An ERP Study of Semantic Processing in Kannada-English Typical Bilingual Individuals – A Pilot Study

Sunil Kumar. Ravi, M.Sc. - SLP
Shyamala. K. Chengappa, Ph.D. – Sp. & Hg.
Vijay Kumar Narne, Ph.D. – Sp. & Hg.

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Abstract

Considerable neurophysiological research has been conducted to explore the neural underpinning of semantic and syntactic processing in bilinguals by using various neuroimaging and electrophysiological techniques. However, the debate of the cortical organization of the two languages in bilinguals is still going on. The present study was carried out with aim of investigating how multiple languages are processed in the human brain. Event related brain potentials, specifically, N1 and N400 potentials were recorded from right handed typical bilinguals during a task involving silent reading. The participants in the experiment were five Kannada – English bilinguals of Karnataka state in southern part of India. The bilinguals, highly proficient in both languages, had exposure in both languages since the age of 5 years. The stimuli were words that would correctly complete a short, meaningful, previously shown sentence, or else were semantically incorrect. The task consisted in deciding whether the sentences were well formed or not, giving the response by pressing a button. The participants read 100 Kannada (50 correct & 50 incorrect) and 100 English (50 correct & 50 incorrect) sentences to compare the processing of the two languages within the group. The findings revealed subtle differences in the latency and amplitude measures of various ERP components such as N1, and N400 potentials. The present paper highlights the several processes that are involved in the differences in processing of these two languages and their implications to the understanding of language processing in clinical populations such as in bilingual aphasia.

Key words: Semantic judgement task, N400, ERPs, Bilinguals, language processing.

Introduction

Bilinguals could be defined as individuals who have “native-like control of two languages” (Bloomfield, 1933). Bilinguals use two different languages simultaneously for social communication. Thus, bilinguals are exposed to extra cognitively demanding tasks, such as language selection and language switching in different social communication settings and situations (Ardilla & Ramos, 2008). This regular use of two languages by bilingual individuals has been shown to have greater impact on language and cognitive functioning of the individual (Bialystok, Craik, Green & Gollan, 2009).

In the process of globalization, the world becomes more interconnected and it is noticeable that bilingual population is rising across the globe including Indian context. Crystal (1997) estimates bilingualism that includes English and another language represents about 235 million people worldwide and that two thirds of children in the world are grown-up in bilingual backgrounds. As per 1991 census of India, approximately 9% of the total population is bilinguals in India (which may be much higher at present as a result of globalization process and change in education systems). Because of the systematic language policy initiatives of the past half century, ‘multilingualism’ is considered as an asset and also as a ‘resource’ and try to make use of this resource for language and social development (Mallikarjun, 2004). Some of the reasons for increase in bilingual population include immigration, or a national situation wherein the official language is different from the community language (e.g., India), or formal education in another language, etc.

Kannada is one of the four Dravidian languages and also one of the four classical languages in India. Around 50 million people of Karnataka state have Kannada language as their native language. According to 1991 census of India, around 16% of the total population of Karnataka state are bilinguals and around 8% of the population are trilinguals. Languages like English, Telugu and Tamil are the major languages seen as second and third language among these bilinguals.

Age of acquisition, manner of acquisition, exposure levels and proficiency levels are considered as important variables in bilingual studies. The importance of these variables is seen in both linguistic and neuroimaging/neurofunctional studies. Previous studies carried out on bilingual population have raised the importance of these variables as there were significant changes in cortical organization of these bilingual individuals.

Focus of This Study

In the present study, we aim to explore semantic processing in both languages of Kannada (L1) – English (L2) bilinguals with high proficiency levels in both L1 and L2 who were exposed to both languages since childhood (early bilinguals). The present study makes use of event related brain potential (ERP) technique specifically N400 potential which is known to vary in amplitude and latency with semantic violations in a particular language.

Linguistic Processing in Bilinguals

Linguistic processing in bilinguals has also been investigated by event-related potentials (ERPs) of the brain. Indeed, ERPs are very useful tools to study the neural basis of language processing, as they provide information on the temporal course of information processing neural flow in different semantic and morphosyntactic tasks. In fact, ERP studies on language (Federmeier, Kluender, & Kutas, 2002; Kutas & Van Petten, 1994; Kutas & Hillyard, 1980) have shown that semantic integration is reflected by the N400 component, a centro-parietal negativity with a latency of around 400 msec very sensitive to word cloze probability.

Numerous studies in different languages have shown that brain's response to a semantic violation is characterized by a greater negativity between 200 – 500 msec post onset compared to that of semantically correct sentences. In monolinguals it is reported that this N400 has a centro-parietal maximum with slight right hemisphere bias. This N400 semantic congruity effect reported to vary with factors like ease of contextual integration, frequency, imageability and word class. Several studies have been carried out on bilinguals in different languages by using ERP methodology. The N400 congruity effect also has been found to have a longer latency in bilinguals processing their less dominant language, the one to which they were exposed later.

Proverbio, Cok, & Zani (2002) measured the electrical activity during syntactic and semantic judgment tasks in Italian monolinguals and Italian – Slovenian high proficient bilinguals. ERP results indicated a strong left side activation reflected by N1 component, of the occipito-temporal regions dedicated to orthographic processing, with a latency of about 150msec for Slovenian words, but bilateral activation of the same areas for Italian words, which was also displayed in topographical mapping. In monolinguals, semantic error produced a long lasting negative response (N2 and N4) that was greater over the right hemisphere, whereas syntactic error activated mostly the left hemisphere than over the right. They also found that the P615 syntactical error responses were of equal amplitude on both hemispheres for Italian words and greater on the right side for Slovenian words. These results suggest that there are interhemispheric and intrahemispheric brain activation asymmetries when monolingual and bilingual speakers comprehend written language. Similar studies were carried out by Fischler, Boaz, McGovern, and Ransdell (1987); Meuter, Donald, and Ardal (1987); Ardal, Donald, Meuter, Muldrew, and Luce (1990); Weber-Fox and Neville (1996); Hahne and Friederici (2001); Hahne (2001); and Moreno and Kutas (2005)

In summary, all the previous studies have used semantic violations relative to correct sentences to study N400 responses and N400 effect within and between mono and bilinguals. The results of the above studies found a significant delay in peak latency of N400 for L2 compared to L1 (Ardal et al., 1990; Weber-Fox & Neville, 1996; Hahne, 2001; Moreno & Kutas, 2005). Among the studies carried out in this area, there were inconsistent findings in terms of latency, amplitude and scalp distribution of N400 response and thereby it is difficult to generalize and apply the results of these studies.

This being the scenario (only few studies) in western context, there were no attempts made to study the language processing more specifically semantic processing in Indian languages and in Indian bilingual population. The research in Indian bilingualism can give more insights into functional processing of two similar languages (eg., Kannada – Telugu bilinguals) and also two distinct languages (Kannada – English bilinguals) which can in turn help in understanding the language properties and their functional organization in detail. Thus the present study is a preliminary attempt aimed at studying the neurofunctional mechanisms involved in semantic processing in Kannada – English bilinguals.

Materials and Method

Participants

Five right handed Kannada (L1) – English (L2) bilingual speakers in the age range of 19 – 26 years with mean age of 22 years were selected for the present study. All the participants were early bilinguals who were exposed to both languages for more than 14 years. All these participants were assessed using International Second Language Proficiency Rating Scale (Wylie & Ingram, 2006) for language proficiency and all the subjects were rated as '*native*' like proficiency in Kannada and '*nearly native'* proficient in English language. The details of language proficiency measures are given in Table 1. All the participants were ruled out for any history of auditory, visual, neurological, psychiatric and any other illness.

Table 1. *Demographic details and ISLPR ratings of all the five subjects.*

Subject	**Age/ Gender**	**Formal education (yrs)**	**Speaking**		**Listening**		**Writing**		**Reading**	
			K*	**E^**	**K***	**E^**	**K***	**E^**	**K***	**E^**
1	26/m	17 yrs	S-5	S-4	L-5	L-4	W-5	W-5	R-5	R-5
2	25/m	17 yrs	S-5	S-4	L-5	L-4	W-5	W-5	R-5	R-5
3	20/m	14 yrs	S-5	S-4	L-5	L-4	W-5	W-5	R-5	R-4
4	20/m	14 yrs	S-5	S-4	L-5	L-4	W-5	W-5	R-5	R-5
5	19/m	14yrs	S-5	S-4	L-5	L-4	W-5	W-4	R-5	R-4
Mean	**MA-22yrs**	**ME-15.2 yrs**	**S-5**	**S-4**	**L-5**	**L-4**	**W-5**	**W-4.8**	**R-5**	**R-4.6**

Note: K: Kannada (L1); E^: English (L2). MA: Mean age; ME: mean of years of education.*

Materials

The stimuli materials are 50 correct sentences and 50 semantically incorrect sentences in Kannada and English making a total of 100 sentences in each language. These sentences are with mean length of utterance (MLU) of 3 – 4 words and these sentences were selected based on the ratings given by two speech language pathologists and two clinical linguists for complexity, abstractness and frequency. Sentence order was randomized within each language set and then presented to the subjects. These sentences were converted into JPEG format with a resolution of 900x600.

Procedure

These sentences which are in picture format are presented to Kannada – English bilinguals and were asked to read sentences for comprehension. The experiment was undertaken after taking a written consent and language proficiency ratings on International Second Language Proficiency Rating scale (ISLPR, Wylie & Ingram, 2006). These stimuli were loaded into Gentask program of STIM2 program, Compumedics Neuroscan Inc and were presented on 17 inch monitor with stimulus duration of 3000msec and with an inter - stimulus interval of 1000msec.

EEG Recording Procedure

Scalp electrical activity was recorded from 19 geodesically spaced Ag-Cl electrodes (Fz, Cz, Pz, FP1/2, F3/4, F7/8, T7/8, C5/6, C3/4, P3/4, & O1/2) embedded in an elastic cap referenced to the left mastoid. Electrode impedances were kept below 5 KΩ and signals 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. The recorded EEG continuous files were corrected offline for eye blinks using independent component analysis (ICA) of Matlab Software 7.10 version. The electrode placement of the present study is given in Figure 1.

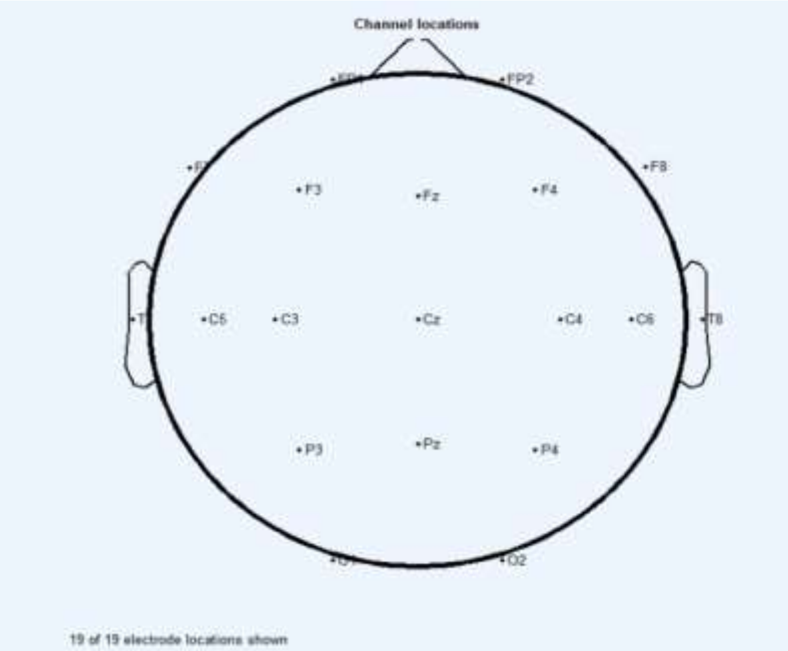

Figure 1. Placement of 19 electrodes according to 10 – 20 international system.

Results

The present study was aimed at studying the processing of semantic content in both L1 and L2 in Kannada – English typical bilinguals. The electrophysiological (EEG) data was analyzed to identify and measure the peak amplitudes and latencies for both N1 and N400 peaks.

For each subject and electrode, distinct ERP averages were computed as a function of sentence type (correct, semantically incorrect) and language (L1 & L2). The recorded EEG continuous files were corrected offline for eye blinks using independent component analysis (ICA) in Matlab software version 7.10 and were analyzed to identify and measure N1 and N400 components.

N1 mean area values were measured at all 19 electrodes between 70 and 120 msec in both Kannada and English. The mean amplitude of N1 component for Kannada incorrect sentences is lesser (M = -1.026 µv) than that of correct sentences (M = -1.856 µv). The analysis revealed an electrode effect indicating greater N1 amplitude over right hemisphere electrodes (F4, F8, O2) (M = -1.63 µv) followed by central (Cz, Fz, Pz) (M = -1.53 µv) and left hemisphere (F7, C5, T7) (M = -1.34 µv) in Kannada or L1. In English, the mean amplitude of N1 component for incorrect sentences is lesser (M = -0.139 µv) than that of correct sentences (M = -1.12 µv). The analysis revealed an electrode effect indicating greater N1 amplitudes in left hemisphere (C3, C5, O1, T7) (M = -0.64 µv) followed by right hemisphere (T8) (M = -0.60 µv) and central electrodes (Fz) (M = -0.27 µv).

N400 mean area values were measured at 11 electrode sites (F7, F3, Fz, T7, C5, Cz, P3, Pz, C4, C6, F4) between 330 and 530 msec. The mean amplitude of N400 component for incorrect sentences is greater (M = -2.566 µv) than that of correct sentences (M= -1.376 µv). Analysis revealed an electrode effect indicating greater N400 amplitudes in left hemisphere (F3, F7, C5, T7) (M = -3.485 µv) followed by central electrodes (Cz, Fz) (M = -2.25 µv) and right hemisphere electrodes (C4, C6, F4) (M = -1.55 µv). These results indicate greater activity in left hemisphere for L1. The grand average ERPs of 19 electrodes in Kannada are plotted in Figure 2.

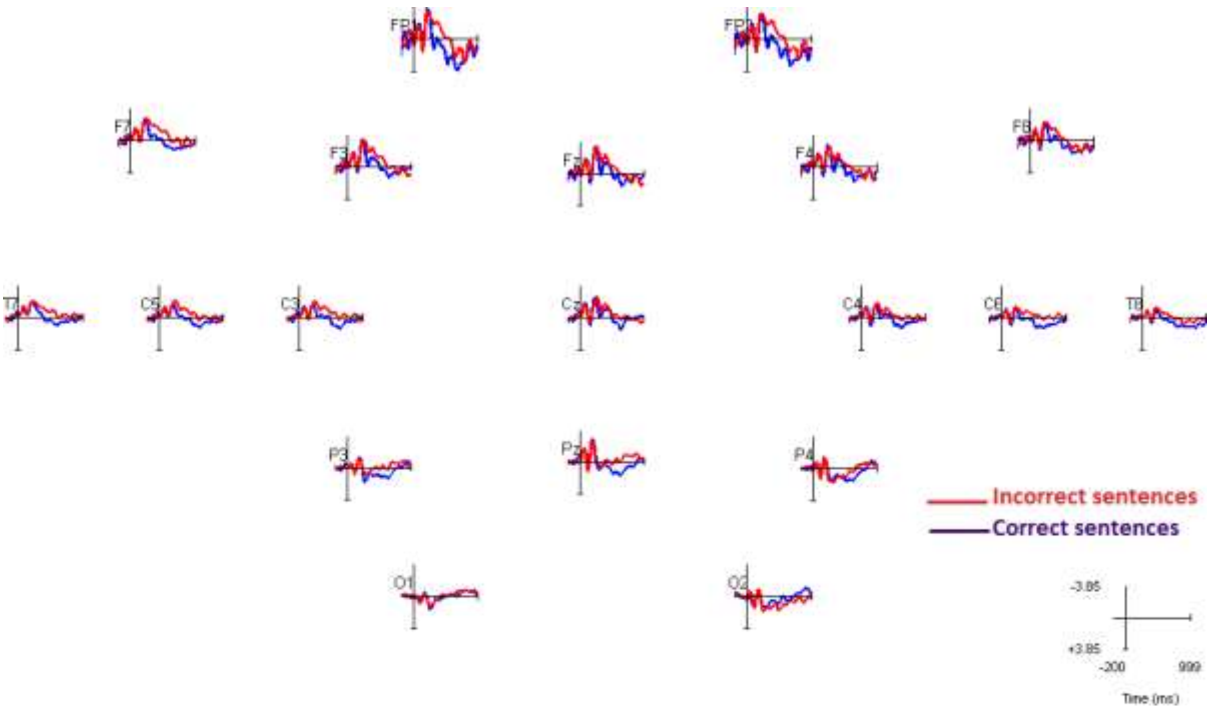

Figure 2. Grand average ERPs for the 19 electrode positions to the semantically incorrect sentences as compared to correct sentences in Kannada.

N400 mean area values were measured at 12 electrode sites (F7, F3, Fz, T7, C5, C3, Cz, Pz, C4, F4, C6, P4) between 330 and 530 msec. The mean amplitude of N400 component for incorrect sentences is greater (M = -0.609 µv) than that of correct sentences (M= -0.138 µv). Analysis revealed an electrode effect indicating greater N400 amplitudes in Left hemisphere (C5, T7, P3) (M = -1.642 µv) followed by right hemisphere (F8, T8, O2) (M = -0.892 µv) and central electrodes (Cz, Fz) (M = -0.75 µv). These results indicate that left hemisphere is more involved in processing semantic information in L2 (English) also. The grand average ERPs of 19 electrodes in English are plotted in Figure 3.

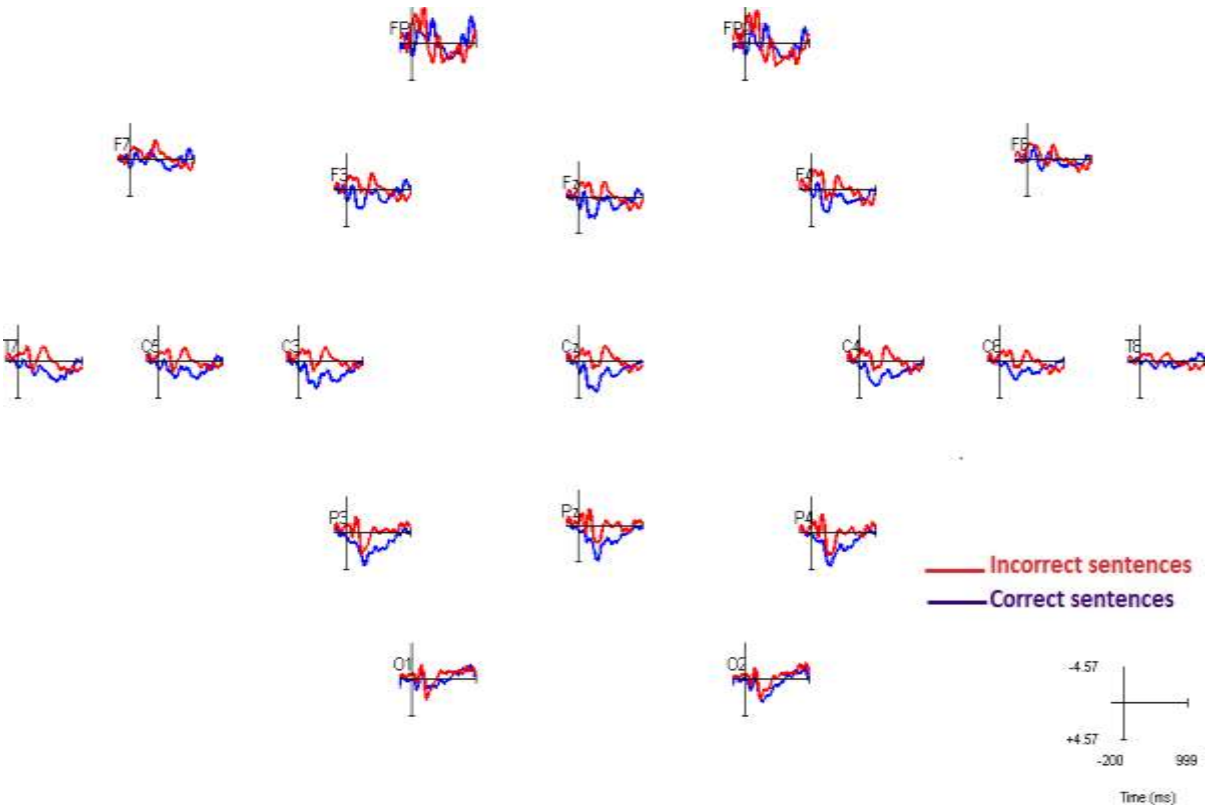

Figure 3. Grand average ERPs for the 19 electrode positions to the semantically incorrect sentences as compared to correct sentences in Kannada.

Discussion

Overall, the subjects performed better in L1 (Kannada) than L2 (English). On whole, ERP data indicate the presence of strong inter- and intrahemispheric differences in the timing and topography of brain responses as a function of language (L1 and L2). These results were similar to that of Proverbio et al (2002) who reported both inter- and intrahemispheric differences in Slovenian – Italian bilingual individuals. Results indicate that in bilinguals, an involvement of right lateral occipital area in the orthographic analysis of Kannada sentences, as reflected by presence of high activation at O2 (-1.60) compared to English (-0.04) for early potential N1. These results are inconsistent with the previous neuroimaging studies done by Polk, et al, 2002 and also the study done by Proverbio et al, 2002 who reported bilateral response in the N1 during the processing of words in Italian (L1) and Left sided response during processing of L2 (Slovenian). This may be due to the differences in distinct orthographies of Kannada (semi-syllabic & semi-alphabetic orthographies; transparent/

surface orthography) and English (alphabetic; deep orthography). Overall, these results indicate that word form system might be able to discriminate between different languages on the basis of orthographical analysis at very early stages of visual processing.

Semantic processing in bilinguals

In the N400 latency range, negative response to incorrect sentences was seen between 350 – 450 msec for Kannada, whereas, the latencies are prolonged for English stimuli extending upto 550msec. This particular delay in latency could be attributed to the proficiency/usage of English language compared to that of Kannada language. All the subjects were able to identify the semantic errors in Kannada much faster than that of errors in English and the same is shown in N400 latencies. Secondly, there was a greater activation seen in Kannada (M = -2.566 µv) than that of English (M= -0.609 µv) as shown by amplitude levels of ERP data in spite of all the subjects being rated as high proficient bilinguals and had exposure since the age of 5 – 8 yrs (early bilinguals). This particular difference in performances in L1 and L2 could be because of the differences in the amounts of exposure or daily usage of L2. In Indian context of Bilingualism, L2 is only used for academic or professional activities (contributing up to 30%) compared to use of L1 (contributing up to 70%) of total language exposure. This may be different to the type of bilingualism seen in Western context where the bilingual individuals get exposed equally in both languages. However, these differences may not be high in Kannada – Telugu or Malayalam – Tamil bilinguals due to similarities in both orthography and spoken language.

On comparison of the performances in Kannada and English, it was seen that N400 for Kannada & English sentences is seen majorly in left hemisphere although subtle intrahemispheric differences present within left hemisphere. The below results indicate differential activation for N400 in L1 and L2 in both left & Right hemispheres. However, when we see all the responses (both greater activation and lower activation electrodes), it was observed that similar areas were activated but with different activation levels.

These results support the following hypotheses in bilingualism research. Language in bilinguals is organized in the same cortical areas, but in *distinct neural circuits (with different activation levels).* Language is organized *partly in common areas* and *partly in specific and* *separate areas* of brain. The above hypothesis is synthesis of two previous hypotheses, i.e., Convergent and Divergent hypotheses. Our study supports the views of some of the early neuroimaging and neuropathological studies by Minkowski, (1927); Aglioti et al., (1996). The support for these hypotheses has come from studies on aphasia in bilinguals, functional recovery in bilingual aphasics, and electrical stimulation of the cortex. Mundy (1983) was the first to suggest that in Bilinguals, the mother tongue and the second language have different lateralization in the two hemispheres by studying a bilingual patient. Later in 1978, Albert & Obler concluded that in bilinguals more often than in monolinguals, linguistic functions are represented in the right hemisphere. Our study supports the views of Albert & Obler (1978) where right hemisphere involvement is seen in bilinguals.

The Right hemisphere is known to be crucially involved in the processing of pragmatic aspects of language use (Chantraine, et al., 1998). During the second language learning, the RH may be more involved in verbal communication, because "beginners" tend to compensate for their limited implicit linguistic competence (lexicon, syntax, phonology) in L2 with pragmatic interferences. Thereby, through this study, we infer that RH is also involved in language processing in bilinguals, but with lesser activation levels compared to that of LH.

Conclusion

The present study was aimed at studying language processing and bilinguals and to get insight into spatio-temporal activation of two hemispheres in high proficient bilinguals. Our results indicated that in high proficient bilinguals, L1 is processed much faster than that of L2 even though they have around 70% of proficiency in L2. This was shown by the prolonged latencies for N400 in English (up to 550 msec) compared to Kannada (350 – 450msec). On the issue of activation levels in different cortical areas, L1 (Kannada) was processed with higher cortical activation compared to that of L2 (English). This difference was very obvious with the mean amplitude levels of N400 in L1 (M= -2.566) and L2 (M= -0.609). The spatio-temporal analysis of ERP components revealed that both hemispheres are involved in language processing in bilinguals but with different levels of involvement. And the same may be due to the RH involvement during language acquisition process in these individuals. The present study results are from only 5 early high proficient Kannada –

English bilinguals and thus these results cannot be generalized to other groups of bilinguals (low proficient or late bilinguals). A series of studies by using fMRI, ERPs, neuropsychological techniques or studies on bilingual aphasia are still needed to come to conclusion about cerebral lateralization debate in bilinguals in both Western and Indian context.

Although, several studies have been carried out in this area by using neuropsychological methods/ techniques, but their results have been rather controversial or contradicting. Many factors such as focusing of attention, languages used during the test, subject's expectancy, proficiency, age of acquisition, manner of acquisition, etc., influence the results, thus making them less uniform. These factors need to be considered while doing studies in future which can provide much needed information about cerebral organization.

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Sunil Kumar. Ravi, M.Sc. - SLP
Junior Research Fellow
Department of Speech Language Pathology
rsunilkumar86@gmail.com

Shyamala. K. Chengappa, Ph.D. – Sp. & Hg.
Professor & Head, Department of Speech Language Pathology.
shyamala.kc@yahoo.com

Vijay Kumar Narne, Ph.D. – Sp. & Hg.
Lecturer in Audiology, Department of Audiology
vijaynarne@gmail.com

All India Institute of Speech and Hearing
Manasagangotri
Mysore 570 006
Karnataka, India