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

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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 for both the groups. Along with those TEOAEs, TEOAEs with contralateral noise for clicks at 60 dB SPL and speech ABR for /da/ syllable were recorded in both ears for both the groups. 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.

Key words: *speech in noise, efferent system, speech ABR*

Introduction

Aging leads to many anatomical and physiological changes in the auditory system. Changes in auditory system due to aging have 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).

Recently 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). It 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 (Sanches & Carvallo, 2006;). Thus, to understand this mechanism, there is a need to explore the efferent functioning system in middle aged subjects.

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, 2010). 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.

Also 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.So 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.

Participants & Instrumentation

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.

All the participants had normal hearing sensitivity (within 15 dBHL) at octave frequencies 250 Hz, 500 Hz,

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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. 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. There was no history of any otological or neurological dysfunction in all the participants and were non diabetic.

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

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. Calibrated GSI tympstar Immittance meter was used to carry out tympanometric and reflexometric evaluations. ILO V6 was used to measure TEOAEs and contralateral suppression of OAEs. Biologic Navigator Pro EP was used to record the click and speech evoked auditory brainstem responses.

Procedure

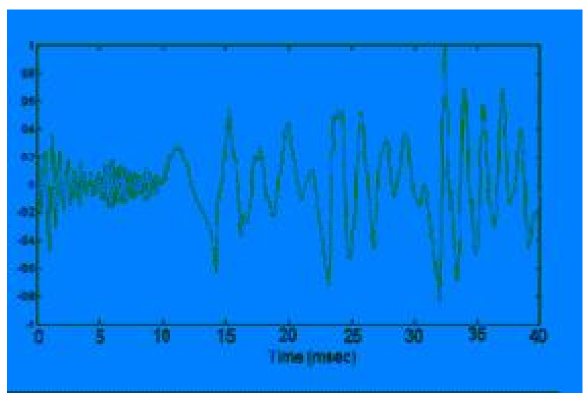
Pure tone audiometry was carried out using modified Hughson Westlake procedure (Carhat and Jerger, 1959) pure-tone thresholds were obtained at octave frequencies between 250 Hz to 8000 Hz for air conduction and between 250 Hz to 4000 Hz for bone conduction for all the participants. Speech audiometry was done using phonetically balanced words list (AshaYathiraj 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 & 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.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.

Then 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.

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 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 absolute 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'.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.

Results

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.

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

To understand the significant difference in mean scores of the different tests between two groups, the Non-Parametric Mann Whitney U test was administered and is given in table 1.

Table 1.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 Table1 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 found 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 and found 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 noted 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.

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.

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 2.

From the above Table 2 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.

Table 2.Comparison of amplitude of TEOAEs and TEOAEs with contralateral noise between younger and middle age groups.

Frequencies (Hz)	Z		Asymp. Sig. (2-tailed)	
	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.

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 3

Table 3.Comparison between amplitude of TEOAEs and TEOAEs with contralateral noise in the middle

and younger age groups.

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

Frequencies (Hertz-Hz)	Middle age group				Younger group			
	Females		Males		Femlaes		Males	
	Z	Asymp. Sig. (2-tailed)	Z	Asymp. Sig. (2-tailed)	Z	Asymp. Sig. (2-tailed)	Z	Asymp. 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

From the Table 3, 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 and it was 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 and it was found 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 and found a significant difference between ears in amplitudes of TEOAEs at 2K Hz and amplitude of CTEOAEs at 2 KHz in younger males group. However no significant difference between ears was noted in any frequencies in any of the groups.

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 2, 3, 4 and 5.

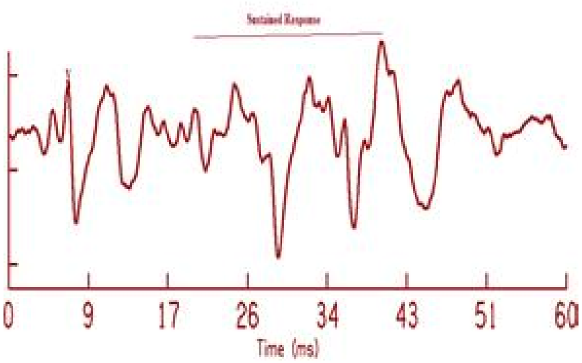


Figure 2.Mean grand average values of speech ABR responses in younger adults of right ear.

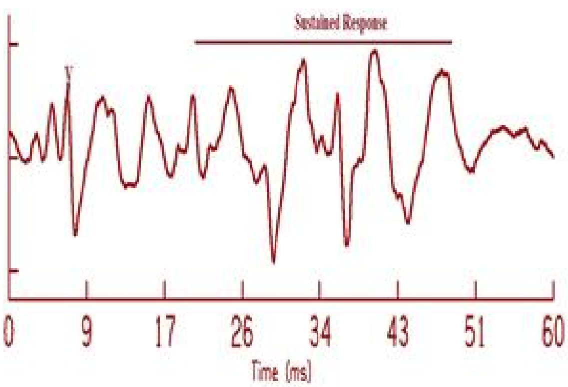


Figure.3.Mean grand average values of speech ABR responses in younger adults of left ear.

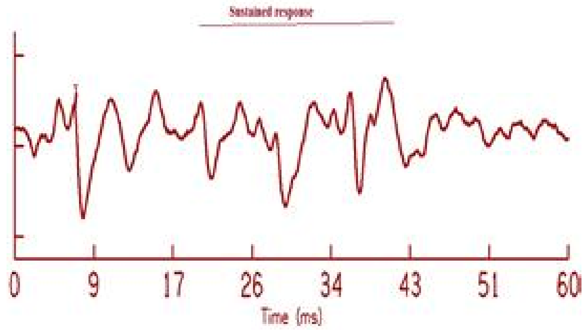


Figure.4 .Mean grand average values of speech ABR responses in older adults of right ear.

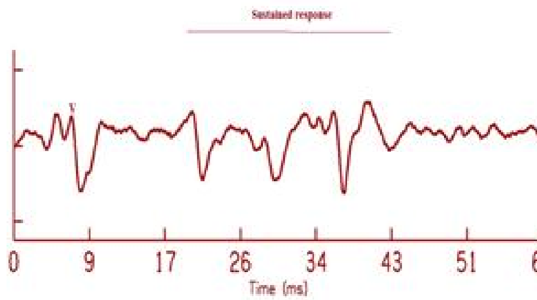


Figure.5. Mean grand average values of speech ABR responses in older adults of left ear.

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 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.

Table 4. 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.

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 and found a 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 and the result was 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 and 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.

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 groupsNon-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 5. From the table 5 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 6and 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 7 and 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 8and 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.

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.

Table.5.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
CTEOAEs4000-L	Correlation Coefficient	0.40	0.66	-0.21	0.03
	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.

Table 6 .Correlation between SPIN, SPIN with contralateral noise scores with amplitudes and V peak latency of speech ABR in Middle age group.

		SPINR	SPINL	CSPINR	CSPINL
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.

Table7. Correlation between SPIN, SPIN with contralateral noise scores with amplitudes of TEOAEs with contralateral noise (CTEOAEs) in younger age group.

		SPINR	SPINL	CSPINR	CSPINL
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-L	Correlation Coefficient	0.17	0.02	-0.03	-0.35
	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.

Table 8.Correlation between SPIN, SPIN with contralateral noise scores with amplitudes and V peak latency of speech ABR in younger age group.

		SPINR	SPINL	CSPINR	CSPINL
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
F2-L	Correlation Coefficient	-0.08	0.06	0.25	-0.14
	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.

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 byDubno (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.

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.

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.

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.

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. 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.

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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