ARF 14

Lexical Semantic Processing in Persons with Aphasia: Correlational Study of psycholinguistic and Neurolinguistic measures

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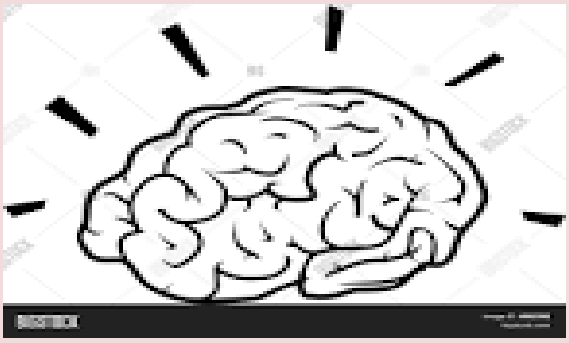

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CHAPTER 1
INTRODUCTION

Language is purely a human and non-instinctive method of communicating ideas, emotions, and desires by means of a system of voluntarily produced symbols. These symbols are produced by the “organs of speech” and perceived through the “organs of hearing”. Language processing occurs in real time and is similar to visual processing as it takes place within fractions of a second. Language processing also involves a lot of collaboration of various aspects of cognition.

Language processing refers to the way the brain monitors understanding and communicating intent, ideas and feelings. Language processing is studied with respect to different levels such as form level, word level and sentence level. Form level or lexical level is the basic component of language processing. The form representation can be of orthographic nature or phonological nature (having to do with speech sound system). The representation of meaning is at the semantic level that map with the form/lexicon at the word level. However, at the syntactic level, the lexicons (words) are combined in specific sequence to convey meaning intended by the speaker/writer.

1.1.Lexical Semantic Processing

Lexical semantic processing is an important component of language processing as meaningful words related the given context are retrieved at this phase. Lexical-semantic processing is a mechanism through which words are chosen from the lexicon (‘what’ of language) denote a concept and the retrieval of the word (‘how’ of language) is governed by the context (Pustejovsky, 1995). Lexicon is the mental state of knowledge about words and hence the term mental lexicon is often used to refer to the information about the processes such as part of speech, pronunciation of the word, meaning and or spelling. The concept of whether the lexicon itself contains the meaning or just provides access to the meaning is still unclear and therefore the mental lexicon is often treated as a system, which contains pointers to meaning. Lexical access, word recognition and word retrieval are generally viewed in the context of lexicon.

1.2 Lexical access

Lexical access refers to the retrieval of the word from the lexicon. It is generally explained in the context of picture naming. When a person is asked to name a picture, the first step would be to recognize the picture on the basis of conceptual/semantic features. During this process, it is assumed that the semantic representation corresponding to the picture is not the only one that is activated but the related semantic representations are also activated. For example, if a person is shown a picture of 'dog', other lexical items/nodes like 'cat' and 'cow' are also activated. The activated conceptual representations spreads proportional activation to the corresponding lexical nodes (words) in the mental lexicon and one lexical node amongst all the lexical nodes is selected, pertaining to the context. This phenomenon is termed as 'lexical activation'. During the lexical activation, the node with the 'highest' level of activation is selected, this lexical node usually corresponds to the concept that the speaker wants to convey.

Following the lexical node activation, phonological retrieval or phonological access takes place. During the phonological retrieval stage, the appropriate phoneme segments corresponding to the shortlisted lexical node/nodes are activated. There are two major views regarding phonological access. The first view is that the activation of the phonological properties of words begins only after the target lexical node is activated and the activation of phonological properties is confined to only the selected lexical node. This view is termed as discrete view of phoneme retrieval (Levelt, 1989). The other view is the cascaded view of phoneme retrieval, which believes that the phonological retrieval occurs much before lexical selection and phonological segments are retrieved for all the activated lexical nodes. Once the phonological segments are retrieved, the access to the articulatory routines corresponding to the phonological properties of the selected word takes place (e.g., positioning the articulators involved in the production of speech).

The models of lexical access are formulated considering the number of stages involved in lexical access (two step models versus three step models), the direction of flow of lexical/word forms (unidirectional versus bidirectional models) and the activity considered for explaining lexical access (picture naming activity versus spontaneous speech).

a) Models based on the stages of lexical activation. The two step and three step models of lexical activation are proposed on the basis of the stages involved in lexical activation. The two step model assumes lexical activation to take place in two steps i.e. word access and phonological access (Bock & Levelt, 1994). The connection that between words and phonological segments is assumed to operate in both top down as well as bottom up conditions. The top down excitatory connections link words to phonemes, while bottom up connections spread activation from phonemic segments to words, with no inhibitory connections. The three step models (Carmazza, 1997), on the other hand, assume lexical activation to occur at three levels in three steps i.e., conceptual activation, word access and phonological access. The conceptual activation is the additional step incorporated in the three step model compared to the two step models. The conceptual node activation is included to account for the conceptual errors, which may arise when a person is not able to develop the correct conceptual representation and as a consequence may activate semantically unrelated word.

b) Models based on the direction of flow. Unidirectional and bidirectional models have been proposed based on the direction of flow between semantic and phonemic levels. The unidirectional model as the term indicates assumes the connections between the semantic and phonemic level to occur in only one direction i.e. from semantic to phonemic levels and not from phonemic to semantic levels. On the other hand, the bidirectional models assume the connection between semantic and phonemic links to be bidirectional i.e. from semantic to phonemic level as well as phonemic level to semantic level.

c) Models based on activity. The models of lexical activation are explained on the basis of different underlying activities. Models of lexical access are generally proposed for the naming activity. Some models of lexical access have even been proposed for spontaneous speech activity also. The 'lexical editor model' is the most prominent model proposed for spontaneous speech activity. According to this model, speakers appear to monitor their planned output, depending upon the planned output. The word which matches a concept is activated and the phonemic segments corresponding to the activated word is activated at the next level. Lexical access should occur in real time irrespective of the underlying activity. The time taken for lexical access is a crucial aspect in lexical activation. For example, picture naming requires duration between 600 and 1200 milliseconds (Postma, 2000). It takes fraction of seconds from the onset of picture presentation to the initiation of vocal response. The speech onset latency is a result of several stages of processing which may or may not overlap in time, the speaker will have to first process the picture visually, this involves extracting visual pictures from borders, corners, shades, overlaps, foreground and background relations. The next step is the categorization of the visually emerging objects as car, table or clock etc. Following this step, lemma activation and retrieval of phonological segments takes place. The time course is dependent most importantly on deriving the conceptual representation as the other stages would subsequently follow. The time course would get delayed, if any of these stages concerning lexical access gets delayed. The time course of lexical activation required for spontaneous speech is the same or even less compared to picture naming as the load on conceptual presentation is relatively short. Lexical activation for spontaneous speech is dependent on the context. Depending upon the context, a list of words is shortlisted from the lexicon and the word/s necessary in denoting the concept/s, are activated.

The three stepped interactive activation model with bidirectional cascaded view for phonemic retrieval can be adapted to explain lexical- semantic processing. The model explains lexical-semantic processing to take place in three stages i.e. conceptual semantic level, lexical semantic level and phonemic retrieval level. The model operates on the basis of parallel processing principle. The model is called interactive model as it assumes that processing units are organized in competitive pools and this model assumes the bidirectional and cascaded view to explain phonemic access as a step in lexical access.

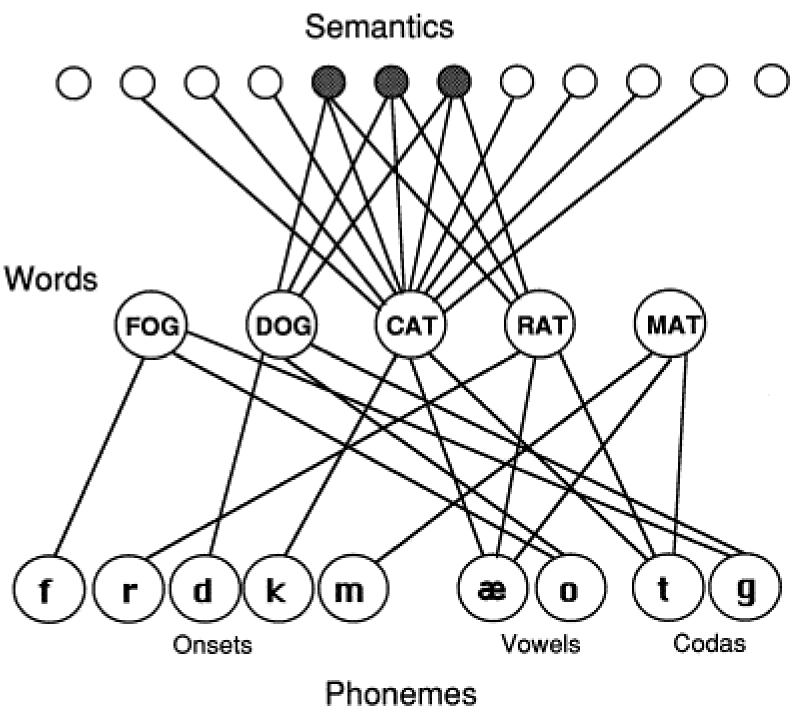


Figure 1.1 *Three stepped, interactive, bidirectional cascade model*.

(Source: "Lexical access in bilingual speakers", Dell and Schwartz, (2000) *Psycologica*, p.400)

1.3 Methods for assessing lexical semantic processing

Researchers have employed different linguistic tasks to study lexical-semantic processing. The linguistic tasks can be employed to test the integrity of lexicon and lexical access. The mental lexicon includes information about words and concepts, different concepts linkages between words as well as between words and pronunciation (McCormick & Schiefelbush, 1984). Since lexical access is the retrieval of word appropriate to the context, it involves a complex array of mechanisms namely encoding, search and retrieval (Forster, 1976; Allport & Funnel, 1981). Integrity of lexicon and lexical access is tested through a series of linguistic tasks such as naming tasks, word association, word definition, open-ended questioning, word recall, semantic description, assigning lexical items to their respective lexical category and rhyming task. These tasks have been adapted by researchers either individually or in combination.

Naming task is the simplest method used to study lexical semantic processing. Naming ability is influenced by many linguistic and non linguistic factors. The linguistic factors include linguistic complexity, imageability and frequency of occurrence of the target word in the linguistic context. The non linguistic factors include the ambiguity of the picture and the sensory motor schema involved in the knowledge of the words referent (Gardner, 1973). Despite the above, confrontation naming is considered as the simplest of the naming tasks. Confrontation naming is elicited in response to pictures, photographs, or real objects among which, picture naming is a widely used technique for the study of lexical access. Picture naming involves a series of stages such as visual recognition of the image, matching the visual image to images stored in memory, selecting the lexical referent, selecting the stored phonological code linked to the lexical referent, and verbalization of the word. Thus the confrontation naming addresses each stage involved in lexical semantic processing (encoding, search and retrieval). It can also localize the step, where in the lexical semantic breakdown takes place since the picture stimulus is thought to directly activate its semantic representation and provide information on the ability of word retrieval to the participant. The other variants of naming test include action naming task, responsive naming and generative naming tasks.

The major limitation of the naming task is that it oversimplifies the mechanisms involved in lexical semantic processing. Word definition, open ended questioning and word association tasks are the other commonly used linguistic tasks used in studying lexical-semantic processing but the utility of these tasks is limited compared to naming tasks. Word definition task involves semantic description of a lexical item by considering the semantic properties owned by the lexical item. Open ended questioning is same as responsive speech. Word association task involves associating two words as related or unrelated, considering the semantic similarities or dissimilarities. The linguistic tasks do not tap speed of processing nor provide inference on the organization of lexical items in the mental lexicon. The shortcomings of linguistic tasks can be overcome by using priming based tasks. Priming task is predominantly used to study 'competence' aspect concerning lexical semantic processing.

Priming refers to increased sensitivity to certain stimuli due to prior exposure &/or experience. Priming is believed to occur outside the conscious awareness. Priming works on the spreading activation principle and taps lexical selection. When a person is asked to name a picture, several semantic representations receive activation. The concept of multiple activations at semantic level has been assumed to operate in two different ways. The first assumption assumes concepts to be denoted as undividable nodes and the second assumption assumes concepts to be organized as a bundle of features. The second assumption assumes concepts to be represented as bundle of features i.e. activation of the word in the example 'dog' would activate bundle of semantic features like 'animal', 'four legs', 'barks', etc.

Priming increases the accuracy, probability or speed of response to stimulus as a consequence of a prior exposure to another stimulus. Priming occurs when the processing of a word is facilitated by a preceding stimulus. The first word or preceding stimulus is called the prime and the word to which a response is made is called the target. The time between the onset of prime and offset of target is called Stimulus Onset Asynchrony (SOA). Priming can be incorporated in lexical decision task (where the target is decided as word and non word), decision or judgment task (making overt judgment regarding two words, based on similarities and differences), picture naming and judgment tasks. Priming can be used to track speed of processing and relationship between lexical items in neuro-typical and clinical population. The limitation of the priming task is that the response may be subjected to 'chance factor' which may arise due either to errors in selection of priming paradigm or to subjective speculations by the participant since it is a psycholinguistic task dependent on behavioural responses.

However, the neuro-imaging and event related potential studies help in understanding the neurolinguistic dimension of lexical semantic processing. Neuro-imaging studies can be used to understand brain-behavior relationship better by localizing the areas of the brain responsible for a particular function. Although, it has certain limitations concerning the expenses and spatial resolution of images, investigators have used event related potentials as an alternative to understand brain behavior relationship pertaining to lexical-semantic processing.

Event related potentials are defined as measured brain response that is the direct result of sensory, cognitive or motor event. P300, Mismatch negativity (MMN), N400, P600, Lexical Processing Negativity (LPN) and Left Anterior Negativity (LAN) are some of the most commonly used event related potentials to study lexical-semantic processing. P300 is generally used to study spoken word processing or auditory processing of phonemes and words. Since P300 is affected by the attention of individual, Mismatch Negativity (MMN) is considered as an alternative to study pre-lexical processing as it can be elicited in the absence of attention (Naatanen, Gaillard & Mantysalo, 1978). MMN is generally elicited when a 'deviant stimulus' is presented along with standard trace (frequent stimulus). The 'deviant stimulus' varies with the standard traces in terms of frequency, intensity and duration. The latency of MMN is generally between 100-200 milliseconds after the stimulus onset, it is a negative ERP with fronto-central distribution. While both P 300 and MMN have been used to reflect auditory processing of speech and non speech sounds, N400 is an event related potential used to study lexical-semantic processing.

N400 is a negative going wave evident between 300 milliseconds and 600 milliseconds after the visual presentation of a word. Though this effect is observed all over the scalp, it is more over the centro- parietal areas and is usually slightly larger on the right side of the head (Kutas, Van putten & Beason, 1988). The N400 is synonymously called as centro- parietal maximum. The N400 is elicited by words presented in all modalities. The size, amplitude and morphology and lexical decision latencies vary with linguistic determinants. For example, low frequency words elicit larger N400 than the high frequency words. N400 is sensitive to repetition task. N400 may reflect lexical-semantic process (Kutas & Hillyard, 1984) and /or lexical semantic integration (Chwilla, Brown & Hagort, 1995). Lexical Processing Negativity (LPN), N280, Early Left Anterior negativity and P600 are other event potentials used to study the other important aspects of lexical semantic processing.

1.4 Studies on ERP's related to lexical semantic processing

Lexical semantic processing became a popular theme of interest after Kutas and Hilyard (1980) reported N400 potential with modified oddball paradigm adapted to elicit the P300 potential. . They observed a large parietally maximal negative potential, which was seen essentially on words with unexpected endings. Although the study suggested that this potential was observed for other words with regular forms as well, the negativity was comparatively large for the former. In their study it was suggested that N400 was negative peak which appeared from 400ms-600ms post stimulus time window and it should not be considered as a specific localizable entity of the neural lesion but as symbol of common functionality. The above was further examined with different stimuli (Kutas & Hillyard, 1983;, Donchin, 1984; Kutas & Van Petten, 1988) in view of the functional sensitivity of N400 as a marker in identifying aspects of language processing. The findings indicate that N400 was not observable for congruent or expected sentence endings, such as simple grammatical errors such as /a dog has four leg/ (*legs*). However a higher amplitude of N400 was observed when the sentences had incongruent words at the end of a sentence such as /a dog has a web in its paw/.

Studies have also shown that incongruent word pairs elicited larger N400 amplitude compared to congruent word pairs in experiments conducted to test theories of levels of processing such as Spreading activation model versus response competition using word pairs. (Bentin, McArthy and Wood, 1985). The study also emphasized that the level of meaning associated with the paradigm of word pair in priming, i.e, semantically unrelated words elicited larger N400 amplitude.

Apart from the findings of the presence of N400 in incongruent sentences, the relation to the initial noun of a sentence to the latter noun is reported to elicit N400 ignoring the sentential meaning (Fischler and Childers, 1983). Two types of sentences, such as "A Sparrow is a Vehicle" and "A sparrow is not a vehicle" showed the presence of N400 in their study the in both conditions. Suggestion were made that it was. This was researched by many authors in the past, of which the most recent was done in 2008, Nieuwland and Kuperberg by presenting their participants with incongruent sentences, with false or highly unexpected words (e.g., "A baby bunny's fur isn't very *hard/soft*…") elicited a larger N400 ERP than true words in highly pragmatically, but negated sentences (e.g., "In moderation, drinking red wine isn't *bad/good*…"). These results suggest that negation poses no principled obstacle for readers to immediately relate incoming words to what they hold to be true.

Studies on priming and semantic judgments, apart from enhancing knowledge about semantic processing, have given directions to design methods for assessing lexical semantic processing. Studies in particular, have examined the effects of stimulus onset asynchrony (SOA)[1] on priming. While De Groot (1984), Neely (1977) and Prather & Swinney (1988) stated that the semantic priming effects lasts only for 500 millisecond under normal reading conditions, for lexical decision task no differential reaction time effect was reported for both short and long SOAs *(* Boddy, 1986). , . Boddy used semantic primes to test automatic activation by manipulating the duration of SOA with 200, 600, and 1000 msec. Boddy's SOA manipulation did not result in a suppression of the contribution of controlled lexical processing. Since the reaction time for priming did not vary much as a function of the duration of SOA, Boddy attributed the N400 effect to controlled processes due to semantic relatedness.

Studies have specifically looked at the kind of stimulus to be used and the factors responsible in eliciting N400 (Brown and Hagoort, 1993). The study was carried with aim of understanding the role of automatic and controlled processing in eliciting N 400. The researchers used semantic matching task. In this study both masked primes and unmasked primes were used. The reaction times for both these presentations showed significant priming effect. The results obtained on masked priming condition reflected the effect of automatic spreading of activation during the process of lexical access. N400 effect was robust for the unmasked presentation condition, but no such effect for the masked presentation condition. The findings of the study showed that N400 tapped both semantic integration processes and lexical access processes.

Masked priming or indirect priming paradigms (where prime is related to another word directly associated with the target) in which the participant does not consciously perceive the prime and hence demonstrates automatic processing has been used by Keifer, Weisbrod, Kern, Maier and Spitzer (1998. . It was observed that the semantic priming strongly shows evidence of spreading activation. In order to know the underlying process of activation resulting in N400, Prasada, Salajagheh, Bowles and Poeppel (2008) conducted a study and reported that the amplitude of the N400 response has been shown to reflect the

[1] SOA is the time gap between the onset of the prime and the onset of response

semantic integration of a word in the presence of a prime which could be a word or a sentence. Their study exhibited that the N400 amplitude is modulated for the same word, in closely related contexts of a sentence. This modulation is attributed to the subtle difference in the morphosyntactic environments of the sentence, for example, in conditions such as either a generic (*grass is green*) or non-generic (*the grass is green*). The results show that amplitude of N400 reflects not only the existence of a semantic computation but it also reflects those processes which are relevant to the type of semantic relation being computed. Specifically, it is sensitive to whether a word is being interpreted as describing a specific kind/type or an instance or that the same word in both sentences stand for two different instances. Through these studies it can be inferred that N400 can tap automatic as well as controlled processing and is sensitive to spreading activation, thus can assess the different processes involved in lexical access.

Researchers were further interested to know the site of origin of N 400 According to the review by Taylor and Baldeweg (2002) on applications of EEG, ERP and intracranial recordings, cited the study of Mcarthy, Nibre, Bentin and Spencer, 1995 in which the site of response for N400 was associated with anterior medial temporal lobe.

The semantic priming effect demonstrated on N 400 is studied across life span. Erger and Mehta (2014) studied semantic priming effect using ERPs. With three lists of related and unrelated word pairs, in three groups of participants- children, young adults and seniors. The study revealed that although semantic priming effect showed that all age groups benefit from contextual cues, the asymmetry of the differential hemispheric activation points to the notion that seniors need to recruit additional and slightly different resources to perform on the automatic tasks.

Imageability and Semantically rich associations are two other important factors which affect the elicitation of N400 as researched by Barber Otten Kousta and Vigliocco in 2013. This study suggests that abstract words elicited the behavioral response faster than concrete words, similarly words which are not easily imageable, triggering a large number of superficial linguistic associations which can be used for response decisions. These differences, in N400 would point to the greater semantic processing which occurs for concrete rather than abstract words during meaning activation.

The elicitation of N400 depends on several other factors. Stimulus must be presented controlling for properties like lexicality (Praamstra & Stegeman, 1993), concreteness (Kounios & Holcomb), and typicality (Stuss, Picton & Cerri AM, 1980). The findings of these studies show that these factors may influence the magnitude of N400. The N400 usually appears when incongruent words are presented at the end of sentences, and if these incongruent words are closely related, N400 is significantly reduced compared with fully incongruent conditions. Hemispherical differences has also been investigated by Federmeier and Kutas (1999) by presenting the words to either to the right visual field (left hemisphere) or the left visual field (right hemisphere). They noticed a graduated response which was interpreted as a sign of a predictive processing trend in the left hemisphere opposed to the integrative processing that is generally associated with the right hemisphere, since predictions are made on the basis of the semantic context.

Further N400 was applied to gather neurophysiological evidence about lexical semantic processing in disorders. Disorders such as aphasia, learning disability, stuttering etc. were studied on a different dimension with the application of N400. N400 is commonly used to study the lexical semantic processing in persons with aphasia owing to a huge prevalence of word finding difficulties in this population. It was possible to deduce several facts about lexical semantic processing in aphasia after the application of evoked potentials like N00 and P 400 as reported in studies.

1.5 Lexical Semantic processing in persons with aphasia

One of the conditions most often investigated for lexical-semantic processing Aphasia. Aphasia is defined as the loss or deficiency in expressive and/or receptive language and is generally caused by a left hemisphere lesion. Persons with aphasia may have cognitive linguistic deficits and exhibit difficulties in one or more of the cognitive aspects. Two main classification systems i.e. anatomical and linguistic classifications have been proposed for aphasia. Combining these two classification systems, the classic division proposes two large groups: anterior aphasia and posterior aphasia. Persons with anterior aphasia may have impaired spontaneous speech, limited phrase length, prosody and deficient articulatory programming, while persons with posterior aphasia may have fluent senseless production with no articulatory effort. Persons with anterior aphasia may have impairments in grammatical systems, whereas persons with posterior aphasia may confront impairments in the lexical/semantic or lexical-semantic aspects of language.

Lexical semantic processing is one of the three important aspects of language processing, the other two being phonological processing and syntactic processing. Lexical semantic processing encompasses, access to the lexicon and to the semantic system. It mainly deals with storage of lexical items in the mental lexicon and access of lexical items. The mental lexicon stores word related knowledge as word, sound, spelling and grammatical properties as well as morphological structure and meaning. Lexical-semantics addresses issues related to how words are stored and organized in lexicon and are retrieved or accessed from the lexicon. Therefore the integrity of lexical-semantic processing is dependent on the integrity of lexicon, organization of lexical items in the lexicon, interconnection of the lexical items and lexical access. Aphasia can impair any of these mechanisms selectively or can collectively affect all these array of mechanisms

The three levels of lexical-semantic deficits include

i. Lexical-Semantic storage and organization deficits: Aphasia may impair the storage and organization of lexical items in the lexicon. The other aspects studied under the storage and organization deficits include lexical-semantic deficits in L1 and L2 and category specific deficits.
ii. Access deficits or retrieval deficits as the name suggests involves deficits in lexical access. The defect can lie either at lexical level or phoneme level. While the lexical level deficit is manifested as word choice errors, the phonemic level is manifested as phonemic errors. Access deficits are explained with respect to automatic versus volitional mechanisms of lexical retrieval and retrieval of nouns and verbs.
iii. The word production deficit involves faulty word production. Failure in word production can reflect the loci of lexical semantic breakdown and is studied with reference to paraphasia, neologism errors, as well as word production as a result of cuing as emphasized in studies on efficacy of cues.

1.6 Studies on lexical semantic processing in persons with aphasia.

Pioneer l Broca in 1985 suggested the lesions for Broca’s aphasia could be the Left inferior prefrontal cortex (LIPc), also known as the Broca’s Area. These evidences were challenged later by many researchers leading to a wealth of knowledge using ERP studies which helps us understand the neurophysiology behind it. Owning to the immense research over the years, Dronkers' research in 1996 revealed that contrary to Broca's assumptions, localized damage to left anterior insula (LAIns) and not Broca's area, is a better predictor of impaired motor speech in chronic stroke. In his study, lesions were demarcated for patients with and without Apraxia of speech (AOS) on a standard brain template using scans obtained by clinical computerized tomography (CT) or magnetic resonance imaging (MRI). The greatest lesion overlap among persons with AOS patients was found in LAIns, with less involvement of Broca's area. Damage to LA Ins was not noted for patients without AOS. Dronker's conclusions not only contradicted Broca's initial findings but, more importantly, suggested that LAIns is the crucial area subserving motor speech processing. Similarly Ogar et al. (2006) tried the lesion overlap method to demonstrate that the LAIns was completely spared in patients without AOS

Later evidence from a study by Richardson, et al (2012) suggested that although Broca's area is commonly referred to and believed to be a single general region, it was highlighted that it consists of different sub-regions, probably varying much in regard to their specific roles in speech and language (Amunts et al., 1999). The caudal portion of Broca's area known as pars opercularis (LIPcCpo), which roughly corresponds to Brodmann's area (BA) 44 – was suggested to play a crucial role in motor speech programming (Bohland & Guenther, 2006; Guenther, 2006; Guenther, Ghosh, & Tourville, 2006) whereas pars triangularis (LIPCpt), and BA 45, to play a greater role in language specific programming (Newman, Just, Keller, Roth, & Carpenter, 2003; Rodd, Longe, Randall, & Tyler, 2010). Their study did not validate the specific role of LIPCpo in speech production, as to whether it is responsible for planning of motor speech movements or, storage of specific motor speech maps that are selectively activated for speech production. This study also draws away from the study of Dronkers by suggesting that damage to the posterior portion of Broca's area is a better predictor of AOS than insula involvement; while, they do not discount the role of the LAIns in speech processing.

Although the involvement of the inferior frontal cortex in syntactic processing has long been hypothesized (Caplan 1987), lesion studies of aphasic patients with agrammatism failed to delineate clearly the crucial brain regions involved in syntax processing. Caplan (Caplan Hildebrandt & Makris 1996), in particular, stressed the variety of brain lesions associated with syntax comprehension impairments. Most functional neuroimaging studies have shown the involvement of the left inferior frontal region and/or adjacent areas as the neural substrates of syntax processing, either for comprehension or for production (e.g., Caplan, Alpert, Waters, & Olivieri, 2000). However, whether such activations reflect highly specific grammatical/syntactic processing or orthogonal working memory involvement remains to be determined (Thierry, Ibarrola, Demonet & Cardebat, 2003).

In an attempt to segregate activations relating to semantic processing from those induced by syntactic processing, Dapretto and Bookheimer (1999) manipulated semantic and syntactic complexity independently in a 2 X 2 factorial design. They proposed a specific role for two different focal portions of the left inferior frontal cortex: *1*) a ventral one (pars orbitalis) associated with semantic judgment and *2*) a dorsal one (pars opercularis) associated with syntactic judgment. A similar study replicated the anatomical dissociation for syntax and semantics using a more implicit task (Ni, Constable, Mencl, Pugh KR, Fulbright, Shaywitz, Shaywitz, Gore, & Shankweiler 2000). Ni et al. presented their volunteers with sentences featuring semantic or grammatical errors with no instruction to attend to anomalies and found specific activation in the left PIFG for grammatical errors. Caplan et al. (2000) addressed the question of the syntactic specificity of activations in the left PIFG, given its major role in verbal working memory. They demonstrated that syntactic activation of BA 45 was obtained for syntactic processing whether participants were involved in interfering repetitive utterance of a word or not, suggesting independence vis-a` -vis verbal memory.

Processing linguistic information embedded in sentences brings in specific processes concerned with the order in which words are perceived and the rules that govern this order. Early electrophysiological studies demonstrated that syntactic processes are independent from semantic processing to some extent because syntactic violation elicits positive ERP components that are very different from the N400. The P600 or syntactic positive shift is elicited upon presentation of a word that is grammatically incorrect or when sentences are made abnormally complex.

An important aspect of syntax processing, the production of sentences, has not been studied as widely as comprehension. Indefrey (2001) described a graded activation localized in the left rolandic operculum, adjacent to the classical Broca's area rather than the left PIFG itself, when subjects produced word sequences, noun phrases, and full sentences. Musso, Moro, Glauche, Rijntjes, Reichenbach, Buchel & Weiller 2003) recently involved monolingual subjects in the learning of the grammatical rules of two foreign languages in two different experiments. Increased activation in the pars triangularis of Broca's area was significantly correlated to the accuracy of learning performance but only when learning was based on the principles of universal grammar (Chomsky, 1981) as opposed to arbitrary rules created by experimenters. However, it is reported that variation in syntax complexity can modulate activity in a much larger neural network than the classical Broca's area, including the left PIFG, the posterior part of the left STG, and to a lesser extent, their right counterparts (Just, Carpenter, Keller, Eddy, and Thulborn, . 1996).

Beyond the mechanisms of detailed sentence structure analysis, a major goal is to characterize the neural architecture involved in connected speech, which is the natural condition of language perception and production. Early studies involving story listening (e.g., Mazoyer, Tzourio , Frak , Syrota, Murayama, Levrier , Salamon, Dehaene, Cohen, & Mehler , 1993) attempted to identify subparts of the language network that are specific to coherent, connected language samples. The authors reported the involvement of the anterior polar aspects of the superior temporal gyrus. Since then, various studies (have confirmed the crucial involvement of this portion of the brain for processing discourse. In addition to anterior temporal activation, Maguire (1999) found activation in the medial parietal posterior cingulate cortex and proposed that the latter was involved in linking the current understanding of a story with prior knowledge. Superior temporal sulcus was found to be responsible stimuli where intelligibility was manipulated by degrading understandable speech (e.g., noise-vocoded voice samples) is reported by , Scott et al., (2000). This study provides major evidence for the existence of a ventral or anterior "what" stream. In an experiment involving words and environmental sounds in series, Thierry, Giraud, and Price (2003) also found activation in the superior medial frontal cortex (BA 8) when contrasting attempts to elucidate the overall meaning of the series (i.e., attempts to make up a story) with semantic categorization of single items (i.e., dealing with words and sounds individually; unpublished results). BA 8 has been shown to take part in planning strategies when subjects are required to make plans that are endogenous to the task (Koechlin , Corrado , Pietrini & Grafman 2000) and might be crucially involved in discourse level comprehension.

The neural basis for processing global discourse coherence has been supported much earlier by George, Kutas, Martinez and Sereno (1999). They presented a text sample word by word and compared a condition in which coherence was prompted by a title with a condition in which no title was given. They found a crucial involvement of the right middle temporal sulcus in the untitled condition, which was meant to be more demanding in terms of coherence extraction.

One drawback of the generalization power expected from neuroimaging lies in the fact that it implies focusing primarily on normal populations. Difference between normal population and post lesional neuroplastic phenomena intervene almost systematically in the course of vascular aphasia and spontaneous recovery as observed for some language deficits. The involvement of the right hemisphere in the compensation of aphasia has long been hypothesized (Gowers, 1887). This hypothesis has even been used as the conceptual basis for several neuroimaging studies of lesion-related language disorders (e.g., Buckner, Corbetta, Schatz, Raichle, & Petersen. 1996, Cardebat, Demonet , Celsis , Puel Viallard and Marc-Vergnes 1994, Senda, Kitamura, Ishii, Mishina & Terashi, 1996).

The contribution of specific right-sided regions in language recovery from aphasia has gained support from recent results. For instance Leff, Crinion, Scott, Turkheimer, Howard, and Wise (2002) presented aphasic patients who had recovered single-word auditory comprehension after left posterior temporal infarction with spoken words at different rates and found significant changes in the physiological responsiveness of the right posterior superior temporal sulcus. In chronic patients with predominant damage in the left frontal region, Blasi (2002) showed that learning to retrieve words can regulate activities in a right frontal-occipital network, suggesting a compensatory role for this cortical network. Indeed, the response of this right-sided network to practice, mimicked that observed in the left frontal cortex in control subjects. In the same vein, lesions localized to the pars opercularis of the third frontal gyrus on the left have been shown to affect activation of homologous right-sided regions during production of propositional speech compared with both healthy subjects and patients with frontal lesions sparing this critical lesion site (Blank, Bird, Turkheimer & Wise 2003).

Converging evidence comes from studies using TMS which have inhibited right hemispheric areas in recovered patients. Flitman, Grafman, Wassermann, Cooper, O'Grady , Pascual-Leone and Hallett (1998), for instance, showed that magnetic stimulation may affect the compensatory functions of right-sided areas as it induces transient language disorders in these patients. However, contradicting this finding, other results have suggested that inhibition of right-sided premotor regions can improve naming abilities in nonfluent aphasic patients at a very late stage (Naeser, Hugo Kobayashi, Martin, Nicholas, Baker and Pascual-

Leone 2002). Overall, the role of the right hemisphere in compensatory mechanisms remains a matter of contention. An early activation study by Knopman (1983) suggested the implication of right-hemispheric structures may be restricted to early stages of poststroke evolution, whereas spared portions of the left hemisphere would become crucially implicated in late recovery. Mimura, Kato, Sano, Kojima, Naeser, and Kashima (1998), who studied correlations between language scores and rCBF measured at rest, showed the inverse pattern. . The compensatory role of the right hemisphere was also the focus of several recent activation studies which in fact showed that in the end spared regions of the left hemisphere were the main substrate of recovery mechanisms.

The critical impact of the level of activity in the left superior temporal cortex for recovery was repeatedly stressed by Heiss and his group. Heiss Kessler Thiel, Ghaemi and Karbe (1999) have used a word repetition task as a common activation task in comparatively large groups of aphasics. They demonstrated that the relative sparing of this region corresponded to both recovery of language functions and restoration of left temporal activation at a later stage. Indeed, massive lesions of the left superior temporal region prevented this region from activating at later stages and was associated with partial recovery of comprehension as well as activation of the right temporal cortex only. Contributions of the left superior temporal region and the right homotopic cortex to the recovery of lexical production were also observed by Cardebat, Demonet, De Boissezon, Marie, Marie, Lambert, Baron, and Puel (2003), who showed correlations between signal change over a long period of time and behavioral performance on word generation tasks. The heterogeneity of these findings comes not only from the many confounding factors due to subject-specific and lesion-specific variability (Cappa, 1998), but also from task heterogeneity (in most cases, tasks are not specific to patients' deficits, and they are often compared with irrelevant control conditions.

An adequate control task should target undamaged language processes, whereas the active task should target a specific dysfunction. Moreover, small discrepancies between group studies emphasize the interest of single case studies in which striking dissociations in psycholinguistic performance can be observed Cardebat, Demonet, Celsis Puel, Viallard, & Marc-Vergnes. 1994). In such studies, patterns of activation observed in a given patient should be compared with a group of control subjects or, even better, to each control subject (Warburton, Price, Swinburn & Wise 1999). Price (1999) proposed that in a patient performing a semantic task correctly, the pattern of activation reveals a set of regions that are necessary to achieve the task. In contrast, the patterns of activation found in normal subjects on the same tasks may involve supplementary areas that are not indispensable but, rather represent accessory mechanisms or strategies used by some subjects to optimize their performance. In this context, using parametric designs in activation experiments would appear to be a particularly fruitful strategy. Dissociations imply poor performance in one task while another task remains possible because of preservation or compensation mechanisms. When a patient attempts to perform a task but fails, numerous "parasite activations" arise that do not reflect task-specific processes but rather the mental effort and effects linked to repetitive and unsuccessful attempts. Thus correlating a subject's performance with activation signals in the whole brain would allow one to tease apart activations reflecting information processing from those merely reflecting parasite phenomena.

Exploring the influence of therapeutic intervention on brain functions in aphasic patients is a new topic. The few available reports concern studies that have mainly focused on behavioral revalidation, with the exception of one report on neuroimaging and pharmacological therapy in aphasia (Kessler, Thiel, Karbe, & Heiss, 2000). This placebo-controlled activation study demonstrated a significant improvement in patients treated with piracetam, a GABA derivative. Indeed, neuroimaging experiments have demonstrated their influence on activation patterns during motor tasks using fMRI (Loubinoux, Boulanouar , Ranjeva, Carel, Berry, Rascol, Celsis, & Chollet, 1999).

Belin, Van Eeckhout, Zilbovicius, Remy, Francois, Guillaume, Chain, Rancurel, and Samson (1996) were the first to address the relationships between specific language therapy in aphasia and neural reorganization explored with PET. These authors focused on speech production and observed better performance in patients who displayed left-sided perilesional activations after melodic intonation therapy. Small, Flores and Noll (1998) studied a single case of acquired dyslexia and performed an fMRI before and after an intensive remediation program. They demonstrated that phonological training resulted in specific activation in the left association visual cortex (lingual gyrus). Similarly, Le´ger (2002) studied an aphasic patient who exhibited a massive speech output deficit and was involved in a language therapy program devoted to rehabilitating the output lexicon. Using fMRI, they found a specific activation in the left PIFG and the superior part of the left supramarginal gyrus posttherapy, after taking into account the activation level before therapy.

Conversely, a relationship between right-sided activation and improvement of auditory comprehension after training was observed by Weiller and co-workers (Musso, Weiller, Kiebel, Muller, Bulau & Rijntjes M 1999), who demonstrated a correlation between activity in the right temporal cortex and comprehension scores. Similarly, training on sentence processing was associated with changes in the right hemisphere during a matching task between spoken sentences and pictures in a patient described by Thompson (2000). Overall, the following pattern seems to emerge: remediation and/or testing of comprehension elicit activation in the right hemisphere, whereas remediation based on phonological processing favors recruitment of the left hemisphere; it may be that some other factors interact with these effects, such as damage versus sparing of critical sites, e.g., the left superior temporal and the inferior posterior frontal cortex, two regions of the brain that were early identified as important for language by Wernicke and Broca, respectively.

A few studies carried out in the area of Aphasia are summarized in Table 1.1 & Table 1.2

Table 1.1
Semantic Paradigm studies in persons with aphasia

Authors	Experimental Paradigm	Task	Sample profile	Stimuli	SOA	Results
Milberg & Blumstein	Paired priming paradigm- Auditory	Lexical decision	6 persons with fluent and non fluent aphasia	90 stimuli- semantically related and semantically unrelated	2000 milliseconds	Broca's performed better than Wernicke's
Prather, Zuriff, Love & Brownell	Semantic priming paradigm	LDT	6 fluent And 6 non fluent	128 semantically related& unrelated randomized stimuli	500 milliseconds	Semantic priming was found in fluent
Mimura, Goodglass and Milberg	Semantic priming paradigm	LDT	6 fluent and 6 non fluent with controls	360 paired words	500 milliseconds	Priming was absent in both aphasia groups, present in controls
Del Toro	Paired priming: Visual	LDT	6 fluent aphasia and non fluent	180 paired words	1000 milliseconds	Priming effect present in both

			aphasia			aphasia subgroups.

Table 1.2
Summary of ERP based studies

Authors	Sample	ERP's recorded	Stimuli	Results
Nautennen	100 control participants and 10 persons with non fluent aphasia	N-400	Words and non words- LDT	Negativity was seen in control
Ferrad	10 persons with non fluent aphasia and 6 persons with anomic aphasia	N 400	Non words and words in the proportion of 2:1	Negativity was seen more in persons with anomic aphasia
Gilmore	7 participants with non fluent aphasia	N 400	Paired words	Negativity was not seen

A few of the major studies carried out by employing priming studies and ERP paradigm have been summarized in Table 1.1 and Table 1.2.. The results of the behavioral studies show discrepancy with respect to nature of stimuli, SOA and results obtained in neuro-typical population and aphasia groups. Thus the need for validating the results with other experimental procedures arises. Likewise many studies on lexical semantic processing based on ERP's have been carried out. The results of these studies also show discrepancy between studies. Hence the need of studying lexical semantic processing by employing tasks based on two different principles has to be carried out.

1.7 Indian studies carried out in this direction

Individual studies on semantic priming paradigm in persons with aphasia have been carried out in Indian context (Abhishek & Prema, 2012; Mandira & Shanbal, 2012). Though these studies provide a basis for understanding the lexical semantic processing and lexical semantic processing deficits in persons with aphasia, the results have been cross validated with other competence evaluation procedures underlying different theoretical principle. Likewise ERP based studies on lexical semantic processing have been carried out in Indian context (Samapth & Goswami, 2013; Sunil & Shymala, 2013). The study by Sampath and Goswami used semantic categorization. The participants were prescribed a semantic category , Clothing in this instance and the participant was asked to categorize a lexical item as a strong contender and weak contender into a category by button press. ERP was recorded. Prominent N400 waveform was not seen. The study reflected the finding that lexical semantic processing was defective in persons with aphasia, however it did not correlate behavioral and ERP measures, The other study by Sunil and Shymala used semantic and structural anomaly and mainly was designed to correlate topographic responses with the responses picked up by the 32 electrodes. Most of the studies have not validated the results of N400with behavioral tasks. Hence there is a need to study lexical semantic processing on cognitive linguistic and neurolinguistic tasks.

CHAPTER 2

METHOD

The aim of the study was to understand lexical semantic processing in persons with aphasia and neurologically healthy individuals by using behavioral and electro physiological measures.

The following objectives were considered

a) Comparison of performance of persons with aphasia and neurologically healthy individuals on behavioral and ERP tasks.
b) Correlation between the behavioral (Reaction time& Accuracy of responses) and ERP measures for persons with aphasia and neurologically healthy individuals.
c) Analysis of amplitude and latency of responses derived on N400 for participants with different types of aphasia.

2.1 Participants

The participants in the study were divided into 2 groups, 10 persons diagnosed with aphasia formed the first group and is designated as PWA (Persons with aphasia) while the second group consisted of 10 neurologically healthy individuals and designated as NHI (Neurologically healthy Individuals). All these participants were native speakers of Kannada. The age range of the participants in group 1 was 30-64 years (mean 42.5) and the age range of participants in group 2 was 30 - 60 (mean 43.4 years). The mean age range of the participants in both groups matched fairly well.

The participants in group 1 were recruited after verifying if they met the following criteria:

a. Aphasic quotient of 92.7 or less on Western Aphasia Battery (Shyamala, Vijayashree & Ravikumar, 2001)
b. Kannada as native language
c. Good comprehension scores on WAB
d. No history of cognitive problems and hearing loss
e. Good dexterity (as the participants were required to carry out button press for the behavioral task.

The participants in group 1 were further sub-grouped on the basis of the type of aphasia. This group comprised of eight participants with Broca's Aphasia and two participants with Anomic aphasia (see Table 2.1). The participants were selected in such a way that they were able to respond to the stimuli by pressing the keys on the keyboard. Persons with severe motor deficits were not included for the study. The details of the participants is listed in Table 2.1

Table 2.1

Details of participants in group 1

Sn.o	Age and gender	Type of aphasia as diagnosed on WAB
1	64/M	Broca's Aphasia
2	31/m	Broca's Aphasia
3	36/M	Broca's Aphasia
4	64/M	Broca's Aphasia
5	40/F	Broca's Aphasia
6	64/M	Anomic Aphasia
7	41/M	Anomic Aphasia
8	48/M	Broca's Aphasia
9	54/M	Broca's Aphasia
10	39/M	Broca's aphasia

Group 2 comprised of neurologically healthy individuals. The group 2 participants were also native speakers of Kannada, age and gender matched with participants in group 1 and had no hearing difficulties or cognitive impairment. The participants in both these groups were administered two tasks: lexical decision and semantic judgment task. The lexical decision and semantic judgment tasks were employed both in behavioral and evoked response potential paradigms.

2.2 Stimulus Preparation

The first task i.e. the lexical decision task required the participants to judge if the target stimuli presented to them was a word or non-word. In semantic judgment task, the participants were presented with pairs of words and the task was to judge if the pair of words were semantically related or not. Two word lists were prepared, one with 40 words and 70 non words for the lexical decision task (LDT) and another word list with 50 related and 70 non related word pairs for semantic judgment task (SJT).

The non words for the lexical decision task were prepared by interchanging the syllable order following the orthographic rules of the English Language. The length of the word did conform to the 400 ms to 800 ms (mean 600 ms) duration and consisted of bisyllabic and trisyllabic words. The stimuli were given to 3 Kannada speakers to judge for familiarity. The judges were to mark the words as unfamiliar, highly familiar or familiar depending on their understanding of the familiarity of the words presented. For the lexical decision task, the judges rated the stimuli 30 words to be highly familiar and 10 words to be familiar 70 were non words and hence non- meaningful. For the SJT task 50 word pairs were marked as familiar and 70 were marked as highly familiar. The word lists are provided in the Appendix I. The words were recorded by a female trained recording artist. 3 samples were taken and the one with highest goodness rating was considered for stimulus presentation. The goodness rating was done on parameters such as clarity, intelligibility, loudness, naturalness and overall quality of the sample. The sample with highest rating was used for stimulus presentation.

2.3 Instrumentation

The following instruments were used to carry out the study:

A laptop with DMDX software version 4.3.0.1 (Forster & Forster 2003) was used for eliciting the behavioral responses. Compumedics Neuroscan instrument with Scan™ 4.4 module along with quick cap ® , model c190 for recoding of cortical evoked potentials and Stim$^{(2)}$ version 4.4 module was used to deliver the stimulus.

2.4 Stimulus presentation

As discussed earlier, the lexical decision task and the semantic judgment task was presented through behavioral and evoked response potentials paradigms. To elicit the behavioral responses the stimulus was presented through DMDX 4.3.0.1. DMDX (Forster & Forster 2003). DMDX is software used by researchers for measuring reaction time (RT) and accuracy. For the LDT task participants were instructed to press “1” for a meaningful word and “0” for a non meaningful word. The target was presented for duration of 2000 milliseconds and this target stimulus was presented in BRH Kannada font with font size of 52 and was aligned at the centre of the screen. The font was in black color and was presented against a white background.

For the SJT task, the participants were asked to press “1” if the first word (prime) was related to the second word (target), and “0” of there is no relationship. The participants were given a trial with 5 words in the LDT task and 5 words pairs in the SJT task for familiarization. The word lists were randomized before each presentation. The font size and color were similar to the lexical decision task.

The ERP recording was mediated through Gentask module in Stim^2 . For the LDT task, the list contained 110 stimuli; for each person these words were randomly presented. The inter-stimulus interval was 2500 milliseconds. Different values of triggers were given for words and non-words. For the SJT task the same word list which was used for behavioral task was used, 120 word pair presented as stimuli, the word pairs was presented with 500 ms silence between the prime and target. The inter-stimulus interval was 3500 ms and different trigger values were specified for related word pairs and non related word pairs. The stimulus was presented binaurally at 80 dBSPL so that the adult population can remain alert.

2.5 Procedure

a) Behavioral task

All the participants were tested individually in a quiet room. The participants were made to sit on a chair comfortable with an eye to monitor distance of about of 50 cms. The stimulus was presented through the laptop speakers. For the LDT task the participants were instructed to listen carefully to the words and press key “1” on the laptop keyboard if the words were meaningful, or press key “0” if they were non-meaningful..

For the SJT task, the participants were asked to listen to the word pairs, and press key “1” if the words are related and “0” if the words are not related. They were asked to respond once the options show on the screen. At the end of the instructions they were given a trial with 5 word for lexical decision task and 5 word pairs for semantic judgment task.

b) ERP recording

The Synamps[2] was used to record the cortical potentials. The participants were made to sit in a comfortable recliner chair. A quick cap consisting of 64 silver chloride electrodes was used for recording the evoked responses or potentials. The ERPs were recorded from 19 electrodes FP1, FP2, Fz, F1, F2, F3, F4, Fpz, Cz, C3, C4, C5, C6, CPz, Pz, P3, P4, T7, T8. Linked mastoid was used as reference electrode. The allocated ground electrode between Fpz and Pz was used as the ground. A syringe with a blunt needle was used to fill the electrode site with Quick gel ™ and clean the electrode site to facilitate good contact.The impedance was maintained at less than 5KOhm for all the participants.

A continuous EEG was recorded with a digitization rate of 1000Hz. A 100Hz low pass filter was used with DC filter as the high pass. 200 milliseconds pre-stimulus duration with a time window of 1000 milliseconds was used for online averaging. The stimulus was encoded with triggers such that the responses are time locked to the stimulus. The participants were introduced to insert earphones through which stimulus would be presented. They were asked to pay attention to the stimulus and try to blink as less as possible during the recording. The recording procedure was approximately one hour per person.

Table 2.2

Stimulus and recording parameters for ERP task

Stimulus parameters	
Stimulus	120 randomized word pairs for semantic judgement task and 110 words for lexical decision task
Transducer	ER 3A insert receivers - Binaural
Polarity	Alternating
Number of sweeps	120 for SJT and 110 for LDT
No of recordings	2
Recording parameters	
Electrode montage	Inverting electrode – linked mastoid Non Inverting electrode: Fz, Cz, Pz Ground: Ground electrode site provide on the quick cap
Filter setting	0.1 – 100Hz
Recording time window	1500 Ms
Notch filter	off
Electrode Impedance	<5 K Ohm

2.6 Analyses

The performance of participants on the behavioral tasks (lST and semantic judgment) was determined through the accuracy scores. Reaction time was not taken into consideration as persons with Broca's aphasia were involved in the study and these participants with Broca's aphasia possess motor deficits. The performance on the ERP task was determined through the latency and amplitude of N 400 responses for the lexical decision and semantic judgment tasks.

CHAPTER 3

RESULTS AND DISCUSSION

The aim of the current study was to compare the behavioral measures of lexical semantic processing with those of ERP measures. Two tasks, lexical decision task (LDT) and semantic judgment task (SJT) were carried out using DMDX[2] and Neuroscan[3]. The reaction times, latencies and amplitudes of N400 were measured for 10 neurologically healthy individuals and 10 persons with aphasia. Of the 10 persons with aphasia 8 were diagnosed with Broca's aphasia and 2 with Anomic aphasia.

I. Analysis of behavioral measures

Descriptive statistics was done initially to compare the two groups. The mean scores for reaction time of the participants for both the tasks; LDT and SJT were computed and presented in Table 3.1.

Table 3.1
Mean reaction times and accuracy for LDT and SJT in NHI and PWA

Group		N	Minimum	Maximum	Mean	Std. Deviation
NHI	Mean Reaction time (LDT)	10	546.78	889.72	673.98	114.08
	Accuracy of Reaction (LDT)	10	78.00%	98.80%	90.96%	6.59%
	Mean Reaction time (SJT)	10	545.14	1504.46	966.35	274.057
	Accuracy of reaction (SJT)	10	87.50%	95.20%	89.78%	2.22%
PWA	Mean Reaction time (LDT)	10	1762.76	3456.23	2649.97	643.55
	Accuracy of Reaction (LDT)	10	72.40%	89.00%	79.63%	5.58%
	Mean Reaction time (SJT)	10	2196.36	4398.78	3257.25	841.32
	Accuracy of reaction (SJT)	10	76.40%	90.40%	81.68%	4.56%

NHI: Neurologically Healthy Individuals, PWA: Persons with aphasia LDT: Lexical decision task SJT: Semantic Judgment task

The mean scores for reaction time of NHI are shorter in both LDT and SJT compared to persons with aphasia. While the mean score for LDT in NHI is 673.98ms with standard deviation of 114.08ms, it was 2649.97ms with a standard deviation of 643.55ms for PWA being higher than NHI. The results indicate that participants in NHI group performed better

[2] DMDX software version 4.3.0.1 (Forster & Forster 2003)
[3] Compumedics Neuroscan instrument with Scan™ 4.4 module along with quick cap ® , model c190 for recoding of cortical evoked potentials and Stim(2) version 4.4 module

than participants in the PWA group. Statistical analysis was performed to confirm the significance in the difference projected by these two groups.

The DMDX software automatically generates the reaction time data. For accuracy measures, reliable measure is not possible with DMDX software because the inter-stimulus interval (ISI) is configured and fixed during programming the stimuli. Since ISI is pre-fixed, a participant who is slow to perform, yet being accurate (treated as failure) or quick to respond but is inaccurate (treated as successful) in the software generated data. For example, in a 4000 ms ISI window, if a participant responds at 3500ms, response is generated as accurate even though it is inaccurate. Hence, for want of reliable data for analysis, only the mean scores of reaction time was considered excluding the accuracy measure. Paired T- test was performed to compare the mean scores for reaction time between the two tasks - LDT and SJT - within the two groups of NHI and PWA. Table 3.2 shows that there was no statistical difference between the mean scores for reaction time and accuracy of LDT and SJT in NHI. However, statistically significant difference was observed between the mean scores for reaction time on LDT and SJT in PWA ($p < 0.005$).

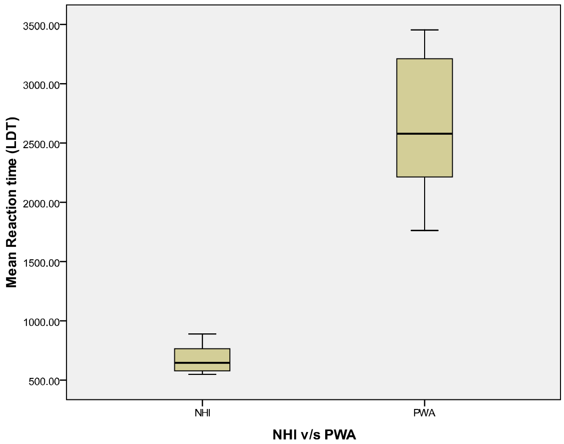
Table 3.2
Paired t-test to compare the mean reaction times for LDT and SJT

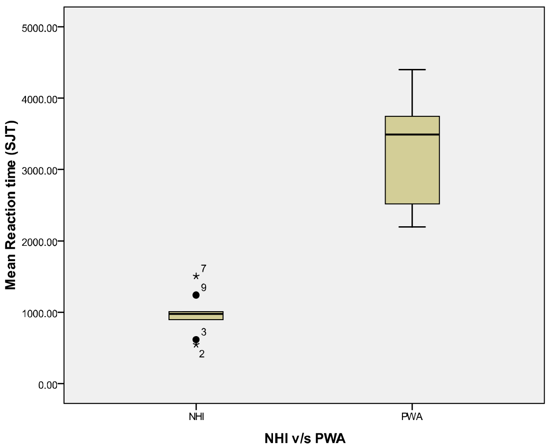
		NHI v/s PWA			
		NHI		PWA	
		Pair 1	Pair 2	Pair 1	Pair 2
		Mean scores for Reaction time (LDT) - Mean scores Reaction time (SJT)	Accuracy of Reaction (LDT) - Accuracy of reaction (SJT)	Mean scores for Reaction time (LDT) - Mean scores for Reaction time (SJT)	Accuracy of Reaction (LDT) - Accuracy of reaction (SJT)
Paired Differences	Mean	-292.3720	1.1800	-607.2833	-2.0555
	Std. Deviation	318.0540	5.9780	338.40210	1.6086
	Std. Error Mean	100.5775	1.8904	112.80070	.5362
95% Confidence Interval of the Difference	Lower	-519.8941	-3.0964	-867.40221	-3.2920
	Upper	-64.8498	5.4564	-347.16445	-.81903
t		-2.907	.624	-5.384	-3.833

df	9	9	9	9
Sig. (2-tailed)	.017	.548	.001	.005

An independent t test was carried out to check the difference between mean scores for reaction time on LDT and SJT for the two groups NHI and PWA. Table 3.3 shows a significant difference between the two groups ($p<0.000$). The results indicate that although there was no difference in the mean scores for reaction times of SJT and LDT tasks within the two groups, a significant difference was observed between the NHI and PWA on both LDT and SJT.

Figure 3.1*: Box plots depicting the mean reaction time of LDT and SJT in NHI and PWA*





The higher mean scores for reaction time can be attributed to the slower processing in persons with aphasia. Kutas and Iragui (1998) and Faustian et al (2007) had reported a linear increase in the latency for response as the age of the participants increases. In the present study, the mean age of the participants in both the groups was around 43 years and in the

PWA group, the responses are further compounded by the neurological pathology resulting in further slowing of the processing as is shown in Figure 3.1.

Table 3.3

Scores of independent T test on the mean reaction time of LDT and SJT between the groups - NHI and PWA

				Equal variances assumed	Equal variances not assumed
Mean Reaction time (LDT)	t-test for Equality of Means		t	-9.57	-9.08
			df	17	8.45
		95% Confidence Interval of the Difference	Sig. (2-tailed)	.000	.000
			Mean Difference	-1975.98	-1975.987
			Std. Error Difference	206.39	217.53
			Lower	-2411.45	-2472.97
			Upper	-1540.52	-1478.99
Mean Reaction time (SJT)			t	-8.16	-7.80
			df	17	9.52
		95% Confidence Interval of the Difference	Sig. (2-tailed)	.000	.000
			Mean Difference	-2290.89	-2290.89
			Std. Error Difference	280.55	293.52
			Lower	-2882.82	-2949.37
			Upper	-1698.96	-1632.42

Figure 3.1 and the independent T test scores shown in Table 3.3 indicate that the mean scores for reaction time for the NHI group was lower for participants in the NHI group than those in the PWA group and this was statistically significant. The results suggest that speed of lexical semantic processing is impaired in persons with aphasia.

II. Analysis of ERP measures

a) Latency of N400

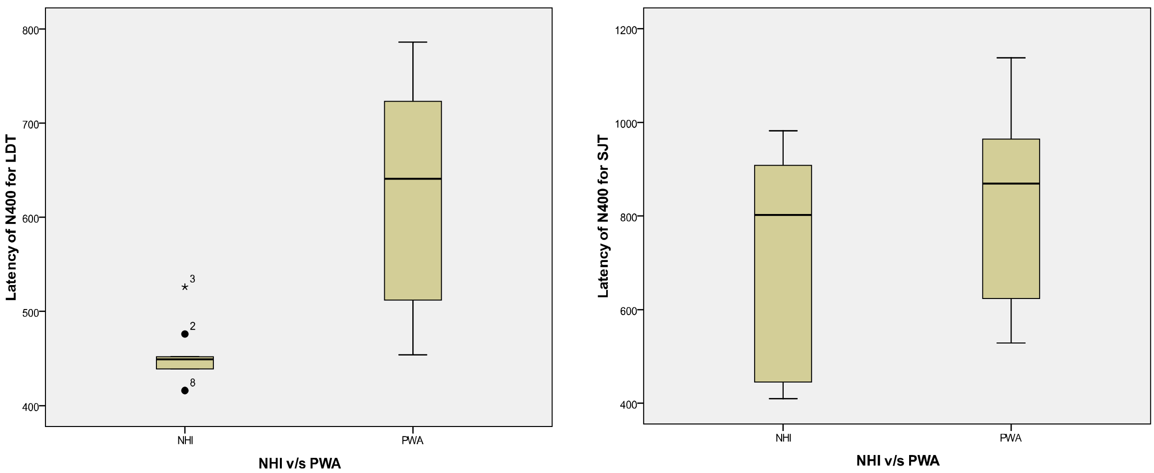
N400 was recorded using Neuroscan using words and nonwords for the LDT task and related and unrelated word pairs for SJT task. Table 3.4 presents the mean and standard deviation of latency of N400 in both the tasks LDT and SJT for both the groups, NHI and PWA. Mean scores for latency of N400 on LDT in persons with NHI is 454.10 milliseconds (ms) with an SD of 29.278ms while that for PWA is 625.78 with a SD of 122.533ms. The mean scores for latency of N400 for SJT in NHI is 710.70ms with SD 244.126ms while the mean scores for latency of N400 on SJT in PWA is 845.44ms with an SD of 227.597ms. The scores are represented in Figure 3.2

Table 3. 4

Mean latency of N400 for LDT and SJT in NHI and PWA

	NHI v/s PWA	Mean	Std. Deviation	N
Latency of N400 for LDT	NHI	454.10	29.278	10
	PWA	625.78	122.533	10
	Total	535.42	121.893	20
Latency of N400 for SJT	NHI	710.70	244.126	10
	PWA	845.44	227.597	10
	Total	774.53	239.998	20

Figure 3.2 shows a box plot depicting the latency of N400 elicited with LDT and SJT tasks in the two groups NHI and PWA.



Atchley & Kwasny (2003) observed N400 over parietal and temporal areas for both auditory and visual stimuli in neurotypical population . But in this study N400 was observed majorly in the Frontal areas Fz, F1, F2, F3, F4 and FCz electrodes (frontal lobe region) in all the participants. Figure 3,3 shows N400 waveform recorded during the LDT task for nonwords. was marked and the Latency and amplitude were calculated at N400 . The green wave shows the grand average ERP waveform for all the participants Group 1 i.e., NHI and the red waveform was recorded from the participants in Group 2 i.e., PWA acquired from the Fcz electrode side. The N400 waveform is marked with a "+".Figure shows that the N400 potential is more negative in the NHI group when compared to the PWA group. Also the overall negativity continues till roughly 1200ms and the waveform is observed to be joining the baseline.

Figure 3.3 *Latency and amplitude for nonwords in LDT*

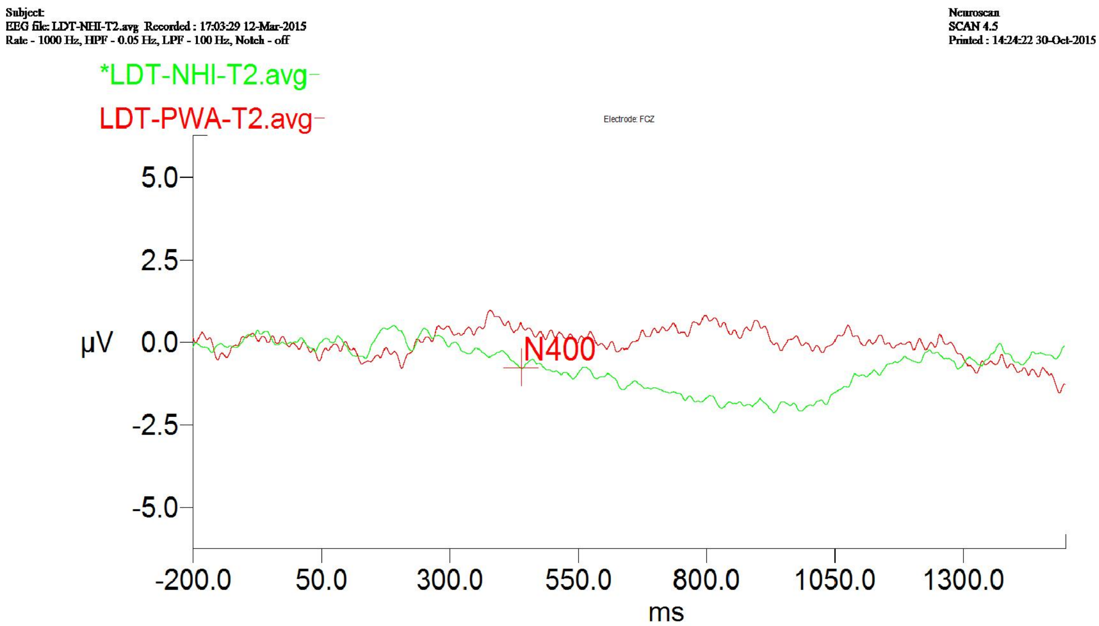
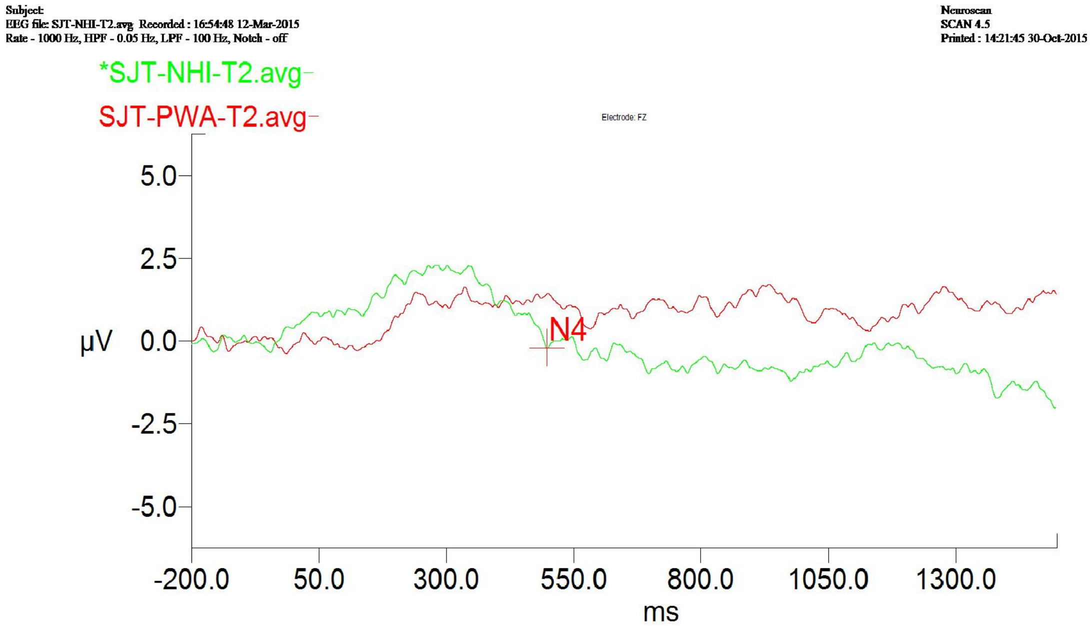


Figure 3.4 shows the grand averaged waveform recorded during the SJT task for both the NHI group and PWA group for the semantically unrelated word pairs. The green wave is the grand average waveform acquired from the NHI group and the red wave is recorded from the PWA group from the electrode site Fz. It can be observed that the latency is earlier in the NHI than in the PWA group and the negativity is higher for NHI compared to PWA.

Figure 3.4 *Latency and amplitude for unrelated word pairs in SJT task*



The SD is relatively low and on performing Shapiro Wilk's test the data is suggested to be normally distributed, Independent sample T test was carried out to test the relationship between the latency of N400 for LDT and SJT in both group 1 and 2. Table 3.5 represents the data showing the relationship between their mean scores.

Table 3.5

Independent sample T test to compare the means of LDT and SJT between the groups 1 and 2

		Latency of N400 for LDT		Latency of N400 for SJT	
		Equal variances assumed	Equal variances not assumed	Equal variances assumed	Equal variances not assumed
Levene's Test for Equality of Variances	F	12.407		.663	
	Sig.	.003		.427	
t-test for Equality of Means	t	-4.309	-4.099	-1.240	-1.245
	df	18	8.823	18	16.971
	Sig. (2-tailed)	.000	.003	.232	.230

The independent sample T test shows the mean latency of N400 for LDT to be statistically significantly different in both the groups as the $p<0.05$.However there was no significant difference in the mean scores for latency of N400 in SJT and LDT. The high standard deviation and insignificant difference between the groups is likely to be due to word duration used for eliciting N400 as the word length of the second word in the word pair varied from 750ms to 1500 ms. that probably would have triggered N400 peak out of the recording window. The mean scores on latencies of LDT and SJT were also compared using paired sample T test (Table 3.6) No significant difference was observed between the mean latencies of N400 for LDT and SJT for NHI as well as PWA ($p > 0.005$). N400 is only a relative negativity around the 400 ms in the presence of incongruent stimuli when compared to congruent stimuli and therefore, visual observation of the waveforms of the ERPs should be made to infer on the latency (Kutas and Federmeier, 2010).

Table 3. 6

Paired sample T test for latencies of LD and SJT within Groups 1 and 2

		NHI v/s PWA	
		NHI Pair 1 Latency of N400 for LDT - Latency of N400 for SJT	PWA Pair 1 Latency of N400 for LDT - Latency of N400 for SJT
Paired Differences	Mean	-256.600	-219.667
	SD	264.293	249.140
	Std. Error Mean	83.577	83.047
95% Confidence Interval of the Difference	Lower	-445.664	-411.172
	Upper	-67.536	-28.161
T		-3.070	-2.645
Df		9	9
Sig. (2-tailed)		.013	.029

b) Amplitude of N400

The amplitude of N400, according to research is that it ranges from -5 Kilo Ohm (KΩ) to + 5 KΩ. The standard deviation of amplitude for SJT task is observed to be high hence nonparametric tests – Mann Whitney U test and Wilcoxon's Signed rank test - were applied. Mann Whitney U test was used to test if there was any significant difference in the performance of NHI and PWA on LDT and SJT tasks separately. Wilcoxon's sign ranked test was carried out within each group to test the relationship between the amplitudes of N400 in LDT (word v/s nonword) and SJT tasks (related v/s unrelated word pairs). The median and standard deviation of the amplitude of N400 in the two tasks LDT and SJT and their subsequent conditions – Word and Non word condition in LDT and related word pairs and unrelated word pair condition - are provided in the Table 3.7.

Table3. 7
Median and standard deviation of the amplitude of N400 for Word and non words in LDT task and for related word pairs and non related word pairs in SJT task

NHI v/s PWA		Amplitude of N400 for words	Amplitude of N400 for Nonwords	Amplitude of N400 for related word pairs	Amplitude of N400 for Unrelated word pairs
NHI	N	10	10	10	10
	Median	-2.4435	-1.9930	-1.1590	-.9835
	Std. Deviation	2.20694	1.76873	2.39840	2.0730
PWA	N	10	10	10	10
	Median	1.9950	.5500	-.9360	-.3070
	Std. Deviation	4.04677	3.8373	3.0533	2.5250
Total	N	20	20	120	20
	Median	-1.7300	-1.4460	-.9360	-.8970
	Std. Deviation	3.39213	2.97456	2.6506	2.2920

Table 3.7 shows that the overall negativity in processing of the stimuli is higher in NHI when compared to the PWA group. The median values suggest the variation in processing of lexical -semantic information in persons with aphasia. And the median values are in consonance with previous research by Kutas and Hilyard in 1980 which suggest that in the presence of language anomaly the N400 is relatively more negative compared to the negative peak which occurs around the same time in the presence of actual words or related word pairs. Mann Whitney U test and Wilcoxon's signed rank test was used to compare the median between the two tasks and the median between the two conditions. Table 3.8 provides details regarding the difference between word and non word condition in LDT task and related word pairs and unrelated pairs condition in SJT task.

The difference between groups NHI and PWA was calculated using the Mann Whitney U test (see Table 3.8) The Z value was observed to be much greater than 0.005, on all observations, which suggests lack of significant difference between the mean latencies of N400 for words maps. The current study employed only 18 electrodes, if all 64 or even 32 electrodes were and non words in the LDT task, and between related and unrelated word pairs for SJT task. (z > 0.005). This points to the imperative role a Neuroscan cap plays in acquiring topographic

Table 3. 8
Amplitude difference between congruent and incongruent stimuli for within tasks using Mann Whitney U test

	Amplitude of N400 for words	Amplitude of N400 for Nonwords	Amplitude of N400 for related word pairs	Amplitude of N400 for Unrelated word pairs
Mann-Whitney U	28.000	44.000	34.000	33.000
Z	-1.388	-.898	-.082	-.980
Asymp. Sig. (2-tailed)	.165	.369	.935	.327
Exact Sig. [2*(1-tailed Sig.)]	.182	.400	.968	.356

used to record the N400 responses a better picture on the activation areas of the brain would have been observed.

Wilcoxon's signed rank test (see Table 3.9) was carried out in order to determine if there was any significant difference within NHI and PWA group for word and nonword pairs on LDT; related and unrelated words of SJT. The results are provided in the Table 3.9. The results indicate that no significant difference between the amplitude elicited by either condition i.e., word or on word in LDT and related word pairs and unrelated word pairs in SJT task (Z> 0.005).

Table 3. 9
Amplitude of N400 within NHI and PWA groups

NHI v/s PWA		Amplitude of N400 for Non-words - Amplitude of N400 for words	Amplitude of N400 for Unrelated word pairs - Amplitude of N400 for related word pairs
NHI	Z	-.415	-1.478
	Asymp. Sig. (2-tailed)	.678	.139
PWA	Z	-.533	-1.125
	Asymp. Sig. (2-tailed)	.594	.260

III a. Correlating ERP measures with behavioral measures for the two groups

The latency of N400 elicited through LDT and SJT is correlated with the mean scores for reaction time of the participants for the same tasks using Pearson's product moment correlation coefficient since the data was normally distributed, which was confirmed using the Shapiro Wilk's test.

Table 3.10
Pearson's correlation coefficient latency of N400 for LDT and mean reaction time of LDT for the 2 groups

NHI v/s PWA			Latency of N400 for LDT	Mean Reaction time (LDT)
NHI	Latency of N400 for LDT	Pearson Correlation	1	.234
		Sig. (2-tailed)		.515
		N	10	10
	Mean Reaction time (LDT)	Pearson Correlation	.234	1
		Sig. (2-tailed)	.515	
		N	10	10
PWA	Latency of N400 for LDT	Pearson Correlation	1	.402
		Sig. (2-tailed)		.283
		N	10	10
	Mean Reaction time (LDT)	Pearson Correlation	.402	1
		Sig. (2-tailed)	.283	
		N	10	10

Pearson's correlation coefficient reveals that there is a low correlation between the mean scores for reaction time and the latency of N400 for the LDT Task. According to Chwilla and Kolk (2005) the N400 amplitude varies as a function of semantic category of words, their concreteness, and also if their meaning matches that of a preceding context. The negativity was more for infrequent, abstract and unrelated words. In the present study also there was more negativity for non words and unrelated word pairs.

Table 3. 11

Pearson's correlation coefficient latency of N400 for SJT and mean reaction time of SJT

NHI v/s PWA			Mean Reaction time (SJT)	Latency of N400 for SJT
NHI	Mean Reaction time (SJT)	Pearson Correlation	1	.667*
		Sig. (2-tailed)		.035
		N	10	10
	Latency of N400 for SJT	Pearson Correlation	.667*	1
		Sig. (2-tailed)	.035	
		N	10	10
PWA	Mean Reaction time (SJT)	Pearson Correlation	1	.138
		Sig. (2-tailed)		.723
		N	10	10
	Latency of N400 for SJT	Pearson Correlation	.138	1
		Sig. (2-tailed)	.723	
		N	10	10

*. Correlation is significant at the 0.05 level (2-tailed).

There is a moderate positive correlation between the mean scores for reaction time of SJT and latency of N400 for NHI and the correlation is significant ($r=0.667$ with a $P<0.05$). The behavioral response and the latency for N400 have a positive relationship which suggests that as the mean reaction time increases the latency increases as well. The results are in consonance with the study done by Nieuwland, and Kuperberg in 2008, which suggested that a larger N400 effect in incongruent word presentation. Very few studies have correlated the behavioral correlates of semantic judgment with that of the ERP measures hence the findings obtained in the current study lacks support.

IV Behavioral responses for aphasia sub types

Table 3.12: *Mean reaction times and accuracy for LDT and SJT in NHI and PWA*

Group		N	Mean	Std. Deviation
Broca's	Mean Reaction time (LDT)	8	1862.76	643.55
	Accuracy of Reaction (LDT)	8	74.00%	5.58%
	Mean Reaction time (SJT)	8	2304.65	841.32
	Accuracy of reaction (SJT)	8	72.40%	4.56%
Anomic	Mean Reaction time (LDT)	2	1664.76	467.55

Accuracy of Reaction (LDT)	2	74.40%	10.78%
Mean Reaction time (SJT)	2	1896.36	420.32
Accuracy of reaction (SJT)	2	80.40%	4.56%

NHI: Neurologically Healthy Individuals, PWA: Persons with aphasia LDT: Lexical decision task SJT: Semantic Judgment task

Persons with Broca's aphasia secured a mean reaction time of 1862. 76 ms on LDT and 2304 .65ms on SJT. the mean reaction time was more on semantic judgment owing to the test complexity the accuracy scores was also better for LDT compared to SJT. Persons with anomic aphasia obtained a mean reaction time of 1664.76ms on LDT and 1896.36ms on SJT. The mean reaction time was more for SJT compared to LDT as in persons with Broca's aphasia. However the accuracy scores were better on SJT compared to LDT. The standard deviation was more for Broca's aphasia compared to Anomic aphasia on both the tasks Statistical analyses was not carried out to verify if there was any significant difference in the two aphasia sub types on lexical decision task and semantic judgment task as only two persons with anomic aphasia were enrolled.

The mean latency and the mean reaction time for both the tasks were compared. Table 3.13 shows the details.

Table 3.13 Comparison of mean latency time between persons with anomic aphasia and Broca's aphasia

		N	Minimum	Maximum	Mean	Std. Deviation
Broca	LDT Latency	8	454	786	623.00	141.311
	SJT Latency	8	529	1138	828.71	259.209
Anomia	LDT Latency	2	630	641	635.50	7.778
	SJT Latency	2	869	939	904.00	49.497

Table 12 shows the mean latency for persons diagnosed with Broca's Aphasia and 2 persons diagnosed with Anomic aphasia. The mean latency for persons with Broca's aphasia is 623 ms with a standard deviation of 141.311ms and the mean for persons with anomic aphasia is 635.50ms with a standard deviation of 7.778ms. High standard deviation may be attributed to the number of participants in the group with participants diagnosed with Broca's aphasia The responses could not be analyzed for the sub types of aphasia as there was variation in the response topography.

V. Topographical inferences

In this study 18 electrodes were used to record the ERP information from 20 participants divided into 2 groups based on their neural health status. The topographical information obtained for each group enabled a comparison of the activity. Figures 3.5 and 3.6 are obtained from the grand average waveform for semantically unrelated word pairs for both NHI and PWA groups. The frames are discussed with respect to the loci of activation and the extent of activation.

Figure 3.5 *Topographical representation of the neural activity of the NHI group for semantic judgment task following the presentation of semantically unrelated words*

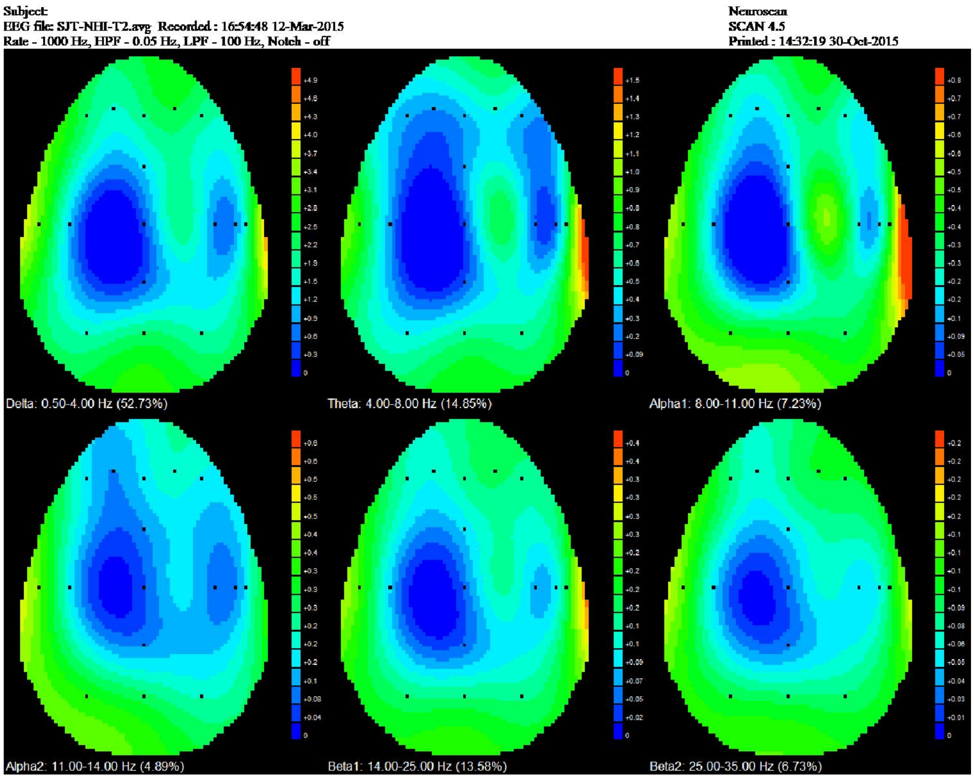
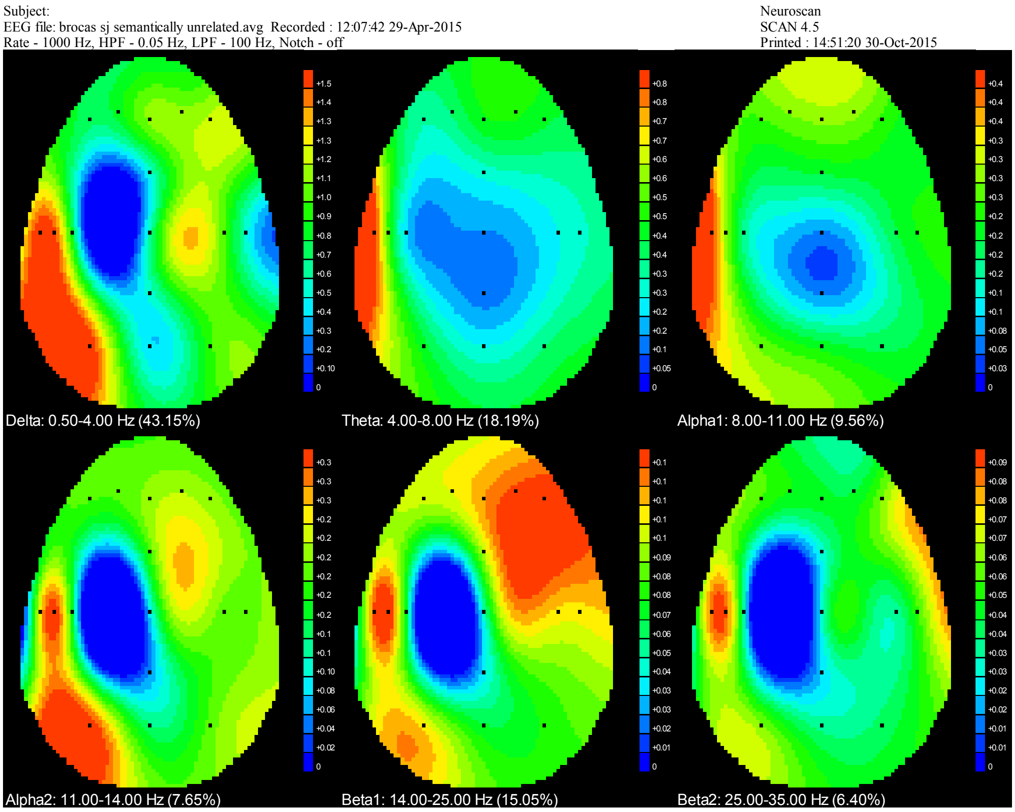


Figure 3.6 *Topographical representation of the neural activity of the PWA group for semantic judgment task following the presentation of semantically unrelated words*



Loci of activation

The center of activation for semantically unrelated word in NHI is observed to be in the left Fronto-parietal area, spreading over to the right parietal area, albeit with a negligible magnitude. Conversely, an overall activation of the cortical area was observed for PWA, including right frontal regions, the parietal region and moving posterior to the tempero-occipital regions, supporting the findings of Musso & Weiller et al 1999 indicating right temporal lobe activity for comprehension in persons with aphasia. This suggests either reorganization or re-recruitment of the typical functional regions during recovery as most of the participants considered for the study were in their recovery phase.

Magnitude of activation

The color coding key next to the EGG head plot suggests the intensity of activation following a stimulus with blue indicating the lowest intensity of response and red, the highest. The NHI responses show a less intense activation compared to the PWA responses. Also the center of activation is not the same. The higher intensity activation was observed for

PWA, whereas for NHI the activation intensity was noticeably low. This may suggest that, while for the NHI group the task imposed less challenges or the participants could perform on the task with ease, for PWA it required significantly higher effort. The responses were more under strategic control for PWA.

General Discussion

The aim of the study was to understand lexical semantic processing in persons with aphasia by employing psycholinguistic and neurolinguistic measures. As a part of psycholinguistic measurement, two tasks namely lexical decision task and semantic judgment task were used. In order to tap lexical semantic processing neuro linguistically, N 400 an ERP was used. 10 PWA and 10 NHI were recruited for the study. Out of 10 persons of aphasia, 8 of them were diagnosed to have Broca's aphasia and the remaining 2 participants were diagnosed to have anomic aphasia. The first objective was to analyze the performance of NHI and PWA on behavioral and ERP tasks. The results were analyzed for LDT and semantic judgment tasks separately. The outputs on these tasks were measured in terms of reaction time and accuracy.

For NHI, the mean reaction time for both these tasks were almost same but the accuracy on semantic judgment task was more than the accuracy for LDT task. Paired sample T test was carried out to see if there was any significant difference, the statistic revealed no significant difference. For PWA, the mean reaction time was more on semantic judgment compared to lexical decision task and accuracy scores on the two tasks was almost same (87 and 85% respectively). Wilcoxon's signed test (as the data did not abide the properties of normal distribution) revealed significant difference between the two tasks. As the reaction time was more on semantic judgment task, it can be inferred that this task was more complex compared to lexical decision task for NHI and PWA.

Further in order to verify if there was any significant difference between NHI and PWA, Mann Whitney U test was carried out and the statistic revealed significant difference between the two tasks for both these groups on lexical decision and semantic judgment task. The performance of PWA was 81% and 87% accurate on lexical decision task and semantic judgment tasks. This would infer the less likeliness of the chance factor resulting from speculation of responses on behavioral task. The mean reaction time ranged from 3546 milliseconds to 5438 milliseconds in PWA against the reaction time of 889 milliseconds to

1048 milliseconds in NHI which could be because of the inclusion of participants with Broca's aphasia or slowed lexical semantic processing seen in persons with aphasia.

The second analyses aimed at analyzing the ERP responses for NHI and PWA. The ERP responses were measured in terms of latency and amplitude of responses. Semantic judgment and lexical decision tasks were employed here as well. NHI, the mean latency of response was 454 milliseconds on lexical decision task and 745 milliseconds for semantic judgment task. In order to verify if there was any significant difference, paired sample T test was used and the statistic revealed no significant difference. The mean latency for persons with aphasia was 625 milliseconds to 845 milliseconds.

In order to verify if there was any significant difference between the two tasks, Wilcoxon's signed rank test was carried and it revealed that there was no significant difference. This showed that the two tasks did not differ much in terms of complexity. However greater latency on semantic judgment seen for NHI and PWA depicts the task complexity showing that the semantic judgment was more complex than lexical decision task. The results were subjected to between group comparisons by employing Mann Whitney U test and the results showed significant difference between NHI and PWA. This again reflects that the speed of processing, would come down in PWA owing to which they would have performed poorly as reported by Chwilla and Kolk (2005) in their research on NHI. The negativity was more for infrequent, abstract and unrelated words.

The results on N 400 was also analyzed in terms of amplitude of the waveform, For NHI as well as PWA, negativity was more for non words compared to words on lexical decision task and un related words compared to related words on semantic judgment task. In order to verify if there was any significant difference, paired sample T test and Wilcoxon's siged rank tests were used and the results indicated no significant difference. In order to verify if there was any significant difference between the two groups (NHI v/s PWA), Mann Whitney U test was carried out and the statistic revealed no significant difference again. However on qualitative analysis it was revealed that there was more negativity for NHI compared to persons with aphasia. This shows the intactness of lexical semantic processing in NHI and impaired processing in PWA.

The other objective considered for the study was to correlate the two measures. Pearson's correlation was carried out. The r values obtained was 0.2 for NHI and 0.45 for PWA. The poor correlation between the two tasks in NHI shows that the tasks are not linear.

Though both the tasks depict responses in terms of time, the measures may not be linear and hence comparison may not be apt. In persons with aphasia also correlation was only moderate, this could be because the tasks are not linear. Further, it is likely that compensation would have taken place in the mechanism after recovery from aphasia as evident through the topographic responses explained in section V. Some other brain areas would have compensated or re organization would have taken place. Also, the 18 electrodes used to record N 400 may not be a sensitive enough to tap this component. Good responses on accuracy measures of behavioral tasks for persons with aphasia strengthen the notion that recovery would have taken place. The responses could not be analyzed for the sub types of aphasia as the response topography varied.

Conclusions

The present study was an attempt to compare the psycho linguistic measures of lexical semantic processing with neurolinguistic measures in neurologically healthy individuals and persons with aphasia. Persons with aphasia regardless of the type of aphasia are known to encounter word finding difficulty. This word finding difficulty is attributed to defective lexical semantic processing. Lexical semantic processing in persons with aphasia are studied by employing naming, priming and event related potentials. Naming tasks are assumed to over simplify the lexical semantic processing. Priming and ERP's are considered to be alternatives. The principle of priming is incorporated ether in a lexical decision task or semantic judgment task paradigm. The performance on lexical decision task is dependent on the integrity of phonological input lexicon while the performance on semantic judgment task is known to tap the integrity at lexical semantic levels. The disadvantage of priming task is that it is subjected to the chance factor i.e. the participant can speculate and give the response this is more likely to happen in persons with aphasia. Hence the results on priming task have to be correlated with other tasks. It cannot be compared with the results of naming task as some persons with aphasia are non verbal and hence estimate cannot be derived. Therefore the present study used ERP's to correlate the behavioral measures.

The results were analyzed separately for behavioral measures, ERP measures and then correlated. The mean reaction time was less and accuracy was more for neurologically healthy individuals compared to persons with aphasia. This shows that the lexical semantic processing is compromised in persons with aphasia when compared to normals. Out of the two behavioral tasks considered to tap lexical semantic processing, there was no statistically significant difference for neurologically healthy individuals but for persons with aphasia significant difference was seen. These results showed that NHI performed better on tasks irrespective of task complexity. Similar results were not obtained for PWA since there was heterogeneity in their linguistic deficits.

Event related potentials, a neurolinguistic task was administered on the same groups. The performance on ERP's was analyzed in terms of latency and amplitude of responses. The latency was more in PWA compared to NHI. The latency for NHI also was not seen exactly at 400 milliseconds as it is dependent on many stimulus related variables like the duration, word length etc. Latency was more on semantic judgment compared to lexical decision for NHI as well as PWA indicating the task complexity. The amplitude of response was also analyzed. The peaks obtained in NHI were more negative than the peaks obtained in PWA again signifying their processing deficits.

The results obtained on behavioral and ERP task was correlated by employing Pearson's product moment correlation and the r values suggested poor correlation in NHI and moderate correlation in PWA. Poor correlation in NHI may be attributed to the tasks. In order to compare the two tasks, the two tasks must be linear. The two tasks considered in our study were not linear. In PWA also only moderate correlation was seen this also could be as the measures are non linear also because the study employed 18 electrodes to study lexical semantic processing. Electrodes representing different sites in the brain were considered, this could not have been sufficient in deciphering details about lexical semantic processing. However there were two positive findings obtained here.

The first finding was that the performance of PWA was consistent and was greater than 80% this rules out the possibility of the chance related responses. This also reflects compensation or recovery with the impaired brain area showing reorganization or other brain area would have acquainted its role besides therapy having contributed to recovery. High scores on the two tasks shows that the task can be employed independently to measure lexical semantic processing. The other interesting finding on latency obtained in this study is regarding is that behavioural responses were seen despite delayed latency on ERP's. The other objective considered in the study was to analyze lexical semantic processing in aphasia sub types. Only two sub groups of aphasia could meet the inclusionary criteria and the responses obtained on ERP's for these two sub types could not be compared as the response picked up by one electrode for one aphasia sub type was not picked by the same electrode for the other aphasia sub type.

Future direction

1) The study can be extended in persons with other types of aphasia who meet the inclusionary criteria (ex conduction aphasia)
2) More electrodes can be used to pick up the responses.
3) Source localization analysis can be carried out to determine the relationship between topographic responses and response morphology.

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Author contributions

Abhishek.B.P: Conceived the idea, helped designing the experiments, wrote the draft in coordination with Ms Phebe (Research officer).

K.S.Prema: Conceived the idea, inputs in designing the experiments, read the draft and made the changes. Both the authors read and finalized the manuscript.

Appendix 1-Stimuli for lexical decision task

1. /viʃranti/ – /katte/
2. /ʃanti/ – /pa:tre/
3. /praʃne/- /drakʃi/
4. /meʈʈilu/ – /jeddilu/
5. /halli/ – /la:ʈi/
6. /mora/- /a:mlaʤanaka/
7. /de:ʃa /-/ʤaja/
8. /hannu/- /lapa/
9. /jele/- /a:sti/
10. /triko:na/ – /sa:hasa/
11. /k^ha:nɖa/ – /ʃa:stra/
12. /ra:gi/-/utsava/
13. /dveʃa/-/a:ramb^{h}a/
14. /mi:nu/-/ne:ra/
15. /karu/-/aramane/
16. /o:du/-/kare/
17. /gaɖija:ra/- /da:ra/
18. /pustaka/-/ʤvara/
19. /raste/-/mu:laŋgi/
20. /ʤana/-/mu:laŋgi/
21. /guttige/-/marana/
22. /kamala/-/rakta/
23. /u:ʈa/ –/pari:kʃe/
24. /daɖa/-/itiha:sa/
25. /mannu/-/kale/
26. /kama:nu/-/simha/
27. /toʈʈilu/-/moʈʈe
28. /mora/-/kuruɖa/
29. /ko:ʃa/-/ʤanana/
30. /kappa:tu/-/naʃva/
31. /sahitja/ - /ko:le/
32. /beʈʈa/-/upa:ja/
33. /ili/ -/benki/
34. /di:pa/ -/mi:se/
35. tanti-ku:lu
36. /ga:li/- /baʈʈalu/
37. /hu:vu/-/ noʈa/
38. /ʧatri/ - /sakkare/
39. /angi/ - /hola/
40. /maprada/-/ʤa:nme/
41. lo:ta

42. /guɖɖa/-/kenne/
43. /ba:lehannu/-/apa:ja/
44. /gudisalu/-/rekke/
45. /bisli/-hubbu
46. /handi/ - /tuppa/
47. /tale/-/havala/
48. /ʧa:ku/- /soppu/
49. /guhe/ - /mu:le/
50. /hagga/-/nore/
51. /ka:lu/-/njaja:laya/
52. /a:sakti/-/go:di/
53. /doni/- /hola/
54. /vodave/- /sa:ru/
55. /kurʧi/-/hava:mana/
56. /hasu/-/meʈʈilu/
57. /nadi/- /toʈʈilu/
58. /pa:ta/-/na:lige/
59. /mane/- /je:nu/
60. /jantra/- /kole/
61. /ʧappali/- /kamba/
62. /lekka/ -/surja/
63. /sama:nu/ - /haga/
64. /va:hana/-/davaɖe/
65. /me:ʤu/ -/paʈʈana/
66. /pustaka/-/kattu/
67. /batta/-/bilupu/
68. /katte/ - /bada:mi/
69. /kavite/- /mola/
70. /a:ne/ -/guri/
71. /su:rja/ - /graham/
72. /do:ni/ - /ambiga/
73. /sarka:ra/ - /mantra/
74. /k^{h}aidi/ - /a:rakʃaka/
75. ʃabda-dvani
76. /kere/ - /kappe/
77. /sama:nu/-/angaɖi/
78. /banna/ – /kempu/
79. /ka:ɖu/- /daʈʈa/
80. ʃabda- pata:ki
81. /va:tsalja/-/ta:ji/
82. /vaʤra/- /muttu/
83. /sambha:ʃane/- /ma:tu/
84. /vadave/- /vastra/
85. /kombu/-/ʤinke/
86. /hu:vu/- /mullu/

87. /hudigi/-/bale/
88. /beeʤa/- /bittane/
89. /maɖike/-/kumba:ra/
90. /vigraha/-/mu:rti/
91. /doɖɖappa/ - /tande/
92. /sainika/- /gaɖi/
93. /ga:ɖi/- /ʧakra/
94. /mo:samba/-/kittale/
95. /ra:ʤja/-/ra:ʤa/
96. /nadige/ - /ka:lu/
97. /ba:vi/-/hagga/
98. /parisara/- /hasiru/
99. /bella/- /kabbu/
100. /kalla/- /daro:ɖe/
101. /ɖabbi/ – /muʧala/
102. /ni:ru/ - /mosale/
103. /ʧali/- /ga:li/
104. /pu:ʤe/- /karpu:ra/
105. /ro:gi/- /vaidja/
106. /u:ru/ - /bi:di/
107. /male/-/ʧatri/
108. /ba:te/-/ʃika:ri/
109. /makkalu/ - /banka/
110. /ʤoɖi/- /jeraɖu/
111. /beʈʈa/-/banɖe/
112. /b^{h}akti/ -/tiristipa/
113. /a:se/-/udde:ʃa/
114. /dra:kʃi/ - /da:limbe/
115. /baɳɳa/- /ʧiʈʈe/
116. /nijjattu/ - /niʃʈe/
117. /ʃikʃane/ -/upade:ʃa/
118. /hoddike/- /ʧa:pe/
119. /spu:rti/-/preraka/
120. /Me:le/ –/yetara/
121. /pu:ʤe/-/habba/
122. /ga:ʤu/-/pa:radarʃakate/
123. /pari:kʃe/-/uttara/
124. /kaɖime/-/korate/
125. /va:dja/-/sangi:ta/
126. /anweʃane/-/samʃodane/
127. Sandarbha=paristidi
128. /sama:ʧa:ra.-/kʃe:ma/

Stimulus for semantic judgment task

129. /viʃranti/ – /katte/
130. /ʃanti/ – /pa:tre/
131. /praʃne/- /drakʃi/
132. /meʈʈilu/ – /jeddilu/
133. /halli/ – /la:ʈi/
134. /mora/- /a:mlaʤanaka/
135. /de:ʃa /-/ʤaja/
136. /hannu/- /lapa/
137. /jele/- /a:sti/
138. /triko:na/ – /sa:hasa/
139. /k^{h}a:nɖa/ – /ʃa:stra/
140. /ra:gi/-/utsava/
141. /dveʃa/-/a:ramb^{h}a/
142. /mi:nu/-/ne:ra/
143. /karu/-/aramane/
144. /o:du/-/kare/
145. /gaɖija:ra/- /da:ra/
146. /pustaka/-/ʤvara/
147. /raste/-/mu:laɳgi/
148. /ʤana/-/mu:laɳgi/
149. /guttige/-/marana/
150. /kamala/-/rakta/
151. /u:ʈa/ –/pari:kʃe/
152. /daɖa/-/itiha:sa/
153. /mannu/-/kale/
154. /kama:nu/-/simha/
155. /toʈʈilu/-/moʈʈe
156. /mora/-/kuruɖa/
157. /ko:ʃa/-/ʤanana/
158. /kappa:tu/-/naʃva/
159. /sahitja/ - /ko:le/
160. /beʈʈa/-/upa:ja/
161. /ili/ -/benki/
162. /di:pa/ -/mi:se/
163. tanti-ku:lu
164. /ga:li/- /baʈʈalu/
165. /hu:vu/-/ noʈa/
166. /ʧatri/ - /sakkare/
167. /angi/ - /hola/
168. /maprada/-/ʤa:nme/
169. lo:ta
170. /guɖɖa/-/kenne/

171. /ba:lehannu/-/apa:ja/
172. /gudisalu/-/rekke/
173. /bisli/-hubbu
174. /handi/ - /tuppa/
175. /tale/-/havala/
176. /ʧa:ku/- /soppu/
177. /guhe/ - /mu:le/
178. /hagga/-/nore/
179. /ka:lu/-/njaja:laya/
180. /a:sakti/-/go:di/
181. /doni/- /hola/
182. /vodave/- /sa:ru/
183. /kurʧi/-/hava:mana/
184. /hasu/-/meʈʈilu/
185. /nadi/- /toʈʈilu/
186. /pa:ta/-/na:lige/
187. /mane/- /je:nu/
188. /jantra/- /kole/
189. /ʧappali/- /kamba/
190. /lekka/ -/surja/
191. /sama:nu/ - /haga/
192. /va:hana/-/davaɖe/
193. /me:ʤu/ -/paʈʈana/
194. /pustaka/-/kattu/
195. /batta/-/bilupu/
196. /katte/ - /bada:mi/
197. /kavite/- /mola/
198. /a:ne/ -/guri/
199. /su:rja/ - /graham/
200. /do:ni/ - /ambiga/
201. /sarka:ra/ - /mantra/
202. /k^{h}aidi/ - /a:rakʃaka/
203. ʃabda-dvani
204. /kere/ - /kappe/
205. /sama:nu/-/angaɖi/
206. /banna/ – /kempu/
207. /ka:ɖu/- /daʈʈa/
208. ʃabda- pata:ki
209. /va:tsalja/-/ta:ji/
210. /vaʤra/- /muttu/
211. /sambha:ʃane/- /ma:tu/
212. /vadave/- /vastra/
213. /kombu/-/ʤinke/
214. /hu:vu/- /mullu/
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218. /vigraha/-/mu:rti/
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224. /nadige/ - /ka:lu/
225. /ba:vi/-/hagga/
226. /parisara/- /hasiru/
227. /bella/- /kabbu/
228. /kalla/- /daro:ɖe/
229. /ɖabbi/ – /muʧala/
230. /ni:ru/ - /mosale/
231. /ʧali/- /ga:li/
232. /pu:ʤe/- /karpu:ra/
233. /ro:gi/- /vaidja/
234. /u:ru/ - /bi:di/
235. /male/-/ʧatri/
236. /ba:te/-/ʃika:ri/
237. /makkalu/ - /banka/
238. /ʤoɖi/- /jeraɖu/
239. /beʈʈa/-/banɖe/
240. /b^{h}akti/ -/tiristipa/
241. /a:se/-/udde:ʃa/
242. /dra:kʃi/ - /da:limbe/
243. /baɳɳa/- /ʧiʈʈe/
244. /nijjattu/ - /niʃʈe/
245. /ʃikʃane/ -/upade:ʃa/
246. /hoddike/- /ʧa:pe/
247. /spu:rti/-/preraka/
248. /Me:le/ –/yetara/
249. /pu:ʤe/-/habba/
250. /ga:ʤu/-/pa:radarʃakate/
251. /pari:kʃe/-/uttara/
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