RELATIONSHIP BETWEEN SPEECH IN NOISE TEST, AUDITORY EFFERENT SYSTEM AND SPEECH ABR: COMPARISON BETWEEN YOUNGER AND MIDDLE AGED ADULTS.

Madalambika, M. B.

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This Dissertation is submitted as part fulfillment
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CERTIFICATE

This is to certify that the dissertation entitled "**Relationship between speech in noise test, auditory efferent system and Speech ABR: Comparison between younger and middle aged adults.**" is the bonafide work submitted in part fulfillment for the degree of Master of Science (Audiology) of the student (Registration No. 14AUD009). 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

May, 2016

Dr. S. R. Savithri

Director

All India Institute of Speech and Hearing,
Manasagangothri, Mysuru-570006

CERTIFICATE

This is to certify that the dissertation entitled "**Relationship between speech in noise test, auditory efferent system and Speech ABR: Comparison between younger and middle aged adults**" has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other University for the award of any Diploma or Degree.

Mysuru

May, 2016

Dr. Sujeet Kumar Sinha

Reader

Department of Audiology

All India Institute of Speech and Hearing,
Manasagangothri, Mysuru.

DECLARATION

This is to certify that this dissertation entitled "**Relationship between speech in noise test, auditory efferent system and Speech ABR: Comparison between younger and middle aged adults**" is the result of my own study under the guidance of Dr. Sujeet Kumar Sinha, Reader, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not submitted earlier in any other University for the award of any Diploma or Degree.

Mysuru

May, 2016

Register No: 14AUD009

Dedication

I dedicate this work to my lovely parents and brother

Acknowledgment

“The essence of all beautiful art is gratitude”-Friedrich Nietzche.

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ABSTRACT

The aim of the study was to find out correlation between speech in noise perception, auditory efferent system functioning and speech encoding at the brainstem in middle aged individuals. Two groups consisting of 15 younger (age range, 18-30 years) and 15 middle aged adults (age range, 40-60 years) with normal hearing participated in the study. Speech in noise test (SPIN) and SPIN with contralateral noise tests were carried out in both ears using recorded phonetically balanced words from PB word list in kannada (Ramya and Yathiraj, 2015) for both the groups. Along with those TEOAEs, TEOAEs with contralateral noise for clicks at 60 dBSPL and speech ABR for /da/ syllable were recorded in both ears for both the groups. Results revealed no significant correlation between speech in noise test (SPIN) and auditory efferent functioning in and younger and middle aged individuals. Also there was no significant correlation between speech in noise test (SPIN) and auditory efferent functioning and brainstem encoding of speech sound in middle aged individuals.

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Chapter 1

Introduction

Aging leads to many anatomical and physiological changes in the auditory system. Changes in auditory system due to aging has been studied since many years. For older and middle aged adult, hearing speech in the presence of background noise such as carrying out conversation in a market, traffic-filled street, busy restaurant, bus-stand or a factory with high levels of noise is a complicated task and they face communication difficulties in these environments. These difficulties can largely be attributed to age-related hearing loss, or presbycusis. However there are studies which suggest that older adults have increased difficulties understanding speech in noise even in the absence of peripheral hearing loss (Dubno et al., 2002, 2003; Helfer & Freyman, 2008).

There are few studies which suggest that certain auditory abilities begin to decline in middle age. For example, middle-aged adults with normal hearing have been shown to perform more poorly than younger adults (but better than older individuals) on tasks such as perception of dichotically presented speech (Barr & Giambra, 1990; Martin & Cranford, 1991; Jerger et al., 1994), speech perception in noise (Ewertsen & Birk-Nielsen, 1971; Plomp & Mimpen, 1979; Era et al., 1986; Gelfand et al., 1986; Kim et al., 2006) or in reverberation (Nabelek & Robinson, 1982), perception of interrupted speech (Bergman, 1971, 1980; Era et al., 1986), time-compressed speech (Vaughan & Letowski, 1997), localization or lateralization of sound (Abel & Hay, 1996; Abel et al., 2000; Babkoff et al., 2002), and duration discrimination (Abel et al., 1990).

We can find several studies in literature where in speech perception in noise for older and younger adults has been compared using different kinds of noise and they report that older adults had poor speech recognition in noise compared to younger adults despite of having normal hearing sensitivity (Takahashi & Bacon 1992; Tun, Kane & Wingfield,2002; Helfer & Freyman 2008; Rajan & Cainer 2008; Gifford, Bacon & Williams 2008; Schoof & Stuart Rosen, 2014). Even the neurophysiologic evidence of older adults has indicated delayed neural timing, reduced response amplitudes and decreased temporal processing ability with age (Burkard & Sims, 2001; Vander Werff & Burns, 2011).

Recently studies have started focusing on aging effects on the auditory system of middle aged adults. Several studies have investigated that the middle aged adults have poor performance in temporal processing skills as few studies have found poor perfomance in dichotic speech task (Barr & Giambra, 1990; Vaughan & Letowski,1997; Helfer & Vargo, 2009; Leigh-affenroth & Elangovan, 2011), perception of time compressed speech and interrupted speech (Bergman, 1971, 1980; Era et al., 1986), duration discrimination (Abel et al., 1990) and localization tasks (Abel & Hay., (1996) in middle aged adults compared to younger ones. Also, the speech recognition in noise has also been reported to be poor in middle aged compared to younger but better than older adults (Helfer & Vargo 2009; Young et al., 2014).

One mechanism thought to aid in listening-in-noise is the medial olivocochlear (MOC) inhibition. The MOC efferents which are in contact with the OHCs modify the action of OHCs to control the gain of cochlear amplifier. (Guinan, 1996) and it has an inhibitory effect on the peripheral auditory system and it also enhances the responses (Siegel & Kim, 1982; Jenkins et al., 1993; Kawase & Liberman, 1993; Liberman et al., 1996).There is growing evidence in normal-hearing subjects that the medial olivocochlear (MOC) auditory efferent system is involved in the detection of signals in noise (Micheyl et al., 1995; Micheyl & Collet, 1996), such as speech sounds (Giraud et al., 1997; Zeng et al., 2000), by modulation of cochlear active physiological mechanisms i.e., Otoacoustic emissions (Kemp, 1978; Brownell et al., 1985). MOC efferent strength can be measured by contralateral suppression of OAEs. Contralateral suppression of distortion product otoacoustic emissions (DPOAEs) with a wideband noise measured by Kim, Frisina and Robert, (2002) suggest that contralateral DPOAEs decline at an earlier age than the age-dependent decrease in DPOAE amplitudes. Yilmaz et al., (2007) reported a decrease in speech in noise test scores with reduced suppression in contralateral TEOAEs with aging. So we can say that age-related difficulty understanding speech in background noise is related to an age-related functional decline of the MOC efferent system.

Recent research has suggested an important role for neural speech coding at the level of the brainstem for successful speech in noise perception (Hornickel et al., 2009; Song et al., 2011; Anderson et al., 2011). Neural speech coding at the brainstem can be assessed non-invasively by measuring the frequency following response (FFR), sometimes (depending upon the exact stimuli used) also referred to as the speech ABR, complex ABR, or envelope following response. The Speech-evoked Auditory Brainstem Response (SEABR) is a measure that maintains intrasubject reliability across test sessions (Song, Nicol, & Kraus, 2010) and has been used to objectively evaluate speech encoding at the level of the brainstem. The speech stimulus that is often used to elicit the waveforms is a /da/ stimulus; it encompasses an initial tone burst of the consonant, which transitions into the steady-state vowel. The brainstem's electrophysiologic response to this stimulus is a complex waveform, which includes transient and sustained elements (Russo et al., 2004).

In most of the studies done in older subjects there is a positive correlation between the amount of OAE suppression and performance in tasks involving signal-in-noise perception (De Boer & Thornton 2008; Giraud et al., 1997; Micheyl & Collet 1996; Micheyl et al., 1997; Yilmaz et al., 2007) i.e. stronger OAE suppression leads to better performance in discriminating CV contrast in noise. Investigations to find the relation between speech ABR with noise and SIN performance suggest that there is decrease in F0 amplitude and prolongation of latencies (Song et al., 2011; Anderson et al., 2011, 2013; De Boer et al., 2010).

In the literature majority of the studies have focused on age related changes in the auditory system of older adults often compared with younger adults with normal hearing. There is very little known about the middle aged adults, if age related changes starts at this period of life then how these might affect their speech recognition in noise and the relation between the efferent auditory system and SPIN has been studied less.

Need of the study:

1. Middle-aged subjects have been shown to perform more poorly than younger listeners (but better than older individuals) on tasks such as perception of dichotically presented speech (Barr & Giambra, 1990; Martin & Cranford, 1991; Jerger et al, 1994), speech perception in noise (Ewertsen & Birk-Nielsen, 1971; Plodmp & Mimpen, 1979; Era et al., 1986; Gelfand et al., 1986) or in reverberation (Nabelek & Robinson, 1982), perception of interrupted speech (Bergman, 1971, 1980; Era et al., 1986). These raises a question that whether the middle aged individuals have some amount of auditory processing problems. In the literature, children with auditory processing problems clinically present listening deficits in noise, a potential involvement of the MOC efferents has been investigated by some researchers as one of the underlying mechanisms of the auditory processing problems (Muchnik et al., 2004; Clarke et al., 2006; Sanches & Carvallo, 2006;). Thus, to understand this mechanism, there is a need to explore the efferent functioning system in middle aged subjects.
2. Recently speech evoked auditory brainstem responses (ABR) have been introduced as a tool to study the brainstem processing of speech sounds (Banai, Nicol, Zecker & Kraus, 2005; Sinha & Basavaraj, 2010a; Sinha & Basavaraj, 2010b). Speech evoked auditory brainstem potentials can objectively assess the neural timing and can also provide important information about the coding of speech cues at the subcortical level.

(Akhoun et al., 2008; Aiken & Picton, 2008). Hence, speech evoked ABR would provide a better idea about the functional changes at the brainstem for complex stimulus such as speech sounds especially in the older population. Thus, there is a need to study the coding of speech stimuli at the brainstem through speech ABR in middle aged individuals.

3. There is dearth of information in the literature regarding the correlation of speech coding at the brainstem and the auditory efferent system functioning in the middle aged participants and hence there is a need to study the correlation between the two.

Aim of the study:

The aim of the present study is to find out a correlation between speech in noise perception, auditory efferent system functioning and speech encoding at the brainstem in middle aged individuals.

Objectives of the study

1. To investigate the correlation between speech in noise test (SPIN) and auditory efferent functioning in middle aged individuals.
2. To find out the encoding of speech stimuli at the brainstem in middle aged individuals.
3. To investigate the correlation between speech in noise test (SPIN) and auditory efferent functioning and brainstem encoding of speech sound in middle aged individuals.

Chapter 2

Literature Review

2.1 Anatomical and physiological changes in the ear across the age.

As we grow older there are some structural and functional changes in all parts of our body. Among them ear is one of the organ where evidently the changes can be observed as the older adults face difficulties in listening to others which results in communication problems.

Several changes occur in the outer ear with aging and some of them are production of excessively large amount of cerumen with inadequate epithelial migration resulting in impacted cerumen (Miyamoto & Miyamoto,1995), collapsed ear canal resulting in artificial air-bone gap in the audiogram especially for high frequencies (Ballachanda,1995;Chandler,1964), hair growth in and around the ear canal in males (Ballachanda,1995), atrophy and loss of elasticity and dehydration of the cartilage of pinna making it prone to trauma and breakdown (Ballachanda,1995). These changes are thought to affect the acoustic properties of the ear (Tsai et al., 1958).

Age related changes also occur in the middle ear; some of the changes which have been reported are thinning, stiffening and loss of vascularity of the tympanic membrane, ossification of the ossicles (Covell, 1952: Rosenwasser, 1964), calcification of the cartilaginous portion of eustachian tube and reduced muscle function to open the tube

(Belal,1975).These above mentioned outer and middle ear changes do not appear to impact the hearing sensitivity greatly as they have minimal effect in impeding the transmission of sounds.

Several anatomical and physiological changes have been reported in the inner ear also. Aydelott, Leech and Crinion, (2010), reported that there is a loss of sensory cells (OHCs), stria vascularis atrophy on the lateral wall of the cochlea, reduction of ganglion-nerve cells, decreased number of synaptic contacts, changes in the excitatory and inhibitory neurotransmitter system and conduction of cochlear duct and changes .

Both types of hair cells undergoes degenerative changes in the basal turn of the cochlea with apical and mid cochlear involvement of the outer hair cells as well (Willot, 1991). The decrease in the hair cells population is greatest in persons over 70 years of age and is most pronounced for outer hair cells. That is, hair cell population is less in older adults, especially for outer hair cells. However, there is significant reduction in the outer hair cell population in the mid age itself. The population of outer hair cells reduces to 78% in the age between 50-60 years. It is important to note that both the outer hair cells and inner hair cells degenerate independently (Otte, Schuknect, and Kerr, 1978).

The substantial loss of outer hair cells in the basal turn of the cochlea affects cochlear mechanics and is responsible for the normal decline in pure-tone hearing with age (Willot, 1991). According to Willot (1991) a loss of about 20% of the outer hair cells may result in minimal sensorineural hearing loss. Bredberg (1968) demonstrated that a

50% to 75% loss of outer hair cells in the apical region is associated with losses of less than 40 dB HL, whereas a 50% of the loss of outer hair cells near the cochlear base is associated with a hearing loss of 50 to 75 dBHL.

Aging also results in the decrease in the number of spiral ganglion cells. Otte et al (1978) demonstrated that the total number of spiral ganglion cells in the cochlea's of young adults between 30,000 and 40,000 declining to less than 20,000 for persons between 81-90 years. There is a progressive loss of about 2,000 neurons per decade. The aging process is also associated with decrease in number of fibers in the cochlear nerve. Crowe, Guild and Polvogt (1934) demonstrated that nerve fiber loss is greatest within 10 mm of the cochlea.

There appears to be a relation between amount of ganglion cell loss and pure tones thresholds. Suzuka and Schuknecht (1988) reported that hearing status in the subjects are unaffected when the ganglion cells loss is less than 20%. Otte et al., (1978) demonstrated that the threshold elevations occur when the total ganglion cells population reduces to around 20,000. Persons with a ganglion cell population of approximately 25,000 (for 30 to 60 years old) may have a mean hearing level within mild range (Otte et al., 1978). Nadol (1981) demonstrated that ganglion cell loss restricted to the basal 3 to 5 mm of the cochlea is not associated with high frequency hearing loss, whereas ganglion cells loss in the excess of 50 % in the basal 10 mm of the cochlea is associated with high frequency hearing loss.

The age related changes are not uniform across the nuclei within the central auditory nervous system and vary greatly among the individuals. Neuronal age related atrophy is characterized by an overall loss of neurons, change in neuron size, and decrease in size of the cell body, nucleus and a decrease in dendritic arborization along with a diminution or disappearance of dendrites (Willot, 1991).

In the central auditory system brainstem structure undergoes major changes in the older individuals. These changes at the brainstem include decrease in number, size and density of neurons, reduced cell density in selected nuclei and an increase in pigmentation (Kirake, Sato & Shitara, 1964). Konigsmark and Murphy (1970) found an evidence of reduction in the volume of neurons in VCN beginning at about 60 years of age; a decrease in the number of well myelinated fibers in the VCN of the older individuals, a decrease in the number of small vessels and capillaries per unit area with increasing age and an increase in lipofuscin accumulation with age. Crace (1970) also noted a decrease in neurons size and density with the age at the cochlea nucleus.
Advancing age also results in reduction of the fibers of lateral lemnisci (Willott, 1991). Furthermore, it has been shown that the neurons which exhibit precise temporal encoding is reduced in the inferior colliculus of aging mice, accompanied by a higher proportion of neurons that display sluggish temporal response pattern (Willot et al., 1988).

Donald et al (2008) studied mammalian central auditory system (rats) through cochleograms of young and old rats and reported that there are changes in the presynaptic release of inhibitory neurotransmitters and changes in composition of the glycine (GlyR) and GABAA (type-A y-aminobutyric acid) receptors with age. Changes in the glycine neurotransmission in dorsal cochlear nucleus (DCN) results in altered intensity and temporal coding by DCN projection neurons (Donald et al., 2008). Aging related changes in the GABA receptors in (IC) inferior colliculus and primary auditory cortex results in altered responses affecting the temporal processing and response reliability.

2.2 Speech perception in older adults.

As the age increases the older adults report that they can hear what people say but have difficulty in understanding the speech because of lack of clarity. For accurately discriminating the speech precise temporal processing is important which is reduced in older adults compared to younger adults. Craig (1992) has reported that speaking at a slower rate improves speech perception in older adults which supports the idea that overall age-related slowing contributes to problems with speech perception (Wingfield et al., 1999; Trembley et al., 2002).

Wiley et al (1998) compared age-related changes in word recognition in quiet and with a single-talker competing message for subjects in four age groups (48–59, 60–69, 70–79, and 80–92 years). Word recognition in quiet and with the competing message was poorer for older age groups and poorer for males than females, even when results were stratified by degree of hearing loss (pure-tone average of 0.5, 1.0, 2.0, 4.0 kHz). Detailed analysis revealed that degree of hearing loss accounted for the largest portion of the variance in speech recognition in quiet and in the competing message; age and gender were much smaller, but significant, contributors.

However, there are studies which demonstrate that there is an overall decline in the speech perception of the older individuals even there is no hearing loss. Above the age of 60 years, the proportion of persons with problems in perceiving speech doubles per decade from 16% at age of 60 years to 32% at the age of 70 years to 64% at the age of 80 years (vanRooji & Plomp, 1992).

In a recent study Calais, Russo and Borges (2008) characterized and compared the hearing abilities of elderly in a monaural speech perception test; in the presence and absence of background noise (Speech Discrimination Test and Speech Perception in Noise). Participants of this study were 55 subjects of both genders, 60 years old or above, with normal hearing sensitivity. It was observed that there was no difference between genders in the speech discrimination test and the speech perception in noise test. A significant reduction in speech perception was observed when the speech stimulus was presented in noise for all the participants.

Gelfand, Piper and Silman (1986) in another attempt evaluated consonant recognition in quiet and in noise using the nonsense syllable test. The speech materials were presented in quiet and at +10 and +5 dB at their most comfortable levels. The findings of the study suggested that normal older individuals listening in quiet and listening in noise experience decreased consonant recognition ability. Although the consonant recognition performance decreased with the age, but the age factor did not interact with different SNR conditions or with nonsense subtests. However, there was no difference in terms of the nature of the phoneme confusion between the younger and the older individuals in the noise.

In another study Plomp and Mimpen (1979) demonstrated that the speech perception problems in the individuals start from the age of 50 years. Plomp and Mimpen (1979) studied the speech-reception threshold for sentences as a function of age and noise level for 140 male subjects (20 per decade between the ages 20 and 89) and 72 female subjects (20 per decade between 60 and 89, and 12 for the age interval 90-96). The authors reported that the speech perception problems in the individuals starts after the age of 50 years and the speech perception problem is more when the speech is presented in noise. Subjects with the same amount of hearing threshold, vary considerably in their ability to understand speech in noise. The data confirm that the hearing handicap of many elderly subjects manifests itself primarily in a noisy environment.

Wedel, Wedel and Streppel (1991) also confirmed the findings that the there is a reduction of speech discrimination ability in noise ability in people aged over 50 years with a substantial drop in the group older than 70 years. The elderly do not only show a substantially poorer overall intelligibility but also show a much more diffuse pattern of consonant errors without any clustering of confusions between particular phonemes. The authors concluded that these results may be caused by growing dysfunctions in the peripheral and central parts of the hearing system, e.g. problems in temporal and frequency selectivity in the elderly.

According to numerous studies there is one type of masker that will mainly affect the hearing of speech in older adults is competing speech (Tun & Wingfield, 1999; Tun et al., 2002; Helfer & Freyman, 2008; Rajan & Cainer, 2008; Rossi-Katz & Arehart, 2009). Helfer and Freyman (2008) examined the perception of syntactically simple sentences in the presence of different types of background noise for older adults and younger adults with normal hearing and with varying degrees of hearing sensitivity. They found that the speech perception of older adults were affected more at two-talker babble than by the steady-state or amplitude-modulated speech-shaped noise.

Similarly, Rajan and Cainer (2008) determined speech reception thresholds (SRTs) for simple BKB sentences. Rajan and Cainer (2008) recorded speech identification scores in the presence of eight-talker babble and steady-state speech-shaped noise in adults with normal hearing (20 - 69 years) by dividing into decade age groups). They observed a decline in performance in the oldest age group (60 - 69 yrs) compared to their younger groups in the presence of the competing talkers.

Nilsson et al, (1994) reported that compared to younger adults in the presence of speech-envelope modulated speech-shaped noise but not steady-state noise. Similarly Gifford et al. (2007) demonstrated that older adults performed poorly than younger adults in the HINT test when presented with 10-Hz square-wave amplitude modulated speech-shaped noise. As most of the studies used relatively simple target materials like syllables

(Stuart and Phillips, 1996; Dubno et al., 2002) or simple sentences (e.g. Peters et al., 1998; Gifford et al., 2007),Grose et al., (2009) studied the fluctuating masker benefit (FMB) using more complex materials. They found that older individuals with normal hearing till 4 kHz performed poorly than younger adults in the presence of 16 or 32 Hz square-wave modulated noise. Stuart and Phillips, (1996) and Dubno et al., 2002, 2003) noted that three of the six studies wherein they studied the effects of age on the speech perception in the presence of modulated noise and also examined the perception of speech in steady-state noise resulted in significant group differences in the unmodulated masker .They suggested that the FMB may partly be dependent on the performance in steady-state noise.

Neurophysiological evidence indicated delayed neural timing and decreased temporal processing ability with age in animals (Walton et al., 1998; Burkard and Sims, 2001; Finlayson, 2002; Recanzone et al., 2011) and in humans (Caspary et al., 2005; Lister et al., 2011; Vander Werff and Burns, 2011; Wang et al., 2011; Konrad-Martin et al., 2012; Parbery-Clark et al., 2012). The neural response of older adults may be affected by reduced levels of inhibitory neurotransmitters in the DCN (Caspary et al., 2005; Wang et al., 2009) and IC (Caspary et al., 1995) and auditory cortices (de Villers-Sidani et al., 2010; Juarez-Salinas et al., 2010;Hughes et al., 2010;) of aging animals. According to (Walton et al., 1998; Caspary et al., 2002, 2008) accurate processing of the rapidly changing aspects of speech depends partly on the sharpening of neural responses through the inhibitory mechanisms. Synchronous neural firing of the auditory brainstem will result in the precise representation of the incoming sound (Kraus et al., 2000) but this is degraded by reduced inhibition or temporal jitter which would result in impaired binaural processing (Pichora-Fuller and Schneider,1992) and deficits in speech perception in older adults (Pichora-Fuller et al ., 2007).

2.3 Speech perception in the middle aged adults.

Age related changes leads us to question that when in the lifespan do the changes in the auditory system occur due to aging. In the literature majority of the studies focus on age related changes in the auditory system of older adults often compared with younger adults with normal hearing. There is little known about the middle aged adults, if age related changes starts at this period of life then how these might affect the speech recognition of adults in the midlife has been answered by many studies.

Several studies have focused research on aging effects on middle aged adults and suggested that certain auditory abilities start to decline in the mid-life. Middle aged adults have been found to perform poorly than younger adults in dichotic speech tasks (Barr and Giambra, 1990; Martin and Cranford, 1991; Jerger et al., 1994),perception of speech in complex conditions like in noise (Ewertsen and Birk-Nielsen, 1971; Plomp and Mimpen, 1979; Era et al., 1986; Gelfand et al., 1986; but see Kim et al., 2006)and in reverberant conditions (Nabelek and Robinson, 1982).Also middle aged adults showed poor performance than younger adults in perception of time compressed speech ((Vaughan and Letowski, 1997) and interrupted speech (Bergman, 1971, 1980; Era et al., 1986), duration discrimination (Abel et al., 1990) and in tasks of localization or lateralization of sounds(Abel and Hay, 1996; Abel et al., 2000; Babkoff et al., 2002).

There are evidences to prove that the changes in perception of speech in middle age may be partly due to the anatomical and physiological changes beyond the cochlea. Geal-Dor et al (2006) noted certain differences between middle aged and younger individuals in event-related potentials (ERPs) and Alain et al., (2004) found the same on the mismatch negativity potential. Ross et al (2007) measured the processing of interaural phase differences both in physiological and behavioral tasks and demonstrated that age-dependent changes in binaural functioning begins in middle age. Farrimond (1959), Pelson and Prather (1974) and Dancer et al (1994) also reported that the lip-reading ability started to show age-related declines in middle age.

Bellis and Wilber (2002) investigated age and gender effects on interhemispheric functions using dichotic listening and auditory temporal patterning tasks and found that it begins to decline earlier in human adulthood than in older age ie., it begins between the ages of 40-55 years and tend to stabilize after that. So they stated that the decline in interhemispheric integrity has resulted to the common complaints of reduced speech understanding in difficult listening conditions and decreased binaural processing in these adults. Several studies have suggested that that despite of normal hearing sensitivity, there was reduction in certain auditory perceptual tasks like dichotic listening and speech perception in noise (Barr & Giambra, 1990; Helfer & Vargo, 2009; Leigh-affenroth & Elangovan, 2011).

Kim et al.,(2006) studied binaural speech recognition performance of different age groups like young (18-37 years), middle age (38-57years) and older(>58 years of age) having normal hearing thresholds in both quiet and noisy situations using HINT questionnaire (Hearing in noise test, Nilsson et al., 1994). The results of the study suggested that performance of the middle aged group on these tasks was lesser compared to the younger counterparts. These authors also found no correlation between the pure tone thresholds and suprathreshold speech performance in elderly subjects indicating auditory processing changes of aging in them. These findings suggest that the age related changes in central portion of the auditory system start to present behaviorally in middle age.

There are studies which have reported older adults perform poorly in auditory processing tasks like low recognition scores in performance and stronger preference for materials presented to right ear in dichotic listening tasks (Noffsinger et al., 1996). Ross and collegues (2007) used cortical auditory responses to provide electrophysiological evidence that age related changes in central auditory system is important for binaural hearing and it begins at the mid-life. They recorded cortical responses to changes in interaural phase differences for amplitude-modulated tones using magneto-encephalography (MEG) in normal hearing young, middle aged (45-55 years) and older adults (ages 65-79 years). Results revealed age related decline in the responses indicating reduced frequency range in detecting interaural phase differences and it was significantly decreased in middle aged adults compared to the younger adults. Also there was decrease in the cortical responses in the older adults but larger variability in this age group suggested that binaural hearing process is not uniform.

Helfer and Vargo (2009) examined speech understanding and temporal processing ability in younger (19-22 years) and middle aged women (45-54 years) with normal hearing sensitivity till 4k Hz .Speech understanding was assessed in the presence of steady state noise and competing speech, temporal resolution using Gaps -In -Noise (GIN) test and Speech, Spatial and Qualities of Hearing Scale to measure the subjective ability to understand speech in complex listening conditions. Results revealed that the performance of middle aged women was significantly poorer than the younger subjects in spatially coincident speech masker strongly correlating with GIN test scores and were unrelated to pure tone thresholds.

In a recent study, Yilmaz, Sennaroglu, Sennaroglu and Kose (2007) studied speech recognition in noise test at a signal to noise ratio of +10 dB, in 53 women and 48 men having normal hearing in six age ranges (10-19, 20-19,30-39,40-49, 50-59 and 60-69 years). The results of Yilmaz et al (2007) confirmed that the speech recognition in noise reduces after the age of 50 years and there is a significant reduction in the speech recognition after the age of 60 years. The authors concluded that aging decreases the ability to recognize speech in background noise.

2.4 Auditory efferent system in older adults.

There are two types of olivocochlear efferents, medial olivocochlear (MOC) and lateral olivo- cochlear efferents (LOC). MOC efferents are thick, myelinated originate in the middle part of superior olivary complex (SOC) courses ipsilaterally and contralaterally and innervate outer haircells of the cochlea whereas thin, unmyelinated LOC efferents originating at the right side of the brain and innervate inner hair cells of cochlea. The pathway of right ipsilateral MOC acoustic reflex starts from cochlea wherein when the sound enters it excites auditory nerve fibers that innervate reflex interneurons in the posteroventral cochlear nucleus .The axons of these cochlear-nucleus interneurons cross the brainstem ventrally to innervate MOC neurons on the contralateral side and then the contralateral MOC neurons innervate to right cochlea in the crossed olivocochlear bundle. The contralateral reflex pathway of right ear involves contralateral auditory nerve fibres innervating reflex interneurons in the contralateral postero-ventral cochlear nucleus. The axons of these interneurons cross the brainstem ventrally and innervate MOC neurons ipsilateral in the right side. These MOC neurons project to the cochlea ipsilateraly through the uncrossed olivocochlear bundle to complete the contralateral pathway (John J. Guinan, Jr (2006). Studies in mammals suggest that the ipsilateral MOC reflex is two or three times stronger than the contralateral MOC reflex. However in humans there are similar numbers of crossed and uncrossed MOC fibers and have almost the same strength (Thompson & Thompson, 1991; Bodian & Gucer, 1980)

Collet et al (1990) found that the otoacoustic emissions in humans can be suppressed by contralateral white noise and noted OAEs suppression when contralateral auditory stimulation was given. They suggested that the only noninvasive and objective method for evaluation of the functional integrity of the medial efferent system and other structures along its pathway.

Evaluating the suppression effect using OAE level at varying levels of contralateral broad band noise as a function of age is one of the ways to examine the efferent activity of the MOS which implicates the ability to hear in noisy backgrounds (Liberman, 1989; Musiek and Hoffman, 1990; Micheyl and Collet, 1996;William, Brookes, and Prasher,1994. Quaranta et al., (2000) reported that sectioning of the olivocochlear bundle eliminates the inhibitory effect on OAEs in contralateral stimulation. Durante and Caevalho (2002) noted that the contralateral suppression of transient evoked otoacoustic emissions (TEOAEs) is present in 88.5% of neonates Ibarguen et al (2008) studied the effect of stimulus frequency and intensity on suppression of EOAEs and found that the effect is greatest when the suppressor and EOAEs have same frequencies and among them white noise and pure tones of 1000 to 2000 Hz have the greatest suppressor effect on TEOAEs. Ian Benjamin Mertes (2014) quantified the repeatability of MOC reflex effects on TEOAEs in normal hearing young adults using contralateral acoustic stimulation of 35db SL broadband noise and found high stability across time.

Amanda et al (2012) examined the changes in efferent innervation of IHCs in old and young C57B/6 mice using transmission electron microscopy and found reduced efferent innervation of IHCs, small number of synapses per IHC, increased loss of OHCs and elevated brainstem thresholds were observed. An age-related reduction in the suppression of TEOAEs by Castor et al (1994) when presented with a continuous contralateral broad band noise at 30 dB SL and it was significantly smaller for older adults (70 -88 years) than young adults (20 and 39 years). Parthasarathy (2001) measured contralateral suppression effects on TEOAEs at different contralateral broadband noise levels at 40, 50, 60, and 70 DB HL in 30 normal hearing individuals of the age range 20-79 years. Contralateral suppression at 60 and 70 dBHL was significantly greater for individuals of the age range 20-59 years compared to 60-79 years of age.

Jodi Hensel (2011) evaluated the effects of stimulus intensity on transient evoked OAE (TEOAE) suppression in three conditions like ipsilateral, contralateral, and binaural noise suppression in both older and younger adults with normal hearing. Results revealed that there was significantly greater TEOAE suppression in the binaural and ipsilateral conditions in younger group compared to older age group. The study indicate that decrease in binaural suppression with age are related to degeneration of MOC with age rather than intensity differences and the findings contribute to the difficulties faced hearing in noise and loss of binaural advantage by older individuals.

Yilmaz et al (2007) studied the influence of age, in normal hearing individuals on masking level difference test, speech recognition in noise test, TEOAEs and contralateral

TEOAEs. Results revealed significant increase in masking level difference test and found decrease in speech in noise test scores with reduced suppression in contralateral TEOAEs with the increase in age. Hence from the above studies it can be concluded that older adults reduced contralateral suppression of TEOAEs than the younger adults.

2.5 Speech evoked auditory brainstem responses in older adults.

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 auditory brainstem response to complex sounds (cABR) domains (Galbraith et al, 1995). It is a noninvasive, 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 domains (Galbraith et al., 1995), and it is consistent and reliable across time (Kraus and Nicol, 2005).

The speech evoked ABR in older individuals have started to appear and there are a few studies which have been reported in the literature. Vander-Werff and Burns (2011) compared speech evoked ABR recorded for 40 msec /da/ speech stimulus from 19 participants in the age range of 20 to 26 years to that participants in the age range of 61 to 78 years. Vander-Werff and Burns (2011) reported that latency of wave V, wave F and wave O was significantly larger in older participants compared to the younger participants. Amplitude of wave V was also significantly smaller in older participants compared to the younger participants. Coding of fundamental frequency and other harmonics was also significantly affected in older individuals. In the study by Vander-Werff and Burns (2011), have considered the participants in the age range of 61 to 78 years. Additionally all the participants in the older group had a significant sensorineural hearing loss in the higher frequency after 1000 Hz. The hearing loss at higher frequency would have affected the latency and amplitude of wave V as well as the coding of the fundamental frequency and the harmonics in the older participants. It has been reported that the sensorineural hearing loss affects the latency and amplitude of wave V (Khladakar, Kartik & Vanaja, 2005) as well the coding of the fundamental frequency and harmonics (Pyler & Krishnan, 2001; Sumesh, 2007).

In another study, Anderson, Clark, Yi and Kraus (2011) recorded speech evoked ABR in two groups of participants in the age range of 60-73 years. The participants of the two groups differed in terms of their speech perception in noise scores. Anderson et al. (2011) reported that individuals with lower speech perception in noise scores had significant latency delay for the peaks evoked by the transition portion of the speech stimuli. Also, the coding of fundamental frequency was deficient in individuals with low speech perception in noise scores compared to the individuals with high speech perception in noise scores. All the participants in two groups had significant sensorineural hearing loss at the higher frequency. Although, the hearing loss in both the groups were similar, it might be possible that amount of changes in the central auditory system due to aging in one group of participant might be different than the other group of participants. It has been reported that the age related changes are not uniform across the nuclei within the central auditory nervous system and vary greatly among the individuals (Willot, 1991).

Anderson, Clark, Schwoch and Kraus (2012) recorded speech evoked ABR utilsing 170 msec /da/ stimulus from a group of participants in the age range of 18-30 years and from another group in the age range of 60-67 years. All the participants in both the groups had normal hearing sensitivity. Results from the study revealed that the older participants had significant latency delay for wave V and for the waves elicited by transition portion of the stimuli. Also, the encoding of the fundamental frequency and harmonics for the older participants were reduced compared to the older adults. The age of the participants in the above study is above 60 years. It has been reported that the changes in the auditory nerve and the brainstem structures starts after 40 years of age (Kirake et al., 1964; Willot, 1991; Xing et al., 2012), it would be interesting to see whether speech evoked ABR also shows any kind of change in the participants aged above 40 years.

Clark, Anderson, Hittner & Kraus (2012) evaluated speech evoked ABR in older and younger participants in the age range of 45-65 years and 18 to 32 years respectively. 170 msec /da/ stimulus was utilized to record the speech evoked ABR. All the participants in both the groups had normal hearing sensitivity. Results from the study revealed that the older participants had significant latency delay for wave V and for the waves elicited by transition portion of the stimuli. In the above study wave V was significantly delay for the older participants, it might be possible that the significant delay obtained for the latency of the waves elicited by the transition portion of the stimuli could be due to the effect of age on the wave V latency which is also seen to have prolonged significantly across age. This is so, as the sustained responses occur after transient responses. The authors should have considered an age correction factor for wave V latency.

Chapter 3

Method

Present study was conducted with an aim of finding out a correlation between speech in noise perception, auditory efferent system functioning and speech encoding at the brainstem in middle aged individuals.

Participants:

Two groups of subjects participated in the study. Group I consisted of 15 participants in the age range of 18-30 years with mean age of 21.06 years and group II consisted of 15 participants in the age range of 40-60 years with mean age of 47.73 years.

Participant selection criteria for group I and group II.

1. All the participants had normal hearing sensitivity (within 15dBHL) at octave frequencies 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000Hz, and 8000 Hz for air conduction and for 250 Hz, 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz for bone conduction.
2. All the participants showed type 'A'/As tympanogram with normal ipsilateral as well as contralateral reflexes present at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz in both the ears.
3. There was no history of any otological or neurological dysfunction in all the participants.

4. Participants of both the groups were non diabetic.
5. There was no history of exposure to loud noise and not working in an industrial set up for all the participants.
6. Participants of both the groups were ruled out of any retro cochlear pathology using auditory brainstem responses.
7. The participants had no history of ototoxicity.
8. The participants had no history of formal musical training.

Instrumentation

1. Calibrated two channel GSI audiostar pro diagnostic audiometer of United states of America, TDH 39 headphones and Radio ear B-71 bone vibrator was used for threshold estimation and for Speech identification scores (SIS) and Speech in noise test (SPIN) scores. The same GSI audiostar pro instrument was used for presenting noise for contralateral suppression of TEOAEs.
2. Calibrated GSI tympstar Immittance meter was used to carry out tympanometric and reflexometric evaluations.
3. ILO V6 was used to measure TEOAEs and contralateral suppression of OAEs.
4. Biologic Navigator Pro EP was used to record the click and speech evoked auditory brainstem responses.

Procedure

1. Pure tone audiometry.

    - Using modified Hughson Westlake procedure (Carhat and Jerger, 1959) pure-tone thresholds were obtained at octave frequencies between 250 Hz to 8000 Hz for air conduction and between 250 Hz to 4000 Hz for bone conduction for all the participants.

2. Speech audiometry.

    - Speech audiometry was done using phonetically balanced words list (Asha Yathiraj and Vijayalakshmi , 2005)
    - Ipsilateral and contralateral Speech in noise test (SPIN) was carried out where in recorded phonetically balanced words from PB word list in kannada (Ramya and Yathiraj 2015) was presented at most comfortable level i.e., at 40 dBSL with 0 dB SNR and for the contralateral SPIN test noise was presented at 0 dB SNR.

3. Immittance evaluation.

- Probe tone frequency of 226 Hz was used to carry out immittance evaluations and ipsilateral and contralateral acoustic reflexes thresholds were measured for 500, 1000, 2000, and 4000 Hz.

4. Oto Acoustic Emissions.(TEOAEs)

    - TEOAEs were recorded using click stimuli (260 stimuli) with the level of 70 dB peak SPL in linear mode. The probe was placed in the ear canal such that a good seal was obtained. Auto adjust option was selected in order to ensure that the stimulus level is within 2 dB of the stimulus level.

- A second TEOAE recording was done by presenting a contralateral Broad band noise through audiometer at 60dBSPL. Three recordings of each condition were compared for similarities in terms of SNR, click level, click stability, and waveform repeatability.

5. Auditory brainstem responses.

Click evoked ABR.

- Click evoked auditory brainstem responses were recorded to rule out retro-cochlear pathology.Insert ER-3A was used to present the stimulus click ipsilaterally which is of 0.1msec duration with the rarefaction polarity and repetition rates of 11.1/s & 90.1/s at the presentation level of 80 dBnHL. Recording parameters included analysis time of 10 msec, 2000 number of sweeps, 2 replications and inter-electrode impedance of <2 kilo Ohms.Amplifier parameters included one channel recording with band pass filter of 100-3000Hz and electrode montage was inverting electrode at M1, non-inverting electrode at Fz and ground at M2 positions. The electrodes were placed with the help of skin conduction paste and surgical plaster was used to secure them tightly in the respective places. Participants were instructed to relax and refrain from extraneous body movements to minimize artifacts.

Speech evoked ABR.

- Speech evoked auditory brainstem responses was recorded using stimulus of 40-ms [da] syllable synthesized in KLATT (Klatt, 1980). The test stimulus used (/da/) in the present study is the default stimulus available with the BIOLOGIC NAVIGATOR PRO instrument in the BIOMARK protocol.

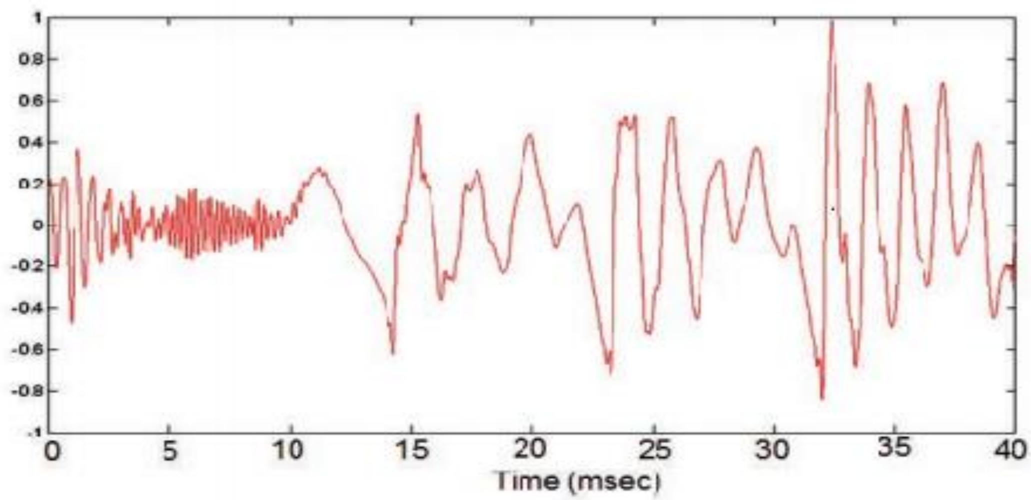


Figure 3.1 **Stimulus waveform of /da/ stimulus.**

- This /da/ stimulus is a 40 ms synthesized speech syllable, which has been produced using KLATT synthesizer (Klatt, 1980). The fundamental frequency (F0) of the /da/ stimulus linearly rises from 103 to 125 Hz with voicing beginning at 5 ms and an onset noise burst during the first 10 msec. The first formant (F1) rises from 220 to 720 Hz, while the second formant (F2) decreases from 1700 to 1240 Hz over the duration of the stimulus. The third formant (F3) falls slightly from 2580 to 2500 Hz, while the fourth (F4) and fifth formants (F5) remain constant at 3600 and 4500 Hz, respectively.

- Insert ER-3A was used to present the stimulus /da/ ipsilaterally which is of alternating polarity and repetition rates of 10.9/s at the presentation level of 80 dB SPL. Recording parameters included analysis time of 60 msec including pre-stimulus period of 10 msec, 2000 number of sweeps, 2 replications and inter-electrode impedance of <2 kilo Ohms. Amplifier parameters included one channel recording with band pass filter of 100-3000Hz and electrode montage was inverting electrode at M1, non-inverting electrode at Fz and ground at M2 positions.
- The electrodes were placed with the help of skin conduction paste and surgical plaster was used to secure them tightly in the respective places. Participants were instructed to relax and refrain from extraneous body movements to minimize artifacts.

Analysis of data

- Speech identification scores and SPIN test scores with and without contralateral noise were analyzed by calculating the words which were identified correctly out of 25 words.
- TEOAEs and TEOAEs with contralateral noise were analyzed based on the OAE amplitude.

- Click and Speech ABR was documented with respect to the amplitude, latency and spectral components of onset response as well as sustained response.
- The onset response was measured with respect to the peak amplitude and latency of wave ‘V’ as well as wave ‘A’.
- The sustained response will be measured with respect to the amplitude, latency of the wavelet ‘D’, ‘E’, ‘F’.

FFT Analysis

- To know the encoding of the first formant frequency and higher harmonics, a Fast Fourier transform (FFT) of the waveform was done. FFT was analyzed from 16 ms to 44 ms of the waveform. To do the FFT analysis, activity occurring in the frequency range of the response corresponding to the fundamental frequency of the speech stimulus (103-121 Hz), and first formant frequencies of the stimulus (220-720 Hz) and higher harmonics (721 Hz to 1200 Hz) was measured for all the subjects. This was done as per the guidelines given in earlier studies.44,26,32 The raw amplitude value of the F0 or F1 frequency component of the response FFR were then noted. All FFT analysis was done using a custom-made programme using MATLAB software. Brainstem Toolbox developed at Northwestern University was also utilized along with MATLAB, to get the FFT information.

Chapter- 4

Results

Present study was conducted with an aim of finding out a correlation between speech in noise perception, auditory efferent system functioning and speech encoding at the brainstem in middle aged individuals. Data was collected from both the younger and middle aged groups were analyzed. Shapiro- Wilk test was administered to the whole data to check for normality.4 subjects were identified as outliers and they were removed from the data. So the total number of individuals were 26, each group consisted of 13 subjects and in each group 7 were females and 6 males. SPIN and ABR data showed p-value of <0.05 in many conditions which indicated that the data are not normally distributed, hence non-parametric tests were administered for SPIN and ABR. The test results for normality of TEOAEs showed p-value of > 0.05 in all frequencies which indicated that the data is normally distributed, however the descriptive statistics results showed high standard deviation for TEOAEs in all the frequencies, so even for TEOAEs non-parametric test was administered.

4.1 Speech identification scores (SIS) and Speech in Noise test (SPIN)

Speech identification test, Speech identification in noise test and speech identification noise test in presence of contralateral noise was done for both the groups. List of 25 words were used to measure all the results of three tests. The raw score obtained in these three tests were subjected for further analysis. Descriptive statistics was done to find out the mean and standard deviation of the speech identification scores, speech identification scores in noise and speech identification scores in the presence of contralateral noise. The mean and the standard deviations of the speech identification scores, speech identification scores in noise and speech identification scores in the presence of contralateral noise for both the groups are given in Table 4.1.1.

Table 4.1.1

Mean and standard deviations of SIS, SPIN and SPIN with contralateral noise of the two groups

		Mean			Std. Deviation		
	Groups	Females	Males	Total	Females	Males	Total
SIS –right ear	Middle age	24.00	24.83	24.38	0.58	0.40	0.65
	Younger	25.00	24.83	24.92	0.00	0.41	0.28
	Total	24.50	24.83	24.65	0.65	0.39	0.56
SIS –left Ear	Middle age	24.14	24.67	24.38	0.69	0.82	0.77
	Younger	24.86	25.00	24.92	0.38	0.00	0.28
	Total	24.50	24.83	24.65	0.65	0.58	0.63
SPIN-right ear	Middle age	16.71	14.16	15.54	3.59	2.79	3.38
	Younger	17.42	18.50	17.92	2.64	2.74	2.63
	Total	17.07	16.33	16.73	3.04	3.47	3.20
SPIN-left ear	Middle age	18.43	14.33	16.54	3.05	2.34	3.38
	Younger	17.71	18.17	17.92	2.56	1.47	2.06
	Total	18.07	16.25	17.23	2.73	2.73	2.83
Contralateral SPIN-right ear	Middle age	16.71	14.17	15.54	3.59	2.79	3.38
	Younger	17.43	18.50	17.92	2.64	2.74	2.63
	Total	17.07	16.33	16.73	3.05	3.47	3.21
Contralateral SPIN-left ear	Middle age	18.43	14.33	16.54	3.05	2.34	3.38
	Younger	17.71	18.16	17.92	2.56	1.47	2.06
	Total	18.07	16.25	17.23	2.73	2.73	2.83

Note-SIS-speech identification score, SPIN-speech in noise, R-right, L- left and CSPIN-contralateral SPIN

It can be seen from Table 4.1.1 that the mean speech identification scores for middle aged individuals were lesser compared to younger participants for both males and females. It can also be seen that mean speech identification scores in noise test was also better for younger group compared to the middle aged group except for right ear for females. For Speech in noise test with contralateral noise the scores were better for younger group compared to the middle aged participants except for right ear for females.

To understand the significant difference in mean scores of the different tests between two groups, the Non-Parametric Mann Whitney U test was administered. The results of the Mann-Whitney U test is given in Table 4.1.2.

Table 4.1.2.

Comparison of SIS and SPIN scores between the groups.

	Z	**Asymp. Sig. (2-tailed)**
SIS-R	2.51	0.01
SIS-L	2.21	0.03
SPIN-R	1.86	0.06
SPIN-L	1.22	0.22
CSPIN-R	1.17	0.24
CSPIN-L	0.72	0.47

Note-R-right, L-left, SIS-speech identification score, SPIN-speech in noise and CSPIN-contralateral SPIN.

It can be seen from Table 4.1.2 that there was overall group differences for speech identification scores for right ear and left ear. However, there was no significant difference between the two groups from Speech in Noise and Speech in Noise in the presence of contralateral noise except SIS scores in both ears.

Gender effect on Speech identification scores, Speech in Noise test and Speech in Noise test in the presence of contralateral noise.

To understand the significant differences in mean scores of the two genders within each group, Mann-Whitney test was administered to see the differences in SIS, SPIN and SPIN with contralateral noise scores and it is tabulated in Table 4.1.3.

Table 4.1.3.

Comparison of Speech identification scores, Speech in Noise test and Speech in Noise test in the presence of contralateral noise between males and females for each group.

	Middle aged		Younger	
	Z	Asymp. Sig. (2-tailed)	Z	Asymp. Sig. (2-tailed)
SIS-R	2.38	0.01	1.08	0.28
SIS-L	1.50	0.13	0.93	0.35
SPIN-R	1.09	0.27	0.73	0.47
SPIN-L	1.89	0.06	0.65	0.51
CSPIN-R	0.69	0.49	0.61	0.54
CSPIN-L	0.90	0.37	0.70	0.48

Note-SIS-speech identification score, SPIN-speech in noise and CSPIN-contralateral SPIN

It can be seen from Table 4.13 that in the middle aged group participants a significant difference was observed only for Speech identification scores in right ear and speech in noise test in the left ear between males and females. For rest of the parameters there was no difference between the males and females for the younger participants and the middle aged participants.

Further, to understand the significant differences for Speech identification scores, Speech in Noise test and Speech in Noise test in the presence of Contralateral noise within each gender for the two groups, Wilcoxon signed-ranks test was carried out. The results of the Wilcoxson signed rank test are given in Table 4.14.

Table 4.1.4

Comparison of Speech identification scores, Speech in Noise test and Speech in Noise test in the presence of Contralateral noise within each gender for the two groups.

	Females		**Males**	
	Z	Asymp. Sig. (2-tailed)	Z	Asymp. Sig. (2-tailed)
SIS-R	3.05	0.00	0.00	1.00
SIS-L	2.11	0.03	1.00	0.31
SPIN-R	0.26	0.80	2.27	0.02
SPIN-L	0.27	0.80	2.77	0.05
CSPIN-R	0.69	0.50	0.72	0.47
CSPIN-L	1.66	0.10	0.50	0.61

Note-SIS-speech identification score, SPIN-speech in noise and CSPIN-contralateral SPIN

It can be seen from Table 4.1.4 that within females group for the speech identification scores a significant difference was observed for the right and the left ear between younger and the older participants. Within male group, a significant difference was observed for speech identification in noise for right and left ear between the younger and the middle aged participants.

Ear effect on Speech identification scores, Speech in Noise test and Speech in Noise test in the presence of contralateral noise.

Comparison between the ears in both the groups was done using Wilcoxon signed-ranks test and the results are given in Table 4.1.5.

Table 4.1.5.

Comparison between right and left SIS and SPIN scores in all the groups.

		SISL – SISR	**SPIN-L – SPIN-R**	**CSPIN-L – CSPIN-R**
Females-middle age	Z	1.00	2.16	0.00
	Asymp. Sig. (2-tailed)	0.31	0.03	1.00
Males-middle age	Z	1.00	0.11	0.58
	Asymp. Sig. (2-tailed)	0.32	0.91	0.56
Females-younger age	Z	1.00	0.41	0.45
	Asymp. Sig. (2-tailed)	0.32	0.68	0.65
Males-younger age	Z	1.00	0.22	1.73
	Asymp. Sig. (2-tailed)	0.32	0.83	0.08

Note-SIS-speech identification score, SPIN-speech in noise and CSPIN-contralateral SPIN

From the table 4.1.5.we can note a significant difference between SPIN of right and left ear in middle aged females. However there was no significant difference between the ears in any conditions in the rest of the groups.

4.2 Transient evoked oto acoustic emissions (TEOAEs) and Contralateral suppression of TEOAEs (CTEOAEs).

Amplitudes of transient evoked oto-acoustic emissions (TEOAEs) and TEOAEs with contralateral for five frequencies (1000, 1414, 2000, 2828 & 4000 Hz) were calculated in the younger and middle aged groups for both ears. Then those amplitudes were subjected to analysis using descriptive statistics wherein mean and standard deviations were calculated for both the groups and it is tabulated in Table 4.2.1.and Table 4.2.1.

Table 4.2.1.

Mean and standard deviation of amplitude of TEOAEs of both the younger and middle aged groups.

			Mean (μV)			Std. Deviation		
	Groups		Females	Males	Total	Females	Males	Total
	Middle age	R	-6.84	-0.31	-3.83	2.96	7.42	6.23
		L	-6.11	-8.57	-7.24	2.92	6.50	4.85
	Younger	R	-3.71	-8.22	-5.80	5.15	2.31	4.58
TEOAEs-1000 Hz		L	-5.12	-7.81	-6.37	1.37	1.70	2.08
	Total	R	-5.28	-4.27	-4.81	4.35	6.68	5.45
		L	-5.62	-8.19	-6.80	2.24	4.55	3.66
	Middle age	R	-4.23	-3.10	-3.70	3.52	7.02	5.20
		L	-1.74	-6.07	-3.74	2.89	1.26	3.14
	Younger	R	-1.35	-7.01	-2.51	3.35	3.40	5.41
TEOAEs-		L	1.96	-7.28	-2.31	7.82	2.67	7.52

1414 Hz	Total	R	-1.43	-5.06	-3.11	4.39	5.64	5.24
		L	0.11	-6.67	-3.02	5.98	2.09	5.69
	Middle	R	-5.48	-5.15	-5.33	5.75	7.62	6.38
	age	L	-3.97	-8.67	-6.14	7.05	4.14	6.16
TEOAEs-	Younger	R	2.06	-3.12	-0.33	4.42	4.71	5.12
2000 Hz		L	1.44	-7.75	-2.80	8.41	2.57	7.80
	Total	R	-1.71	-4.13	-2.83	6.29	6.13	6.22
		L	-1.26	-8.21	-4.47	7.97	3.32	7.10
	Middle	R	-3.61	-7.68	-5.49	5.56	7.56	6.61
	age	L	-6.13	-9.77	-7.81	5.65	6.68	6.17
	Younger	R	-2.21	-4.55	-3.29	5.55	4.66	5.09
TEOAEs-		L	0.48	-5.71	-2.38	8.80	6.53	8.17
2828 Hz	Total	R	-2.91	-6.12	-4.39	5.39	6.21	5.89
		L	-2.82	-7.74	-5.09	7.89	6.64	7.62
	Middle	R	-3.98	-3.22	-3.63	5.46	12.81	9.13
	age	L	-4.90	-13.51	-8.88	6.63	5.21	7.30
TEOAEs-	Younger	R	-0.97	-9.67	-4.98	3.87	8.30	7.52
4000 Hz		L	2.75	-8.16	-2.28	8.35	4.60	8.70
	Total	R	-2.47	-6.44	-4.30	4.80	10.83	8.23
		L	-1.07	-10.84	-5.58	8.26	5.45	8.56

Note-R-right ear, L-left ear, and TEOAEs-Transient evoked otoacoustic emissions.

From the above Table 4.2.1. It can be observed that the TEOAEs amplitude of younger adults was greater than middle aged adults in all the frequencies in both the ears.

Table 4.2.2.

Mean and standard deviation of amplitudes of TEOAEs with contralateral noise (CTEOAEs) of both the younger and middle aged groups

Frequency			**Mean(µV)**			**Std. Deviation**		
	Groups		Females	Males	Total	Females	Males	Total
	Middle	R	-5.60	-3.01	-4.40	5.29	6.44	5.75
	age	L	-8.26	-4.00	-6.29	4.34	5.22	5.06
	Younger	R	-6.66	-9.18	-7.82	7.39	3.30	5.80
CTEOAEs		L	-4.21	-8.45	-6.16	1.84	1.80	2.81
1000 Hz	Total	R	-6.12	-6.10	-6.11	6.20	5.84	5.92
		L	-6.23	-6.22	-6.23	3.83	4.38	4.01
	Middle	R	-4.67	-2.95	-3.88	3.55	6.74	5.10
	age	L	-2.57	-3.43	-2.97	3.37	5.20	4.14
	Younger	R	-0.07	-8.32	-3.88	5.13	3.05	5.95
CTEOAEs		L	-2.04	-8.13	-4.85	5.53	3.16	5.43
1414 Hz	Total	R	-2.37	-5.63	-3.88	4.86	5.72	5.43
		L	2.31	5.78	3.91	4.41	4.78	4.82
	Middle	R	-6.07	-4.45	-5.32	5.61	7.50	6.32
	age	L	-1.05	-6.07	-3.37	8.22	5.96	7.44
CTEOAEs	Younger	R	0.68	-2.85	-0.95	4.92	5.97	5.51
2000 Hz		L	-1.07	-7.98	-4.26	5.25	3.86	5.73

	Total	R	-2.70	-3.65	-3.13	6.16	6.52	6.22
		L	-1.06	-7.02	-3.81	6.63	4.89	6.52
	Middle age	R	-4.80	-7.23	-5.92	5.26	7.80	6.38
		L	-6.96	-7.42	-7.17	6.79	7.60	6.87
	Younger	R	-3.08	-5.68	-4.28	6.84	3.88	5.61
CTEOAEs 2828 Hz		L	-3.36	-6.00	-4.58	4.93	6.89	5.81
	Total	R	-3.94	-6.46	-5.10	5.93	5.93	5.95
		L	-5.16	-6.71	-5.87	6.00	6.95	6.37
	Middle age	R	-4.43	-9.25	-6.65	5.44	8.35	7.08
		L	-5.87	-7.07	-6.42	6.87	6.30	6.37
	Younger	R	-1.65	-11.5	-6.22	4.57	6.38	7.33
CTEOAEs 4000 Hz		L	1.11	-8.07	-3.12	5.46	7.13	7.68
	Total	R	-3.04	-10.40	-6.44	5.03	7.18	7.06
		L	-2.38	-7.57	-4.78	6.98	6.44	7.01

Note-R-right ear, L-left ear and CTEOAEs- TEOAEs.in presence of contralateral noise.

From the above Table 4.2.2. it can be observed that the amplitude of TEOAEs with contralateral noise (CTEOAEs) of younger adults was lesser than the middle aged adults at 1000 Hz in both the ears and at 2000 Hz in left ear. The amplitude of TEOAEs with contralateral noise (CTEOAEs) of younger adults was greater than the middle aged adults at 1414 Hz, 2828 Hz, and 4000 Hz in both ears and at 2000 Hz in right ear.

Comparison of amplitudes of TEOAEs and CTEOAEs between groups.

To compare the amplitudes of TEOAEs and TEOAEs with contralateral noise of younger and middle aged adults, Non parametric Mann-Whitney test was carried out. The results of the Mann-Whitney U test are given in Table 4.2.3.

Table 4.2.3.

Comparison of amplitude of TEOAEs and TEOAEs with contralateral noise between younger and middle age groups.

Frequencies	**Z**		**Asymp. Sig. (2-tailed)**	
(Hz)	Right	Left	Right	Left
TEOAEs-1000	-0.53	-0.72	0.59	0.47
TEOAEs-1414	-0.64	-0.26	0.52	0.80
TEOAEs-2000	-2.03	-1.05	0.04	0.29
TEOAEs-2828	-0.97	-1.67	0.33	0.09
TEOAEs-4000	-0.13	-1.85	0.90	0.06
CTEOAEs1000	-1.44	-0.13	0.15	0.90
CTEOAEs-1414	-0.13	-1.31	0.90	0.19
CTEOAEs-2000	-1.77	-0.31	0.91	0.08
CTEOAEs-2828	-0.51	-1.00	0.61	0.32
CTEOAEs-4000	-0.31	-1.03	0.76	0.30

Note-R-right ear, L-left ear and TEOAEs-transient evoked oto acoustic emissions, CTEOAEs - TEOAEs in presence of contralateral noise.

From the above Table 4.2.3.it was found that there was significant difference in the amplitude of TEOAEs between the younger and middle aged groups at 2k Hz of right ear. However there was no significant difference between the two groups in rest of the parameters.

To compare the amplitude of TEOAEs with amplitude of TEOAEs with contralateral noise in both the groups Wilcoxon signed-ranks test was administered. The results of Wilcoxon signed-ranks test are provided in table 4.2.4.

Table.4.2.4.

Comparison between amplitude of TEOAEs and TEOAEs with contralateral noise in the middle and younger age groups.

Frequencies (Hertz-Hz)	**Middle age group**				**Younger group**			
	Females		Males		Femlaes		Males	
	Z	Asym p. Sig. (2-tailed)	Z	Asym p. Sig. (2-tailed)	Z	Asym p. Sig. (2-tailed)	Z	Asym p. Sig. (2-tailed)
CTEOAEs1000R - TEOAEs1000R	-0.08	0.93	-0.68	0.50	-0.51	0.61	-1.21	0.22
CTEOAEs1000L - TEOAEs1000L	-1.86	0.06	-1.36	0.17	-0.84	0.40	-1.16	0.25
CTEOAEs1414R - TEOAEs1414R	-0.42	0.67	-0.13	0.90	-1.78	0.07	-2.01	0.04
CTEOAEs1414L - TEOAEs1414L	-1.15	0.25	-0.94	0.34	-1.18	0.23	-1.99	0.05
CTEOAEs2000R - TEOAEs2000R	-0.84	0.40	-1.21	0.22	-2.37	0.01	-0.94	0.34
CTEOAEs2000L - TEOAEs2000L	-1.01	0.31	-1.15	0.25	-1.69	0.09	-0.31	0.75
CTEOAEs2828R - TEOAEs2828R	-1.86	0.06	-0.13	0.89	-1.38	0.16	-2.00	0.04
CTEOAEs2828L - TEOAEs2828L	-2.20	0.03	-0.10	0.92	-2.37	0.01	-1.46	0.14
CTEOAEs4000R - TEOAEs4000R	-1.52	0.13	-0.94	0.34	-2.20	0.03	-1.68	0.09

CTEOAEs4000L - TEOAEs4000L	-2.20	0.03	-1.78	0.07	-1.35	0.18	-0.31	0.75

Note- R-right ear, L-left ear and TEOAEs-transient evoked oto acoustic emissions, CTEOAEs - TEOAEs in presence of contralateral noise.

From the Table 4.2.4 it can be observed that there was significant difference between amplitude of TEOAEs and amplitude of TEOAEs with contralateral noise (CTEOAEs) at 2828 Hz and at 4K Hz of left ear in middle aged females, however no significant difference was noted in males at any frequencies. In younger females, there was significant difference between amplitude of TEOAEs and amplitude of TEOAEs with noise (CTEOAEs) at 2K Hz and 4K Hz of right ear and at 2828 Hz of left ear. In younger males the significant difference was seen at 1414 Hz of both right and left ears and at 2828 Hz of right ear.

Gender effect on amplitude of TEOAEs and TEOAEs with contralateral noise in the middle and younger age groups.

Mann-Whitney U test was administered to see the difference in amplitudes of TEOAEs and CTEOAEs between the genders in both the groups. The results of the Mann-Whitney U test are given in Table 4.2.5.

Table.4.2.5.

Comparison of amplitudes of TEOAEs and CTEOAEs between genders in both the groups

	Older group				Younger group			
	Z		Asymp. Sig. (2-tailed)		Z		Asymp. Sig. (2-tailed)	
	Right	Left	Right	Left	Right	Left	Right	Left
TEOAEs1000	-1.71	-1.14	0.09	0.25	-1.57	-2.43	0.11	0.01
TEOAEs1414	-0.71	-2.57	0.47	0.01	-2.71	-2.43	0.08	0.01
TEOAEs2000	0.00	-1.29	1.00	0.20	-1.57	-2.15	0.12	0.03
TEOAEs2828	-0.64	-0.71	0.52	0.47	-1.00	-1.07	0.31	0.28
TEOAEs4000	-0.14	-2.00	0.89	0.05	-1.57	-2.71	0.17	0.08
CTEOAEs1000	-0.86	-1.43	0.39	0.15	-0.71	-3.00	0.00	0.00
CTEOAEs1414	-0.71	-0.43	0.47	0.68	-2.29	-2.14	0.02	0.03
CTEOAEs2000	-0.50	-0.86	0.62	0.39	-1.00	-2.00	0.31	0.05
CTEOAEs2828	-0.43	-0.29	0.67	0.77	-1.57	-0.64	0.15	0.52
CTEOAEs4000R	-1.00	-0.43	0.31	0.67	-2.14	-2.29	0.03	0.02

Note- R-right ear, L-left ear and TEOAEs-transient evoked oto acoustic emissions, CTEOAEs - TEOAEs in presence of contralateral noise.

From the above Table 4.2.5.it can be observed that in the middle aged group there was significant difference between males and females in amplitudes TEOAEs at 1414Hz and at 4k Hz in the left ear. Among younger adults there was significant difference between genders in amplitudes of TEOAEs at 1K Hz of left ear, at 1414 Hz of both ears and at 2K Hz of right ear. Also significant difference was seen in amplitudes of TEOAEs with contralateral noise (CTEOAEs) at 1K Hz of right ear and left ear, at 1414 Hz of both right and left ears, at 2K Hz of left ear 4K Hz of both right and left ears in younger age group.

To compare the amplitudes of TEOAEs and amplitudes of TEOAEs with contralateral noise (CTEOAEs) within each gender for both the groups Mann-Whitney U test was administered. The results are provided in Table 4.2.6.

Table.4.2.6.
Comparison of amplitudes of TEOAEs and CTEOAEs within each gender for both the groups.

	Female group				**Male group**			
	Z		Asymp. Sig. (2-tailed)		Z		Asymp. Sig. (2-tailed)	
	Right	Left	Right	Left	Right	Left	Right	Left
TEOAEs1000	-1.09	-0.96	0.28	0.34	-1.76	-0.40	0.08	0.69
TEOAEs1414	-2.49	-0.70	0.01	0.48	-1.28	-1.28	0.20	0.20
TEOAEs2000	-2.49	-0.96	0.01	0.34	-0.48	-0.64	0.63	0.52
TEOAEs2828	-0.83	-1.34	0.40	0.18	-0.83	-1.12	0.38	0.26
TEOAEs4000	-1.34	-1.72	0.18	0.08	-0.64	-1.60	0.52	0.10
CTEOAEs1000	-0.32	-2.11	0.75	0.03	-1.92	-1.60	0.55	0.10
CTEOAEs1414	-1.86	-3.12	0.06	0.75	-1.44	-1.45	0.15	0.15
CTEOAEs2000	-2.15	-0.38	0.03	0.70	-0.48	-0.96	0.63	0.33
CTEOAEs2828	-1.15	-1.21	0.25	0.22	-0.48	-0.32	0.63	0.75
CTEOAEs4000R	-1.15	-1.85	0.25	0.06	-0.32	-0.40	0.75	0.69

Note- R-right ear, L-left ear and TEOAEs-transient evoked oto acoustic emissions, CTEOAEs - TEOAEs in presence of contralateral noise.

From the above table 4.2.6 it can be observed that in female group there was significant difference between younger and middle aged females in amplitude of TEOAEs at 1414 Hz and 2K Hz of right ear and in amplitudes of TEOAEs with contralateral noise at 1K Hz of left ear and at 2K Hz of right ear. However no significant difference was noted between younger and middle aged males in any parameters.

Ear effect in amplitudes of TEOAEs and TEOAEs with noise (CTEOAEs)

To compare the amplitudes of TEOAEs and CTEOAEs between ears Wilcoxon signed Rank test was administered. The results of Wilcoxon signed Rank test are tabulated in Table 4.2.7

Table 4.2.7.

Comparison of amplitudes of TEOAEs and contralateral TEOAEs between ears in both the groups.

Frequencies	**Middle age group**				**Younger group**			
(Hertz-Hz)	Females		Males		Femlaes		Males	
	Z	Asymp. Sig. (2-tailed)	Z	Asymp. Sig. (2-tailed)	Z	Asymp. Sig. (2-tailed)	Z	Asymp. Sig. (2-tailed)
TEOAEs1000L - TEOAEs1000R	-0.34	0.73	-1.36	0.173	-1.10	0.27	-0.10	0.92
TEOAEs1414L - TEOAEs1414R	-1.35	0.18	-0.94	0.34	0.00	1.00	-0.10	0.92
TEOAEs2000L - TEOAEs2000R	-0.76	0.45	-1.36	0.17	-0.51	0.61	-2.20	0.03
TEOAEs2828L - TEOAEs2828R	-1.35	0.18	-0.94	0.34	-1.18	0.24	-0.31	0.75

TEOAEs4000L - TEOAEs4000R	-0.51	0.61	-1.36	0.17	-1.52	0.13	-0.31	0.75
CTEOAEs1000 L- CTEOAEs1000 R	-0.84	0.40	-0.67	0.50	-0.84	0.40	-0.31	0.75
CTEOAEs1414 L- CTEOAEs1414 R	-1.52	0.13	-0.40	0.69	-0.68	0.50	-0.73	0.46
CTEOAEs2000 L- CTEOAEs2000 R	-1.18	0.24	-0.67	0.50	-0.76	0.45	-2.20	0.03
CTEOAEs2828 L- CTEOAEs2828 R	-1.18	0.24	-0.68	0.50	-0.68	0.50	-0.10	0.92
CTEOAEs4000 L- CTEOAEs4000 R	-0.84	0.40	-0.94	0.34	-1.87	0.06	-1.21	0.22

Note-R-right ear, L-left ear and TEOAEs-transient evoked oto acoustic emissions, CTEOAEs - TEOAEs in presence of contralateral noise.

From table 4.2.7 we can observe that there was significant difference between ears in amplitudes of TEOAEs at 2K Hz and amplitude of CTEOAEs at 2K Hz in younger males group. However no significant difference between ears was noted in any frequencies in any of the groups.

4.3 Speech evoked auditory brainstem responses. (cABR)

The amplitudes of fundamental frequency (F0), first formant (F1), second formant (F2) values and V peak latency of the responses for /da/ syllable of both the younger and middle aged groups were calculated. The mean grand average values of younger and middle age adults are given in figures 4.3.a, 4.3.b, 4.3.c and 4.3.d.

*Figure.4.3.a.*Mean grand average values of speech ABR responses in younger adults of right ear.

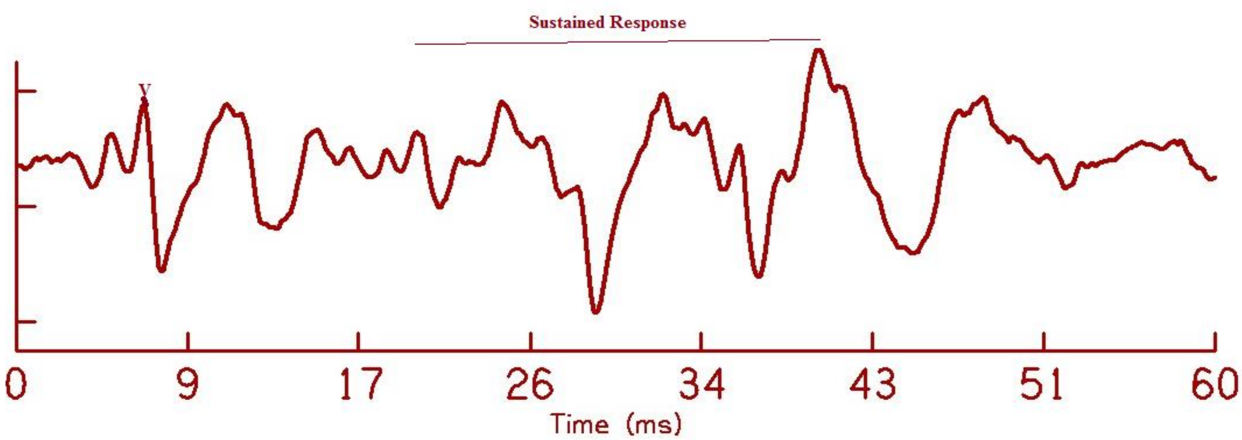


*Figure.4.3.b.*Mean grand average values of speech ABR responses in younger adults of left ear.

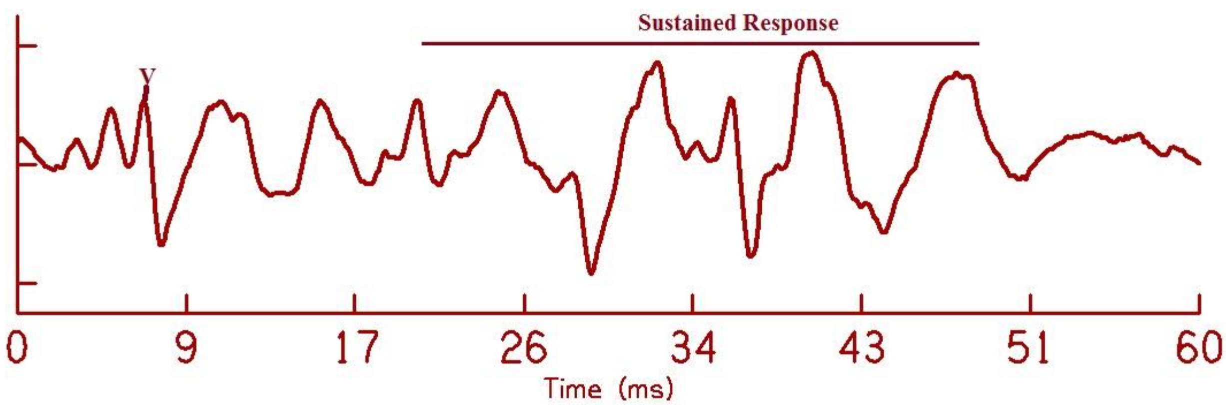


*Figure.4.3.c.*Mean grand average values of speech ABR responses in older adults of right ear.

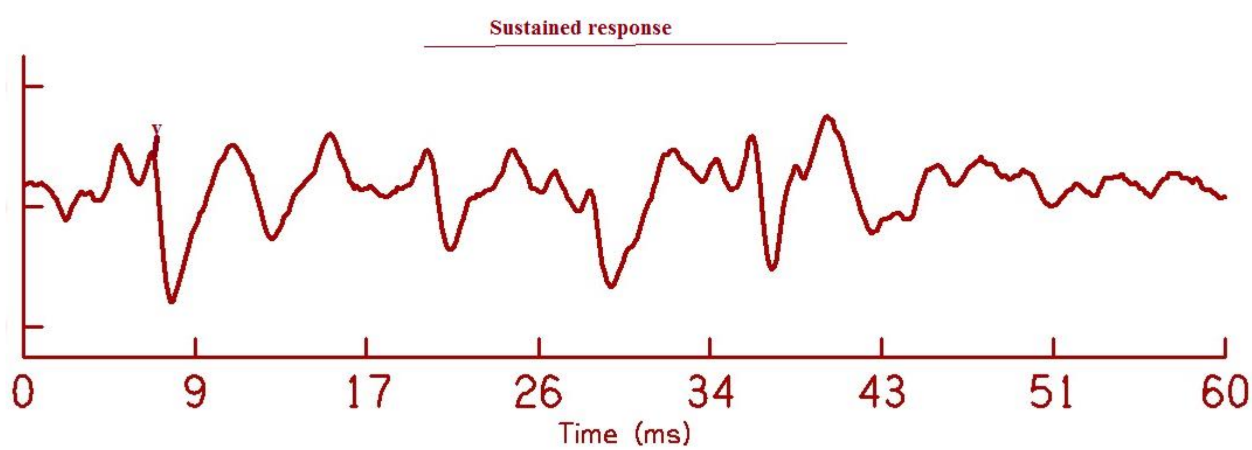
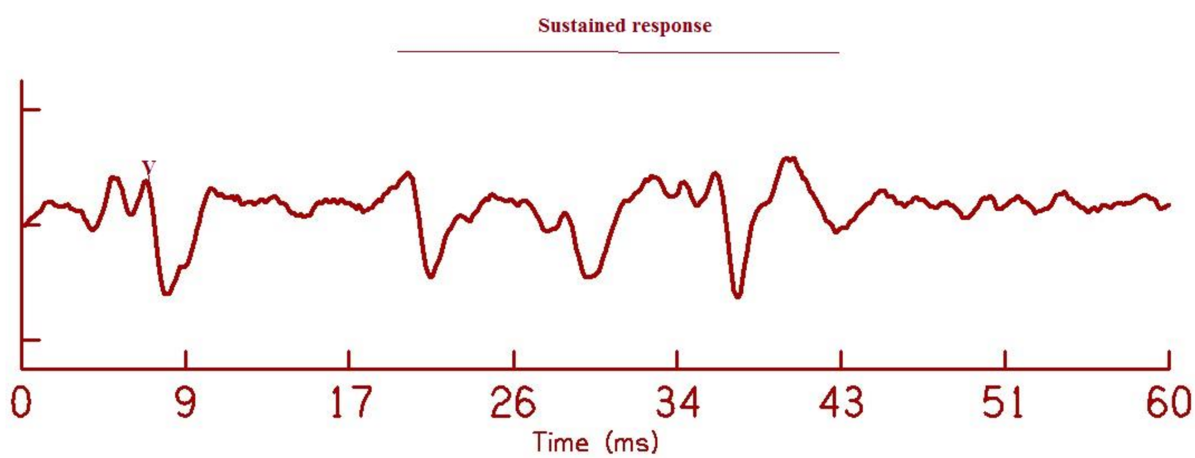


*Figure.4.3.d.*Mean grand average values of speech ABR responses in older adults of left ear.



Descriptive statistics was done to find the mean and standard deviation values of the amplitudes of F0, F1 F2 and V peak latencies of speech ABR responses for both the groups. The results are tabulated in Table 4.3.1.

Table 4.3.1.

Mean and standard deviation of amplitudes of ABR values of both the groups

	Gender	**Groups**	**Mean(µV)**		**Std. Deviation**	
			R	L	R	L
		Middle	8.71	5.33	2.02	1.14
	Female	Younger	12.92	15.95	10.78	13.93
		Total	10.82	10.64	7.77	10.98
		Middle	9.07	5.30	8.21	2.97
(F0)	Male	Younger	13.91	10.05	9.80	6.91
Amplitude		Total	11.49	7.67	8.98	5.64

of		Middle	8.87	5.31	5.49	2.08
fundamental	Total	Younger	13.38	13.22	9.91	11.24
frequency		Total	11.12	9.27	8.18	8.89
		Middle	0.91	0.78	0.26	0.28
	Female	Younger	1.38	1.32	0.23	0.39
		Total	1.14	1.05	0.34	0.43
		Middle	0.83	0.76	0.29	0.32
(F1)	Male	Younger	0.98	0.88	0.41	0.42
Amplitude		Total	0.90	0.82	0.34	0.36
of first		Middle	0.88	0.77	0.26	0.29
formant	Total	Younger	1.19	1.11	0.37	0.45
		Total	1.03	0.94	0.36	0.41

		Middle	0.36	0.28	0.08	0.07
	Female	Younger	0.54	0.54	0.12	0.16
		Total	0.45	0.41	0.14	0.18
		Middle	0.32	0.29	0.08	0.10
Am`plitude	Male	Younger	0.38	0.32	0.13	0.06
of second		Total	0.35	0.31	0.11	0.08
formant		Middle	0.34	0.29	0.08	0.09
(F2)	Total	Younger	0.47	0.44	0.15	0.16
		Total	0.41	0.36	0.13	0.15
		Middle	6.17	6.30	0.25	0.30

	Female	Younger	6.09	6.17	0.14	0.19
		Total	6.13	6.23	0.20	0.25
		Middle	6.11	6.42	0.24	0.28
Latency of	Male	Younger	6.26	6.38	0.28	0.27
V peak		Total	6.19	6.40	0.26	0.26
		Middle	6.15	6.36	0.24	0.29
	Total	Younger	6.17	6.27	0.23	0.25
		Total	6.16	6.31	0.23	0.26

Note-ABR-auditory brainstem response, V- fifth peak latency and F0, F1,F2 are amplitudes of speech ABR.

It can be seen from table 4.3.1 that the mean amplitude of cABR amplitudes F0, F1 and F2 were higher in younger group compared to middle aged group except in case of females where F2 amplitude of middle age females was slightly greater than younger females in both ears. The V peak latency was slightly more in middle aged females compared to younger females however in males V peak latency is slightly more in younger compared to middle aged individuals in right ear.

Comparison of amplitudes of F0,F1,F2 and V peak latency of speech ABR between middle and younger age groups.

To compare the amplitudes of fundamental frequency (F0), first formant (F1), second formant (F2) and V peak latency of the responses for /da/ syllable between the younger and middle aged groups Mann-Whitney U test was administered. The results are provided in Table 4.3.2.

Table 4.3.2.

Comparison of amplitudes and V peak latency of speech ABR between younger and middle age groups.

	Z	Asymp. Sig. (2-tailed)
F0-R	-1.15	0.25
F0-L	-2.33	0.02
F1-R	-2.02	0.04
F1-L	-1.85	0.06
F2-R	-2.23	0.03
F2-L	-2.90	0.00
V-R	-0.44	0.66
V-L	-0.75	0.45

Note-V- fifth peak latency and F0, F1,F2 are amplitudes of fundamental, first and second formants of speech ABR.

Results given in table 4.3.2 revealed that there was significant difference between the younger and middle aged group in the amplitude of F0 of left ear, F1 of right ear, F2 of right and left ears.

Gender effect on the amplitudes and latency of speech ABR responses.

To compare the amplitudes and V peak latency of speech ABR responses across gender within each group Mann-Whitney U test was administered. The results are tabulated in Table 4.3.3.

Table.4.3.3.

Comparison of amplitudes and V peak latency of speech ABR responses across gender within in each group.

	Middle age		Younger age	
	Z	Asymp. Sig. (2-tailed)	Z	Asymp. Sig. (2-tailed)
F0-R	-1.00	0.32	-0.14	0.89
F0-L	-0.29	0.77	-0.42	0.67
F1-R	-0.57	0.57	-2.00	0.05
F1-L	-0.43	0.67	-1.71	0.09
F2-R	-0.86	0.39	-2.14	0.03
F2-L	-0.14	0.89	-3.00	0.00
V-R	-0.58	0.56	-1.01	0.31
V-L	-0.94	0.35	-1.38	0.17

Note-R-right, L-left, V- fifth peak latency and F1, F2, F3 are amplitudes of fundamental, first and second formants of speech ABR.

From the above Table 4.3.3 it can be observed that there was significant difference between males and females in F1 amplitude of right ear, F2 amplitude of right and left ears in younger age group. However no significant difference was seen between males and females in middle age group in any of the parameters.

To compare amplitudes and V peak latency of speech ABR responses within gender across the groups Mann-Whitney U test was administered. Results are tabulated in Table 4.3.4.

Table 4.3.4.

Comparison of amplitudes and V peak latency of speech ABR responses within gender across the groups.

	Female		Male	
	Z	Asymp. Sig. (2-tailed)	Z	Asymp. Sig. (2-tailed)
F0-R	-0.32	0.75	-1.28	0.20
F0-L	-1.73	0.08	-1.60	0.11
F1-R	-2.37	0.02	-0.48	0.63
F1-L	-2.37	0.02	-0.32	0.75
F2-R	-2.49	0.01	-0.64	0.52
F2-L	-3.01	0.00	-1.28	0.20
V-R	-0.79	0.43	-1.13	0.26
V-L	-0.84	0.40	-0.33	0.74

Note-R-right, L-left, V- fifth peak latency and F1, F2, F3 are amplitudes of fundamental, first and second formants of speech ABR.

From the above Table 4.3.4 it can be observed that in females there was significant difference between younger and middle aged females in F1 and F2 amplitudes of right and left ears. In males there was no significant difference between younger and middle age group in any of the parameters.

Ear effect on amplitudes and V peak latency of speech ABR responses

Mann-Whitney test was administered to see the ear effect on amplitudes and V peak latency of speech ABR responses in both younger and middle aged group. Results are tabulated in Table 4.3.5.

Table 4.3.5

Table 4.3.5.Comparison of amplitudes and V peak latency of speech ABR responses between ears in younger and middle aged groups.

		F0 L- F0 R	F1 L- F1 R	F2 L- F2 R	Vl – Vr
Middle age-Females	Z	-2.20	-2.37	-1.61	-1.26
	Asymp. Sig. (2-tailed)	0.03	0.09	0.18	0.21
Middle age-Males	Z	-0.73	-0.73	-1.15	-2.21
	Asymp. Sig. (2-tailed)	0.46	0.46	0.25	0.03
Younger age-Females	Z	-1.18	-0.17	-0.51	-1.36
	Asymp. Sig. (2-tailed)	0.24	0.87	0.61	0.17
Younger age-Males	Z	-1.15	-0.73	-0.94	-1.51
	Asymp. Sig. (2-tailed)	0.25	0.46	0.34	0.13

Note- R-right, L-left,-fifth peak latency and F1, F2, F3 are amplitudes of fundamental, first and second formants of speech ABR.

From above given table 4.3.5. it can be noted that there was significant difference between ears in F0 amplitude of middle aged females and also significant difference was seen in V peak latency of speech ABR of middle aged males. However no significant difference was observed in younger age group in any of the parameters.

4.4. Correlation between SIS, SPIN, SPIN with noise scores, amplitude of TEOAEs, TEOAEs with noise, amplitudes and V peak latency of speech ABR responses in younger and middle age groups.

To know the correlation between SIS, SPIN, SPIN with noise scores, amplitude of TEOAEs, TEOAEs with noise, amplitudes and V peak latency of speech ABR responses in younger and middle age groups Non- parametric correlations were done. Spearman's correlation coefficients were calculated for all the responses.

Correlations in the middle age group.

Spearman's correlation coefficients were calculated to know the correlation between SIS, SPIN, SPIN with noise scores with amplitude of TEOAEs with contralateral noise in middle age group and they are tabulated in Table 4.4.1.

Table.4.4.1.

Correlation between SPIN, SPIN with contralateral noise scores with amplitudes of TEOAEs with contralateral noise in Middle age group.

		SPINR	**SPINL**	**CSPINR**	**CSPINL**
CTEOAEs1000-R	Correlation Coefficient	-0.33	-0.05	-0.62	-0.20
	Sig. (2-tailed)	0.27	0.86	0.02	0.52
CTEOAEs1000-L	Correlation Coefficient	-0.23	-0.14	-0.33	-0.35
	Sig. (2-tailed)	0.46	0.66	0.27	0.24
CTEOAEs1414-R	Correlation Coefficient	-0.52	-0.33	-0.49	-0.23
	Sig. (2-tailed)	0.07	0.27	0.09	0.44
CTEOAEs1414-L	Correlation Coefficient	0.10	0.27	-0.38	-0.22
	Sig. (2-tailed)	0.75	0.37	0.20	0.47
CTEOAEs2000-R	Correlation Coefficient	-0.06	-0.09	-0.56	-0.49
	Sig. (2-tailed)	0.84	0.76	0.05	0.09

CTEOAEs2000-L	Correlation Coefficient	0.23	0.59	-0.34	0.01
	Sig. (2-tailed)	0.44	0.03	0.25	0.97
CTEOAEs2828-R	Correlation Coefficient	0.40	0.36	-0.39	-0.27
	Sig. (2-tailed)	0.17	0.23	0.19	0.36
CTEOAEs2828-L	Correlation Coefficient	-0.06	0.13	-0.40	-0.17
	Sig. (2-tailed)	0.83	0.66	0.18	0.58
CTEOAEs4000-R	Correlation Coefficient	0.38	-0.44	-0.41	-0.20
	Sig. (2-tailed)	0.20	0.13	0.16	0.52
	Correlation Coefficient	0.40	0.66	-0.21	0.03
CTEOAEs4000-L	Sig. (2-tailed)	0.18	0.01	0.48	0.91

Note-R-right ear, L-left ear, CTEOAEs -TEOAEs in presence of contralateral noise, SPIN-speech in noise and CSPIN- SPIN with contralateral noise.

From the table 4.4.1. it can be noted that there was significant negative correlation between amplitude of CTEOAEs at 1K Hz of right ear with contralateral SPIN score of right ear and amplitude of CTEOAEs of 2k Hz of right ear with contralateral SPIN score of right ear. There was a positive correlation between amplitude of CTEOAEs at 2K Hz of left ear with SPIN score of left ear. Also there was significant positive correlation between CTEOAEs at 4K Hz of left ear with SPIN score of left ear.

Spearman’s correlation coefficients were calculated to know the correlation between SPIN, SPIN with noise score with amplitudes (F0, F1, and F2) and V peak latency of speech ABR. Results are tabulated in Table 4.4.2.

Table 4.4.2.

Correlation between SPIN, SPIN with contralateral noise scores with amplitudes and V peak latency of speech ABR in Middle age group.

		SPIN R	SPIN L	CSPIN R	CSPIN L
F0-R	Correlation Coefficient	0.10	0.03	0.08	0.15
	Sig. (2-tailed)	0.75	0.92	0.80	0.63
F0-L	Correlation Coefficient	0.2	0.03	-0.03	-0.01
	Sig. (2-tailed)	0.51	0.91	0.30	0.97
F1-R	Correlation Coefficient	-0.08	-0.23	0.56	0.12
	Sig. (2-tailed)	0.79	0.44	0.04	0.69
F1-L	Correlation Coefficient	-0.18	-0.29	0.53	0.31
	Sig. (2-tailed)	0.55	0.34	0.06	0.29
F2-R	Correlation Coefficient	0.61	0.44	0.47	0.13
	Sig. (2-tailed)	0.03	0.13	0.10	0.67
F2-L	Correlation Coefficient	0.19	-0.17	0.34	-0.12
	Sig. (2-tailed)	0.53	0.59	0.25	0.70
V-R	Correlation Coefficient	0.20	0.32	0.32	0.04
	Sig. (2-tailed)	0.51	0.29	0.28	0.87
V-L	Correlation Coefficient	0.24	0.36	0.18	-0.10
	Sig. (2-tailed)	0.42	0.22	0.56	0.72

Note-R-right, L-left, V-fifth peak latency and F1, F2, F3 are amplitudes of fundamental, first and second formants of speech ABR., SPIN-speech in noise and CSPIN- SPIN with contralateral noise.

From table 4.4.2 it can be observed that there was positive correlation between speech ABR F1 amplitude of right ear with SPIN score with contralateral noise of right ear and speech ABR F2 amplitude of right ear with SPIN score of right ear.

Correlations in the younger age group.

Spearman's correlation coefficients were calculated to know the correlation between SPIN, SPIN with noise score with amplitudes (F0, F1, and F2) and V peak latency of speech ABR for younger group. Results are tabulated in Table 4.4.3.

Table.4.4.3

Correlation between SPIN, SPIN with contralateral noise scores with amplitudes of TEOAEs with contralateral noise (CTEOAEs) in younger age group.

		SPIN R	**SPIN L**	**CSPIN R**	**CSPIN L**
CTEOAE1000-R	Correlation Coefficient	-0.08	0.33	-0.43	-0.03
	Sig. (2-tailed)	0.79	0.28	0.14	0.92
CTEOAE1000-L	Correlation Coefficient	0.10	-0.15	0.07	-0.27
	Sig. (2-tailed)	0.74	0.61	0.81	0.37
CTEOAE1414-R	Correlation Coefficient	-0.05	0.11	-0.02	-0.09
	Sig. (2-tailed)	0.87	0.71	0.94	0.78
CTEOAE1414-	Correlation Coefficient	0.17	0.02	-0.03	-0.35

L	Sig. (2-tailed)	0.57	0.94	0.92	0.24
CTEOAE2000-R	Correlation Coefficient	-0.05	0.43	-0.01	0.43
	Sig. (2-tailed)	0.88	0.14	0.97	0.14
CTEOAE2000-L	Correlation Coefficient	.039	.073	-.129	-.307
	Sig. (2-tailed)	0.90	0.81	0.67	0.31
CTEOAE2828-R	Correlation Coefficient	0.13	0.42	-0.40	-0.20
	Sig. (2-tailed)	0.68	0.01	0.17	0.52
CTEOAE2828-L	Correlation Coefficient	0.81	0.30	0.06	-0.05
	Sig. (2-tailed)	0.00	0.32	0.86	0.88
CTEOAE4000-R	Correlation Coefficient	0.30	0.26	0.07	0.04
	Sig. (2-tailed)	0.31	0.38	0.98	0.91
CTEOAE4000-L	Correlation Coefficient	0.12	0.04	-0.22	-0.32
	Sig. (2-tailed)	0.69	0.90	0.47	0.28

Note-R-right, L-left,-CTEOAEs -TEOAEs in presence of contralateral noise, SPIN-speech in noise and CSPIN- SPIN with contralateral noise.

From the above table 4.4.3 it can be noted that there was a significant positive correlation between amplitude of CTEOAEs of 2828 of left ear with SPIN scores of right ear and amplitude of CTEOAEs of 2828 of right ear with SPIN scores of left ear. However no significant correlation was seen in any of the parameters.

Spearman's correlation coefficients were calculated to know the correlation between SPIN, SPIN with noise scores with amplitudes (F0, F1, and F2) and V peak latency of speech ABR in younger age group. Results are tabulated in Table 4.4.4.

Table 4.4.4.

Correlation between SPIN, SPIN with contralateral noise scores with amplitudes and V peak latency of speech ABR in younger age group.

		SPIN R	**SPIN L**	**CSPIN R**	**CSPIN L**
F0-R	Correlation Coefficient	-0.52	-0.25	-0.02	0.11
	Sig. (2-tailed)	0.07	0.41	0.94	0.72
F0-L	Correlation Coefficient	-0.21	-0.18	0.12	-0.02
	Sig. (2-tailed)	0.49	0.56	0.70	0.95
F1-R	Correlation Coefficient	-0.50	-0.00	-0.25	-0.11
	Sig. (2-tailed)	0.08	0.99	0.42	0.72
F1-L	Correlation Coefficient	-0.19	-0.31	-0.11	-0.36
	Sig. (2-tailed)	0.54	0.29	0.71	0.22
F2-R	Correlation Coefficient	-0.34	0.21	0.25	0.08
	Sig. (2-tailed)	0.25	0.50	0.40	0.80
	Correlation	-0.08	0.06	0.25	-0.14

F2-L	Coefficient				
	Sig. (2-tailed)	0.78	0.83	0.41	0.64
V-R	Correlation Coefficient	0.02	-0.43	0.19	-0.08
	Sig. (2-tailed)	0.95	0.15	0.53	0.81
V-L	Correlation Coefficient	-0.10	-0.50	-0.05	-0.22
	Sig. (2-tailed)	0.75	0.08	0.86	0.45

Note-R-right, L-left, V-fifth peak latency and F1, F2, F3 are amplitudes of fundamental, first and second formants of speech ABR. SPIN-speech in noise and CSPIN- SPIN with contralateral noise.

From the above Table 4.4.4. it can be observed that there was no significant correlation between amplitudes of speech ABR with SPIN scores in both ears of younger age group.

Chapter-5

Discussion

In the present study the hypothesis was that the efferent system functioning start to decline at the middle age, if so then we can see that effect in reduction in contralateral suppression of TEOAEs, reduced SPIN scores and poor neural encoding of speech. In other terms we had hypothesized that there is significant correlation between speech ABR, Contralateral TEOAEs and SPIN scores. Ipsilateral and Contralateral SPIN test was done to check the speech perception abilities in noise. Then TEOAEs were recorded by presenting contralateral white noise and Speech ABR was recorded for syllable /da/ to study neural encoding of speech at the brainstem level for both younger and middle aged groups.

5.1. Findings in Speech identification scores (SIS) and Speech in Noise test (SPIN)

The mean speech identification scores, was significantly higher for younger group. However, no significant difference was observed for speech in noise and Speech in noise test with contralateral noise scores between middle aged individuals and younger participants.

The results are in support with the study by Barrenäs and Wikström (2000) wherein they measured speech recognition scores (SRS) using monosyllabic words presented in background noise on 1895 patients and reported that there was no effect of age on speech recognition in noise in people with normal hearing. Another study by Dubno (2015) also supports these results where they have studied age related decline in speech recognition in quiet and in presence of babble in middle age to older adults and reported that the word recognition decreases and it accelerates during 65 to 70 years.

In contrast to these results there is a study by Helfer and Vargo (2007) wherein they studied speech understanding ability and temporal processing in younger (19-22 years) and middle aged females (45-54 years) with normal hearing and found that the performance of middle aged subjects were significantly poorer than the younger participants in the presence of spatially coincident speech masker and that speech performance was strongly correlated with a temporal measure of gap detection.

5.2. Findings in Transient evoked Oto acoustic emissions (TEOAEs) and contralateral suppression of TEOAEs (CTEOAEs).

The amplitude of the Transient evoked otoacoustic emission with and without contralateral noise did not show a definite pattern of age related changes for the middle aged individuals. Overall results showed that there was no significant difference in amplitude of otoacoustic emission with and without contralateral noise between younger and middle aged group.

Otoacoustic emissions provide information about physiologic changes in auditory function associated with age. A substantial amount of research suggests that OAEs are produced by the motile activity of the outer hair cells (Mountain, 1980; Kim, 1984; Zenner, 1986; Brownell, 1990). Consequently, damage to outer hair cells due to excessive noise exposure, ototoxic drug treatment, or anoxia is associated with the reduction or disappearance of OAEs (Schmiedt, 1986; Lonsbury-Martin et al, 1993). If this is true in presbycusis, OAEs may be a noninvasive way of examining cochlear function as a function of age and degree of hearing loss.

Several investigators have reported abnormal OAEs associated with advancing age, suggesting that clinical OAE measurements may be more accurately interpreted using age adjusted normative values. Bonfils et al (1988) reported an age-related decline in the prevalence of transient-evoked otoacoustic emissions (TEOAEs) in age groups from less than 10 years to approximately 88 years. Responses were detected in all ears of subjects less than 60 years old. Above this age, the prevalence of TEOAE fell to 35 percent. In a similar study, TEOAEs were measured in 166 ears from individuals ranging in age from 6 weeks to 83 years (Collet et al, 1990). Results supported those of Bonfils et al (1988) in that the presence of TEOAEs decreased with advancing age. In both of these studies, however, older subjects had some degree of hearing loss, especially at the high frequencies. Therefore, the drop in TEOAE prevalence in the older age groups may have been caused largely by the hearing loss and not by age alone.

More recent investigations have attempted to examine the direct effect of age on distortion product otoacoustic emissions (DPOAEs) by better controlling for the confounding effects of peripheral hearing loss. Lonsbury-Martin et al (1991) measured DPOAEs in 60 ears from individuals ranging in age from 31 to 60 years. Their findings revealed a tendency for older ears to generate smaller amplitude DPOAEs, particularly at the highest frequencies. Although their mean data showed audiometric thresholds equal to or better than 20 dB HL for all groups, there was a large range in some groups. All subjects within the 30- to 40-year age group had audiometric thresholds less than or equal to 20 dB HL between 0 .25 and 8 kHz. In the older groups, however, 7 of 10 subjects had elevated thresholds at 3, 4, and/or 8 kHz. Thus, as with the earlier TEOAE studies, there was a significant age effect on audiometric thresholds.

This discrepancy in findings is likely attributed to methodologic issues relating to degree of peripheral hearing loss. In the present study, all subjects had 15 dB HL or better thresholds from 0.25 through 8 kHz. Although the majority of previous studies attempted to control for the confounding effect of hearing sensitivity, none were successful in recruiting a subject pool demonstrating normal hearing sensitivity at all frequencies without significant differences in thresholds between age groups. Since it is well established that hearing loss produces decreased OAE amplitude, which is systematically related to the degree of sensitivity loss (Bonfils et al, 1990; Kemp et al, 1990; Kimberley et al, 1994), it is likely that previously reported OAE amplitude differences may solely reflect reported variability in audiometric thresholds. Present results showed no significant age effect on audiometric thresholds among groups. Thus, when the degree of peripheral hearing loss is adequately controlled, there is no direct effect of age on otoacoustic measures.

The results of present study are in support with study by Quaranta, Debole, & Di Girolamo (2001) where they have studied TEOAEs with and without contralateral acoustical stimulation on 52 subjects (20-78 years) with normal hearing and found that amplitude of TEOAEs and the amount of suppression of TEOAEs decreased with age but it was not significant across the age.

Also study by Parthasarathy (2001) where TEOAEs in presence of contralateral noise were recorded in 30 subjects (20-79 years) with normal hearing and he found that the contralateral suppression is more for subjects between 20-59 years than those between 60-70 years of age which supports our study suggesting no difference between younger and middle age group in amplitudes of TEOAEs with contralateral noise.

5.3. Findings in Speech evoked auditory brainstem responses

Results of the wave V latency of speech evoked ABR did show a significant difference between the younger and the middle aged group.

Wave V of speech evoked ABR reflects a synchronized response to the onset of the stimulus and is similar to the wave V elicited by click stimulus (Russo, Nicole, Mussachia & Kraus, 2004.Previous studies utilizing click stimulus have reported an increase in latency with advancing age (Jerger & Hall, 1980; Burkard & Sims, 2001). The increase in latency of wave V elicited by click stimulus with advancing age has been reported in individuals with essentially normal hearing sensitivity. Jerger and Hall (1980) reported an increase in latency of wave V elicited by click stimulus of about 0.2 msec for a group of individuals with normal hearing sensitivity in the age range of 25 to 55 years. Rosenhall, Björkman, Pedersen and Kall (1985) also reported a significant increase in latency of wave V in a group of normal hearing individuals after the age of 50 years.

Literature in speech evoked ABR in aging population have just started to appear and these studies also indicated an increase in wave V latency elicited by speech stimulus in elderly population (Anderson, Clark, Han-Gyol-Yi & Kraus, 2011; Vander werff & Burns, 2011; Anderson, Clark, White-Schwoch & Kraus, 2012; Clark, Anderson, Hittner & Kraus, 2012). Anderson et al. (2011) reported a significant delay in onset responses elicited by speech stimulus for a group of participant with hearing threshold within 25 dB HL, in the age range of 60-73 years in their experiments carried out in two groups comparison. In another study, Anderson et al. (2012) utilizing the same /da/ stimulus reported a significant delay in latency of wave V in a group of participant in the age range of 60-67 years compared to the participants in the age range of 18 to 30 years in their 2 groups of comparison. Clark et al. (2012) utilizing a 170 msec /da/ stimulus, also reported a delay in latency of wave V of speech evoked ABR in a group of normal hearing individuals (45 to 65 years) compared to the younger counterparts with normal hearing in the age range of 18 to 30 years.

However, in the present study, a significant difference between younger and middle aged group was not observed for wave V latency. The difference in the results of the present study compared to earlier studied could be due to the age effect. That is in earlier studies utilizing speech evoked ABR most of their participants were above 60 years of age, whereas in the present study all the participants were below 60 years of age.

Results of sustained portion of Speech evoked ABR shows significantly higher F2 values for both the ears for younger group compared to the middle aged group. Speech

ABR also showed a significantly higher F0 and F1 values for the left ear of younger group compared to the middle aged group.

The present study showed a significant reduction in amplitude of F0 coded at the brainstem in participants above 55 years of age. Utilising the speech stimulus /da/, Anderson et al. (2012) also reported a significant reduction in amplitude of the F0 in elderly individuals having normal hearing compared to the younger participants. The present study supports the findings of Anderson et al. (2012).

In another study by Anderson et al. (2011), in a group of 28 participants with hearing loss, also reported a reduction in the amplitude of F0 with increase in age (age 60-73 years). In the present study all the participants had normal hearing threshold. Despite having normal hearing threshold the elderly participants showed a significant reduction in amplitude compared to the younger group.

In another study by Clinard, Tremblay and Krishnan (2010) utilizing different tone-burst stimulus to evoke the frequency following responses, and reported an age related decline in the encoding of the pitch of the stimulus frequencies at and slightly below 1000 Hz. Clinard et al (2010) also reported decline in encoding of F0 below 500 Hz and was well correlated with increase in difference limen for frequency, indicating a possible reduction in encoding of the pitch of the stimulus in elderly participants.

In contrast, Vander-werff and Burns (2011) also reported reduced amplitude of fundamental frequency and harmonic components. However, the participants in the study by Vander-werff and Burns had significant hearing loss in the high frequency. However, when mean values were adjusted to account for hearing thresholds F0 amplitude did not differ significantly in older participants compare to the younger counterparts.

The significant reduction in amplitude of F0, F1 and F2 in participants in the age range of 40-60 years could be due to reduced phase locking ability in these individuals. The reduction in encoding of F0, F1 and F2 could also be due to the changes in neural synchrony of the peripheral auditory nerves (Clinard et al. 2010). This disrupted neural synchrony may arise due to age related changes in the metabolic activity of the cochlea (Mills et al. 2006) or due to reduction in the auditory nuclei (Mills et al.2006). There also might be an age related change in the capacitance of the inner hair cells or there might also be a possibility of damage to the synapse between the inner hair cells and the auditory nerve (Moser et al. 2006). The age related changes in the capacitance of the inner hair cells or the synapse between the inner hair cells are important for the phase locking (Moser et al.2006). Such changes might result in reduction in the amplitude of the encoding of the F0, F1 and F2 in middle aged individuals compared to younger participants.

As it can be noted that only the sustained responses that is amplitude of F0, F1 and F2 were affected in middle aged individuals and wave latency was almost equal to the younger participants. It has been suggested that the transient response and frequency following responses elicited by speech stimuli reflect two different neural mechanisms within the brainstem (Akhoun et al. 2008). Probable neural mechanism which is responsible for generations of transient response are lesser in number or affected more with age compared to the mechanism responsible for generation of sustain responses. This might have resulted in differential affect on both the transient and sustained response.

The evidence for a different site of generation of the transient versus sustained responses also comes from the effect of noise or higher repetition rate on speech evoked ABR. Cunningham et al. (2001) and Russo et al., (2004) reported that the background noise affects the latency of the onset responses more than the latency of the frequency following responses. Furthermore, increasing the repetition rate of the stimuli selectively affects the latency of the onset responses and does not affect the latency of the sustained responses (Krizman, Skoe & Kraus, 2010). In the present study also, the sustained responses were affected whereas the transient responses were not affected.

5.4. Correlation between SPIN, SPIN with contralateral noise, contralateral suppression of TEOAEs and speech ABR.

Both for the young individual group and middle aged there was no definite pattern of any correlation between different tests administered. Only at few frequencies OAE showed some correlations with other tests, also SPIN showed some correlation with some other tests. But at large there was no correlation between the different tests.

These results suggest that the contralateral suppression of TEOAEs is correlated with speech processing in background noise at higher frequency i.e., above 2K Hz which is in support with study by Kim , Frisina and Robert Frisina (2006) where they have found significant correlations between speech perception in noise and degree of contralateral suppression of DPOAEs in normal hearing young and older adults. Another study by Yilmaz et al (2007)also support the above findings where they found decrease in speech in noise test scores with reduced suppression in contralateral TEOAEs with increase in age. This is due to the age related functional decline in the MOC efferent system.

In the middle age group there was positive correlation between speech ABR F1 amplitude of right ear with SPIN score with contralateral noise of right ear and speech ABR F2 amplitude of right ear with SPIN score of right ear but it was not seen younger adults. This indicate that in middle age group the speech performance in noise is correlated with encoding of speech sounds at F1 and F2 formants frequency regions but not at fundamental frequency which is in contrast with results obtained by Anderson, Parbery-Clark, Yi & Kraus, (2011) wherein they found reduction in response magnitude and reduced neural representation at the fundamental frequency (F0) of the speech stimulus in the group which had poor SIN (speech perception in noise) scores.

The difference in results of the present study could be due to the different subjects age group taken in different studies. Most of the studies have taken subjects above 60 years also, whereas all the participants in the present study were below 60 years of age.

The difference could also be due to the fact that after 60 years of age hearing loss is a confounding factor, affecting the various test results. In the present study all the participants had hearing threshold below 15 dBHL for all the frequencies.

Chapter-6

Summary and Conclusions

Anatomical and physiological changes in the auditory system with the age has resulted in poor performance in many auditory tasks .One among them is speech understanding in the presence of noise which is reported to be poorer in normal hearing older adults compared to normal hearing younger adults. Recent studies suggest that the central auditory processing skills start degrading at the middle age. MOC efferent system plays an important role in speech perception in noise which can be studied using SPIN and contralateral suppression of TEOAEs. It has also been studied that there is a crucial role of neural speech encoding at the brainstem level for successful perception of speech in noise which can be studied using speech ABR. Hence the present study was conducted with the aim of finding out a correlation between speech in noise perception, auditory efferent system functioning and speech encoding at the brainstem in middle aged individuals.

Two groups consisting of 15 younger (age range, 18-30 years) and 15 middle aged adults (age range, 40-60 years), 8 females and 7 males in each group participated in the study. After confirming normal hearing sensitivity with pure tone and speech audiometry, immittance and oto acoustic emissions evaluations, speech evoked auditory brainstem responses, speech in noise test (SPIN) and SPIN with contralateral noise tests were carried out in both ears using recorded phonetically balanced words from PB word list in kannada (Ramya & Yathiraj 2015) for both the groups.

Speech identification scores and SPIN test scores with and without contralateral noise, amplitude of TEOAEs and TEOAEs with contralateral noise were calculated. In speech evoked ABR, latency of wave V and amplitude of sustained responses (F0, F1 & F2) were calculated for both the groups.

The data obtained were initially checked for the normality and it was observed that the data did not follow normal distribution curve, hence non parametric test was applied for the data. The results of the study showed following results:

Speech identification scores, Speech in Noise and Speech in Noise with contralateral noise

Mann Whitney U test results showed a significant difference between younger and middle age group only in SIS scores in both ears and not in SPIN tests. Also no significant difference between males and females was seen in SIS, SPIN and SPIN with contralateral noise in both ears except SIS score in right ear. Wilcoxon signed-ranks test revealed a significant difference between SPIN of right and left ear in middle aged females and not in other groups.

Transient evoked Otoacoustic emission

Mann Whitney U test revealed significant difference in the amplitude of TEOAEs between the younger and middle aged groups at 2k Hz of right ear and no difference was noted in rest of the parameters. Comparison between amplitude of TEOAEs and TEOAEs with contralateral noise in the middle and younger age group revealed significant difference at 2828 Hz and at 4K Hz of left ear in middle aged females, at 2K Hz and 4K Hz of right ear and at 2828 Hz of left ear in younger females and at 1414 Hz of both right and left ears and at 2828 Hz of right ear in younger males whereas no significant difference was observed in middle aged males. Gender effect was also checked using Mann Whitney U test which showed significant difference between males and females in amplitudes TEOAEs at 1414Hz and at 4k Hz in the left ear in middle age group, at 1K Hz of left ear, at 1414 Hz of both ears and at 2K Hz of right ear in younger age group.

In amplitudes of TEOAEs with contralateral noise (CTEOAEs) significant difference was seen between genders at 1K Hz of right ear and left ear, at 1414 Hz of both right and left ears, at 2K Hz of left ear 4K Hz of both right and left ears in younger age group. Within each gender comparison for amplitudes of TEOAEs and CTEOAEs for both the groups done using Mann-Whitney U test showed significant difference between younger and middle aged females in amplitude of TEOAEs at 1414 Hz and 2K Hz of right ear and in amplitudes of TEOAEs with contralateral noise at 1K Hz of left ear and at 2K Hz of right ear. No difference was noted in male group. Wilcoxon signed-ranks test to check the ear effect revealed significant difference between ears in amplitudes of TEOAEs at 2K Hz and amplitude of CTEOAEs at 2K Hz in only younger males group.

Speech evoked auditory brainstem responses:

Mann-Whitney U test was done to compare the amplitudes of fundamental frequency (F0), first formant (F1), second formant (F2) and V peak latency of the responses for /da/ syllable between the younger and middle aged groups which showed significant difference between the younger and middle aged group in the amplitude of F1 of left ear, F2 of right ear, F3 of right and left ears. Gender effect was evaluated using Mann-Whitney U test which showed significant difference between males and females in F1 amplitude of right ear, F2 amplitude of right and left ears in younger age group. However no significant difference was seen between males and females in middle age group in any of the parameters. In females there was significant difference between younger and middle aged females in F1 and F2 amplitudes of right and left ears whereas no difference were seen among males. Mann-Whitney test was administered to see the ear effect significant difference between ears in F0 amplitude of middle aged females and also significant difference was seen in V peak latency of speech ABR of middle aged males. However no significant difference was observed in younger age group in any of the parameters.

Correlation between different test findings in young and middle aged group

Spearman's correlation coefficients were calculated to know the correlation between SIS, SPIN, SPIN with noise scores, amplitude of TEOAEs, TEOAEs with noise, amplitudes and V peak latency of speech ABR responses in younger and middle age groups which revealed significant negative correlation between amplitude of CTEOAEs at 1K Hz of right ear with contralateral SPIN score of right ear and amplitude of CTEOAEs of 2k Hz of right ear with contralateral SPIN score of right ear. There was a positive correlation between amplitude of CTEOAEs at 2K Hz of left ear with SPIN score of left ear. Also there was significant positive correlation between CTEOAEs at 4K Hz of left ear with SPIN score of left ear in middle age group. A positive correlation between speech ABR F1 amplitude of right ear with SPIN score with contralateral noise of right ear and speech ABR F2 amplitude of right ear with SPIN score of right ear in the middle age group.

In younger age group there was a significant positive correlation between amplitude of CTEOAEs of 2828 of left ear with SPIN scores of right ear and amplitude of CTEOAEs of 2828 of right ear with SPIN scores of left ear. Also there was no significant correlation between amplitudes of speech ABR with SPIN scores in both ears of younger age group.

Conclusions

The findings of this study indicate that there is an aging effect on the different tests administered on middle aged individuals. Transient evoked otoacoustic emissions and few parameters of speech evoked ABR, Speech identification scores and speech identification scores in noise shows an aging effect in middle aged individuals. The results of the study indicate that certain audiological test shows an age effect in the middle aged individuals itself. However, the results of the study failed to show any definite correlation between the different tests findings, which implies that certain auditory structures might start to degenerate faster compared to the other auditory structures. To conclude, the effect of aging on different audiological tests might start in the middle age itself with certain tests findings showing more poor results compared to few other audiological tests.

Implications of the study:

- ❖ The study can be utilised to study the changes in various auditory structures in middle aged individuals.
- ❖ This knowledge could lead to objective diagnostic tests as well as techniques to determine appropriate intervention strategies in middle aged individuals.
- ❖ The data obtained helps us to understand how the different auditory structures decline with aging.
- ❖ It highlights the necessity of further studies in different clinical populations.

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