BEHAVIORAL AND ELECTROPHYSIOLOGICAL CORRELATES (N400) OF LEXICAL ACCESS IN BILINGUAL ADULTS WITH STUTTERING

Project funded by A.I.I.S.H Research Fund (ARF)

(2015-2016)

Sanction Number: SH/CDN/ARF-24/2015-16

Total Grants: ₹ 4,33,000

Total Duration of the Project: 12 MONTHS

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ACKNOWLEDGEMENTS

Our sincere gratitude to our Director, Prof. S R Savithri, All India Institute of Speech and Hearing, Mysore, for funding and providing the infrastructure to carry out the project. We extend our gratitude to, Head, Department of Speech-Language Sciences for providing us the departmental facilities to carry out the project work. Our thanks are due to all the Persons with stuttering for their valuable participation.

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EXPERIMENT 1

BEHAVIORAL AND ELECTROPHYSIOLOGICAL CORRELATES (N400) OF LEXICAL ACCESS IN ADULTS WITH AND WITHOUT STUTTERING

Introduction

The growing research in the field of stuttering is in agreement with the notion of stuttering as a multifactorial disorder (Riley & Riley,1979; Smith &Kelly, 1997; Starkweather, Gottwald, & Halfond, 1990; Van Riper, 1982; Wall & Myers; 1995; Zimmermann, 1980; Zimmermann, Smith, & Hanley, 1981). According to this concept, unless a single factor, the complex interaction of multiple systems (involving linguistic, motoric, cognitive & emotional) can contribute to the development of stuttering. As per psycholinguistic theories of stuttering, multiple facets of linguistic processing could be affected in individuals who stutter which include lexical access/lexical retrieval, phonological encoding and syntactic encoding (Bernstein Ratner, 1997; Perkins, Kent, & Curlee, 1991; Postma & Kolk, 1993; Wingate, 1988).

In the current study, we investigated difference in lexical access and phonological access between adults who stutter (AWS) and who do not stutter (AWNS) using behavioral and electrophysiological measures (N400). The process by which the basic sound-meaning connections of language, i.e., lexical entries are activated is termed as lexical access. The process by which the information on basic sound units is drawn is referred to as phonological access. In order to investigate lexical access, primed lexical decision task was used in the study which included semantically related, semantically unrelated and word – non word priming conditions. Where as a lexical decision task was used to investigate the phonological access including words and pronounceable non words.

In the primed lexical decision task priming was incorporated in a lexical decision task. Priming refers to the influence of a previous stimulus during the performance of a cognitive task. When a prime is either phonemically or semantically, related to the target it leads to faster response. This is because the prime triggers semantic spreading activation resulting into encoding of new concepts from the already activated concepts which would yield in a faster decision making (Collins & Loftus, 1975; Meyer, 1973; Meyer & Schvaneveldt, 1971; Neely, 1977). Many researchers have investigated lexical semantic organization or lexical semantic activation or semantic spreading activation using primed lexical decision task (Blumstein, Milberg, & Shrier, 1982; Crowder, 1982). Thus primed lexical decision is considered to be an appropriate measure to study lexical semantic processing (which involves storage, access and retrieval) deficits in adults who stutter even though picture naming task is widely used by previous investigators (Hartfield &Conture,2006;Pellowski & Conture,2005). Over the years researchers have reported slow lexical access and inefficient semantic spreading activation in adults who stutter using behavioral measures (Bosshardt & Fransen ,1996; Howell,2015; Newman & Ratner ,2007; Prins, Main, & Wampler, 1997; Wingate,1988). However there are only limited event related potential (ERP) evidences which also suggest atypical lexical semantic processing in AWS (Huffman, 2009; Maxfield, Pizon- Moore, Frisch, & Constantine, 2012; Weber-Fox & Hampton, 2008).

Researchers have studied the phonological processing deficits in stuttering individuals using nonword repetition, nonword reading, rhyme judgment, phonological priming and phoneme monitoring tasks. These behavioral studies revealed that phonological encoding, phonological working memory and phonological access deficits exists in adults who stutter (Burger & Wijnen, 1999; Byrd, Vallely, Anderson, & Sussman, 2012; Ludlow, Siren, & Zikria, 1997; Sasisekaran, 2013). The studies using electrophysiological measures implicating phonological processing deficits are limited in stuttering research (Weber-Fox, Spencer, Spruill & Smith, 2004).

In the present study, we have used lexical decision task in which the participants were asked to make decision regarding words and nonwords to assess phonological access in adults who stutter. To our knowledge, there is only one previous study reported in literature, which revealed phonological processing deficits in children with stuttering using lexical decision task (Alvarez, Jaramillo , & Cabrera, 2014). According to Alvarez et al. (2014) lexical decision could be considered as a suitable measure of word processing in reading since it involves lexical access in isolation, but not articulation/verbalization as in nonword repetition and nonword reading tasks.

In the current study, the behavioral experiment for both primed lexical decision task and lexical decision task was designed using E-Prime (Psychology software tools) software in order to obtain the accurate measures of reaction time and accuracy. The measure of reaction time gives insight into the time course of lexical access/lexical encoding. Even though the behavioral measures will reflect temporal aspects of linguistic processing difficulties, it is necessary to look beyond behavioral, the covert processes, on investigating stuttering as a clinical phenomenon. Hence, along with the behavioral measures we have recorded N400, an event related potential that accounts for the covert aspects of lexical access and phonological access. The correlation of behavioral measures and electrophysiological measures was done to confirm lexical access deficits in stuttering. The results of the current study would indicate the role of linguistic factor contributing to stuttering suggesting the importance of assessing pre-articulatory central processing in individuals who stutter.

Need of the present study

When stuttering is viewed as a multifactorial disorder, it is important to understand how the linguistic factors play a role in the development of stuttering. In the present study, we attempt to explore the linguistic processing at lexical and phonological level in adults who stutter. Most of the studies have used behavioral measures in probing lexical access and phonological access in stutterers. The behavioral measures are subjected to lot of variability as they are prone to speculation related factors, reducing the objectivity of the behavioral measures. Hence these measures have to be cross-verified by employing electrophysiological measures. Also in the available literature most of the studies are done in English. There is limited evidence in other languages. Hence, further studies are necessary in other languages with more objective measures.

The purpose of the present study is to investigate difference in lexical access and phonological access in Kannada speaking adults who stutter and who do not stutter. In order to evaluate the behavioral and electrophysiological evidences of lexical access and phonological access, primed lexical decision task and lexical decision task were used. Previous studies reported in the literature have used lexical naming, picture naming, verb naming, noun generation phoneme monitoring, nonword repetition, nonword reading tasks to understand the lexical and phonological processing in stuttering population. The issue with those studies is that, they do not separate the oral production aspects of stuttering from linguistic formulations. The reliance on the speech motor production would have influenced the findings in these studies. Since our study involves primed lexical decision task and lexical decision task, task is simply deciding whether the target is word or nonword which does not entail verbalization. Hence, we expect that both primed lexical decision task and lexical decision task would address the issues in the previous studies.

In summary, the present study was designed to investigate the behavioral and electrophysiological correlates of lexical access through primed lexical decision task and behavioral and electrophysiological correlates of phonological access through lexical decision task in adults who stutter and who do not stutter.

Research Questions and Hypotheses

The research questions of our current study include the following:

i) Is there any difference in behavioral and electrophysiological measures of lexical access between AWS and AWNS on primed lexical decision task including semantically related, semantically unrelated and word- non word pairs

ii) Is there any difference in behavioral and electrophysiological measures of phonological access between AWS and AWNS on lexical decision task including words and pronounceable nonwords.

Our hypotheses include the following:

i) AWS will perform poorly in primed lexical decision task compared to AWNS in both behavioral and electrophysiological measures. There will be a delay in processing of semantically related, semantically unrelated, and word- nonword pairs in AWS compared to AWNS

ii) AWS will also perform poorly in lexical decision task compared to AWNS in both behavioral and electrophysiological measures. There will be a delay in processing of words and nonwords in AWS compared to AWNS.

If the first hypothesis is correct, then the current study would add on to existing evidences suggesting lexical access/lexical semantic activation deficits in adults with stuttering (Bosshardt & Fransen ,1996; Huffman,2009; Newman & Ratner ,2007; Prins et al.,1997). If the second hypothesis is correct, then it would confirm the phonological processing difficulties in stuttering as evidenced by previous researchers (Alvarez et. al., 2014; Hennessey, Nang, & Beilby, 2008; Sasisekaran, De Nil, Smyth, & Johnson, 2006).The current study would also support the multifactorial theory of stuttering (Smith & Kelly, 1997) which explains the contribution of linguistic factor as the source of stuttering.

Review of literature

Stuttering is a developmental disorder which is "disruption in the fluency of verbal expression characterized by involuntary, audible or silent repetitions or prolongations of sounds or syllables" (Buchel &Sommer, 2004). As per stuttering foundation, around 1% of overall world population stutters. Over the years many theories and hypothesis have been proposed in order to explain the cause of stuttering. Few researchers consider stuttering as the disorder of speech motor control system keeping the hypothesis that stuttering is the result of improper timing or co- ordination between different subsystems of speech (Caruso, Max, & McClowry, 1999; Kent, 2000; Nudelman, Herbrich, Hess, Hoyt, &Rosenfield, 1992; Peters, Hulstijn, & van Leishout, 2000; Peters &Starkweather, 1990; van Lieshout, Hulstijn, & Peters, 2004). Another important hypothesis regarding the cause of stuttering is that linguistic processing deficits in stuttering individuals may lead to delayed input to the speech motor system and stuttering would result when attempts are made in order to cope up with this delay(Bosshardt, 2006; Howell & Au-Yeung, 2002; Karniol, 1995;Newman & Ratner, 2007; Peters & Starkweather, 1990; Postma & Kolk, 1993).In the present study we attempt to focus on language processing (lexical and phonological access) deficits in adults who stutter. The following sections would cover the possible psycholinguistic explanations for the development of stuttering.

Psycholinguistic explanations of stuttering

The current section would include the possible psycholinguistic theories and explanations for stuttering to occur.

Demands and Capacities Model:

According to Starkweather (1987) stuttering occurs “when intrinsically self-imposed and environmental demands exceed the speaker’s capacities for speech production”. The motoric, linguistic, cognitive and socio-emotional demands could lead to stuttering. The linguistic demand would include any load on semantic, syntactic, phonologic and pragmatic aspects of language processing. Capacities refer to inherent strengths or weakness to speak fluently. The supportive environment including the parents and teachers also play a major role in reducing the development of stuttering behaviors.

Dynamic Multifactorial Model:

This is one of the recent models which consider the heterogenic causes of stuttering. According to this model, a single factor cannot be accounted for development of stuttering (Smith & Kelly, 1997). Stuttering is the results of interaction of multiple factors (motoric, linguistic, cognitive, social and emotional) non linearly, and proposes a dynamic way of change over time.

Packman & Attanasio 3 factor causal model:

This is a newly proposed model incorporating physical and linguistic elements to explain the development of stuttering. According to this model the first causal factor of stuttering is genetic predisposition of “impaired neural processing” (Packman, 2012). The structural and functional deficiencies in the brain will cause instability in the systems of person who stutter. The second factor being increased linguistic demand such as linguistic complexity or variable stress or altered speed and rhythm. The third factor is the physiological arousal or the readiness of the body to react to external stimuli.

Other potential explanation of involvement of linguistic factor in stuttering is Covert Repair hypothesis. As per Covert repair hypothesis (Postma & Kolk, 1993) stuttering is the result of phonological encoding deficits which causes repair of phonological plan covertly when the speaker intent to speak at a faster rate exceeding the existing capacity of phonological encoding system. It is also assumed that any pre-motor planning errors while assigning of specific phonetic features to the syllabic frame can cause stuttering (Perkins et al., 1991). Researchers have proposed that the phonological encoding deficits can disrupt the link between linguistic planning and motor execution which may lead to stuttering (Howell & Au-Yeung, 2002; Wingate, 1988).Considering there is a deficit in phonological decoding in stutterers; the reason for this deficits could be inefficient semantic activation or the problem with the phonological encoding system itself (Postma &Kolk, 1993).

Linguistic variables in stuttering

Linguistic variables associated with specific locations of stuttering have been studied since Brown (1938). Brown (1945) found that occurrence of stuttering is due to four main linguistic factors: word length i.e., number of syllables in the word, word type: grammatical class of the word i.e., content or function words, word position i.e., initial position of sentence or clause and the phoneme from which the word starts i.e., word starting with consonant or vowel. The linguistic variables which effects stuttering behaviors include syntactic, lexical, phonological and morphological structure of words. Hannah and Gardner (1968) and Wells (1979) analyzed the spontaneous speech samples of adults who stuttered on sentences and they reported that syntactic position as well as syntactic complexity had an effect on frequency of stuttering. The results of these studies highlight the influence of syntactic factors on the frequency of stuttering. There are number of studies which report that syntactic complexity increases the dysfluencies in children's speech (Bernstein Ratner & Sih, 1987; Weiss & Zebrowski, 1992). Marshall (2005), to study the effect of morphology on stuttering in English, analyzed the spontaneous speech samples of 16 males with stuttering in the age group of 16 to 47 years. From the analyzed speech samples the words were classified as having simple phonology, complex phonology and words with uninflected and inflected morphology. The results revealed that stuttering rates were not associated with phonological complexity as well as morphology. There are no much studies to provide information with respect to relationship between morphology and stuttering.

Other authors also studied the effect of additional linguistic factors which demonstrate their strong influence on the occurrence of stuttering events. Some of them are utterance length and syntactic complexity (Brundage & Ratner, 1989), phonetic complexity (Geetha, 1978) and word type (Bloodstein & Gantwerk, 1967; Helmreich & Bloodstein, 1973). Stuttering is more likely to occur on longer words or multisyllabic words compared to short ones (Brown, 1945; Williams, Silverman, & Kools, 1969). Also many authors have found that occurrence of dysfluency is generally on consonants than vowels (Brown, 1938, 1945; Hahn, 1942; Hejna, 1955; Quarrington, Conway, & Siegel, 1962; Geetha, 1978).

The effect of word position on stuttering is studied by many authors. It was found that the frequency of stuttering is more at beginning of the sentence or a clause compared to other positions (Bernstein, 1981; Brown, 1938; Conway & Quarrington, 1963; Griggs & Still, 1979; Soderberg, 1967; Wingate, 1979). Jayaram (1984) studied the distribution of stuttering in sentence with respect to sentence length and clause position, and results showed that occurrence of stuttering was always at the beginning of the clause irrespective of sentence length and clause position. The results suggested that breakdown in the speech occurs due to demands on motor planning of speech which occurs particularly at the beginning of sentences. Another study by Koopmans, Slis, and Rietveld (1992), also found that stuttering occurrence was high at the initiation of the clause and dysfluency occurred on function word in first and second word position than on lexical words, whereas lexical words were stuttered at third word position, this was attributed to speech planning process where function words required decision making.

Lexical factors that influence stuttering are word frequency, word class/word type. Previous research evidences reveal that occurrence of stuttering is high on low frequency words compared to high frequency words (Hejna, 1955; Newman & Ratner, 2007; Soderberg, 1966). The word class is another major factor which is studied by many authors and the results are conflicting. Some authors found that stuttering occurs mainly on content words (Jayaram, 1981; Dayalu, Kalinowski, Stuart, Holbert, & Rastatter ,2002) and other authors found that stuttering occurs on function words rather than content words (Griggs & Still, 1979). Howell, Au-Yeung, and Sackin (1999), analyzed the spontaneous speech of people who stutter and people who do not stutter in the age group from 2 to 40years to find the relationship between dysfluency of function and content words. Results revealed that people without stuttering had higher occurrence of dysfluency on function words whereas in people with stuttering the occurrence of dysfluency on content & function words changed over age groups. There was higher percentage of dysfluency on function words in younger age group with stuttering and as their age increased the dysfluencies on function words gradually decreased. This study concludes that due to incomplete planning of content words, adults with stuttering have high percentage of dysfluency on these words. They suggested that the content words may increase the demand on planning and production in speech motor system due to increased syllable complexity. Another explanation for this was based on generalized adaptation hypothesis (Dayalu et al,2002) which reduction of stuttering on function words over the age is attributed to the increased frequency of occurrence leading to adaptation effect. And it is also suggested that reduced use or familiarity of content words would have increased the frequency of stuttering on them.

The literature supports the view that even though stuttering is a speech disorder, there are many linguistic variables which would influence the overt stuttering behaviors. Hence, it is speculated that the knowledge of covert linguistic processes such as lexical or phonological processing in stuttering individuals could explain such behaviors.

Models of lexical access

Lexical access is defined as the process of activation of lexical entries in the mental lexicon which are the basic sound-meaning connections of language. It requires the retrieval of a lexical item/word which is a suitable match for the context, among many other lexical entries that are activated. The contemporary models of lexical access could be categorized as the models based on the stages of lexical access, models based on the direction of flow of lexical/word forms and models based on the activity considered for explaining lexical access.

Models based on the stages of lexical access

Considering the number of stages involved in lexical access two step and three step models were proposed. According to the two step model, word access and phonological access are two stages of lexical activation (Bock & Levelt, 1994; Goldrick & Rapp,2007). This involves operation of both top down and bottom up connection between the words and the phonological units. The connection that operates between words and phonological segments is assumed to operate in both top down as well as bottom up conditions. Words to phoneme units are linked via top down connections where as the phonemes to words are linked via bottom up connections which are excitatory in nature.

As per three step models (Carmazza, 1997; Dell, 1986), lexical access occurs in three steps. The distinct series of stages involves conceptual preparation, word access/lemma retrieval and phonological access. The conceptual preparation stage involves activation of the underlying concepts which are semantically related or associated with the target word. Thus a conceptual error would account for activation of semantically unrelated concepts.

Models based on the direction of flow.

Based on the direction of flow of word forms, the lexical access models are classified as unidirectional and bidirectional models. The unidirectional models of lexical access assumes that the flow of lexical forms occur between semantic to phonemic level i.e. only in one direction. Whereas the bidirectional models proposes a two way connection between semantic and phonemic level.

Models based on activity.

The models of lexical access are explained on the basis of different activities such as picture naming and spontaneous speech. One of the well known models of lexical access for spontaneous speech is the 'lexical editor model'. According to this model, in the first stage of lexical access the suitable concept match is activated. In the later stage, the suitable lemma/word and the phonological forms corresponding to that word is activated. The time taken for lexical access is a key aspect in lexical access irrespective of the underlying activity. The time course for lexical access would include the time taken for conceptual activation, word retrieval and phonologic form activation. Thus any delay in one of these stages would delay the time for lexical access too. The conceptual activation during the picture naming would be based on the visual feature of the object and it involves visual processing. Whereas during spontaneous speech the concepts are activated based on the context. Thus the time taken for lexical access would vary depending on the activity. According to Postma(2000) reaction time for picture naming would range from 600 to 1200 milliseconds.

Lexical semantic processing could also be explained based on interactive activation model (McClelland & Rumelhart, 1981). The model assumes that lexical-semantic processing occurs in three stages i.e. conceptual semantic level, lexical semantic level and phonemic retrieval level. The parallel processing principle is the background for this model. It assumes a bidirectional flow of information via bottom up and top down interactive connections. According to this model, phonemic access is a step involved in lexical access.

Lexical access is studied into both normal and pathological population such as aphasia, stuttering etc. In persons with stuttering semantic activation, phoneme encoding etc (Bernstein Ratner, 1997; Perkins et al.,1991; Postma & Kolk, 1993; Wingate,1988) have been explored. Most of the studies in this direction have employed behavioral measures to explore lexical access in stutterers.

Lexical access in stuttering

Over the years the impact of lexical factors on lexical access and speech production has been studied in individuals with stuttering. If any of the stages of lexical access (conceptual activation, word retrieval and phonological form activation) is effected in an individual with stuttering, we can expect that the impact of lexical factors would be greater on that particular stage of processing. For example, if there is a deficit at the level of accessing the word/lemma in an individual who stutter, the word frequency effect would be greater. This would be reflected as a significant difference in speed and accuracy while accessing low frequency words and high frequency words between AWS and AWNS. If there is no differential effect of lexical factors between AWS and AWNS, it would suggest absence of lexical access impairments in AWS.

Based on previous studies the lexical processing deficits in individuals with stuttering are always commented by the researchers. According to Scripture and Kittredge(1923) stuttering features reflects some kind of word retrieval or word access disability based on which it can be considered as a psycholinguistic impairment.

There are evidences for the lexical factors affecting the pattern of fluency which include word frequency, neighbourhood density and neighbourhood frequency. It has been noted that the less frequent words in the language are stuttered more compared to the more frequent words (Anderson & Linton, 2004; Arnold, Conture, & Ohde, 2005; Danzger & Halpern,1973; Hubbard & Prins,1994;Palen & Peterson, 1982; Prins et al.,1997; Ronson,1976; Soderberg,1966). Newman and Ratner (2007), studied the role of lexical factors-word frequency, neighborhood density and neighborhood frequency on confrontation naming accuracy, reaction time and stuttering episodes in 25 adults who stutter and 25 adults who do not stutter who were matched for age, gender and education level. The results revealed that adults who stutter had slower reaction time and less naming accuracy compared to adults who do not stutter. There was effect of word frequency on stuttering rate, but the other two lexical factors- neighborhood density and neighborhood frequency did not have any effect on stuttering rate in adults who stutter. Hence the authors concluded that adults who stutter have impairment in lexical retrieval which is at the level of phonological representation.

Limited research has been conducted on children and adults with stuttering to investigate whether these individuals have difficulty in lexical retrieval. This is investigated by either lexical decision task or lexical naming task using different priming paradigm. Studies have revealed a longer lexical decision time in AWS (Hand &Haynes, 1983; Rastatter & Dell,1987). Arunkumar and Yeshoda (2006) compared individuals with stuttering and individuals with no stuttering using lexical decision task and results revealed that they had longer reaction time compared to individuals with no stuttering and also reaction time increased as the word length increased in individuals with stuttering. Another study by Santosh and Arunkumar (2006), investigated the lexical access using semantic priming task in persons with stuttering and persons with no stuttering. Results revealed stutterers had longer speech reaction time across all 3 priming condition compared to persons without stuttering. Both groups had shorter speech reaction time for related priming condition compared to other two primes.

The studies have reported that children with stuttering have increased response time on picture naming tasks and greater interference on presentation of conceptually related prime prior to the target picture compared to controls suggesting impaired lexical activation in children with stuttering (Hartfield &Conture,2006; Pellowski & Conture,2005). Pellowski and Conture(2005)have reported there was no difference in performance between fluent and nonfluent groups on phonological priming paradigm. This suggested that the fluent and nonfluent speakers differ in terms of their semantic organization or lexical activation and not in terms of the phonological organization implicating a deficit at concept and word activation stages and not in sublexical or form based levels. Hartfield and Conture (2006) investigated the effect of perceptual and conceptual properties of words in children who stutter and children who do not stutter in the age range of 3-5 years. This was investigated in picture naming task which was associated with 4 auditory lexical priming conditions-neutral, physical, functional, and categorically related speech reaction time and accuracy scores were measured. Results indicated that children who stutter took more speech reaction time in all priming conditions compared to children who do not stutter and children who stutter had faster naming latencies in functional related prime condition compared to physical related prime condition. Results indicated that lexical retrieval was influenced by conceptual/functional than perceptual aspects in children who stutter. Studies also report that stuttering individuals takes longer time to respond than fluent control subjects on sentence processing and word processing tasks which implicates impaired lexical activation in PWS (Kempen &Huijbers,1983 ;Prins et al.,1997).In general studies have also shown that the reaction time increases on less frequent words compares to more frequent words on picture naming tasks. It is postulated that PWS tend to have access and retrieval deficits on picture naming task on presentation of less frequent target stimuli (Jescheniak & Levelt, 1994; Oldfield & Wingfield, 1965).But access deficits or retrieval deficits are not considered as the main cause for stuttering.

Lexical access of grammatical classes such as nouns and verbs in stuttering individuals also has been studied by previous researchers, since verb processing involves complex lexicalization compared to nouns (Lindsley,1976). As per literature, both verb processing and use was observed to be atypical in children and adults who stutter (Bernstein,1981; Prins et al,1997; Wagovich & Bernstein Ratner,2007). Even though verb processing is difficult than processing if nouns in general, this difference is suspected o be greater in persons with stuttering (Szekely et al., 2005). The longer latency periods on verb naming than noun naming has been reported in PWS compared to controls (Prins et al., 1997).Howell(2015) postulated that this difference could be due to increased semantic difficulty of verbs. The complex lexicalization of verbs imparts a delay in verb processing(Lindsley, 1976). This deficient lexicalization could lead to a stuttering event(Postma &Kolk,1993; Prins et al,1997 ;Wingate ,1988).

A recent study by Bretherton-Furness and Ward (2012) investigated lexical access, story re-telling and sequencing skills in eight adults who clutter in comparison with adults who do not clutter. Lexical access was assessed through three subtests: naming on description, category naming and semantic and phonological word generation and response time was measured. Sequencing skill and story recall was used to analyze the maze behaviors. The results revealed that adults who clutter were slower in lexical access tasks and also there were more maze behaviors in sequencing skills compared to control group, but there was no difference between the groups in story retelling task.

Hennessey et al. (2008), studied linguistic encoding deficits in adults who stutter and adults who do not stutter. Auditory priming was used in picture naming which included four priming conditions-semantically related, phonologically related, unrelated and no prime. Also word versus non word comparison in simple reaction time and choice reaction time was done. Results of picture naming revealed that, there was no significant difference in mean reaction time between the two groups. Both groups had slower naming reaction time, when auditory prime was semantically related to target picture compared to other three priming conditions. This was supported by semantic inhibition effect which has caused slower reaction when prime was semantically related. Results for simple verbal reaction time also revealed no significant difference between the two groups for word verses non words, where in choice reaction time persons with stuttering were slower compared to persons with no stuttering. The findings are consistent with PWS not being deficient in the time course of lexical activation and selection, phonological encoding, and phonetic encoding. Potential deficits underlying slow choice RTs outside of linguistic encoding are discussed.

Packman, Onslow, Coombes, and Goodwin (2001), tested the prediction that for stuttering to occur, lexical retrieval is one of the factors. They investigated this in reading task which does not require any lexical retrieval; the task was reading aloud a Standard English passage and also a passage with non words, in three adults who stutter. The results showed that stuttering was present even in non-words in all 3 subjects and hence the authors conclude that stuttering can occur even in the absence of lexical retrieval. This study contradicts the above studies suggesting that lexical retrieval is not the major factor.

Phonological access in stuttering

The process of obtaining information on basic sound units is referred to as phonological access. According to the models of lexical access; phonological access is considered to be distinct stage involved in lexical processing. The first stage is accessing the meaning of a word (lexical semantics) and the second stage is accessing the sound code (lexical phonology) (Caramazza, 1997; Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Griffin & Bock, 1998; Levelt, Roelofs, & Meyer,1999; Rapp & Goldrick, 2006). The second stage is referred to as lexical phonological access.

Among the explanations regarding the linguistic deficits, the one based on the Levelt's model is most relevant. As per Levelt's model after lexical and sublexical level of encoding the phonological encoding occurs where in the sound segments are arranged within the syllabic frame. According to Au-Yeung and Howell (2002) the last stage is affected in individuals with stuttering. On similar lines, Wingate (1988) suggested that persons with stuttering exhibit problems in retrieving words which occurs at the phonological encoding stage; hence they have difficulty maintaining fluent speech.

The studies in which nonword repetition tasks in order to check the phonological knowledge and phonological working memory capacity have revealed that children with stuttering perform poorer than normal fluent children (Baddeley, Gathercole ,&Papagno, 1998). Bosshardt(1993,1994) have reported that AWS have slow reaction time on rhyme judgment task indicating impaired phoneme monitoring and phonological encoding ability. Another study in adults with stuttering revealed that PWS are slow in monitoring the target phoneme on a picture naming task (Sasisekaran et al.,2006) implicating the slow phonological encoding in PWS.

However Newman and Bernstein Ratner (2007) have observed that there is an effect of neighbourhood density and neighbourhood frequency on picture naming tasks in PWS which indicates that sublexical level of encoding also might be affected in them. Few of the research studies in order to test the phonological processing using the phonologically related primes have noted that there is no difference between the phonological encoding between the PWS and PWNS, instead PWS were slower to respond compared to control group (Burger & Wijnen,1999; Hennessey et al.,2008; Melnick, Conture, & Ohde ,2003; Meyer,1991).

Hennesey et al. (2008) studied the linguistic encoding deficits in PWS using auditory priming during picture naming tasks and reaction time for words and nonwords. They reported that even though PWS were slower than controls in both the tasks, this difference is not significant which suggests that the time course of lexical and phonological encoding is not deficient in individuals who stutter.

A study by Burger and Wijnen (1998) revealed that the performance of AWS on lexical retrieval task was increased with more phonological priming information i.e. they performed better with priming initial consonant and following vowel compared to initial consonant only priming. Whereas AWNS required only consonant priming while performing the task.

Byrd et al. (2012) explored the phonological working memory deficits in adults who stutter using non word repetition task and phoneme elision task. The results revealed that AWS were less accurate in both the tasks indicating phonological working memory deficits in them.

Event related potentials in stuttering

Previous studies have reported language processing being atypical in persons with stuttering based on the difference in underlying neural activities and structure from electrophysiological studies. Significant amount of studies have been reported in the recent years on ERP's in persons who stutter (Cuadrado & Weber-Fox,2003; Weber-Fox & Hampton, 2008; Weber- Fox, Hampton Wray, & Arnold,2013 ;Weber-Fox et al.,2004). ERPs reflect the electrophysiological responses during particular events. It involves the recording of electrical responses elicited due to firing of neurons while processing any information.

In an electrophysiological study, Blomgren, McCormick, and Gneiting (2002) revealed longer latencies of auditory P300 on linguistic stimuli compared to non linguistic stimuli in adults who stutter compared to adults who do not stutter. This is one of the earlier electrophysiological studies in stuttering literature suggesting a delay in linguistic processing in stuttering population. Further, researchers have investigated linguistic processing in stutterers using N400 and P600. N400 which reflects the semantic processing and P600 which reflects the syntactic processing have been found atypical in persons with stuttering.

Weber-Fox (2001) investigated the role of neurolinguistic factors in stuttering using Event-related potentials in nine adults who stutter and control group in the age range of 17 to 34 years. Participants were asked to read sentences silently which were presented on the computer screen and had to respond by pressing the button to judge whether sentence made any sense or not. ERP's elicited for adults who stutter for closed-class, open-class and semantic anomalies were characterized by reduced negative amplitude compared to the control group. Results showed that there were alterations in linguistic processing for adults who stutter were related to neural functions that are common to word classes and perhaps involve shared, underlying processes for lexical access. Cuadrado and Weber-Fox (2003) studied the syntactic processing using the behavioral and ERPs while the IWS and NS made judgments about the subject-verb agreement violations in simple and more syntactically complex sentences. The behavioral responses were obtained in both off-line and online tasks. The judgment accuracy for IWS was lower than the NS more so for syntactically more complex sentences. Further, the amplitudes of the P600 responses for IWS were reduced when compared to NS. Weber-Fox et al. (2004) investigated the phonological processing in AWS. They recorded behavioral and ERPs from AWS and NS while the participants did a phonological rhyme judgment task. Although RTs, accuracy of responses and ERPs were similar between AWS and NS, topographic pattern for ERPs were different between two groups of individuals. Weber-Fox & Hampton (2008) studied neural processing of semantic and syntactic constraints as indexed by N400 and P600 responses in AWS and AWNS. They reported significantly differences in AWS when compared to AWNS. In Weber-Fox, Spruill, Spencer, and Smith (2008) study, ERPs were recorded while CWS and CWNS did a visual rhyming task. Results suggested N400 responses with respect to phonological rehearsal and target word anticipation was atypical in CWS. Further, there was also atypical processing with hemispheric contribution towards the linguistic integration stage of processing. Weber-Fox et al. (2013) studied CWS and CWNS while the participants listened to sentences which had either semantically or syntactic (phrase structure) violations. There were differences in both the N400 and P600 amplitudes for both semantic and syntactic violations. Usler and Weber-Fox (2015) studied neural processing of syntactic and semantic structures in, persistent, and recovered 6-7 year old CWS. Their responses were also compared to age and gender matched normal children. ERPs were recorded while these children listened to sentences which had semantic and syntactic violations in English and Jabberwocky sentences. Results suggested neural processing of syntactic structures may be less well developed in 6-7 year old children with persistent development stuttering.

Huffman (2009) studied the lexical semantic activation in PWS and PWNS using a picture naming task. They looked for the effect of semantic and phonological priming on picture naming using behavioral and ERP (N400) measure. The results revealed that N400 priming for semantically related stimuli was not operational in PWS compared to PWNS. Whereas N400 effects of phonological priming task did not differentiate the two groups. The results implied impaired semantic network activation in persons who stutter.

Maxfield et al. (2012) have studied how the performance of adults with stuttering varies with semantic and phonological priming on picture word naming task compared to typically fluent adults using Event Related Potentials(N400). The results revealed that the priming effect was greater in typical fluent speakers and AWS exhibited reduced semantic priming effects and increased phonological priming which reflected atypical semantic and phonologic processing in AWS. In another ERP study by Maxfield, Morris, Frisch, Morphew, and Constantine(2015) cognitive/language processing during naming task was compared across AWS and typically fluent adults. The target pictures were followed by prime words and both prime and target was either mismatched /identical. The effect of priming in naming and the performance was correlated with the vocabulary knowledge. They found that reaction time and accuracy improved with priming in both groups with longer reaction time in AWS. The longer reaction time in AWS was in positive correlation with the receptive vocabulary in TFA. Electrophysiological results revealed that posterior-P1 amplitude negatively correlated with expressive vocabulary in TFA versus receptive vocabulary in AWS. Frontal/temporal-P1 amplitude correlated positively with expressive vocabulary in AWS. Results suggest that poorer expressive vocabulary in AWS indicates greater suppression of conceptual information which is irrelevant. Topographically restricted N400 indicates weaker connections for lemma in AWS. In conclusion the study indicates difference in underlying cognitive/language processing during picture naming in AWS than TFA. Maxfiled, Huffman, Frisch, and Hinckley(2010) have also looked for semantic activation spreading on picture naming in AWS using ERP measures on picture word priming task. Before the participant names the picture an unattended probe word was presented auditorily which was either semantically related or semantically/phonologically unrelated to picture names for which ERP's were recorded.ERP results revealed that posterior N400 amplitude was enhanced for both semantically related and unrelated probes in TFA than in AWS.N400 results suggests that while picture naming there is a strategic inhibitory effect on semantic activation spreading in AWS. The authors report that the difference in N400 amplitude as suggestive of difference in attention allocation in AWS compared to TFA. In general, ERP studies evidence the atypical neural processing during language related tasks in persons with stuttering.

In summary, the review of literature revealed linguistic processing deficits, further research to explore and understand the depth of language processing and the neural resources of lexical access and phonological access in persons who stutter are warranted.

METHOD

In the this experiment, behavioral and electrophysiological correlates (N400) of lexical access were compared between adults who do and do not stutter. Primed lexical decision task and lexical decision task were used for both behavioral and event related potentials.

Participants

Two groups of participants were recruited for experiment 1. Group I consisted of 15 male participants who stutter in the age range of 18 – 40 years(mean age 21.9 years, SD 4.6 years) (See Table 1).Group II comprised of 15 age and gender matched participants without stuttering in the same age range (Mean age 22.1 years, SD 4.5 years) for comparison (See Table 2). Participants in both the groups were native speakers of Kannada. For group I participants, stuttering severity was determined with the Stuttering Severity Instrument-Fourth Edition (SSI-4; Riley, 2009). Among the 15 participants in Group I, 10 participants were with moderate stuttering, 4 participants were with mild stuttering and 1 participant was with very mild stuttering. All the participants met the following inclusion criteria: (a) no speech, language, and hearing problems apart from stuttering, (b) no known neurological or psychological problems or learning disabilities, and (c) not taking any medications that may have possible effects on sensory or motor systems. All the participants in both Group I and Group II were right handed based on the self report. Participation of the participants in the study was voluntary and participants were enrolled only after obtaining their written consent.

Table 1. Individual participant characteristics for the stuttering group.

ID[1]	Age (years)	SSI[2]score	Severity of stuttering	Handedness[3]	History of speech therapy[3]
S1	24	24	Moderate	Right	Yes
S2	19	25	Moderate	Right	Yes
S3	23	18	Mild	Right	Yes
S4	18	26	Moderate	Right	Yes
S5	21	21	Mild	Right	Yes
S6	18	28	Moderate	Right	Yes
S7	35	12	Very Mild	Right	Yes
S8	26	27	Moderate	Right	Yes
S9	22	25	Moderate	Right	Yes
S10	20	28	Moderate	Right	Yes
S11	18	26	Moderate	Right	Yes
S12	25	21	Mild	Right	Yes
S13	24	27	Moderate	Right	Yes
S14	18	19	Mild	Right	Yes
S15	18	28	Moderate	Right	Yes

[1]Participant identification number.[2]Severity of stuttering is based on the Stuttering Severity Instrument for Children and Adults – Fourth Edition (SSI-4, Riley, 2009). [3]Handedness and history of therapy are based on self-report

Table 2. Individual participant characteristics for the monolingual control group

ID[1]	Age (years)	Handedness[2]
N1	24	Right
N2	19	Right
N3	23	Right
N4	19	Right
N5	20	Right
N6	18	Right
N7	36	Right
N8	24	Right
N9	21	Right
N10	20	Right
N11	19	Right
N12	25	Right
N13	25	Right
N14	19	Right
N15	20	Right

[1]Participant identification number.[2]Handedness based on self-report

Stimuli

The experiment had two tasks such as primed lexical decision task and lexical decision task in Kannada language. For primed lexical decision task the initially 150 semantically related, 150 semantically unrelated, prime–target word pairs were prepared where both prime and the target were in Kannada.

As part of stimulus preparation a total of 400 commonly used Kannada words were listed. Later 250 pronounceable nonwords in Kannada were prepared by transposition of syllables within the original word (Prema, 2009). The nonwords are pronounceable words which are not accepted by the native speakers because it does not convey any meaning. The initially prepared word list included the words of noun class and their syllable length ranged from 2-4 syllables. Further, from the initial word list, all the words in Kannada prepared for both primed lexical decision task and lexical decision task were given for familiarity check. 5 SLPs who are native speakers of Kannada rated the familiarity of words on a 3 point scale as very familiar, familiar and unfamiliar. The words which were rated as very familiar and familiar were only chosen to prepare the final set of stimuli and it contained 350 true words. Another word list consisting of 250 nonwords were also given to 2 experienced SLPs. They were asked to rate them as easily pronounceable and not easily pronounceable considering the length and complexity as well. From the 250 nonword list, the complex, lengthier and difficult to pronounce nonwords were removed and the rest of them only were used to prepare the final nonword list for lexical decision task in Kannada and to prepare the nonword pairs for primed lexical decision task.

The 210 nonwords which were accepted after the rating was used to prepare the nonword pairs for primed lexical decision task. Further, the final stimuli were prepared for primed lexical decision task and lexical decision task (see Figure 1).

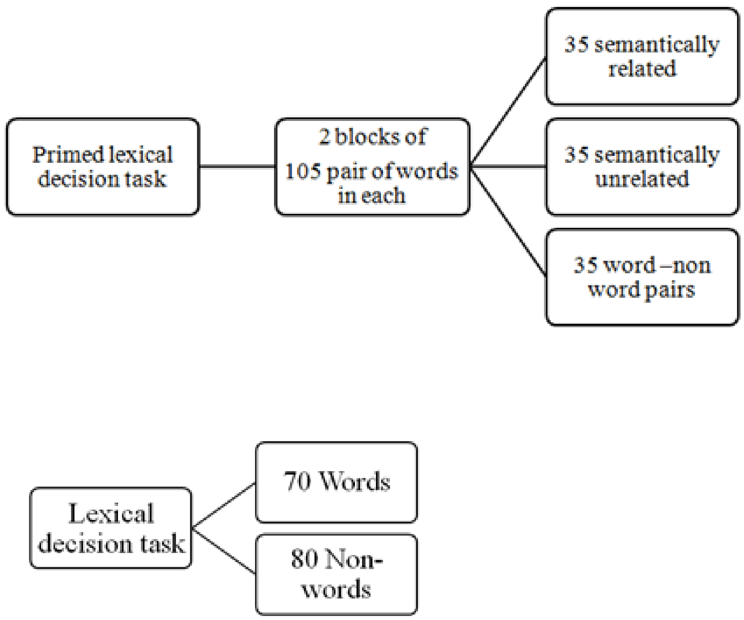

Figure 1: Diagram indicating the final word list after the rating by SLP's

Stimuli selection

For *primed lexical decision* task, two blocks consisting of 105 word pairs in Kannada were used. Any one block of stimuli was presented to the individuals. Stimuli included pair of words, the first word being the prime and second word being the target. Out of 105 word pairs, in each condition 35 word pairs had prime and target which are semantically related(e.g. /thale/-/ku:dalu/, 35 semantically unrelated (e.g./kurchi-tiketu/ and 35 non-words(e.g. /a:ne-labatha).In the semantically related prime-target condition, the prime was semantically or associatively related with the target word where as in the semantically unrelated condition the prime and target were not semantically or associatively related to each other (Chiarello ,Burgess, Richards, & Pollock, 1990; Hines ,Czerwinski, Sawyer, & Dwyer, 1986 ; Lupker ,1984).

The second task was *lexical decision task*. Stimuli for this task comprised of 150 stimuli (70 words and 80 nonwords) in Kannada.

Procedure for behavioral task:

Primed lexical decision task

For the primed lexical decision task, one of the block containing a total of 105 word pairs with 35 semantically related, 35 semantically unrelated, and 35 nonwords was used. The presentation of word pairs was programmed in E-Prime.2.0 software (Psychology Software Tools. Inc). E-Prime.2.0 software is used extensively for priming studies to get reaction time and accuracy measurements (Andrade, Juste, &Tavares, 2012; Heyman, Van Rensbergen, Storms, & Hutchison, 2015; Van de Weijer, Paradis, Willners, & Lindgren, 2012; Silkes & Rogers,2010). The experimental paradigm which was used in the current study was similar to the paradigm used by Fullenkamp (2013) and Murphy(2012).

In the current study the overall experiment consisted of a training procedure and a testing procedure. The training procedure consisted of 10 prime-target trials also comprising of semantically related, unrelated and nonwords which were presented initially to familiarize the participants with the task. Prime and the target words appeared in white font color and were aligned at the centre of screen.Words were displayed in "Times New Roman" font, with a font size of 72 on a black background. The prime was displayed for duration of 1000 milliseconds.

The prime word was followed by a fixation period of 500 milliseconds, after which the target word was displayed for duration of 1000 milliseconds. The next prime word appeared after 2500 milliseconds. The task for the participants was to decide if the presented target is a word or non word (see Figure 2).

Instructions:

"I will present few pair of words. Among them second word will appear after a "+" sign following the first word. Pay attention to the second word which will appear after "+" sign. Press "1" if it is a true word and "2" if it is a nonsense word as soon as possible."

Lexical decision task:

For *the Lexical decision task* only target words were presented for 1000 milliseconds with an interstimulus interval of 2000 milliseconds. Stimuli for this task comprised of 150 stimuli (70 words and 80 nonwords) in Kannada. The task for the participants was to decide if the presented target is a word or nonword (see Figure 2).

Instructions: "I will present few true words and nonsense words. Press "1" for true words and "2" for nonsense words as soon as possible."

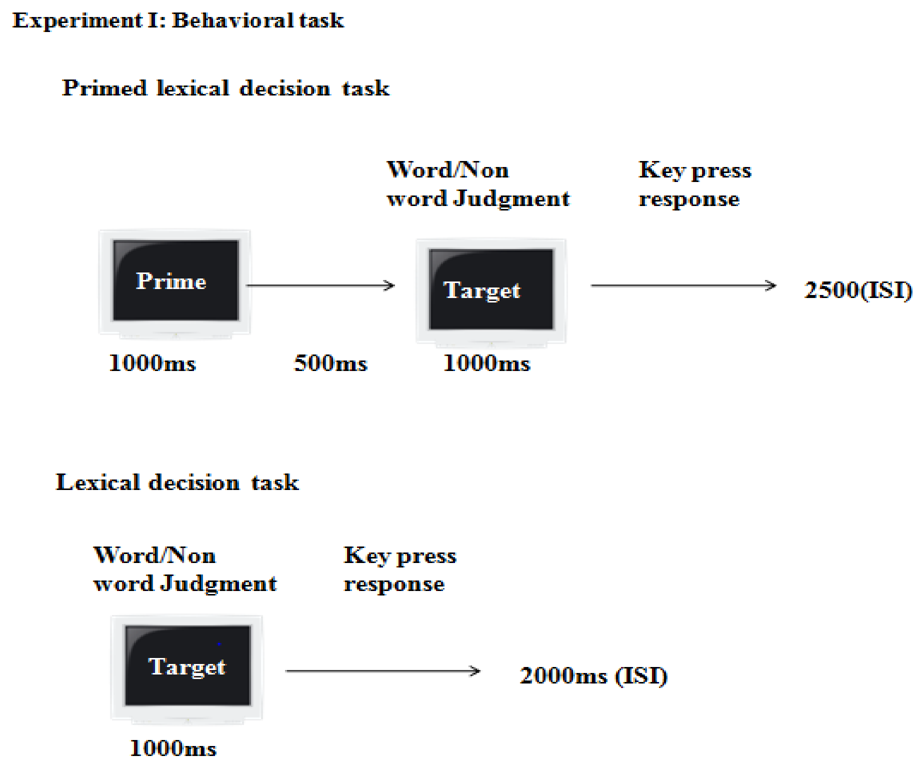

Figure2: Schematic diagram of presentation of stimuli for primed lexical decision task and lexical decision task for behavioral task

Behavioral responses

For both primed lexical decision task and lexical decision task, the mean reaction time and accuracy of responses were measured using E-Data aid module of E-Prime software. Reaction time is defined as the interval of time between presentation of stimulus and appearance of voluntary response (Key press in the current study) in the subject (Batra ,Vyas, Gupta , Gupta, & Hada, 2014). The accuracy of responses was measured in percentage for both primed lexical decision task and lexical decision task. For the primed lexical decision task, the mean reaction time and accuracy of target responses for semantically related, unrelated, and word-nonword pair conditions were extracted. Similarly, mean reaction time and accuracy for words and nonwords for lexical decision task were also obtained. The performance of AWS and AWNS on primed lexical decision and lexical decision were compared in order to see if there is any difference in lexical access between the two groups.

ERP recording

ERP recording was done after behavioral task. Minimum of two days of gap was given between the behavioral and ERP data collection for an individual. Continuous EEG recording was done for both primed lexical decision task and lexical decision task. The same set of stimuli which was used for behavioral task was used while recording ERP's for lexical decision task in Kannada. The second block of stimuli was used for primed lexical decision task including semantically related, unrelated and non-word pairs wherein the word pairs were repeated thrice and presented in random order. The second block was considered for continuous EEG recording in order to avoid practice effect.

The cortical event related potentials were recorded using Compumedics Neuroscan instrument with $SynAmps^2$ amplifier. The participants were seated comfortably on a reclining chair. An elastic cap (Quick-cap by Compumedics- Neuroscan) with 64 sintered silver chloride electrodes was used for recording event related potentials. Twenty electrodes were placed on the following locations FPz, Fz, FCz, Cz, CPz, Pz, Oz, F3, F4, FC3, FC4,C3, C4, CP3, CP4, P3, P4, TP7, TP8, O1 & O2 based on international 10-10 system (see Figure 3).

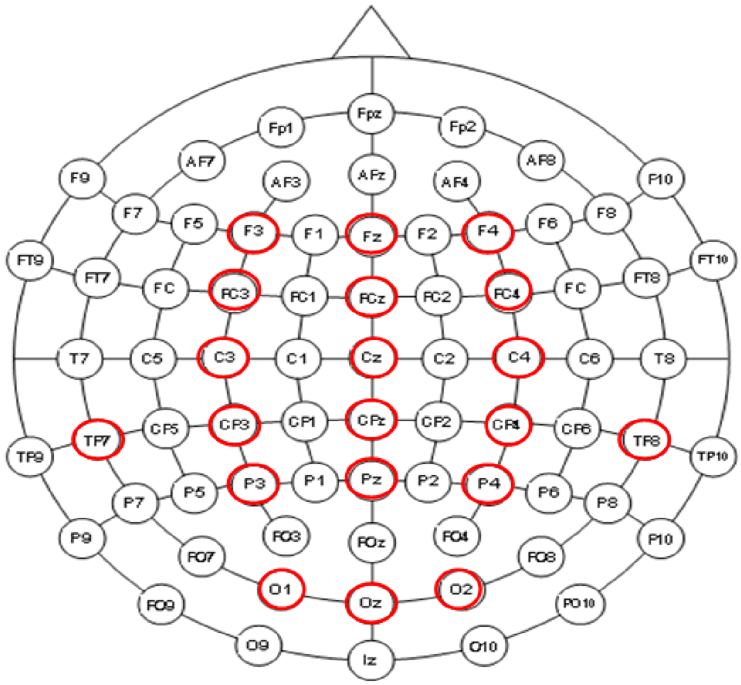

Figure 3: Diagram representing the electrode sites from where the continuous EEG was recorded using Compumedics Neuroscan.

Bipolar electrodes were placed over left and right outer canthi to monitor horizontal eye movements and over the left inferior and superior orbital ridge to monitor vertical eye movements. Linked mastoid served as a reference/ active electrode during recording. The impedance at all the electrode sites was below 5kΩ. Quick Gel™, a conduction gel was taken in the syringe and was injected into the electrode sites to link the scalp with the electrode surface. The visual stimulus was presented on a VIEWPixx monitor which is a specifically designed display tool box used in visual science labs with a display resolution of 1920(H) x 1220(V) pixels. A continuous EEG data was recorded at a sampling rate of 1000 Hz with a low pass filter at 100 Hz, and high passing DC. The time window of 1500 ms with a pre stimulus interval of 200 ms was considered for online averaging of target stimulus. The overall duration of the recording was around one hour and 30 minutes for each participant.

Procedure for primed lexical decision task:

The prime was displayed for duration of 1000 milliseconds. The prime word was followed by a fixation period of 500 milliseconds, after which the target word was displayed for duration of 1000 milliseconds. Following the target a fixation period of 1000 mili seconds was given. Hence, the next prime word appeared after 3500 milliseconds after the target word (see Figure 4).

Instructions for primed lexical decision task:

"I will present few pair of words. Among them second word will appear after a "+" sign following the first word. Pay attention to the second word which will appear after "+" sign. After the second word a question mark will appear on the screen. Press "1" if it is a true word and "2" if it is a nonsense word only when you see a question mark."

Procedure for lexical decision task:

For *the Lexical decision task* only target words were presented for 1000 milliseconds followed by a fixation period of 1000 milliseconds. The next target appeared with an interstimulus interval of 2500 milliseconds (see Figure 4).

Instructions for lexical decision task:

"I will present few true words and nonsense words. A question mark will appear on the screen after each word. Press "1" for true words and "2" for nonsense words only when you see the question mark.

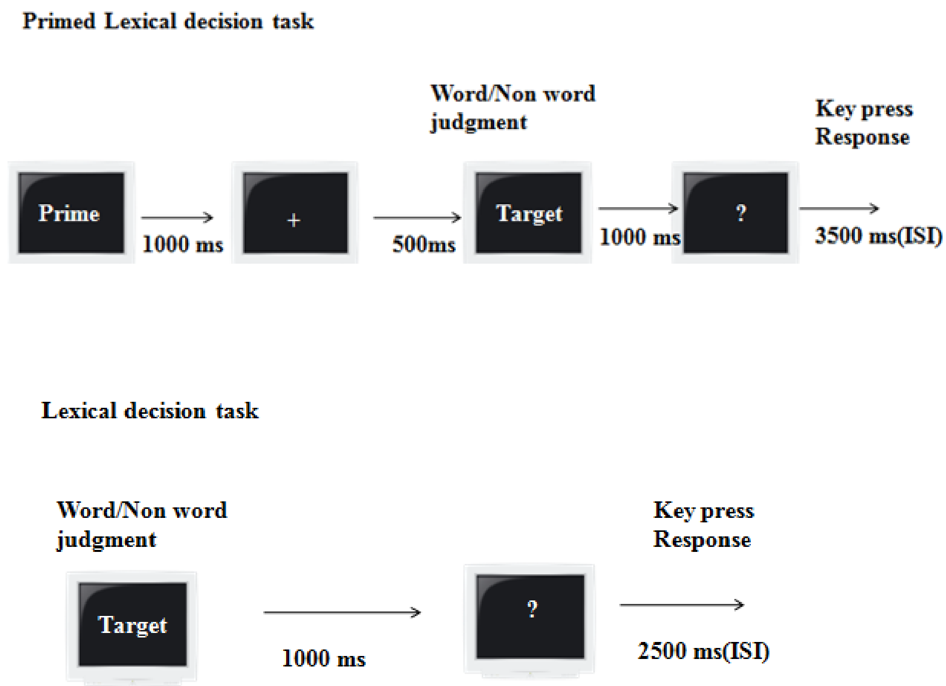

Figure 4: Schematic diagram of presentation of stimuli for primed lexical decision task and lexical decision task for electrophysiological task

While recording ERP's participants were asked to respond only during fixation period (i.e. when the question mark appears) after the target to avoid contamination of N400 by the eye movement artifacts. They were also asked to reduce eye blinking during the trials since eye movements are the major source of contamination of EEG (Croft & Barry, 1999)

Offline analysis of ERP waveforms: During offline processing, the continuous EEG data was DC offset corrected and DC corrected waveforms were band pass filtered at 0.1-30 Hz with a 48 dB roll off to eliminate the high frequency noise component. The eye artifacts were removed from the EEG signal. The continuous filtered EEG waveform was epoched from 100 to 1000 msec.

Further, voltage dependant artifact rejection was carried out and baseline corrected. Further the averaging of the epoched file was done to obtain different waveforms for target words in semantically related, unrelated and nonword pair conditions in primed lexical decision task and for words and nonwords in lexical decision task. The amplitude and latency measures of N400, an ERP which signifies the semantic processing in an individual was considered for further analysis.N400 is a negative going deflection which peaks around 400 milliseconds post stimulus onset, although it can extend from 250-500 milliseconds(Holcomb, Coffey, & Neville, 1992). The amplitude, latency and topographical distribution could vary according to the priming conditions, semantic relatedness and also for congruent and incongruent words (Holcomb & Neville, 1991; Kutas, Lindamood, & Hillyard, 1984).In the current study we look for how the amplitude and latency of N400 varies with respect to semantic relatedness and while processing words and nonwords between AWS and AWNS.

RESULTS

The obtained data was analyzed using the Statistical Package for the Social Sciences (SPSS) software package (Version 20.0) to understand differences in lexical access in monolingual adults who stutter and who do not stutter.

Behavioral results:

The results of descriptive statistics for primed lexical decision task (see Table 3) revealed that AWS have longer mean reaction time and reduced mean accuracy scores for all the three priming conditions than control subjects. Repeated measure ANOVA was conducted to analyze the effect of priming conditions on reaction time within and between the two groups. The results revealed a statistically significant main effect of priming conditions and interaction effect of priming conditions*group on reaction time during primed lexical decision task ($p<0.05$) (See Table 4). The result also revealed a statistically significant group effect on mean reaction time ($p=0.000$) (see Figure 5). Further comparison of mean reaction time for all the three priming conditions between AWS and control groups on MANOVA (See Table 5) also revealed a statistically significant difference($p<0.05$) between two groups in all the three conditions. The effect of priming conditions on mean accuracy was analyzed using repeated measure ANOVA and the results suggested that different priming conditions significantly affected the mean accuracy scores($p<0.05$)(See table 4). Whereas the interaction effect of priming conditions*group and the between group effect on mean accuracy scores (see Figure 6) was not statistically significant.

Table 3:

Mean reaction time (RT) and Standard Deviation (SD) in AWS and controls for three priming conditions for Primed lexical decision task

Priming conditions	**Group**	**Reaction time**	**Accuracy**
SR	AWS	673.20(123.28)	93.93(7.37)
	Control	455.24(92.91)	96.26(3.12)
SUR	AWS	767.24(158.46)	92.80(6.75)
	Control	498.44(85.51)	95.06(2.98)
NW	AWS	995.65(246.06)	88.33(5.87)
	Control	620.73(76.11)	85.73(5.31)

Note: SR-semantically related, SUR-semantically unrelated, NW- non word

Table 4:

Within group effect comparison of dependant variables with repeated measure ANOVA for primed lexical decision task on Mean reaction time and Mean accuracy measures

Behavioral Measures	**Factors**	**F ratio**	**p value**	**Partial Eta Squared**	**Observed power**
Mean reaction time	Priming conditions	F(1.30,38.85) =60.89	0.000*	0.685	1.000
	Groups	F(1,28) = 40.616	0.000*	0.592	1.000
	Priming conditions *Group	F(1.30,38.85) =6.16	0.004*	0.181	0.874
Mean accuracy	Priming conditions	F(1.53,46.73) =28.00	0.000*	0.500	1.000
	Groups	F(1,28) = 0.200	0.658	-	-
	Priming conditions *Group	F(1.53,46.73) =2.94	0.061	0.095	0.552

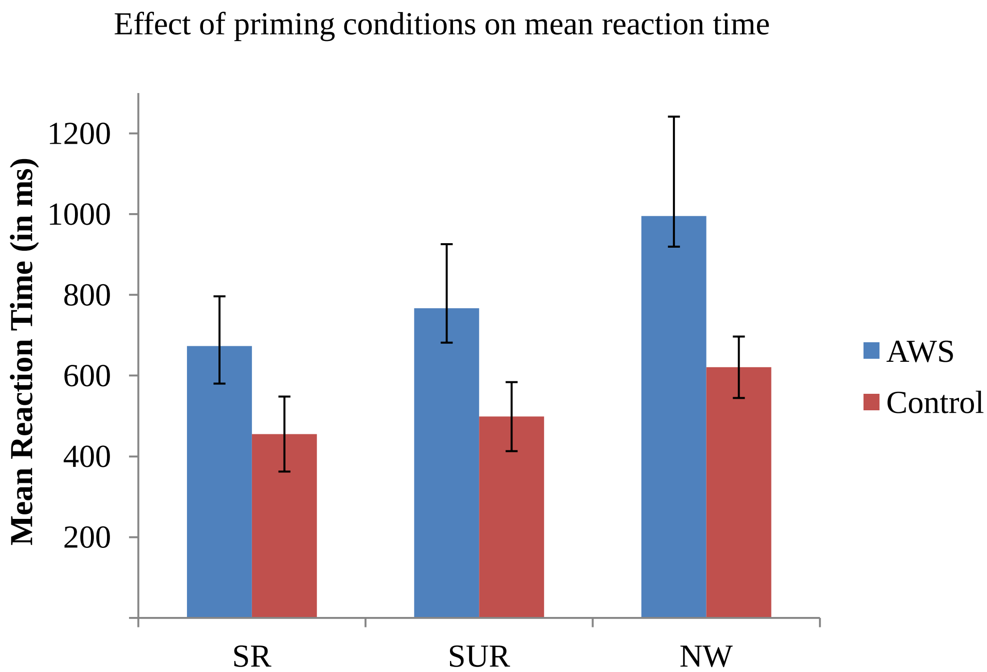

Figure 5: Effect of semantically related (SR), semantically unrelated (SUR) and word-non word (NW) priming conditions on mean reaction time for adults who stutter (AWS) and controls

Table 5:

Between group effect comparison of dependant variables with MANOVA for primed lexical decision task on Mean reaction time

Priming conditions	F ratio	p value	Partial Eta Squared	Observed power
SR	F(1,28)= 29.90	0.000*	0.516	1.000
SUR	F(1,28)= 33.42	0.000*	0.544	1.000
NW	F(1,28)= 33.42	0.000*	0.532	1.000

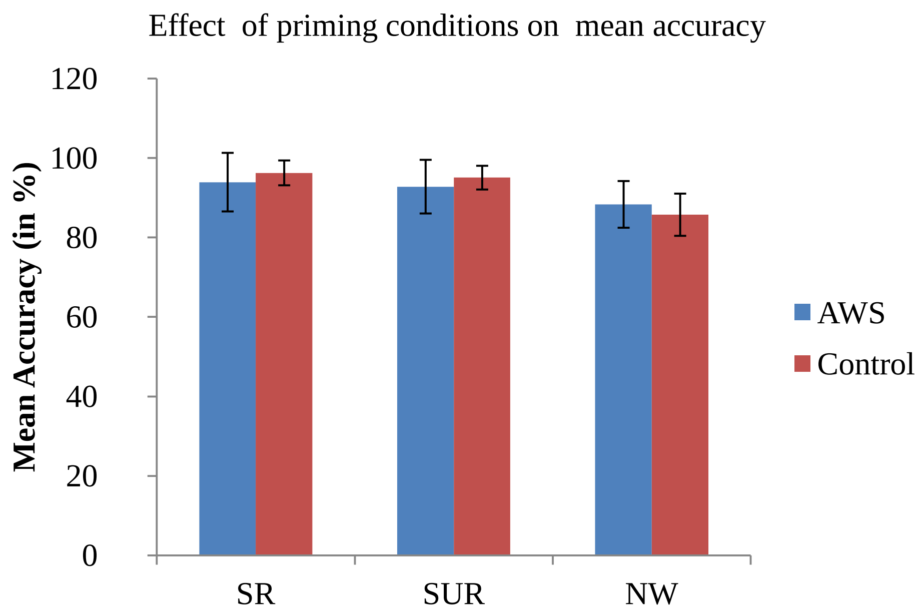

Figure 6: Effect of semantically related (SR), semantically unrelated (SUR) and word-non word (NW) priming conditions on mean accuracy for adults who stutter (AWS) and controls

Statistical analysis of lexical decision task results (see Table 6) revealed that the mean reaction time for words (Mean=856.33, SD =203.3) was greater in AWS compared to age and gender matched control subjects (Mean =715.12, SD= 53.1).Similarly the mean reaction time for nonwords (Mean= 1094.99, SD=285.66) was also greater in AWS compared to control subjects.

Table 6:

Mean reaction time (RT) and Standard Deviation (SD) in AWS and controls for words and non words for lexical decision task

Stimuli	**Group**	**Reaction time**	**Accuracy**
Word	AWS	856.33(203.30)	92.46(5.34)
	Control	715.12(53.18)	93.80(2.39)
Non word	AWS	1095.00(285.66)	80.40(14.14)
	Control	781.09(65.58)	90.46(3.09)

Further the effect of words and nonwords on Mean reaction time and Mean accuracy in both the groups was analyzed using repeated measure ANOVA and the results revealed a statistically significant main effect of type of stimuli and statistically significant type of stimuli*group interaction effect on both mean reaction time and mean accuracy scores ($p<0.05$) (See Table 7) .

Table 7:

Within group effect comparison of dependant variables with repeated measure ANOVA for lexical decision task on Mean reaction time and Mean accuracy measures

Behavioral Measures	**Factors**	**F ratio**	**p value**	**Partial Eta Squared**	**Observed power**
Mean reaction time	Type of stimuli	F(1,28) =47.34	0.000*	0.628	1.000
	Groups	F(1,28) = 13.465	0.001*	0.325	0.943
	Type of stimuli*Group	F(1,28) =15.21	0.001*	0.352	0.964
Mean accuracy	Type of stimuli	F(1,28) =13.29	0.001*	0.322	0.940
	Groups	F(1,28) = 8.848	0.006*	0.240	0.819
	Type of stimuli*Group	F(1,28) =4.27	0.048*	0.132	0.515

There was a statistically significant difference between the two groups on both mean reaction time ($p=0.001$) (see Figure 7) and mean accuracy ($p=0.006$) (see Figure 8). Hence MANOVA was carried out to know the dependant variables which contribute to the group effect on mean reaction time and mean accuracy scores (See Table 8). The results of MANOVA revealed that the mean reaction time for both words and nonwords and the mean accuracy for nonwords were statistically significant across the two groups ($p<0.05$)

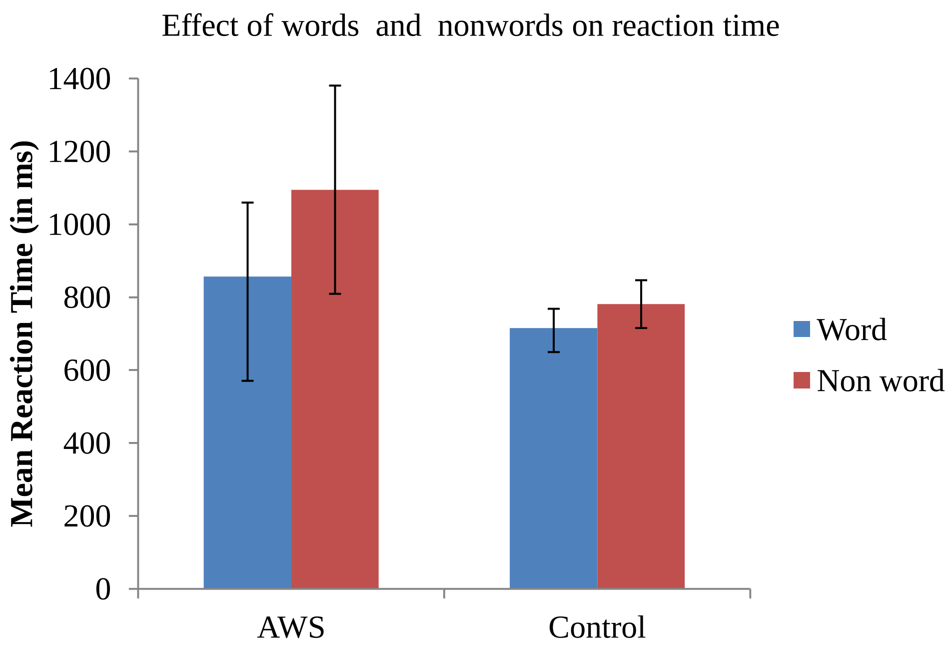

Figure 7: Effect of words (W) and nonwords (NW) on mean reaction time for adults who stutter (AWS) and controls

Table 8:

Between group effect comparison of dependant variables with MANOVA for lexical decision task on Mean reaction time and Mean accuracy measures

Behavioral measures	**Type of stimuli**	**F ratio**	**p value**	**Partial Eta Squared**	**Observed power**
Mean reaction time	Words	F(1,28)= 6.77	0.015*	0.195	0.710
	Non words	F(1,28)= 17.20	0.000*	0.381	0.979
Mean Accuracy	Words	F(1,28)= 0.77	0.385	-	-
	Non words	F(1,28)=7.25	0.012*	0.206	0.739

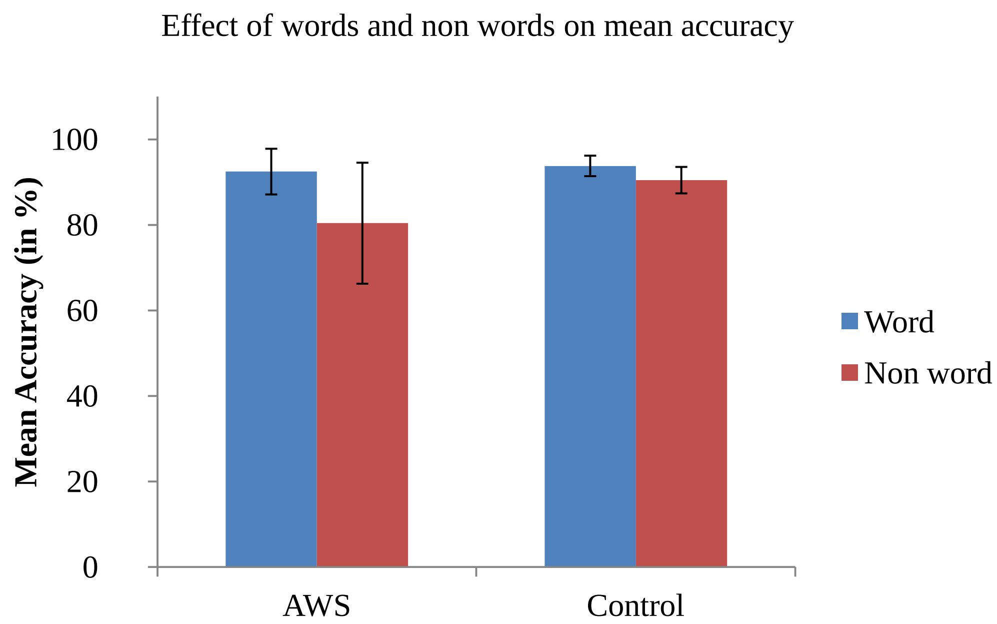

Figure 8: Effect of words (W) and non words (NW) on mean accuracy for adults who stutter (AWS) and controls

Electrophysiological results:

The latency and amplitude of N400 peak was obtained for all electrode sites and for all the types of stimuli in both AWS and controls. Further, the amplitude and latency data were statistically analyzed to understand the lexical processing in AWS and controls.

Primed Lexical Decision task:

Descriptive statistics revealed that the priming effect is reduced in AWS than in controls. The measure of mean latency for three region of interests(ROI); central (Fz, FCz, Cz, CPz, Pz and Oz),right (F4,FC4,C4,CP4,P4,O2 and TP8) and left(F3,FC3,C3,CP3,P3,O1 and TP7) channels were also longer in AWS than in controls(see Table 9)(see Figure 9).

Table 9:

Mean latency, Mean amplitude and Standard deviation measures of N400 for semantically related (SR), semantically unrelated (SUR) and nonword conditions on primed lexical decision task in AWS and controls

N400 measures	**Priming Conditions**	**ROI**	**Group**	**Mean(SD)**
Latency	SR	right	AWS	411.93(17.69)
			Control	381.49(21.87)
		left	AWS	406.22(20.20)
			Control	375.66(12.11)
		central	AWS	404.01(18.78)
			Control	368.95(31.81)
	SUR	right	AWS	432.48(18.30)
			Control	404.49(32.88)
		Left	AWS	413.66(22.25)
			Control	389.09(36.31)
		central	AWS	421.24(25.74)
			Control	387.28(39.27)
	NW	right	AWS	434.93(35.39)
			Control	413.02(26.36)
		Left	AWS	427.63(30.78)
			Control	413.93(27.46)
		central	AWS	423.20(32.46)
			Control	408.59(28.65)
Amplitude	SR	right	AWS	2.74(2.04)
			Control	0.60(4.57)
		Left	AWS	0.39(2.68)
			Control	-1.61(4.37)
		central	AWS	0.96(2.47)
			Control	-1.21(4.75)
	SUR	right	AWS	1.34(2.09)
			Control	-0.34(5.28)
		Left	AWS	-1.38(2.75)
			Control	-2.97(4.72)
		central	AWS	-0.87(3.36)
			Control	-2.73(4.83)
	NW	right	AWS	1.09(2.74)
			Control	-0.40(4.67)
		Left	AWS	-0.86(2.17)
			Control	-3.13(5.00)
		central	AWS	0.87(2.72)
			Control	-2.27(5.27)

The repeated measure ANOVA revealed a statistically significant group effect with p=0.001.Further, the results also indicated statistically significant main effect for priming conditions and also for regions of interest on N400 latency measures.

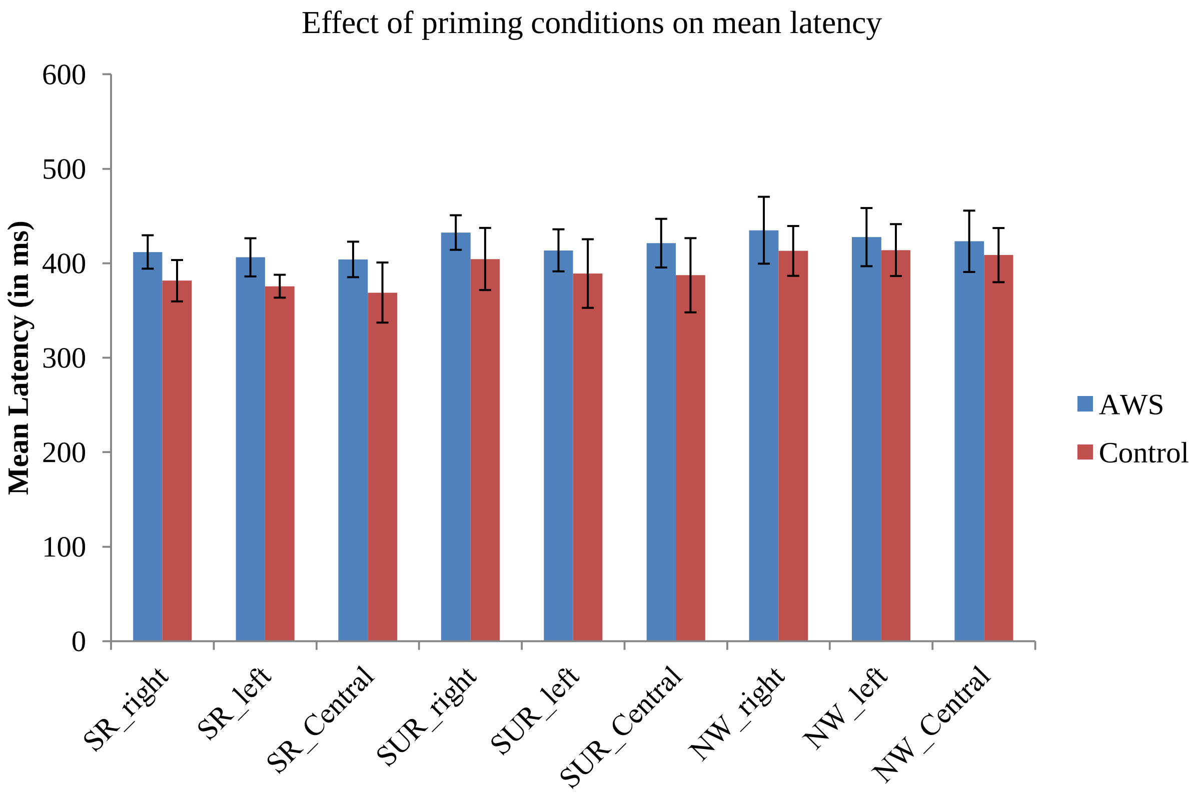

*Figure 9:*Effect of semantically related (SR), semantically unrelated (SUR) and word-non word (NW) priming conditions on mean latency on right, left and central channels for adults who stutter (AWS) and controls

The interaction effect for priming conditions*groups, regions of interest*groups, priming conditions*regions of interest as well as priming conditions*regions of interest*groups on latency was not statistically significant (See Table 10).

Table 10:

Within group effect comparison of dependant variables with repeated measure ANOVA for primed lexical decision task on N400 latency and amplitude measures

N400 measures	**Factors**	**F ratio**	**p value**	**Partial Eta Squared**	**Observed power**
Latency	Priming conditions	F(1.58, 45.11)= 13.01	0.000*	0.334	0.996
	Groups	F(1,26) = 14.084	0.001*	0.351	0.951
	Priming conditions *Group	F(1.58, 45.11)= 1.009	0.372	-	-
	ROI	F(1.77, 51.06)= 12.15	0.000*	0.319	0.994
	ROI*Group	F(1.77, 51.06)=0.618	0.543	-	-
	Priming conditions *ROI	F(3.11, 96.84)= 2.29	0.065	-	-
	Priming conditions *ROI*group	F(3.11, 96.84)=0.609	0.657	-	-

Further the results from MANOVA also demonstrated significant difference between the two groups for semantically related and semantically unrelated word pairs in all the three regions of interest ($p<0.05$) (See Table 11).

Table 11:

Between group effect comparison of dependant variables with MANOVA for primed lexical decision task on N400 latency

Priming conditions	**Regions of interest**	**F ratio**	**p value**	**Partial Eta Squared**	**Observed power**
SR	Right	F(1,26)= 16.37	0.000*	0.386	0.973
	Left	F(1,26)= 23.56	0.000*	0.475	0.997
	Central	F(1,26)= 12.61	0.001*	0.327	0.927
SUR	Right	F(1,26)= 7.74	0.010*	0.230	0.764
	Left	F(1,26)= 4.66	0.040*	0.152	0.547
	Central	F(1,26)= 7.32	0.012*	0.220	0.741
NW	Right	F(1,26)= 3.45	0.075	-	-
	Left	F(1,26)= 1.54	0.225	-	-
	Central	F(1,26)= 1.59	0.218	-	-

The descriptive statistics revealed that greater negative amplitude for semantically unrelated and non word priming conditions for all the three regions of interest in control subjects than AWS (see Table 9) (see Figure 10,11,12).

As the data was not normally distributed, the non parametric Mann-whitney test was done to compare the mean amplitude of different conditions between AWS and controls. The results revealed no significant difference in the mean amplitude between the two groups for SR, SUR and NW pairs in all the channels of interest [SR-right (Z = -1.314 , p > 0.05), SR-left (Z = -1.314 , p > 0.05), SR-central (Z = -1.423, p > 0.05), SUR-right (Z = -0.164, p > 0.05), SUR-left (Z = -0.328 , p > 0.05), SUR-central (Z = -0.493 , p > 0.05), NW-right (Z = -0.876, p > 0.05), NW-left (Z = -0.766 , p > 0.05), NW-central (Z = -0.876, p > 0.05)]

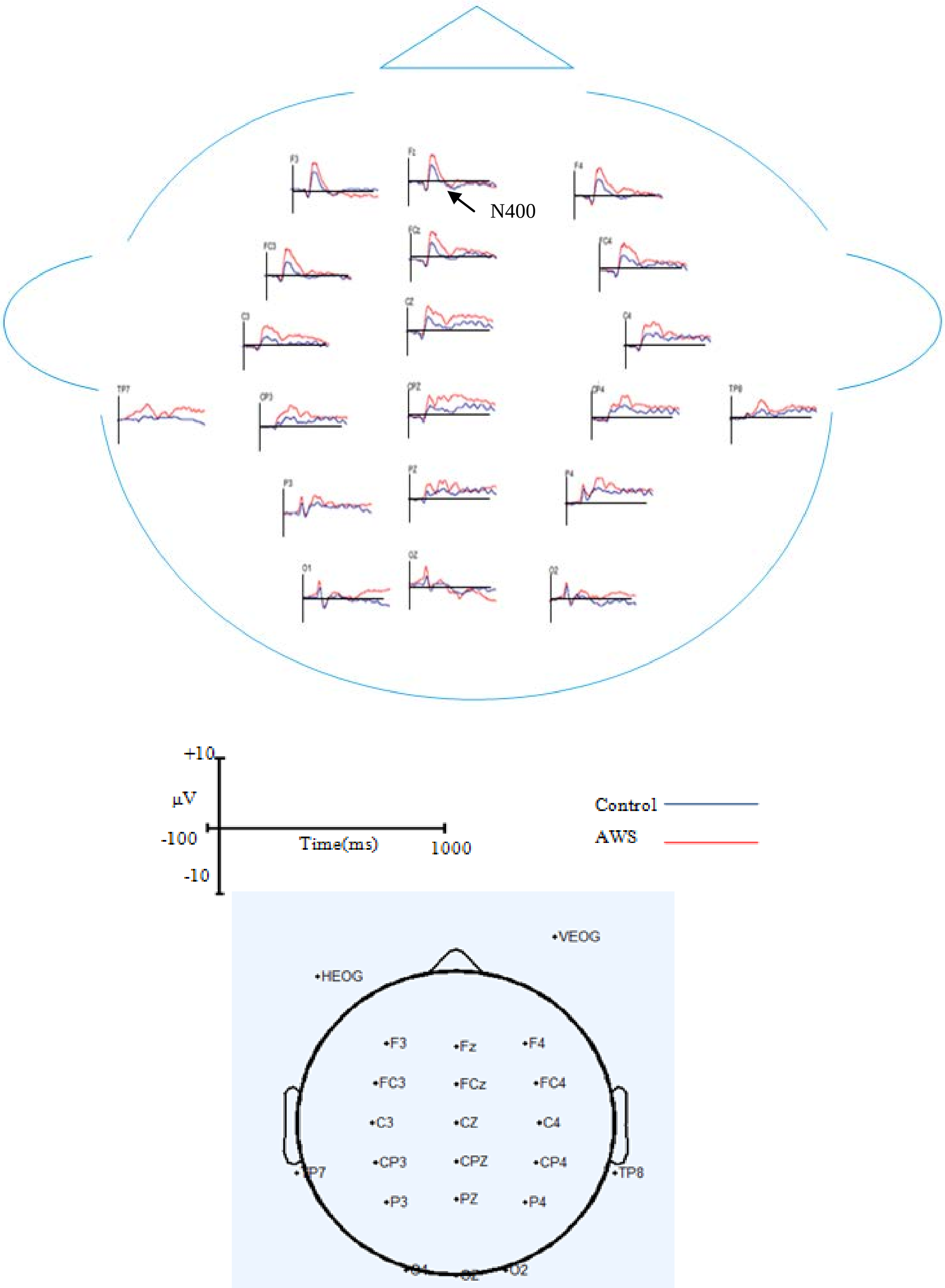

Figure 10: Comparison of grand average ERPs elicited by semantically related (SR) priming conditions in controls (blue) and AWS (red)

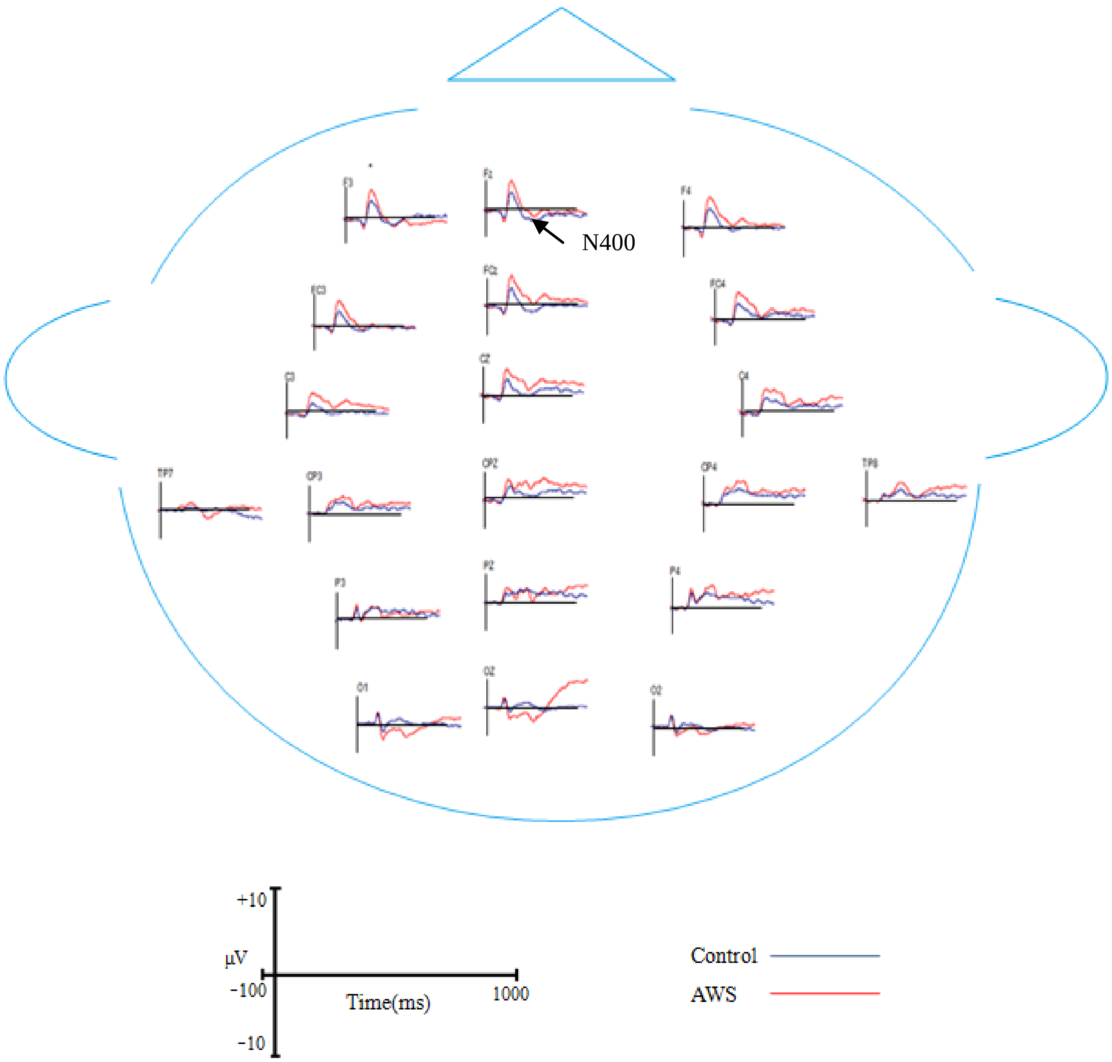

Figure 11: Comparison of grand average ERPs elicited by semantically unrelated (SUR) priming conditions in controls (blue) and AWS (red)

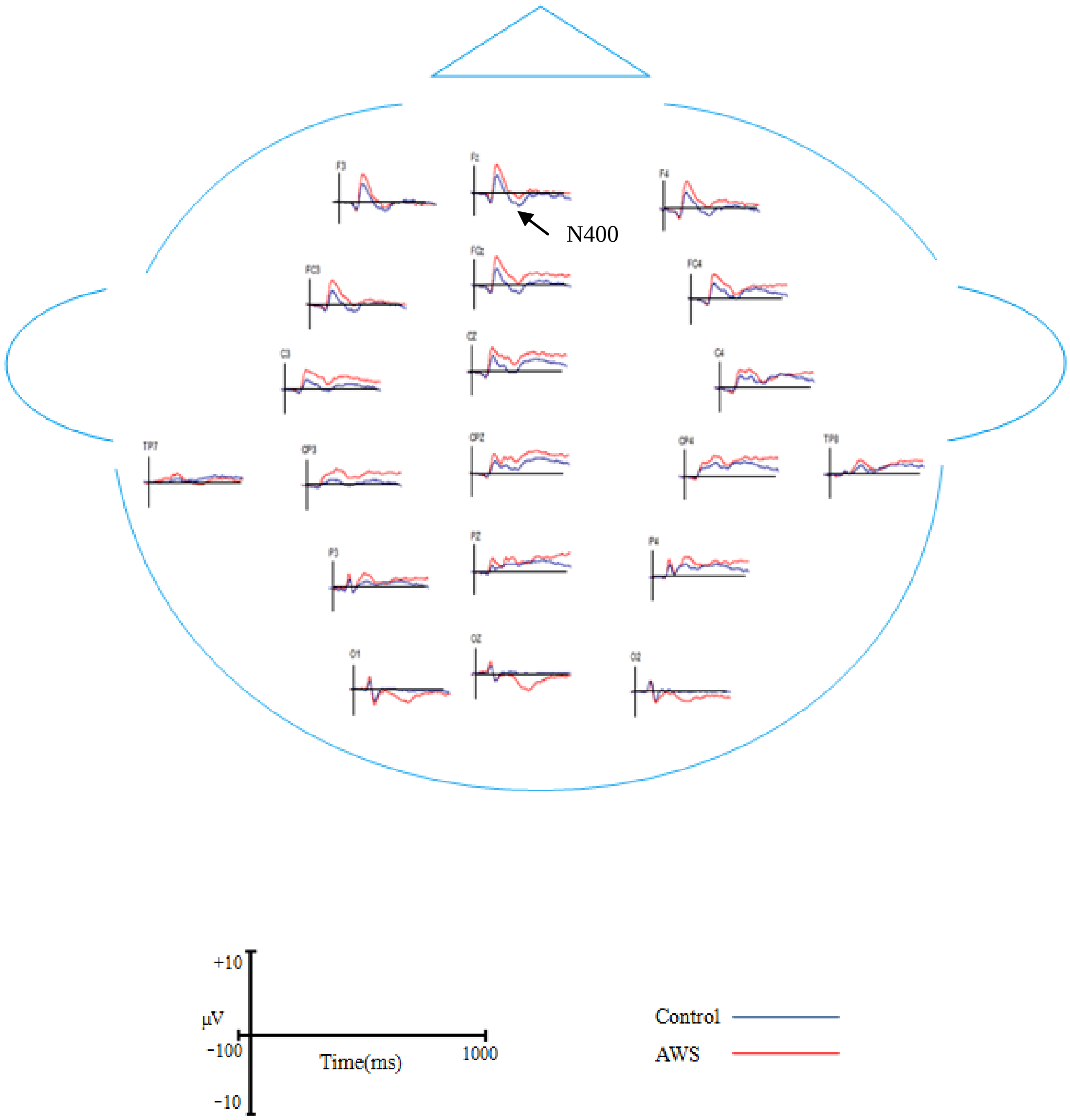

Figure 12: Comparison of grand average ERPs elicited by word-nonword priming conditions in controls (blue) and AWS (red)

Lexical Decision task:

The results of descriptive statistics (see Table 12) revealed that AWS were slower in processing words and nonwords which was indicated as longer latency in all the three regions of interest compared to control subjects. The repeated measure ANOVA results (see Table 13) revealed a statistically significant main effect on N400 latency measures for type of stimuli, whereas the main effect of regions of interest was not statistically significant on latency.

Table 12:

Mean latency, Mean amplitude and Standard deviation measures of N400 for words and non words on lexical decision task in AWS and controls

N400 measures	**Stimuli**	**ROI**	**Group**	**Mean(SD)**
Latency	Words	Right	AWS	395.13 (24.88)
			Control	386.07(20.89)
		Left	AWS	390.66(26.48)
			Control	384.01(13.10)
		central	AWS	395.88(28.40)
			Control	384.85(21.42)
	Non words	Right	AWS	418.68(29.47)
			Control	399.51(41.01)
		Left	AWS	413.30(38.18)
			Control	397.37(33.21)
		central	AWS	416.86(35.03)
			Control	403.88(35.32)
Amplitude	Words	Right	AWS	-1.51(3.81)
			Control	0.22(4.21)
		Left	AWS	-2.87(4.30)
			Control	0.71(4.55)
		central	AWS	-2.78(4.73)
			Control	-0.12(4.40)
	Non words	Right	AWS	-2.33(3.67)
			Control	0.46(5.48)
		Left	AWS	-2.60(4.36)
			Control	0.72(5.57)
		central	AWS	0.34(15.78)
			Control	0.34(5.58)

There was no statistically significant interaction effect on N400 latency for types of stimuli*groups, regions of interest*groups, types of stimuli *regions of interest and types of stimuli *regions of interest*groups. Further the results of repeated measure ANOVA revealed no significant group effect (p>0.05) (see Figure 13).

Table 13:

Within group effect comparison of dependant variables with repeated measure ANOVA for lexical decision task on N400 latency and amplitude measures

N400 measures	Factors	F ratio	p value	Partial Eta Squared	Observed power
Latency	Type of stimuli	F(1,27) =13.491	0.001*	0.333	0.943
	Groups	F(1,27) = 1.955	0.173	-	-
	Type of stimuli*Group	F(1,27) =0.481	0.494	-	-
	ROI	F(1.46,42.84) =1.274	0.288	-	-
	ROI*Group	F(1.46,42.84) =0.143	0.867	-	-
	Type of stimuli *ROI	F(1.78,53.40)=0.086	0.918	-	-
	Type of stimuli*ROI*group	F(1.78,53.40)=0.397	0.674	-	-

The greater negative amplitude for N400 in all the three regions of interest while processing words in AWS compared to control subjects was revealed from descriptive statistics (see Table 12). Similarly there was greater negative amplitude for N400 in right and left regions while processing non words in AWS than control subjects (see Figure 15, Figure 16). The comparison of mean amplitude for words and nonwords on all three regions of interest was done using non parametric Mann-Whitney test. The test results revealed significant difference in mean amplitude for words [right ROI (Z= -1.088, p = 0.277), Left ROI (Z= -2.339, p< 0.05), central ROI (Z=-1.741, p = 0.082] and non words [right ROI(Z= -1.414, p = 0.157),Left ROI(Z= -2.013, p< 0.05), Central ROI (Z= -1.958, p= 0.05)].

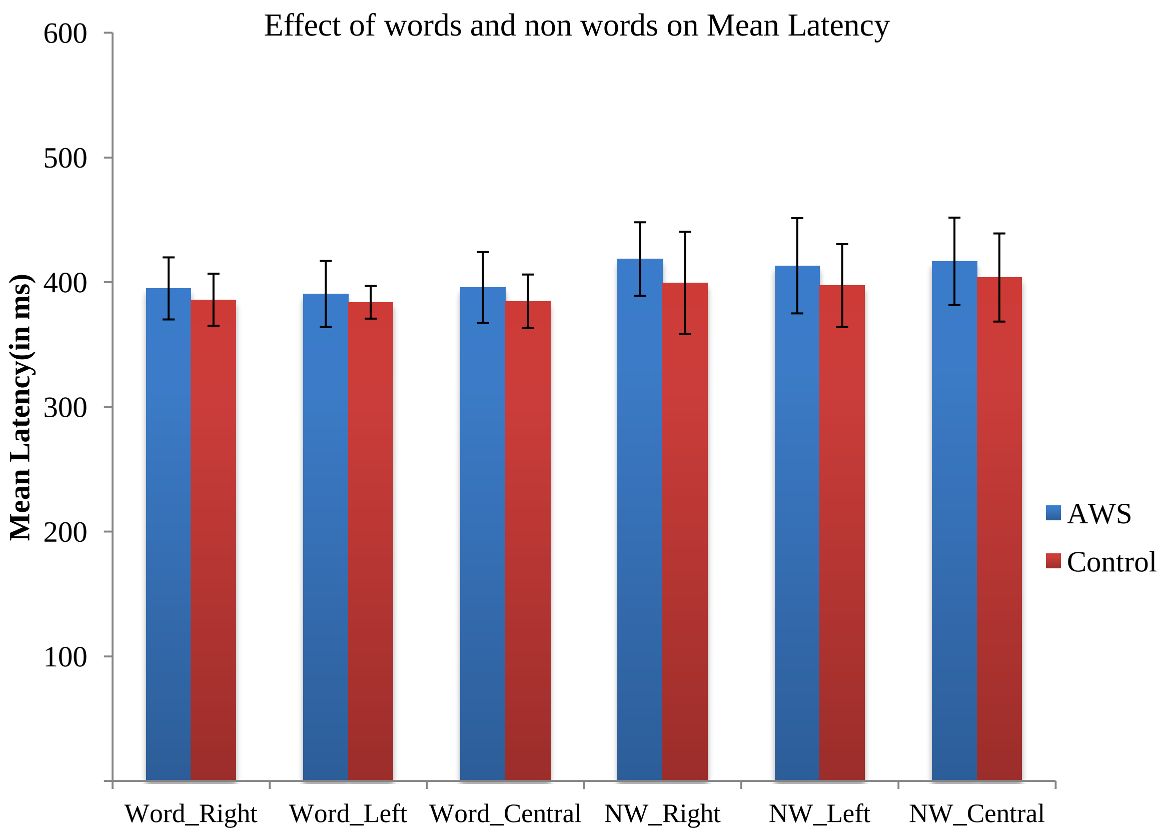

Figure 13: Effect of words (W) and non words (NW) on mean latency on right, left and central channels for adults who stutter (AWS) and controls

Overall results of the current study based on behavioral and electrophysiological measures revealed difference in the time course of lexical access and phonological access between AWS and control subjects indicating a clear delay in linguistic processing in adults who stutter.

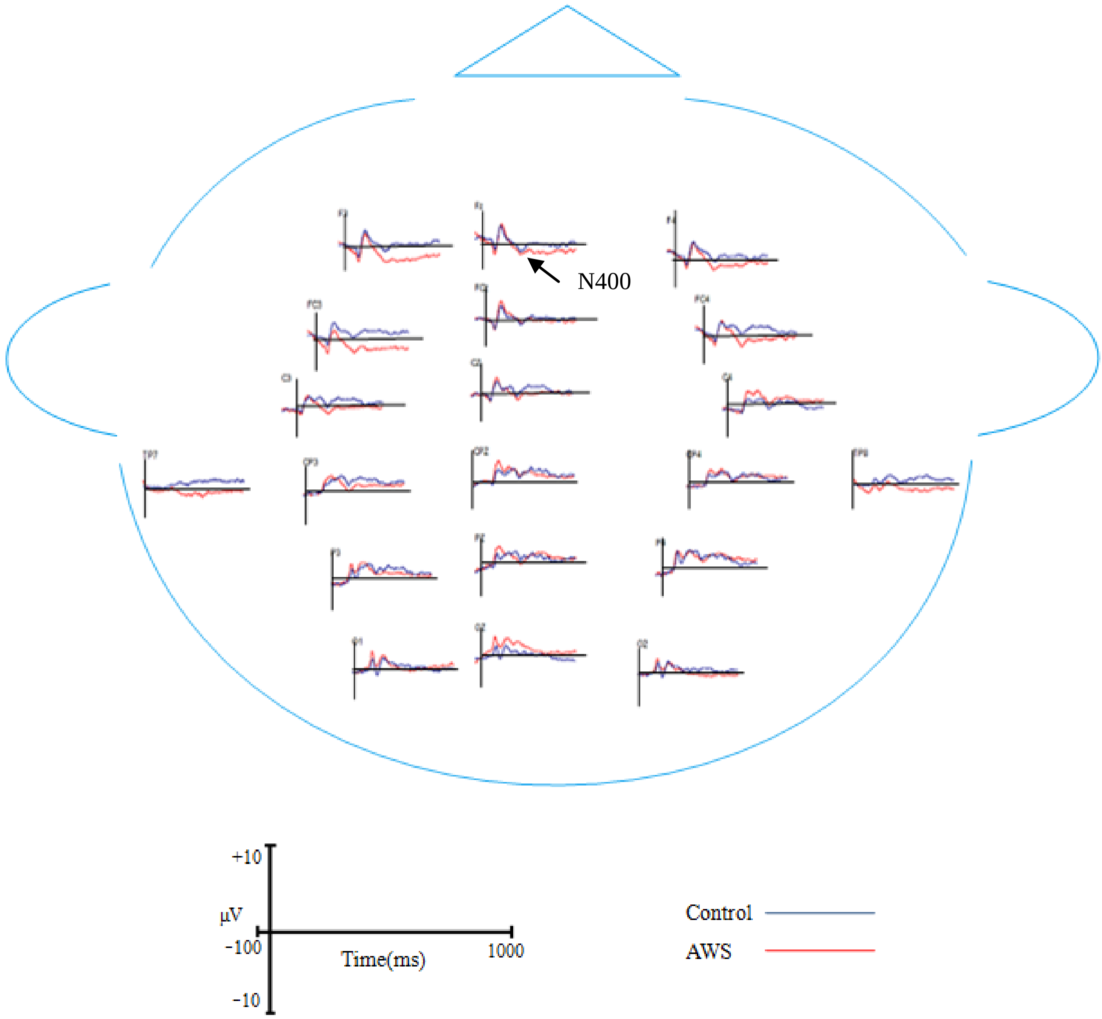

Figure 14: Comparison of grand average ERPs elicited by words in controls (blue) and AWS (red)

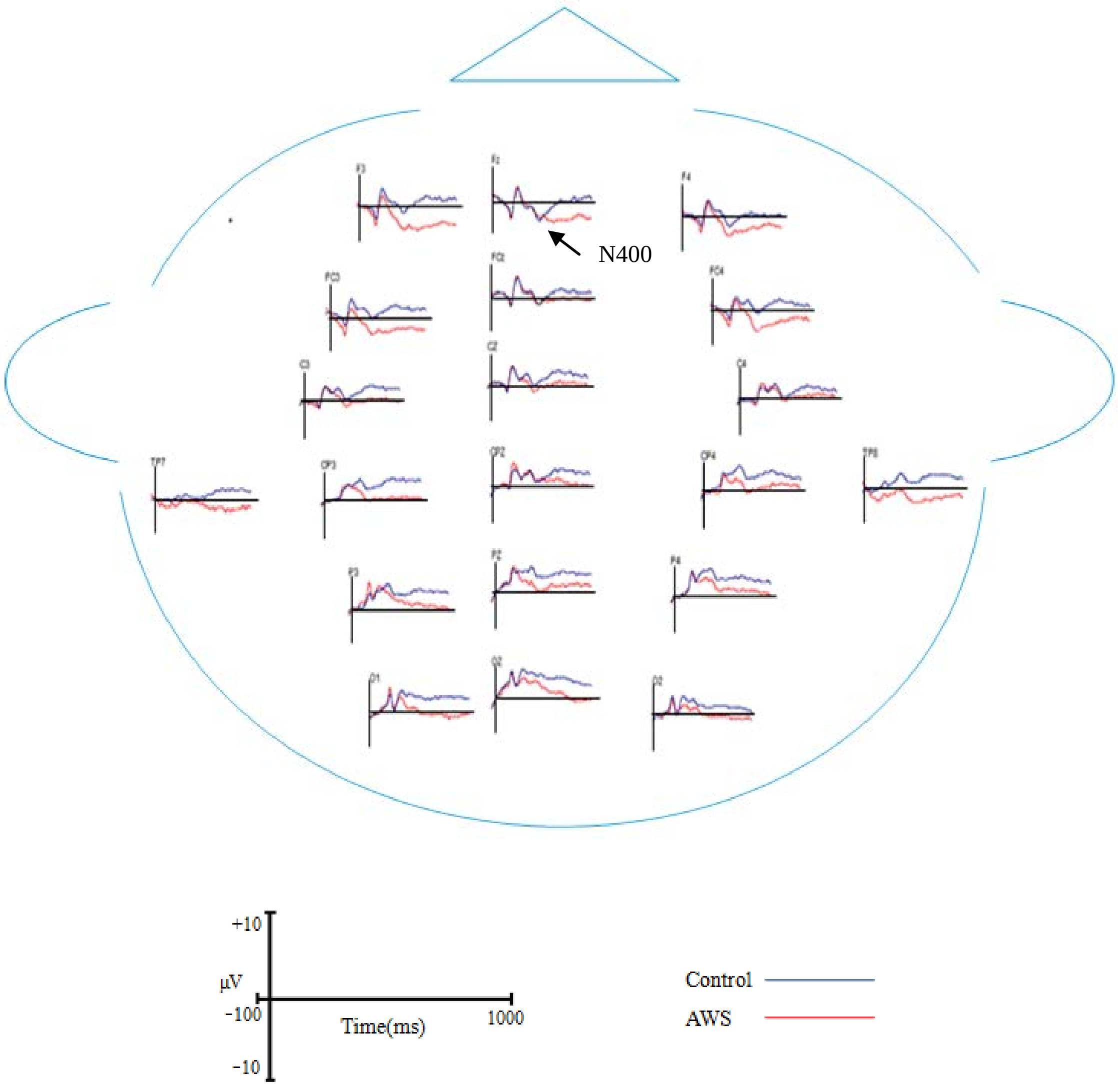

Figure 15: Comparison of grand average ERPs elicited by non words in controls (blue) and AWS (red)

DISCUSSION AND CONCLUSIONS

The primary objective of the current study was to investigate the difference in lexical access in adults with and without stuttering using primed lexical decision task. The experiment included semantically related, semantically unrelated, and word- nonword pairs to understand difference in the lexical semantic activation between two groups. The priming effect would result in much faster decision regarding whether a letter string is a word, when the prime is related than unrelated. The semantic spreading activation during the presentation of a prime can result into encoding of new concepts from the already activated concepts which would yield in a faster decision making (Collins & Loftus, 1975; Meyer, 1973; Meyer & Schvaneveldt, 1971; 1976; Neely, 1977). Thus the primed lexical decision task was used to understand the conceptually driven processes in lexical access in individuals with stuttering (Crowder, 1982). The results of the primed lexical decision task revealed a significantly longer reaction time in all the three priming conditions in AWS compared to control subjects. Whereas the mean accuracy did not differ significantly between AWS and control subjects. The results also revealed that the mean reaction time was less and mean accuracy was more for semantically related, followed by semantically unrelated followed by word- nonword pairs suggesting that priming effect is operational in both the groups. But the slower priming effect compared to control subjects reflects the delayed but accurate lexical semantic activation in AWS. Even though the current experiment used a comparatively simple task than semantic judgment, the results implicates a significant difference in temporal aspects of lexical access in AWS compared to control subjects. But this difference does not imply a deficiency in lexical access because the time taken for lexical access which is the crucial aspect in lexical activation is within 600-1200 msec (Postma, 2000). The results of the current experiment also suggests that the way of activation of lexical-semantic system is not different in AWS compared to controls since the facilitation effect of semantically related pairs and inhibitory effect of semantically unrelated pairs and word- non word are present in both the groups (Becker,1980). Becker's verification model for visual word recognition could be applicable in the current study since we have used visual lexical decision task. According to this model, if the prime and the target are strongly related or associated, the semantic set activated would be small and this would result in facilitation and there won't be a delay in comparing the target and semantic set to make a lexical decision. In our study this effect was reflected as lesser reaction time for semantically related word pairs in both the groups. The model also proposes that if the prime and target relation or association is limited or absent, then the semantic set activated would be large and would result in a delay for matching the target to the activated semantic set. This was reflected as increased reaction time for semantically unrelated and word- nonword pairs in both AWS and control subjects in our experiment. Further, it is inferred that the longer reaction time in AWS for all the three priming conditions compared to controls could be due to the delay in both facilitation and inhibition effect compared to controls. The nonword decision on presentation of word- nonword pairs involves comparison or search of mental representation of nonword with already activated entries from the mental lexicon. The longest reaction time for word-nonwords pairs compared to semantically related and semantically unrelated pairs reflects that it takes longer time to terminate this higher number of comparisons(Neely,1977). And this process is more delayed in AWS compared to control subjects.

Similar to the results of our present study indicating slow lexical access in AWS, Howell(2015) also had reported that time line for lexicalization of nouns and verbs was affected in AWS compared to controls. It has been evidenced that atypical language processing starts from childhood in stuttering population from a study by Pellowski and Contoure (2005). They studied difference in lexical access between CWS and CWNS using semantic priming paradigm in picture naming task. The results revealed slow speech reaction time in CWS compared to CWNS.

The current study points to the fact that semantic spreading activation is inefficient in AWS compared to AWNS because automatic spreading activation of semantically related words was not found in AWS compared to AWNS. This is reflected as longer mean reaction time even for semantically related priming conditions in AWS than AWNS. These results are in consonance with Wingate (1988) who reported that AWS performed poorly on verbal scale of Wechsler Adult Intelligence Scale (WAIS). They used fewer synonyms in the definition generation task which indirectly indicates poor semantic spreading activation. In a different study, Bosshardt and Fransen (1996) reported slower reaction time in AWS while identifying the category specific words in sentences which also indirectly suggests the weak semantic network activation in AWS. Prins et al. (1997) reported longer latencies on picture naming task in AWS. They also observed that low frequency words had a major effect on lexicalization time regardless of the vocabulary levels of AWS. Prins et al. (1997) hypothesized that slow lexical access or semantic activation of words could be the source for disrupted fluency in AWS. The reason for slow lexical access could be due to inefficient lexical activation. Inefficient lexical activation may be the result of less restraints on spreading activation mechanism i.e, more number of words are semantically activated which include desirable as well as undesirable words on presentation of a prime in AWS, which further demands more number of semantic matching with the target, which is time consuming. This leads to a longer reaction time in AWS compared to AWNS. This was also evidenced in a study by Newman and Ratner (2007) which reported that low frequency words were more difficult in AWS than AWNS on a confrontation naming task and the naming errors were lower in frequency which implies less restrained spreading activation mechanism in the mental lexicon of AWS.

The behavioral results are consistent with electrophysiological findings in the current study. The measure of neural activity using electrophysiological measures also suggested delayed lexical access or lexical semantic activation in AWS compared to control subjects on primed lexical decision task. In order to understand the neural activity underlying the lexical processing we recorded N400 potential in the current experiment.N400 is a negative going deflection which peaks around 250-550 msec after the stimulus onset, indicating the ease of lexical access and integration (Holcomb et al., 1992; Kutas & Federmeir, 2011; Kutas & Hillyard, 1980; Kutas & Van Petten, 1994; Neville, Mills, & Lawson,1992). The semantically related priming conditions will reduce the amplitude of ERP component where as the semantically unrelated priming conditions will increase the amplitude. The nonwords would increase the N400 amplitude suggesting a cognitive linguistic load on semantic processing systems. In the current study N400 components elicited in AWS displayed significantly longer peak latencies for semantically related and semantically unrelated priming conditions in central, right and left regions of interest compared to the control subjects. These findings imply that the lexical access or lexical semantic activation requires more time for AWS while processing different semantic contextual information. These results confirm the increased mean reaction time for different priming conditions in the behavioral study. From the descriptive results it was also evident that the processing of word – nonword pairs are more difficult for AWS than controls even though this difference is not significant. The presentation of word- nonword pairs imparts equal processing load in both AWS and controls, comparatively more load on AWS.

In our current study, the semantic priming conditions elicited similar N400 mean amplitude in both AWS and controls. The mean amplitude for all the three priming conditions did not differ significantly between AWS and controls in all the three regions of interest. Even though there is greater mean negative amplitude for semantically unrelated and non word conditions in controls compared to AWS, this difference is not statistically significant which would suggest that the amount of neural activation for lexical semantic processing is similar in both AWS and controls. Overall findings from primed lexical decision task suggest that AWS are relatively slower in lexical access or lexical semantic activation. Huffman (2009) also reported similar findings which suggest that semantic and phonological priming effect on N400 activation is affected in AWS. They noted that semantic picture word priming did not elicit a robust N400 in AWS as AWNS and N400 effect for phonological priming could not differentiate AWS from AWNS. In another ERP study, Blomgren et al. (2002) revealed longer P300 latencies for linguistic stimuli in AWS which implies that linguistic processing rate is slower in them. Maxfield et al. (2012) also investigated the neural activity (N400) of semantic and phonological processing in AWS and controls using picture naming task. They evidenced reduced semantic priming and reverse phonological priming suggestive of unstable semantic and phonologic spreading activation in AWS than AWNS. According to Maxfield et al. the diminished N400 in AWS could be due to unstable activation state of semantic representations which is not adequate for spreading activation. This instability at semantic level could have led to unstable state of phonological representations also, but the heightened attention based processing elicited a large amplitude N400 effect (reverse phonological N400 priming) in AWS. They also explain that the reduced accuracy for picture naming would be result of inefficient lateral inhibition of semantic sets that are incompatible to the target. Our ERP findings are also in line with other researches evidencing atypical N400 (Cuadrado & Webe-Fox, 2003; Weber-Fox, 2001; Weber-Fox & Hampton, 2008) suggesting semantic and syntactic processing difficulties in AWS. All the findings of the current study using primed lexical decision task and the previous findings outlined here indirectly implies difference in lexical access and inefficient semantic spreading activation in line with our N400 results.

The second objective of our study was to investigate the difference in phonological access in AWS and controls using lexical decision task. Although there are not many studies which have used lexical decision of words and nonwords in persons with stuttering, many earlier studies are available which have used nonword repetition, nonword reading, phonologic priming and rhyme judgment task to evidence the phonological encoding deficits in persons with stuttering. Among these tasks, nonword reading is considered to be a higher predictor of phonological processing skills (Gibbs & Bodman, 1997). According to Campbell and Butterworth (1985) nonword reading requires skills that are not needed for word reading. Non word reading requires the decoding of unfamiliar strings of letters which would tap the phonological integration. In the meanwhile reading of the regular words may involve the use of letter sound knowledge for decoding, use of sight vocabulary to recognize the word or spoken vocabulary for clues to word's identity. Reading of nonwords does not make use of sight vocabulary and spoken vocabulary which are based on visual processing and meaning. However, nonword reading and non word repetition will not distinguish the phonemic encoding , speech motor planning and execution since it involves verbalization; the word and non word lexical decision task would tap the phonological encoding deficits in isolation. In the current study, we have used visually presented words and pronounceable nonwords as stimuli in order to understand the phonological processing and it involves silent word and non word reading without any verbalization.

In the current experiment the participants were asked to make judgment of words and nonwords visually presented to them. The behavioral results revealed a significantly longer mean reaction time and reduced accuracy for both words and nonwords during the lexical decision task in AWS compared to control subjects which implies delayed phonological processing in AWS compared to control participants. On similar lines, Alvarez et al. (2014) had investigated lexical and phonological processing in CWS and CWNS aging from 8-13 years, using a lexical decision task in Spanish language. The results revealed that CWS had slower reaction time and made greater number of errors on lexical decision of words and pseudowords. They also reported presence of syllable frequency effect which suggests an absence of automated phonological route and poorly organized phonological system in CWS compared to CWNS. In support of the view that phonological processing is affected in PWS, Hennessey et al. (2008) reported that reaction time facilitation from phonological priming was numerically longer for AWS than AWNS. In contradictory to this, Burger and Wijnen (1999) and Huffman(2009) reported no difference in reaction time between the two groups on phonological priming task. The studies using non word repetition and non word reading in AWS and controls also revealed the existence of phonological encoding deficits and phonological working memory deficits in AWS (Byrd et al., 2012; Ludlow et al., 1997; Sasisekaran & Byrd, 2013).

Supporting these behavioral findings, even though not significant; longer mean N400 latencies in AWS compared to controls in right, left and central regions of interest were evidenced from the electrophysiological results in the present study. Eventhough behaviorally AWS and AWNS differed significantly on lexical decision task, the underlying aspects of phonological processing did not differ significantly as evidenced by ERP's. This suggests that it is important to look beyond behavioral, to the underlying processes, while investigating stuttering as a clinical phenomenon. In the current experiment visual inspection of the grand averaged waveforms for words and nonwords indicated more N400 amplitude for AWS than AWNS even though not statistically significant. This could be because of the anticipation effect in AWS causing greater number of words automatically gaining the activation and thus longer time in decision making. Since the lexical decision task does not involve any prime, unlike the primed lexical decision task the number of words activated purely depends on the initial phoneme/letter string of the word.

Our ERP results are in conjunction with the observation of Weber-Fox et al. (2004) who reported atypical N400 and P600 in AWS. According to their results the time course of ERP's were delayed in AWS on rhyme judgment task using printed words as the stimuli. They observed that even without phonological or orthographic incongruency, AWS exhibited slower phonological monitoring which implied a deficient phonological processing mechanism. In a previous study, Sasisekaran et al. (2006) also revealed that some aspect of phonological processing is slower in AWS by monitoring the internal speech of target phonemes during a picture naming task.

The studies point to the fact that lexical decision could be considered as a suitable measure of word processing in reading since it involves lexical access, but not articulation (Alvarez et al., 2014). From the results it could be inferred that if stuttering is purely due to factors affecting speech production, then difference in reaction time /accuracy between AWS and control would not be expected because the lexical decision task does not require the participants to verbalize or articulate. Henceforth, the drawn inferences from the results indicates that stuttering could be due to difficulty at lexical/ sublexical level which are central processes occurring prior to the speech production/articulation of words, reflected as some differences among AWS and AWNS during the lexical access. The results from both primed lexical decision task and lexical decision task suggests that lexical semantic activation and phonological encoding is indeed impaired in AWS. Such difficulties could result into dysfluencies during speech. This explanation is in accordance with the language based theory of stuttering and could significantly add on to the evidences for multimodal theory of stuttering such as dynamic multifactorial theory (Smith & Kelly, 1997). According to Smith (1999) and Smith and Kelly (1997) stuttering is identified as an emerging, dynamic motor disorder with complex interactions between multiple systems (linguistic, cognitive and emotional) and that eventually destabilize the speech motor system. Even though single factor has not been identified as the cause of stuttering, difficulties in lexical access and phonological access seems to play an important role from the current evidences from our study.

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EXPERIMENT 2

BEHAVIORAL AND ELECTROPHYSIOLOGICAL CORRELATES (N400) OF LEXICAL ACCESS IN L1 AND L2 IN BILINGUAL ADULTS WITH STUTTERING

Introduction

Bilingualism is defined as “the regular use of two or more languages” (Grosjean ,1992). Grosjean states that bilinguals are “those people who need and use two (or more) languages in their everyday lives”. Research in bilingual clinical population has been of great importance in the current scenario. Different linguistic processes have been studied in individuals with bilingual aphasia, dyslexia and stuttering. Recently, clinicians and researchers are interested to study the relation between stuttering and bilingualism. However the data on stuttering and bilingualism is inadequate.

Stuttering is a developmental speech disorder which disrupts the flow of speech. According to Grosjean (2010) over 50% of the world’s population is bilingual and 1% of total population stutters (Bloodstein, 1995). The onset of stuttering is between 2 and 4 years of age and 50% of children continue to stutter. The prevalence of stuttering was reported to be more in bilingual children compared to monolingual children (Howell, Davis, & Williams, 2009; Stern, 1948; Travis, Johnson, & Shover, 1937). Considering the risk of stuttering in bilinguals, researchers have examined how the manifestation of stuttering varies in bilinguals across different languages (Ardila, Ramos, & Barrocas, 2011; Cabera, Bernstein, & Ratner, 2000; Maruthy, Raj, Geetha, & Priya, 2015; Robb, 2012). They explained this difference in stuttering manifestation based on different factors such as proficiency, language dominance, age of acquisition of languages, language complexity etc.(Howell et al.,2009; Howell et al.,2004; Janekelowitz & Bortz,1996; Jayaram,1977; Lebrun, Bijleveld, & Rousseau,1990; Lee, Robb, Ormond, & Blomgren,2014; Lim, Lincoln, & Chan, 2008; Scott Trautman & Keller,2000). It has been noted that the severity of stuttering is more in less proficient language than more proficient language (Janekelowitz & Bortz, 1996; Lim et al.,2008; Scott Trautman & Keller,2000).

According to Schafer and Robb (2012) this difference in stuttering manifestation is related to language dominance. They postulated that the language system for second language is weakly developed compared to first language (dominant language) in bilingual adults who stutter. Lim et al.(2008) suggested that this difference in stuttering manifestation across two languages could be explained based on the differences in lexical access in sequential bilinguals. It has been proposed that lexical access from L1 and L2 varies in bilingual individuals. In bilinguals, the L1 lexical semantic system is directly linked to conceptual level whereas L2 lexical semantic system has no direct link to the conceptual level, but it is relayed via L1 lexical semantic system. It is reported that the phonology, vocabulary and the grammar of L1 can influence or interfere with the formulation of linguistic structures in L2 (Chen & Leung, 1989; Kroll & Stewart, 1994; Lim et al., 2008). In sequential bilinguals, there is always a high linguistic demand to overcome the cross linguistic interference. Thus increased linguistic demand in bilingual adult with stuttering may impose more load on the existing weak speech motor system increasing the frequency of stuttering (Lim et al., 2008). However, till today, not many studies have been conducted to investigate whether bilingual individuals with stuttering access their L1 and L2 differently. In the current study we investigate lexical access in bilingual adults who stutter.

In bilinguals who know languages which differ in phonology and orthography, it is important to study the process of phonological access. There are many studies available on phonological access in typical bilingual population (Macizo,2016; Van Wijnendaele & Brysbaert,2002; Zhou, Chen, Yang, & Dunlap ,2006). However phonological access in bilingual clinical population especially in bilingual stuttering has not been given much attention by researchers who view stuttering as a multifactorial disorder (Riley & Riley; 1979; Smith &Kelly,

1997; Starkweather, Gottwald, & Halfond, 1990; Van Riper, 1982; Wall & Myers,1995; Zimmermann, 1980; Zimmermann, Smith, & Hanley, 1981).

In the current study, we investigated lexical access and phonological access in bilingual adults who stutter using behavioral and electrophysiological (N400) measures. The process by which the basic sound-meaning connections of language, i.e., lexical entries are activated is termed as lexical access. The process of activation or retrieval of lexical entries from the mental lexicon by the individuals who speak two languages is referred to as bilingual lexical access. The process by which the information on basic sound units is drawn is referred to as phonological access. In order to investigate lexical access, cross linguistic primed lexical decision task was used in the study which included semantically related, semantically unrelated and word – non word priming conditions in both L1-L2 and L2-L1 directions. Whereas a lexical decision task (in both L1 and L2 separately) was used to investigate the phonological access including words and pronounceable nonwords.

In most of the studies, researchers have used lexical decision task and picture naming task in order to investigate bilingual lexical access (Costa, Miozzo, & Caramazza, 1999; Lee & Williams, 2001; Maldonado, 1997). Among these tasks, primed lexical decision task is most commonly used to understand bilingual lexical access (Meyer & Schvaneveldt, 1971). During priming, the presentation of a stimulus prior to the target increases the accuracy and speed of responses. In general cross-linguistic lexical decision task is carried out incorporating semantic priming, translation priming and repetition priming paradigms (Altarriba, 1990, Chen & Ng,1989; Jiang & Forster,2001; Williams, 1994). Cross-linguistic priming tasks help to understand the operations of bilingual memory. Semantic priming studies are widely used in aphasics to understand the semantic memory deficits in aphasics and to find out the lexical semantic processing (Salles, Holderbaum, Parente, Mansur, & Ansaldo, 2012) and extensively adopted in bilingual research. In the current research, we have used cross-linguistic semantic priming incorporated in a lexical decision task in order to investigate lexical access in bilingual adults who stutter.

Researchers have used phonological priming paradigm in order to give insight into the interlingual phonological access in bilinguals (Brysbaert, Van Dyck, &Van Poel, 1999; Van Wijnendaele & Brysbaert,2002). Similar to methods which study lexical access, naming and lexical decision tasks are also used to study phonological access in bilinguals. In the current study we have used lexical decision task separately in L1 and L2 to understand how the phonological representations are activated in bilinguals. Lexical decision task helps to understand how the words are accessed from the mental lexicon (Rueckl & Aicher, 2008).During lexical decision task the subject is asked to make the judgments of words and nonwords. Since the current study used a visual lexical decision task it requires the participants to read the regular words as well as nonwords. This taps the phonological processes since it involves the use of alphabetic rule, the knowledge of sequencing of phonemes and grapheme to phoneme correspondence (Hoover & Gough, 1990).

In the current study, the behavioral experiment for both cross-linguistic primed lexical decision task and lexical decision task was designed using E-Prime (Psychology software tools) software in order to obtain the accurate measures of reaction time and accuracy. The measure of reaction time gives insight into the time course of lexical access/lexical encoding. Even though the behavioral measures will reflect temporal aspects of linguistic processing difficulties, it is necessary to look beyond behavioral, the covert processes, on investigating stuttering as a clinical phenomenon. Hence, along with the behavioral measures we have recorded N400, an event related potential that accounts for the covert aspects of lexical access and phonological access in bilingual adults who stutter. Researchers have conducted ERP experiments to understand the underlying electrophysiology of language processing using similar tasks and have analyzed N400 amplitude and latency in normal as well as in clinical groups such as aphasics, Right Hemisphere Damage, Alzhiemer's disease, Parkinsosn's disease, dyslexics, stuttering etc. Hagoort, Brown, and Swab(1996) have reported that N400 amplitude reduction in persons with aphasia and right hemisphere damaged individuals with severe comprehension deficits using a priming paradigm. Similarily, Jednorog, Marchewka, Tacikowski, and Grabowska (2010) have reported a delayed N400 in dyslexic children on semantic priming task. Event related potentials were also used to understand the language processing in adults and children who stutter (Huffman, 2009; Maxfield, Morris, Morphew, & Constantine, 2014; Weber-Fox, 2001; Weber-Fox & Hampton, 2008). These studies provide evidences on the impaired lexical activation in PWS in general; however the focus with respect to language processing differences in bilingual stutterers were not given much attention by the researchers. It is important to understand how the neural activation varies when a bilingual stutterer processes in two different languages and access words from one language to another language.

In summary, the investigation of language processing in Kannada-English bilinguals with stuttering would help in understanding the influence of languages with different structure on lexical access and phonological access. Kannada and English are largely different in terms of semantics, syntax, morphology, phonology, syllable structure and orthography. The results of the study would provide the neural evidence of lexical processing in persons with stuttering and also provide information on the effect of language proficiency on the lexical access and its relationship with stuttering. Thus the aim of the present study was to compare the lexical access using cross linguistic semantic priming paradigm and phonological access using lexical decision task in Kannada-English bilingual adults who stutter. And exploring the relationship between language and stuttering also will help clinician to diagnose and modify the treatment strategies accordingly.

Need of the present study

In the current scenario, bilingualism is more prevalent in India and most of the bilinguals acquire English either simultaneously or sequentially along with their native language. English as the second language plays an important role in education and employment system. Hence it is important to study whether the interaction of the two languages which differ in semantics, syntax, phonology and morphology would influence the language processing in terms of lexical access and phonological access in bilingual children and adults. Even though there are chances of cross-linguistic interference while accessing words in particular language, bilinguals successfully select the words from their mental lexicon. This process of bilingual lexical access has been reported by psycholinguistic studies in typical population and clinical population including aphasics and dyslexics.

Considering the high prevalence of stuttering in bilinguals, the information on lexical access and phonological access in bilingual adults who stutter is very limited till date. However there are studies available to evidence the lexical access and phonological access in monolingual adults and children who stutter (Alvarez, Jaramillo, & Cabrera, 2014; Hartfield & Conture, 2006; Pellowski & Conture, 2005; Sasisekaran & Byrd, 2013). Most of the studies have used behavioral measures in probing lexical access and phonological access in stutterers. The behavioral measures are subjected to lot of variability as they are prone to speculation related factors, reducing the objectivity of the behavioral measures. Hence these measures have to be cross-verified by employing electrophysiological measures. In order to comment on the differences in cross-linguistic processing between bilinguals who stutter and other typical/clinical population, it is important to understand how the mechanism of lexical access and phonological access operates in them. Hence, the current study aims to establish the trend of lexical access and phonological access in bilingual adults who stutter using both behavioral and electrophysiological measures. The first objective of the current study is to investigate whether the effect of cross-linguistic semantic priming on lexical access is in the predicted direction in bilingual adults who stutter using a cross-linguistic primed lexical decision task. The second objective is to investigate the difference in phonological access between two acquired languages in bilingual adults who stutter using a simple lexical decision task. Thus the aim of the current study is to investigate lexical access and phonological access in Kannada-English bilingual adults who stutter who had acquired Kannada (L1) as their native language and English as their second language (L2). Kannada is a Dravidian language which is different in its structure compared to English. This would also help to understand whether the language specific difference in terms of orthography, phonology and semantics would influence cross linguistic lexical access and phonological access in Kannada- English (K-E) bilingual adults who stutter (BAWS). Overall, the results of the current study would be the first ever evidence in psycholinguistic research incorporating behavioral and electrophysiological measures to understand the process of lexical access and phonological access in BAWS.

Research Questions and Hypotheses

The research questions of our current study include the following:

i) How does cross-language semantic priming effects the lexical access in L1 and L2 in Kannada-English bilingual adults who stutter on a cross-linguistic primed lexical decision task in L1-L2 and L2-L1 directions (based on behavioral and electrophysiological measures) including semantically related, semantically unrelated and word- nonword pairs.

ii) How does the phonological access differ between two acquired languages on a lexical decision task in Kannada and English (based on behavioral and electrophysiological measures) including words and pronounceable non words.

Our hypotheses include the following:

i) BAWS will perform poorly on L2-L1 primed lexical decision task compared to L1-L2 direction in both behavioral and electrophysiological measures. There will be a delay in processing of semantically related, semantically unrelated and word- non word pairs in L2-L1 direction compared to L1-L2 direction indicating a typical pattern of cross-linguistic semantic priming effect in BAWS.

ii) BAWS will perform better in Kannada compared to English in both behavioral and electrophysiological measures of lexical decision task. There will be a delay in processing of words and non words in English (L2) compared to Kannada (L1). This would suggest phonological access better in L1 than L2 in K-E bilingual adults who stutter.

If the above hypotheses are correct, then the current study would be the first ever behavioral and electrophysiological evidence to report the cross linguistic lexical access and phonological access in bilingual adults who stutter.

Review of Literature

The research in the area of stuttering across different cultures and languages reveal that stuttering is exhibited by both monolinguals and bilinguals (Finn & Cordes, 1997).It is also believed that stuttering is more prevalent in bilinguals than monolinguals (Eisenson, 1984; Karniol, 1992; Mattes & Omark, 1991; Shames, 1989). Researchers have tried to explore the relationship between stuttering and bilingualism. According to Travis et al.(1937) there is a direct relation between bilingualism and stuttering. They reported that the age of onset of stuttering coincided with the age at which second language was introduced in 26% of bilinguals with stuttering. It is observed that expression of stuttering would differ across the languages. Over the years researchers have tried to find the cause for difference in stuttering manifestation across two languages in bilingual stutterers.

Many authors report language related factors as the cause of this difference in stuttering manifestation across the two languages. Karinol(1992) reported that syntactic overload would be the reason for stuttering in a Hebrew-English bilingual child which can be explained based on Neuroscience model of stuttering(Nudelman, Herbrich, Hoyt,& Rosenfield,1989).According to this model, more stuttering in English is due to additional processing time required for either outer loop for ideation and linguistic programming or inner phonatory loop for motor programming of speech motor control leading to instability. Few of the researchers have also reported that the change in environment during the second language acquisition can lead to high risk of anxiety which might lead to developing stuttering in children (Mussafia,1967 ; Travis et al., 1937). Lebrum and Paradis(1984) reported that linguistic input with mixed utterances from both the languages can cause the development of stuttering in bilingual children. On similar lines Cabera, Bernstein, and Ratner (2000) reported a relation between code switching behaviors and dysfluencies in Spanish-English bilingual boy. According to the authors difficulty to formulate the language will result in fluency failures. Ardila et al.(2011) have reported that specific pattern of stuttering may be found in each languages based on a case study done in a 27 year old Spanish –English bilingual boy who has acquired both the languages simultaneously and English was the dominant language. Results revealed that stuttering occurred twice more in verbs, adjectives, conjunctions and adverbs in non dominant language (Spanish) indicating language specific pattern of stuttering. Schaffer and Robb(2012) have analyzed how the stuttering frequency varies across function and content words in German-English bilingual stutterers. The analysis of the language samples revealed that stuttering frequency was more in the second language (English) compared to first language (German). In the first language content words were more dysfluent than function words whereas in second language no significant difference was noticed between word types. They have also noticed that across L1 and L2, more function word dysfluencies and less content word dysfluencies were in L2.The authors report that reason for the difference in performance could be attributed to poorly developed language system.

The researchers report that the bilingual stutterers would stutter in both the languages and the severity of stuttering would vary across the languages. The factors affecting the varying severity in the languages are also of research interest. Researchers have proposed various reasons for this variation of stuttering across languages. The available investigation reports reveal that degree of stuttering is affected by language proficiency. It has been noted that the severity of stuttering is more in less proficient language than more proficient language (Janekelowitz& Bortz, 1996; Lim et al.,2008; Scott Trautman & Keller,2000). On similar lines, a study by Maruthy et al.(2015) in Kannada –English bilingual PWS has focused on how the degree of stuttering will vary across two languages. The result revealed increased stuttering in L2 (English) compared to L1

(Kannada) and the analysis of frequency of stuttering on content words and function words between two languages have revealed that content words were more stuttered in L1 and function words more stuttered in L2.The overall findings indicated that frequency of stuttering would be more in least proficient language compared to more proficient language. However few researchers argues that BWS stuttered more frequently in their more proficient language compared to less proficient language(Howell et al.,2004; Jayaram,1983).It was found that the dysfluencies increased on content and function words in first language than second language in Spanish-English BWS(Howell et al.,2004).They also reported that stalling dysfluencies(phrase repetitions , and filled or silent pauses) were less than nonstalling dysfluencies(prolongations, part-word repetitions and complete stops) in L1 than L2.The current evidences indicate that the findings on effect of language proficiency on the severity and type of stuttering are inconsistent.

The researchers are also interested to know how the similarities of the languages known for the bilinguals affect the occurrence of stuttering in them. Thus the concern on this regard is whether stuttering is more in the individuals who speak two related or totally unrelated languages. It could be postulated that the closely related languages can lead to confusion and thus more dysfluencies or the nonrelated languages results in increased demand in learning two different syntactic and lexical systems leading to more dysfluencies (Van Borsel, Maes, & Foulon, 2001).Currently there are no evidences to support either of these views.

Another factor which was studied by the investigators is the relation between age of second language learning and the onset of stuttering. Studies have reported that young children are more prone to stutter when they are learning two languages (Au-Yeung, Howell, Davis, Charles, & Sackin, 2000; Stern, 1948).According to Stern (1948) the frequency of occurrence of stuttering was more in individuals who acquired two languages before the age of 6 years than monolingual speakers. The noticeable fact is that stuttering onset is not reported in adults who learn second language. It could be hypothesized that early bilinguals are more susceptible to stuttering because they use same brain structures to learn both the languages. And thus stuttering results from the functional overload executed on those brain structures. Whereas prevalence of stuttering is less in bilingual adults since the processing of the two languages take place in different brain structures (Van Borsel et al., 2001).The several brain imaging studies also highlights difference in hemispherical dominance in bilingual stutterers for language processing(Braun et al.,1997; Braun &Ludlow,1995;Fox et al.,1996).Few imaging studies support the role of proficiency on cortical representation of language rather than age of acquisition of bilingualism. On similar lines Perani et al.(1996) found that PET studies revealed different type of cortical activity in low proficient bilinguals who stutter than high proficient BWS regardless of age of acquisition of second language.

Expression of stuttering in bilinguals

Over the years studies have reported different patterns of stuttering manifestations in bilingual PWS. These patterns could be explained based on the hypotheses proposed by Nwokah(1988). One of the possible pattern include the existence of stuttering in one language and not in the other, second possibility is that stuttering might occur in both the languages with similar speech problems(same hypothesis) and the last probable pattern is the occurrence of stuttering in both the languages but speech problems vary from one to another(difference hypothesis).The literature reveals that there are very few studies which support that stuttering occurs in one language and not in the other. In support of this pattern Dale (1977) reported that all four

Spanish-English bilingual adults in his study exhibited stuttering only in Spanish. In a study Van Riper (1971) reported that a Japanese –German bilingual adult with stuttering exhibited fear on the same sounds in both the languages which supports the second pattern. These findings are consistent with studies done by Howell et al., 2004; Howell et al., 2009; Jayaram, 1977; Lebrun et al.,1990, and Lee et al.,2014.It was noted that there are two viewpoints related to difference hypothesis which is based on the proficiency level. The study by Jayaram (1983) in Kannada-English bilingual adults with stuttering revealed that the frequency of stuttering was more in non-dominant language i.e. English during spontaneous speech but the pattern of distribution of stuttering did not differ across languages. However there are variations noted in other studies with respect to degree and distribution of stuttering in both the languages. Bernstein Ratner and Benitez (1985) reported that the loci of stuttering varied in a Spanish-English bilingual adult with stuttering who used both the languages almost equally. A case study by Hernandez-Jaramillo & Gomez (2015) in a Spanish-English bilingual adult also reported more frequency of stuttering in English(second language) compared to Spanish(first language) and in both the languages function words were more stuttered than content words. According to Nowkah (1988) nature and degree of stuttering varied in Igbo-English bilingual adults during spontaneous speech and reading even though they were equally competent in both the languages. On similar lines a study by Jankelowitz and Bortz(1996) in English-African adult male with stuttering suggests that language proficiency and dysfluent behavior were interrelated, and the language ability influenced the location, extent and nature of stuttering behaviors.

There are limited studies focusing the effect of characteristics of different languages and the mastery of languages on frequency of stuttering. One among the study by Lim et al. (2008) discussed about the influence of language dominance on the type and severity of Mandarin-

English bilingual individuals across a wide age range. The results revealed that the frequency of stuttering in both the languages did not differ in balanced bilinguals. Whereas the less dominant language was more stuttered by Mandarin dominant and English dominant bilingual individuals. It was also observed that the type of dysfluencies is not influenced by language dominance. On similar lines Schafer and Robb (2012) reported that more stuttering was found in L2(English) than L1(German) in German-English bilingual speakers and this difference is related to language dominance which indicate that L2 is weakly developed language system in bilingual adult with stuttering. Increased stuttering in L2 compared to L1 could be explained on the basis of differences in the lexical access in two languages in sequential bilinguals (Lim et al., 2008). However, till today, not many studies have been conducted to investigate whether bilingual individuals with stuttering access their L1 and L2 differently. Hence the current study aims to understand the lexical access differences in individuals with stuttering across two languages and to investigate the underlying electrophysiology while processing in different languages.

Models of lexical access in bilinguals

The process by which the basic sound-meaning connections of language, i.e., lexical entries are activated is termed as lexical access. The process of activation or retrieval of lexical entries from the mental lexicon by the individuals who speak two languages is referred to as bilingual lexical access. In bilinguals there should be suppression of lexical entries from the language not in use when asked to perform a task in particular language. For example when a Kannada-English bilingual adult is asked to name a picture of a cat in Kannada, he should be able to suppress the lexical items which are activated in English and name the picture appropriately in Kannada.

There are various models of lexical access in bilinguals to answer whether they have same or different mental lexicon for the known languages. The most popular models of lexical access are Word association model, Concept mediation model, Revised hierarchical model and mixed model which tries to explain the language processing in bilinguals.

Word association model (Potter, So, Von Eckardt & Feldman, 1984)

As per Word association model (see Figure 1), L2 word is linked to its conceptual information only through L1.If a speaker has to access the meaning of a word in L2 then they have to first activate the equivalent word in L1 and then the meaning of required word is accessed.

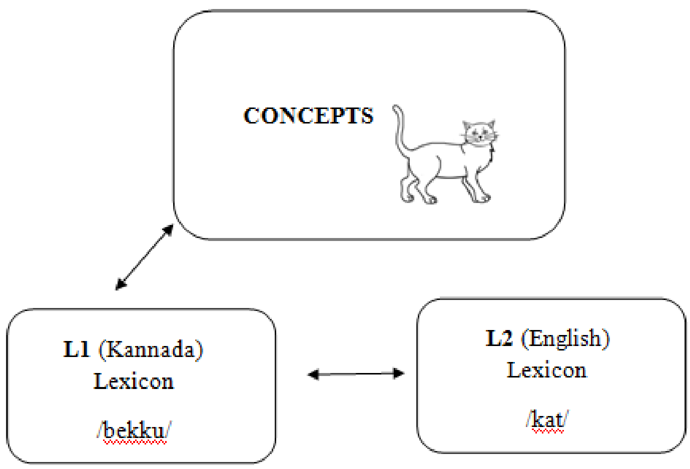


Figure 1: Word association model (Potter, So, Von Eckardt & Feldman, 1984)

Concept Mediation model (Potter et al., 1984)

Potter et al., 1984 (see Figure 2) proposed that L1 and L2 are directly linked to the conceptual system. The words in L1 and L2 can be accessed directly from the concept.

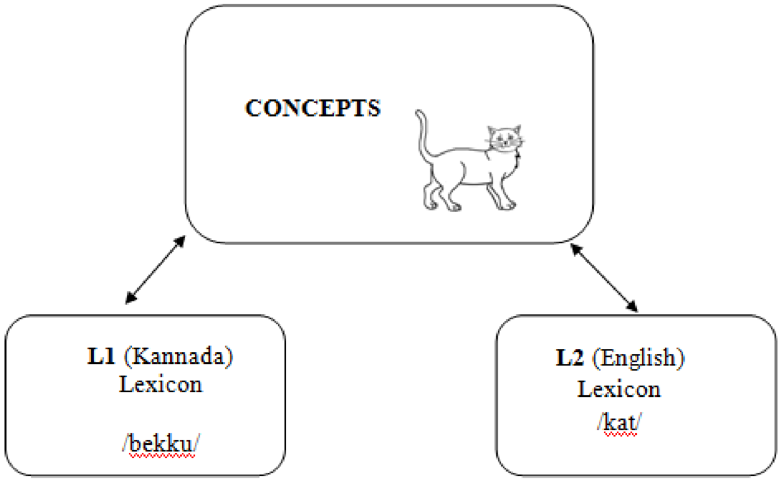


Figure 2: Concept Mediation model (Potter et al., 1984)

Mixed model (De Groot, 1992)

De Groot, 1992 (see Figure 3) proposed that in a bilingual individual the lexicon in each language have a direct link between each other and they are indirectly linked through shared semantic representations.

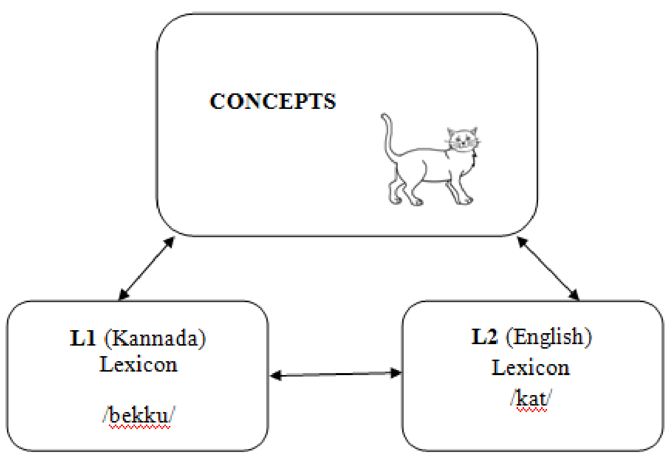


Figure 3: Mixed model (De Groot, 1992)

Revised hierarchical model (Kroll and Stewart, 1994)

According to this model, there is an asymmetry in the lexical system for L1 and L2 .The model postulates that there is lexical and conceptual link between L1 and L2 (see Figure 4).The lexical mediated link is stronger in L2-L1 direction than in L1-L2 direction. On the other hand, the conceptual mediated link is stronger in L1-L2 direction than L2-L1 direction.

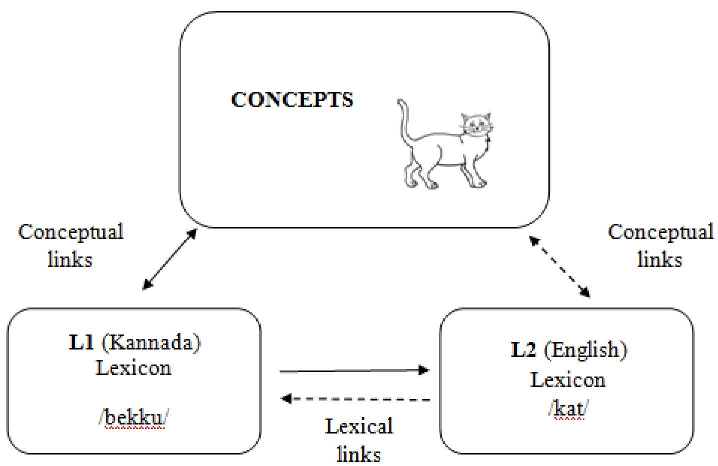


Figure 4: Revised hierarchical model (Kroll and Stewart, 1994)

Lexical access in bilinguals

Lexical access has been studied in typical and clinical bilingual population to understand the cross linguistic differences at the level of conceptual representation. Researchers have tried to answer to various questions related to the lexical access in bilinguals such as a) is there a parallel activation of semantic system in a bilingual with two mental lexicon? b) while selecting the lexicon in a particular language ,is there any interference by the equivalent lexicon of the other language? The studies to answer these questions have used various methods to understand the lexical access in bilinguals which include lexical decision task, picture naming and semantic categorization.

Lexical access in typical bilingual population has been discussed by various researchers. A study by Costa et al. (1999) addressed the interference effect during word selection in Catalan–Spanish bilinguals. They have conducted a picture- word interference experiment, wherein bilinguals named pictures in Catalan language. The distractor words were printed in Catalan (same) or Spanish (different) language. Results revealed that the naming responses were more for same language pairs and for the semantically related picture-distracter pairs compared to different language pairs suggesting competing lexicons while performing lexical selection in bilinguals. It is also postulated that there is lexical competition in bilinguals while using a selected language. Maldonado(1997) had studied the organization of mental lexicon in Spanish-English bilinguals using a lexical decision experiment with repetition priming. The results revealed that repetition priming was stronger in L1-L2 direction than L2-L1 direction in low proficient bilinguals whereas no such difference was noticed in high proficient bilinguals. Lee & Williams (2001) had investigated lexical selection in English-French unbalanced bilinguals using a picture naming task. It was observed that the reaction time was increased and accuracy was reduced in French language i.e. the non dominant language. The results suggest that bilingual individual's exhibits language specific lexical selection. The performance of bilinguals during a lexical decision task may vary according to the proficiency level in each of the acquired languages. It is reported that the reaction time during lexical judgment task is increased in the less proficient language compared to more proficient language (Deema & Prema, 2005).The reason for this could be the simultaneous activation of lexical representation in both the languages makes the lexical access difficult in bilinguals (Finkbeiner, Almeida, Janssen, & Caramazza ,2006) leading to slow reaction time during the lexical judgment tasks. Finkbeiner et al.(2006) had also tested language suppression hypothesis using picture naming task with language switching trials. As per language suppression hypothesis, the lexical activation of non target language needs to be inhibited for appropriate selection in the target language (Green, 1998). The result indicated that the participants did not take long time to name the pictures in their dominant language compared to the non switch trials. The result was not in accordance with the prediction based on language suppression hypothesis. The lexical deficits in bilinguals compared to monolinguals are further evidenced by the cross linguistic priming experiments. Ivanovo & Costa (2007) investigated the difference in lexical access between monolinguals (Spanish) and bilinguals (Spanish- Catalan) using a picture naming task. The results revealed that the bilinguals were slower in performing in both dominant and non dominant languages compared to monolinguals. Researchers have also investigated the lexical processing in bilinguals using event related Potentials. Geyer, Holcomb, Midgley, and Grainger (2011) have studied how the words are processed in two languages in Russian-English bilinguals using a cross linguistic translation priming study using a lexical decision task. They have revealed increased N400 amplitude suggesting a stronger switching effect from L1-L2 direction and a smaller and later N400 in L2-L1 direction. Few studies had also reported slow word recognition has also been evidenced in bilinguals compared to monolinguals (Martin, Costa, Dering, Hoshino, Wu, &Thierry, 2012). Martin et al.(2012) had reported that English-Welsh bilinguals had difficulty in discriminating words and pseudo words compared to monolinguals. Zhao, Li, Liu, Fang, & Shu (2011) had studied translation and semantic priming in Chinese-English bilinguals using translation equivalent and semantically related word pairs. The results indicated a priming asymmetry reflected as larger priming from L1-L2 than from L2-L1 direction.

There are few cross linguistic studies in Indian languages carried out to understand lexical access in typical bilingual population. Deema and Prema(2005) had reported priming effects to be stronger and larger in L1-L2 condition than L2-L1 condition in Kannada-English bilingual adults. The results were in agreement with the predictions of Revised Hierarchical Model. The literature also reports lexical access studies in bilingual clinical population and most of these studies are done in aphasics. Kiran and Lebel (2007) had studied cross linguistic semantic and translation priming in Spanish-English(S-E) bilingual aphasics. They reported that English target were more accurate(S-E direction) than Spanish targets (E-S) in bilingual aphasics. There are studies reported in literature highlighting the lexical access in monolingual adults who stutter (Hand &Haynes, 1983; Jescheniak & Levelt, 1994; Rastatter & Dell,1987). However the lexical access in bilingual adults who stutter has not been received much attention by the researchers. Only one study was reported in bilingual adults with stuttering by Sindhupriya and Maruthy(2013) in Kannada-English bilinguals. They have checked the lexical access in 15 Kannada-English bilingual adults using a cross modal priming paradigm using a picture naming task. Lexical access in Kannada and English was separately assessed in three different conditions: neutral prime, semantically related, semantically unrelated prime-target word pairs and lexical access using cross linguistic priming included translation equivalent, semantically related and semantically unrelated prime-target word pairs. The results revealed that there was no significant difference in lexical access within languages in both in persons who stutter and those who do not stutter. There was a slow reaction time in L2-L1 cross linguistic priming condition compared to L1-L2 condition for translation equivalent and related prime target pairs.

In summary, only a limited number of studies have highlighted the cross language semantic priming effects in bilingual clinical population such as stuttering. There have been no electrophysiological studies which have more objectivity than behavioral measures on this regard. Studies are required to examine the process of bilingual lexical access in adults who stutter using behavioral as well as objective measures. Our research investigated lexical access using cross linguistic semantic priming in Kannada-English bilingual adults who stutter.

Phonological access in bilinguals

There are many studies on the question regarding how does lexical access operates in bilinguals. However there is much less research on phonological access in bilinguals. Recently there has been an increasing amount of studies on this regard. The process of obtaining information on basic sound units is referred to as phonological access. According to the models of lexical access; phonological access is considered to be distinct stage involved in lexical processing. The first stage is accessing the meaning of a word (lexical semantics) and the second stage is accessing the sound code (lexical phonology) (Caramazza, 1997; Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Griffin & Bock, 1998; Levelt, Roelofs, & Meyer, 1999; Rapp & Goldrick, 2006). The second stage is referred to as lexical phonological access. In bilinguals who know languages which differ in phonology and orthography, it is important to study the process of phonological access. Interlingual phonological access has been studied using phonological priming paradigm in most of the studies. Similar to methods which study lexical access, naming and lexical decision tasks are also used to study phonological access in bilinguals. Marc, Goedele, and Marijike(1999) studied phonological access in Dutch- French bilinguals using masked phonological priming paradigm. They reported that interlingual phonological priming effect was equal in L1-L2 and L2-L1 directions in Dutch- French bilinguals. On similar lines, Van Wijnendaele and Brysbaert(2002) had noticed that cross linguistic phonological priming operate in both L1-L2 and L2-L1 directions in French- Dutch bilinguals suggesting phonological access is less language specific in bilinguals. Zhou et al. (2006) had used naming task and lexical decision task in order to investigate bilingual phonological representations in Chinese- English bilinguals incorporating homophone priming paradigm. They also reported priming effects in both language directions suggesting integrated lexicon activation while accessing the phonological representation in both naming and lexical decision task. Dyuk (2005) also had reported that while processing the phonology of target language , phonology of the non target language also would be automatically activated in a priming task on the basis of results from a study in Dutch- English bilinguals using pseudo homophones. When we consider that reading involves phonologic access, reading two languages which differ in orthography and phonology also would provide information on phonological access in bilinguals. It is evidenced that bilinguals are slower to read aloud printed words in L2 than L1. La Heij, Hooglander, Kerling, and Van der Velden (1996) had noticed that bilinguals took longer time to name the colors in L2 than L1. On similar lines, Kroll and Stewart (1994) had also reported similar results on word naming task. A recent study by Macizo(2016) investigated phonological activation in Spanish- English bilinguals using color naming task. Participants were asked to name colors in L2. Meanwhile the target words were either phonologically related or unrelated to the L1 words. It was reported that the naming latency was slower when the target words (L2) were phonologically related to the L1 words. The results suggested co activation of phonology of L1 and L2 and influence of L1 phonology on L2. Literature reports few studies which have used lexical decision task alone in order to understand how phonological representations are operated in bilingual adults. Dijkstra, Grainger, and Van Heuven (1999) reported longer decision time for English words which were homophonic to Dutch words than English control words in Dutch-English bilinguals on a lexical decision task. The results indicated that activation of phonological representations in second language might also activate phonological representation in dominant language. In another study, Brysbaert et al.(1999) had reported that primes in dominant language which is phonologically similar to the target words in second language would facilitate lexical decision.

An overview of literature suggests that naming and lexical decision task with or without priming is widely used in bilingual adults in order to investigate phonological access. Among these tasks phonological priming and naming are lexically supported which can't isolate phonological access alone. In the current study we have used lexical decision task in which subjects were asked to judge words and non words in L1 and L2 separately in order to understand phonological access in bilingual adults who stutter.

In summary, the review of literature revealed the evidence of stuttering manifestations in bilinguals, the important models to highlight the process of lexical access in bilinguals and lexical access and phonological access in bilingual adults in general. There were limited evidence reporting lexical access and phonological access in bilingual clinical population especially in adults who stutter.

Method

In the current experiment behavioral and electrophysiological correlates (N400) of lexical access were compared between L1 and L2 in Kannada-English bilingual adults with stuttering using primed lexical decision task and lexical decision task. The primed lexical decision task included cross-linguistic priming paradigm (L1 to L2 and L2 to L1) and lexical decision task was carried out in both L1 and L2 separately.

Participants

15 male participants who stutter in the age range of 18-40 years (Mean age=23.66 years; SD=5.42 years) were recruited for the study. All the participants in the study had acquired Kannada as native language (L1) and English as second language (L2). They all had minimum of 8 years of exposure to English. They were asked to rate their proficiency on each language on Language Experience and Proficiency Questionnaire (LEAP-Q) which is a self-rating scale. It was developed by Marian, Blumenfeld, and Kaushanskaya (2007). The presented study used the questionnaire in Kannada which was adapted and validated by Ramya and Goswami (2009). Each participant rated their proficiency in known languages with respect to different domains such as understanding, speaking, reading, and writing. Each domain was rated on a scale ranging from 0 to 4 i.e. zero proficiency to native like/perfect proficiency. Table 1 shows the self rated language proficiency score in bilingual adults with stuttering (BAWS) on 4 domains in both Kannada and English.

Table 1: *A description of Bilingual Adults who do Stutter including their age and LEAP-Q scores in L1 (Kannada) & L2 (English)*

BAWS	**Age**	**LEAP-Q scores for L1**	**LEAP-Q scores for L2**
S1	21	U-4;S-4;R-3;W-3	U-3;S-3;R-3;W-3
S2	18	U-4;S-4;R-3;W-3	U-3;S-3;R-3;W-3
S3	23	U-4;S-4;R-4;W-4	U-4;S-3;R-3;W-3
S4	40	U-4;S-4;R-4;W-4	U-4;S-3;R-3;W-3
S5	20	U-4;S-4;R-4;W-4	U-4;S-4;R-4;W-4
S6	21	U-4;S-4;R-4;W-4	U-3;S-3;R-3;W-3
S7	20	U-4;S-4;R-4;W-4	U-3;S-3;R-3;W-3
S8	24	U-4;S-4;R-4;W-4	U-4;S-4;R-4;W-4
S9	28	U-4;S-4;R-4;W-4	U-4;S-3;R-3;W-3
S10	29	U-4;S-4;R-4;W-4	U-4;S-3;R-4;W-4
S11	21	U-4;S-4;R-4;W-4	U-3;S-3;R-3;W-3
S12	21	U-4;S-4;R-4;W-4	U-3;S-3;R-3;W-3
S13	25	U-4;S-4;R-4;W-4	U-4;S-4;R-4;W-3
S14	21	U-4;S-4;R-4;W-4	U-3;S-3;R-3;W-3
S15	23	U-4;S-4;R-4;W-4	U-4;S-3;R-3;W-3

(1-Zero proficiency; 2-Low Proficiency; 3-Good Proficiency; 4-Native like/Perfect) U-Understanding; S-Speaking; R-Reading; W-Writing

In the current study stuttering severity was determined in both Kannada and English with the Stuttering Severity Instrument-Fourth Edition (SSI-4; Riley, 2009).For this, reading and spontaneous speech samples in Kannada and English were collected from all the participants. Inclusion criteria included (a) confirmation of the diagnosis of stuttering based on spontaneous speech and reading speech samples, (b) the onset of stuttering occurred prior to the age of 6, (c) no speech, language or hearing problems other than stuttering, (d) no known neurological or psychological problems or learning disabilities, and (e) not taking any medications that may have possible effects on sensory or motor systems. Table2 shows the participants details including the age, stuttering severity in L1 and L2.All the participants in the study were right handed based on the self report. Participation of the participants in the study was voluntary and participants were enrolled only after obtaining their written consent.

Table 2: *Demographic details of bilingual adults who stutter (BAWS)*

Bilingual Adults who stutter	**Age**	**Handedness**	**Severity of Stuttering in Kannada**	**Severity of Stuttering in English**
S1	21	Right	Mild	Mild
S2	18	Right	Very Severe	Very Severe
S3	23	Right	Severe	Severe
S4	40	Right	Moderate	Moderate
S5	20	Right	Severe	Severe
S6	21	Right	Mild	Mild
S7	20	Right	Moderate	Moderate
S8	24	Right	Moderate	Moderate
S9	28	Right	Moderate	Moderate
S10	29	Right	Severe	Severe
S11	21	Right	Moderate	Moderate
S12	21	Right	Severe	Severe
S13	25	Right	Moderate	Moderate
S14	21	Right	Moderate	Moderate
S15	23	Right	Mild	Moderate

Table 3: *SSI scores of bilingual adults who stutter (BAWS) in Kannada and English*

Bilingual adults who stutter	**SSI score in Kannada**	**SSI score in English**
S1	18	19
S2	37	37
S3	31	32
S4	24	26
S5	32	32
S6	19	20
S7	25	27
S8	25	24
S9	25	28
S10	31	33
S11	25	28
S12	32	34
S13	26	26
S14	26	25
S15	22	25

Stimuli

The experiment included primed lexical decision task and lexical decision task in order to check lexical access in bilingual adults with stuttering. Primed lexical decision task was carried out using a cross-linguistic priming paradigm in which the prime and the target were presented in the following conditions.

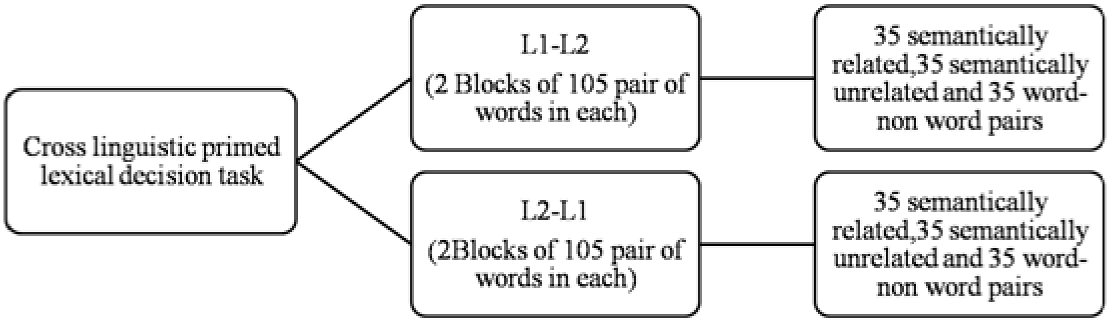
(i) Prime in L1(Kannada) and target in L2 (English)

(ii) Prime in L2(English) and target in L1(Kannada)

Both of the above conditions included semantically related, semantically unrelated prime-target pairs and word- nonword pair conditions.

Cross linguistic priming paradigms are widely used by the researchers in order to understand the effect of language directions on lexical access in bilinguals (Brown & Altarriba, 2007; Jiang & Foster, 2001; Kiran & Lebel, 2007). Lexical decision task was carried out separately in both Kannada and English to understand the difference in lexical access between the two languages.

As part of stimulus preparation, a total of 300 commonly used Kannada words and 300 commonly used English words were listed. Later 200 pronounceable nonwords in Kannada were prepared by transposition of syllables within the original word (Prema, 2009) and a list of 200 pronounceable nonwords in English was prepared by randomly changing the sequences of syllables. In the current study, nonwords were pronounceable letters/phoneme strings that do not form a valid word, however they followed the phonotactic structure in the testing language .Further from the initial list, all the words in Kannada and English prepared for both primed lexical decision task and lexical decision task were given for familiarity check. Kannada words were rated by 5 SLPs who are native speakers of Kannada and English words were rated by 5 SLP's who are highly proficient in English on a 3 point scale as very familiar, familiar and unfamiliar. The words which were rated as very familiar and familiar were only chosen to prepare the final set of stimuli and it contained 280 true words in Kannada and 250 true words in English. Another word list consisting of 200 nonwords in Kannada and 200 nonwords in English were also given to 2 experienced SLPs. They were asked to rate them as easily pronounceable and not easily pronounceable considering the length and complexity of words. From the initial nonword list, the complex, lengthier and difficult to pronounce nonwords were removed and the rest of them only were used to prepare the final nonword lists for lexical decision task in Kannada, English and to prepare the nonword pairs for primed lexical decision task. The 160 nonwords in Kannada and 150 nonwords in English which were accepted after the rating were used to prepare the nonword pairs for primed lexical decision task. Further, the final stimuli were prepared for primed lexical decision tasks (in L1-L2 and L2-L1 priming conditions) and lexical decision task (in Kannada and English) (See Figure 5).



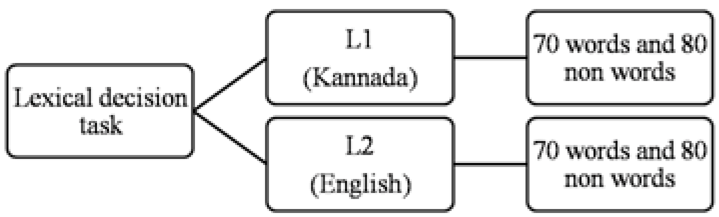


Figure5: Diagram indicating the final word list after the rating by SLP's

Stimuli selection

Two tasks were done for this experiment. First task was *primed lexical decision task* in cross-linguistic conditions (L1 to L2 and L2 to L1). The second task was *lexical decision task* separately in L1 and L2. For *primed lexical decision* task, two blocks consisting of 105 word pairs in L1 to L2 and L2 to L1 were used. Any one block of stimuli was presented to the individuals. Out of 105 word pairs, in each condition 35 word pairs had prime and target which are semantically related, 35 semantically unrelated and 35 nonwords. In the semantically related prime-target condition, the prime was semantically or associatively related with the target word whereas in the semantically unrelated condition the prime and target were not semantically or associatively related to each other (Chiarello, Burgess, Richards, & Pollock 1990; Hines, Czerwinski, Sawyer, & Dwyer, 1986; Lupker ,1984)

The second task was *lexical decision task*. Stimuli for this task comprised of 150 stimuli (70 words and 80 nonwords) in Kannada and English separately (See Figure 5).

Procedure for behavioral task

Primed lexical decision task:

For the primed lexical decision task, the word pairs comprised of 35 semantically related, 35 semantically unrelated, and 35 nonwords in both L1 to L2 and L2 to L1 condition. The presentation of word pairs was programmed in E-Prime.2.0 software (Psychology Software Tools. Inc). E-Prime.2.0 software is used extensively for priming studies to get reaction time and accuracy measurements (Andrade, Juste , &Tavares, 2012 ; Heyman, Van Rensbergen, Storms, & Hutchison, 2015; Van de Weijer, Paradis, Willners, & Lindgren, 2012;Silkes & Rogers,2010).The experimental paradigm which was used in the current study was similar to the paradigm used by Fullenkamp (2013) and Murphy (2012).

In the current study the overall experiment in each condition (L1-L2 and L2-L1) consisted of a training procedure and a testing procedure. The training procedure consisted of 10 prime-target trials also comprising of semantically related, unrelated and non words which were presented initially to familiarize the participants with the task. Primes and the target words appeared in white font color and were aligned at the centre of screen Words were displayed in “Times New Roman” font, with a font size of 72 on a black background. The prime was displayed for duration of 1000 milliseconds. The prime word was followed by a fixation period of 500 milliseconds, after which the target word was displayed for duration of 1000 milliseconds. The next prime word appeared after 2500 milliseconds. The task for the participants was to decide if the presented target is a word or nonword.

Cross linguistic priming paradigm was carried out to test if the other language (L1 while testing L2 and L2 while testing L1), will have any influence on the lexical access of bilingual participants. In other words, this could possibly tell if the other language is facilitating or interfering with the lexical access of the language under test.

Instructions for L1-L2 cross linguistic primed lexical decision task:

"I will present few pair of words. The first word will be in Kannada and the second word in English. The English word will appear after a "+" sign following the Kannada word. Pay attention to the English word which will appear after "+" sign. Press "1" if it is a true word and "2" if it is a nonsense word as soon as possible."

Instructions for L2-L1cross linguistic primed lexical decision task:

"I will present few pair of words. The first word will be in English and the second word in Kannada. The Kannada word will appear after a "+" sign following the English word. Pay attention to the Kannada word which will appear after "+" sign. Press "1" if it is a true word and "2" if it is a nonsense word as soon as possible."

Lexical decision task:

For *the Lexical decision task* (Separately for Kannada and English) only target words were presented for 1000 milliseconds with an interstimulus interval of 2000 milliseconds. Stimuli for this task comprised of 150 stimuli (70 words and 80 non words) in each of the languages. The task for the participants was to decide if the presented target is a word or non word.

Instructions: “I will present few true words and nonsense words. Press “1” for true words and “2” for nonsense words as soon as possible.”

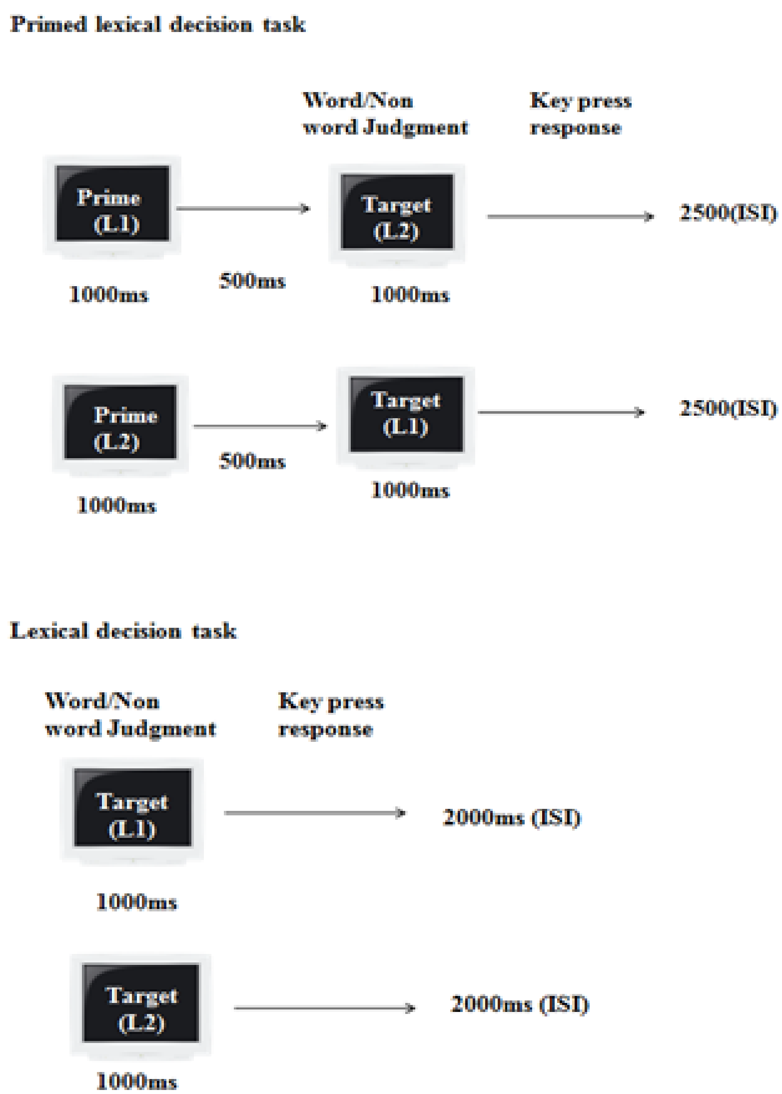


Figure 6: Schematic diagram of presentation of stimuli for cross linguistic primed lexical decision task and lexical decision task for behavioral task

Behavioral responses

For both cross-linguistic primed lexical decision task (in both L1-L2 and L2-L1 condition) and lexical decision task (in Kannada and English), the mean reaction time and accuracy of responses were measured using E-Data aid module of E-Prime software. Reaction time is defined as the interval of time between presentation of stimulus and appearance of voluntary response (Key press in the current study) in the subject (Batra ,Vyas, Gupta, Gupta, & Hada, 2014). The accuracy of responses was measured in percentage for both cross-linguistic primed lexical decision tasks in L1-L2 and L2-L1 condition and lexical decision tasks in both Kannada and English. For the cross-linguistic primed lexical decision task, the mean reaction time and accuracy of target responses for semantically related, unrelated, and word-nonword pair conditions were extracted in L1-L2 as well as in L2-L1 condition. Similarly, mean reaction time and accuracy for words and nonwords for lexical decision task in Kannada and English were also obtained. Further, the reaction time and accuracy of AWS were compared between L1-L2 and L2-L1 priming conditions and also with respect to the lexical judgment across Kannada and English.

ERP recording

As in the behavioral task, apart from the cross-linguistic primed lexical decision task (L1-L2 and L2-L1), the lexical decision task was also administered on each participant in both L1 and L2 conditions. ERP recording was done after behavioral task. Minimum of two days of gap was given between the behavioral and ERP data collection for an individual. Continuous EEG recording was done for both cross-linguistic primed lexical decision task and lexical decision task. The same set of stimuli which was used for behavioral task was used while recording ERP's for decision task in Kannada (L1) and English (L2). The second block of stimuli was used for cross-linguistic primed lexical decision task in L1-L2 and L2-L1 condition including semantically related, unrelated and nonword pairs wherein the word pairs were repeated thrice and presented in random order. The second block was considered for continuous EEG recording in order to avoid practice effect. The cortical event related potentials were recorded using Compumedics Neuroscan instrument with SynAmps^2 amplifier. The participants were seated comfortably on a reclining chair. An elastic cap (Quick-cap by Compumedics- Neuroscan) with

64 sintered silver chloride electrodes was used for recording event related potentials. Twenty electrodes were placed on the following locations FPz, Fz, FCz, Cz, CPz, Pz, Oz, F3, F4, FC3, FC4,C3, C4, CP3, CP4, P3, P4, TP7, TP8, O1 & O2 based on international 10-10 system (See Figure 7). Bipolar electrodes were placed over left and right outer canthi to monitor horizontal eye movements and over the left inferior and superior orbital ridge to monitor vertical eye movements. Linked mastoid served as a reference/ active electrode during recording. The impedance at all the electrode sites was below 5kΩ. Quick Gel™, a conduction gel was taken in the syringe and was injected into the electrode sites to link the scalp with the electrode surface. The visual stimulus was presented on a VIEWPixx monitor which is a specifically designed display tool box used in visual science labs with a display resolution of 1920(H) x 1220(V) pixels.

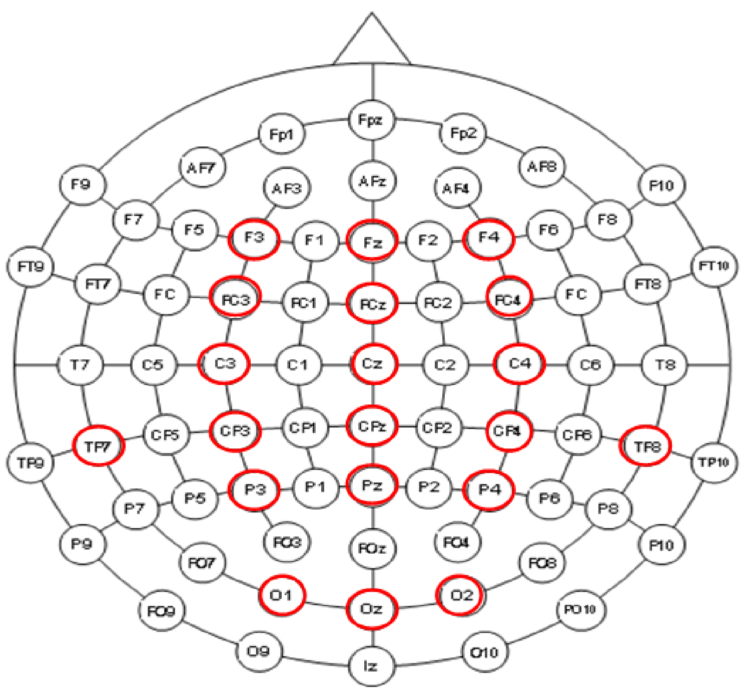


Figure 7: *Diagram representing the electrode sites from where the continuous EEG was recorded using Compumedics Neuroscan.*

A continuous EEG data was recorded at a sampling rate of 1000 Hz with a low pass filter at 100 Hz, and high passing DC. The time window of 1500 ms with a pre stimulus interval of 200 ms was considered for online averaging of target stimulus. The total duration of the testing was approximately two hour and 30 minutes per participant in the current experiment.

Procedure for cross linguistic primed lexical decision task:

The prime and the target appeared in two different conditions similar to the behavioral task (See Figure 8).

(i) Prime in L1(Kannada) and target in L2 (English)

(ii) Prime in L2(English) and target in L1(Kannada)

The prime was displayed for duration of 1000 milliseconds. The prime word was followed by a fixation period of 500 milliseconds, after which the target word was displayed for duration of 1000 milliseconds. Following the target a fixation period of 1000mseconds was given. Hence the next prime word appeared after 3500 milliseconds after the target word.

Instructions for L1-L2 cross linguistic primed lexical decision task:

"I will present few pair of words. The first word will be in Kannada and the second word in English. Among them the English word will appear after a "+" sign following the Kannada word. Pay attention to the English word which will appear after "+" sign. After the English word a question mark will appear on the screen. Press "1" if it is a true word and "2" if it is a nonsense word only when you see a question mark."

Instructions for L2-L1cross linguistic primed lexical decision task:

"I will present few pair of words. The first word will be in English and the second word in Kannada. Among them the Kannada word will appear after a "+" sign following the English word. Pay attention to the Kannada word which will appear after "+" sign. After the Kannada word a question mark will appear on the screen. Press “1” if it is a true word and “2” if it is a nonsense word only when you see a question mark.”

Procedure for lexical decision task:

Lexical decision task was carried out in both Kannada (L1) and English (L2) separately.

For *the Lexical decision task* only target words were presented for 1000 milliseconds followed by a fixation period of 1000 milliseconds. The next target appeared with an interstimulus interval of 2500 milliseconds.

Instructions for lexical decision task:

“I will present few true words and nonsense words. A question mark will appear on the screen after each word. Press “1” for true words and “2” for nonsense words only when you see the question mark.

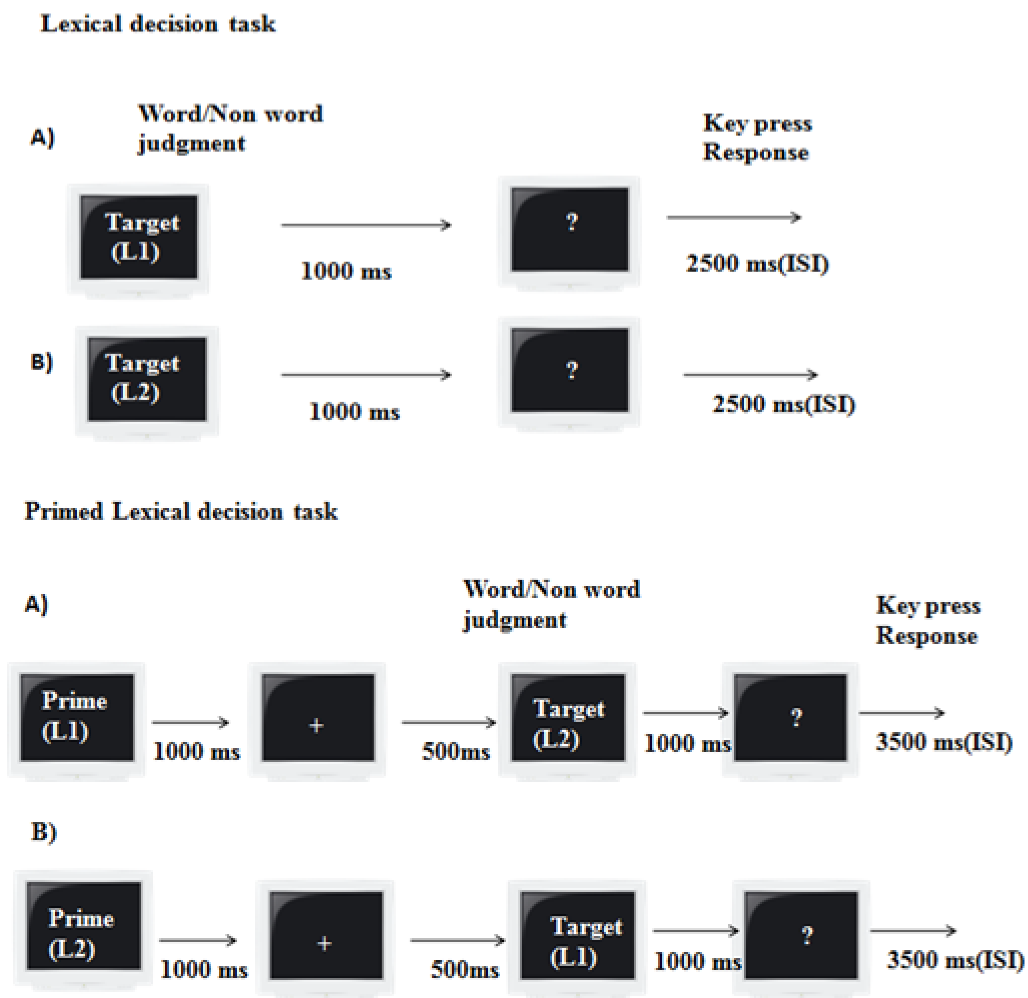


Figure 8: *Schematic diagram of presentation of stimuli for primed lexical decision task and lexical decision task for electrophysiological task*

While recording ERP's, participants were asked to respond only during fixation period (i.e. when the question mark appears) following the target to avoid contamination of N400 by the eye movement artifacts. They were also asked to reduce eye blinking during the trials since eye movements are the major source of contamination of EEG (Croft and Barry, 1999).

Offline analysis of ERP waveforms: During offline processing, the continuous EEG data was DC offset corrected and DC corrected waveforms were band pass filtered at 0.1-30 Hz with a 48 dB roll off to eliminate the high frequency noise component. The eye artifacts were removed from the EEG signal. The continuous filtered EEG waveform was epoched from 100 to 1000 msec. Further, voltage dependant artifact rejection was carried out and baseline corrected. Further the averaging of the epoched file was done to obtain different waveforms for target words in semantically related, unrelated and non word pair stimuli in primed lexical decision task (including bothL1-L2 and L2-L1 condition) and for words and non-words in lexical decision task(In both Kannada and English). The amplitude and latency measures of N400, an ERP which reflects the semantic processing in an individual was considered for further analysis.N400 is a negative going deflection which peaks around 400 milliseconds post stimulus onset, although it can extend from 250-500 milliseconds(Holcomb, Coffey, & Neville, 1992). The amplitude, latency and topographical distribution could vary according to the priming conditions, semantic relatedness and also for congruent and incongruent words (Holcomb & Neville, 1991; Kutas, Lindamood, & Hillyard, 1984).In the current study we look for how the amplitude and latency of N400 varies with respect to semantic relatedness in L1-L2 and L2-L1 cross linguistic primed lexical decision task and while processing words and non words across Kannada (L1) and English (L2).

Results

The Mean reaction time and Mean accuracy scores of behavioral tasks and the amplitude and latency measures from electrophysiological recordings were statistically analyzed using Statistical Package for the Social Sciences (SPSS) software package (Version 20.0) to understand whether the language has any effect on lexical processing in stutterers.

Behavioral results:

The results of descriptive statistics on cross-linguistic primed lexical decision task (L1-L2 and L2-L1) (see Table 4) revealed that L2-L1 primed condition have longer mean reaction time for all the three priming conditions than L1-L2 primed condition(see Figure 9). The mean accuracy scores were reduced for L2-L1 primed condition than L1-L2 primed condition(see Figure 10).

Table4:

Mean reaction time (RT) and Standard Deviation (SD) for three priming conditions on cross linguistic primed lexical decision task

Priming conditions	**Language order**	**Reaction time**	**Accuracy**
SR	L1-L2	646.25(83.52)	93.80(4.60)
	L2-L1	772.57(252.32)	86.66(8.91)
SUR	L1-L2	692.78(141.48)	91.20(4.72)
	L2-L1	847.48(231.72)	83.20(11.76)
NW	L1-L2	862.03(168.56)	87.33(7.30)
	L2-L1	1021.25(276.75)	78.66(17.99)

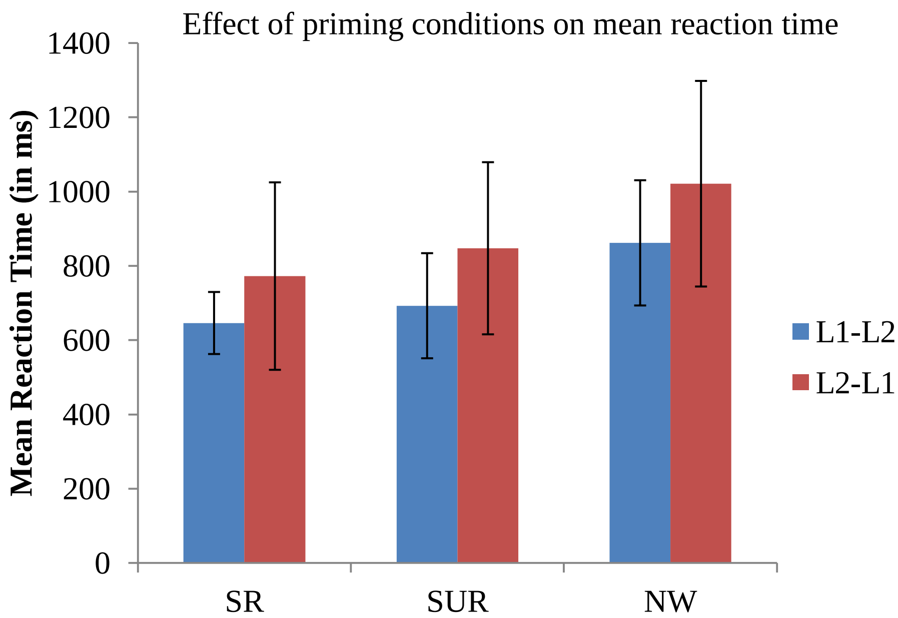


Figure 9: Effect of semantically related (SR), semantically unrelated (SUR) and word-non word (NW) cross linguistic priming conditions on mean reaction time for L1-L2 and L2-L1 language order.

Further, the results of repeated measure ANOVA revealed that there is a statistically significant main effect of priming conditions on the mean reaction time measures during the lexical judgment task ($p<0.05$).Where as there was no significant interaction of priming conditions and language order ($p>0.05$)(see Table 5) .The language order effect was significant with $p=0.039$ and the results of MANOVA revealed a statistically significant difference for semantically unrelated priming condition across L1-L2 and L2-L1($p<0.05$)(See Table 5)

Table 5:

Within group effect comparison of dependant variables with repeated measure ANOVA for cross linguistic primed lexical decision task on Mean reaction time and Mean accuracy scores

Behavioral Measures	**Factors**	**F ratio**	**p value**	**Partial Eta Squared**	**Observed power**
Mean reaction time	Priming conditions	F(1,28) =62.26	0.000*	0.690	1.000
	Language order	F(1,28) = 4.686	0.039*	0.143	0.552
	Priming conditions *Language order	F(1,28) =0.31	0.581	0.011	0.084
Mean accuracy	Priming conditions	F(1.66,51.05) =5.20	0.008*	0.157	0.809
	Language order	F(1, 28) = 8.477	0.007*	0.232	0.802
	Priming conditions *Language order	F(1.66,51.05) =0.05	0.943	0.002	0.058

Further, the results on repeated measure ANOVA on mean accuracy scores revealed a significant main effect ($p<0.05$) of priming conditions (see Table 5) and a between language order effect with $p=0.007$. The mean accuracy scores for semantically related and semantically unrelated conditions were statistically significant across L1-L2 and L2-L1 condition as per MANOVA results (see Table 6).

Table 6:

Between group effects comparison of dependant variables with MANOVA for cross linguistic primed lexical decision task on Mean reaction time and Mean accuracy scores

Behavioral measures	**Priming conditions**	**F ratio**	**p value**	**Partial Eta Squared**	**Observed power**
Mean reaction time	SR	F(1,28)= 3.38	0.076	0.108	0.428
	SUR	F(1,28)= 4.87	0.036*	0.148	0.568
	NW	F(1,28)= 3.62	0.067	0.115	0.451
Mean accuracy	SR	F(1,28)=7.58	0.010*	0.213	0.757
	SUR	F(1,28)=5.97	0.021*	0.176	0.655
	NW	F(1,28)=2.98	0.095	0.096	0.386

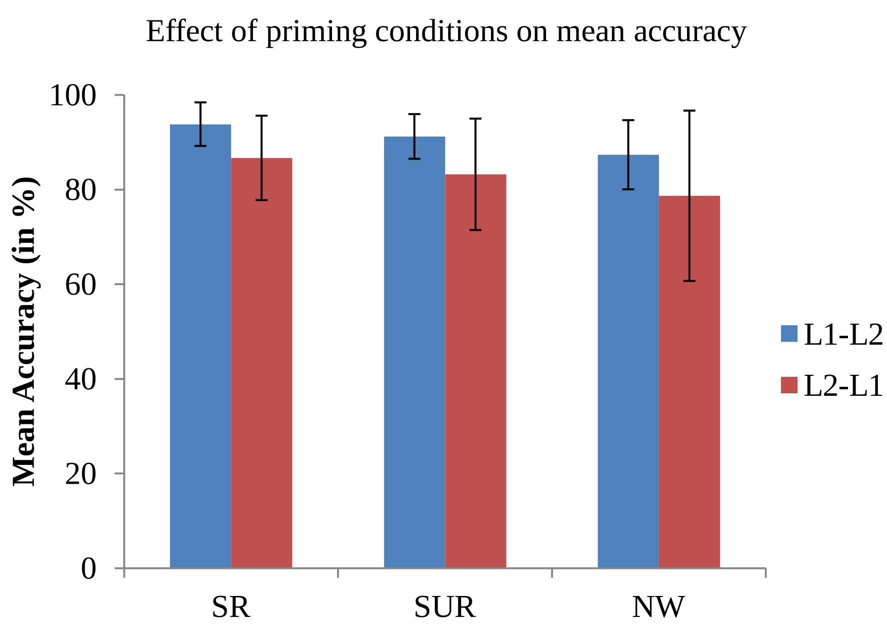


Figure 10: Effect of semantically related (SR), semantically unrelated (SUR) and word-nonword (NW) cross-linguistic priming conditions on mean accuracy for L1-L2 and L2-L1 language order.

Statistical analysis of lexical decision task results (see Table 7) revealed that the mean reaction time for words was greater in Kannada (Mean=896.80, SD =185.31) compared to English (Mean =777.64, SD= 127.61).Similarly the mean reaction time for nonwords was also greater in Kannada (Mean= 1075.45, SD=209.03) compared to English(Mean=937.17, SD=202.44). The mean accuracy scores and mean reaction time of Kannada was reduced compared to English as per the results (see Figure 11, Figure 12)

Table 7:

Mean reaction time (RT) and Standard Deviation (SD) in Kannada and English for words and non words for lexical decision task

Stimuli	**Language**	**Reaction time**	**Accuracy**
Word	Kannada	896.80(185.31)	90.46(6.92)
	English	777.64(127.61)	93.93(4.13)
Non word	Kannada	1075.45(209.03)	81.06(15.59)
	English	937.17(202.44)	89.40(5.55)

The repeated measure ANOVA results (see Table 8) revealed that the type of stimuli (words and non words) significantly affect the mean reaction time during lexical decision task in Kannada and English ($p<0.05$).

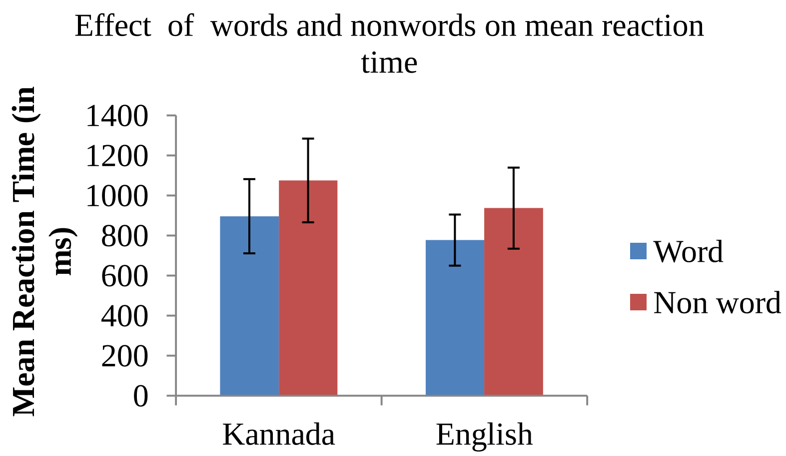


Figure 11: Effect of words (W) and non words (NW) on mean reaction time for Kannada and English

It also revealed that the mean reaction time was significantly different between Kannada and English (p=0.05).Further, it was revealed that the mean reaction time for words differed significantly across the two languages as per MANOVA results (p<0.05) (See Table 8).

Table 8:

Within group effect comparison of dependant variables with repeated measure ANOVA for lexical decision task on Mean reaction time and Mean accuracy scores

Behavioral Measures	**Factors**	**F ratio**	**p value**	**Partial Eta Squared**	**Observed power**
Mean reaction time	Type of stimuli	F(1,28) =69.23	0.000*	0.712	1.000
	Language	F(1,28) = 4.044	0.054*	0.126	0.493
	Type of stimuli*Language	F(1,28) =0.22	0.642	0.008	0.074
Mean accuracy	Type of stimuli	F(1,28) =11.96	0.002*	0.299	0.916
	Language	F(1,28) = 4.801	0.037	0.146	0.502
	Type of stimuli*Language	F(1,28) =1.46	0.237	0.050	0.215

The statistical analysis of mean accuracy scores using repeated measure ANOVA revealed that the mean accuracy scores differ significantly between Kannada and English ($p=0.037$) and there is a statistically significant main effect of type of stimuli ($p<0.05$) used on mean accuracy scores (see Table 8).

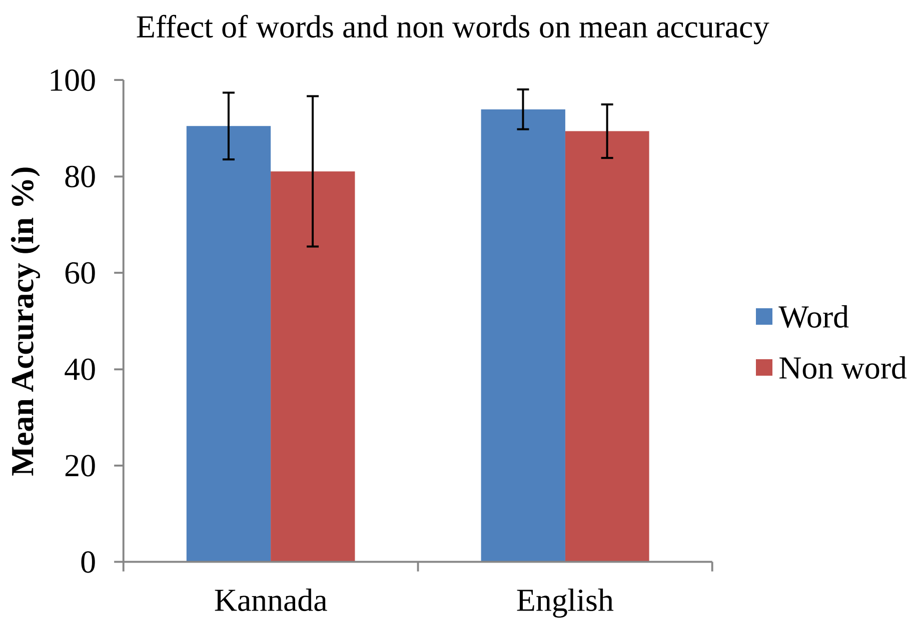


Figure 12: Effect of words (W) and non words (NW) on mean reaction accuracy for Kannada and English

Table 9:

Between group effects comparison of dependant variables with MANOVA for lexical decision task on Mean reaction time and Mean accuracy scores

Behavioral Measures	**Type of stimuli**	**F ratio**	**p value**	**Partial Eta Squared**	**Observed power**
Mean reaction time	Words	F(1,28)= 4.20	0.050*	0.131	0.508
	Non words	F(1,28)= 3.38	0.076	0.108	0.428
Mean Accuracy	Words	F(1,28)=2.77	0.107	0.090	0.362
	Non words	F(1,28)=3.79	0.061	0.119	0.469

Electrophysiological results:

The latency and amplitude of N400 peak during lexical decision task in Kannada and English and in L1-L2 and L2-L1 primed lexical decision tasks was obtained for all electrode sites and for all the types of stimulus conditions. Further, the amplitude and latency data were statistically analyzed to understand the lexical processing across different languages and across two languages in order.

Primed Lexical Decision task:

Descriptive statistics revealed longer latency in L2-L1 than L1-L2 condition. The measure of mean latency for three region of interests(ROI); central (Fz, FCz, Cz, CPz, Pz and Oz),right (F4,FC4,C4,CP4,P4,O2 andTP8) and left(F3,FC3,C3,CP3,P3,O1 and TP7) channels were also longer in L2-L1 than in L1-L2 condition (see Table 10)(see Figure 13).

Table 10:

Mean latency, Mean amplitude and Standard deviation measures of N400 for semantically related (SR), semantically unrelated (SUR) and non-word conditions on cross linguistic primed lexical decision task, L1-L2 and L2-L1.

N400 measures	Priming conditions	ROI	Language order	Mean(SD)
Latency	SR	right	L1-L2	355.19(42.62)
			L2-L1	394.84(46.32)
		left	L1-L2	353.41(33.14)
			L2-L1	384.80(48.78)
		central	L1-L2	364.44(32.40)
			L2-L1	400.94(33.25)
	SUR	right	L1-L2	352.76(43.98)
			L2-L1	394.05(46.05)
		left	L1-L2	341.50(31.90)
			L2-L1	387.70(31.90)
		central	L1-L2	360.16(36.73)
			L2-L1	409.05(29.40)
	NW	right	L1-L2	361.03(40.06)
			L2-L1	396.00(37.36)
		left	L1-L2	357.07(32.77)
			L2-L1	384.98(46.98)
		central	L1-L2	357.07(34.01)
			L2-L1	384.98(19.24)
Amplitude	SR	right	L1-L2	2.48(2.35)
			L2-L1	2.66(2.10)
		left	L1-L2	0.52(2.32)
			L2-L1	0.75(2.05)
		central	L1-L2	0.70(2.79)
			L2-L1	0.84(3.02)
	SUR	right	L1-L2	2.04(2.46)
			L2-L1	2.06(3.41)
		left	L1-L2	-0.23(3.87)
			L2-L1	0.70(3.14)
		central	L1-L2	0.45(3.30
			L2-L1	-0.06(3.70)
	NW	right	L1-L2	1.46(2.90)
			L2-L1	2.05(2.62)
		left	L1-L2	-0.21(2.77)
			L2-L1	0.58(2.60)
		central	L1-L2	-0.29(3.59)
			L2-L1	0.35(3.42)

The repeated measure ANOVA revealed a statistically significant group effect with p=0.001 on the latency measures. Further, the results also indicated statistically significant main effect of regions of interest on N400 latency measures (p=0.046). The main effect of priming conditions and The interaction effect for priming conditions*language order, regions of interest*language order, priming conditions*regions of interest as well as priming conditions*regions of interest*language order on latency was not statistically significant (see Table 11).Further the results from MANOVA also demonstrated significant difference between the two groups for semantically related and semantically unrelated word pairs in all the three regions of interest and for non word priming conditions in the right and central regions of interest(p<0.05) (See Table 11).

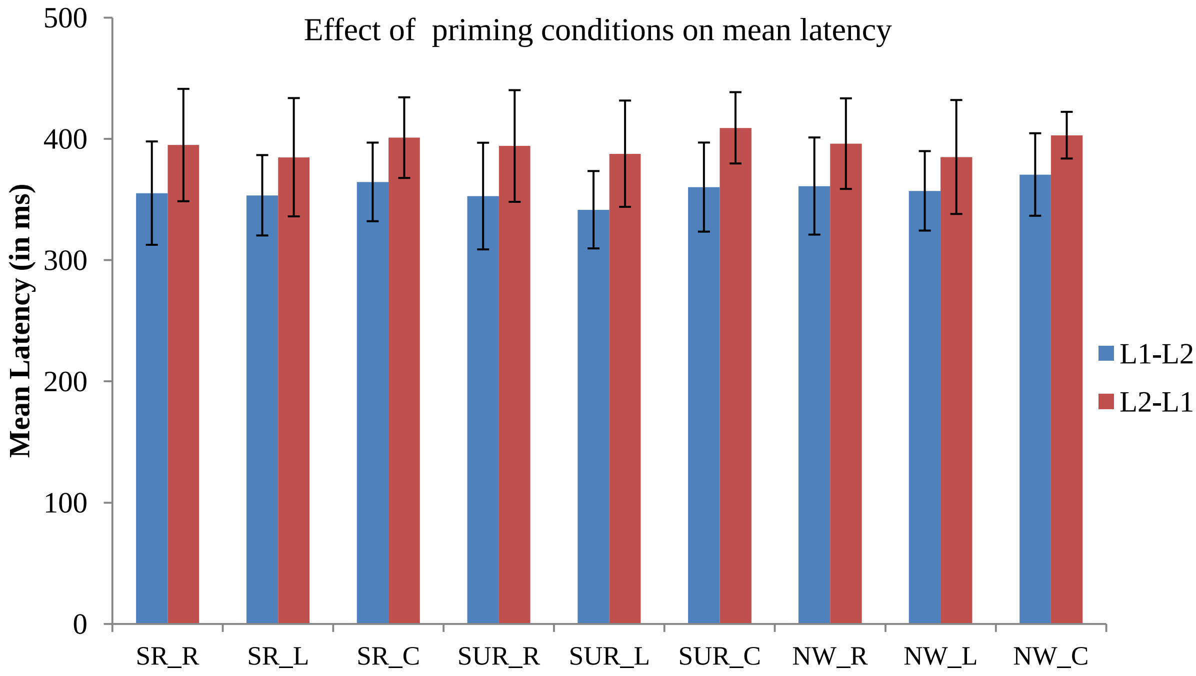


Figure 13: Effect of semantically related (SR), semantically unrelated (SUR) and word-non word (NW) cross linguistic priming conditions on mean latency of right (R), left (L) and central (C) channels for L1-L2 and L2-L1 language order.

The mean amplitude for all the three priming conditions between the two language orders (L1-L2 & L2-L1) were compared using non parametric Mann-whitney test (Also see Figure 14, Figure 15, Figure 16). The results revealed no significant difference in the mean amplitude between L1-L2 and L2-L1 conditions for SR, SUR and NW pairs in all the channels of interest [SR-right ($Z = -0.436$, $p > 0.05$), SR-left ($Z = -1.141$, $p > 0.05$), SR-central ($Z = -0.187$, $p > 0.05$), SUR-right ($Z = -0.062$, $p > 0.05$), SUR-left ($Z = -0.601$, $p > 0.05$), SUR-central ($Z = -0.436$, $p > 0.05$), NW-right ($Z = -0.726$, $p > 0.05$), NW-left ($Z = -1.016$, $p > 0.05$), NW-central ($Z = -0.061$, $p > 0.05$)]

Table 11

Within group effect comparison of dependant variables with repeated measure ANOVA for primed lexical decision task on N400 latency and amplitude measures

N400 measures	Factors	F ratio	p value	Partial Eta Squared	Observed power
Latency	Priming conditions	F(1.92,56)=0.800	0.455	0.028	0.180
	Language order	F(1, 28) = 12.423	0.001	0.307	0.925
	Priming conditions *Language order	F(1.92,56)=1.80	0.174	0.061	0.362
	ROI	F(1.83,56)=3.24	0.046*	0.104	0.596
	ROI*Language order	F(1.83,56)=0.059	0.943	0.002	0.058
	Priming conditions *ROI	F(4.95.32)=0.546	0.703	0.019	0.178
	Priming conditions *ROI* Language order	F(4.95.32)=0.760	0.553	0.026	0.238

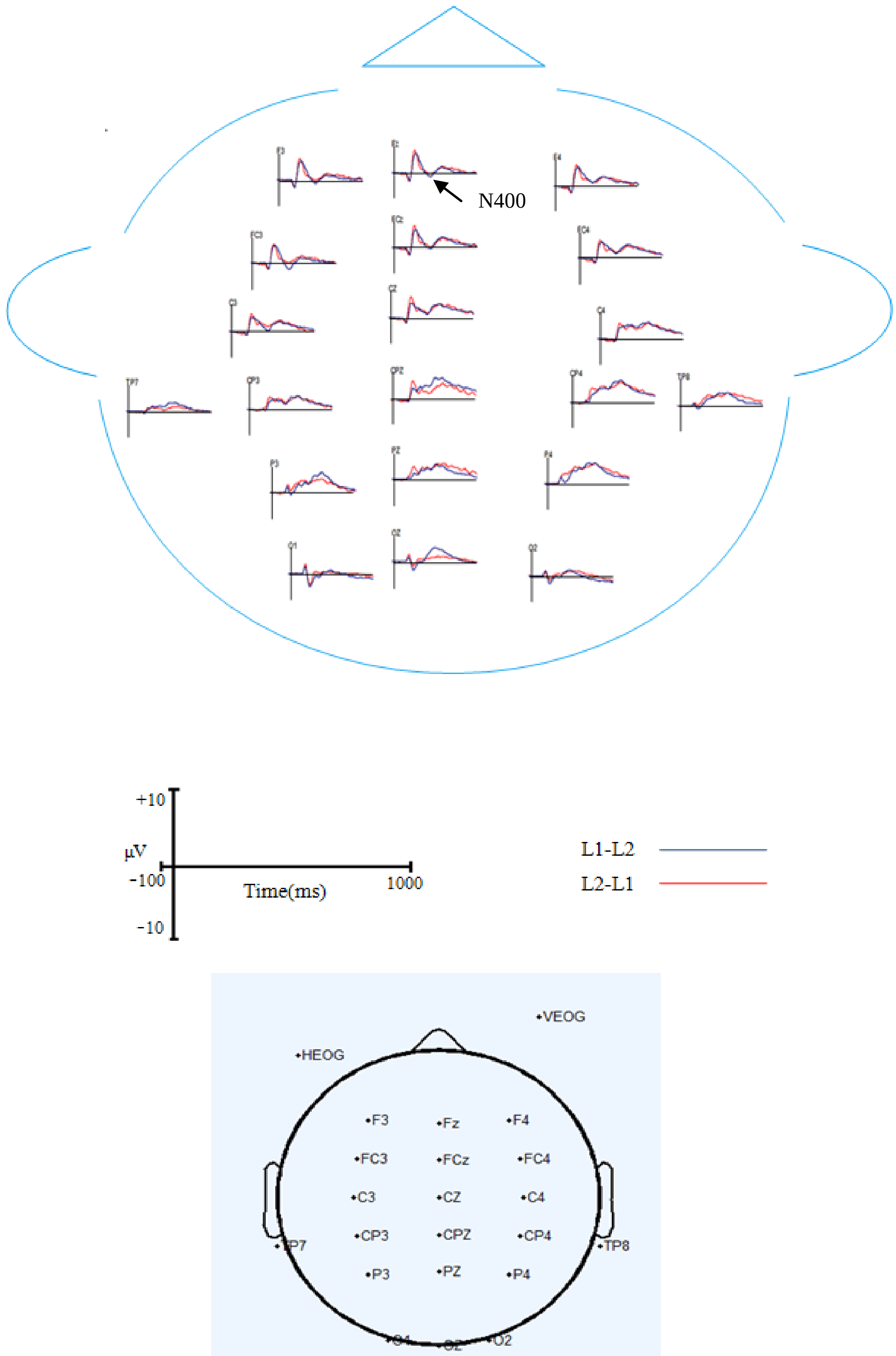


Figure 14: Comparison of grand average ERPs elicited by semantically related (SR) priming conditions in L1-L2 (blue) and L2-L1 (red) language order.

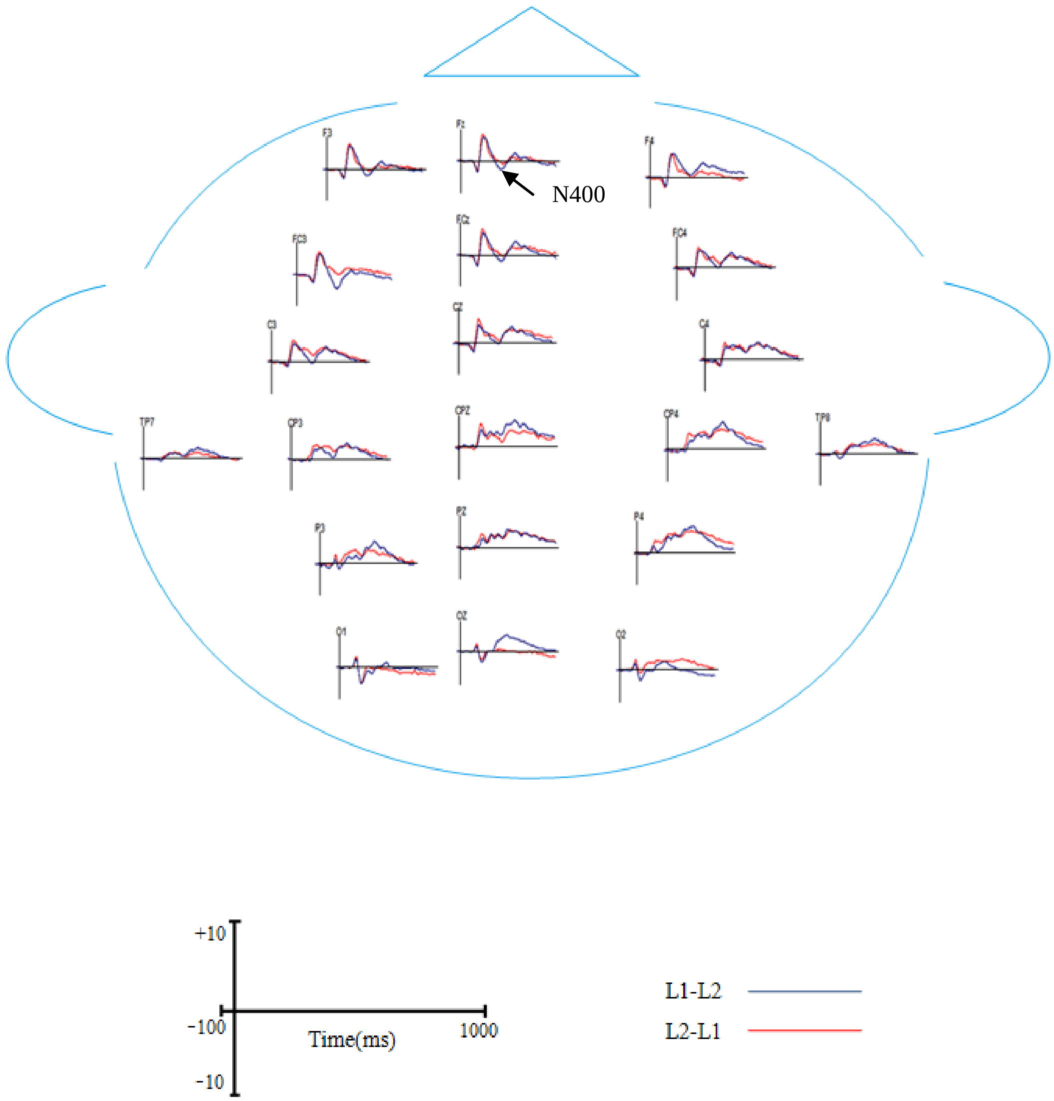


Figure 15: Comparison of grand average ERPs elicited by semantically unrelated (SUR) priming conditions in L1-L2 (blue) and L2-L1 (red) language order.

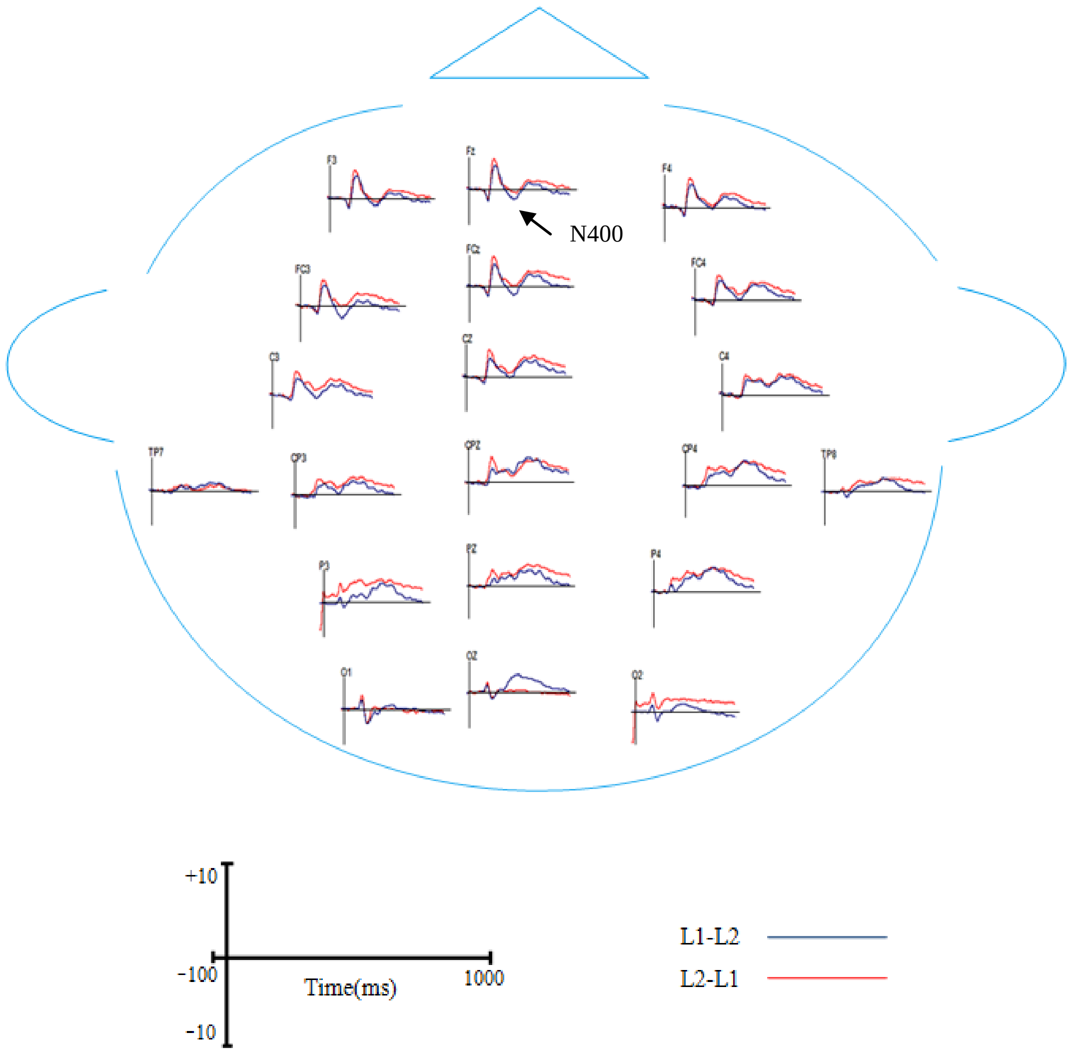


Figure 16: Comparison of grand average ERPs elicited by word-non word priming conditions in L1-L2 (blue) and L2-L1 (red) language order.

Table 12

Between group effect comparison of dependant variables with MANOVA for primed lexical decision task on N400 latency

Priming conditions	**Regions of interest**	**F ratio**	**p value**	**Partial Eta Squared**	**Observed power**
SR	Right	F(1,28)= 5.953	0.021*	0.175	0.654
	Left	F(1,28)= 4.247	0.049*	0.132	0.512
	Central	F(1,28)= 9.268	0.005*	0.249	0.836
SUR	Right	F(1,28)= 6.306	0.018*	0.184	0.679
	Left	F(1,28)= 10.893	0.003*	0.280	0.890
	Central	F(1,28)= 16.196	0.000*	0.366	0.973
NW	Right	F(1,28)= 6.112	0.020*	0.179	0.665
	Left	F(1,28)= 3.559	0.070	0.113	0.445
	Central	F(1,28)= 10.316	0.003*	0.269	0.873

Lexical Decision task:

The results of descriptive statistics (see Table 13) revealed that longer latencies for Kannada than English in all the three regions of interest on lexical decision task (see Figure 17).

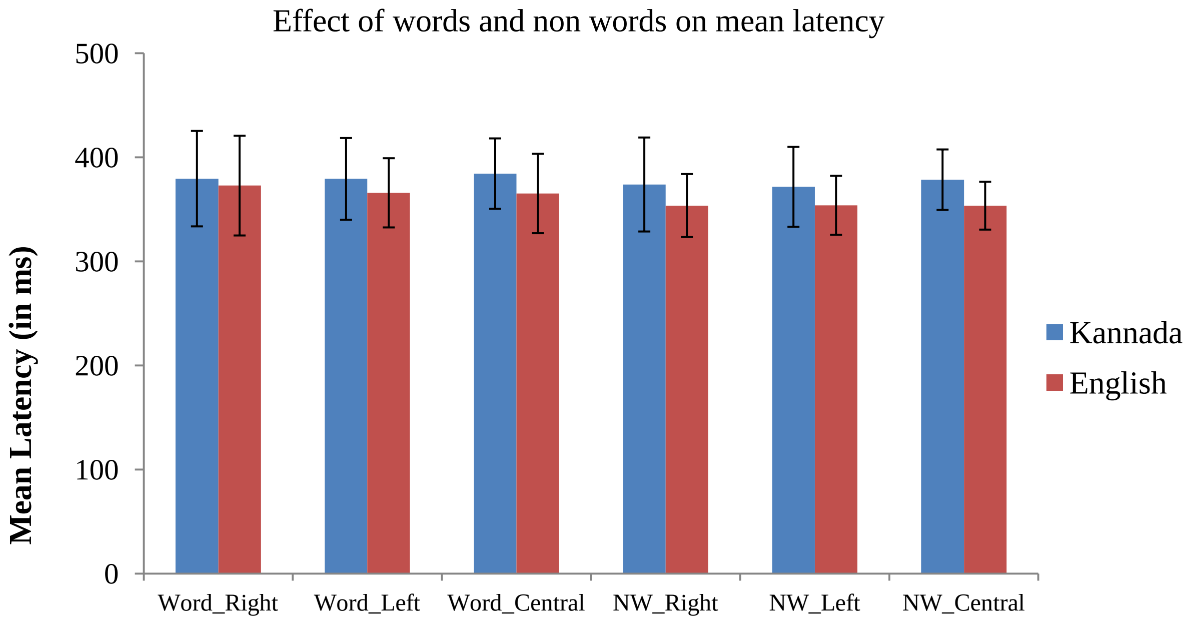


Figure 17: Effect of words (W) and non words (NW) on mean latency on right, left and central channels for Kannada and English

The repeated measure ANOVA results (see Table 14) revealed a statistically significant main effect on N400 latency measures for both words and non words. Whereas the main effect of regions of interest was not statistically significant on latency. There was no statistically significant interaction effect on N400 latency for types of stimuli*language, regions of interest*language, types of stimuli *regions of interest and types of stimuli *regions of interest*language. Further the results of repeated measure ANOVA revealed no significant group effect ($p>0.05$).

Table 13

Mean latency, Mean amplitude and Standard deviation measures of N400 for words and non words on lexical decision task in Kannada and English

N400 measures	**Stimuli**	**ROI**	**Language**	**Mean(SD)**
Latency	Words	Right	Kannada	379.53(45.84)
			English	372.84(47.91)
		Left	Kannada	379.32(39.23)
			English	365.91(33.23)
		central	Kannada	384.40(33.80)
			English	365.26(38.16)
	Non words	Right	Kannada	373.91(45.15)
			English	353.69(30.27)
		Left	Kannada	371.67(38.35)
			English	353.96(28.29)
		central	Kannada	378.54(29.06)
			English	353.57(23.00)
Amplitude	Words	Right	Kannada	1.23(1.58)
			English	-0.45(3.00)
		Left	Kannada	0.61(1.91)
			English	-0.73(1.98)
		central	Kannada	0.13(1.82)
			English	-1.47(1.57)
	Non words	Right	Kannada	0.13(1.67)
			English	-1.05(1.91)
		Left	Kannada	-0.21(1.75)
			English	-1.22(1.84)
		central	Kannada	-1.63(2.25)
			English	-2.29(1.82)

Table 14

Within group effect comparison of dependant variables with repeated measure ANOVA for primed lexical decision task on N400 latency and amplitude measures

N400 measures	**Factors**	**F ratio**	**p value**	**Partial Eta Squared**	**Observed power**
Latency	Type of stimuli	F(1,25)= 4.645	0.041*	0.157	0.545
	Language	F(1,25) = 2.533	0.124	-	-
	Type of stimuli*Language	F(1,25)=0.679	0.418	0.026	0.125
	ROI	F(1.91,50)= 0.112	0.895	0.004	0.066
	ROI*Language	F(1.91,50)= 0.262	0.770	0.010	0.089
	Type of stimuli*ROI	F(1.67,46.40)= 0.172	0.842	0.007	0.075
	Type of stimuli*ROI*Language	F(1.67,46.40)= 0.305	0.738	0.012	0.096

The greater negative amplitude for N400 in all the three regions of interest while processing words and non words in English compared to Kannada was revealed from descriptive statistics (see Table 13) (see Figure 18, Figure 19).The mean amplitude of words and non words between the two languages were compared using non parametric Mann-whitney test. The test results revealed significant difference in the mean amplitude for words in central ROI only between Kannada and English [words-right (Z= -1.667, p>0.05), words-left (Z= -1.410, p>0.05), words-central (Z= -2.231, p<0.05), non words-right (Z= -1.359, p>0.05), non words-left (Z= -1.410, p>0.05), non words-central (Z= -0.385, p>0.05)]

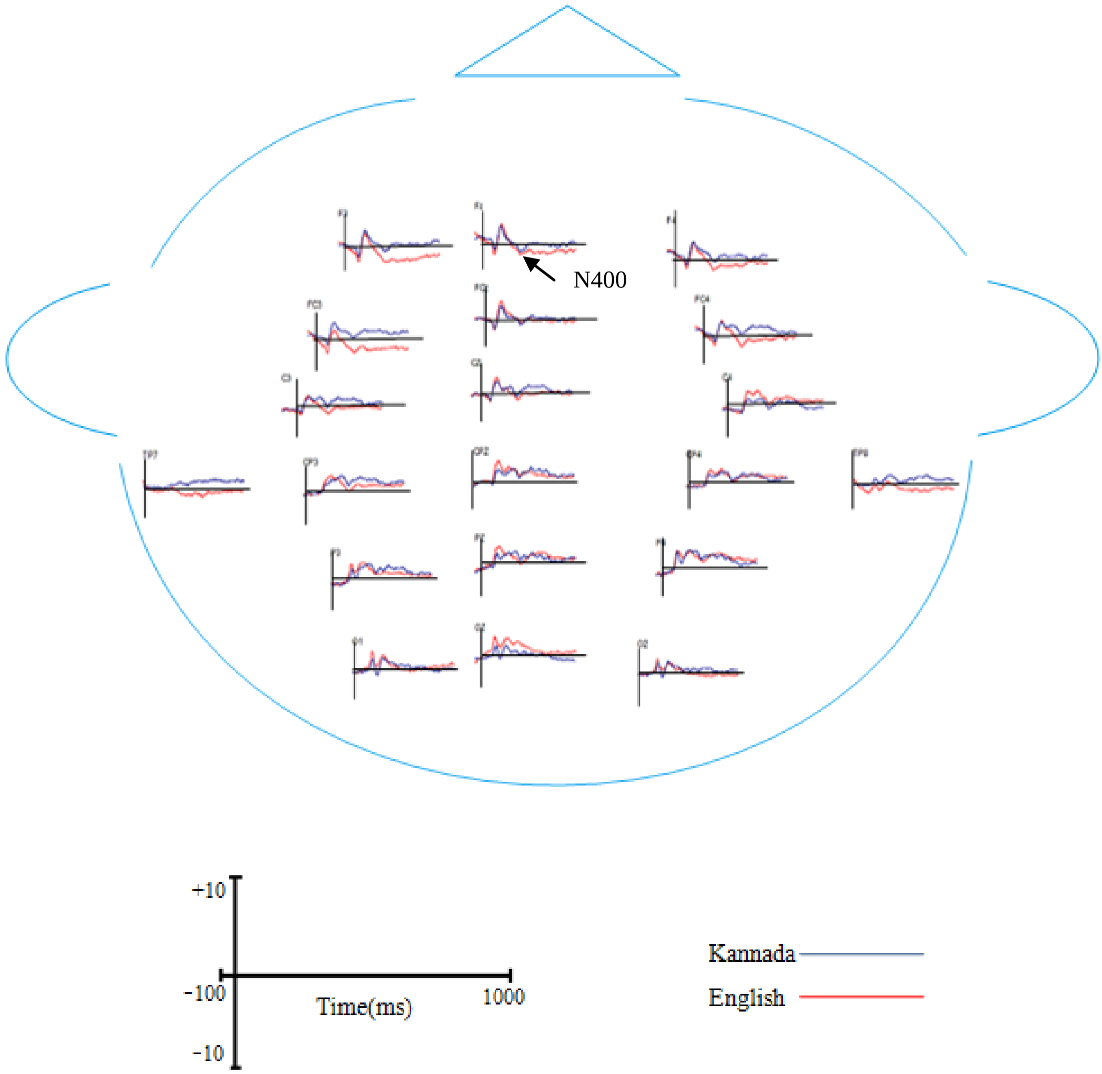


Figure 18: Comparison of grand average ERPs elicited by words in Kannada (blue) and English (red)

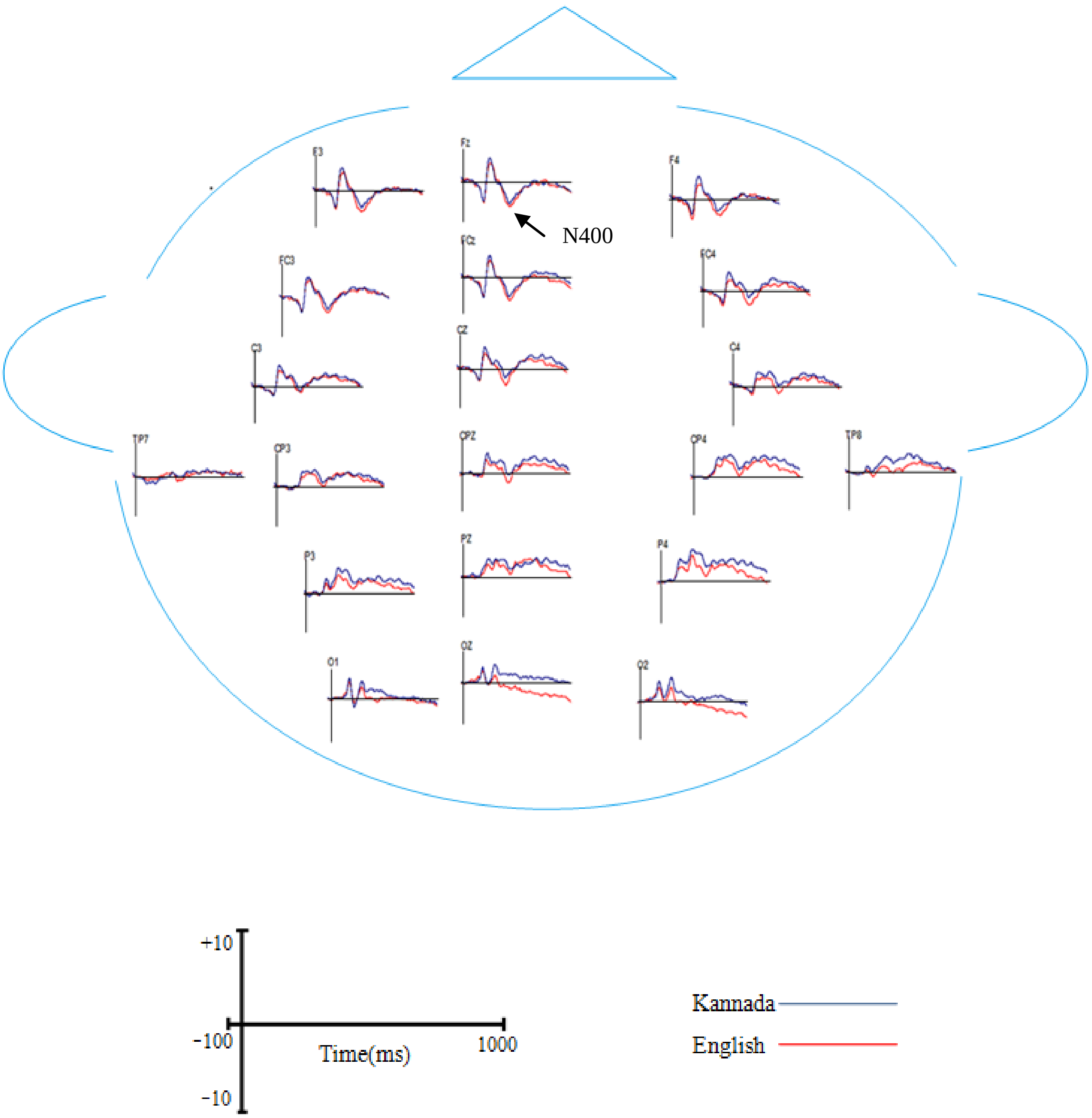


Figure 19: Comparison of grand average ERPs elicited by non words in Kannada (blue) and English (red)

Discussion and conclusions

The primary objective of the current experiment was to investigate the lexical access and phonological access in Kannada-English (K-E) sequential bilingual adults who stutter (BAWS). To check the lexical access in bilinguals a cross-linguistic priming paradigm was used. And lexical decision task in Kannada and English was done separately to understand the phonological access in Kannada and English in K-E bilingual adults who stutter.

Cross-linguistic lexical access in Kannada-English Bilingual adults who stutter:

We have adopted a cross-linguistic semantic priming paradigm incorporated in a lexical decision task in order to study whether L1 (Kannada) and L2 (English) have a common conceptual representation in K-E bilingual adults who stutter. In general, the priming experiments are used to evidence lexical activation and lexical access in adult bilinguals. In order to justify the cross linguistic differences at the level of conceptual representation evidences from cross linguistic semantic priming studies could be used (Kroll & Sunderman, 2003). In the literature, cross-language semantic priming experiments in bilingual adults have revealed that words in different languages would prime each other (Altarriba, 1992; Schwanenflugel & Rey, 1986). Hence we have used semantically related, semantically unrelated and word-nonword pairs in the current experiment. Here, we discuss the results of the cross-linguistic primed lexical decision task in BAWS based on bilingual access models.

The behavioral results of the cross-linguistic primed lexical decision task in BAWS revealed significant difference in the mean reaction time for semantically unrelated words and significant difference in mean accuracy for semantically unrelated and nonword pairs across L1-L2 and L2-L1 directions. The faster reaction time and the better accuracy in L1-L2 direction compared to

L2-L1 would clearly suggest that the semantic priming facilitation operates from the dominant language to the non-dominant language during lexical access and not in the other direction. The behavioral results are consistent with electrophysiological findings in the current study. The N400 latency was significantly longer on L2-L1 direction than L1-L2 direction for semantically related and semantically unrelated word pairs which also implicates a slow lexical access or slow semantic spreading activation operating from L2-L1 direction.

The results of cross-linguistic primed lexical decision task could be explained based on Revised Hierarchical Model. RHM explains bilingual lexical access based on the evidences from cross-linguistic translation and semantic priming studies. According to this model, L1 words have strong connections to the conceptual representations, whereas L2 words have strong connections to corresponding L1 words at lexical level. As the level of proficiency in L2 increases the conceptual links would substitute/weaken the lexical links. So as the proficiency in L2 increases the accessing from L2-L1 by means of word association would change to accessing by means of concept mediation. The former (word association) would take much longer processing time compared to the later (concept mediation). In the current study since all the bilingual participants do not have a native like proficiency in their L2, the semantic connections from L2-L1 is operating through word association and not through concept mediation, which is reflected as longer reaction time and longer N400 latencies in L2-L1 direction than L1-L2 direction. Thus the results suggest that the pattern of lexical access in bilingual adults who stutter is comparable to that of bilingual adults who do not stutter. The result of the current experiment is in accordance with study by Keatly, Spinks, and De Gelder (1994). They found that semantic priming operates only from L1-L2 and not from L2-L1 in Chinese learners of English. On similar lines, Fox(1996) had reported that cross language priming was noticed in both L1-L2 and L2-L1 directions but there existed an asymmetry which was reflected by more negative priming in L1-L2 direction in agreement with the predictions of RHM. Similar studies have been reported in languages that have common script (Costa ,Santesteban, & Caño, 2005; Duñabeitia, Perea, & Carreiras, 2010; Lemhofer et al., 2008; Van Assche, Duyck, Hartsuiker, & Diependaele, 2011;Van Assche ,Drieghe, Duyck, Welvaert, & Hartsuiker, 2009) and in languages that differ in scripts (Gollan, Forster, & Frost 1997; Hoshino & Kroll, 2008; Kim & Davis, 2002; Voga & Grainger,2007) which also indicate that cross language priming occurs only in one direction (L1-L2) and is weak/ absent in the other (L2-L1) direction. Here in our study Kannada and English differ in script, i.e, Kannada is an alpha syllabic language and English is an alphabetic language.

Another explanation for our results could be based on the sense model (Finkbeiner, Forster, Nicol, & Nakamura, 2004). Sense model explains the asymmetrical priming effects on lexical decision. Senses refer to the conceptual features, which have specific activation levels. The activation of the senses would decide the priming effects in bilinguals. As per this model, the activation of senses would lead to cross linguistic activation and priming. According to sense model, it could be inferred that L2-L1 priming did not occur or there was only weak priming in BAWS which was reflected as longer reaction time and longer latency, because L2 prime could pre activate only a limited number of senses (conceptual features) in L2-L1 direction. This difference in the ratios of senses (conceptual features) in L1-L2 and L2-L1 direction would have lead to priming asymmetry in L1-L2 and L2-L1.

The results of cross linguistic primed lexical decision task in BAWS could also be discussed based on the proficiency in each of the language. All the participants in the current study had acquired their English (L2) sequentially and they were comparatively less proficient in English (L2) than Kannada (L1). Considering this; the faster reaction time for L1-L2 direction in the current paradigm would suggest stronger connections from L1 - L2 word forms than from L2 - L1word forms. This could be due to the increased proficiency in L1 than L2 in BAWS. According to De groot, 1995,2002; Kroll and Tokowicz,2005 the strength of these interlingual connections varies depending on various factors such as level of proficiency, context of use of languages, context of acquisition of languages, the activation level of representation in each languages, similarity of words and frequency of co-activation of particular word pairs. The resting levels of activation for L2 words are lower because they are infrequently used in low and intermediate proficient bilinguals (Dijkstra &Van Heuven, 2002; Van Heuven, Dijkstra, & Grainger, 1998). Hence L2 words require more activation to exceed their threshold of activation resulting in slower recognition process. The degree of proficiency in the languages highly influences the resting level of activation of lexical representations in the specific language. It is also reported that proficiency in the language of the prime word would also affect the word recognition. The less proficiency of prime word (L2) would be the cause of a temporal delay in decision making in L2-L1 condition in the current study. If BAWS were highly proficient in both the languages we would have expected an equal amount of priming effects with no difference in reaction time and latency across language priming conditions. In conclusion the temporal delay in L2-L1 than in L1-L2 during cross linguistic primed lexical decision task in BAWS would replicate a usual pattern of lexical processing in adult bilinguals who do not stutter. There are no previous evidences reporting the lexical access using a cross linguistic lexical decision task in bilingual adults who stutter. As per our knowledge this is the first ever study to report the process of cross linguistic lexical access in bilinguals who stutter.

Phonological access in Kannada-English bilingual adults who stutter:

In order to investigate phonological access in BAWS, a simple lexical decision task in Kannada and English was carried out separately. In the current experiment the participants were asked to make judgment of words and non words visually presented to them in both Kannada and English separately.

Although there are not many studies which have used lexical decision of words and non words in persons with stuttering, many earlier studies are available which have used non word repetition, non word reading, phonologic priming and rhyme judgment task to evidence the phonological encoding deficits in persons with stuttering. Among these tasks, non word reading is considered to be a higher predictor of phonological processing skills (Gibbs & Bodman, 1997). According to Campbell and Butterworth (1985) non word reading requires skills that are not needed for word reading. Non word reading requires the decoding of unfamiliar strings of letters which would tap the phonological integration. In the mean while reading of the regular words may involve the use of letter sound knowledge for decoding, use of sight vocabulary to recognize the word or spoken vocabulary for clues to word's identity. Reading of non words does not make use of sight vocabulary and spoken vocabulary which are based on visual processing and meaning. However, non word reading and non word repetition will not distinguish the phonemic encoding , speech motor planning and execution since it involves verbalization; the word and non word lexical decision task would tap the phonological encoding deficits in isolation. In the current study, we have used visually presented words and pronounceable non words as stimuli in order to understand the phonological processing and it involves silent word and non word reading without any verbalization.

The behavioral results of lexical decision task revealed a longer reaction time and reduced accuracy for words and non words in Kannada than English even though this difference was significant only for words. The electrophysiological results revealed a longer N400 latency for both words and non words in Kannada than English in all the three regions of interest, but this difference was not significant for both N400 latency and amplitude. Since we have used visually presented words and non words for lexical decision task the difference in Kannada and English could be attributed to inherent differences of the languages with respect to reading time and related factors. The possible differences in mean reaction time and latency between the two languages on lexical decision task could be due to differences in orthography, grain size and information density of the two languages. The longer reaction time and latency for lexical decision task in Kannada compared to English may be attributed to its larger grain size and high information density which would have resulted in slower processing. Larger the grain size, it indicates larger number of orthographic symbols which would reduce the speed of reading process (Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001). Kannada has alphasyllabic script with consonants and inherent vowels. In Kannada larger grain size is due to the presence of vowels which itself have their own representation, consonants in combination with vowels are subjected to modification and the consonant clusters with primary and secondary forms. This would result into slow processing of Kannada compared to English even though Kannada is orthographically consistent compared to English. The amount of information in a given time to read is referred to as information density. Larger the information density the processing would be slower (Schotter & Rayner, 2013; Zeigler & Goswami, 2005). English is reported to have comparatively less information density compared to Kannada. Thus in the current study the larger grain size and more information density of Kannada compared to English would have resulted into a temporal delay in lexical decision making of Kannada stimuli compared to English.

It could also be noted that the temporal difference in lexical decision task across the two languages is not statistically significant which implies that the bilingual participants in the current study are skilled enough to read the languages which differ in orthographic consistency. That is Kannada having a transparent orthography which has one to one mapping from grapheme to phoneme and requires phonological route for reading (Plaut, McClelland, & Seidenberg,1995).English having an opaque orthography requires both semantic/lexical and phonological route to be activated. In skilled readers of English both semantic and phonological route become fully competent and later they choose the more economical and rapid semantic route (Oney, Peter, & Katz, 1997).

Thus it is expected that skilled readers of Kannada and English, uses less rapid phonological route for reading Kannada and more rapid semantic/lexical route for reading English. This would also be the cause of less reaction time for English than Kannada in the present study even though not statistically significant.

The reaction time for words was less compared to non words in both Kannada and English in the current study. The lesser reaction time for words could be due to high level of orthographic familiarity due to their frequent usage compared to non words. This would result in automatic mapping of grapheme to phoneme for words which is less resource demanding (Plaut et al., 1995; Seidenberg & McClelland, 1989; Van Orden & Goldinger, 1994). Thus orthography to lexical phonology route is direct for familiar words compared to non words (Baluch & Besner, 1991; Besner & Hilderbrandt, 1987; Grainger,1990; Morton, 1982; Rumelhart & McClelland, 1982; Sebastian-Galles,1991; Seidenberg, Plaut, Petersen, McClelland, & McRae, 1994; Share, 1995).

In conclusion, the results of both cross linguistic primed lexical decision task and lexical decision task in BAWS revealed a pattern of lexical access and phonological access comparable to that of BAWNS. In order to comment on the temporal difference of lexical access and phonological access between BAWS and BAWNS, future research could be carried out including age and gender matched K-E bilingual adults who do not stutter as control participants.

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