BINAURAL INTERACTION COMPONENT FOR SPEECH EVOKED ABR IN OLDER ADULTS.

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CERTIFICATE

This is to certify that this dissertation entitled **"Binaural Interaction Component for speech evoked ABR in older adults**.**"** is a bonafide work submitted in part fulfilment for degree of Master of Science (Audiology) of the student Registration Number: 16AUD006. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru
April, 2018

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CERTIFICATE

This is to certify that this dissertation entitled "**Binaural Interaction Component for speech evoked ABR in older adults**." has been prepared under my supervision and guidance. It is also been certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled **"Binaural Interaction Component for speech evoked ABR in older adults."** is the result of my own study under the guidance of Dr. Ganapathy M. K., Lecturer in Audiology, Department of audiology, All India Institute of Speech and Hearing, Mysuru, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru, **Registration No. 16AUD006**

April, 2018

DEDICATED TO MY APPAJI, AMMA AND MY BROTHER,WITHOUT THEIR SUPPORT THIS WORK WOULDN'T HAVE COMPLETED

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ABSTRACT

Binaural processing refers to the analysis of the differences between signals arriving at the two ears. The binaural interaction of the auditory system can be obtained by the binaural interaction component (BIC). One of the important component for processing of temporal information is via binaural inputs. The important factor identified for poor speech perception is the reduced temporal resolving power of the auditory system. Difficulty in understanding speech, particularly in challenging listening situations which is a major problem for older adults both with and without significant hearing loss.

Objective: The present study was carried to find out the difference in the Binaural interaction component for speech evoked ABR in older adults and to normal young adults. And also the study was carried out to study the effect of ageing of speech evoked ABR.

Method: Speech evoked ABR for /da/ stimulus were administered on 45 participants with normal peripheral hearing. Two groups including 13 young adults in Group I (18-28) and 32 older adults in Group II. The Group II was divided into Group II A in the age range of >50 to 55 years, Group II B in the age range of >55 to 60 years and Group II C. The latency, amplitude and FFT of BIC were analysed.

Results: The results showed that the peak latencies are prolonged and reduced amplitudes of speech ABR in Group II compared to Group I. The amplitude of fundamental frequency and formants of BIC were reduced in Group II compared to Group I. The trend of ageing for the amplitudes of fundamental frequency and formants of BIC within the subgroups of Group II was not observed significantly.

Conclusion: The results of the current study that due to changes in the aging auditory system older adults had prolonged latencies, reduced amplitude of speech evoked ABR and also

reduced amplitude of fundamental frequency and formants when compared to young adults. These results indicate that delay or asymmetry of binaural inputs to the ears might affect the temporal processing at higher level even with hearing sensitivity within normal limits.

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Chapter 1

Introduction

The auditory temporal processing refers to the processing of the acoustic stimuli by the auditory system. Binaural temporal processing requires the processing of stimuli over time by both ears. For this type of processing to occur, stimuli presented to the two ears must be compared at some central location in the auditory system. Speech stimuli and other background sounds vary over time, making temporal processing an important component in the ability to understand speech in quiet and in background noise. (Rawool, 2006)

The important factor identified for poor speech perception is the reduced temporal resolving power of the auditory system (Dreschler & Plomp, 1985). One of the important component for processing of temporal information is via binaural inputs. Binaural processing refers to the analysis of the differences between signals arriving at the two ears. The binaural interaction of the auditory system can be obtained by the binaural interaction component (BIC). Wada and Starr, (1989) found that there is a non-linear interaction of binaural stimulation on auditory brainstem potentials in both humans and animals.

BIC of ABR can be calculated by subtracting the binaural amplitude of ABR from the summed monaural amplitudes for both left and right. It can be formulated as BIC= (R+L)-B where B is the amplitude of the simultaneous stimulation of both ears. And R and L are the amplitudes for the right and left recorded ABR respectively. BIC provides us the information about the neural activity which are specially tuned when stimulated binaurally.

Numerous studies have reported difficulty in understanding speech, particularly in challenging listening situations which is a major problem for older adults both with and without significant hearing loss (James Jerger, Jerger, Oliver, & Pirozzolo, 1989)(Humes, Coughlin, &

Talley, 1996); (Dubno, Lee, Matthews, & Mills, 1997).These psychoacoustic studies suggest that age related problems could be due to degraded binaural processing. Findlay & Schuchman, (1976)reported reduced performance in older adults with peripheral hearing loss for binaural tasks. Also older adults tend to do worse than young adults at various dichotic listening tasks. The electrophysiological studies reported delays in click evoked Auditory Brainstem Responses (ABR) peak latencies in older adults (Rowe 3rd, 1978); Oku & Hasegewa, 1997). Further some studies have reported significant delay in latencies in older adults even with normal audiometric thresholds (Wilson, Kelly-Ballweber, & Dobie, 1985; (Sturzebecher & Werbs, 1987)). These age related decline in speech understanding could have central origins (James Jerger, Chmiel, Allen, & Wilson, 1994); (Pichora-Fuller, Schneider, & Daneman, 1995); (Gordon-Salant & Fitzgibbons, 1997) as most of the studies report differences in older adults even with normal hearing.

The binaural processing is the degree to which interaction takes place between the two ears. If no interaction occurs between the two ears the binaural system is affected leading to problems in sound localization and difficulty in hearing in noise. The ability of neurons in auditory system to accurately encode temporal features for speech may be limited by impaired neuronal activities.

Binaural processing deficits can lead to different degrees of auditory processing disorders (APD) in older adults. The binaural interaction is measured in clinical settings using behavioural tests such as masking level difference, dichotic tests, and/or binaural fusion tests. However, these behavioural tests may be difficult to conduct on older population. Also the behavioural tests will be affected by attention, interest towards the task. Further studies reporting of delay in brainstem evoked potentials have used clicks (Rowe 3rd, 1978), (Wilson et al., 1985)(Sturzebecher & Werbs, 1987))

BIC of ABR is proposed to be an objective test in assessing binaural hearing Moreover, BIC help in studying the neural correlates of binaural psychoacoustic phenomenon such as localization and hearing in noise. Gopal & Pierel, (1999)measured BIC of click-evoked ABR in nine children with suspected APD. They reported a significant reduction in the amplitude of BIC occurring around the latency region of peak V in children with suspected APD. (Delb, Strauss, Hohenberg, & Plinkert, 2003)studied the sensitivity and specificity of BIC of ABR in identifying children with APD on a larger group of subjects. Their results showed that BIC for ABR can be used as an indicator of APD, with a sensitivity and specificity of 76%. However, when present, the amplitudes and latencies of BIC of ABR showed a high degree of overlap between a normal group and APD group; hence, they concluded that the latencies and amplitudes of BIC recorded for click stimulus cannot be used as a diagnostic criterion to identify individuals with APD.

Hence, the use of an objective measure with speech stimuli would provide a tool with high clinical utility to quantify the binaural hearing deficits in older adults. Also by controlling the degree of peripheral hearing level, changes in the temporal processing could be more strongly attributed to ageing.

1.1 Need for the study:

Difficulty in understanding speech particularly in challenging listening situations is often reported for older adults both with and without hearing loss Jerger et al., (1989)).; Humes et al., (1996); Dubno et al., (1997). Binaural hearing improves speech understanding in complex listening situations (Weihing & Musiek, 2008) Binaural processing is the degree to which interaction takes place between the ears and if interaction breaks down the individuals can have difficulty in localization and hearing in noise. As reported the older adults even with

normal peripheral hearing have difficulties in adverse listening even with normal peripheral hearing.

Further there are limited studies on binaural processing ability in older adults for complex stimuli. Binaural Interaction Component in Speech Evoked Auditory Brainstem. Uppunda, Bhat, D'costa, Raj, & Kumar, (2015) recorded ABR in the age range of 17-25 and reported that BIC were present in all subjects tested (100%), and can be reliably recorded in adults.

The earlier studies on BIC were evoked by click and tone-burst stimuli. (Cone-Wesson, Ma, & Fowler, 1997)recorded BIC for low-frequency tone-burst stimuli. Comparison of these results with published results from adults demonstrated immaturity of binaural interaction in neonates. Also studies with click stimulus for recording BIC report delay of peak latencies in older adults (Rowe 3rd, 1978); (Wilson et al., 1985); (Sturzebecher & Werbs, 1987). Use of complex stimuli may be more effective than simple stimulus, and thus speech evoked ABR and BIC could give further insight into the binaural processing deficits in older adults.

The binaural interaction is reflected in electrophysiological activity of neurons activated by binaural stimulation. Binaural interaction occurs at superior olivery complex, nucleus of lateral lemniscus and inferior colliculus (Moore, 1991). The BIC reflects the ongoing binaural processing (Jiang & Tierney, 1996); (Fowler & Swanson, 1988). Thus the BIC for speech stimulus could be reliable tool to assess the binaural processing in older adults.

By controlling the degree of peripheral hearing level the changes in the BIC could be more strongly attributed to changes due to ageing. Also use of complex stimuli may be more effective than simple stimuli.

For the analysis of the speech ABR a frequency domain representation can be generated using Fourier analysis. This method can be used to measure the precision and magnitude of neural phase locking at specific frequencies or frequency range.

The principle underlying Fourier analysis is that a complex waveform consisting of many frequency components is decomposed into a set of sine waves. The magnitude of each sine wave corresponds to the amount of energy contained in the complex waveform at that frequency. The spectral composition of a complex wave can be represented by plotting the frequency of the sine wave on the x-axis and the magnitude on the y-axis.

The fast Fourier transform (FFT) is the most common algorithm for performing spectral analysis. The FFT is most efficient (i.e., faster) when the signal N (defined as the number of points) is a power of two. However, software such as MATLAB do not require the input to be a set length. Fourier analyses can also be used to generate a frequency-domain average. For cABRs, frequency spectra are analysed with respect to the frequency composition of the stimulus. Because stimulus and response amplitudes occur on different scales, the amplitudes must be normalized in order to plot the two spectra on the same plot. This can be achieved by converting both spectra to decibels (Aiken & Picton, 2006) or by dividing each spectral amplitude by the corresponding spectral maximum (Lee, Skoe, Kraus, & Ashley, 2009).When analyzing the response in the frequency domain, spectral maxima corresponding to the stimulus F0 and its harmonics are identified, and the phase and amplitude (modulus of the FFT) of the maxima are recorded.(Skoe & Kraus, 2010)

1.2 Aim for the study:

To assess the binaural interaction component in older adults using speech stimuli.

1.3 Objectives:

1. To study the effect of ageing on speech evoked ABR

2. To study the effect of ageing on BIC for speech evoked ABR
3. To study the effect of ageing on BIC for speech evoked ABR between the subgroup of older adults.

Chapter 2

Review of Literature

Ageing is the process during which anatomical and functional degenerative changes accumulate in an organism as a result of the passage of time. (James Jerger et al., 1994) defines aging as "a persistent decline in the age-specific fitness components of an organism due to internal physiological degeneration". Seidman, Ahamed, Joshi, Thawani, & Quirk, (2004) reported that a variety of biochemical and molecular changes occur due to ageing. Resultantly these changes have an adverse effect on the auditory system of aging individuals. There are several studies that have documented changes in the auditory system due to ageing.

Difficulty in understanding speech especially in adverse listening situations is one of the most common problems in older individuals although their hearing sensitivity is within normal limits. As per the report of the Committee on Hearing and Bioacoustics and Biomechanics of the National Research Council, the factors affecting speech perception in older adults include deterioration of the peripheral and central auditory system, and the cognitive system.

Studies show that age-related temporal processing deficits lead to difficulty in listening in the presence of noise (Robert Frisina & Frisina, 1997; Pichora-Fuller & Souza, 2003). According to Robert Frisina & Frisina, (1997)regardless the fact that older adults have adequate cognition as well as normal hearing sensitivity, their diminished abilities to listen in noisy condition could be accounted to the temporal resolution deficits in the auditory brainstem or auditory cortex.

2.1 Changes in peripheral auditory system with ageing

Changes in the conductive component of the hearing apparatus associated with ageing have been described, including collapse of the cartilaginous external auditory canal and stiffening of the tympanic membrane and ossicular chain. However, the effect on the auditory threshold of these changes is minor and does not contribute significantly to the hearing loss associated with ageing. Despite extensive investigation the exact aetiology of the physiological changes described in the cochlea is unclear. As there is little redundancy within the cochlea, with each region in the cochlea transducing a particular frequency of sound, it follows that the loss of any of this small population of cells will have a noticeable effect on the person. (Howarth & Shone, 2006)**.**

2.2 Changes in the cochlea

Study done by Shimada, Ebisu, Morita, Takeuchi, & Umemura, (1998) reported that four types of histological changes reported in humans as increase in age, that is, loss of spiral ganglion cells, atrophy of the organ of Corti, atrophy of the stria vascularis, and thickening of the basilar membrane were observed in dogs. The prominent charges were seen at the base of the cochlea. Less intense changes in apex of the cochlea. The degree of these changes appeared to progress as a function of age. cochlear nuclei changes including nerve cell loss, The morphological changes seen in the cochlea and cochlear nuclei of dogs were qualitatively and quantitatively similar to those reported in aged humans, indicating that changes in the inner ear may be due to aging plus exposure to certain environmental ototoxic factors and similar results was observed in Rokay & Pénzes, (1988)

2.3. Changes in auditory brainstem and auditory cortex

The age dependent neuronal changes are attributed to overall loss of neurons such as neuronal shrinkage, decreased size of cell body and nucleus, decreased arborisation and loss of dendrites (Powers, 1994; Shankar, 2010; Willott et al., 1991). The input-output function of the compound action potential is shallow in older animals which shows evidence of loss of auditory nerve function with ageing (Gates & Mills, 2005). Gates and Mills (2005) reported that asynchronous activity in the auditory nerve with ageing may be caused due to combined factors such as; synapse between hair cells and auditory nerve, degeneration of spiral ganglion cells, and reduced endolymphatic potential. Konigsmark & Murphy, (1972) showed evidence that around the beginning of 60 years of age, there is decline in the volume of neurons in ventral cochlear nucleus along with decrease in number of myelinated fibers, reduced vessels and capillaries.

According to Crace, 1970, an increase of neurons containing pigment was seen within cochlear nucleus and many neurons degenerated with age. (Willott, 1996) reported that aging resulted in a decrease in number of nerve fibers within lateral lemniscus and inferior colliculus. Based on animal studies, Frisina & Walton, (2006)evidenced that there will be primary ageing changes in dorsal cochlear nucleus that are driven by the loss of cochlear input.

Ling, Hughes, & Caspary, (2005) have noted a decrease in GABA release due to age related changes in the peripheral auditory system. Further study done by (Raza, Milbrandt, Arneric, & Caspary, (1994)revealed that, deficits in speech discrimination and speech in noise is a manifestation of neuro-chemical changes in central auditory system due to ageing. The central nervous system reduces in volume and weight due to ageing(Shankar, 2010) .

Shankar (2010) reported that the pre-frontal cortex is most affected and the occipital lobe is least affected by ageing. (Chance, Casanova, Switala, Crow, & Esiri, 2006)studied the organization of neurons in primary auditory cortex and they reported that thinning was seen in

auditory association cortex but not in the primary auditory cortex due to ageing. These results do not indicate a significant structural change of the primary auditory cortex that does not explain the clinically observed auditory behaviours in older adults.

Ageing affects the central nervous system in several ways, resulting in the atrophy of grey and white matter, changes in the levels of cortical metabolites and in functional deterioration leading to cognitive decline.(Profant et al., 2015)

Caspary et al., (1999) reported age-related decrease in the GABA enzyme levels in the primary auditory cortex of rats and it is possible that a loss of normal GABA transmission contributes to loss of speech understanding with ageing humans. Further Ling et al., (2005) reported a significant decrease in GABA in primary auditory cortex in aged rats but adjacent regions of parietal cortex did not show any significant change. According to these observations the temporal coding of older adults is likely to get altered due to the loss of GABA neurotransmission in primary auditory cortex, which in turn will affect their speech understanding.

2.4 Audiological findings in older adults

The audiological tests show a variety of results in older adults. The findings from numerous studies indicate variable results from pure-tone audiometry to CAEPs. A review of findings on different results due to ageing is given below. Increasing age during adulthood is often associated with elevation of pure-tone thresholds. Wiley, Chappell, Carmichael, Nondahl, & Cruickshanks, (2008) studied hearing threshold changes due to ageing as well as gender difference between 48 and 92 years. The study revealed an increase in pure-tone thresholds and steeper slope in the higher frequencies, with increase in age and gender difference, with men showing poorer thresholds in comparison with age matched women.

Wiley et al., (2008) further observed that nearly 60% of the individuals between 80 to 92 years, 40% between 70 to 79 years, and 10% between 60 to 69 years have greater than 60 dB HL of hearing loss. Often hearing loss due to ageing is variable i.e., the threshold change is not same within age range and between gender. Brant & Fozard, (1990) reported that after 50 years of age there is an increased rate of decline in hearing thresholds; about 41% of older adults above the age of 60 years report of hearing difficulties. Often, older adults with decreased pure-tone thresholds have the high frequencies affected, which gradually extend to lower frequencies with further increase in age (Sharashenidze, Schacht, & Kevanishvili, 2007)& Miller, 1990).

The word recognition ability is seen to decline with age and a rapid reduction in scores is seen in men (Cooper & Gates, 1991); Wiley et al., 2008)). Studies performed in older adults reveal poorer performance on speech understanding tasks. These findings infer that the primary cause for speech understanding difficulties in older adults is age-related peripheral hearing loss or presbycusis (Divenyi et al., 2005; Dubno et al., 1984; Gordon-Salant, 2005). Gelfand et al., 1986; Pichora-Fuller et al., 1995 reported poorer speech understanding in older adults compared to younger individuals despite of normal hearing sensitivity. Studies reveal that most of the elderly individuals experience difficulty in understanding speech when in noise, or at a faster rate, or when the amount of information is loaded even if they do not have hearing loss (GordonSalant, 2005). These studies reveal inconsistent results of speech understanding older adults. Mukari, Wahat, and Mazlan (2014) studied the effect of hearing loss and ageing on speech perception in quiet and in background noise. They reported that older adults perform better in quiet environment than in noisy environment. Further, they mentioned that factors such as central auditory processing and cognitive functions might play an important role in understanding speech in difficult listening conditions.

The hearing loss leads to reduced audibility and also can affect spectral and temporal resolution (Humes, 1996). However, peripheral hearing loss does not explain the speech understanding problem in older adults as they have poorer speech perception scores in degraded environment, even when they have normal hearing thresholds (Gelfand, Piper, &Silman, 1986; Pichora-Fuller et al., (1995). Further, speech perception is usually poorer in elderly individuals than in the young adults with similar degree of hearing loss (Divenyi, Stark, &Haupt 2005; Gordon-Salant, 2005). In older adults it is reported that temporal resolution is affected (Gońdon-Salant & Fitzgibbons, 1993; Snell, 1997). Temporal resolution helps in identifying phonetic contrasts and also contributes in understanding speech in noise. These temporal deficits in older adults may lead to speech perception deficits. Further, older adults perform poorer than young adults when the rate of speech increases. On time compressed speech tests, older adults showed poorer scores when compared to younger counterparts (Letowski & Poch, 1995), and the scores were drastically affected when presented in background noise (Tun, 1998). These results reflect slow perceptual processing in older adults thus leading to affected speech perception, with or without hearing loss.

2.5 Auditory Evoked Responses in older adults.

Wave V of the auditory brainstem response was measured for younger and older adults with normal hearing latencies were similar to those of younger subjects but amplitudes were smaller. (Poth, Boettcher, Mills, & Dubno, 2001) similar studies has been found by (J Jerger & Hall, 1980). Latency of wave I was larger in young adults than in older adults amplitudes decrease with increasing age. For waves I and III, age-related amplitude decrements were greatest at a low (11/sec) click rate. At the 11/sec rate, the model-based mean wave III amplitude was significantly smaller in older compared with younger subjects even after adjusting for wave I amplitude. Aging also increased ABR peak latencies, with significant

shifts limited to early waves. Konrad-Martin et al., 2012 and Martini, Comacchio & Magnavita (2009) also studied effects of ageing and the results confirm previous reports of a latency shift of all principal components of ABR.

2.6 Speech evoked Auditory Brainstem Response (ABR) in older adults.

It is a non-invasive, an objective tool that gives information about the ability of brainstem to process frequency and the temporal features of the speech stimulus. The frequency following response (FFR) of the speech ABR is a more suitable tool for evaluating centrally based processes involved in SIN perception as it represents the sound input well both in the time and frequency domain (Galbraith et al, 1995), and it is consistent and reliable across time (Kraus and Nicol, 2005). In the last decade speech stimuli has been extensively researched to study the brainstem responses for speech. (S. Anderson, Parbery-Clark, White-Schwoch, & Kraus, 2012) recorded ABR for speech stimulus in older adults with normal hearing, and reported that they had delayed brainstem responses for rapid format transition and reduced phase locking. They suggested that these responses in older adults in part may lead to their speech perception deficits. However, (Vander Werff & Burns, 2011) recorded speech evoked ABR for younger and older adults with normal hearing. The results showed smaller amplitude and prolonged latencies of onset and offset responses.

Further, the sustained components of the speech ABR showed no significant effect of age, suggesting intact temporal coding for the harmonics of the speech stimuli. Similar findings were reported by Neupane, Gururaj, Mehta, & Sinha, (2014). They reported no change in the encoding of fundamental frequency of the speech stimulus in older adults even with change in repetition rates. Thus, suggesting speech perception deficits because of ageing may be due to more central deficits.

The pitch (F0), timing (speech onsets, offsets and transitions between phonemes) and timbre (harmonics) are the characteristics of the speech signal which is necessary to extract the target speech from the competing background noise. These cues are well represented in the brainstem response to complex sounds (cABR) domains Galbraith, Arbagey, Branski, Comerci, & Rector, (1995). An an event-related potential (ERP) biomarker - the auditory brain-stem response (ABR) to complex sounds (cABR) - that appears to be particularly well-suited for predicting response to at least one form of cognitive remediation that targets auditory information processing. Uniquely, the cABR quantifies the fidelity of sound encoded at the level of the brainstem and midbrain. This ERP biomarker has revealed auditory processing abnormalities in various neurodevelopmental disorders, correlates with functioning across several cognitive domains, and appears to be responsive to targeted auditory training.(Tarasenko, Swerdlow, Makeig, Braff, & Light, 2014).

The understanding of speech in presence of background noise in older adults is difficult even in individuals who have normal hearing from age-related declines in central auditory processing of the temporal and spectral components of speech and this has been studied by Samira Anderson, Parbery-Clark, Yi, & Kraus, (2011) both in quiet and noisy condition and they found that in quiet condition reduced neural representation of the fundamental frequency of the speech stimulus and an overall reduction in response magnitude. In the noise condition, demonstrated greater disruption in noise, reflecting reduction in neural synchrony. The role of brainstem timing is particularly evident in the strong relationship between SIN perception and quiet-to-noise response correlations.

The neural representation of simple (tone) and complex (/da/) stimuli declines with advancing age. Tone-FFR phase coherence decreased as chronological age increased. For the consonant-vowel FFRs, transient onset and offset response amplitudes were smaller, and

offset responses were delayed with age. Sustained responses at the onset of vowel periodicity were prolonged in latency and smaller in amplitude as age increased. FFT amplitude of the consonant-vowel FFR fundamental frequency did not significantly decline with increasing age. The ability to encode a simple signal was related to degradation in the neural representation of a complex, speech like sound. Tone-FFR phase coherence was significantly related to the later vowel response components but not the earlier vowel components.(Clinard & Tremblay, 2013)

Uppunda et al., (2015) recorded ABR in the age range of 17-25 and reported that BIC were present in all subjects tested (100%), and can be reliably recorded in adults. The earlier studies on BIC were evoked by click and tone-burst stimuli. (Cone-Wesson et al., 1997)recorded BIC for low-frequency tone-burst stimuli. Comparison of these results with published results from adults demonstrated immaturity of binaural interaction in neonates. Also studies with click stimulus for recording BIC report delay of peak latencies in older adults (Rowe 3rd, 1978); (Wilson et al., 1985); (Sturzebecher & Werbs, 1987). Use of complex stimuli may be more effective than simple stimulus, and thus speech evoked ABR and BIC could give further insight into the binaural processing deficits in older adults.

The binaural interaction is reflected in electrophysiological activity of neurons activated by binaural stimulation. Binaural interaction occurs at superior olivery complex, nucleus of lateral lemniscus and inferior colliculus (Moore, 1991). The BIC reflects the ongoing binaural processing (Jiang & Tierney, 1996); (Fowler & Swanson, 1988).

In clinical populations, BIC measurements have been employed to evaluate the integrity of binaural processing (eg., Furst et al. 1985; Gordon et aal 2012). The effect of age on the BIC representing the binaural hearing has so far received only little attention (Fowler,

2004) and a systematic investigation how the effect of the binaural cues on the BIC is modified with age is lacking.

Chapter 3

METHOD

The present study was conducted with an aim of finding out the differences between Binaural Interaction Component in older adults compared to the younger adults using speech ABR. To study this /da/ stimulus was used, speech evoked ABR was recorded and compared across the different age groups.

3.1 Participants

A total of 45 participants in the age range of 18 to 65 years were selected for the study. Participants were divided into two groups:

Group I: Thirteen young adults between the age range of 18-25 years was included in the study.

Group II: Thirty two older adults between the age range of 50 to 65 years was included. The Group II was further subdivided in three subgroups viz:

Group II A: Ten older adults in the age range of 50 to 55 years.

Group II B: Twelve older adults in the age range of >55 to 60 years.

Group II C: Ten older adults in the age range of >60 years to 65 years.

3.2 Tests for selection of participants:

The following tests were carried out for selection of the participants:

A structured interview was conducted to rule out otological and neurological problems. Following which pure-tone testing was carried out. Air-conduction (AC) thresholds at octaves between 250 Hz to 8000 Hz and bone-conduction (BC) thresholds for octaves between 250 Hz

to 4000 Hz were established for each ear. This was done using a calibrated clinical audiometer, TDH-39 head phone encased in MX 41AR ear cushion for AC testing and Radio Ear B-71 bone vibrator for BC testing. Tympanometry was carried out, by making the participants sit comfortably on a chair and was instructed to close their eyes and not to move until the test was completed. Immittance testing was administered with a probe tone of 226 Hz. Tympanogram and acoustic reflex thresholds for 1000 Hz were estimated to ensure normal middle ear functioning in each ear.

Speech audiometry was administered using a CD containing recorded phonemically balanced (PB) test in Kannada developed by Yathiraj and Vijayalakshmi (2005) in quiet condition.

Cognitive testing was carried out using Mini Mental State Examination (Folstein, Folstein, & McHugh, 1975). This is a questionnaire with 30 questions was used to screen for cognitive impairment which samples various functions including arithmetic, memory and orientation. It was administered on participants in Group II, to rule out cognitive deficits. The maximum score is 30. Participants obtaining a score of <24 are interpreted as having cognitive deficits and wasn't included in the study.

3.3 Test environment:

All tests were carried out for each individual in an air-conditioned acoustically treated single- or double- room setting. The noise levels in these rooms were within permissible limits (ANSI S 3.1 1991).

3.4 Equipments:

The following instruments were used for subject selection criteria and for performing speech evoked ABR

a. GSI 61 a Calibrated dual channel clinical audiometer was used for pure tone and speech audiometry.
b. Middle ear analyser GSI tympstar meter was used for evaluating middle ear status.
c. Biologic Navigator Pro with smart EP software was used for recording and analyzing auditory evoked potentials.

3.5 Test Stimulus

The BIC was recorded using speech stimulus /da/. Because stop consonants provide considerable phonetic information and their perception is particularly vulnerable to background noise in both normal and clinical populations, a five-formant synthesized /da/was chosen for the stimulus (Klatt, 1980).

The stimulus duration was 40 milliseconds (ms). The consonant contained an initial 10 ms burst; the fundamental frequency of the /da/ linearly raises from 103-124 ms with voicing beginning at 5 ms and an onset noise burst during the first 10 msec. The first formant rises from 220 to720 Hz, while the second formant decreases from 1700 to 2400 ms over the duration of the stimulus.

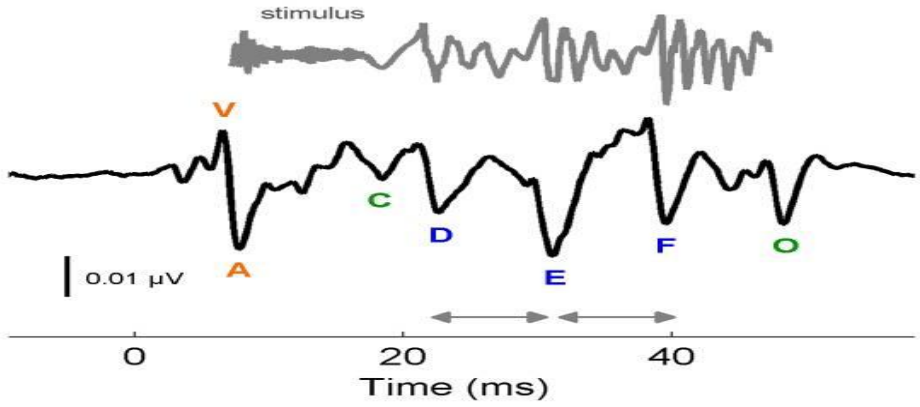

Figure 3.1: The representation of stimulus /da/ and its evoked onset and frequency following resoponse response

3.6 Recording of speech ABR and BIC:

The participants was made to sit in a comfortable reclining chair and was asked to relax. The disc electrodes was placed using conduction paste and priory cleaned with skin preparation gel. An absolute impedance of less than 5 k ohms and relative impedance of less than 2 k ohms was ensured. The participants was asked to close the eyes and stay relaxed and making sure that the EEG gets stabilized. ABR for /da/ stimulus was recorded monaurally for left and right ears and binaurally.

Table 3.1: *Protocol summary for recording ABR*

Stimulus parameters	
Stimuli	/da/
Transducer	Inserts
Ear	Binaural, Right and left ear
Intensity	80 dBnHL
Repetition rate	7.1/s
Filter settings	30-3000
Stimulus duration	40ms
Polarity	10 ms /d/ and 30 ms /a/ Alternating
Acquisition Parameters:	
Electrode locations	Cz – Non-inverting Fpz – Ground Inion -Nape of the Neck
Total number of sweeps	1500 per recording
Analysis time	70ms
Filter settings	30-3000 Hz

Amplification	1,00,000

3.7. Analysis

The onset response elicits V and A response and the transition harmonic portion of the speech stimulus gives rise to the frequency-following response (D, E, and F). The latency and amplitude of these responses were analyzed.

The raw amplitude value of F0, F1, F2 frequency component of the response FFR were then noted. All FFT analysis was done using a custom-made program using MATLAB software. Brainstem Toolbox developed at Northwestern University was also utilized along with MATLAB, to get the FFT of BIC obtained for young and older adults.

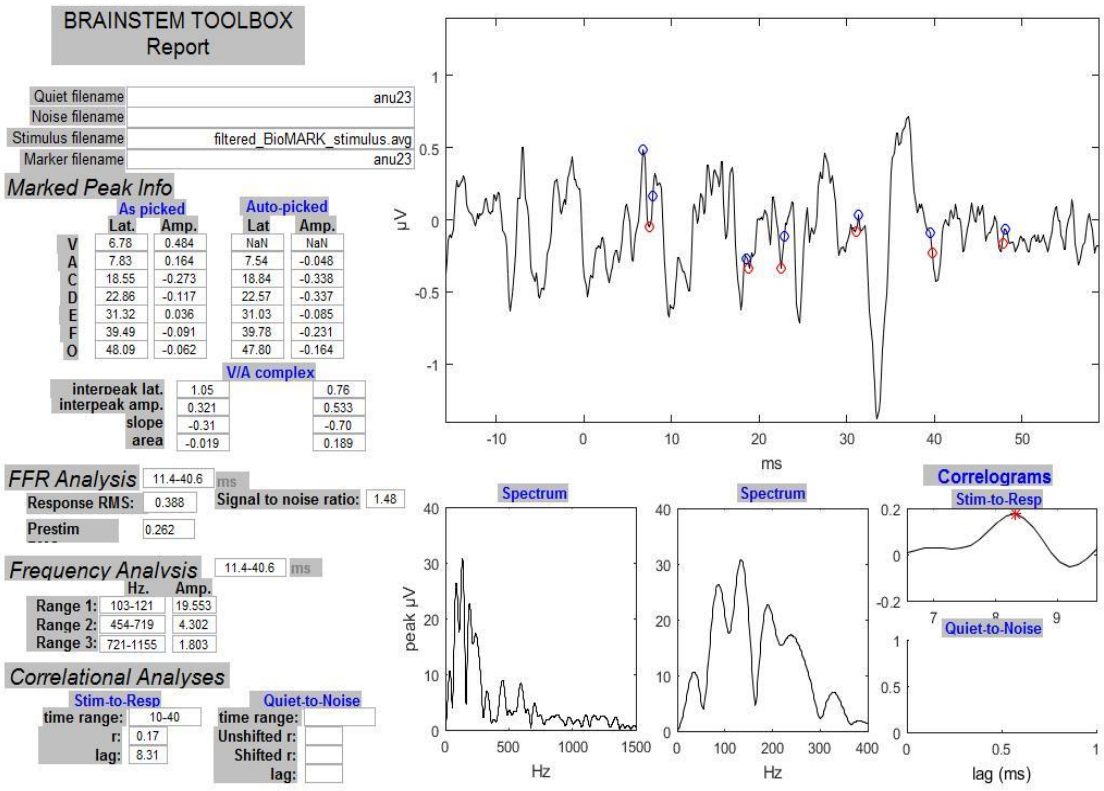

Figure 3.2: The FFT analysis of one of the participant performed in BRAINSTEM TOOL BOX using MATLAB

3.7. Statistical Analyses:

The data of onset and change response of BIC (i.e., dependent variable) to speech stimuli (i.e., independent variables) from participants in four age groups were tabulated. The data obtained were subjected to statistical analysis using Statistical Package for Social Sciences (SPSS) software (SPSS version 20). Descriptive statistics was carried out to estimate the mean and standard deviation. Normality test was carried out and based on the Shapiro-Wilk test which revealed that all parameters were not normally distributed ($p<0.05$). Hence, non-parametric statistical tests were administered.

The chi-square test was carried out to study the association between age groups. Then Mann-Whitney U test was carried to compare between the different age groups

Chapter 4

Results

The present study aimed to find out the binaural interaction component (BIC) in young adults and older adults. Four groups including 13 young adults in Group I (18-28) and 32 older adults in Group II. The Group II was divided into Group II A in the age range of >50 to 55 years, Group II B in the age range of >55 to 60 years and Group II C in the age range of >60 years to 65 years each group consisted of 10, 12, 10 individuals respectively.

4.1 To study the effect of ageing on speech evoked ABR

The speech evoked ABR was recorded using /da/ stimulus with the duration of 40ms. The amplitudes and latency comparison was made across different normal hearing older adult age groups. The Right, Left, Binaural and R+L grand averaged waveforms of Group I, Group IIA GroupII B Group II C is as shown in the figures 4.1, 4.2, 4.3, 4.4, 4.5,

4.6, 4.7 and 4.8 respectively

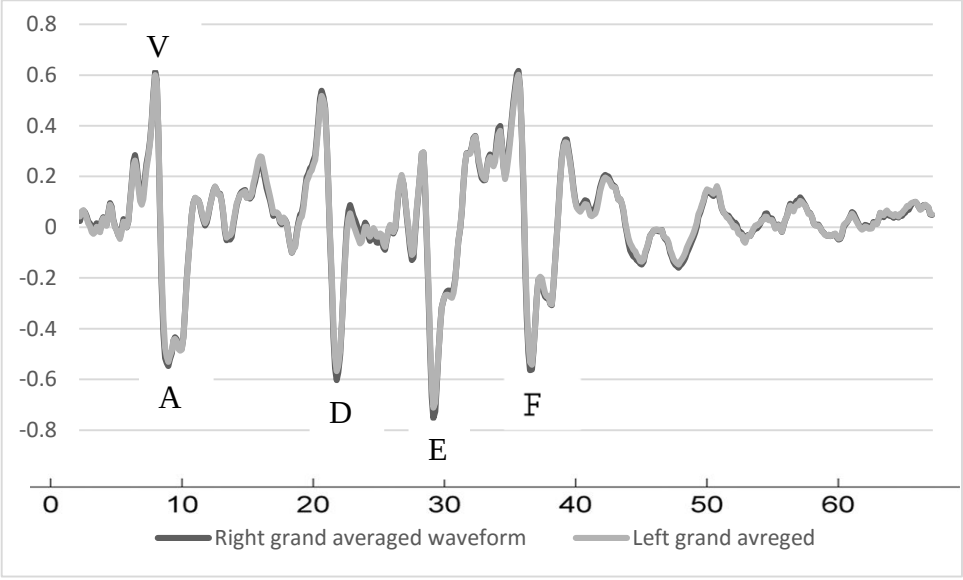

Figure 4.1: The grand average waveform of Group I

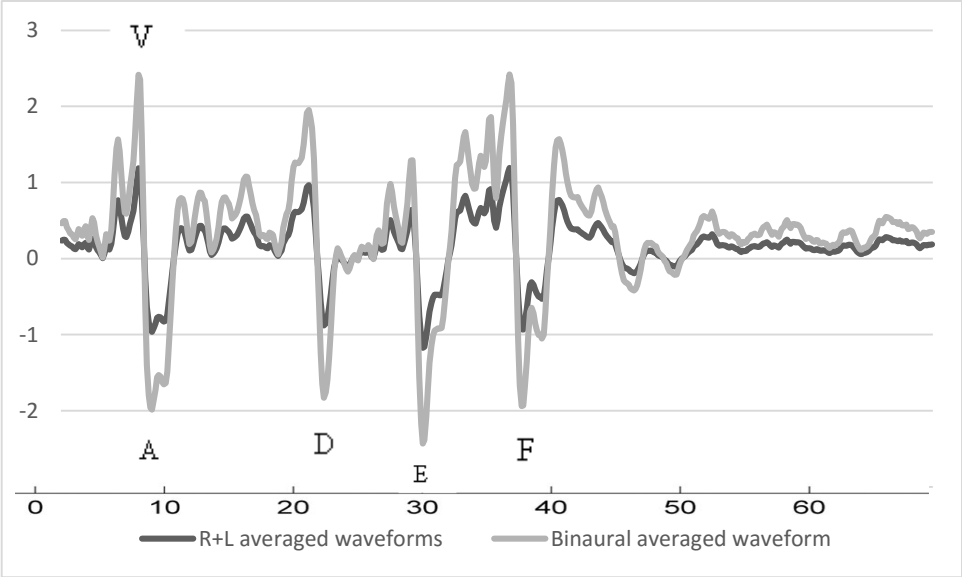

Figure 4.2: Right + left averaged waveforms and Binaural averaged waveform of Group I

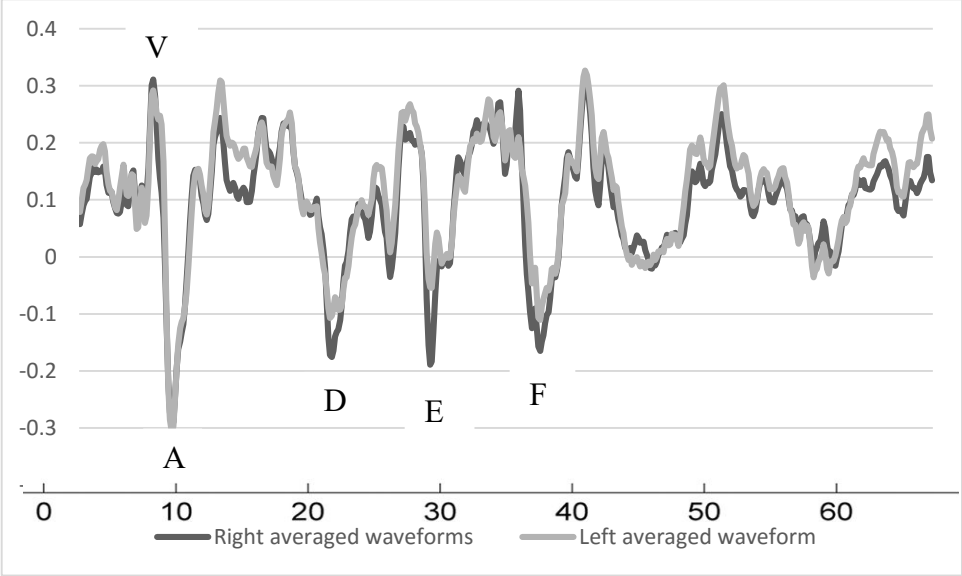

Figure 4.3: Right and left averaged waveforms of Group II A

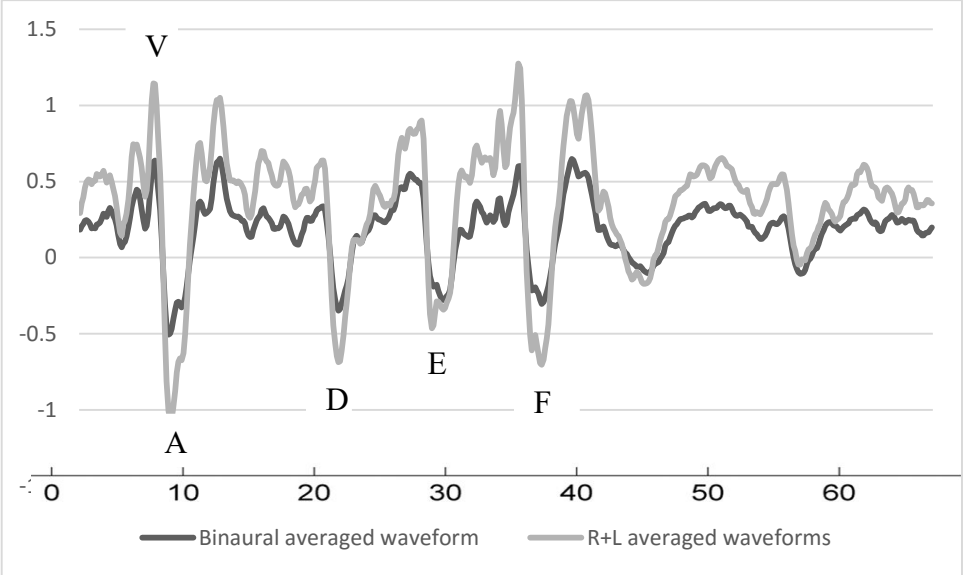

Figure 4.4: Right + left averaged waveforms and Binaural averaged waveform of Group II A

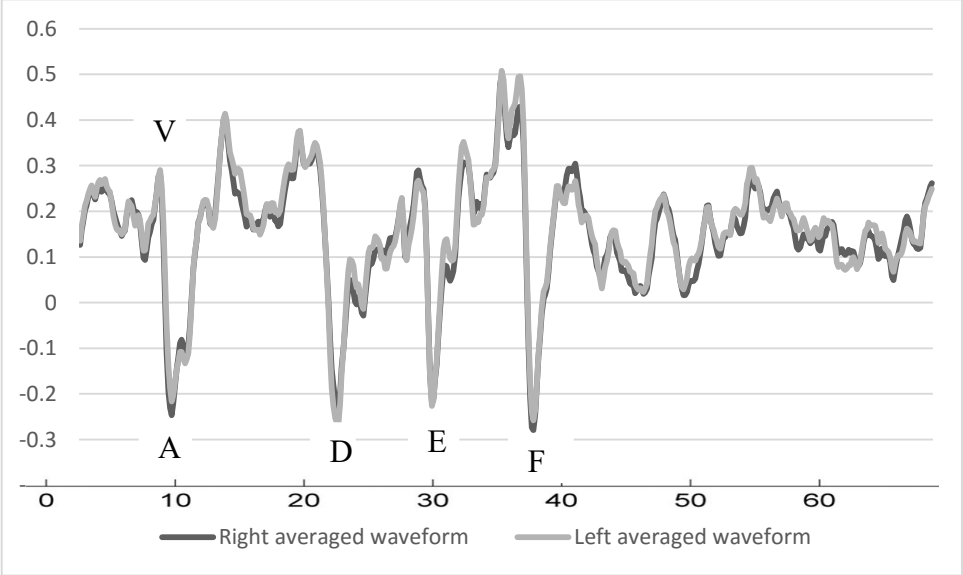

Figure 4.5: Right and left averaged waveforms of Group II B

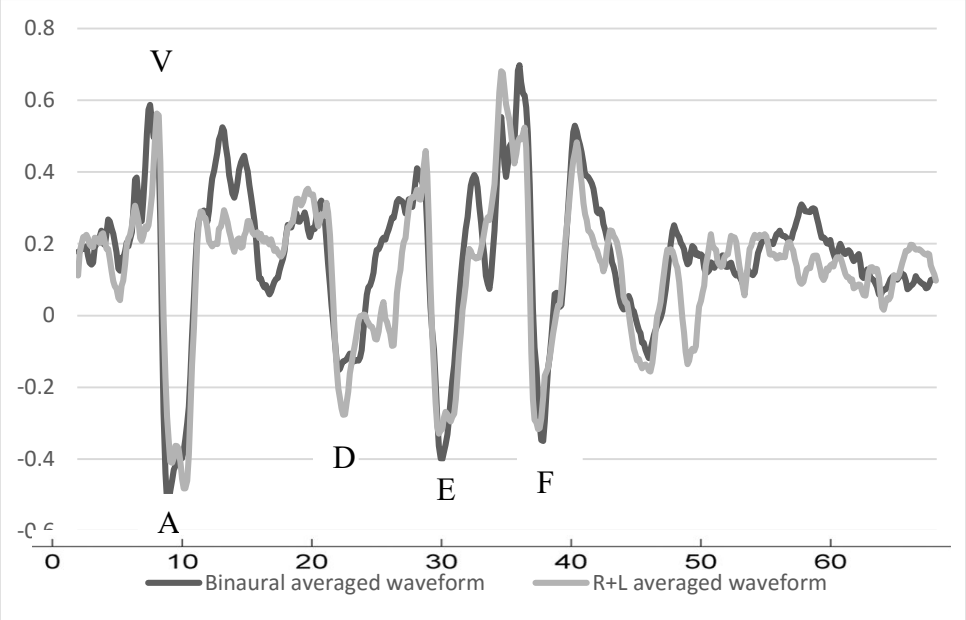

Figure 4.6: Right + left averaged waveforms and Binaural averaged waveform of Group II B

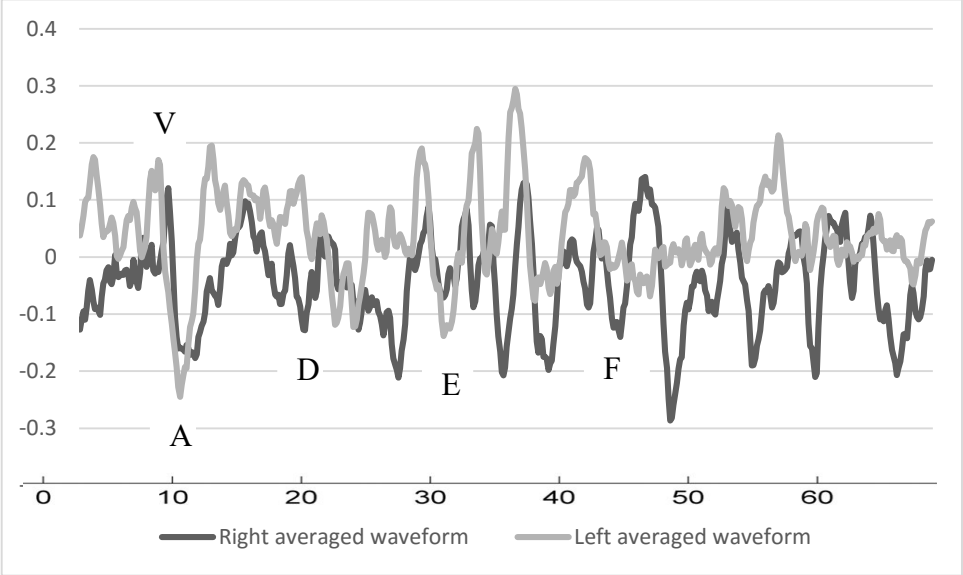

Figure 4.7: Right and left averaged waveforms of Group II C

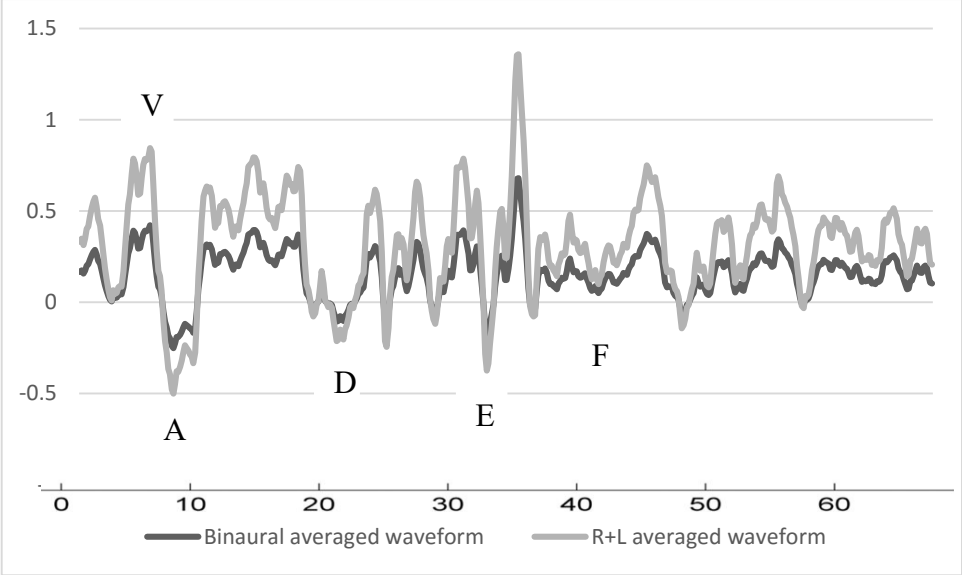

Figure 4.8: Right + left averaged waveforms and Binaural averaged waveform of Group II C

4.1 To study the effect of ageing on speech evoked ABR

The speech evoked ABR was recorded using /da/ stimulus with the duration of 40ms. The amplitudes and latency comparison was made across different normal hearing older adult age groups. The mean and standard deviation of amplitude and latencies for both right and left ear are given in the table 4.1 and 4.2 respectively.

Table 4.1

The mean and standard deviation (SD) of the amplitude of speech evoked ABR across different age group for right ear.

Table 4.2

Groups	N	Mean/ SD of peak V	Mean/ SD of peak A	Mean/ SD of peak D	Mean/ SD of peak E	Mean/SD of peak F

Group I	13	0.228/.12	0.357/.11	0.336/.14	0.364/.12	0.336/.13
Group IIA	10	0.253/.09	0.352/.11	0.387/.09	0.391/.07	0.312/.03
GroupII B	12	0.275/.12	0.235/.09	0.276/.13	0.296/.13	0.260/.10
GroupII C	10	0.163/.06	0.190/.12	0.218/.12	0.189/.12	0.201/.11

Group I	13	5.97/46	7.02/.39	22.09/.81	30.33/.51	38.17/2.34
Group II A	10	6.06/.42	7.02/.27	22.14/1.16	30.84/.91	39.10/.60
GroupII B	12	6.10/.30	7.31/.58	23.09/1.8	30.90/.91	40.37/.35
GroupII C	10	6.52/.39	7.80/.73	23.86/2.03	32.17/1.68	40.37/1.84

The mean and standard deviation (SD) of the Latency of speech evoked ABR across different age group for right ear

Mann- Whitney U test was carried out to compare amplitudes between Group I with Group IIA Group II B and Group III C and the results shows that amplitudes of peak A in Group II B compared with Group I had significantly difference and all the peaks i.e V, A, D, E and F had significant difference in the Group I and Group II C. The results are given in the table 4.3

Table 4.3

Mann- Whitney U test for Comparison of amplitudes of the right ear between Group I with Group IIA Group II B and Group III

	Peaks

Groups	V	A	D	E	F
			Z- Values		
Group I and II A	-.652	-1.925	-.652	-.311	-.342
Group I and II B	-.218	-2.920*	-1.470	-1.580	-1.335
Group I and II C	-2.639*	-2.948*	-2.081*	-2.793*	-2.113*

*=Significant difference (p= >0.05)

Mann - Whitney U test was carried out to compare latencies between Group I with Group IIA Group II B and Group III C and the results shows that amplitudes of peak E and F in Group II B compared with Group I had significantly difference and all the peaks i.e V, A, D, E and F had significant difference in the Group I and Group II C. The results are given in the table 4.4

Table 4.4

Mann- Whitney U test for Comparison of latency of the right ear between Group I with Group IIA Group II B and Group III C.

	Peaks				
Groups	V	A	D	E	F
			Z- Values		
Group I and II A	-.220	-.094	-.124	-1.155	-1.345
Group I and II B	-1.335	-1.374	-1.39	-2.19*	-2.903*
Group I and II C	-3.413*	-2.74*	-2.642*	-3.018*	-2.963*

*=Significant difference (p= >0.05)

Table 4.5

The mean and standard deviation (SD) of the amplitude of speech evoked ABR across different age group for left ear.

Groups	N	Mean/ SD of peak V	Mean/ SD of peak A	Mean/ SD of peak D	Mean/ SD of peak E	Mean/SD of peak F
Group I	13	0.323/.21	0.323/.21	0.270/.21	0.334/.25	0.322/.27
Group II A	10	0.338/.11	0.252/.11	0.287/.19	0.391/.17	0.312/.93
GroupII B	12	0.278/.19	0.235/.09	0.276/.13	0.296/.13	0.260/.10
GroupII C	10	0.185/.08	0.190/.12	0.218/.12	0.189/.12	0.201/.11

Table 4.6

The mean and standard deviation (SD) of the latency of speech evoked ABR across different age group for left ear.

Mann- Whitney U test was carried out to compare amplitudes between Group I with Group IIA Group II B and Group III C and the results shows that amplitudes of peak V in all three groups had significant difference compared with Group I and all the peaks i.e V, A, D, E

and

F had

Groups	N	Mean/ SD of peak V	Mean/ SD of peak A	Mean/ SD of peak D	Mean/ SD of peak E	Mean/SD of peak F
Group I	13	5.90/.15	7.06/.50	22.12/.91	30.37/.62	38.95/.69
Group II A	10	6.19/.44	7.39/.65	22.22/.88	30.87/.54	39.40/1.40
GroupII B	12	6.17/.36	7.39/.44	22.29/.93	30.69/.88	39/.34
GroupII C	10	6.49/.53	7.90/.53	23.47/1.74	31.19/1.05	39.54/.81

significant difference in the Group I and Group II C. The results are given in the table 4.7.

Table 4.7

Mann- Whitney U test -Comparison between amplitude Group I with Group IIA Group II B and Group III C.

Groups	Peaks V	A	D	E	F
	Z- Values				
Group I and II A	-2.360*	-.186	-.497	-1.305	-.455
Group I and II B	-3.13*	-1.25	-.163	-2.044	-.518
Group I and II C	-3.353*	-2.978*	-1.46*	-2.147*	-1.959*

*=Significant difference (p= >0.05)

Mann - Whitney U test was carried out to compare latencies between Group I with Group IIA Group II B and Group III C and the results shows that amplitudes of peak V in all three groups had significant difference. And in Group I had significantly difference and all the peaks i.e. V, A, and E had significant difference with Group II C except for D and F peaks. The results are given in the table 4.8.

Table 4.8

Mann- Whitney U test -Comparison between latencies Group I with Group IIA Group II B and Group III C.

	Peaks				
Groups	V	A	D	E	F
	Z- Values				
Group I and II A	-2.08*	-1.029	-1.717	-1.126	-1.092
Group I and II B	-2.051*	-1.75	-.191	-.522	-1.29
Group I and II C	-3.201*	-2.923*	-1.774	-2.028*	-1.932

*=Significant difference (p= >0.05)

4.2 To study the effect of ageing on BIC for speech evoked ABR

The BIC was obtained by subtracting binaural averaged waveforms from added monaurally elicited right and left waveforms. To obtain the amplitude of the BIC i.e fundamental frequency and its formants (Fo, F1 and F2) FFT was carried out using Brainstem tool box in MATLAB. Descriptive statistics were carried out to obtain the mean and standard

deviation of the amplitude of the Fo, F1 and F2 in different age groups and the results are as shown in table 4.9

Table 4.9

The mean and standard deviation (SD) of the Fo, F1 and F2 in different age group.

Groups	N	Mean/ SD of Fo	Mean/ SD of F1	Mean/ SD of F2
Group I	13	17.04/9.17	5.61/1.74	1.87/.47
Group II A	10	17.39/4.77	3.09/1.05	1.23/.33
GroupII B	12	12.83/7.63	3.90/1.93	1.53/.45
Group II C	10	9.08/4.30	3.53/2.49	1.40/.55

Kruskal- Wallis test was carried out to study the association between age groups of Fo, F1 and F2 in different age group. The results shows that there was significant different across the age groups is as shown in the table 4.10.

Table 4.10

Kruskal- wallis test for Comparison of association of all the 4 groups.

χ^2 values

	Fo	F1	F2
Comparison of 4 groups	9.541*	13.583*	11.159*

*=Significant difference (p= >0.05)

The Kruskal-Wallis test results showed significant difference, Mann Whitney U test was carried out to study between which groups there was statistically significant difference. The results reveal that except for Fo of the Group IIA and Group II B, all other groups indicated statistically significant difference. These results indicate that in older adults the amplitude will be lesser when compared to older adults. The results are given in the table 4.11

Table 4.11

Mann- Whitney U test for Comparison of Fo, F1 and F2 of BIC of Group I and Group II A, B and C

Groups	z values Fo	z values F1	z values F2
Group I and II A	-.496	-3.535*	-2.915*
Group I and II B	-1.088	-2.393	-1.523*
Group I and II C	-2.295*	-2.543*	-2.603*

*=Significant difference (p= >0.05)

4.3 To study the effect of ageing on BIC for speech evoked ABR between the subgroup of older adults.

The BIC was obtained by subtracting binaural averaged waveforms from added monaurally elicited right and left waveforms. To obtain the amplitude of the BIC i.e fundamental frequency and its formants (Fo, F1 and F2) FFT was carried out using Brainstem tool box in MATLAB. The Kruskal-Wallis test results showed significant difference, Mann Whitney U test was carried out to study between which groups of older adults there was significant difference. The results reveal that except for the comparision of groups I whereas III and all other groups had no significant difference. The results are given in the table 4.12. The BIC waveform for Group I and Group II is as shown in the figure 4.12

Table 4.12

Mann- Whitney U test for Comparison of Fo, F1 and F2 of BIC within older adult age groups

Groups	z values		
	Fo	F1	F2
Group II A and II B	-1.714	-.693	-1.550
Group II B and II C	-1.088	-.990	-.990
Group II A and II B	-2.948*	-.529	-.680

*=Significant difference (p= >0.05)

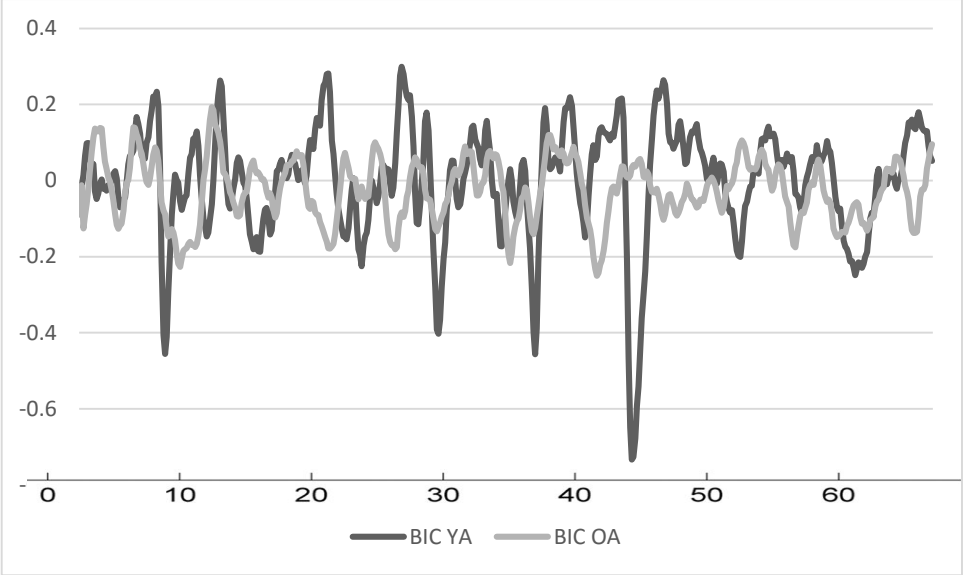

Figure 4.9: BIC waveform of normal and older adults

Chapter-5

Discussion

The aim of the present study was to difference between Binaural Interaction Component in young adults and in older adults. To study this, the following objectives were taken (1) To study the effect of ageing on speech evoked ABR (2) To study the effect of ageing on BIC for speech evoked ABR (3) To study the effect of ageing on BIC for speech evoked ABR between the subgroup of older adults.

5.1 The effect of ageing on speech evoked ABR

The average amplitudes of the peaks V, A, D, E and F of Group I was compared with subgroups of Group II. The results of the present study show that the mean amplitudes of all the peak decreased as age increased, however it was only statistically significant in the Group II C. These findings are in congruence with the study done by Vander Werff & Burns, (2011) they recorded speech evoked ABR for younger and older adults with normal hearing. The results showed reduced amplitude. The temporal and spectral components of speech in normal older individuals has been studied by Samira Anderson et al., (2011) both in quiet and noisy condition and they found that in quiet condition reduced neural representation of the fundamental frequency of the speech stimulus and an overall reduction in response magnitude.

The average latencies of the peaks V, A, D, E and F of Group I was compared between subgroups of Group II and the results showed that there were prolongation of peak latencies in the subgroups of Group II when compared with Group I. However, it was statistically significant in the Group II C. In other sub groups of Group II it was not statistically significant and this finding is supported by the study done Anderson et al., (2012). They recorded ABR for speech stimulus in older adults with normal hearing, and reported that they had delayed

brainstem responses for rapid format transition and reduced phase locking. Vander Werff & Burns, (2011) recorded speech evoked ABR for younger and older adults with normal hearing. The results showed prolonged latencies of onset and offset responses.

5.2 The effect of ageing on BIC for speech evoked ABR

To study the effect of ageing on the amplitudes of the F0, F1 and F2 in Group II was compared with Group I. The results of the present study revealed that the amplitudes of Group II A had significant difference in F1 and F2 compared to Group I. Group II B had significant difference of amplitude in F2 compared to Group I however in Group II C all the amplitudes of F0, F1 and F2 were significantly different from the Group I this is in support with the study done by Samira Anderson et al., (2011) they studied cABR both in quiet and noisy condition they found reduced neural representation of the fundamental frequency of the speech stimulus and an overall reduction in response magnitude. And it is contradicting the study done by Vander Werff & Burns, 2011 reported that latencies of onset and offset responses were delayed but the sustained components of the speech ABR showed no significant effect of age, suggesting intact temporal coding for the harmonics of the speech stimuli. Similar findings were reported by Neupane, Gururaj, Mehta, & Sinha, (2014). They reported no change in the encoding of fundamental frequency of the speech stimulus in older adults.

In the figure 4.12 we can observe that the morphology of BIC in Group II is poorer compared to BIC of Group I. From the study it can be inferred that the BIC can be used as a tool to assess the older individuals who reports of problem in understanding speech in background noise and other challenging listening conditions.

5.3 The effect of ageing on BIC for speech evoked ABR between the subgroup of older adults

To study the effect of age on amplitudes of F0, F1 and F2 within the subgroups of Group II was done. The results of the present study revealed that the ageing effects were seen in subgroups of Group II A and Group II B however a trend of ageing is not seen within the subgroups of older adults. and similar results has seen in the study done by Neupane, Gururaj, Mehta, & Sinha, (2014). They reported no change in the encoding of fundamental frequency of the speech stimulus in older adults even with change in repetition rates. Thus, suggesting speech perception deficits because of ageing may be due to more central deficits. Another study by Vander Werff & Burns, 2011 reported that latencies of onset and offset responses were delayed but the sustained components of the speech ABR showed no significant effect of age, suggesting intact temporal coding for the harmonics of the speech stimuli.

From these results we can infer that there is significant difference between Group I and Group II however within the subgroups of Group II there is no significant difference. The results also indicate that there are brainstem and central changes which could be the reason for speech understanding problems in older adults.

Chapter 6

Summary and Conclusion

The present study aimed to find out the binaural interaction component (BIC) in young adults and older adults. Four groups including 13 young adults in Group I (18-28) and 32 older adults in Group II. The Group II was divided into Group II (>50 to 55 years), Group II B (>55 to 60 years) and Group II C (>60 years to 65 years) each group consisted of 10, 12, 10 individuals respectively.

The results of the study revealed that the latency and amplitudes of the speech ABR were different across age groups. The Group II had prolonged latencies and reduced amplitudes compared to the Group I and Group II C had greater difference in amplitude and latencies compared to other Groups. This also indicated that the aging in the auditory system affects and makes difficult for the speech perception in the older adults even in the presence of normal peripheral hearing sensitivity.

It is usually seen that older adults complaining of speech understanding problems especially in adverse listening conditions and studies have also reported the same (Dubno, Lee, Matthews, & Mills, 1997; Gelfand, Piper, &Silman, 1986). The current study was carried out on normal hearing older adults and the Frequency following response data shows that with increase in age the latencies and amplitudes were reduced. Vander Werff & Burns, (2011) recorded speech evoked ABR for younger and older adults with normal hearing. The results showed smaller amplitude and prolonged latencies of responses.

Further the comparison of Binaural Interaction Component was calculated i.e the amplitudes of all the Group II population showed significant difference in the F0, F1 and F2. Group II B showed difference in only F2, Group II A showed F1 and F2 difference and in the Group II C all the amplitudes were reduced, however there are no consistent pattern of results

within subgroups of Group II, hence we can infer that the amplitudes of the responses in older adults will be affected either in F1, F0, F2, any two of it or all three. Hence more research about the changes in all these aspects of speech evoked ABR in the older adults can give better inferences.

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