DOES EAR ADVANTAGE CHANGES WITH AGE?

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A dissertation submitted in part fulfillment for the degree of

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CERTIFICATE

This is to certify that this Dissertation entitled **"DOES EAR ADVANTAGE CHANGES WITH** AGE?" is a bonafide work in part fulfillment for the Master's degree (Audiology) of the student **Registration No : A0490014** This has been carried under the guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any diploma or degree.

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CERTIFICATE

This is to certify that this Dissertation entitled **"DOES EAR ADVANTAGE CHANGES WITH AGE?"** has been prepared under my supervision and guidance. It is also certified that this Dissertation has not been submitted earlier to any other University for the award of any Diploma or Degree.

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DECLARATION

I hereby declare that this dissertation entitled **"DOES EAR ADVANTAGE CHANGES WITH AGE?**" is the result of my own study and has not been submitted earlier to any other University for that award of any Degree or Diploma.

Mysore
May 2006

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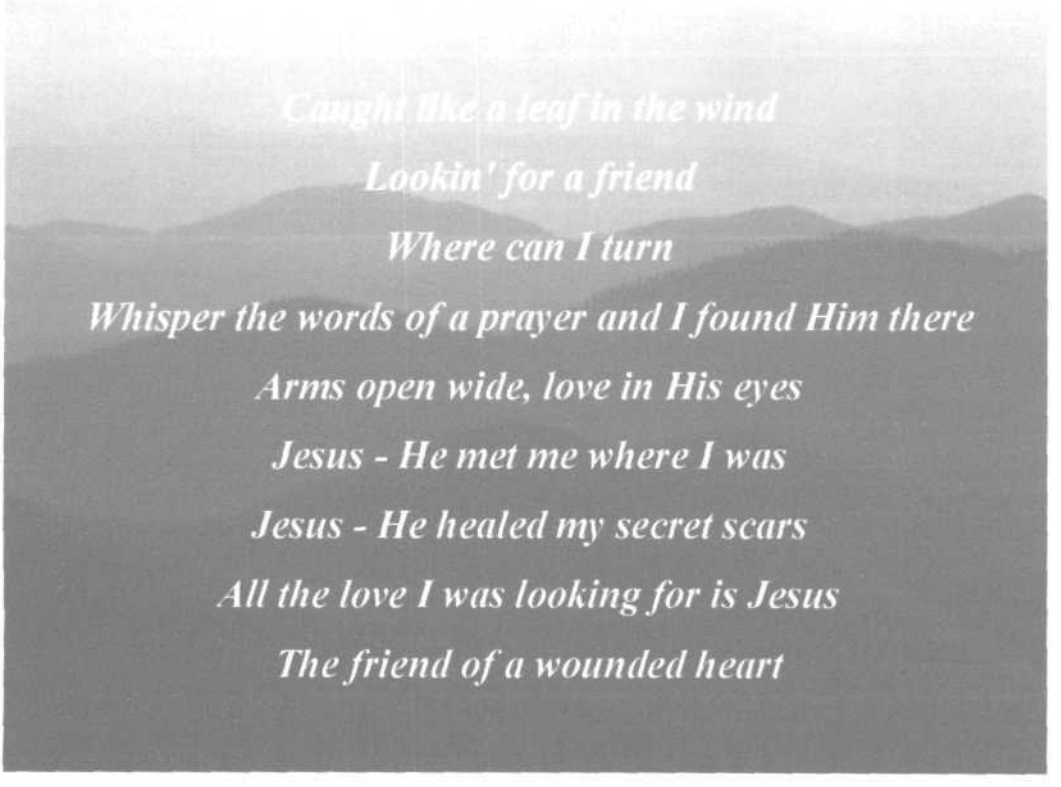
Caught like a leaf in the wind
Lookin' for a friend
Where can I turn
Whisper the words of a prayer and I found Him there
Arms open wide, love in His eyes
Jesus - He met me where I was
Jesus - He healed my secret scars
All the love I was looking for is Jesus
The friend of a wounded heart

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'The best way to learn is to learn from the best"

Animesh sir	*I admire you for your knowledge and potentiality of doing things quicker. Thank you Sir, for guiding me.*
Prof. Jayaram	*My sincere thanks to Prof. M. Jayaram for permitting me to carry out the study.*
Asha mam	*the joys of learning only comes from you for u make things simply wonderful to know.*
Rajalakshmi mam	*u were a sweet teacher and a true mentor, thanks mam*
Vanaja mam and Manjula mam	*Im fortunate that I had teachers as wonderful as you are.*
Dathu sir ,Binoy sir, Ann mam, Pallavi mam	*thanks for building my basics in speech and hearing.*
Sandip sir,	*A kind gesture from u all at the time of need really made a difference. Thank ufor Ur generous spirit.*
Hari	*thanks for helping me in the department.*
Mamtha mam	*we have something common I'll miss those chat sessions and thanks for helping me whenever I needed.*
My seniors	*jicy chechi, aryappa ,biny chechi,gannu,vathu and rampo, thanks a lot for the lessons I learned from u all.*
Ashly, Sujita and Divya	*your timely help will be remembered always.*

A family is a bond that we cherish forever..... love & laughter, fun fights& special memories...that we carry in our heart always, no matter where we go.

Appa	*In just the right ways at just the right time, U does just the right thing.*
And the glory of children is their father. Proverbs 17:6	*I will be always Ur little gal*
Amma	*Tears of pain, joy, pride, love. Tears that nurtured me every step of the way.*
	Thank you ma. I love you so much

Rupa	*We feel each others pain and we share each others joy-* *I thank god for giving me the gift ofu……U r one in a million.*
Alby chettan n amma	*I'm very glad that we are "family". Thanks for loving me so much.*
All	*U means a lot to me .1 love u so much. Your smile makes my day*

I believe in friends and the healing that comes from laughter, tears and stories Shared.

I believe in the wisdom that can be found in having fun and the bonds that are formed of trust and honesty.

I believe in the strength of one hand holding another through times of trouble and the miracles of perfectly timed hugs and smiles.

I believe in friendship like our's.

Jinu, Neeta, Nerin, Vinu, Dipu, Sibin, Ammu	***I'd*** *like to be the sort of friend that you have been to me. I'd like to be the help that you've been always glad to be; I'd like to mean as much to you each minute of the day, as you have meant. Thanks for always being there 4me.*
Suresh	*Absence makes the heart grow fonder. We each take different paths in life, but no matter where we go, we take a little of each other, everywhere.*
Kunal ,Phaneth	*even though being far from me u both always stood beside me . I treasure Ur friend ship.*
Kaushal ,sudip *and* ***orin***	*u made my life in AIISH easy . U are my fren in deed. Being with me for the past 5 years u know me well sorry for those little pranks.*
Dino, neenu, swats, grace, lida, sannu, binto	*can't tell u how much I miss u guys it was great to b with u all as a classmate. Our friendship totally rules.*
Mani	*"Time isn't what makes a friendship last...It's love and devotion that keeps the tie between souls. ""How lucky I am to have known someone who was so hard to say goodbye to..*
Anu	*the fun we had was awesome; gona miss u*
Vidya	*Shared moment's r never forgotten. I know we share the joy of being together. Thanks for listening to me and for the Unfavorable support. Will miss u so much.*

Minakshi	*Disco diva, I love your company .we understand each other so well. Thanks for always being there through the good and the bad.*
Rims	*Nobody appreciates my styles like u do I mean Ur d only one. Thanks baby.*
Sharda	*my partner ur sweet.*
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Rachu	*will miss ur health dialogues.*
Vedha, powlin	*will miss u both.* ***Vedha*** *especially your bad words n Iove2wards KAU*
Deepa	*u are like my sis always needs push from me.*
Rani	*My ex roomie it was fun with u, will miss u.*
Shiva	*Ur timely help and care helped me to survive in AIISH.u were there whenever I needed help.*
Suji baby	*I will really miss the fights we had. Thanks for being concerned about me.*
Raj	*Ur simply great. I enjoy being with u.n u can approach me any time for life confusions as u know I am good in what.*
Peelu	*will miss u n the fun we had. We shud continue our research wherever we go.*
Nikku	*"You'll always be one among my best friends, you know too much!"*

Myclassmates, *Noor, Prawin, Babs, SujitRaj, Shiva, Sudip, KaushalRachu, Minu, Rims, Bindu, Sharda, Sumi,& Vidya supporting and understanding are the words I would like to give to them. Am happy I had such wonderful classmates.*

Towi n team Mangalore, Neha[2], Maria, Neerja, KrupaRranju, Karuna, Supriya, Indu, & Priyanka u all been such schweet juniors for me will missya

Thankfulness is woven from the delicate threads of sharing
May the happiness u shared in my life return to u
In the same special way you offered it.

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INTRODUCTION

The longer we live, the more likely we will be adversely affected by the degenerative effects of aging. Evidence suggesting that aging refers to the decline of hearing associated with various types of auditory system dysfunction, (peripheral and central). Changes accompanies aging have been reported widely.

Such as

(1) The structural pathology of the aging ear, causes ranging from biochemical factors and metabolic changes

(2) The central nervous system based auditory processing/comprehension problems seen among many aging persons and

(3) Social and psychological problems facing the elderly individual with presbycusis

Changes in auditory system which accompanies aging are called as "presbycusis" the term 'presby' means elder, the word "presbycusis" literally means the acuity of the elder.

Most early studies consisted to observations relating to changes in hearing level in accordance with increasing age. With advances in technology, more detailed histopathological studies proved that the areas which might be affected more would be cochlea, the spiral ganglion, the brainstem auditory pathways, and the auditory cortex. (Willot, 1991)

The normal auditory system is characterized by at least one functional asymmetry. The two hemispheres of the brain appear to be uniquely specialized for

different aspects of auditory processing. One consequence of this hemispheric specialization is that the right ear enjoys a slight advantage over the left when exposed to acoustic stimuli. This preference of one part of the body over the other part is known as laterality. (C. Porac and S. Coren, 1978).This asymmetry is observed in the auditory system also. (Willot, 1991)

It has been reported that the right ear got better thresholds than that of left ear when compared the pure tone thresholdsof both the ears. (Chung, Mason, Gannon, & Wilson, 1983., Mc Fadden, 1993). When used different tests assessing auditory systems found with the same results with otoacoustic emissions, auditory brainstem responses, latelatency potencials, and central audtitory processing tests. In peripheral level OAE amplitudes indicated that right ear amplitudes are higher than left ear ampltiudes in normal hearing indivuals. (Sherif F. Tadros, susan T. Frisinia, Frances Mapes, SungHee kim, Robert Frisinia, and Robert.D.Frisinia, 2005., Bilger etal, 1990., Chung et al, 1983., Mc Fadden,1993). In brainstem potentials, the study by Sininger, Cone, and Abdala, in 1998 reported right ear latencies to be better than left ear latencies. Study done by Teri James Bellis, Trent Nicol and Nina Kraus in 2000 confirmed in cortical level also there is a right ear advantage that is the right latencies are shorter than the left latencies. These all studies showed that there is a right ear advantage in different levels of auditory system.

Where in study by Frisinia S.T., Mapes.F, Kim.S, Frisinia D.R, Frisinia RD, in 2005 by means of transient evoked otoacoustic emissions found that left ear amplitudes are better than right ear amplitudes in individuals with age related sloping

hearing loss. It indicates that the peripheral right ear advantage is lost with age related sloping hearing loss.

As there is a change in laterality at peripheral level with age related hearing loss individuals, it evokes the interest to understand the changes in the other levels of the auditory system with aging and age related sloping hearing loss. And also to analyze whether these changes are due to aging or because of the presence of peripheral hearing loss.

Thus this study was undertaken to evaluate whether there is any change in laterality of auditory system across the ages, and if there is a change we need to know at what age and at the level at such changes in the auditory system takes place. And also to observe the age related deterioration in the performance of auditory perception across the ages.

Need of the study

- It is reported in literature that aging causes poor performance in auditory system as there is lack of literature so it is necessary to see across the ages in what extent the deterioration can take place.
- Study by Frisinia etal (2005) observed altered laterality at peripheral level in subjects with age related sloping hearing loss. Hence, it is essential to know whether such changes occur only in individuals with hearing loss or the individuals without such significant peripheral hearing loss.

- It is necessary to see whether the change in laterality is purely peripheral so, need to be assessed at different levels of auditory systems in presbycusis subjects.
- There is a need to identify appropriate test to administer to know about ear advantage. So that we might know the level at which physiological changes occur.

Aim of the study

Thus the present study is taken up to investigate :

- Whether the different levels of the auditory system functions similar through out the age.
- Whether there is any change in laterality across the ages.
- If there is a change in laterality, at what level the physiological changes takes place.
- What is the age at which one can expect such changes.

REVIEW

The fact is we are an aging society. Hearing loss is a common disorder associated with aging and about 30-35 percentages of adults aged 65 years and above have a hearing loss. It is estimated that 40-50 percent of people 75 and older have a hearing loss. (National Institute of Deafness and other Communication Disorders, 1997).

Age related declines in auditory functions have been reported widely. The aging process affects both the peripheral as well as central auditory systems. Histopathological studies have shown age related changes in the cochlea, major brainstem nuclei and auditory cortex. The information gathered has been mentioned in different headings.

Affect of aging in peripheral level

Jerger (1973) reported that aging process produces systematic changes in each of the two critical dimensions of hearing impairment –loss in threshold sensitivity and the loss in the ability to understand suprathreshold speech.

Study done by James Jerger, Susan Jerger, Terrey Oliver and Francis Pirozzolo in 1989 evaluated speech understanding of elderly persons in the age range from 51 to 91 years. They concluded that speech understanding declines progressively with age.

Abdala, Carolina, Sininger and Yuonnes(1996) by means of their research in otoacoustic emissions found that OAE is a good tool to monitor age related changes in the cochlear level. The study found that there is decrease in OAE amplitude with increasing age.

In the elderly group of 58-76 years, TEOAE and DOPAE were done to evaluate the cochlear changes with aging. Result showed that there is significant decrease in amplitude as the age progresses (Frisnia etal, 2005).

As it's already been stated that there would be age related charges in peripheral level, it is necessary to use auditory evoked potentials as a tool to evaluate such changes in elderly at the higher levels.

Affect on brainstem level

Study carried out by Chu (1985) using auditory brainstem responses indicated that in older adults without hearing loss the absolute latencies were delayed compared to young individuals.

Maurizi, M., Ottaaviani, F., & Bambini, M. (1982) found that the subjects with sensori neural hearing loss and elderly group both showed deterioration in latencies for Auditory Brainstem responses.

A comparative study done by Mamtha (2003) reported that age related sensory neural hearing loss subjects and elderly subjects without hearing loss both had latency shift. The latency shift was more in the sensory neural hearing loss group.

Affect on cortical level

The effects of age on late component (N_{100}, P_{200}, N_{200} and P_{300}) were investigated in 50 normal subjects (18 to 70 years of age). Results showed that there is an age related change in latency. (Bahramai, Gordon, Lagopoulos, & Lim, 1999., Cranford & Martin, 1991)

Affect on Central processing level

Significant increase in longevity and the concomitant growth of the older population has intensified our need to understand the impact of aging on complex auditory processing.

Martin and Cranford (1991) evaluated binaural processing in elderly and observed that the dichotic digits recognition task scores deteriorated with aging.

Study done to evaluate the effects of aging on binaural and spatial hearing, reported that the ability of older listeners to localize sound sources, to obtain a gain in speech intelligibility in noise when speech and noise are separated, to improve the detection of signals in noise by using binaural cues, and to discriminate inter aural difference in time and intensity, decline with increasing age. (Janet, Koehnke & Joan M. Besing, 2001).

Two aspects of age related declines in auditory temporal processing may contribute to the difficulties that older adults have perceiving speech in everyday listening situations: ability to code the temporal properties of the envelope, including cues to phonemic contrasts.

According to Bruce, Schneider and Kathreen Pichora Fuller(2001) significant age related declines are found in discriminating specific phonemic contrasts based on gaps. This decline in temporal processing observed in older adults with good audiogram. However the same were not correlated with audiometric threshold.

When synthetic sentence identification test was done in elderly group the result indicated that age accounted for significant unique variance in the test across. (Henry, Lew & Jerger James, 1991).

When young subjects with normal hearing sensitivity were compared with elderly group with normal hearing in hearing in noise test, it was found that there was a significant decline in the scores of elderly subjects. (Frisinia , et al, 2005). Thus there is a decline in auditory skills reported in literature because of aging as well as of age and related hearing loss.

Evidence suggests that aging also alters the laterality.

It is well established that there are asymmetries between right and left auditory function.

Central lateralization is well known as evidenced by the asymmetrical anatomy of the human brain. (Geshwind & Levitsky, 1968; & Galaburda, A.M., Sanides, F., Geschwind, (1978).

Asymmetries appear early during ontogenetic development, with structural and functional differences between right and left hemispheres appearing before birth in auditory regions, example as early as 31 weeks of gestation .(Chi, Dooling, & Gillies,1977).

Evidence suggests that hearing sensitivity is better in right ear than in left ear. (Chung, Mason, Gannon, & Wilson, (1983)., Mc Fadden, 1993).

It's been reported that greater spontaneous otoacoustic emissions are present in the right than the left ear. (Bilger, Matthies,Hammel, & Demoest, 1990).

Transient evoked otoacoustic emission (TEOAE) done in normal hearing adults in different age groups proved that, there is an increased amplitude in right ear in comparison to left ear. On the other hand, in Presbycusis group these results were reversed. (Frisinia etal, 2005)

Study carried out in Presbycusis group by means of PTA, SRT and OAE's justified that there is a left ear advantage found in these groups (Frisinia , Mapes, Kim, & Frisinia , 2005).

It is also necessary to see whether these changes are only restricted to peripheral level or also present in higher levels.

Evoked potential electro physiological responses reflect processes that require synchronous activity across populations of neurons. So left/right asymmetry can be explained based as electrophysiological tests.(Teri James Bellis, Trent Nicol and Nina Kraus, 2000)

The study investigated whether age affects the degree of left/right asymmetry in neural representation. By means of brainstem potentials, Sininger,Y.S., Cone,

W.B.,Abdala, c. (1998) explained that there is a right ear advantage which suggests that the right latencies were better than the left ear latencies.

Auditory evoked potentials from 27 scalp and additional EOG channels in 12 healthy volunteers performing a free report dichotic listening task with simple speech sounds was done. The findings were a 15ms shorter average latency of the N1-AEP recorded from scalp approximately overlying the left supra temporal cortical plane compare to the N1-AEP over the homologous right side. (Eichele T, Nord by H, Rimol LM, Hugdahl. K 2005)

Findings demonstrated from the LLR study that the pattern of left sided dominance in the neural representation of speech sounds seen in children and young adults is not evident in older adults. (Teri et al, 2000)

An event related brain potential study done by Radouane , Yagoubi and Mirrelle Besson (2005) in younger as well as elderly group suggested that the hemisphere asymmetry (left hemispheric advantage) for adults was reduced in older adults (age related hemisphere asymmetry reduction).

So there is a need to evaluate that whether the right ear advantage is lost with age for is it due to the high frequency hearing loss that usually accompanies aging.

Dichotic listening test administered in young individuals with normal hearing sensitivity proved significant right ear advantage (Azanon, & Sebastian, 2005). Study done by Frisinia etal (2005) performed hearing in noise test (HINT) in 2 groups of

individuals. 21 subjects with normal hearing threshold 58-76 years and 35 subjects with high frequency hearing loss characteristic of presbycusis. Results suggested that the central right ear advantage in speech discrimination was maintained with age, with no effect of age related sloping hearing loss. (Frisinia etal, 2005)

When approaching the problem of understanding what biological changes takes place to cause age related asymmetry reduction, it is beneficial to consider at what points in the system special deterioration can occur.

Study by Frisinia et al (2005) evaluated asymmetry at different levels that is audiograms; TEOAE's and DPOAE's were used to assess cochlear function. Hearing in noise test was used to assess central auditory function. The finding of the study concluded the following points.

1) The peripheral right ear advantage in OHC function is lost with age related sloping hearing loss which is not the same in elderly adults with normal hearing.
2) Age plays a major role in MOC function deterioration.
3) The central right ear advantage in speech discrimination is maintained with age.

Study done in elderly group of 61-80 years age related hearing loss indicated that tests measuring central auditory processing proved to have right ear advantage whereas the tests measuring peripheral auditory resolution indicated left ear advantage. (Teri et al ,2000)

Performance asymmetries at the cortical level that is separating peripheral hearing loss from intrinsic aging has not been investigated systematically as a function of age. Hence, the present study was taken to observe age related changes in

auditory function at different auditory level and also to observe is there a shift in laterality with age and also in presbycusis group.

METHOD

The present study intended to evaluate the change in laterality across the ages, and in individuals with hearing loss due to aging. The study was also aimed to check age at which such changes can be noticed, if any.

Subjects

To accomplish the above-mentioned aims the study was done on two groups of subjects.

Group-1-control group

Control group consisted of normal hearing adults. Normal hearing is operationally defined as 'pure-tone average of 15dB HL or less at octave frequencies between 250HL and 8000HL (ANSI, 1996)'. The following criteria were followed for subject selection:

- A' type tympanogram with reflexes present.
- No history of otological or neurological symptoms.
- Also made it a point that the physical condition of the subjects was fit for testing.

Participants were divided in to 4 groups based on their age seen as bellow.

Age	***Number of subjects***
30-40 years	10
40-50 years	10
50-60 years	10
60 years and above	10

Group-2-Experimental group

Experimental group consisted of subjects with symmetrical sensorineural hearing loss acquired due to aging. The following factors were taken care prior to testing;

- They did not have any history of significant noise exposure, ear infections and intake of ototoxic drugs.
- It was taken care while selection that, the subjects did not have previous otological history and history of head trauma, seizures, neurological disorders or chemotherapy.
- All the subjects in all the groups had 'A' type tympanogram with presence or elevated reflexes.
- Also made it a point that the physical condition of the subjects was fit for testing.

Subjects were then distributed based on their age in to 3 subgroups are as follows :

Age	***Number of subjects***
40-50 years	5
50-60 years	5
60 years and above	5

Tests administered to observe age related changes of ear advantages were :

1. Transient evoked otoacoustic emissions (TEOAE) to assess the changes in peripheral level.
2. Auditory brainstem response (ABR) to assess the changes at brainstem.
3. Late latency responses (LLR) to assess the changes at cortical level.
4. Speech in noise test (SPIN) to assess the changes in central auditory processing.

Instrumentation

The following instruments were used for the study:

- A calibrated two channel diagnostic audiometer to perform pure tone threshold and SPIN.
- CD player to present recorded speech material.
- A calibrated immittance meter to perform tympanometry and acoustic reflex testing.
- An evoked potential system – intelligent hearing system version 3140 to record ABR and LLR.
- ILO 292 Echo port plus OAE system application software (version 5) to record and analyze TEOAE's.

Test material

To test speech perception in noise CD developed by Varghese (2004) was used. The CD was recorded by test material developed by Vandana (1996) in the presence of speech babble at 0 d B SNR.

Test administration

Test administration was carried out in two phases.

- **Phase 1**

Selection of subjects based on otological evaluation, pure tone evaluation and immitance evaluation. Pure tone thresholds were obtained using modified version of Hughson Westlake procedure (Carhart and Jerger, 1959) across octave frequencies from 500, 1000, 2000 and 4000 kHz for both air and bone conduction(mastoid placement).

Tympanometry was carried out to know the status of the middle ear for all the subjects, the subjects were made to sit comfortably and were asked not to swallow during the testing period.

- **Phase 2**

After the detailed evaluation the tests for assessing the age related ear advantage were carried out.

Transient Evoked Otoacoustic Emission

Responses were elicited using non-linear detection paradigm. The time locked averaging was done for 260 sweeps of 100 ms click. The responses obtained were then subjected to time domain analysis. Reproducibility of greater than 65% was considered significant in any frequency band. And SNR of 3d B counted to be the presence of TEOAE. TEOAE amplitude at each frequency band independly was noted.

Electro physiological testing

Electro physiological testing included recording of auditory brainstem responses and late latency responses. Both types of potentials were recorded for clicks.

Protocol used to elicit evoked potentials as follows

Parameters	**Auditory brainstem responses**	***Late latency responses***
Stimuli	Clicks	Clicks
Stimulus polarity	Rarefaction	Rarefaction
Transducer	Head phones	Head phones
Repetition rate	30.1/s	3.1/s
Number of sweeps	1500	500
Transducer	Head phones	Head phones
Filter setting	30-3000Hz	1-30 Hz
Analysis window	10ms	300ms
Electrode montage	Vertical montage: Positive-C_2 : Negative-M_1, M_2 : Ground-Nasion.	Vertical montage : Positive-C_2 ; Negative-M_1 , M_2 : Ground-Nasion
Electrode impedance	< 5 Kohms	< 5 Kohms.

The information's collected from the evoked potentials were peak IIIrd and Vth latency and and P_1, N_1, P_2 and N_2 latency.

Speech perception in noise

To test speech perception in noise, CD developed by Varghese (2004) was used in noise at 0dBSNR at 40dB SPL. Subjects were instructed to repeat the words and scores obtained separately for right and left ear for monaural presentation through headphones.

Analysis

The data was then subjected to the statistical analysis using the statistical package SPSS version 10.00 obtained in different audiological tests and in age groups were analyzed using MANOVA to check for interaction effect, because the data included number of variables. To compare the age groups and age related decline Post Hoc Tuky test was carried out. Paired t-test was administered to check for laterality between the ears.

RESULTS

To study the age effects and changes in laterality across the ages and at different auditory levels, the tests used and parameters assessed were as follows.

Test administered to detect peripheral changes was:

- Transient Evoked Otoacoustic Emissions (TEOAE) of right and left ears in the frequency bands of 1 kHz, 2 kHz and 4 kHz.

Test administered to assess brain stem level was:

- Auditory brain stem responses (ABR): latency values of IIIrd and Vth peaks were considered.

Test administered to evaluate cortical level was:

- Late latency responses (LLR): separate latency values of P_1, N_1, P_2 and N_2 for right and left ears were taken.

Test administered to assess central auditory processing was:

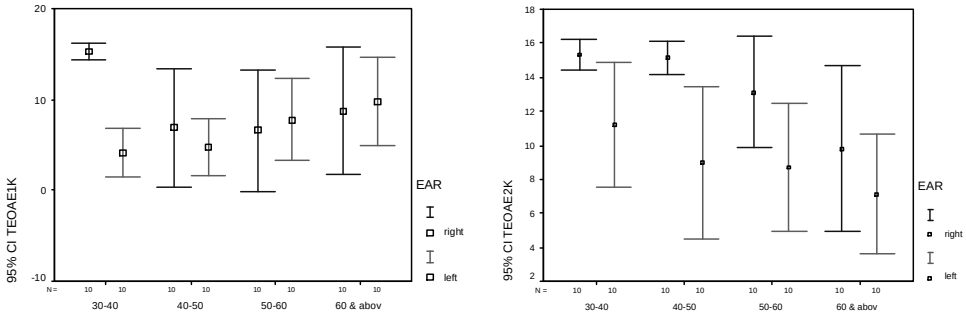
- Speech in noise test (SPIN): SPIN scores separately for right and left ear were obtained.

For checking the interaction effect MANOVA was used, for age effects. Post Hoc Tuky test was used and for evaluating the significance difference, paired t-test

was used. The level of significance was confirmed when the P value is greater than 0.05.

1. AGE RELATED CHANGES OBSERVED AT THE PERIPHERAL LEVEL

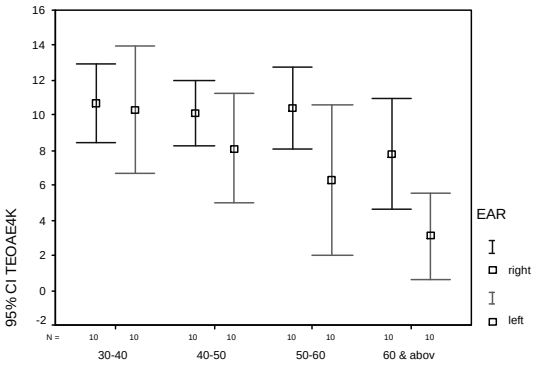
Transient evoked otoacoustic emissions



Graph 1 : The TEOAE amplitudes of right and left ear at 1KHZ and 2 kHz frequency band obtained in control groups

It can be seen in Graph 1 that the mean of right and left TEAOE amplitudes reduced with the increase in age especially for 2 kHz frequency band. Individual to individual variation of TEOAE amplitude was greater for older age group.

TEOAE amplitudes were always higher for right ear than left ear. This difference in TEOAE amplitude between the ears was statistically significant which can be seen in table 1.



Graph 2 : The TEAOE amplitudes of right and left ear at 4 kHz frequency band obtained in control group

TEOAE amplitude at 4 kHz which also decreased with the increase in age. Right ear TEOAE amplitude was greater than the left ear TEOAE amplitude in all the groups. And this difference is significant in all the age groups.

Table 1 : t-values between the right and left ear TEOAE amplitudes in control group

Age	TEOAE		
	1	2	4
30-40	1.25	3.2*	0.61
40-50	1.3	3.8*	2.4*
50-60	-0.5	2.7*	2.4*
60 & above	-0.5	1.6	3.1*

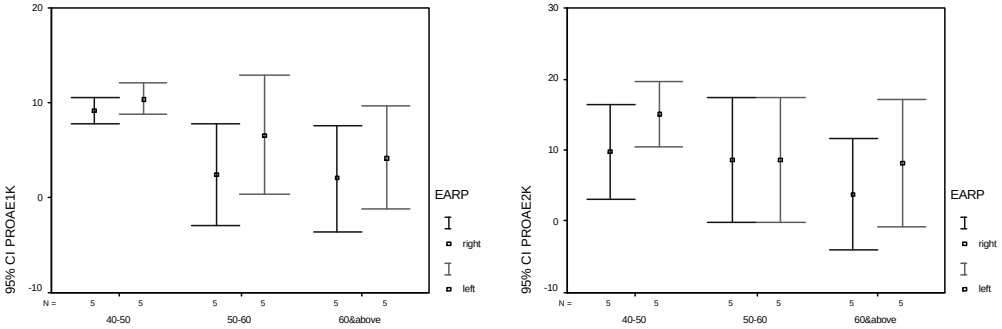
* Indicates significant difference

MANOVA performed in TEOAE scores showed that interaction effect is significant between TEOAE scores of right ear at 2 KHz and 4 KHz frequency bands in the whole group. Where in the other frequency bands did not indicate any significant interaction effect. In different age groups the interaction effect was only obvious in 2 KHz frequency band in right ear and in 4 KHz frequency band in right and left ear.

Table 2 : The significant difference between the mean for TEOAE Amplitude at 1 KHz 2 kHz and 4 KHz frequency band for control group across the age group

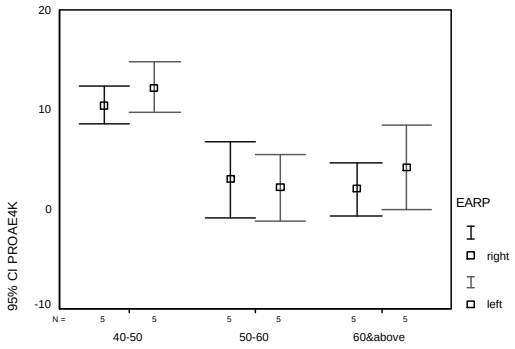
Ear	Age group	1Khz	2Khz		4Khz	
		1	1	2	1	2
Right	30-40	6.60	10.30		7.8	-
Right	40-50	6.70	13.10	13.10	10.1	-
Right	50-60	6.90	15.10	15.10	10.4	-
Right	60 & above	6.70	-	15.30	10.7	-
Left	30-40	4.1	7.10		3.1	-
Left	40-50	4.8	8.70	-	6.3	6.3
Left	50-60	7.8	9.0	-	8.1	8.1
Left	60 & above	9.8	11.2	-	-	10.3

It is evident from the table 2 that, in right ear theTEOAE amplitudes at the 1 kHz frequency band did not vary significantly across the age. TEOAE amplitude at 2 kHz frequency band of 60 years and above group varies significantly from 30-40 years age group TEOAE amplitude in right ear. But TEOAE amplitude did not vary significantly for the left ear at 2 kHz. Where as TEOAE, amplitude at 4 kHz of right ear did not differ significantly between any two groups. But in left ear 60 years and above group TEOAE amplitude differ significantly from 1st sub group.



Graph 3 : The TEOAE amplitudes of right and left ear at 1KHZ and 2 kHz frequency band obtained in experimental groups

It can be inferred from graph 3 that the mean TEOAE amplitude of right and left ear amplitudes reduced with the increase in age. The TEOAE amplitude of left ear was always higher than that of right ear. And the difference in amplitude was significant at 1 kHz and 2 kHz frequency band. The individual to individual TEOAE amplitude variation was more for older group than the younger group.



Graph 4 : The TEOAE amplitudes of right and left ear at 4kHz frequency band obtained in experimental groups

It can be seen in graph 4 that TEOAE amplitude at 4 kHz frequency band in experimental group followed the same pattern as seen in other 2 frequency bands. However the TEOAE amplitude between the right and left ear did not differ significantly for older groups.

Table 3 : t-values between the right and left ear TEOAE amplitudes in experimental group

Age	TEOAE		
	1 kHz	2 kHz	4 kHz
40-50	-6.0*	-3.8*	-4.8*
50-60	-9.7*	-6.0*	1.2
60 & above	-11.*	-5.2*	-1.4

* Indicates significant difference

Table 4 : Shows the significant difference between the mean for TEOAE at KHz 2 kHz and 4 KHz frequency band for experimental group across the age 1

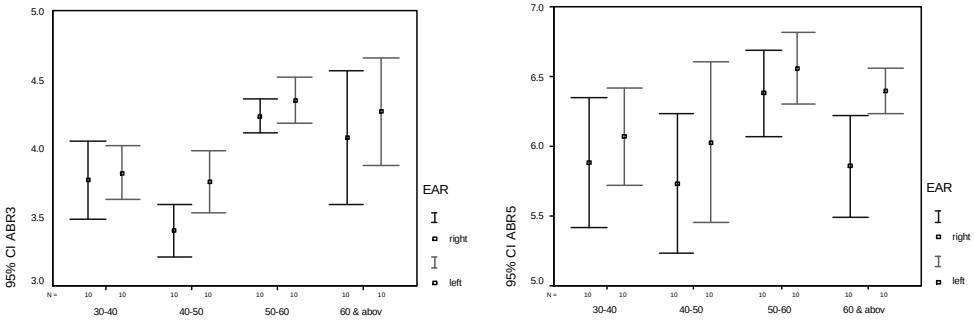
Ear	Age group	1 Khz		2 Khz	4 Khz	
		1	2	1	1	2
Right	40-50	9.2	-	3.8	2.0	-
Right	50-60	-	2.4	3.8	3.0	-
Right	60 & above	-	2.0	9.8		10.4
Left	40-50	10.4	-	8.20	2.2	-
Left		4.8	4.8	8.6	4.2	-
Left	60 & above	-	10.4	15.00	-	12.2

Table 4 indicates that the 1 kHz frequency band amplitudes in right ear were not significantly different between 50-60 group and in 60 above age group. But 40-50 group had significantly higher TEOAE amplitude than the other 2 groups. However TEOAE amplitudes at 2 kHz frequency band did not differ significantly between any two age groups. At 4 kHz frequency band TEOAE amplitudes of IIIrd group showed significantly higher amplitudes than other two groups.

In left ear TEOAE amplitude at 1 kHz frequency band of 40-50 and 50-60 groups did not show any significant difference but was different from 60 and above age group. TEOAE amplitude at 2 and 4 kHz frequency band showed the similar results as that seen in right ear. Thus, it can be concluded that peripheral changes can be noticed with the increase in age. The significant change can be noticed only after 60 years of age. The peripheral ear advantages can be seen only in individuals with hearing loss due to aging.

2. AGE RELATED CHANGES AT BRAINSTEM

Auditory brainstem evoked responses (ABR)



Graph 5 : Latencies of IIIrd peak and Vth peak of right and left ear in control groups

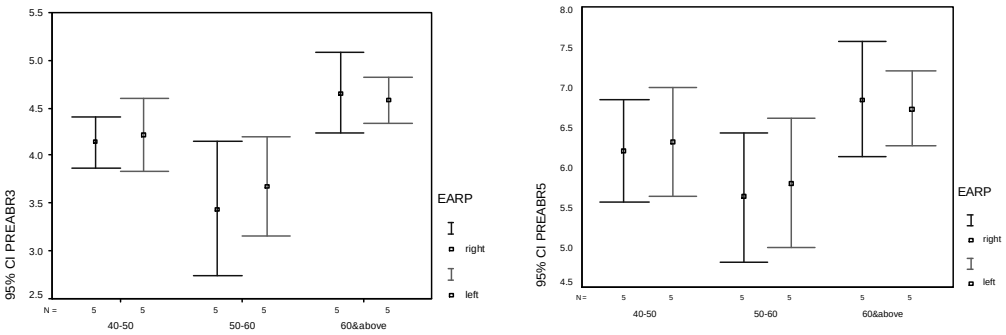
It is evident in the graph 5 that there is increase in peak IIIrd and Vth latency with the increase in age for both right and left ear. Right ear latencies were shorter than the left ear latency for all the age groups. The difference in right and left ear latencies significant in almost all the age groups which can be seen in table 5. The variation in peak latencies across the age group was not uniform.

Table 5 : The t-value between the two ear latencies in control group

Age	ABR	
	IIIrd	Vth
30-40	-0.5	-2.8*
40-50	-3.1*	-8.0*
50-60	-1.9	-4.7*
60 & above	-4.3*	-5.8*

* Indicates significant difference

MANOVA did not reveal any significant interaction between the whole group and ABR results of right and left ear. When the different age groups were considered, there was an effect of interaction between the latency of IIIrd peak of right and left ears with the different age groups.



Graph 6 : Latencies of IIIrd and Vth peak of right and left ear experimental group

It can be seen in above figure that latency of peak IIIrd and Vth of experimental group did not show the similar pattern that has been observed in control group. IIIrd and Vth peak latencies were minimum in 50-60 age group and maximum in 60 above age group. The reasons for such changes are not clear. The difference in right and left ear wave IIIrd and Vth latency did not show any significant difference at any age group.

Table 6 : **The t-value between the right and left ear latencies in experimental group**

Age	IIIrd	Vth
40-50	-1.6	-2.0
50-60	-1.1	-0.5
60 & above	0.42	0.41

Table 7 : The significance difference between the mean for right and left ear

Ear	Age group	Control group			Experimental group			
		IIIrd peak		Vth peak	IIIrd peak		Vth peak	
		1	2	1	1	2	1	2
Right	30-40	3.40		5.73	-	-	-	-
Right	40-50	3.77	3.77	5.85	3.44	-	5.634	-
Right	50-60	-	4.08	5.88	-	4.14	6.2	6.2
Right	60 & above	-	4.23	6.37	-	4.65	-	6.85
Left	30-40	3.75	-	6.02	-	-	-	-
Left	40-50	3.82		6.07	3.68		5.8	-
Left	50-60	-	4.264	6.39	-	4.2	6.32	6.32
Left	60 & above	-	4.34	6.55	-	4.58	-	6.79

latencies of IIIrd & Vth peak of control group and experimental group across the age

It is evident from the table 7, that there is no significant difference in wave Vth latency between any two subgroups of control group though there is increase in latency noticed with the increase in age. Where as significant increase in peak IIIrd latency was noticed after 50 years of age in right and left ear.

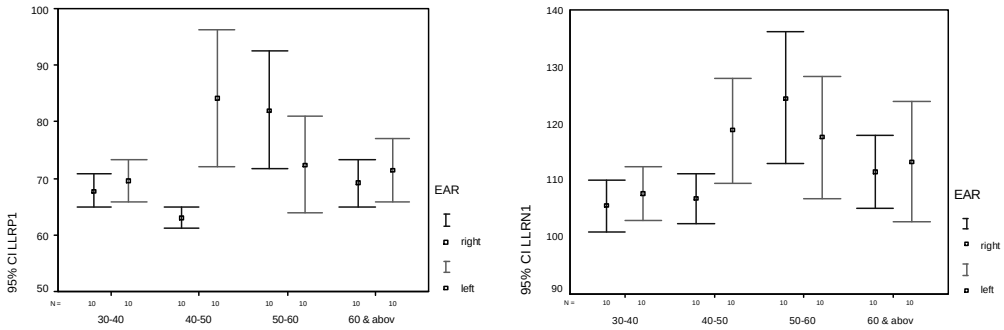
In experimental group significant increase in latency is noticed for both wave IIIrd and Vth for both right and left ears. Increase in latency is significant above 60 years.

Thus it can be concluded that age related changes are evident at the brainstem level which is more with individuals with hearing loss due to presbycusis. This effect is more evident after the age of 60 years.

It can also be concluded that right ear latency is always shorter than the left ear latency in any age group in both experimental and control group. Hence the right ear advantage does not change with age and hearing loss due to aging.

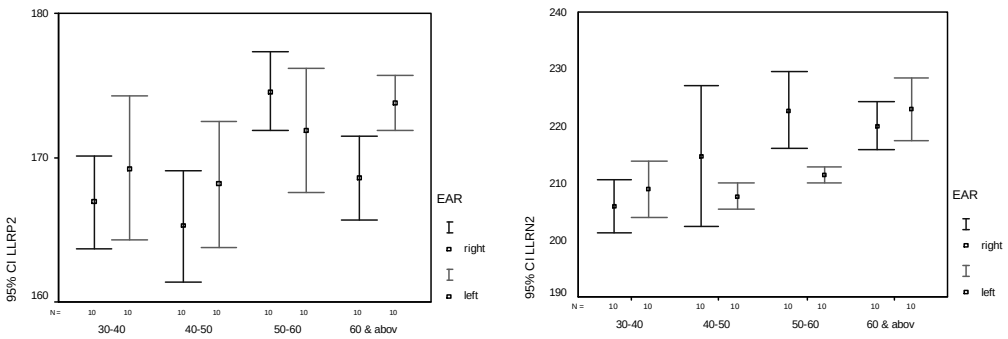
3. CHANGES AT CORTICAL LEVEL

Late latency responses



Graph 7 : The P_1 and N_1 latency of right and left ear obtained in the control groups

It can be seen in the graph 7 that the change of P_1 and N_1 latency did not show any specific pattern with the age. However, it is clear that P_1 and N_1 latency observed in right ear is usually shorter than the left ear. The difference in right and left ear latency is significant for the subjects above 40 years, which can be seen in the table 8.



Graph 8 : The P_2 and N_2 Latency of right and left ear in the control group

It can be seen in the above graph that P_2 latency showed the similar variation as seen for P_1 and N_l both in terms of latency changes with age and difference between right and left ear latency. However, similar changes could not be obtained for N_2 indicating wide range of variability.

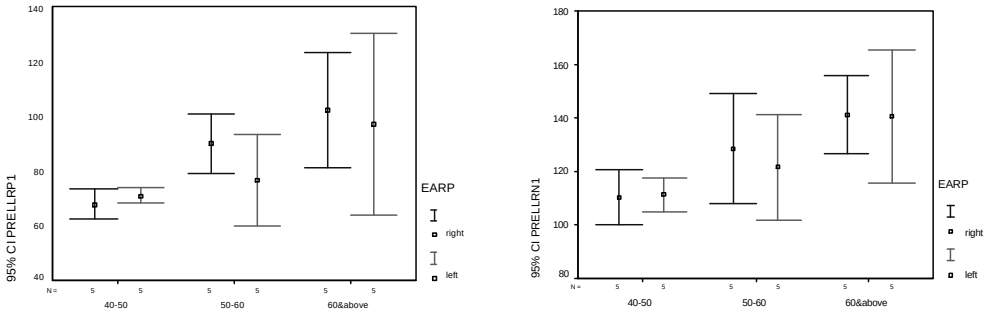
Table 8 : The t-values between the right and left ear latencies of P_1, N_1, P_2 and N_2 in control group

Age	P_1	N_1	P_2	N_2
30-40	-1.9	-2.1	-0.9	-2.4*
40-50	-3.9*	-3.0*	-3.7*	1.36
50-60	1.6	0.91	0.97	3.5*
60 & above	-3.0*	-0.9	-11*	-1.3

MANOVA indicated that the interaction effect is significant between right ear P_1, N_1, P_2 and the whole group. Left ear P_2 and N_2 also indicated significant interaction effect with the whole group. Across the age groups the interaction effect was significant between right ear P_1, N_1, P_2 and N_2 latencies with different age groups.

Table 9 : The significance difference between the mean of P_1, N_1, P_2 and N_2 latencies of control group across the age

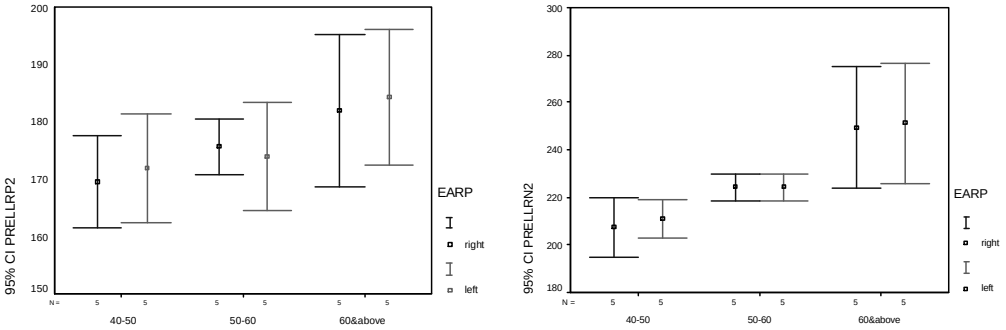
It is evident in table 9 that P_1, P_2 and N_2 latency obtained in 60 years and above age group is significantly prolonged in compare to latency obtained in other age groups in right ear. The N_1 and P_2 latency of left ear did not show any significant changes between any two age groups. However, P_1 latency and N_2 latency in left ear obtained in 60 and above age group is significantly prolonged compare to other groups.



Graph 9 : The P_1 and N_1 latencies of right and left ear obtained in the experimental group

Graph 9 illustrates that there is an increase in latency of P_1 and N_1 with increase in age with both right and left ear. The individual variation in P_1 and N_1 latency also increased with increase in age. However the mean value of P_1 and N_1 latency of the right ear is shorter than that of left ear which has failed to reach the significance level as seen in table 10.

Ear	Age group	P_1		N_1		P_2		N_2	
		1	2	1	2	1	2	1	2
Right	30-40	63.00		105.50		165.30		205.90	
Right	40-50	67.00		106.70		166.90		214.70	214.70
Right	50-60	69.00		111.40		168.60			220.00
Right	60 & above		82.10		124.50		174.60		222.80
Left	30-40	69.50		107.60		168		207.70	
Left	40-50	71.40	71.40	113.30		169		208.90	
Left	50-60	72.500	72.500	117.50		171		211.50	
Left	60 & above		84.20	118.70		173			223.10



Graph 10 : The P_2 and N_2 latencies of right and left ear obtained in the experimental group

Graph 10 also highlights the similar trend in P_2 and N_2 latency variation and individual variation in latency with age for both right and left ear as seen in N_1 and P_1 latency. However, there is hardly any difference in P_2 and N_2 mean latency between the two ears. This failed to reach the significance level as seen in table 10 except for P_2 in 1st group.

Table 10 : t-values between the right and left ear P_1, N_1, P_2 and N_2 latencies obtained in experimental group

Age	P_1	N_1	P_2	N_2
40-50	-1.6	-0.7	-3.7*	-1.4
50-60	1.4	0.50	0.31	1.13
60 & above	0.79	0.16	-0.6	-0.2

*** Indicates significant difference**

Table 11 : Significance difference between the mean for P_1, N_1, P_2 & N_2 latencies of presbycusis group across the age groups

Table 11 shows that in presbycusis groups P_1 latency of right ear 1st group which is significantly different from 50-60 and 60 & above age groups. In right ear N_1 latencies of 40-50 group and 50-60 age group did not vary significantly except 60 and above group. Right ear P_2 latencies did not vary significantly across the age range. N_2 latencies of 40-50 and 50-60 groups of right ear did not vary significantly but these latencies varied significantly from 60 & above age group.

Left ear latencies of P_1 peak shows that there is no significant difference between the age groups. It was observed that N_1 latency of 40-50 and 50-60 group did not vary significantly where in 60 and above age group varied from 40-50 and 50-60 age group. In left P_2 latencies there was no significant difference between the age groups.

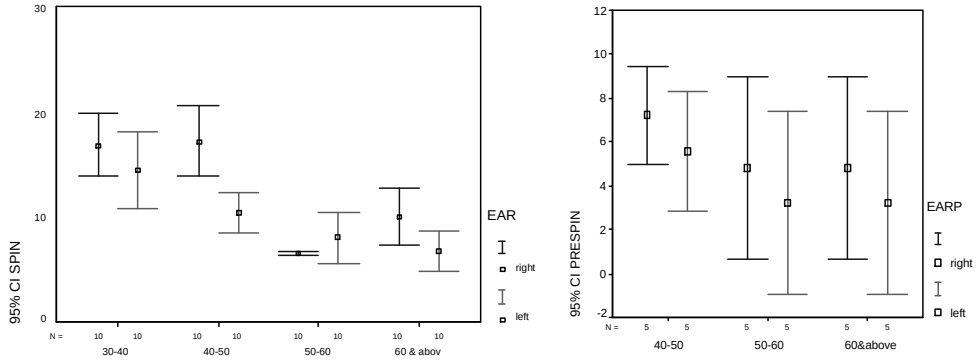
Ear	Age group	P_1		N_1		P_2	N_2	
		1	2	1	2	1	1	2
Right	40-50	67.80	-	110.20	-	169.60	207.400	
Right	50-60	-	90.00	128.40	128.40	175.60	224.20	
Right	60 & above	-	102.40	-	141.20	182.00		249.40
Left	40-50	71.00	-	111.40	-	171.80	211.20	
Left	50-60	76.60	-	121.60	121.60	174.00	219.00	
Left	60 & above	97.00	-	-	140.60	184.40		251.20

It was also observed that N_2 peak latencies of 40-50 and 50-60 group did not vary significantly where as 60 and above age group varied from 40-50 and 50-60 age group.

In general it can be concluded that there is increase in latency of P_1, N_1, P_2 and N_2 with the increase in age. It is difficult to establish the ear advantage at any age for any group as there is very negligible difference in latency between the two ears.

4. AGE RELATED CHANGES OBSERVED FOR CENTRAL AUDITORY PROCESSING

Speech in Noise Test (SPIN)



Graph 11 : SPIN scores of right and left ear in control group and experimental group

Graph 11 indicated that the mean scores of right and left ears reduced with the increase in age in control group and in experimental group. Scores were always higher for right ear than left ear. It can be seen from the significance table number 12. The variation in scores across the age groups were not uniform.

Table 12 : t-values between the right and left ear scores of control group and

Age	Control Group	Experimental group
30-40	1.20	
40-50	11.1*	1.63
50-60	-3.7*	1.0
60 & above	4.0*	1.0

experimental group

* Indicates significant difference

The interaction analysis performed in SPIN showed that there is a significant effect of interaction between the whole group and SPIN scores of right and left ears.

The interaction effect was also obvious between the different age groups and both ears' scores.

Ear	Age group	CONTROL GROUP		EXPERIMENTAL GROUP
		1	2	1
Right	30-40	10.0	-	-
Right	40-50	11.6	11.6	7.2
Right	50-60	-	16.8	4.8
Right	60 & above	-	17.2	4.8
Left	30-40	6.8	-	-
Left	40-50	8.0	-	5.6
Left	50-60	10.4	10.4	3.2
Left	60 & above	-	14.4	3.2

Table 13 : The right and left ear scores obtained in control group and experimental group

It was found that the SPIN scores in 30-40 and 40-50 scores did not vary significantly but these scores were significantly different from 50-60 and 60 above age group in right ear.

In left ear 30-40, 40-50, and 50-60 scores did not vary significantly except the SPIN scores obtained in 60 and above age group.

In experimental group there was no significant difference in the scores between the age groups in both right and left ear.

From the above results it is evident that SPIN scores is likely to reduce with the age especially for normal hearing population. However right ear advantage is maintained across the age and also in both control and experimental group.

DISCUSSION

Results of this study indicate that there is deterioration in audiological tests results with aging. Such changes are noticed from peripheral to cortical level. It has been demonstrated that right side specialization which is widely accepted as, a normal phenomena, is being maintained in the normal hearing group across the age group, where as in presbycusis group show left ear advantage at peripheral level. A significant change has been noticed age above 60 years.

The above results have been discussed as follows:

Changes observed in the peripheral level

Ear differences of outer hair cell (OHC) motility and functionality are reflected by TEOAE amplitude differences between the two ears.

It is observed that TEOAE amplitude is greater in the right ear than in the left ear in the control group across all the age range. This is suggestive of enhanced auditory processing in the right ear. Thus suggests that, the peripheral right-ear advantage retained over the age. A similar observation also reported by Frisinia etal. 2005.

In the present investigation, the peripheral right –ear advantage was clearly evident in the normal hearing group. It was also significant that as the age progresses the amplitudes reduced in both the ears. It indicates that OHC motility and functionality had been equally affected in both ears by age.

On the contrary, in the presbycusis group, the left ear otoacoustic emissions became more predominant (significantly higher TEOAE amplitudes). These results indicate that the deterioration in OHC function was greater in the right ear than the left ear in presbycusis.

The right/left differences in otoacoustic emission amplitudes despite the symmetry of the pure tone thresholds in both ears may be related to the origin of otoacoustic emissions versus how the inner ear processes pure tones. The otoacoustic emissions originate from the OHC's, while the peripheral processing of pure tones is a conjoint function of both inner hair cells and OHCs, and the auditory nerve fibers. The OHC of the cochlea is more vulnerable to ischemia than the inner hair cells. (Kimura etal., 1958).The aged ear has less capacity to maintain stable blood flow and thus may be more vulnerable to stress factors that affect cochlear function starting with deficits in OHC's.This might answer the findings reported in this study. However the reason for change in peripheral laterality in presbycusis is not clear.

Changes observed in brainstem level

Auditory brainstem potentials were used to evaluate the function of brainstem. It was observed that as the age progresses there is a significant increase in the absolute latencies for right and left ears which is in support to the fact that aging affects the brainstem level adversely. Chu in 1985 and Mamatha (2003) also observed the similar changes in latency with aging.

Normal hearing group results reflected the fact that right ear advantage is maintained through out the age groups. The same is been observed and supported by the study of Sininger et al in 1998.

In presbycusis groups there was no significant difference obtained between the right and left ear latencies. This suggests the symmetrical changes at the level of brain stem. However, Teri James Bellis, Trent Nicol and Nina Kraus, in 2000, they found that the pattern of left sided dominance in the neural representation of speech sounds seen in children and young adults is not evident in older adults. From this study one can suspect that as the age progresses there is a chance of deterioration in the left hemispheric response for nonspeech sounds, which is not observed in this case.

Changes observed in cortical level

Results showed that there was significant age related deterioration in latencies for both the ears which is in support with the study which had mentioned earlier by Bahramali and Gordon in 1999.

Right ear advantage was maintained through out the normal age group which is accordance with the study by Terry et al (2000). There was an exceptional change found in N2 latency, this would be due to state of arousal of the individual or attention paid to stimulus as N2 usually get affected by such factors. In presbycusis group it was observed that as the age increases the laterality was getting disappeared. This is in accordance with the study reported by Terry et al (2000) who explained that the right ear advantage is lost in elderly. He came to this conclusion when he compared

the younger group and elder group. Radouane E, Yagoubic and Mirrelle Besson, 2005 also reported that as the age progresses the ear advantage of right over left is getting lost. The reason might be because of the presence of age related changes and the hearing loss might be altering the sensory representation of auditory signals.

Changes observed in the central processing level

The SPIN tests are generally accepted as a measure to assess central auditory processing because of the obligatory involvement of central and brainstem binaural pathways. The test scores are consistent with the previous finding by Frisinia etal (2005) that aging causes progressive decline in the central processing of speech. The present study proved that the right ear advantage phenomenon in the normal hearing individuals is maintained across the age groups. Where in the presbycusis group showed no significant difference between the ears in all the age groups, which is not supporting the study reported in review by Frisinia etal. (2005). Thus it suggests that no matter there might be shift in ear advantage in peripheral level due to age and hearing loss, central nervous system is reluctant to show such changes, which shows more symmetric changes in both ears.

SUMMARY AND CONCLUSIONS

The present study aimed to evaluate the age effects and laterality changes across the ages in normal hearing adults and in presbycusis population.

The normal hearing group consisted subjects in the age range of 30-40years, 40-50years, 50-60 years and 60 above age groups. Each group consisted of ten subjects. Experimental group (hearing loss due to aging) also was further subdivided in to 40-50 years, 50-60years and 60 above subgroups.

To explore the age related changes, different levels of auditory systems were assessed.

- Peripheral level
- Cortical level
- Brain stem level
- Central processing level

These mentioned levels were analyzed using different audiological tests, to assess the peripheral level transient evoked otoacoustic emissions (TEOAE) was used. Auditory Brainstem Responses (ABR) evaluated the Brainstem level .Cortical level was analyzed by means of Late Latency Responses (LLR) and Speech in noise test was the test used to analyze the changes in Central processing level.

Interaction effect was assessed by means of MANOVA test. And for assessing age related decline Post Hoc Tuky test was carried out. Evaluating ear difference between the groups “t” test was used.

Results reported that as the age increased there was deterioration at all levels of the auditory system that is at peripheral, brainstem, cortical and central processing level. The present study showed an evidence of right ear advantage which is maintained through out the age in the normal hearing adults at different levels of auditory system, where as, the age related sloping hearing loss altered the laterality at peripheral level.

The possible conclusions from the study are:

1. Gives an idea that as the age increases there is significant deterioration at all the levels of the auditory system in normal hearing individuals.
2. When checked for the ear advantage at different levels of the auditory system it is evident that there is a significant increased performance of right ear over the left in normal hearing adults.
3. In presbycusis adults it is evident that at cochlear level the left ear performance is better than the right, and this change was significant from 40 years of age.
4. In presbycusis adults, there is no significant difference between the right and left ear scores at central and cortical level. This indicates that this might be because of the presence of peripheral hearing loss present which can alter the sensory representation of auditory signals.

Thus it can be concluded that age related deterioration in auditory performance can take place at any level independly or at all the level simultaneously. Change in audibility performance is likely to be more affected after 60 years of age. However, one may not observe the change in laterality at higher level either due to age or due to hearing loss caused by aging.

Implications

1. Information about requirement of different normative data for different age group.
2. The information about ear advantage might be useful in hearing aid prescription and for training purpose.
3. Appropriate remedial plan can be taken, may be more training is required depending upon ear at which is less advantageous.
4. Gives an idea about choice of tests to be used to evaluate the age related changes and the levels at which the tests have to be evaluated.

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