

# Processing of Frequent versus Infrequent Words in Neuro-typicals and Persons with Broca's Aphasia- ERP Study

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## Abstract

The frequencies of occurrence of words have been studied in neuro-typical and persons with brain damage using behavioral and electrophysiological measures. Present study investigated the reaction time and accuracy of responses using frequent and infrequent words in persons with Broca's aphasia and their performances were compared with neuro-typical participants and also measured N400 component in neuro-typicals. Results showed an obvious difference in both the accuracy and reaction time for both frequent and infrequent words in persons with Broca's aphasia and a clear difference between frequent and infrequent words for latency and amplitudes of N400 was observed.

**Keywords** - *aphasia, semantic, neuro-typical, accuracy, ERP, reaction time*

## Damage to Human Brain

The brain is one of the largest and most complex organ in the human body. Most of the growth of brain comes from the cerebral cortex. Cortex has left and right sides which are broadly similar in shape. Some areas show more lateralization towards particular activity. Left hemisphere is dominant for language and right hemisphere plays a minor role. For other functions like spatiotemporal reasoning, abstract thinking right hemisphere plays a dominant role compared to left hemisphere. The human brain is vulnerable to different types of damage; most

common are head injury, stroke, infections, tumours etc. It is also susceptible to different degenerative disorders (Mohr JP, Dennis Choi , James Gotta & Philip Wolf, 2004).

## **Aphasia**

Aphasia is a disorder that results due to the damage to portions of the brain that are responsible for language. For most people, these areas are located in the left side (hemisphere) of the brain. Most of the time aphasia is sudden in nature, as result of head injury or stroke. The expression and understanding of, language as well as reading and writing may get affected in persons with aphasia. Aphasia has been classified into two categories viz. fluent and non-fluent aphasia (Basso, 2003). Fluent aphasia includes Wernicke's aphasia, transcortical sensory aphasia, conduction aphasia and anomic aphasia and non-fluent aphasia consists of global aphasia, Broca's aphasia and transcortical motor aphasia (Basso, 2003).

## **Language and Human Brain**

Two major areas in the human brain which are responsible for language- Broca's area which is partially responsible for production of language and then the other one is Wernicke's area which is accountable for processing of language. Broca's aphasia is a language disorder resulting from damage to Broca's area or its surroundings. Speech of persons with Broca's aphasia is rarely grammatical and slow in production. They generally preserve their vocabulary, but have difficulty in understanding the complex sentences. They are fully conscious of their difficulties and the rest of their abilities are unimpaired (Kent, 1994). Some persons with Broca's aphasia preserve certain grammatical abilities, including the ability to process certain types of syntax. As a result, Broca's area is evidently involved in grammar and language, but some other areas of brain also have overlapping functions. The other components of language (phonology,

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morphology, syntax, semantics and pragmatics) could also be affected due to aphasia (Kent, 1994).

### **Broca's Aphasia and Semantics**

One of the components of language which is affected in persons with Broca's aphasia is semantics. Semantic system stores the information and applies meaning to their sensory and production skills of auditory (spoken words) and visual (written words) modes of representations (Caplan, 1993). More deficits in semantic categories are observed in persons with aphasia (Schuell & Jenkins, 1961).

### **Lexical Decision Task**

Lexical decision task has been assessed using English words and pronounceable non-words which were preceded by semantically related, unrelated, or non-words in persons with Wernicke's, Broca's, Conduction and Global aphasics were asked to judge semantic judge pairs (Milberg & Blumstein, 1981). Results showed that persons with Broca's and conduction aphasia showed significantly shorter latencies in making real-word identifications when preceded by a semantically related word, whereas persons with Wernicke's aphasia performed similar to normals. It suggests that persons with Broca's and conduction aphasia shows impairment while performing the semantic-judgment, while such deficits were not observed in persons with Wernicke's aphasia.

### **Semantic Facilitation**

Semantic facilitation effects in a visual lexical decision task were administered in Wernicke's and other persons with aphasia with severe comprehension deficits (Milberg & Blumstein, 1981). Persons with Wernicke's, Global, Broca's, and Conduction aphasia were administered a lexical decision task in the auditory modality. Participants were also given a

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simple semantic judgment task using the word pairs from the lexical decision task. Performance of the semantic judgment task correlated with the severity of auditory comprehension deficits, whereas the consistency of the semantic facilitation effect did not. Even participants with severe comprehension deficits showed semantic facilitation. These findings decrease the likelihood of the notion that auditory comprehension deficits are due to semantic organization.

### **Lexical Decision Task vis-à-vis Wernicke's and Broca's Aphasia**

Lexical decision task was compared in persons with Wernicke's and Broca's aphasia. Participants were instructed to judge whether third word of each triplet presented through auditory mode was real or not (Milberg, Blumstein & Dworetzky, 1987). Persons with Broca's aphasia did not show any semantic facilitation in any priming conditions. In contrast, Persons with Wernicke's aphasia performance was similar to normals. They showed selective access to different meanings of the ambiguous words, as demonstrated by the fact that the context provided by the first word affected semantic facilitation on the third word. These results were in support with previous findings, proposing that the semantic representations may be largely spared in persons with Wernicke's aphasia and processing deficits were observed in persons with Broca's aphasia.

### **Auditory Lexical Decision Task**

Auditory lexical decision task was studied in persons with Broca's aphasia and normal control participants using stimulus pairs containing ambiguous (semantically-related) or unambiguous (unrelated) words as primes (Katz, 1988). Faster response (faster reaction time) for target words proceeded by semantically related than unrelated words (i.e., semantic priming). Persons with Broca's aphasia, though having considerably longer latencies, produced a pattern of results similar to normals; namely, faster reaction times for target words.

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## **Lexical Access**

Lexical access of words (varying in the number of meanings and frequency of occurrence) was examined in persons with Wernicke's, Broca's aphasia, and control group of non-brain damaged adults using a lexical decision task (Gerratt & Jones, 1987). Faster reaction time for high number of meanings and with high frequency of occurrence words compared to low number of meanings and with low frequency of occurrence in all participants.

Carreiras, Vergara and Barber (2005) have carried two event-related potential (ERP) experiments to elicit syllabic unit modulate early ERP components. To check the match or mismatch between the syllable boundaries and the colour boundaries visually coloured words and pseudo words were presented in Experiment 1. P200 time window colour-syllable congruency effect was seen and N400 amplitude for lexicality modulated, even though no effects of this variable were obtained at the P200 window. Congruent and incongruent conditions the high-and low-frequency words and pseudo words were presented in experiment 2. For low-frequency words and pseudo words congruency effects at the P200 was observed and it was not seen for high-frequency words. Lexicality and lexical frequency effects were seen at the N400 component.

## **Lexical Decision**

Lexical decision task was evaluated by character strings (half if words were frequent words and other halves were infrequent words) by Polich and Donchin (1988). All the participants were asked to decide whether the character strings presented were true word or not. Reaction time and event related potentials were recorded using the stimulus. These results shows that word frequency initiate early during processing. Frequent words (common words) require

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less processing time compared to infrequent words (uncommon words). Infrequent words were taken longer time to responds and longer P300, amplitude and slower responses.

Studies done on semantic categorization using lexical decision task in persons with Broca's aphasia suggests that semantic deficits were observed more in Persons with Broca's aphasia (Milberg & Blumstein, 1981; Milberg, Blumstein & Dworetzky, 1987). Slower reaction times and more types of errors were observed in persons with Broca's aphasia compared to normals (Katz, 1988). It shows that processing and understanding of language and meaning of words (semantic relation between word pairs) effected in persons with Broca's aphasia. Thus, the main purpose of the study was to explore the semantic categorization/ judgment of words based on frequency of occurrence on persons with Broca's aphasia and normals. This study in turn may give an idea about frequency of words have effect on semantic processing in persons with Broca's aphasia.

## **Method**

### **Participants**

A total of twenty participants were taken up for the study. They were divided into two groups in which the first group one consisted of 10 male monolingual persons with Broca's aphasia and second group consisted of age matched 10 monolingual neuro-typical male participants. All the participants were native Kannada speakers. It is a southern Dravidian language spoken in India predominantly in the state of Karnataka, India.

### **Inclusion Criteria for Participants**

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All participants in group one were diagnosed as Broca’s aphasia by a Speech-Language Pathologist/ Neurologist using Western Aphasia Battery- Kannada (Chengappa & Ravi, 2008). All the participants in both the groups had no pre-morbid psychological, neurological, sensory (visual & auditory) or any known organic deficits. All the participants were right handed.

### Stimulus Preparation

Frequent and infrequent words were taken as stimuli, mostly used words in daily communication are frequent words and which are less frequently used in daily communication are infrequent words. A total of hundred frequent words and infrequent words were taken from various resources and were given for rating by 10 speech language pathologists (native Kannada speakers) on a 3-point rating scale for familiarity check. In this rating scale, ‘0’ indicates infrequent word and ‘2’ indicates the frequent word. 20 frequent and 20 infrequent words were considered in the present study depending on the rating by speech language pathologists. The rating scale used for familiarity is shown in Table 1.

Table 1: Rating scale used for frequent and infrequent words.

Stimulus	0-2 rating scale		
	0	1	2
Frequent vs. infrequent words	Infrequent word	Can’t say	Frequent word

## **Recording of Stimuli**

Audio recording was done using Adobe Audition 3.0 by an adult female speaker (Kannada- L1). Recording was done in a sound treated room; unidirectional microphone was used for recording which was kept at a distance of 10cm from the speaker's mouth. 32 bit resolution and 44.1 kHz sampling rate was used in recording. The intensity of the stimulus was calibrated according to the intensity levels in the neuro-scan Inc. data acquisition system. In order to equalize the intensity for all the stimulus normalization was done.

During the selection of participants ethical guidelines as stated by AIISH, Mysore were followed. The caregivers of the persons with Broca's aphasia were explained about the purpose and the procedure of the study. Prior written consent was taken from the caregivers and participants.

## **Procedure**

Neuro-Scan Inc was used for the measurement of reaction time. It consists of two monitors, one is used for stimulus presentation i.e. Stim2 and the other one for response and data storage i.e. Scan 4.4. ER-3A insert ear phones for auditory stimulus and response pad for participant's response were used. Stim2 consists of various programs for different types of stimuli. Gentask Synamps2 was used for the presentation of frequent and infrequent words.

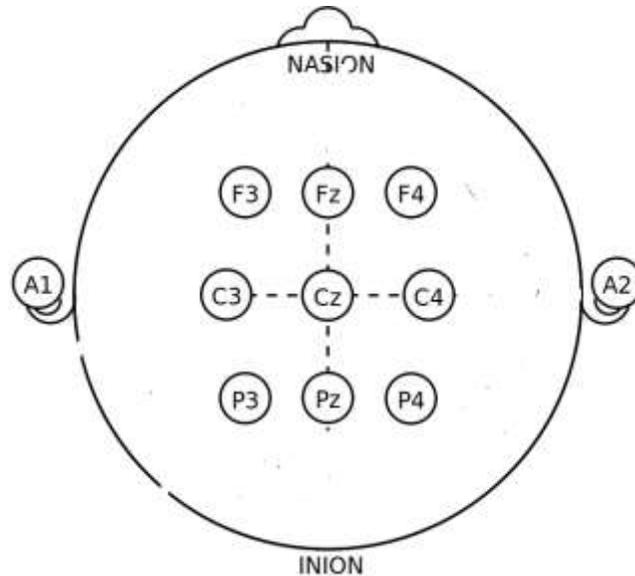
## **Behavioral Test**

All the participants were made to sit in a comfortable position in a quiet room. Prepared frequent and infrequent words were randomly presented to the participants through auditory mode using ER-3A insert ear phones. All participants were instructed to press the button "1" on

response pad if, the presented stimulus was frequent and instructed to press “2” if the presented stimulus was infrequent words. For each stimulus reaction time measured in a milliseconds. In both persons with Broca’s aphasia and neuro typical groups for frequent and infrequent stimuli in Kannada was measured.

### **Electrophysiological Method**

Event related potentials were recorded only for neuro-typical participants. Silver-chloride electrodes placed cap (quick cap) was used to record the potentials .Event related potentials were measured using scalp electrical activity from 9 electrode placements (Fz, F3, F4, Cz, C3, C4, Pz, P3 & P4) and referenced to the left mastoid. Electrode impedances were kept below 5 K $\Omega$  and signal were amplified within a band pass of 0.01 to 100 Hz and continuously digitized at a sampling rate of 1000 Hz. ERPs were then computed for epochs extending from 200 msec before stimulus onset to 1000 msec after stimulus onset. Matlab software 7.9 version was used for correcting the recorded EEG continuous files offline for eye blinks using independent component analysis (ICA). The N400 latency and amplitude values were measured for both frequent and infrequent words. The electrode placement of the present study is given in Figure 1.



*Figure 1:* Electrode placements used for event related potentials

The obtained data were appropriately tabulated and subjected to statistical measures. SPSS software (version 17.0.) package was used for statistical analysis. The tabulated scores were used for obtaining the mean (M) and standard deviation (SD). Parametric tests were utilized to obtain the significant difference measures. For the analyses, MANOVA was used to compare the reaction time between persons with Broca's aphasia and neuro typical groups for frequent and infrequent words. Paired t-test was used to compare the N400 latency and amplitude for frequent and infrequent in neuro-typical group.

## **Results and Discussion**

The results of the present study are explained in behavioral and electrophysiological findings. Table 2 represents the mean and standard deviation for frequent and infrequent words in both neuro-typical and persons with Broca's aphasia. Average reaction times for frequent and infrequent words in neuro-typical group were 936.65 and 1045.95 milliseconds respectively; for

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persons with Broca's aphasia were 3676.94 and 3901.45 milliseconds respectively. The accuracy of response of neuro-typical group was 98% for both frequent and infrequent words whereas 68% for frequent words and 60% for infrequent words in persons with Broca's aphasia.

Table 2. Mean, standard deviations of reaction time and accuracy for frequent and infrequent words in two groups.

Groups	Stimulus	Mean	Std. deviation	Accuracy
Neuro-typicals	Frequent	936.65	25.05	98%
	Infrequent	1045.95	36.32	98%
Persons with Broca's aphasia	Frequent	3676.94	71.508	68%
	Infrequent	3901.45	54.402	60%

Mixed ANOVA (Analysis of variance) repeated measures ANOVA was done using SPSS 17 for comparison of frequent and infrequent words within and between neuro-typical and persons with Broca's aphasia

The main effect for stimuli (frequent & infrequent words) within the groups ( $F= 96.422$ ,  $p<0.01$ ) was statistically significant; between groups ( $F= 36904.9$ ,  $p<0.01$ ) there was a statistically significant difference was observed. An interaction effect ( $F= 11.485$ ,  $p<0.01$ ) was seen between groups and stimuli. Paired t-test was done as there was an interaction effect between groups and stimuli. Paired t-test results showed that there was a statistical significant difference between neuro-typical group ( $t= 9.399$ ,  $p<0.01$ ) and persons with Broca's aphasia ( $t= 7.028$ ,  $p<0.01$ ) between frequent and infrequent words. Figure 1 displays the mean reaction times

for frequent and infrequent words in both neuro-typical and persons with Broca's aphasia. Y-axis represents the reaction time in milliseconds, X-axis represents groups.

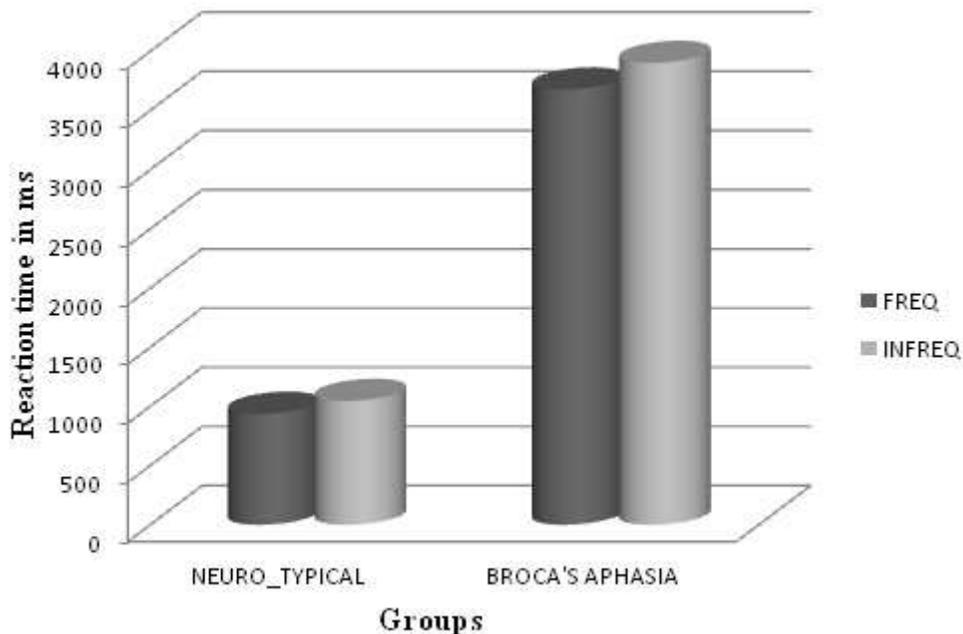


Figure 2. Mean reaction times for frequent and infrequent words in neuro-typical and Broca's aphasia.

Measurement of reaction time was done for both frequent and infrequent words in neuro-typical and persons with Broca's aphasia. Table 2 shows the means and standard deviation values for the frequent and infrequent words in both groups. It shows that quicker reaction time for frequent words than infrequent words in both neuro-typical and persons with Broca's aphasia. Neuro-typical participants responded faster than person with Broca's aphasia for both the stimuli (frequent and infrequent words). Accuracy of responses was also less in persons with Broca's aphasia than neuro-typicals. Thus, it suggests that semantic categorization in judgment task was

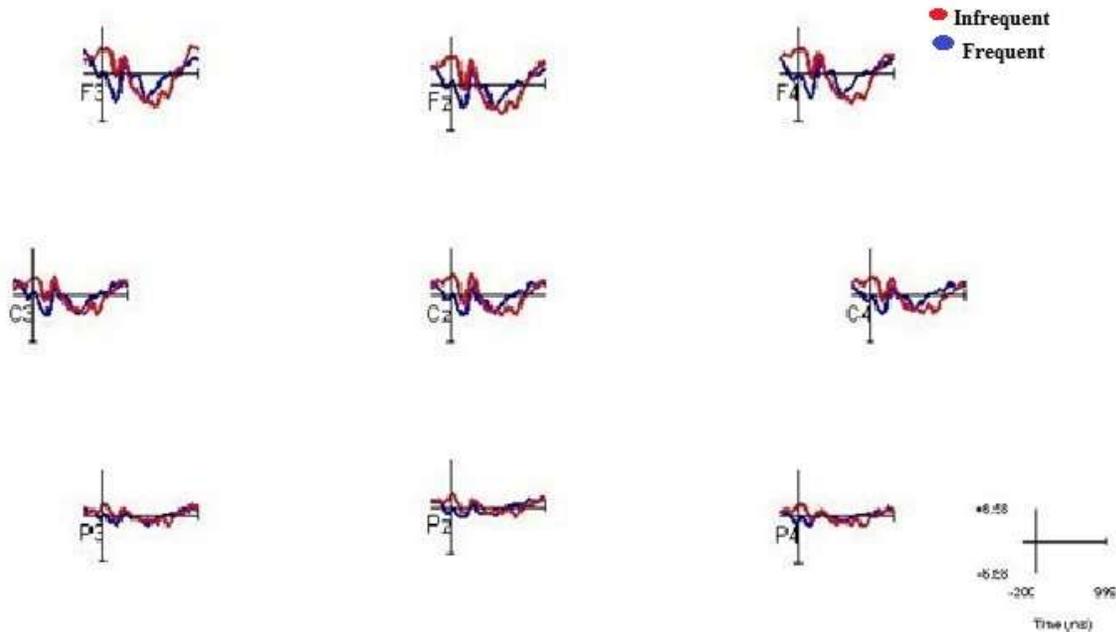
poorer in persons with Broca's aphasia compared to neuro-typicals both in terms of reaction and accuracy.

Table 3. Mean and standard deviation (SD) values of N400 latency and amplitude for infrequent words and infrequent words at 9 electrode placements neuro-typical group.

Electrodes	Frequent words				Infrequent words			
	Mean latency	SD	Mean amplitude	SD	Mean latency	SD	Mean amplitude	SD
F3	492.5	2.63	1.68	.16	520.5	7.6	2.75	.13
Fz	491.5	2.41	1.52	.17	564.5	12.3	2.91	.17
F4	465	11.05	2	.15	509.5	13.6	2.44	.10
C3	470	12.47	1.91	.12	489	4.5	2.35	.13
Cz	470	9.42	1.78	.33	491.5	2.4	2.35	.15
C4	471.5	9.73	1.36	.08	459.5	16.2	2.03	.22
P3	470.5	13.42	.71	.12	506.5	14.1	1.20	.18
Pz	478.5	9.73	1.16	.21	491.4	17.5	1.30	.12
P4	468.5	12.48	1.1	.13	496	19.9	1.24	.11

The mean latency and amplitude of N400 for frequent and infrequent words in neuro-typical groups at 9 electrodes {three frontal (F3, Fz & F4), three central (C3, Cz & C4), & three parietal (P3, Pz & P4)} was showed in table 3. The mean latencies for frequent words at F3, Fz, F4, C3, Cz, C4, P3, Pz and P4 was 492.5ms, 491.5ms, 465ms, 470ms, 470ms, 471.5ms, 470.5ms, 478.5ms and 468.5ms respectively. The more latency was seen at F3 and lowest was seen at P4. Whereas, the mean latencies were 520ms, 564.5ms, 509ms, 489ms, 491.5ms, 459.5ms, 506.5ms, 491.4ms and 496ms at F3, Fz, F4, C3, Cz, C4, P3, Pz and P4 for infrequent

words and more was seen at F3 and less was seen at C4. The more amplitude was seen for frequent words at F4 (2 $\mu$ v) and less was seen at P3 (.71  $\mu$ v); more amplitude was seen at Fz (2.91 $\mu$ v) and less at P3 (1.20 $\mu$ v) for infrequent words. Figure 3 displays the N400 waveforms for frequent and infrequent words at 9 electrodes.



*Fig*

ure 3: N400 waveforms at nine electrodes for nine electrodes for frequent and infrequent words of neuro-typical group participants.

The mean latency values of central electrodes (Mean latency- 470.5ms) were shorter compared to frontal (mean latency – 483ms) and parietal electrodes (mean latency- 472.5ms) for frequent words. The mean latency values of central electrodes (Mean latency- 480ms) were shorter compared to frontal (mean latency – 531.5ms) and parietal electrodes (mean latency- 497.9ms) for infrequent words. Therefore, the central electrodes activation was more compared

to other frontal and parietal electrodes for both frequent and infrequent words. The mean differences were seen between electrodes and stimuli (frequent & infrequent words). Thus, paired t-test was done to see the differences between stimuli and electrodes. Paired t-test was used to check the differences between frequent and infrequent words at each electrode in neuro-typicals. For latency, there was statistical significant difference between frequent and infrequent words at all electrodes except for C4, P3 and P4 electrodes. For comparison of amplitude of N400 the significant difference was observed at all nine electrodes. Therefore, at 6 electrodes differences was seen between frequent and infrequent words for N400 latency but at all electrodes difference was seen for amplitude between frequent and infrequent words.

The results of the study clearly show that for semantic judgment task (SJT) persons with Broca's aphasia shows obvious processing deficits. The poor reaction time seen in persons with aphasia for SJT could indicate that though these persons may not have any obvious processing deficits for highly semantic loaded stimuli, but when a constraint induced stimuli is presented, they show obvious deficits.

The deficits are not only observed for speed task but also for the performance task. Thus, it can be stated that the lesion in left hemisphere and more specifically in and around the Broca's area does affect the speed and accuracy of persons with Broca's aphasia for SJT. The frequency of word does have a role in SJT in persons with aphasia.

The present study results do have the supporting evidence from the previous research studies. More deficits in semantic categories were observed in persons with aphasia (Schuell & Jenkins, 1961). Lexical decision task was done on normal's (control group) and different types

of aphasia (Wernicke's, Broca's, Conduction and Global aphasics) and results show that persons with aphasia were impairment in performance on the semantic-judgment task compared to control group (Milberg & Blumstein, 1981). Similarly faster reaction time for high number of meanings and with high frequency of occurrence words compared to low number of meanings and with low frequency of occurrence in persons with Wernicke's, Broca's aphasia, and control group of non-brain damaged adults (Gerratt & Jones, 1987).

Semantic representations may be largely spared in persons with Wernicke's aphasia (Milberg, Blumstein & Dworetzky, 1987). Processing deficits automatically accessing the lexical representation of words were observed in persons with Broca's aphasia. Slower reaction times and more types of errors were observed in persons with Broca's aphasia compared to normals (Katz, 1988). It shows that processing and understanding of language and meaning of words (semantic relation between word pairs) effected in persons with Broca's aphasia. Carreiras, Vergara and Barber (2005) have done two experiments and they found that lexicality and lexical frequency effects were seen at the N400 component indicative of high frequent words have better N400 components compared to low frequent words.

## **Conclusion**

The present study was aimed to study the compare the semantic categorization of frequent and infrequent words in neuro-typicals and persons with Broca's aphasia. Researchers found that semantic categorization deficits were more in persons with Broca's aphasia than normal's (Milberg & Blumstein, 1981).

Present study results show that faster reaction time for neuro-typical than the persons with Broca's aphasia and the accuracy of response was also better in neuro-typical participants.

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Frequent words elicited faster reaction time than the infrequent words in both neuro-typical and persons with Broca's aphasia. Difference in N400 latency and amplitude between frequent and infrequent words in neuro-typicals, infrequent words elicited longer latencies and more amplitudes than frequent words on total nine (three central, three parietal and three frontal) electrodes. Central electrodes activation was more compared to other electrode placements. In previous study also found that faster reaction times for high number of meanings and with high frequency of occurrence words than low number of meanings and with low frequency of occurrence words. On a whole it shows that semantic categorization deficits were seen more in persons with Broca's aphasia than neuro-typical group. Future studies needed to study the semantic categorization deficits in different types of aphasia and also in larger sample size and event related studies also needed to study in neuro-typicals for different age population and persons with Broca's aphasia.

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## APPENDIX

Sl.No	Frequent Words	Infrequent words
1.	/onḍu/	/sa:həsa/
2.	/i:ga/	/gəti/
3.	/məṭṭu/	/kəle/
4.	/a:ḍare/	/oḍəgu/
5.	/əvəru/	/hubbu/
6.	/e:nu/	/əḍḍu:ri/
7.	/me:le/	/a:ḍhi:na/
8.	/nəmme/	/upəva:sa/
9.	/na:nu/	/kəḍe/
10.	/iḍu/	/kətʃeri/
11.	/illi/	/kərune/
12.	/əḍu/	/kəlpəne/
13.	/ja:va/	/gərb <sup>h</sup> ini/
14.	/ḍIna/	/vəki:la/
15.	/ho:gi/	/tʃəluvaḷi/
16.	/əvənu/	/səmiṭi/
17.	/na:vu/	/səmskruti/
18.	/erəḍu/	/təpəssu/
19.	/mūḍe/	/tə:dʒəssu/
20.	/nənəge/	/ḍəje/

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