better on the FQ when compared to the individuals with Broca's aphasia (BA). However, on inference questions such as inference generation (IGQ) and inference revision questions (IRQ), a reverse pattern was observed where individuals with BA performed better when compared to Anomic aphasia. On lexical decision, individuals with Anomic aphasia had shorter RT and better accuracy when compared to individuals with BA.

Chapter 5: Discussion

The present study aimed at understanding the inference generation and revision skills of individuals with aphasia. Performance of individuals with aphasia was compared with neurotypicals in terms of reaction time (RT) and accuracy measures. The study consisted of two tasks- first a lexical decision task using cross-modal lexical priming paradigm and second an off-line tasks of yes/no questions of three types: factual questions (FQ), inference generation questions (IGQ) and inference revision questions (IRQ).

The findings of the present study are discussed under following sections:

5.1 Comparison of individuals with aphasia and neurotypicals on inference revision skills.

5.2 Comparison of performance of individuals with aphasia and neurotypicals on RT and accuracy measures of lexical decision and priming effect.

5.1 Comparison of performance of individuals with aphasia and neurotypicals on inference revision skills

The findings of the study unveiled that individuals with aphasia (IA) had higher error rates for inference questions than the factual questions, though there was no statistical significance across the three types of questions i.e., FQ, IGQ and IRQ. In contrast to this the performance of NT individuals was significantly better when compared to IA on all the three questions i.e., FQ, IGQ and IRQ. The pattern observed was similar across the two groups in terms of better performance on the factual questions than the inference questions (See figure 4.7).

Focusing on individuals with aphasia, errors on factual and inference questions could be attributed to poor working memory capacity often seen in individuals as a result of brain damage (Matlin, 2003; Friedmann & Gvion, 2003). These deficits in working memory capacity of the IA could have led to difficulty in retaining the facts and retrieving the information required for comprehension of factual questions. For example, for following the sentence pair “Aryan screamed as the sailboat began to sink. Aryan’s mother calmed him and, gave him another boat to play with”, IA could correctly answer the first FQ based on the first sentence. However, for the second FQ they gave incorrect answer. Comparing the two statements based on sentence length, the second sentence is more complex thereby increasing the load on working memory capacity. This increased complexity of the sentence and load on impaired WM capacity of IA could be considered as the reason for their poor performance on FQ. The poor performance on inference questions when compared to factual questions could be attributed to incomplete or faulty transformations of the surface structure of a given sentence to deduce the meaning. As drawing inferences is more complex than comprehension of explicit or stated information, the number of transformations involved is more to deduce implicit meaning which was needed to answer the inference questions. However, the information required to answer the FQ was stated explicitly with one-to-one relation between the surface and deep structure. Thus, reducing the complexity and number of transformations involved (Chomsky, 1968; Cohen, 1979; Singer, 1988) FQ questions when compared inference questions.

Among the inference generation and inference revision questions the errors were found to be greater on inference revision questions, though there was no significant difference in the error rate between the two types of questions. Such differences could also be attributed to the process of activation of referents and suppression of non-referents in inferencing skills. Gernsbacher et al. (1990, 1991) proposed that inference making is accompanied with activation of words in the mental lexicon. She proposed that this does not involve only the enhancement of the activation of referents but also includes suppressing the activation of non-referents. It could be speculated that individuals with aphasia may not be able to process complex verbal information such as those in the sentences requiring inference generation and revision. This could be their inability to activate referents and/or suppress non-referents in a given sentence. For example in the present study, considering a sentence pair from the present study "Samrat bumped the car in front of him while going around the curve. At the end of the ride, Samrat got out of the bumper car". The individual with aphasia could answer FQs like "Was Samrat on a plane? Was Samrat in a bumper car?" based on explicitly stated information. In the present example, after the complete presentation of the sentence pair, referent word becomes a 'funpark' or 'fair' and non-referent or competing word is 'accident'. IA could generate inference based on the first sentence i.e., Samrat met with an accident, but they faced difficulty in suppressing the activation of non-referent (in this case 'accident') after the listening to the second sentence. Thus, giving incorrect response for the inference revision question "Was Samrat at a fair?" Higher error rates on inference revision could also be attributed to difficulty in inhibiting or revising the initial interpretations for an inference related task (Tompkins & Mateer, 1985; Gernsbacher et al., 1990, 1991;

Tompkins, Lehman, & Baumgaertner, 1999; Wright & Newhoff, 2004; Blake & Lesniewicz, 2005). However, the findings of Tompkins et al. (1994) were slightly different where the individuals with LHD were found to perform better on inference revision than inference generation. This could be due to the fact that in Tompkins et al.'s (1994) study not all the individuals with LHD exhibited aphasia. Also the task and the stimuli used varied from the present study.

In the present study it was observed that individuals with aphasia performed better for the inference generation questions than inference revision questions. This can be further understood based on Kintsch's (1988) "*Construction-integration model of discourse processing*" (see Figure 2.1) which proposes that inferential process takes place in two phases, the first phase comprising of inference generation and the second phase including integration of the drawn inferences into a coherent text base. The construction phase is said to have four steps. The first step includes a merger of the linguistic input and the general knowledge forming a concept or proposition. In the second step, each concept or proposition leads to activation of the related information. Here the information with maximum activation makes it way to the working memory and finally an inference is formed. Thus, in the present study, the processing involved in the first two steps of the construction phase can be considered to be relatively intact which leads to formation of inferences in IA based on the first sentence of the pair.

In the third step additional inferences or counterexamples are created. Occasionally, formation of the additional inferences increases the demands on the working memory by claiming active concentration on the information present in the working memory. In the present study, this could have occurred on presentation of the second sentence when there was competing information provided and this in turn could have increased the demands on working memory capacity.

The fourth and the final step is the formation of interconnections between the inferences and general knowledge. In the integration phase, once the activation is stabilized, the text base integrates into a "coherent whole". In the present study the inability to revise the interpretations indicates the difficulty faced at fourth step of construction phase and second phase of integration. Thus, it could be attributed that the comprehension deficits observed in IA could be due to impaired integration of lexical content into higher order representation of the preceding sentence (Swaab, Brown & Hagoort, 1997).

Another reason for poor performance on inference revision could be rigidity of interpretation and poor cognitive flexibility which impairs the ability of an individual to update their interpretations with on-going inflow of information in a discourse (Brownell et al., 1986). Alongwith poor cognitive flexibility, limited cognitive resources for processing complex linguistic materials could be another underlying cause for poor performance on inference revision when compared to factual questions. In other words, in individuals with aphasia in the present study, the neural insult could have affected the availability of these processing resources. Thus, as the complexity of the task increased from factual to inference questions and thereby the cognitive demands the performance of individuals with aphasia deteriorated (Kahneman, 1986; Nicholas & Brookshire, 1995).

Poor performance on inference questions than factual questions as observed in the present study can also be justified based on the anatomical and physiological functions of the implicated brain areas. In the present study individuals with aphasia included Broca's type and Anomic type. The findings of the present study uncovered that individuals with Broca's aphasia performed better on inference questions (inference generation and revision) when compared to individuals with Anomic Aphasia. However, for FQ individuals with Anomic aphasia had better accuracy scores. A better performance by Broca's aphasia on inference questions could be attributed to better comprehension abilities in non-fluent aphasia i.e., Broca's aphasia when compared to the fluent group i.e., Anomic aphasia. (Samuels & Benson, 1979; Chapman & Ulatowska, 1989; Selnes, Knopman, Niccum, Rubens, & Larson, 1983).Virtue et al., (2006) reported activation or increased activity in right and left superior temporal gyrus and left inferior frontal gyrus during the presentation of implied (related to drawing inferences) versus explicit (related to factual information) information in a discourse. Therefore, neural insult to these areas in the brain which are supposed to be responsible for implied meaning related to drawing inferences could be the underlying cause for poor performance in different type aphasias as seen in the present study.

Findings of the present study in terms of better performance on factual questions (explicitly stated information) than inference questions (implicit information) by individual with aphasia is supported by several other studies (Wapner, Hamby & Gardner, 1981; Brookshire & Nicholas, 1984b, Wright & Newhoff, 2004) .

5.2 Comparison of performance of individuals with aphasia and neurotypicals on RT and accuracy measures on lexical decision and priming effect.

The findings of the present study revealed that the performance of individuals with aphasia was poorer (longer RT and higher error rates) in comparison to NT individuals (Table 4.5 and 4.6). In the present study longer RT observed in individuals with aphasia could be attributed to reduced processing speed for lexical activation. This could be considered as a result of damage to the cortical centers which aid in lexical activation by activating the nodes (Prather, Zurif & Love, 1997); Wright & Newhoff, 2004). It was observed that for individuals with aphasia the mean RT was fastest for the nonwords followed by control words and target words. This could be justified with nonwords being phonologically or morphologically similar to the target words. There were subtle changes in the syllable structure and thus participants could have perceived it as true words due to mere lack of attention. Better performance for the control words could be due to the frequency effect, as most of the control words were common words. Several other studies in literature have also reported the presence of frequency effect seen in individuals with aphasia (Kittredge, Dell, Verkuilen, & Schwartz, 2008; Bose, van Leishout, & Square, 2007; Gerratt & Jones, 1987).

Among the NT individuals, RT was found to be shortest for the target words followed by nonwords and control words. A better processing time for the TW could be attributed to the influence of context i.e., the preceding sentence (Swinney, Zurif, & Nicole, 1989; Wright & Newhoff, 2001). However, accuracy was more for control words, nonwords and then the target words. As discussed for the individuals with aphasia, even in NTs better accuracy for control words could have been due to the frequency effect

(Brysbaert, Lange, & van Wijnendaele, 2000; Morrison & Ellis, 2000; Gerhand & Barry, 1999; Ferreira, Henderson, Anes, Weeks, & McFarlane, 1996).

Since there was no significant difference in the RT of target words and control words, no significant priming effects were observed for either of the groups in the present study. Participants of the present study differed on pre-morbid amount of exposure and experience with English language. The absence of significant priming effect in the present study could be attributed to the proficiency of the participants in language used for testing (L2 for participants) when compared to studies reported in literature where the test was carried out in their native language. These findings were in contrast with the findings of the study done by Wright and Newhoff (2004) where priming effect was observed for NT and non-fluent aphasia group and Swinney, Zurif and Nicole (1989) who studied the effect of preceding context on lexical decision task in individuals with aphasia (Broca’s and Wernicke’s) and NT individuals. They found significant priming effect for the NT and Wernicke’s aphasia group. However, for the Broca’s aphasia group, priming occurred only for the most frequent sense of the ambiguous word irrespective of the context. In the present study, on qualitative analysis it was observed that individuals with Anomic aphasia performed better on lexical decision when compared to individuals with Broca’s aphasia, though the difference across the two types of aphasia was not significant. These differences could be attributed to the difference in severity of deficits across the two types of aphasia and also the predominant role of anterior cortex in lexical access (Swinney et al., 1996; Swinney et al., 1989).

Summary and Conclusion

Language processing is considered as a complex process and not just a mere mechanism of relating words to meanings. Engaging in complex language behavior requires the knowledge of various aspects of language such as phonology, morphology, syntax, semantics, pragmatics and discourse. A balanced interaction of all these aspects of language with other cognitive processes leads to language comprehension and/or production. A wide range of cognitive processes ranging from attention and memory to thinking, reasoning and drawing inferences are involved in language processing. Inference generation is one such cognitive process which aids in sentence and discourse comprehension. Literature reports significant comprehension deficits in individuals with aphasia. A processing breakdown at word level will be an indication of severe aphasia while sentence or discourse comprehension deficits usually indicate mild to moderate impairment. This implies a likelihood of difficulty in inference generation in individuals with aphasia (Harris-Wright & Newhoff, 2004).

The present study thus aimed to explore and understand inference revision processing in individuals with aphasia. The study assessed inference revision and lexical decision skills during comprehension of language. The present study considered two groups: clinical group (individuals with aphasia-IA) and the age-, gender- and education matched control group (neurotypical individuals-NT).Performance on inference revision revealed that both the groups performed better for the factual questions (FQ) than the inference questions (IQ). This could be attributed to lesser complexity and reduced cognitive load involved in factual questions than the inference questions. In comparison to the NT, individuals with aphasia were found to have lower accuracy scores for both factual and inference questions. Poor accuracy scores on factual questions in IA could be attributed to impaired working memory capacity which in turn affects the storage and retrieval of facts needed to answer FQs. The higher error rates on inference generation and revision in IA could be attributed to a reduced working memory capacity, difficulty inhibiting or suppressing competing information, reduced cognitive flexibility and difficulty revising initial interpretations. Also impaired integration of lexical content into higher order representation of the preceding sentence and availability of limited cognitive resources for processing complex linguistic stimuli could be held responsible for poor accuracy scores in IA.

The study also showed that individuals with aphasia had longer RT and poor accuracy scores on LDT which is attributed to slow processing speed or slower activation of lexical nodes. Better accuracy scores for control words (CW) in IA could be attributed to word frequency effect. Absence of priming effect observed for either of the groups in the present study could be due to low proficiency of the participants in English language used for the test (L2) unlike earlier studies where testing was done in L1.

Thus, to conclude the present study unveils the fact that individuals with aphasia with left hemisphere damage have difficulty in inference revision processing which is considered a significant higher order comprehension skill. It is a known fact that structures in the left hemisphere are implicated in comprehension of a coherent discourse, and damage to these can lead to impairment in processing complex linguistic materials. This may hamper the overall communication skills in aphasias, who have retained a few of their verbal communication abilities due to a brain damage in the left hemisphere.

Implications of the study

The findings of the present study help us to have a better understanding of inference skills in individuals with aphasia. It unveils the deficits in sentence comprehension in individuals with Aphasia at different levels - at the lexical level and at a higher level such as the inference generation and inference revision which ultimately is crucial for understanding any information. The results provide theoretical implications in terms of performance of individuals with aphasia and NT adults. It adds on the existing literature on inference skills in aphasia. A few explanations of relation of working memory capacity, meta-comprehension skills (Matlin, 2003) and cognitive flexibility to inference skills will also aid in better understanding of deficits by a Speech Language Pathologist's and influence their approach during assessment and intervention. Incorporating such tasks in regular aphasia test batteries will be helpful, especially for those who have good prognosis and sometimes recover from aphasia and labeled only as 'cognitive deficits'.

The present study also opens the door for future research to explore inference skills in different types of aphasias and their comparison in terms of different levels of auditory comprehension. The present study also warrants the comparison of individuals with left hemisphere damage (LHD) and individuals with right hemisphere damage (RHD) with respect to the differences in processing mechanism for comprehension and inference deficits. The present study is also encouraging to conduct studies in various other languages, bilingual, multilingual, cross language based effects and so on to explore on the different levels of processing deficits in individuals with aphasia and their effects on auditory comprehension.

Limitations of the study

The findings of the present study cannot be generalized due to a small sample size in the clinical group and also the heterogeneity of the sample. The study can be done on larger sample size and performance can be compared across different types of aphasia as well.

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Appendix

Test Stimuli: Each stimulus set consisted of a sentence pair, words for LDT and questions related to the given sentence pairs in each set.

Sl.No.	Sentence pairs	Words for LDT	Questions
	Practice items		
1	Parimal lay anxiously while blood came from his arm. The nurse collected it in plastic sack.	hurt, hort, book blood, bloob	Was the blood coming from his arm? (Y) Was the blood flowing onto the ground? (N) Did Parimal injure his arm? (N) Was Parimal donating blood? (Y)
2	Jamuna cried in disbelief as she listened to what her husband said. Jamuna couldn't believe that her husband got her a diamond ring.	sad, sab, cat surprise, surpirse	Did Jamuna laugh as her husband talked? (N) Did Jamuna'shusband get her a diamond ring? (Y) Was Jamuna'shusband divorcing her? (N) Was Jamuna'shusband happy with her? (Y)
	Test items		
1	Greeshma shrieked when she stepped into the steamy shower. Greeshma watched the cockroach crawl across the shower curtain.	hot, hud, net scared, scarad	Did Greeshma shriek? (Y) Did a cat crawl across the shower? (N) Did the shower water burn Greeshma? (N) Was Greeshma scared of cockroaches? (Y)
2	Sheela hung out the window as the fire got closer to her.	blast, blost, tree	Did Sheela lean closer towards the fire? (N) Did the director yell 'cut'? (Y)

	Finally the director yelled ‘cut’ and the scene was over.	film, filn	Was Sheela trapped in a real burning building? (N) Was Sheela an actress? (Y)
3	Aryan screamed as the sailboat began to sink. Aryan’s mother calmed him and, gave him another boat to play with.	drown, droun, school toy, tey	Did Aryan’s sailboat sink? (Y) Did Aryan’s mom freak out? (N) Was Aryan about to drown on his sinking boat? (N) Was Aryan playing with his toys in the water? (Y)
4	Laxmi was in tears when she saw the condition of her kitchen after the party. Laxmi’s husband had spent all night making the kitchen spotless.	dirty, durty, temple clean, cleen	Was Laxmi in tears? (Y) Did Laxmi’s husband spend the night at work? (N) Was Laxmi sad? (N) Did Laxmi’s husband clean the kitchen? (Y)
5	Manoj looked around nervously before he broke the car window. Manoj couldn’t believe he had locked his keys in the car.	steal, stael, lotus forgetful, fargetful	Did Manoj look around nervously? (Y) Did Manoj lock his shoes in the car? (N) Was Manoj a burglar? (N) Was Manoj trying to get his keys out of the locked car? (Y)
6	Jeevan was not prepared for the sudden downpour. Jeevan’s friends poured color water on him as it was Holi.	rain, raim, lamp festival, festivul	Was Jeevan prepared for the downpour? (N) Was Jeevan’s friends hiding? (Y) Was Jeevan caught in a rainstorm? (N) Was the water colored? (Y)
7	Simba, the dog, almost caught the furry thing	rat, ret, pot	Was Simba chasing a cat? (N)

	he was chasing. Simba's owner laughed as he watched Simba run in circles.	tail, tial	Was Simba's owner laughing? (Y) Was Simba trying to catch a ball? (N) Was Simba chasing his own tail? (Y)
8	Rajesh was burning from head to toe. He had always been jealous of his colleagues.	fever, fevar, brush jealousy, joelousy	Did Rajesh's clothes catch fire? (N) Was Rajesh really burning? (N) Was Rajesh jealous? (Y) Did Rajesh have good rapport with his colleagues? (N)
9	Jyoti couldn't believe how the book ended. Jyoti was amazed that she could write such a suspenseful novel.	disbelief, desbelief, sheep writer, wroter	Was Jyoti shocked at how the movie ended? (N) Was the novel suspenseful? (Y) Did Jyoti purchase the book? (N) Was Jyoti the author of the book? (Y)
10	Bhima fell forty feet. As Bhima surfaced he realized he scored a perfect ten on his dive.	injury, injory, wheat diving, diveng	Did Bhima fall? (Y) Did Bhima score a zero? (N) Did Bhima jump from a building? (N) Did Bhima jump from a diving port? (Y)
11	Janki cried as she watched Rajesh walk away. The cast and crew names rolled before Janki's tears dried.	separate, siperate, night movie, muvie	Was Janki laughing? (N) Did the cast and crew names roll? (Y) Did Rajesh leave Janki? (N) Was Janki at the movie? (Y)
12	Samrat bumped the car in front of him while going around the curve.	accident, accidunt, potato	Was Samrat on a plane? (N) Was Samrat in a bumper car? (Y)

	At the end of the ride, Samrat got out of the bumper car.	game, gome	Was Samrat in an accident? (N) Was Samrat at a fair? (Y)
13	Sheela stood in front of the class and gave a lecture on Indian history. The next day, the teacher assigned grades for the oral presentations.	teacher, teachor, ankle Presentation, prisentation	Was Sheela standing behind the class? (N) Did the teacher assign grades? (Y) Was Sheela the teacher? (N) Was Sheela a student? (Y)
14	Jyoti saw an old, wrinkled, face staring back at her when she looked in the mirror. She removed the mask and tried another.	aged, agid, leaf mask, mosk	Was Jyoti looking in the window? (N) Did Jyoti remove the mask? (Y) Was Jyoti an old woman? (N) Was Jyoti getting ready for Fancy dress? (Y)
15	Rama stood in the dark as sweat ran down her forehead. The spotlight clicked on and Rama began her dance.	nervous, nervuos, teeth performance, performence	Did sweat run down Rama’s forehead? (Y) Did Rama begin singing? (N) Was Rama in a dark house? (N) Was Rama a dancer? (Y)
16	Sushant moved faster as the man following came closer. Sushant was relieved as he crossed the finish line first.	follow, folow, child won, wun	Did Sushant slow down? (N) Did Sushant cross the finish line? (Y) Was Sushant being stalked? (N) Was Sushant running a race? (Y)
17	As Sangeeta walked it became more and more difficult. The water finally reached Sangeeta’s head and	tired, tirid, year swim, swem	Was walking difficult for Sangeeta? (Y) Did Sangeeta start drowning? (N) Was Sangeeta injured? (N)

	she started swimming.		Was Sangeeta in the river? (Y)
18	Seema's eyes opened wider each time the man approached her. Seema relaxed as the eye doctor pulled the exam light away.	afraid, afriad, packet eye-test, eye-tist	Did Seema's eyes open wide? (Y) Was Seema at the flower shop? (N) Was Seema in danger? (N) Was Seema having an eye exam? (Y)
19	Tears streamed down Hina's face . The onion soup would be ready in another twenty minutes.	upset, upsat, crow cook, couk	Were there tears on Heena's face? (Y) Was the soup vegetable soup? (N) Was Heena sad? (N) Was Heena slicing onions? (Y)
20	Prabhu scored lower on each test. Prabhu's doctor was happy that his cholesterol level was falling.	fail, fial, seed Healthy, helthy	Did Prabhu score low on the tests? (Y) Was Prabhu's doctor angry at her? (N) Was Prabhu failing in school? (N) Was Prabhu's health improving? (Y)
21	Ramesh held the gun tightly as he aimed at his target. Ramesh could blow off the center balloon with one bullet.	shoot, shood, apple game, gane	Did Ramesh hold a stick? (N) Did Ramesh hit the balloon? (Y) Was Ramesh a killer? (N) Was Ramesh at a fair? (Y)
22	Meeta looked at the beautiful sunset sky. Meeta was amazed by looking at her creation.	nature, natore, sister painting, pianting	Did Meeta look at the grass? (N) Was Meeta amazed? (Y) Was Meeta looking at a rainbow? (N) Was Meeta an artist? (Y)
23	Keerti screamed as she put her coffee cup on the table.	hot, het, wall	Did Keerti scream? (Y) Was Keerti an hour early? (N)

	Keerti realized she was already an hour late for work.	late, lati	Did the coffee burn Keerti? (N) Was Keerti running late for work? (Y)
24	With a loud noise the whole place was filled with smoke. The mechanic repaired the car in no time.	bomb, bumb, nest repair, repiar	Did the whole place fill with smoke? (Y) Was the mechanic filling air to tyre? (N) Was the car in an accident? (N) Was the car getting repaired? (Y)
25	As Rajni walked through the plus size section at the store. Just a few more weeks left before Rajni would give birth.	shopping, shoppeng, peackock, Pregnant, pregnent	Was Rajni walking through a candy store? (N) Did Rajni have a few more weeks until her due date? (Y) Was Rajni an overweight woman shopping for clothes? (N) Was Rajni pregnant? (Y)
26	The sirens and bright lights made Rishi's heart pump faster. Rishi made the last basket and handed the prize to his coach.	police, pulice, grade win, wen	Were there sirens and bright lights going on and off? (Y) Did Rishi miss the last basket? (N) Was Rishi a fireman putting out a fire? (N) Was Rishi playing basketball? (Y)
27	Sree watched anxiously as the storm ripped apart everything in its path. Sree is always amazed how real disasters are on the big screen.	storm, strom, statue television, televisoin	Did Sree watch a rainbow? (N) Was Sree amazed at how real the disasters are on screen? (Y) Was Sree's town destroyed by a storm? (N) Was Sree at the movies? (Y)
28	Sujan drooled over the menu. Sujan's family was deciding menu for his sister's wedding.	hunger, hungur, swing wedding, weddeng	Did Sujan drool over the water? (N) Was Sujan's family deciding menu? (Y) Was Sujan in a restaurant? (N) Was Sujan's sister getting married? (Y)

29	Girish spent additional time looking at the short answer questions of the test. The questions must have been clear because all the students did well.	exam, exem, hotel easy, eosy	Did Girish spend extra time on the questions? (Y) Did the students do poorly? (N) Was Girish a student in the class? (N) Was Girish the teacher of the class? (Y)
30	Girija lay quietly as the bright light and heat beat down on her. The nurse opened the door and turned the scanning machine down.	sunny, sanny, board scan, scon	Did Girija stand in the bright light? (N) Did the nurse open the door? (Y) Was Girijalying out at the beach? (N) Was Girija in hospital for scanning tests? (Y)