EFFECT OF PREVOICING ON SPEECH ABR ACROSS DIFFERENT AGE GROUPS IN INDIVIDUALS WITH NORMAL HEARING SENSITIVITY

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MAY, 2014.

Dedicated to my GURU & my Guide

CERTIFICATE

This is to certify that this dissertation entitled "**Effect of prevoicing on speech ABR across different age groups in individuals with normal hearing sensitivity** " is a bonafide work submitted in part fulfilment for the Degree of Master of Science (Audiology) of the student (Registration No.: 12AUD023). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any of the University for the award of any other Diploma or Degree.

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CERTIFICATE

This is to certify that this dissertation entitled "**Effect of prevoicing on speech ABR across different age groups in individuals with normal hearing sensitivity**" has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in other University for the award of any Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled "**Effect of prevoicing on speech ABR across different age groups in individuals with normal hearing sensitivity**" is the result of my own study under the guidance of Dr. Animesh Barman, Reader, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier in other University for the award of any Diploma or Degree.

Mysore Register No.: 12AUD023

May, 2014.

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INTRODUCTION

The auditory brainstem responses (ABRs) are synchronous firing response of structures along the ascending auditory pathway includes auditory nerve, cochlear nucleus, superior olivary complex, lateral lemniscus, and inferior colliculus (Møller & Jannetta, 1985). Auditory brainstem response is one of the objective measures used to assess the neural integrity. Non speech stimuli like click and tone burst stimulus are often used to check the neural synchrony of the auditory brainstem. In addition to non speech stimuli, ABRs can also be evoked using a speech stimuli and are used to study encoding of speech stimulus at the brainstem level which is known as speech ABR. The speech-evoked ABR can be divided into transient and sustained response which is known as frequency-following response (FFR) (Johnson, Nikol & Kraus, 2005).

Speech evoked Auditory Brainstem measures (ABR) are recently being used as a tool to study the brainstem processing of speech sounds. The understanding of speech evoked ABR has applications both in research as well as for clinical purposes. Studying the processing of speech sounds at the brainstem may provide knowledge regarding the central auditory processes involved in normal hearing individuals and also in clinical population.

Russo, Nicol, Musacchia and Kraus (2004) reported that speech evoked ABR contains a series of peaks ranging from peak V, A, C, D, E, F, and O. Waves V and A signal the response to onset of sound. Wave C is thought as a response to the onset of the vowel. Peaks D, E, F represent vibration of the vocal folds. The interpeak intervals between these peaks correspond precisely to the wavelength of the F0 of the utterance. Wave O is the response to the cessation of sound. The harmonic portion of the speech stimulus gives rise to the frequency-following response. The small higher frequency fluctuations between waves D, E and F, corresponds in frequency to that of the first formant (F1) and second formant (F2) of the stimulus.

Most often consonant-vowel speech syllables, such as /da/ developed by Kraus et al. (2005) are used in eliciting speech evoked ABR. Song, Banai, Russo and Kraus (2006) reported that the vowel that follows the consonant is a sustained periodic signal that is usually much louder than the consonant. Because of this higher amplitude, longer portion of the stimulus may actually mask the brief consonant onset which is critical for eliciting the onset portion of the speech-evoked ABR.

Using a /bɑ/ syllable, Akhoun et al. (2008) explored how the timing of the speech-evoked onset response and FFR, across different intensity level (0 to 60 dB SL, in 10 dB increments). Both response components showed systematic latency shifts with increasing intensity. However, the FFR peaks showed a steeper latency-intensity function than the onset response, suggesting that the onset response and speech evoked FFR reflect distinct neural processes (Hoorman et al. 1992).

Anderson, White-Schwoch and Kraus (2012) have observed that older adults usually have delayed ABR’s especially in response to the rapidly changing formant transition and greater response variability. Also older adults have deficit in phase locking and smaller response magnitude than younger adults.

Aging can lead to a structural or a functional deficit at various levels of the central auditory system (Walton, Frisina, Ison & O'Neill, 1997; Hinjosa & Nelson, 2011; Nelson & Hinjosa, 2011; Suta, Rybalko, Jelanova, Popelar, & Syka, 2011). Felder and Schrott-Fischer (1995) suggested that there was degeneration in mylelin sheath in individuals aged lesser than 60 years.

At the level of the brainstem, majority of these structural or functional changes have been reported in the cochlear nucleus within multipolar cells, decline in neuronal number (Willot, Parham & Hunter, 1988), bushy cells (Briner & Willot, 1989) octopus cells, (Willot & Bross, 1990), and decrease in the overall volume of the cochlear nucleus (Konigsmark & Murphy, 1972; Gandolfi, Horoupian & DeTeresa, 1981).

Apart from the structural changes, aging would also results in various functional changes like decline in efficiency of synaptic transmission between the auditory nerve and the bushy cells (Wang & Manis, 2005), reduction in the width of the response area of the various neurons (Willot, 1991), and decline in the inhibitory effects in shaping the neurophysiologic responses (Caspary, Schatteman & Hughes, 2005). The decline in the inhibitory effect has been observed to be due to decrease in the various inhibitory neurotransmitters such as Glycine and GABA (Caspary et al. 1995; Milbrandt & Caspary, 1995). It has been reported that the changes in these cochlear nucleus neurons occurs after 40 years of age (Arnsesn, 1982; Hinjosa & Nelson, 2011).

The changes in aging auditory systems are evident not only at the level of cochlea nucleus but also at the level of inferior colliculus. These changes include significant reductions in the density of GABA+ and GABA- synaptic terminals (Helfer, Sommer, Meeks, Hoffsettler & Hughes, 1999), shift in the average threshold of the central nuclei neuron of inferior colliculus (Palombi & Caspary, 1996), and poor response for the auditory stimuli at the level of inferior colliculus (Palombi & Caspary, 1996). The frequency response areas of the central nuclei of the inferior colliculus have also been found to become broader and more asymmetric with aging (Leong, Barsz, Allen & Walton, 2011). The response properties and numbers of neurons in the inferior colliculus also reduces in the middle age (Willott, Parham, & Hunter, 1988).

Need for the study

Above literature highlight that there is a decline in the auditory system, both anatomically and physiologically, which happens throughout the lifespan of an individual. A significant change in both anatomy and physiology can be noticed in the middle age i.e from 40 years of age. (Engstrom, Hillerdal, Laurell & Bagger-Sjoback. 1987; Felder & Schrott-Fischer, 1995; Scholtz et al. 2001).

Studies have also reported deficits in temporal processing in individuals above 40 years of age (Schneider et al., 1998; Fitzgibbons & Gordon-Salant, 1995; Grose, Hall & Buss, 2006; Kumar & Sangamnath, 2011). Thus one could expect some changes in the neural processing of speech stimulus at the brainstem level. This can be studied using either psychophysical experiment or electrophysiological experiment. As psychophysical experiments are often affected by several factors like state of the subjects, test environment etc, in the current study speech evoked ABR was conducted to assess the physiological changes that could occurs at the brain stem level due to aging.

Most of the speech ABR studies have been carried out using synthesized /da/ stimulus developed by Kraus et al. (2005). This /da/ stimulus does not have prevoicing in it, which is essential for sound to be perceived as voiced in Indian context. There are no study which has explored the effect of prevoicing either in transient or sustained parts of speech ABR response. Thus current study has been taken up to know how the brain stem process the speech signal having prevoicing from that of without prevoicing and also whether age has any influence in processing of these speech signal.

Aim of the study

The present study aims to evaluate the effect of prevoicing on speech ABR across different age groups.

Objectives of the study

The objectives of the study were to:

- Know whether stimulus with and without prevoicing elicit different responses at the level of brainstem in individuals with normal hearing sensitivity.
- Know whether the age has any effect on neural processing of these two stimuli.
- Age at which a significant change could be noticed, if any.

CHAPTER-2

REVIEW OF LITERATURE

Human hearing system is capable of coding pure tones as well as the complex stimuli like noise and speech. Neural coding begins at auditory nerve and continues at brainstem till cortex. Auditory neurons response is different for different acoustic stimuli. Auditory brainstem response is one of the objective measures used to assess the neural integrity. The auditory brainstem responses (ABRs) are a result of synchronous firing of structures along the ascending auditory pathway includes auditory nerve, cochlear nucleus, superior olivary complex, lateral leminiscus, and inferior colliculus (Møller & Jannetta, 1985).

Examining the effect of different stimulus presentation rates on the response is done by measuring adaptation and synchrony in an evoked response. As the presentation rate of the stimulus increases, ABR latencies typically become longer and amplitude decreases. In the ABR of an individual with normal hearing ,the latency of Wave V tends to increase more than that of Wave I Picton, Stapells and Campbell (1981), whereas the amplitude of Wave I decreases more than that of Wave V Harkins, (1981); Picton et al., (1981).

ABR is usually present in all normal hearing subjects (Kumar and Basavaraj 2010) . Hall, (1992); Kraus and McGee, (1992) considered ABR as a valid and reliable vehicle to assess the structural and functional integrity of neural transmission of stimuli at the level of brainstem.

Aging can lead to a structural or a functional deficit at various levels of the central auditory system. Apart from the structural changes, aging would also results in various functional changes. Schneider et al.(1998) ; Banai et al. (2009) concluded that ABR is a good tool to assess the changes that occurs at the brain stem level due to aging.

Speech ABR is a clinical procedure for assessing the auditory processing through speech stimuli which can be evaluated through an objective and non invasive method. It was revealed that subcortical processing of sound is not complex and hardwired, the subcortical responses to speech showed a longer developmental trajectory than click-ABRs (Johnson et al 2008).

Kumar and Basavaraj (2010) studied speech evoked ABR as a tool to understand brainstem encoding of speech sounds which has applications both in research as well as in clinical purposes and is also useful in studying the function of the central auditory system . It also helped in diagnosing individuals with learning disabilities and auditory processing deficits. Speech evoked ABR was also found to be useful in studying temporal encoding of amplitude modulations and also in understanding tonal language processing skills.

Speech evoked ABR in population with normal hearing sensitivity

Reddy, Kumar and Vanaja (2004) studied ABR evoked by speech bursts of stop consonants and compared the responses with that elicited by click stimulus in 11 subjects with normal hearing. The stimuli used were /tha/, /ta/, /pa/ and /ka/ syllables. Results indicated that overall wave morphology of ABR evoked by speech bursts were good and

/ta/ and /tha/ syllables had relatively better morphology. There were robust VI and VII peaks with better morphology than that of clicks. It was concluded that this could be because of neural excitation at the nuclei central to generator of wave V. Click evoked ABR showed normal or slightly delayed latencies in the order of /ka/, /ta/, /tha/ and /pa/ and these difference in latencies was attributed to the spectro-temporal differences in stimuli whereas speech burst evoked ABR exhibited statistically significant delayed latencies for wave V.

Song, Nicol and and Kraus (2011) studied the test - retest reliability of the speech-evoked ABR in young adults. ABRs were obtained by two methods. Thirty-one young adults having normal hearing were tested with a 170 ms /da/ syllable which was presented in quiet as well as 2-talker and 6-talker babble background noise condition and Forty-five young adults were tested with a 40 ms /da/ syllable presented in quiet. Test–retest reliability of the responses was analyzed in the frequency and time domains. Overall it was found that high test-retest reliability of the brainstem response to speech syllables was present in quiet and noisy listening conditions in young adults. Results reveal that there were no significant test-retest differences in measures that quantify the response in either time (i.e., peak latencies, stimulus-to-response and response-to-response measures) and frequency domains (frequency representation and response magnitude) regardless of the type of stimulus used (40 ms vs. 170 ms/da/) or background listening conditions (quiet vs. 2- and 6-talker babble). It was concluded that the subcortical auditory pathway produces stable response to a complex sound which is replicable from session to session.

Akhoun et al (2008) did an experimental parametric study using response (speech ABR) characteristics depending on recording conditions and hearing status. As the similarities between the recording and the speech stimulus enveloped, there was a great risk of artefactual recordings. This study sought to systematically investigate the source of artefactual contamination in Speech ABR response. Sound level thresholds were measured over which artefactual responses were obtained, for different types of transducers and experimental setup parameters. It was found that impedances between the electrodes had a great effect on electromagnetic susceptibility and that the most prominent artefact is due to the transducer's electromagnetic leakage. The only artefact-free condition was obtained with insert-earphones shielded in a Faraday cage which was linked to common ground.

Kumar et al *(2014)* investigated the effect of stimulus polarity on speech evoked auditory brainstem response (S-ABR). In order to accomplish it a 40ms /da/ stimulus was used with various stimulus polarities. The recording was done on 17 normal hearing adults (8 males & 9 females) in the age range of 17 to 30 years. The result revealed differential effect of stimulus polarity on components of speech evoked ABR. Latency of peaks for onset, sustained and offset responses of speech evoked ABR were found to be not significantly different across stimulus polarities. In contrast, the amplitude of first formant and high frequency components was found to be significantly reduced for alternating polarity compared to single polarity which can be attributed to cancellation of spectral FFR as a consequence of adding the response from both the polarities, while amplitude of fundamental frequency response between condensation and rarefaction polarity was not affected because reversing the polarity of the stimulu does not alter the spectral characteristics and hence the response obtained was similar for both the polarities.Thus from this study it was concluded that speech evoked ABR may be recorded using single polarity rather than using alternating polarity.

Kumar and Basavaraj (2011) studied Speech evoked ABR in 30 subjects with normal hearing sensitivity using a 40ms consonant vowel (CV) stimulus /da/.The consonant and vowel portion were analysed separately to see the brainstem encoding of speech sounds. Based on the evaluations of the subjects the speech evoked ABR latency and amplitudes of different peaks were also analysed. Results revealed that Speech evoked ABR was present in all the normal hearing subjects. The consonant portion of the stimulus elicited peak V in response waveform. Response to the vowel portion elicited a frequency following response (FFR) which further showed a coding of the fundamental frequency (F0) and the first formant frequency (F1). The two measures in Speech evoked ABR that is the transient and frequency following responses provide information regarding auditory pathway encoding of consonant and vowel portion of the stimuli. It was concluded that Speech evoked ABR provides valid and reliable information about the speech coding at the brainstem level.

Kumar et al (2013) studied acoustic basis of context dependent brainstem encoding of speech. 14 normal hearing adults participated in the study in whom brainstem responses were recorded for a high pass filtered /da/ in the context of syllables that had either same or different spectral structure. It was concluded that spectral structure is one of the parameters which cue the context dependent subcortical encoding of speech. The results also revealed that brainstem can encode pitch even with negligible acoustic information below the second formant frequency. Thus from this study it was concluded that context plays a role in the brainstem encoding of speech and spectral structure is a cue for this context dependent brainstem encoding.

Speech evoked ABR in population with sensorineural hearing loss

Akhoun et al (2008) recorded speech auditory brainstem responses in unilateral deaf subjects and bilateral normal hearing subjects using artefact-free condition with the insert-earphones used to deliver the stimulation. Responses were recorded separately from the better-hearing ear and the ear with hearing loss of 6 subjects with syllable /da/ being used as the stimulus. The ear with hearing loss was stimulated to confirm that the speech-evoked ABR was a true auditory response rather than an artifact-generated response and also the inserts were unplugged from the ears, so that the subjects did not perceive the stimulus. Results revealed that no responses were obtained from the deaf ear of unilaterally hearing impaired subjects, nor in the insert-out-of-the-ear condition in all the subjects, concluding that Speech ABR reflects the functioning of the auditory pathways.

Musser (2010) evaluated the effect of unilateral hearing loss on Speech evoked ABR in the prescence of noise. The study aimed to characterize speech-evoked ABR measures for two groups of adult participants, those with normal hearing in both ears but stimulated in one ear, and those with unilateral hearing loss .Speech sound /da/ was used and a total of 24 participants (12 adults with normal hearing and 12 adults with unilateral hearing loss) participated in the study. Results revealed ,across participants noise significantly degraded the response and affected both latency and magnitude. Therefore, it was concluded that some differences may exist in the processing of complex acoustic stimuli at the subcortical level for adults with unilateral hearing loss.

Carter (2013) evaluated the Speech-evoked auditory brainstem responses and speech recognition measures in children with unilateral hearing loss and normal hearing. Twenty-four children (Twelve children having unilateral hearing loss and 12 children having normal hearing) aged 7-17 years participated in the study. The study aimed at evaluating the reliability of the speech-evoked ABR in children with unilateral hearing loss and a control group of normal hearing, in assessing the effects of noise, and to evaluate speech recognition in noise in both the study groups. Significant differences between both the groups were noted for all three conditions. It was observed that children with unilateral hearing loss performed worse and had significantly longer latencies and smaller amplitudes compared to children with normal hearing.

Speech evoked ABR in other clinical population

Speech evoked ABR was also utilized to assess processing abilities in learning disabled children.

Nicol and Kraus (2005) aimed at establishing a functional relationship between brainstem and cortical auditory processing in 11 children with language-based learning problems (LP). Speech sound /da/ was used as the stimulus. The effect of noise on correlations between cortical responses to repeated stimuli was studied along with the duration of the wave .The group of children selected for the study demonstrated abnormal encoding of speech sounds on both individual measures of brainstem and cortical processing. Prolonged wave duration and susceptibility of cortical correlations to degradation by noise were both interpreted as reflecting diminished synchrony of response generator mechanisms. Thus it was concluded that the relationship between brainstem and cortical auditory processing helped in, delineating auditory language based learning problems.

Kraus (2011) investigated the sex differences in auditory subcortical function. The aim was to determine if the subcortical response to a complex auditory stimulus is encoded differently between the sexes. Speech syllable /da/ was used and 76 native-English speaking young adults participated in the study. A dissimilarity between males and females was seen in the neural response to the components of the speech stimulus that change rapidly over time; but not in the slowly changing low frequency information in the stimulus. Females have earlier peaks relative to males in the onset of the speech sound and the higher-frequency elements of the speech syllable are also encoded differently between males and females, with females having greater representation of spectrotemporal information for frequencies above the F0. The results provided a baseline for interpreting the higher incidence of language impairment (e.g. dyslexia, autism, specific language impairment) in males, and the subcortical deficits associated with these disorders. These results also paralleled the subcortical encoding patterns for good and poor readers in which poor readers differ from good readers on encoding fast but not slow components of speech which helped in concluding, the higher incidence of reading impairment in males as compared to females.

Banai and Kraus (2007) developed insights from brainstem processing of speech sounds. 88 normal hearing children aged 8-12 years participated in the study and speech syllable /da/ was used as the stimulus. According to this study speech evoked auditory brainstem responses provided a reliable marker of learning disability in a group of individuals with language based learning problems. Results revealed that 40% of LDs have abnormal speech-ABRs and are also likely to exhibit abnormal cortical processing . This was attributed to the fact that the acoustic characteristics of the speech syllable /da/ was more challenging to the auditory system of individuals with LD , since the periodic portion of the vowel may mask the abrupt onset of the consonant.

Kraus (2005) investigated that subcortical representation of speech fine structure is related to reading ability. 51 normal hearing children aged 8-13 years participated in the study. A synthesized 170ms /da/ syllable was used to assess auditory brainstem representation of higher harmonics within a consonant vowel formant transition.The readers were compared on the spectral magnitude of their responses in the three frequency ranges (Fo , low harmonics and high harmonics) and the responses were analyzed in three ways: a single stimulus polarity, adding responses to inverted polarities which emphasized low harmonics , and subtracting responses to inverted polarities which emphasized high harmonics. Results revealed that poor readers had an impaired perception of consonants along with reduced representation of higher speech harmonics for subtracted polarities and single polarity and no group differences were found for the fundamental frequency. These findings strengthen the evidence of subcortical encoding deficits in poor readers for speech fine structure.

Speech evoked ABR in aged population

Anderson, White-Schwoch and Kraus (2012) conducted a study to assess the neural processing of electrophysiological stimulus due to aging using speech syllable /da/ in 17 normal hearing younger adults (18 –30 years old) and 17 older adults (60 – 67 years old) . Older adults were found to have greater response variability and delayed auditory brainstem responses, especially in response to the rapidly changing formant transition which can be attributed to decreased inhibitory neurotransmission. It was also found that older adults had decreased phase locking and smaller response magnitudes than younger adults. Together the results support the theory that older adults have a loss of temporal precision in the subcortical encoding of sound, which is attributed to variability in neural firing.

Rishiq (2013) studied the effects of Aging and Spectral Shaping on the Sub-cortical (brainstem) Differentiation of Contrastive Stop Consonants. Sixteen younger adults and 11 older adults participated in the study and a 100ms speech syllable /da/ was used as the stimulus. Speech-ABR responses were analyzed and older adults were found to have more robust categorical perception, or better defined categories, than the younger adults thereby concluding that cognitive involvement was the factor contributing to the variability in speech perception in normal-hearing older adults.

Brainstem responses to speech in younger and older adults was carried out by Werff and Burns (2011) which mainly aimed to evaluate whether neural encoding of speech features at the brain stem level is altered in the aging auditory system. Speech evoked ABR was recorded using a synthetic 40ms /da/ stimulus from both ears of participants in two groups, 19 normal hearing younger adults and 18 normal hearing older adults. The effect of minimal peripheral hearing loss on speech evoked auditory brain stem response and interactions with aging were also examined. Speech evoked ABR latencies, amplitudes, and sustained response mean data were obtained for both younger adults and older adults. Results revealed that older adults had significantly smaller onset and offset responses for the speech ABR, with delayed offset latencies and also amplitude at the onset was decreased significantly which is attributed to the finding that older listeners had a general reduction in synchronous neural firing in response to transient speech information at the onset of a speech syllable and impaired timing of the neural response at the offset of the stimulus.

Based on the above review it can be concluded that since there are no studies which has explored the effect of prevoicing on sustained parts of speech ABR response, the current study which used /da/ as stimulus that does not have any prevoicing has been taken up to know how the brain stem differentially processes the prevoiced speech signal from that of the signal without prevoicing. It also helped in determining the effect of age in processing of these speech signals. Thus the need of the study is justified.

CHAPTER - 3

METHOD

The aim of the study is to evaluate the effect of prevoicing on speech ABR in individuals with normal hearing sensitivity across different age groups. To achieve the aim of the study three different age groups of participants were taken.

Participants:

Three groups of individuals with normal hearing sensitivity were taken for the study. The groups consisted of adults having normal hearing.

In group I the data was obtained from 30 ears of 15 normal hearing individuals in the age range of 18-30 yrs.

In group II the data was obtained from 14 ears of 07 normal hearing individuals in the age range of 40-50 yrs.

In group III the data was obtained from 14 ears of 07 normal hearing individuals in the age range of 50-60 yrs.

Subject selection criteria:

The following criteria was adopted to select the participants for all the three groups.

- None of the subjects had any past or present history of otological or neurological problems.
- Auditory behavioural thresholds of all the participants were within 15dB HL over the octave frequency range of 250 Hz to 8000 Hz for air conduction and 250Hz to 4000Hz for bone conduction.

- All of them had 'A' type tympanogram with bilateral reflexes present at 500Hz, 1000Hz and 2000Hz and 4000Hz to rule out presence of middle ear pathology.
- Normal auditory brainstem response to clicks stimuli were recorded from all the subjects participated in the study.
- SPIN test score was more than 60% at 0dB SNR, to rule out presence of CAPD.
- TEOAE was present in all the subjects indicating normal OHCs function.

The participants who fulfilled the given criteria were included in the study.

Instrumentation

Following equipments were used for the study:

1) Pure Tone Audiometer

A calibrated two channel Madson OB922 clinical audiometer with TDH-39 head phone housed in MX 41 AR ear cushion with audio cup was used for pure tone audiometry and speech audiometry. Bone vibrator Radio ear B-71 was used to estimate the bone conduction threshold.

2) Immittance meter

Tympanometry and reflexometry was carried out using a calibrated automatic immittance meter with visual display (Grason - Stadler GSI-TS).

3) Auditory evoked potential system

To record click evoked ABR and speech evoked ABR an auditory evoked potential system BIOMARK Navigator Pro, version 7 with calibrated insert earphone was used.

4) Oto-acoustic emissions (OAEs)

Transient evoked oto-acoustic emissions (TEOAEs) was recorded using a calibrated ILO - version 6 OAE instrument.

Test environment

All the tests were carried out in an acoustically treated room. The ambient noise in the test room was within the permissible noise levels as recommended by ANSI-S3.1 (1991).

Generation of test stimulus used to record Speech ABR

To record speech ABR first a synthesized /da/ stimulus was generated without having prevoicing. This stimulus was generated using the KlySIN software, Klatt synthesizer (as used by Kraus, 2005). The generated voiced stimulus /da/ has fundamental frequency (F0) in the range of 125 Hz to 123 Hz. The frequency of first formant (F1) rose from 200 Hz to 720 Hz. The frequency of second formant (F2) fall from 1700 Hz to 1240 Hz with third formant frequency (F3) fall from 2800 Hz to 2400 Hz. All the formants reached plateau at around 40ms from the onset of the stimulus /da/. The waveform and spectrogram of the stimulus /da/ can be seen in figure 3.1.

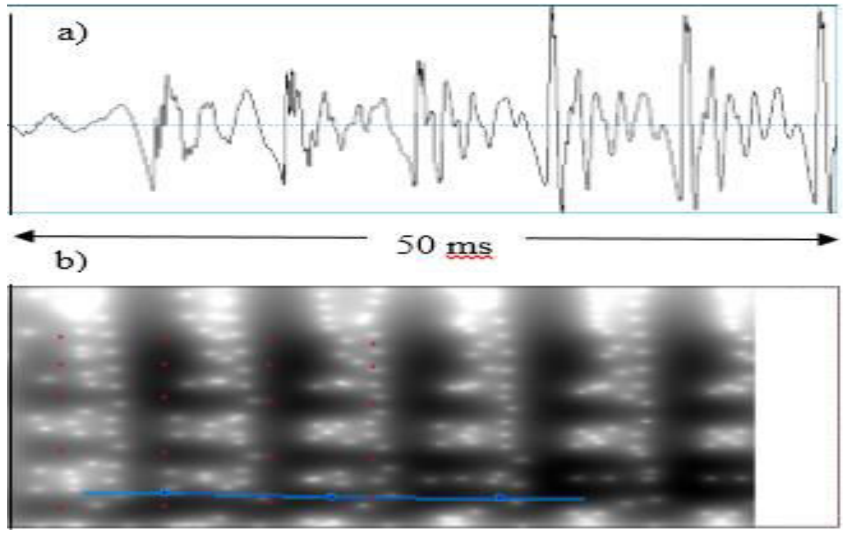

Figure 3.1: Stimulus /da/ (50 ms). a) Waveform for the stimulus /da/.
b) Spectrogram of the stimulus /da/.

Generation of stimulus with prevoicing:

Ten native adult Kannada speakers were taken and /da/ stimulus was recorded for the generation of stimulus with prevoicing. The prevoicing acoustic parameters was spectrally analysed from the recording of all the speakers. These prevoicing components was then averaged and concatenated with the /da/ stimulus generated earlier to generate a /da/ stimulus with prevoicing having 30ms prevoicing duration. Thus the stimulus with prevoicing had duration of 80 ms. To maintain the duration of stimulus a period of 30 ms silence was added to the stimulus which has no prevoicing. The stimulus with and without prevoicing can be seen in figure 3.2 and 3.3.

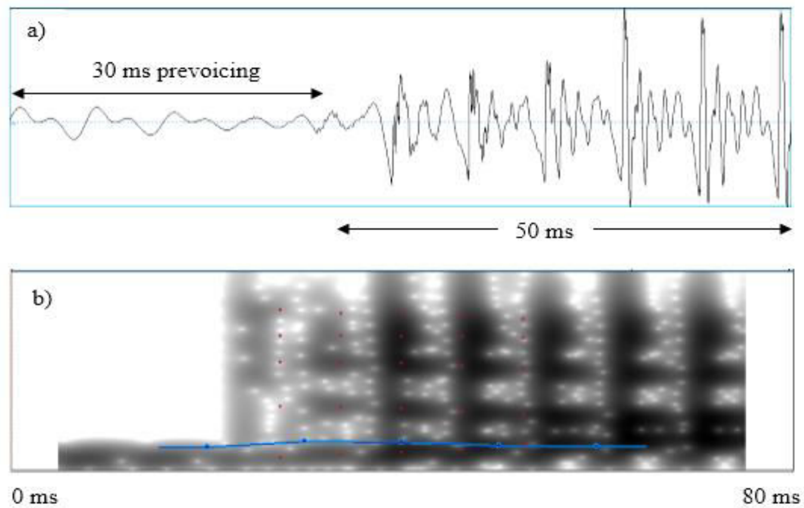

Figure 3.2: Stimulus /da/ with prevoicing (80 ms). a) Waveform for stimulus /da/ with prevoicing. b) Spectrogram of the stimulus /da/ with prevoicing.

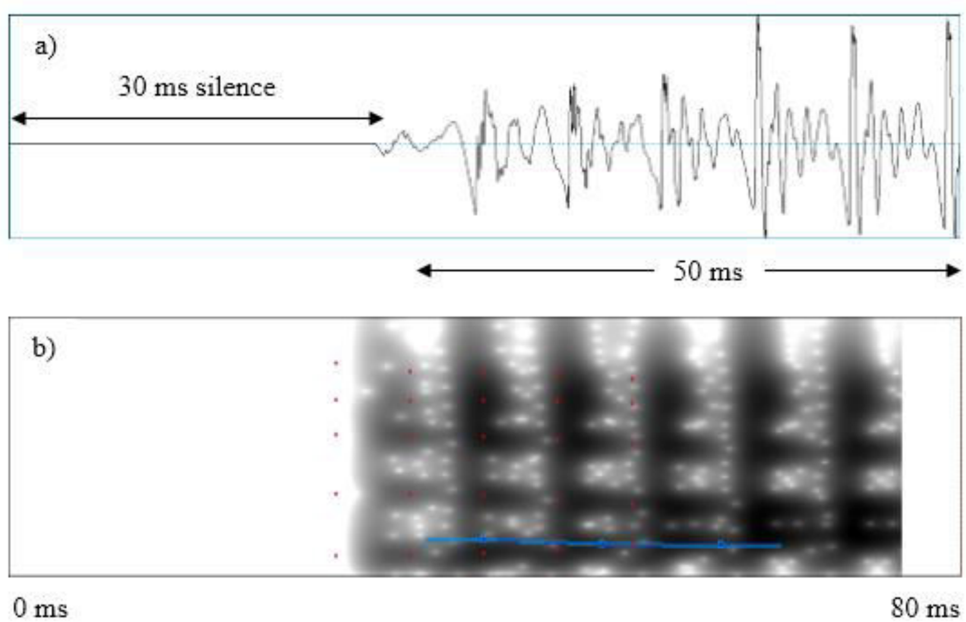

Figure 3.3: Stimulus /da/ without prevoicing (80 ms). a) Waveform for stimulus /da/ without prevoicing. b) Spectrogram of the stimulus /da/ without prevoicing.

PROCEDURE

In two phases the audiological tests were carried out. In phase I audiological tests were carried out to select the subjects based on the test results and criteria mentioned earlier. Phase II was carried to collect data from the selected subject. As a part of subject selection criteria following audiological tests were carried out:

1. Pure tone audiometry

Pure tone stimuli was used to obtain the behavioural air conduction thresholds in the octave frequencies from 250 Hz to 8 KHz under the headphone condition and bone conduction thresholds in octave frequencies from 250 Hz to 4 KHz with bone vibrator radio ear B71. The modified Hughson and Westlake procedure (Carhart & Jerger, 1959) was used to obtain the thresholds for all the subjects participated in the study.

2. Speech Audiometry

To obtain speech recognition threshold (SRT) speech audiometry was carried out using a standardized paired word list developed by Rajashekhar (1978). Using the PB word list developed by Vandana (1998) speech identification scores (SIS) was obtained . Speech Identification Scores were obtained at 40 dB SL with reference to SRT or Most Comfortable Level. At this supra threshold level, the numbers of correct words uttered over the total words was calculated and converted into percentage to obtain the speech identification scores.

3. Speech perception in noise

To obtain SPIN scores the above mentioned PB word list were presented at 0 dB SNR. Both the stimulus and noise were presented at 40 dB SL the procedure used to obtain SIS was also adopted to obtain SPIN scores. The corresponding speech identification score in quiet and at 0 dB SNR was obtained from each subject monoaurally for both ears in subjects with normal hearing.

4. Immittance Audiometry

Middle ear evaluation was done using 226 Hz probe tone. Tympanogram was obtained by sweeping the pressure from +200 dapa to – 400 dapa. In reflexometry, both ipsilateral and contralateral acoustic reflex thresholds were measured for 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz reflex eliciting pure tone at peak pressure. The minimum intensity of the reflex eliciting acoustical signal that lead to 0.03 ml changes in admittance value was taken as the threshold.

5. Otoacoustic emissions (OAEs)

Nonlinear click presented at 80 dBpeSPL was used to record transient evoked otoacoustic emissions (TEOAEs). To obtain the emissions and amplitude of the TEOAEs and noise floor the responses of 256 sweeps were averaged. The responses were consider to be present when the emission amplitude was more than 3 dB SPL above the noise floor and had reproducibility more than 70%. OAEs were present in all the groups indicating normal cochlear function.

6. Auditory brainstem response (ABR)

During the testing participants were instructed to sit comfortably on a reclining chair and asked to relax. To avoid any occular artifacts the participants were instructed to close their eyes during the testing. Skin preparing gel was used to clean the skin at recording sites. Gold plated disc electrodes were placed on the recording sites with conduction paste and placement was secured with adhesive tape. It was ensured that intra electrode impedance was within 5 KΩ and inter electrode impedance was within 2 KΩ. Standard protocol was used to recored ipsilateral single channel click evoked ABR.

Table 3.1: *Parameter used to record click evoked ABR*

Stimulus parameter		**Acquisition parameter**	
Stimulus type	Click	**Analysis time**	10 ms
Repetition rate	11.1/sec & 90.1/sec	**Filter setting**	100-3000 Hz
Polarity	Rarefaction	**Electrode placement**	Fz – Non-inverting Test ear mastoid – Inverting, Non test ear mastoid – Ground
Click duration	100 µsec	**Artifact rejection**	31 µV
Intensity	90 dBnHL	**Amplification**	100,000
Transducer	Insert earphone	**No. of sweeps**	1500

To ensure the reproducibility of the waveform, ABR was recorded twice from each ear at each repetition rate using above mentioned protocol.

Procedure to obtain data:

1. Speech evoked auditory brainstem response (Speech ABR)

The speech evoked auditory brainstem responses were recorded in all the participants for the study. Speech ABR was recorded using ipsilateral single channel recording for each stimulus. Prior to the recording all the subjects were prepared for speech evoked ABR as mentioned under click evoked ABR. The protocol used to record speech evoked ABR is given below:

Table 3.2: *Parameters used to record speech evoked ABR*

Stimulus Parameter		**Acquisition parameter**	
Stimulus	CV syllable - /da/, with prevoicing and without prevoicing.	**Electrode montage**	Non-inverting electrode: High forehead, Inverting electrode: Test ear mastoid, Ground electrode: Non test ear mastoid.
Duration	80 ms	**Data points**	1024
Level	90 dB SPL	**Artifact rejection**	31 µV
Rate	9.1/sec	**Amplification**	100000
No of sweeps	3000 sweeps for each recording	**Filter band**	80 to 3000 Hz
Transducer	Bio- logic Insert earphone	**Time window**	100 ms
Polarity	Alternating	**Pre-stimulus recording**	10 ms

To ensure the reproducibility of the waveform the speech ABR was recorded twice from each ear using above mentioned protocol. To visually identify presence and absence of response the recorded speech ABR wave forms from each individuals were given to three experienced audiologist. They were also asked to mark the duration of the response for prevoicing for the stimulus with prevoicing and FFR for both the stimulus. This was done to exactly copy the response duration and fed into the MATLAB program to obtain amplitude of F0, F1, F2 and also amplitude of prevoicing response (only for stimulus with prevoicing).

Objective evaluation of FFR for amplitude of fundamental frequency (F0), first formant (F1) and second formant (F2) and amplitude of prevoicing response:

For this purpose FFT was done for FFR of speech evoked ABR for stimulus with prevoicing and stimulus without prevoicing. For this purpose response was analysed and that response was set into the analysis window and the F0, F1 and F2 amplitude were analysed for both the stimuli. A 2 ms on and 2 ms off Hanning ramp was applied to avoid the spectral splatter. To include in the analysis Subject's auditory evoked responses were to above the noise floor. This was done by decoding, the magnitude of F0, F1 and F2 frequency component of FFR by the spectral magnitude of pre-stimulus period. The response was considered above the noise floor if the quotient of the magnitude was greater than one and hence the F0, F1 and F2 was coded at the auditory brainstem, hence the response was considered to be present. The amplitude of the F0, F1 and F2 was expressed in arbitrary unit as recommended by Russo et al, (2004). It gave the information of coding of F0, F1 and F2 and the amount of activity at these frequencies. All the raw value of amplitude of fundamental frequency and the first formant component of frequency followed response was noted. All the analysis part of FFT was done by custom made programme in MATLAB Software.

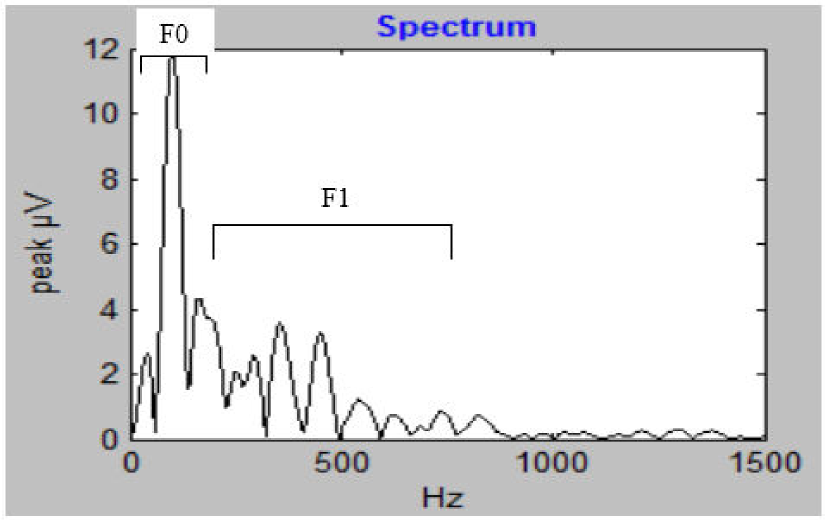

Figure 3.4: Spectrum of FFR obtained after FFT representing energy at F0 and F1

The response of stimulus with prevoicing was also analyzed for prevoicing response. The response of prevoicing was set into the analysis window and checked for the response amplitude, if the response amplitude is greater than 1 then response was consider as present and taken for analysis. Across the groups the amplitude of prevoicing response was taken.

Analysis of the data

The F0, F1, F2 amplitude and also amplitude of prevoicing response were noted after the FFT analysis. These data were compared across groups and also between stimulus to see the effect of stimulus condition and across age groups on speech evoked FFR using appropriate statistical analysis.

CHAPTER- 4

RESULTS

The present study aimed to evaluate the effect of prevoicing on speech ABR across different age groups having normal hearing sensitivity. To achieve the aim of the study the amplitude of the fundamental frequency (F0), first formant frequency (F1) and second formant frequency (F2) responses for /da/ stimulus with and without prevoicing across the age groups were taken and the data was compared between the groups to evaluate the significant difference across the age groups and also to see the effect on neural processing of these two stimuli.

Statistical Analysis

The obtained data was tabulated and subjected to statistical analysis using SPSS (Statistical Packages for the Social Science) software (version, 21.0). The following statistical analyses were administered to achieve the aim of the study.

1. Kolmogorov Smirnov test of normality was done to check whether the collected data is normally distributed or not.
2. Descriptive analysis was administered to obtain mean and standard deviation of F0, F1 and F2 amplitude and amplitude of prevoicing response across the age groups for both the stimulus conditions.
3. Mixed ANOVA was done to see the significant main and interaction effect between stimulus conditions and groups for F0, F1and F2 amplitude separately.

4. MANOVA was administered to see the significant difference between groups for F0, F1and F2 amplitude if required.
5. One way ANOVA was administered to see the main effect of age on response elicited by prevoicing portion of stimulus.
6. Paired sample t-test was carried out to see the significant difference in F0, F1 and F2 amplitude between the stimulus conditions within groups if mixed ANOVA showed significant main effect of stimulus.
7. Pearson correlation was administered to see the relationship between amplitude of response elicited by prevoicing and the amplitude of fundamental frequency (F0) of stimulus having prevoicing across the age groups.

Speech Evoked ABR response for /da/ stimulus with and without prevoicing

The data of the present study was obtained from a total of 58 ears from 29 individuals with normal hearing sensitivity and were divided into three groups. The first group consisted of 15 individuals with the age range from 18-30yrs, the second group consisted of 7 individuals with the age range from 40 – 50yrs and the third group consisted of 7 individuals from 50 – 60 yrs. Speech ABR response were present in all the individuals (30 ears) in group I, and speech ABR responses were present in all14 ears in group II and 14 ears in group III. So, totally speech ABR responses were recorded from all 58 ears. The Speech ABR waveforms recorded from one of the subjects from each group for /da/ stimulus without prevoicing can be seen in figure 4.1.

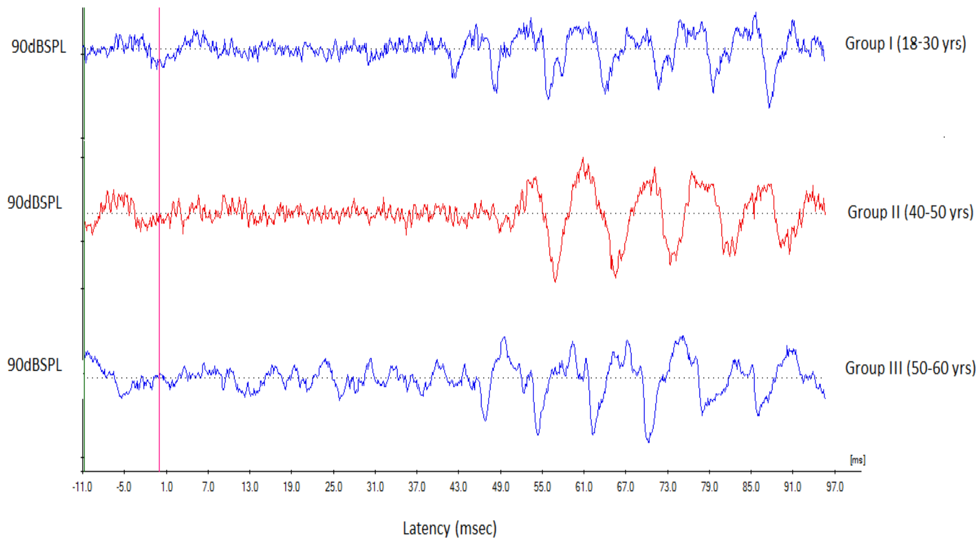

Figure 4.1 Speech ABR waveform recorded from one of the subjects from each group using 80ms /da/ stimulus without prevoicing at 90 dB SPL.

The Speech ABR waveforms recorded from one of the individual from each group using /da / stimulus with prevoicing are seen in figure 4.2.

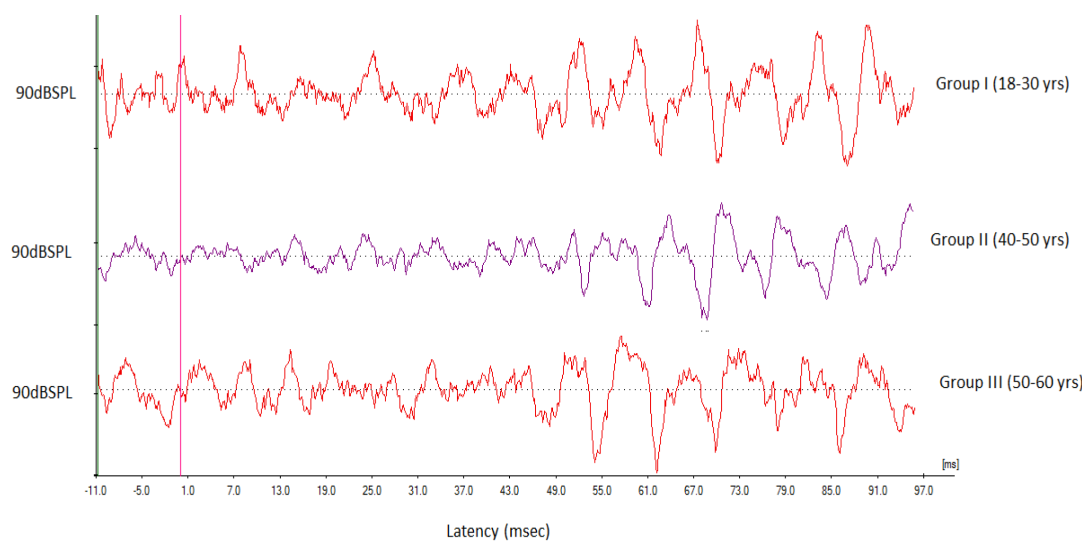

Figure 4.2 Speech ABR waveform recorded from one of the subjects from each group using 80ms /da/ stimulus with prevoicing at 90 dB SPL.

Effect of age and stimulus on F0 (Fundamental frequency) amplitude

The mean and Standard deviation was calculated for the amplitude of F0 (Fundamental frequency) for the /da/stimulus with and without prevoicing in three age groups having normal hearing sensitivity i.e. Group I (18-30yrs) and Group II (40-50yrs), and Group III (50-60yrs) using descriptive statistical analysis. The same can be seen in table 4.1.

Table 4.1 *Mean and SD of amplitude of F0 (Fundamental frequency) obtained using /da/ stimulus with and without prevoicing in Group I, Group II & Group III*

F0 amplitude of FFR					
Group	Number of ears	Without prevoicing		With prevoicing	
		Mean amplitude (µv)	SD	Mean amplitude (µv)	SD
Group I	30	3.37	1.54	3.11	1.27
Group II	14	4.28	1.17	3.28	1.65
Group III	14	2.98	1.63	2.64	1.21

It can be observed from the table 4.1 that the mean amplitude of F0 (Fundamental frequency) for the /da/stimulus with and without prevoicing are different among the groups. The mean amplitude of F0 (Fundamental frequency) for Group II for the /da/ stimulus without prevoicing was higher compared to other groups. The mean amplitude of F0 (Fundamental frequency) was higher for the /da/ stimulus without prevoicing than the stimulus with prevoicing in all three the age groups. F0 amplitude was least for group III for both the stimulus elicited response. The same can be seen in figure 4.3

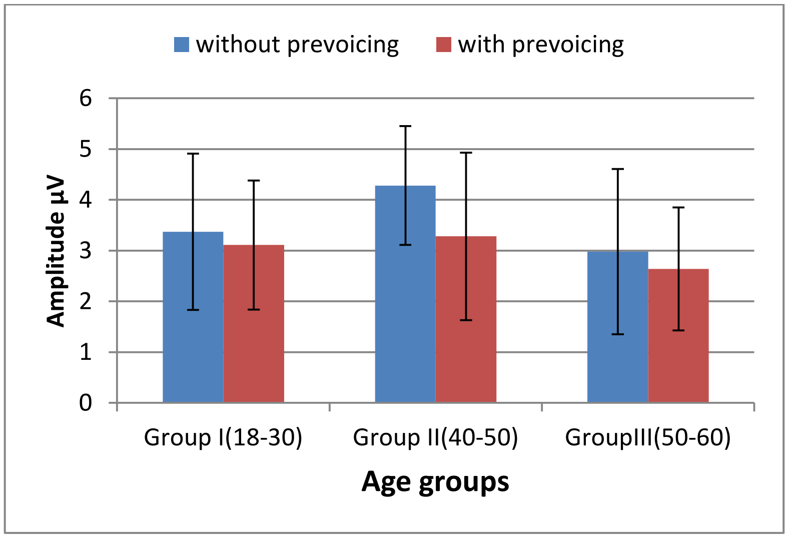

Figure 4.3: Mean and SD of F0 amplitude of FFR for two stimuli across three groups.

Mixed ANOVA was done to see the significant main effect for stimulus with and without prevoicing and groups and also interaction effect between group and stimulus condition. Mixed ANOVA results for F0 amplitude revealed no significant main effect of group [F(1,55)=1.972, p>0.05]. Whereas stimulus has shown significant main effect [F(1,55)=10.39, p<0.05] and no interaction effect between stimulus and groups [F(2,55)=1.94, p>0.05] was observed. As the mixed ANOVA did not show significant main effect of groups or significant interaction between group and stimulus condition, MANOVA was not administered to see the significant group difference for each stimulus.

Effect of stimulus condition on F0 amplitude

As the mixed ANOVA showed significant main effect of stimulus condition Paired sample t-test was done see the significant difference in F0 amplitude between stimulus condition within group. Group II showed the significant difference for stimulus with and without prevoicing [$t(13)=2.91$, $p<0.05$]. However group I and group III did not show significant difference i.e group I [$t(29)=1.34$, $p>0.05$] and group III [$t(13)=0.95$, $p>0.05$].

Effect of age and stimulus on F1 (First formant frequency) amplitude

The amplitude value of F1 (First formant frequency) elicited by /da/ stimulus with and without prevoicing was noted for all the three groups. Descriptive analysis was done to obtain mean and standard deviation of F1 amplitude (First formant frequency) across the age groups for both stimulus conditions. The same can be seen in table 4.2.

Table 4.2: *Mean and SD of amplitude of F1 (First formant frequency) obtained using /da/ stimulus with and without prevoicing in Group I, Group II & Group III*

F1 amplitude of FFR					
Group	Number of ears	Without prevoicing		With prevoicing	
		Mean amplitude (µv)	SD	Mean amplitude (µv)	SD
Group I	30	0.39	0.12	0.37	0.13
Group II	14	0.40	0.13	0.36	0.08
Group III	14	0.40	0.15	0.38	0.13

It can be observed from the table 4.2 that the mean amplitude of F1 for stimulus without prevoicing is almost same across the age groups. There is no much difference in F1 amplitude noted across the age groups for stimulus with prevoicing also. However, F1 amplitude elicited by stimulus without prevoicing is slightly higher than that elicited by stimulus with prevoicing. The same can be seen in figure 4.4.

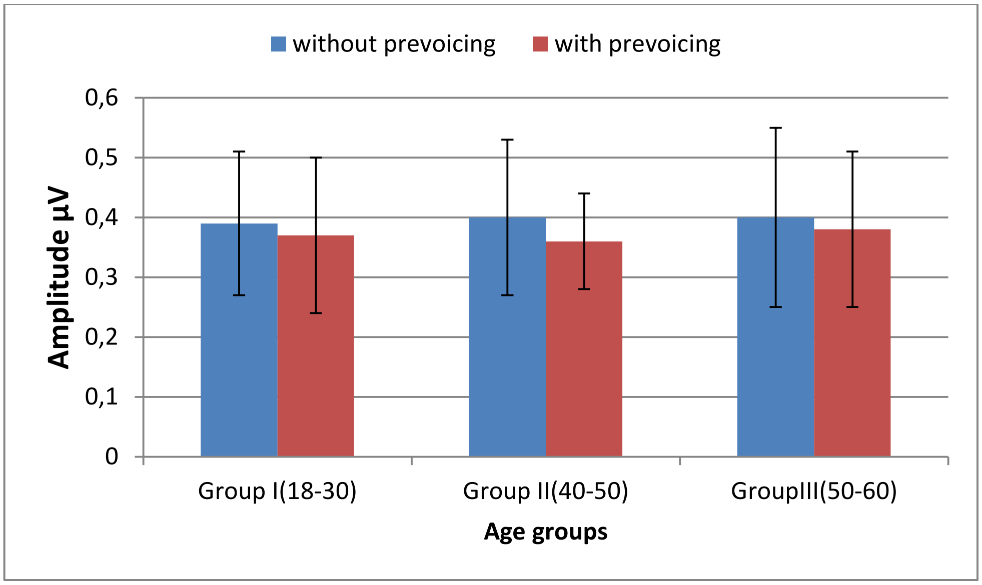

Figure 4.4: Mean and SD for F1 amplitude of FFR for two stimuli across three groups.

Mixed ANOVA was done to see the significant main effect and interaction effect for stimulus with and without prevoicing and also between group and interaction effect of stimulus condition and group. Mixed ANOVA results for F1amplitude revealed no significant main effect of group [F(1,55)=0.02, p>0.05], and stimulus [F(1,55)=3.02, p>0.05] and no interaction effect between stimulus and groups [F(2,55)=0.18, p>0.05].

Further statistical analysis was not carried out as mixed ANOVA results did not show any significant main effect or interaction effect of variables.

Effect of age and stimulus on F2 (Second formant frequency) amplitude

The amplitude value of F2 (Second formant frequency) elicited by /da/ stimulus with and without prevoicing was noted for all the three groups.

Descriptive analysis was done to obtain mean and standard deviation of F2 (Second formant frequency) across age group and for both stimulus condition. The same can be seen in table 4.3.

Table 4.3: *Mean and SD of amplitude of F2 (Second formant frequency) obtained using /da/ stimulus with and without prevoicing in Group I, Group II & Group III*

F2 amplitude of FFR					
Groups	Number of ears	Without prevoicing		With prevoicing	
		Mean amplitude (µv)	SD	Mean amplitude (µv)	SD
Group I	30	0.24	0.19	0.20	0.06
Group II	07	0.23	0.06	0.21	0.07
Group III	07	0.21	0.09	0.32	0.24

It can be observed from table 4.3 that the mean amplitude of F2 for stimulus without prevoicing did not differ much among the age groups but for stimulus with prevoicing the amplitude for the third group was more than the other groups. The same can be seen in figure 4.5 also.

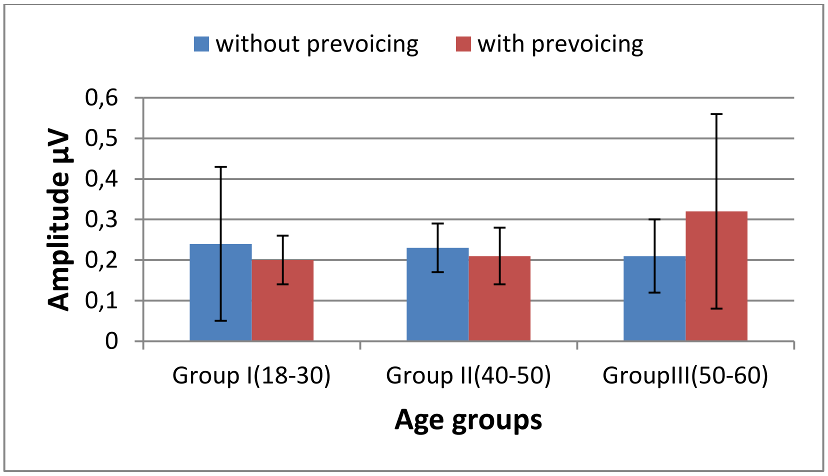

Figure 4.5: Mean and SD of F2 amplitude of FFR for two stimuli across three groups.

Mixed ANOVA was done to see the significant change in F2 amplitude elicited by prevoicing and also between group and the interaction effect of stimulus condition and group. Mixed ANOVA results for F2 amplitude revealed no significant main effect of group [$F(2,55)=0.9$, $p>0.05$], and stimulus [$F(1,55)=0.31$, $p>0.05$] and also no interaction effect between stimulus and groups [$F(2,55)=2.64$, $p>0.05$].

Effect of age on prevoicing response elicited by prevoicing portion of the stimulus

Response amplitude of prevoicing was noted and descriptive analysis was done to obtain mean and standard deviation across group. Details can be seen in table 4.4.

Table 4.4 *Details of Mean and the standard deviation for prevoicing response recorded using /da/ stimulus with prevoicing across groups*

	Amplitude of prevoicing response					
	Group I		Group II		Group III	
Stimulus with	Mean	SD	Mean	SD	Mean	SD
Prevoicing	3.11	1.27	3.28	1.65	2.64	1.21

It can be seen from table 4.4 that the mean amplitude of F0 for stimulus with prevoicing is more for group II compared to other groups. The same can be seen in figure 4.6.

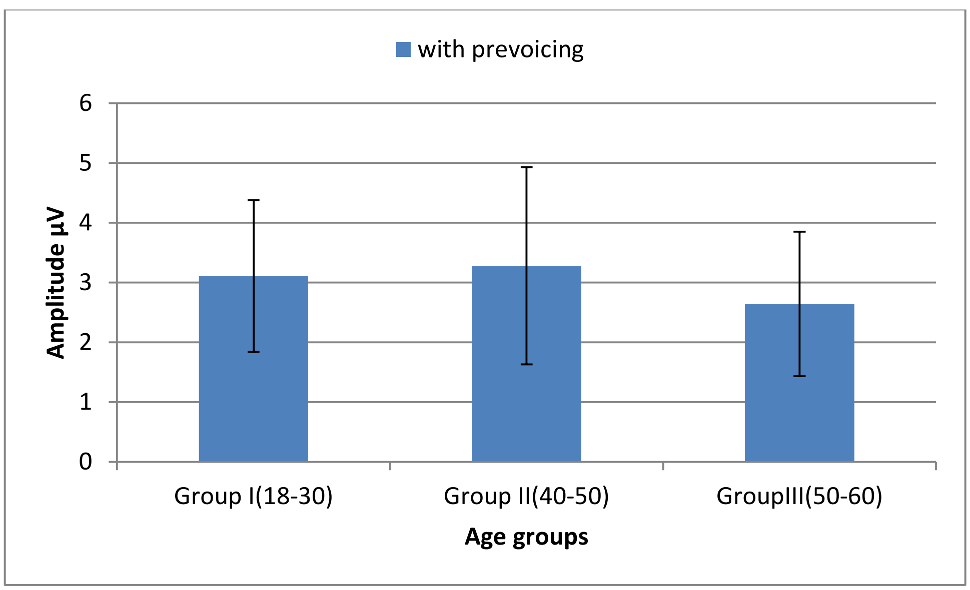

Figure 4.6 Mean and SD for prevoicing response amplitude elicited using stimulus with prevoicing across three groups.

The prevoicing response for /da/ stimulus with prevoicing for all the three age groups were noted and one way analysis of variance was carried out to see the effect of age on amplitude of prevoicing response. The results revealed there was no significant difference among the three age groups [$F(2,55)=1.0$, $p>0.05$].

As one way ANOVA did not show any significant effect of age group on amplitude of response elicited by prevoicing further statistical analysis was not carried out to see the group difference.

Relationship between amplitude of prevoicing response and amplitude of F0 for stimulus with prevoicing

To see the effect of prevoicing on the F0 (Fundamental frequency) pearson’s correlation was done between F0 amplitude and prevoicing response for all the groups. There was a negative correlation for group I [$r = -11$, $p>0.05$] and group III [$r = -.39$, $p>0.05$] which was statistically not significant but for group II [$r = .12$, $p>0.05$] there was a minimal positive correlation which was also not statistically significant.

CHAPTER- 5

DISCUSSION

The aim of the study was to know whether the synthesized /da/ stimulus with and without prevoicing elicit different responses at the level of brainstem in individual with normal hearing sensitivity across the three different age group. Results obtained from the three groups are discussed below.

Effect of stimulus on F0 amplitude

The F0 amplitude for /da/ stimulus without prevoicing was more than the F0 amplitude of /da/ stimulus with prevoicing. The reduction in F0 amplitude for stimulus with prevoicing could be due to the presence of prevoicing component in the stimulus. Presence of prevoicing energy would have caused masking effect and resulted in reduced SNR. Presence of prevoicing would have also had forward masking effect or would have caused adaptation, resulting in reduced compound action potential for F0. Thus all the factors would have resulted in reduce F0 amplitude for stimulus with prevoicing. In a study by Li and Jenga (2011) observed that response energy at F0 decreased as SNR was degraded from no noise to -12dB. However till date none of the study have seen effect of prevoicing on F0 amplitude of FFR.

Song, Banai, Russo and Kraus (2006) reported that the vowel that follows the consonant is a sustained periodic signal that is usually much louder than the consonant. Because of this higher amplitude, longer portion of the stimulus may actually mask the brief consonant onset which is critical for eliciting the onset portion of the speech-evoked ABR. In the current study probably longer prevocing portion present in the acoustic stimulus which would have caused forward masking effect and resulted in reduced F0 amplitude.

Effect of stimulus on F1 amplitude

The /da/ stimulus with and without prevoicing had no significant difference on the amplitude of F1. Till date no study have compared the effect of prevoicing on F1 amplitude. Hence exact reason for not having any significant difference effect on F1 is needed to explore.

The amplitude for the stimulus without prevoicing was more than the amplitude of F1 for /da/ with prevoicing. This may indicate the addition of prevoicing adding extra noise in the stimulus or causing the internal masking leading to reduced amplitude of F1. In speech evoked FFR the amplitude of F0 and F1 is reduced in presence of noise as compare to quiet condition is observed by Russo, Nicol, Musacchia and Kraus (2004). In the current study presence of long duration prevoicing would have cause forward masking effect on F1 amplitude also.

Effect of stimulus on F2 amplitude

The /da/ stimulus with and without prevoicing had no significant effect on F2 amplitude. However till date no study have compared the effect of prevoicing on F2 amplitude which needs to be explored.

Overall effect of stimulus on FO, F1 and F2 amplitude

F0 showed higher amplitude compare to other formants frequencies for both the stimulus across the groups. The maximum energy at F0 is consistent with the earlier studies. Song, Banai, Russo and Kraus (2006) reported that the vowel that follows the consonant is a sustained periodic signal that is usually much louder than the consonant. Because of this higher amplitude, longer portion of the stimulus may actually mask the brief consonant onset which is critical for eliciting the onset portion of the speech-evoked ABR. Also F0 has lower frequency as compared to its harmonics and it is well known that lower frequency has better phase locking response (Gelfend, 1998). Thus the F0 having greater energy and better coding could have resulted in robustly F0 amplitude than its harmonics.

Sinha and Basavaraj, (2010) also reported that speech evoked ABR was present in all the normal hearing individuals and measurement of the FFR analysis showed that the amplitude of the F0 is more compare to F1. They attributed this to the stimulus characteristics and the phase locking properties of the auditory neurons and stated that the stimulus has higher energy at the F0 region compared to the harmonics and higher energy components are represented better at the neuronal level.

Effect of age on neural processing of stimulus with prevoicing and stimulus without prevoicing

The amplitude of F0, F1 and F2 elicited by /da/ stimulus with prevoicing did not differ significantly across the age groups. The /da/ stimulus without prevoicing also did not show any significant difference in F0, F1 and F2 amplitude across age. However amplitude of F0, F1 and F2 were less for group III. The speech evoked ABR was done at higher intensity that is 90 dB SPL which elicited same response for both the stimuli and did not show change in any neural processing across age groups, However this finding is contradictory to the findings of other studies. Clinard (2009) reported that older adults having normal hearing sensitivity may have auditory perceptual deficits compared to the younger age groups, which may be related to decline in the neural representation of frequency and stated that FFR declined with increasing age and FFR amplitude at and slightly below 1000 Hz showed significant decrease as age increased. This probably suggest that why F2 amplitude did not differ significantly across age.

Clinard (2013) also reported that neural representation for complex /da/ stimuli declines with advancing age and sustained responses from the onset of vowel periodicity were decreases in amplitude with advancing age. Parbery-Clark et al., (2011) observed that there were differences in processing of transition region of the speech syllable /da/ with advancing age.

Hedrick and Younger, (2007) reported that timing delays are not found in normal hearing older adults in the steady state region of the responses for the /da/ stimulus. This is in consonance with the finding of the current study.

Age at which a significant change is noticed

The response analysis across the three age groups revealed that there was no significant age effect. However the amplitude of F0, F1 and F2 was relatively low for group III.

Parbery-Clark et al., (2011b) observed that there were differences in processing of the transition region of the speech syllable /da/ as age increased. Burns (2009) reported that the brain stem responses were found to be significantly reduced in amplitude in older individuals compared to younger individuals and concluded that older individuals had a general reduction in synchronous neural firing.

Kraus et al (2012) reported overall decrease in representation of speech cues in older adults and older adults had less consistent brainstem responses than younger adults due to diminished neural precision and poor phase locking ability and decreased inhibitory neurotransmission which might be a factor in reduced amplitude for group III.

Anderson, Clark, and Kraus (2012) has observed age related reduction in inhibitory neurotransmitter levels and delayed neural recovery which can contribute to decrease in temporal precision of the auditory system. Decreased precision may lead to neural timing delay, reduction in neural response magnitude and a disadvantage in processing of rapid acoustic changes in speech.

The amplitude of the ABR is a direct function of the number of neurons and the synchrony of the neurons contributing to the response. This suggests that age-related changes in speech ABR amplitudes seen in group III could be result of (a) a reduction in the number of neurons available to respond to a given signal, (b) a reduction in the synchronized activity of neurons responding to a given signal, and/or (c) a reduction in the evoked potential.

CHAPTER- 6

SUMMARY AND CONCLUSION

The auditory brainstem responses to assess the auditory neural integrity is usually checked through non speech stimuli like click or tone bursts. Although clicks and tone bursts stimuli are used widely to assess the auditory neural integrity, they are poor estimates of processing of speech sounds that we encounter in everyday. In addition to non speech stimuli, ABRs can also be evoked using a speech stimuli and are used to study encoding of speech stimulus at the brainstem level which is known as speech ABR. Speech stimuli is used to assess the reponse of the auditory system to speech. Recent studies on speech ABR has shown that the processing of speech sounds in the brainstem provide an insight into the central auditory processing involved in people with normal hearing sensitivity and clinical population.

The understanding of speech evoked ABR has applications both in research as well as in clinical purposes. Most often consonant-vowel speech syllables, such as /da/ are used in eliciting speech evoked ABR.

Aging affects neural precision of speech encoding. Older adults frequently report that they can hear but cannot understand the meaning. Aging can leads to a structural or a functional deficit at various levels of the central auditory system. Thus the current study speech evoked ABR was conducted to assess the physiological changes that could occurs at the brain stem level due to aging.

Most of the speech ABR studies have been carried out using /da/ stimulus synthesized by Kraus et al. (2005). This /da/ stimulus does not have prevoicing in it, which is essential for sound to be perceived as voiced in Indian context. Thus current study has been taken up to know how the brain stem process the speech signal having prevoicing from that of without prevoicing and also whether age has any influence in processing of these speech signal.

In this study individuals with different age groups with normal hearing sensitivity were taken to see the effect of prevoicing across the age groups. The age groups were divided into three groups. The group I consisted of 15 individuals from the age range 18-30yrs , group II consisted of 7 individuals in the age range 40-50yrs and group III consisted of 7 individuals in the age range 50-60yrs having normal hearing sensitivity.

Klatt synthesizer was used to obtain the /da/stimulus with and without prevoicing. The synthesized /da/ stimulus with and without prevoicing was used and the data was collected from 30 ears from 15 individuals for group I, 14 ears from 7 individuals each for group II and III.

The amplitude of F0, F1 and F2 for stimulus with prevoicing and stimulus without prevoicing were taken for response analysis using FFT. ABR response for prevoicing portion of stimulus was also analyzed and amplitude was noted. The results obtained were compared across the age groups and also across stimulus condition. Statistical analysis was done to see the significant difference across the groups and stimulus condition for F0, F1 and F2 amplitude and also across group for prevoicing response.

All the individuals who participated in the study had speech ABR reponses to both the stimulus condition, and the results varied across the groups and for both the stimulus condition. The results obtained can be summarized as follows:

F0 amplitude revealed no significant difference across the age groups, where as stimulus has shown signicant difference across groups, group II shows significant difference for stimulus with and without prevoicing, where as group I and group III did not show significant difference for the stimulus condition.

F1 amplitude for stimulus without prevoicing was slightly higher than the stimulus with prevoicing, but there was no significant difference in the F1 amplitude across the age groups. F2 amplitude also did not show any significant difference across of groups and also stimulus condition.

Overall F0 amplitude for /da/ stimulus with and without prevoicing was more than the amplitude of F1 and F2 for both the stimulus condition. As F0 has the low frequency energy components the brainstem responses are represented well than the other frequency i.e F1 and F2.

Conclusion:

The following conclusion can be made based on the results obtained in the current study:

1. Speech ABR for the /da/ stimulus with prevoicing and without prevoicing would elicit responses in all individual with normal hearing.
2. Older individuals (Group III) with normal hearing sensitivity are likely to show poor response amplitudes compared to the younger adults.

3. Stimulus without prevoicing might elicit higher F0 amplitude than stimulus with prevoicing.

Implications of the study:

1. The results of the study suggest that it can be used to assess the effect of prevoicing in other clinical population like learning disability, Auditory processing deficits.
2. The study can be used to see after training effect in individuals with speech processing deficit.

Limitations of the study are :

1. The obtained results would have been more appropriate if equal number of subjects were taken in all the groups.
2. Number of subjects taken for group II and III are less, however further study can be carried out using large population to generalize the findings

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