Effect of Music on Neural plasticity of Efferent Auditory system

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ALL INDIA INSTITUTE OF SPEECH AND HEARING

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CERTIFICATE

This is to certify that this dissertation entitled **"Effect of Music on Neural plasticity of Efferent Auditory system"** is a bonafide work in part fulfillment for the PG Diploma In Neuro Audiology of the student (Registration No.10DNA003). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore

June, 2011

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DECLARATION

This dissertation entitled "**Effect of Music on Neural plasticity of Efferent Auditory system"** is the result of my own study under the guidance of Dr.Sandeep M, Lecturer in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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Chapter 1

INTRODUCTION

The hearing system is composed of integrated afferent and efferent auditory pathways. The two distinct efferent auditory pathways (medial and lateral) between the brain and the cochlea modify the auditory input before it reaches the brain (Warr & Guinan, 1979). The mammalian cochlea receives innervations from the superior olivary complex (SOC) of the brainstem, through the olivocochlear bundle. The lateral efferent neurons arise from the lateral superior olivary complex and they synapse with the cochlear afferent neuron dendrites, close to inner hair cells. The medial olivocochlear system originates from medial nuclei of superior olivary complex. These neurons project mainly contralaterally to innervate the outer hair cells which are presumably the source of Otoacoustic emissions (OAEs) (Rasmussen, 1946; Kemp, 1978).

The role of the efferent auditory system in hearing is yet to be completely explored. However, based on human and animal research, certain functions have been attributed to the medial olivocochlear system which includes location of sound sources, auditory attention, improved auditory sensitivity, improved detection of acoustic signals in the presence of noise (Micheyl & Collet, 1996) by modulating cochlear active mechanisms, and protection of cochlea against acoustic injury (Reiter & Liberman, 1995). Acoustic stimulation of one cochlea may modify afferent fiber responses in the contralateral cochlea (Buno, 1978). So in humans the medial olivocochlear system functioning can be studied noninvasively by coupling contralateral stimulation with OAE recording. The result is a frequency specific

decrease of OAE amplitude, which is known as contralateral suppression of OAE (Berlin et al., 1993).

Musical experience has a pervasive effect on the nervous system. Recent studies (Chandrasekaran & Kraus, 2010) shows that lifelong musical experience enhances neural encoding of speech as well as music. Musicians have enhanced subcortical auditory processing of speech, higher language learning ability (Musacchia, Sams, Skoe & Kraus, 2007) and musical experience appears to enhance the ability to hear speech in challenging listening conditions (Clark, Skoe, Lam & Kraus, 2009). Musical experience also limits the degradative effects of background noise on neural processing of sound (Clark, Skoe & Kraus, 2009). This is because, musicians have a variety of perceptual and cortical specializations compared to non musicians. Musical experience induces neuroplastic changes throughout the anervous system. Neural plasticity, which is also known as neuroplasticity or brain plasticity is the changing of the structure, function, and organization of neurons in response to new experiences. It specifically refers to strengthening or weakening nerve connections or adding new nerve cells based on outside experiences (Kandel, Schwartz, & Jessell, 2001)

Perrot, Micheyl, Khalfa and Collet (1999) found that MOCB activity is generally larger in professional musicians than in nonmusicians (subjects with no particular musical experience). Similarly, Kumar, Hegde and Mayaleela (2010) reported improved contralateral suppression after short term training on discrimination of non-native speech sounds. These studies indicate changes in neural plasticity of efferent neurons secondary to training.

1.1 Justification for the Study

It is found in literature that musical experience induces plastic changes in the brain (Chandrasekaran & Kraus, 2010). There are also many studies (Kumar, Hegde & Mayaleela, 2010) that report of neural plastic changes of efferent auditory neurons secondary to auditory training. However, it is not clear from these studies whether listening to music is enhancing the efferent plasticity or formal practice of music is enhancing plasticity. Hence, the effect of training on efferent auditory neural physiology is studied is yet to be completely explored.

Hence the present study is taken up to assess the functioning of efferent system in music listeners by comparing three groups of population who are different in terms of their musical exposure and training. The null hypothesis of the study is that there will be not be any difference in the efferent suppression across the three groups.

1.2 Objective of the Study

To compare the amplitude of contralateral suppression across individuals, who do not listen to music, who are regular music listeners and vocal musicians.

Chapter 2

REVIEW OF LITERATURE

OAEs are the acoustic energy produced as a result of the micromechanical activity of OHCs on the organ of corti. This is based on the evidence from animal experiments that mammalian OHCs are motile in response to change in cellular potentials (Brownell, Bader, Bertrand & Ribauierre, 1985). They appear to be responsible for the sharp turning of the basilar membrane. They are the active mechanisms vulnerable to cochlear pathology (Johnstone, Patuzzi & Yates, 1986) due to intensive noise exposure, ototoxic drugs, etc. These OHCs are innervated predominantly by efferent auditory nerve fibers.

The efferent auditory pathway is formed by the descending motor nerve fibers which take their origin at the neuronal somata in the superior olivary cochlear bundle (OCB). The pathway was first described by Ramussen (1946). The total number of OC neurons ranges from 500 to 2500 per cochlea depending on the spcies (War, 1992).

The OCB is composed of mainly 2 separate systems;

1. The lateral olivary cochlear (LOC) projections.
2. The medial olivary cochlear (MOC) projections.

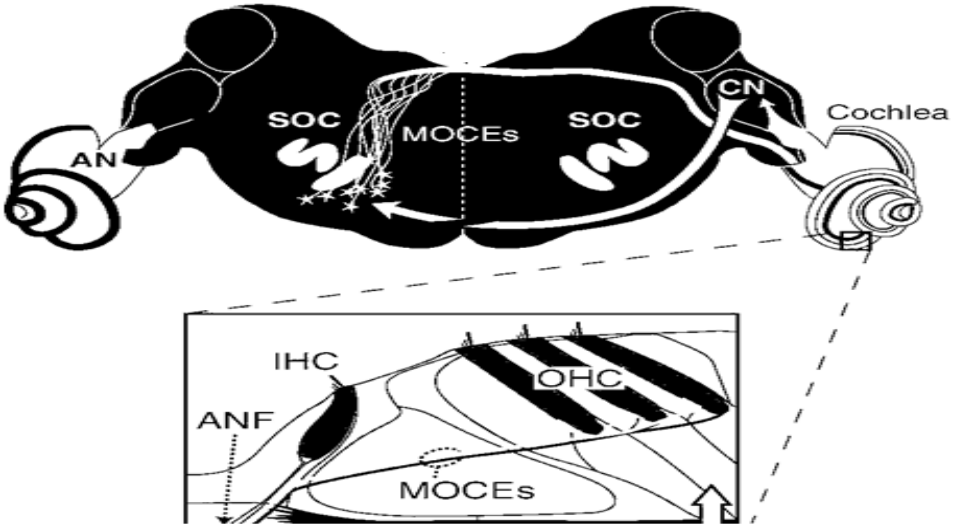

Figure 2.1: Depicts the pathway and distribution of MOC neurons.

The MOC projections distribute primarily to OHC (Warr & Guinan, 1979). They contains the myelinated nerve fiber, hence are readily stimulated by extracellular currents (Hallin & Torebjork, 1973; Fitzerald & Woolf, 1981). The Figure 2.1 depicts the pathway and distribution of MOC neurons. On the other hand, the LOC projections distribute primarily to IHC (Warr & Guinan, 1979). They contain unmyelinated nerve fiber, hence are not readily stimulated by extracellular currents (Hallin & Torebjork, 1973; Fitzerald & Woolf, 1981).

The mammalian cochlea receives efferent innervations from both ipsilateral and contralateral superior olivary complex. Approximately 72% to 74% of MOC fibers travel to the contralateral cochlea and supply the OHCs. The remaining 26% to 28% course ipsilaterlly whereas, approximately 89% to 91% of LOC fibers destined to terminate in the ipsilateral IHC and remaining 9% to 11% project to contralateral IHCs (Warr, 1992).

Medial and lateral efferents have different patterns of innervation along the length of the cochlea. Medial efferent innervation is largest near the center of the

cochlea with crossed innervation biased towards the base compared to the uncrossed innervations. In contrast, lateral innervation is relatively constant in the center and base of the cochlea (Guinan, Warr & Norris, 1984; Liberman, Dodds & Pierce, 1990).

2.1 The role of MOC and LOC Neurons in the Auditory Function

Although, the existence of an efferent innervation to the mammalian cochlear was described more than 50 years ago (Rasmussen, 1946), the functional role of auditory efferent fibers in hearing is still a matter of debate. However continued attempts have been made to understand the functions of efferent systems. Conclusions regarding its functions have been drawn from both animal as well as human research. In general the OCB has an inhibitory effect on the auditory periphery. Because of its predominantly inhibitory nature, it has been hypothesized that the efferent system serves a protective role in the auditory system (Rajan, 1988). It is also hypothesized that the activation of OCB enhances the detection of sound in noise (Micheyl & Collet, 1996) and maintains the cochlea at an optimum mechanical state for efficient function of active processes (Johnstone, et al.,1986).

Most of the physiological studies on the OC systems have investigated the action of MOC neurons (reviewed by Guinan, 1996). This conclusion stems from the fact that MOC axons are relatively large in diameter between, 0.5 and 2.75 um in cat and myelinated. Hence can be easily stimulated (Hallin & Torebjork, 1973; Fitzgerald & Woolf, 1981).

The MOC fibers can be activated by-

1. The electrical stimulation at the fourth ventricle (Galambos, 1956) or
2. The contralateral acoustic stimulation (Buno, 1978).

Much of the existing data on efferent effects has been obtained by exciting the olivo cochlear bundle (OCB) with shocks from an electrode at the midline of the floor of the fourth ventricle (Reviewed by Guinan, 1996). This location is used as efferent fibers are close to the surface and easy to access (Galambos, 1956). McCue & Guinan found that both crossed and uncrossed medial efferent fibers can be stimulated by a midline electrode. The stimulation of efferent system can affect the activity of different physiological processes.

2.2 Influence of Efferent Auditory Neurons on Otoacoustic Emissions

A variety of experiments indicate that medial efferent activity influences OAEs. Such effects are of interest because of OAEs are thought to reflect aspects of basilar membrane motion. OHCs over the basilar membrane are known to be cochlear amplifier. OAEs are believed to be generated by active mechanisms in the cochlea which involves OHCs. Since OHCs receive direct efferent innervations, they may be affected by contralateral acoustic stimulation (CAS) of olivocochlear bundle (Kim, 1986). There is wide variety of mechanisms by which medial efferents might affect OAEs. At low to moderate sound levels, medial efferent induces depression of basilar membrane (Dolan & Nuttall, 1994). It affects the operation of OHCs, i.e., it may reduce the OHC receptor potential, which would reduce OHC motion (Santo-sachi & Dilger, 1988). It hyperpolarizes the cell, which moves the membrane potential away from the optimum voltage for voltage to length transduction (Roddy,

Hubbard, Mountain & Xue, 1994). Efferent induced contractions of OHCs distort the organ of corti, thereby lowering the gain of the cochlear amplifier (Rajan, 1990). Finally, medial efferents reduce the endocochlear potential which reduces the gain of the cochlear amplifier (Sewell, 1984).

Efferent stimulation is shown to affect all types of OAEs. Medial efferents produce small changes in SOAEs. SOAEs frequency shifts to higher frequencies and amplitude can change in either direction (Mott, et al., 1989; Harrison & Burns, 1993). Efferent stimulation usually decreases DPOAEs, but sometimes it increases them (Mountain, 1980; Siegel & Kim, 1982). Efferent inhibition of DPOAE is greatest for low-level primaries and decreases as primary tone level is increased (Mountain, 1980). Similarly, activity in medial efferents affects click evoked OAEs Tone-burst OAEs and stimulus frequency OAEs. The usual effect is to inhibit with greatest inhibition for responses to low level sounds (Guinan, 1986, 1991; Collect, et al., 1990; Ryan, Kemp & Hinchcliffe, 1991; Norman & Thornton, 1993).

Although early literature emphasizes efferent effects at low sound levels (Galambos, 1956; Mountain, 1980), recent work suggests that the most significant effect of medial efferents may be at moderate and high sound levels (Guinan & Stonkovic, 1995).

The efferent stimulation through contralateral acoustic stimulation is dependent upon the type of contralateral stimulus. The contralateral acoustic stimulus to stimulate efferent system can be a pure tone (Mott, Norton, Neely & Warr, 1989; Berlin, Hood, Wen, Szabo, Cecola & Rigby, 1993a; Harrison & Burns, 1993), Clicks (Veuillet, Bazin & Collet, 1991), Narrow band noise (Veulliet, Bazin & Collet, 1991; Chery-Croze, 1993) or by Broad band noise (Veulliet, 1991, 1992; Berlin, 1993).

Among all BBN seems to be most effective stimulus since, the OCB activation increases with increase in bandwidth of CAS (Norman & Thorton, 1993). Among the TEOAE, DPOAE and SOAE with the contralateral BBN, TEOAE achieves the maximum suppression (reviewed by Hall, 2000). Experiments conducted on subjects with stable SOAEs, where there are clear amplitude peaks at particular frequency have shown changes in both intensity and frequency of these peaks with contralateral pure tones (Mott et al., 1989).

Veuillet, et al., (1991) studied the suppression of emissions evoked using 1 kHz and 2 kHz tone pips by contralateral NBN at intensity of 50 dB SPL and found that the amount of suppression was greatest when the noise band was centered on the central emission frequency. Moryl (1992) studied the suppression of click evoked emission by contralateral pure tone and found suppression in some frequency bands of the emission from 250 Hz tone but, no significant effect from higher frequency tone at the same intensity.

Norman & Thorton (1993) found that 0.5 kHz NBN produced most suppression at low frequencies, the 1 kHz band at mid-frequencies and 2 kHz band at high frequencies, but a significant result was obtained only at 1 kHz band within the emission where the amount of suppression was itself significant from all the noise bands. Thus, from the above studies, it can be inferred that the change in the response of OAEs may some degree of frequency specificity if the contralateral stimulus is frequency specific.

The main effect of efferent stimulation is the physiologic alteration of outer hair cells (Ashmore, 1987; Canlon & Brudin, 1991). It is reported that efferent innervation of outer hair cells probably controls the cochlear amplifier, reduces the

masking effects of noise, and protects the cochlea from the negative effects of acoustic over stimulation (Kumar & Barman, 2002; Wiederhold & Kiang, 1970).

Thus, the role of efferent auditory system in the auditory function is quite well understood. However, there is a dearth of research on the plasticity of efferent auditory system. The universally accepted training related plasticity in the auditory afferent system is attributed to the feedback from the top-down pathway. Training has been reported to modify the corticofugal regulation of the brainstem physiology (Chandrasekaran & Kraus, 2009; Madhok & Sandeep, 2011). However, the physiology of olivocohlear bundle before and after the auditory training is yet to be explored in detail. Kumar, Hegde and Mayaleela (2010) studied contralateral suppression of OAEs before and after discrimination short-term training of non-native speech sounds. They found increase in suppression followed by auditory training and attributed to the plastic changes in efferent physiology. But the effect of long-term training on the efferent physiology is not explored. Hence the present study was taken up.

Chapter 3

METHOD

In the present study, it was attempted to test the null hypothesis, 'music experience does not influence contralateral suppression of OAEs'. A combination of True experimental design and standard group comparison research design were used. The following method was adopted to verify the objectives of the study.

3.1 Participants

A total of 60 participants with normal hearing sensitivity participated in the study. They were in the age range of 18 to 30 years. Of the 60 subjects, 25 subjects were females and the remaining 35 were males. They were divided into three groups based on their musical experience. All the three groups had 20 participants each. The subdivision was as follows:

Group 1(Control group); had 20 individuals who do not listen to music on a regular basis.

Group 2 (Listener group); had 20 individuals who listen to music on a regular basis.

Group 3 (Musicians group); had 20 individuals who listen to music on a regular basis and practice vocal music formally.

The following table provides the demographic information about the 60 individuals who participated in the study.

Table 3.1

Number of individuals who participated in the study

	Gender	Number of subjects
Control group	Males	14
	Females	6
Listener group	Males	13
	Females	7
Musician group	Males	8
	Females	12

3.2 Participant Selection Criteria

Prior to the audiological screening, an otoscopic examination was done to rule out the presence of structural abnormalities of external ear or tympanic membrane. Individuals who fulfilled the following selection criteria were included in the present study in all the three groups.

1) Normal hearing sensitivity as tested on pure tone audiometry (Pure tone thresholds within 15dB HL at octave frequencies between 250 Hz & 8 kHz).

2) Normal middle ear functioning as tested on immittance evaluation. All the subjects had ‘A’ type tympanogram with normal ipsilateral and contralateral acoustic reflex threshold.

3) More than 90% speech identification scores in speech audiometry.

4) No past or present history of otological or neurological dysfunctions.

5) More than 3 dB SPL TEOAEs between 1 kHz and 4 kHz.

6) No complaint of difficulty in understanding speech in the presence of back ground noise, and no history of exposure to noise (occupational noise exposure or other).

3.3 Instrumentation

Following equipments were used in the study. A calibrated, two channel diagnostic audiometer (Orbiter 922) with TDH 39 head phones was used for pure tone and speech audiometry. The same was used to present Broad band noise (BBN) to the contralateral ear through the insert receiver. A calibrated Immittance meter (Grason-Staddler Tympstar) was used for recording the tympanogram and acoustic reflexes. A Madsen Capella Cochlear Emission Analyzer was used to record click evoked nonlinear otoacoustic emissions.

3.4 Test Environment

All the testing was carried out in an acoustically treated air-conditioned room with adequate illumination and ambient noise within permissible limit (ANSI S3.1; 1991). Pure tone and speech audiometry were carried out in a two room suite while immittance and OAE measurements were in a single room situation.

3.5 Test Procedure

Only the individuals who fulfilled all the above mentioned criteria were included for the present study. To ensure that the subjects had normal hearing, pure

tone audiometry was carried for all the three groups. Thresholds were tracked using modified Hughson and Westlake method (Carhart & Jerger, 1959) for octave frequencies from 250 to 8000 Hz. The individuals who had pure tone threshold within 15 dB HL were included in the study.

To rule out middle ear pathology, Immittance test was carried out using 226 Hz probe tone frequency. Subjects who had 'A' type tympanogram with present ipsilateral and contralateral reflexes were included in the study.

3.6 Acquisition Paradigm of Transient Evoked Otoacoustic Emissions

Stimulus Parameters

For the measurement of TEOAEs, the patients were made to sit comfortably on chair inside a sound treated room. The probe with a tip was positioned in the external ear canal and was adjusted to give flat frequency spectrum across frequency range. Stimulus spectrum showed a smooth distribution of energy across frequencies ensuring a good probe fit, as shown in Figure 3.1.

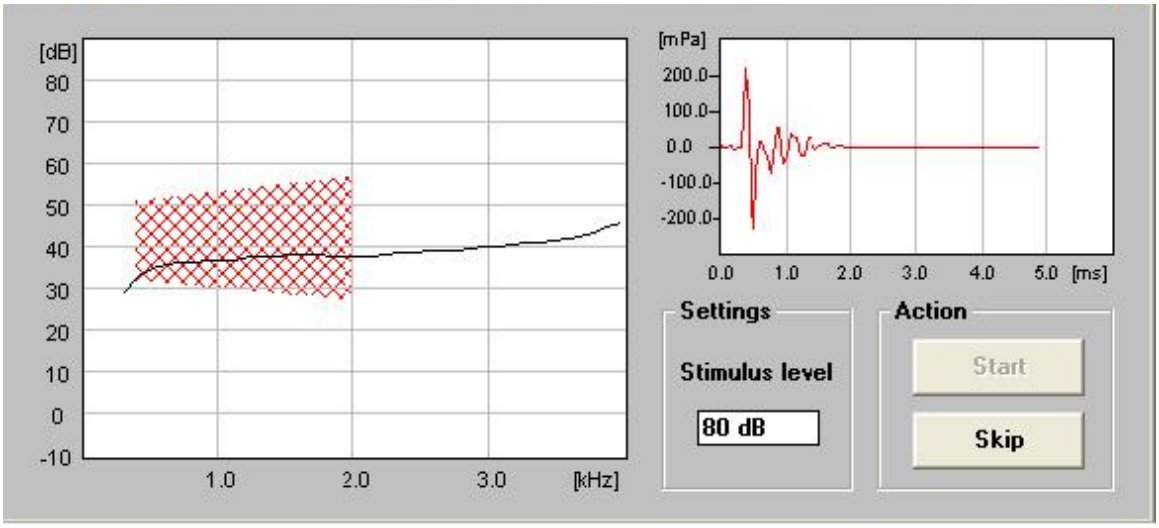

Figure 3.1: Shows the smooth distribution of energy of stimulus spectrum across frequencies.

Using Madsen Capella OAE analyzer, TEOAE response for 260 sweeps of clicks were averaged at intensity around 75 dB SPL. Clicks were presented in nonlinear paradigm. Each sweep contained four clicks where the first three clicks were of same polarity and the fourth click was of opposite polarity but with the amplitude three times the amplitude of earlier three clicks. The duration of click was 80 µsec and acoustical bandwidth was between 500 to 4000Hz +/- 5 dB @ 1000Hz.

Response Parameters

The data of the two buffers were automatically cross correlated and used to determine reproducibility of the measure of TEOAEs. The stimulus stability was more than 90% to consider the recording as valid. The response was considered present, only when the amplitude of OAEs at the individual frequency was more than 3 dB SPL with reproducibility above 80%. This was considered as the base line TEOAE response and was used as the reference.

3.7 Recording Paradigm of Contralateral Suppression of TEOAEs

Stimulus Parameters

To assess the suppression of TEOAE response seen in the presence of contralateral acoustic stimulus, Insert receiver of the audiometer was placed in the external ear canal opposite to that of the probe ear. TEOAEs were measured by presenting 50 dB SL BBN through the insert receiver. The noise was presented for a minimum of 1 minute during the TEOAE recording. It initiated and cessated with TEOAE stimulus. The SNR across frequencies were recorded after each recording. Care was taken to ensure that the position of probe was not altered during the measurement of contralateral suppression.

In the present study attempt was made to take 2 baselines – one before the presentation of contralateral noise and the other after 5 minutes of cessation of contralateral suppressor.

Response Parameters

For each groups, the testing conditions (stimulus intensity and stability, and the number of noisy presentations) and the response measurements (TEOAE amplitudes with and without contralateral noise) were averaged separately for the recordings with and without the CAS. The CAS effect of each groups was calculated as the difference between the mean TEOAE SNR with CAS and the mean TEOAE SNR without CAS. In a similar manner, the same values were calculated for the entire group.

3.8 Statistical Analysis

The data obtained was tabulated and statistically analyzed, to see the significance of difference between the means across frequencies for all the three groups. The data obtained from three groups were analyzed using Statistical Package for the Social Sciences (version 17.0). The following analyses were done to verify the objectives of the study:

1. Comparison of Mean and standard deviation of TEOAEs in baseline condition across frequencies.
2. Comparison of Mean and standard deviation of TEOAEs across four age groups in baseline condition.
3. Comparison of TEOAE-SNR across three conditions.
4. Comparison of Mean suppression amplitude across three groups.

Chapter 4

RESULTS

The aim of the present study was to compare the SNR of contralateral suppression at different frequencies, across individual who do not listen to music, who are regular music listeners, and vocal musicians. To arrive at the aim initially baseline measure of TEOAE was taken, where TEOAE amplitude, SNR and reproducibility were recorded. Then SNR of CS of TEOAE was measured in the presence of broad band continuous noise. Finally TEOAE SNR was recorded one more time in the absence of contralateral broad band noise at different frequencies. The data obtained from all the three groups (Control group, music listeners and musicians) were tabulated and analyzed using statistical package for social sciences (SPSS) software version 17. The following statistical analyses were done both within and across the subject groups.

1. Descriptive statistics for all the condition (SNR of Baseline 1, contralateral suppression and Baseline 2) at different frequencies was done to find out the mean and standard deviation for all the three groups.
2. Repeated measure ANOVA was done to compare the difference in TEOAE SNR across the three conditions for all the three groups at different frequencies.
3. One way ANOVA was done to compare the SNR of TEOAEs across the groups.

To start with, Mean and standard deviation of SNR of TEOAE across frequencies in the three age groups for the three conditions were calculated and is given in Table 4.1. The Table 4.1 shows the mean SNR of TEOAEs in baseline conditions (Baseline 1 and Baseline 2) and SNR in the presence of contralateral noise. Baseline 1 was the SNR of TEOAEs before the presentation of noise and baseline 2, after 5 minutes of cessation of noise.

Table 4.1

Mean (M) and Standard deviation (SD) of TEOAE SNR obtained at different frequencies for the three conditions and 3 groups

		Group 1			Group 2			Group 3		
Conditions		B1	CS	B2	B1	CS	B2	B1	CS	B2
1K	M	8.80	6.66	9.92	11.30	9.21	12.34	16.66	10.69	16.16
	SD	4.72	4.24	5.32	5.58	5.86	5.50	6.00	5.35	5.71
2K	M	13.01	10.49	13.93	12.86	10.88	13.71	20.11	14.39	19.20
	SD	4.33	5.06	3.46	5.53	6.07	5.38	4.34	4.18	3.91
3K	M	11.82	10.89	12.49	11.34	9.96	11.96	17.77	14.16	17.20
	SD	4.99	4.64	3.98	5.39	5.30	5.52	5.81	5.49	5.48
4K	M	8.87	8.30	10.77	9.87	8.84	10.07	14.47	11.90	14.38
	SD	6.75	5.98	5.84	4.21	4.03	4.74	5.18	5.12	4.79
5K	M	6.35	6.12	8.14	4.99	4.76	5.70	11.36	8.34	11.06
	SD	4.71	4.53	4.88	4.91	4.20	5.06	5.92	5.93	5.69
Global	M	9.17	7.79	10.50	10.18	8.83	11.19	15.61	11.59	15.55
	SD	4.52	4.14	4.28	4.48	4.09	4.10	3.68	3.35	3.61

B1: Baseline 1, B2: Baseline 2 & CS: with Contralateral suppression

4.1 Effect of Group on Baseline TEOAE SNR

Comparison across frequencies showed that mean SNR of TEOAEs is lesser at 4 and 5 kHz compared to lower frequencies. The lowest SNR was obtained at 5 kHz. This was true for all the three groups. Comparison across the three age groups showed that mean TEOAE SNR was higher in Group 3(Musician group) compared to other groups at all the frequencies. One way ANOVA was done to compare the whether the SNR of baseline TEOAEs of the three groups were different from each other. The baseline prior to the presentation of noise (Baseline 1) was taken for this purpose. Results are shown in Table 4.2.

Table 4.2

Result of one way ANOVA on baseline 1 TEOAE SNR with group (music experience) as independent variable

SNR at	df (error)	F	p
1 kHz	2 (166)	21.61	0.000*
2 k Hz	2 (166)	30.52	0.000*
3 k Hz	2 (166)	17.52	0.000*
4 k Hz	2 (166)	11.87	0.000*
5 k Hz	2 (166)	16.54	0.000*
Global	2 (166)	26.53	0.000*

(* Significant difference)

From the Table 4.2 it is clear that, the mean TEOAE SNR of Baseline 1 at different frequencies of all the three groups were significantly different from each other. Bonferroni post hoc test was done for pair wise comparison of the Mean TEOAE SNR at different frequencies. Results are depicted in Table 4.3. From the Table 4.3 it is clear that:

1. The SNR in the group 3 was significantly different from the other two groups in global measure as well as SNR at individual frequencies.
2. The group 1 and group 2 TEOAE SNR did not differ from each other at any of the frequencies.

Table 4.3

Results of Bonferroni post hoc test pair-wise comparison of TEOAE-SNR across three groups

Measure	Group	1	2	3
1 k Hz	1			
	2			
	3			
2 k Hz	1			
	2			
	3			
3 k Hz	1			
	2			
	3			
4 k Hz	1			
	2			
	3			

Measure	Group	1	2	3
5 kHz	1			
	2			
	3			
Global	1			
	2			
	3			

4.2 Effect of Condition on TEOAE SNR

In the Table 4.1, it can also be seen that among the 3 conditions, condition 2 (CS-in the presence of contralateral suppressor) had lesser amplitude compared to baseline 1 and baseline 2. This was true in all the frequencies and in both the groups. Repeated measure ANOVA was done to verify whether differences in mean SNR across the three conditions were statistically significant. In this, the three conditions (which differed in the three groups) were taken as within subject variable. Results of ANOVA showed that there is significant main effect of condition. Also, music experience was an interacting variable in this result. Results of the test are depicted in Table 4.4.

From the Table 4.4, it is clear that the TEOAE SNR in different conditions (Baseline 1 (B1), Baseline 2 (B2) and Contralateral suppression (CS) condition) varied significantly. The results (Table 4.4) showed that suppression in TEOAE-SNR was significant at 0.00 probabilities in global measure as well as at all the frequencies. From the table, it is also clear that there is significant interaction of group effect.

Table 4.4

Results of repeated measure ANOVA testing the group and stimulus effect

SNR at	Effect of condition			Interaction of group effect		
	df (error)	F	P	df (error)	F	P
1 kHz	2 (166)	90.39	0.000*	4 (83)	8.78	0.000*
2 kHz	2 (166)	86.18	0.000*	4 (83)	10.51	0.000*
3 kHz	2 (166)	35.43	0.000*	4 (83)	5.84	0.000*
4 kHz	2 (166)	30.32	0.000*	4 (83)	4.17	0.003*
5 kHz	2 (166)	25.48	0.000*	4 (83)	6.27	0.000*
Global	2 (166)	102.48	0.000*	4 (83)	13.37	0.000*

(* Significant difference)

Because there was significant interaction of the group and condition, repeated measure ANOVA was done separately for each group to understand the independent effect of condition. Result indicated that there was significant difference between the three conditions, in all 3 groups (except for 3 kHz, 4 kHz and 5 kHz in the control group), which clearly states that there was presence of contralateral suppression in all the three groups.

Results of the statistical analysis are shown in the Table 4.5. From the Table 4.5, it is clear that contralateral suppression of TEOAEs are absent at high frequencies for the control group.

Table 4.5

Results of repeated measure ANOVA comparing the conditions in each groupat different frequencies

	Measure	df	Error	F	P
Group 1	Global	2	26	9.99	0.001
	1 k	2	26	9.84	0.001
	2 k	2	26	12.58	0.000
	3 k	2	26	6.55	0.005*
	4 k	2	26	3.30	0.052*
	5 k	2	26	1.88	0.172*
Group 2	Global	2	26	40.34	0.00
	1 k	2	26	39.93	0.00
	2 k	2	26	29.40	0.00
	3 k	2	26	40.15	0.00
	4 k	2	26	70.19	0.00
	5 k	2	26	27.28	0.00
Group 3	Global	2	26	60.05	0.00
	1 k	2	26	60.92	0.00
	2 k	2	26	34.18	0.000
	3 k	2	26	17.89	0.000
	4 k	2	26	22.84	0.000
	5 k	2	26	18.88	0.000

(*No significant difference)

Results of Bonferroni test showed that in all the frequencies and global SNR, CS condition was significantly different from that of baseline 1 and baseline 2 (except at 4 kHz and 5 kHz for the control group). However, there was no difference between

the SNRs of baseline 1 and baseline 2. Since there was no significant difference between the baseline 1 and baseline 2, pair wise comparison was done only between between the baseline 1 and the CS condition. The results are shown in the Table 4.6.

Table 4.6

Represents significance of suppression in 5 different frequencies and global SNR in the 3 groups

SNR at	Group 1	Group 2	Group 3
1 kHz	S	S	S
2 kHz	S	S	S
3 kHz	S	S	S
4 kHz	NS	S	S
5 kHz	NS	S	S
Global	S	S	S

(S = $p<0.05$ NS = $p>0.05$)

From the Table 4.6, it is clear that both the listener group (group 2) and musician group (group 3) had presence of contralateral suppression at all the frequencies. But for the control group, contralateral suppression was absent at high frequencies (4k and 5 k).

4.3 Effect of Group on Suppression Amplitude

To check whether the amount of contralateral suppression was different among the groups, initially, suppression amplitudes were determined. This was done by subtracting the SNR in CS condition from that of baseline 1, and only for the

global SNR. Because Bonferroni test did not show significant difference between SNRs in baseline 1 and baseline 2, it was assumed that the results would be same with respect to baseline 2. The mean and standard deviation of the suppression amplitude are given in Table 4.6.

Table 4.6

Mean (M) and standard deviation (SD) of suppression amplitude

Group	Mean	SD
Controls (1)	1.38	2.27
Music listeners (2)	1.34	1.66
Musicians (3)	4.02	2.34

The mean data showed that the suppression was more in the group 3-Musicians compared to the other two groups. There was only a marginal difference in the mean suppression of group1-controls and group 2-music listeners. To verify the statistical significance of mean differences, one-way ANOVA was done on the suppression amplitudes derived from the global SNRs. The results indicated that there was overall difference [$(F(2,117) = 20.94, p<0.01]$ in the suppression amplitude across the 3 groups. Because there was an overall difference, pair-wise comparison was tested using Bonferroni test. Results showed that there was significant difference ($p<0.05$) between group1 and group 3, and also between group 2 and group 3. But there was no significant difference between group 1 and 2 in their suppression amplitudes.

Chapter 5

DISCUSSION

The objective of the present study was to compare the contralateral suppression in music listeners and musicians to that in control individuals. The findings of the study are discussed under the following headings.

5.1 Results of Baseline TEOAEs

Results of the study showed that the musicians had higher SNR TEOAEs compared to controls and the music listeners. This was an interesting finding that was actually not within the scope of this study. Significantly better TEOAEs in musicians indicate that the outer hair cell activity is more robust in these individuals compared to music listeners and controls.

Earlier studies have reported enhanced pitch discrimination in musicians on a behavioral paradigm (Bidelman, Krishnan & Gandour, 2011, recent among relevant studies). It could be inferred that this enhanced pitch discrimination could be partly due to enhances frequency selectivity regulated by robust outer hair cell activity seen in musicians. However, this notion needs to be experimentally investigated.

5.2 Efferent Inhibition of TEOAEs

In the present results, it was found that TEOAEs reduced in amplitude in the presence of contralateral noise compared to the baseline and post test conditions. This reduction in TEOAEs may be the result of activation of medial efferent neurons as has been reported earlier (Norman & Thornton, 1993). Activation of medial efferent neurons results in the release of acetylcholine at the synapse which, in turn, induces alterations in the shape and/or compliance of outer hair cells. These alterations can

damp micromechanical activity, reduce the sensitivity of the basilar membrane (Geisler, 1991; Neely & Kim, 1986), and thus reduce the amplitude of TEOAEs. The justification that the suppression of TEOAEs is mediated by efferent neurons is further supported by analyzing the suppression across frequencies. Figure 5.1 shows that mean suppression across frequencies and in global SNR for the 3 groups.

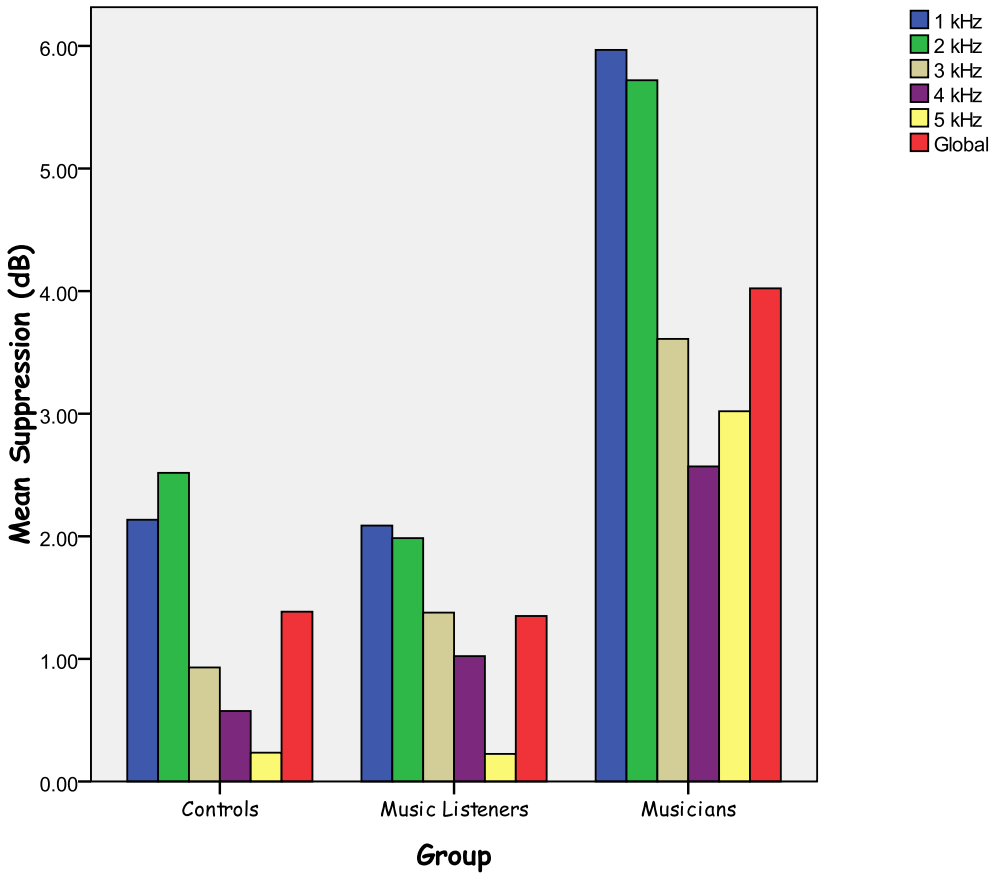

Figure 5.1: Shows that mean suppression across frequencies and in global SNR for the 3 groups.

As can be seen in Figure 5.1, in all the three groups suppression was maximum at 1 and 2 kHz, relatively less at 3 kHz and least at 4 kHz. This shows that the suppression mediated by the medial efferents. Medial and lateral efferents have different patterns of innervation along the length of the cochlea. Medial efferent

innervation is largest near the center of the cochlea with crossed innervation biased towards the base compared to the uncrossed innervations. In contrast lateral innervation is relatively constant in the center and base of the cochlea (Guinan,Warr & Norris,1984; Liberman, Dodds & Pierce,1990).

The mean amplitude of suppression found in the present study in the group 1 (1.38 dB) and group 2 (1.34 dB) were similar to that reported by Hood et al. (1996). However, magnitude of suppression found in musicians (4.02) was higher than that reported in earlier reports (Hood et al, 1996; Sandeep & Jayaram, 2008; Badariya & Sandeep, 2011).

The notion that the efferent inhibition is triggered only in the presence of contralateral noise, is also supported in this study. TEOAEs were measured 2 times in this study; once before suppression condition (baseline 1) and second time after 5 minutes of cessation of the suppressor (Baseline 2). Results showed that there was no significant difference in the 2 baseline conditions. Hence, it can be concluded that the suppression of TEOAEs is triggered by the contralateral noise only.

5.3 Effect of Music Experience on Efferent Inhibition

The 3 different groups of subjects taken in the study were to understand whether musical experience enhances efferent inhibition. If yes, is the enhancement due to listening to music on a regular basis or due to practicing actively (singing) on a regular basis. Results showed that there was a significant difference between controls and musicians, and also between listeners and Musicians. Musicians had higher amplitude of suppression than the other 2 groups. However, there was no significant difference between controls and listeners in their suppression amplitudes.

The finding that musicians have greater suppression than controls is in agreement with the earlier studies (Perrot, Micheyl, Khalfa & Collet, 1999; Kumar, Hegde & Mayaleela, 2010). Thus it can be inferred that formal music training facilitates neural plasticity in efferent neurons and enhances efferent inhibition. Efferent system has positive influence on auditory physiology (Ashmore, 1987; Canlon & Brudin, 1991). It is reported that efferent innervation of outer hair cells controls the cochlear amplifier, reduces the masking effects of noise, and protects the cochlea from the negative effects of acoustic over stimulation (Geisler, 1974; Kumar & Barman, 2002; Wiederhold & Kiang, 1970). It is also reported to enhance speech perception in noise (Kumar & Vanaja, 2004).

In terms of suppression amplitude, it was seen that the mean suppression of global SNR in musicians was 4 dB which is much higher than what is reported by Perrot, et al. (1999). This difference could be because of the difference in the number of years of formal training.

In the present study, there was no difference between controls and music listeners in their mean suppression amplitudes. But this finding should not be interpreted as the absence of neural plasticity in music listeners. As can be seen in Figure 5.1 and Table 4.6 (chapter 4), suppression was significant at 4 and 5 kHz in music listeners while it was not significant in controls. That is, in music listeners, although there is no significant difference in the suppression of global SNR when compared to controls, there was significant suppression at higher frequencies that was absent in controls. Therefore, it can be concluded that efferent inhibition is enhanced just by listening to music but this enhancement will not be equal that by formal training in music.

From these findings it can be inferred that, although olivo cochlear neurons primarily originate from superior olivary complex, it is influenced by the centrifugal pathway. Given that the MOCB constitutes a final string in chain of descending auditory pathways originating in the auditory cortex, it is conceivable that differences in the centrifugal activity between musicians, music listeners and controls (who do not listen to music) proceed from differences in the degree of activation of more central auditory structures. Thus the findings of the study support a link between the activity of central nervous system and olivocohlear systems.

Chapter 6

SUMMARY AND CONCLUSIONS

The present study was started with an objective to compare the amplitude of contralateral suppression across individuals who do not listen to music, who are regular music listeners and vocal musicians. The purpose was to examine the effects of music exposure on efferent inhibition.

A total of 60 adults with normal hearing sensitivity participated in the study. They were divided into 3 groups of 20 each, based on their musical experience. Group 1(Control) would not listen to music on regular basis, Group 2 (music listeners) would listen to music as hobby on regular basis since several years, and Group 3 (Musicians) formally practiced vocal music for more than 5 years.

In all the subjects, TEOAEs were recorded in 2 baseline conditions (without contralateral noise and one suppression condition (with contralateral noise). TEOAEs were measures in terms of global signal to noise ratio (SNR) and SNR at 1 kHz, 2 kHz, 3 kHz, 4 kHz, and 5 kHz. The mean SNRs were compared across the 3 conditions and across 3 groups on repeated measures ANOVA and One-way ANOVA.

Results showed a significant difference in SNR across the 3 conditions. The finding has been attributed efferent mediated suppression of the outer hair cell activity. Among the 3 groups, there was enhanced baseline TEOAEs in Musicians which has been inferred as the possible contributor for the enhanced pitch discrimination and frequency selectivity in musicians.

Suppression amplitude was significantly high in Musicians. Thus, it can be inferred that formal music training facilitates neural plasticity in efferent neurons and enhances efferent inhibition. Also, in music listeners, there was significant suppression at higher frequencies which was absent in controls supporting enhanced efferent inhibition due just listening to music.

From these findings it can be inferred that, although olivo cochlear neurons primarily originate from superior olivary complex, it is influenced by the centrifugal pathway. The findings of the study support a link between the activity of central nervous system and olivocohlear systems.

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