EFFECT OF AUDITORY ATTENTION ON CONTRALATERAL SUPPRESSION OF DISTORTION PRODUCT OTOACOUSTIC EMISSIONS (DPOAES)

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May, 2014

CERTIFICATE

This is to certify that the dissertation entitled “**Effect Of Auditory Attention On The Contralateral Suppression Of Distortion Product Otoacoustic Emissions (DPOAEs)”** is a bonafide work submitted in part fulfillment for the Degree of Master of Science (Audiology) of the student (Registration no. 12AUD0002). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any Universities for the award of any Degree or Diploma.

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CERTIFICATE

This is to certify that the dissertation entitled "**Effect Of Auditory Attention On The Contralateral Suppression Of Distortion Product Otoacoustic Emissions (DPOAEs)"** has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in other University for the award of any Degree or Diploma.

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DECLARATION

This is to certify that this dissertation entitled “**Effect Of Auditory Attention On The Contralateral Suppression Of Distortion Product Otoacoustic Emissions (DPOAEs)”** is the result of my own study under the guidance of Dr. Ajith Kumar U, Reader, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier in other University for the award of any Degree or Diploma.

Mysore **Register no:** 12AUD002

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CHAPTER 1 - INTRODUCTION

The mammalian auditory system consists of a series of efferent and afferent neural pathways that originate from the cortex and terminate at the cochlea and vice-versa. The efferent pathway which arises from the cortex extends till the level of the cochlea and also mediates the functioning of the cochlea. This indirect pathway (from the cortex to the cochlea) exists via the olivocochlear system. In 1946, Grant Rasmussen reported his discovery of the olivocochlear (OC) system. The olivocochlear bundle (OCB) emerges from the caudal brainstem in the superior olivary complex and projects toward the cochlea (Brown, de Venecia, & Gunian Jr., 2003).

Efferent system can be activated both acoustically as well as electrically. It has been reported that electrical stimulation of the medial olivocochlear (MOC) bundle at the floor of the fourth ventricle inhibits cochlear and neural potentials (Galambos, 1956; Gunian & Gifford, 1988; Siegel & Kim, 1982). In acoustic stimulation, broadband noise presented to the contralateral ear reduces the amplitude of responses like compound action potential (Folsom & Owsley, 1987; Libermann, 1989), spontaneous rate of auditory nerve (Buno, 1978) and otoacoustic emissions (Berlin et al, 1994; Collet et al, 1990). As the otoacoustic emissions are from the cochlea and reflect the outer hair cell (OHC) functionality, it provides an index of the changes in the cochlear function as MOC fibers are activated (Abdala et al., 1999) by contralateral acoustic stimulus. As more invasive techniques are not possible, contralateral inhibition of otoacoustic emissions

(OAEs) have become an important tool in studying the effects of the MOC fibers in humans.

When distortion product otoacoustic emissions (DPOAEs) are recorded with high frequency resolution, they exhibits a pseudo-periodic variation in levels, which is characterized by the peaks (maxima) and dips (minima) as a function of frequency and is referred to as fine structure. Peaks and dips in the DPOAE gram are thought to be because of constructive and destructive interference between two different sources involved in DPOAE generation. The first source is located at the region of overlap of traveling waves of f_1 and f_2 and is caused by inter modulation distortion. The second source is located at the characteristic frequency region of DPOAE and is generated due to linear reflection. Thus, the ear canal DPOAE is a composite signal comprised of a nonlinear distortion component and a linear reflection component. Although DPOAEs are generally reduced in level by the contralateral acoustic stimulus (CAS), sometimes an enhancing effect is also reported (Deeter, Abel, Calandruccio & Dhar, 2009; Muller, Janssen, Heppelmann & Wagner, 2005; Lisowska et al., 2002). Zhang et al (1997) observed that enhancement of DPOAE magnitudes upon stimulation of MOC fibers was exclusively at the minima of the DPOAE fine structure. These results were later corroborated and extended by other research groups. Differential influence of MOC activation on the two components of the DPOAE signal is thought to be responsible for observed bipolar (inhibition and enhancement) changes in the DPOAE magnitudes upon the stimulation of MOC efferent by CAS. Therefore, in the literature it recommended to measure the contralateral inhibition of DPOAEs either at peaks or at dips in the DPOAE fine structure.

The functions of the MOC auditory pathway can be described as: (1) Improving frequency selectivity by selectively inhibiting hair cells which lie on the margins of the basilar membrane displacement peaks (Capps & Ades, 1968), (2) Improving the signal to noise ratio by anti-masking (Jacobson, Kim, Romney, Zhu, & Frisina, 2003; Micheyl & Collet, 1996; Winslow & Sachs, 1987, 1988), (3) Maintaining the cochlea in an optimal electromechanical state for acoustic signal processing. This is done by changing the OHC motility (Johnstone, Patuzzi, & Yates, 1986; Maison, Micheyl, Chays, & Collet, 1997), (4) Protection of the cochlea from over-stimulation by reducing OHC activity. This results in a temporary threshold shift for a short duration and it happens for high intensity sounds of high frequency (above approx. 8000 Hz) (Maison & Liberman., 2000; Rajan., 1988; Rajan & Johnstone., 1988;Reiter & Liberman., 1995), (5) Mediating selective attention (Museik., 1986)

Attention and Efferent system

Meric, Micheyl, & Collet (1996) found that subjects who were initially measured to have larger contralateral evoked OAE amplitude with a no attention task had the strongest contralateral suppression during visual attention tasks. The authors viewed this as a possible indication of better MOC functioning in certain subjects when compared to subjects with reduced evoked OAE amplitudes and suppression and they also concluded that the efferent system modulates auditory attention. De Boer & Thornton (2007) measured the inhibition of OAE amplitudes in (1) no task, (2) passive visual attention task, (3) active visual attention task and (4) active auditory attention task. A smaller amount of suppression was observed during the active auditory task compared to the no-task condition. There was no significant difference in suppression between the no-task condition and the two non-auditory tasks. This suggests that the main effect of task reflects a specific effect of auditory attention. This study suggests that the MOCB activity is inhibited by top-down influences when selective attention is given to the ear receiving the stimulus

Need for the study

Literature has shown that activation efferent auditory pathway helps in anti masking (e.g. speech perception in noise) and selective auditory attention. These studies have evaluated the two functions of the efferent auditory system independently. However, in day today environments both of these functions are interrelated. Furthermore, in most of the studies functioning of the efferent auditory system was not assessed when the person is performing active speech in noise detection task.

Therefore, the present study aims to evaluate the functioning of efferent auditory system as measured by contralateral suppression of DPOAEs, while the participant performs active speech perception in noise task. As both selective attention and anti-masking are required during speech perception in noise and measuring the activity of efferent auditory system during this task will help in assessing the role of efferent auditory system in anti-masking and selective auditory attention.

Aim of the study

The present study was carried out to investigate the effect of attention on contralateral inhibition of DPOAEs.

Objectives of the study

The following were the objectives of the study

a. To measure the magnitude of contralateral inhibition of DPOAEs when participant actively identified the words presented in white noise stimulus at 0dB signal to noise ratio to the contralateral ear.

b. To measure the magnitude of contralateral inhibition of DPOAEs when the contralateral acoustic stimulus is same as above but time reversed

c. To measure the magnitude of contralateral inhibition of DPOAEs when the contralateral acoustic stimulus is time reversed and participant performs a visual symmetry judgment task.

CHAPTER 2 – REVIEW OF LITERATURE

There are primarily two groups of efferent neurons: a) the caudal group which forms the olivocochlear bundle and, b) the rostral group which forms the cortical efferent system. The rostral efferent system is at the level of the primary auditory cortex and the association areas. The efferent fibers leave these auditory layers and project to the inferior colliculus. The caudal efferent system consists of the olivocochlear bundle and it involves the superior olivary complex and the auditory structures below that. The caudal efferent system has two subsystems- the medial olivocochlear system (MOC) and the lateral olivocochlear system (LOC). The MOC terminates at the outer hair cells (OHC) whereas the LOC terminates on the auditory nerve within the cochlea (Libermann & Gunian, 1998).

The micro-mechanical properties of the outer hair cells (OHCs) play an important role in the transduction process. The OHCs receive direct synapses from medial efferent neurons of the olivocochlear bundle (OCB), and hence allows the cochlear mechanics to be altered by the descending inputs via the medial efferent system. Thus the dynamic properties of the cochlea are mediated by the regulatory actions of the outer hair cells which in turn is under the control of the medial olivocochlear system as the efferent fibers terminate at the OHCs. This alteration in the cochlear mechanics can occur in a frequency-specific manner, since the afferent and efferent fibers with the same characteristic frequencies innervate the same cochlear region and have similar tuning curves. Efferent activation evoked by contralateral acoustic stimulation (CAS) will affect

OHC amplification and subsequent measures of distortion-product otoacoustic emissions (DPOAEs).

Thus, the cochlear-efferent system provides the functional architecture for top-down control of sensory processing at the periphery. Activation of the MOC system increases the threshold of the auditory periphery through modulations of the OHC function. In the absence of MOC stimulation, the OHCs act like cochlear amplifiers, by amplifying the vibrations in the cochlea in response to sounds. This action results in bending of the stereocilia causing opening of the tip links and release of neurotransmitters from the inner hair cells (IHC) base which can result in excitation of the auditory nerve fibers which are in contact with the IHCs. The activation of the MOC fibers on the OHCs changes the OHC response to acoustic activation thereby decreasing their contribution to the amplification process. That is, the MOC reduces the gain of the cochlear amplifier because of which higher levels of sound are required to stimulate the auditory nerve. This value can be as much as 30 dB when the MOC is electrically activated. The sound frequencies mostly affected are from mid to high frequencies (Libermann & Gunian, 1998). MOC fibers can be activated both acoustically as well as electrically. It has been reported that electrical stimulation of the MOC bundle at the floor of the fourth ventricle inhibits cochlear and neural potentials (Galambos, 1956; Gunian & Gifford, 1988; Siegel & Kim, 1982). In acoustic stimulation, broadband noise presented to the contralateral ear reduces the amplitude of responses like compound action potential (Folsom & Owsley, 1987; Libermann, 1989), spontaneous rate of auditory nerve (Buno, 1978) and otoacoustic emissions (Berlin et al, 1994; Collet et al, 1990). Sectioning of the olivocochlear bundle (OCB) shows that cochlear output is not affected by contralaterally presented broadband noise (Libermann, 1989). As the otoacoustic emissions are from the cochlea and reflect the OHC functionality, it provides an index of the changes in the cochlear function as MOC fibers are activated (Abdala et al 1999). Contralateral suppression of DPOAEs have shown an average of 0.5 to 2 dB reduction in the DPOAE amplitude and this reduction depends on the level and frequency of the primary tones (Abdala et al, 1998; Moulin et al, 1993; Williams & Brown, 1997).

Abdala, Ma & Sininger (1999) showed that presentation of contralateral acoustic stimulation (broadband noise) reduced the output of the OHCs. This study was conducted on human adults with normal hearing sensitivity, full term and premature neonates. DPOAEs were measured at three f1 frequencies: 1500, 3000 and 6000 Hz with and without contralateral broadband noise. Results indicate that contralateral suppression was present at 1500 and 3000 Hz but was absent at 6000 Hz for all ages. The suppression effect was presumed to be due to the activation of the medial efferent system through the OHCs. The contralateral suppression was averaged between 1 to 2 dB. The DPOAE suppression was more pronounced at low stimulus levels and was present only at mid and high frequencies. However, other studies have reported both inhibition and enhancement of DPOAE amplitudes upon the presentation of contralateral noise. This effect is due to the interference from the two kinds of DPOAE sources which are non-linear distortions and linear reflections. The nonlinear distortions are caused by the traveling wave and the linear reflections are from the micro-mechanical perturbations (Kalluri & Shera, 2001). According to the backward traveling wave theory, the distortion component is generated at the region of overlap near f2. The energy of the distortion component travels bidirectionally, one is basally towards the ear canal and the other is apically towards the frequency location of 2f1-f2. At this frequency of 2f1-f2, the energy undergoes linear coherent reflection. The reflection component travels toward the ear canal. At the stapes some distortion product energy passes on to the middle ear, while some energy is reflected due to the impedance mismatch and causes multiple reflections (Dhar et al, 2002). According to this theory 2f1-f2 DPOAE is a vector sum of the distortion component, the reflection component and multiple internal reflections. The resulting interference pattern leads to variation in the sound pressure level and phase of the composite DPOAE. This variation in the sound pressure level is quasi periodic with frequency and is known as the fine structure. (Reuter & Hammershoi, 2006). The DPOAE fine structure is characterized by consistent maxima and minima with depth of notches up to 20 dB (Gaskill & Brown, 1990) and a periodicity of 3/32 octave (He & Schmiedt, 1993; Mauermann et al, 1997). Mauermann et al (2004) suggested that the fine structure would help in the identification of early hearing loss.

Measurements using the fine structure separate the distortion and reflection source components. The studies based on fine structure (Abdala et al, 1998; Deeter et al, 2009) have found that, (1) MOC stimulation inhibits both the distortion and linear components and also shifts their phase. The reflection component is found to be more affected than the distortion component, (2) the DPOAE dips are produced by the phase cancellation of the distortion and reflection components. The MOC induced phase changes moves the cancellation frequencies upward, (3) reduction of cancellations specially at the dips produces MOC induced DPOAE enhancements and also consistent DPOAE reductions are found when the measurements are made at the fine structure peaks (Gunian, 2010)

Functional Significance of the Efferent System

The proposed functions of the efferent system are: (1) Protection from acoustic over stimulation, (2) maintaining the cochlea in an optimal electromechanical state, (3) sharpening the frequency resolution, (4) improving the signal to noise ratio by means of anti-masking, and (5) in selective attention.

Due to the inhibitory nature the efferent system, it has been reported to show a protective role in the auditory system and it has also been reported to enhance the ability of speech perception in background noise (Rajan, 1990; Micheyl & Collet, 1996). The study by Cody and Johnstone (1982); Rajan and Johnstone (1988) demonstrated that continuous acoustic stimulation evokes an MOC response and this response protects the ear from noise trauma. They found that this protection mechanism does not take place when the OCB activation is suppressed. Kujawa and Liberman (1997) showed that the noise induced hearing loss is more severe in the auditory systems with severed OCB.

The activity of the MOC enhances the perception of speech signals in noise. Giraud, Garnier, Micheyl, Lina, Chays, & Chery-Croze (1997) conducted a study to measure the anti-masking ability of the efferent system. Subjects with normal hearing abilities were compared with subject who had undergone vestibular neurectomy. The effectiveness of the efferent system was assessed through contralateral suppression of otoacoustic emissions along with speech in noise intelligibility. The speech detection in the presence of noise ability was compared between both the subject groups. Poor speech-in-noise ability was seen for the subjects who were neurectomized when compared to the subjects with normal hearing abilities. Subjects with normal hearing reported improved speech perception in the presence of noise upon the activation of the MOC. Hence they concluded that the efferent system plays a role in anti-masking that is, it helps in the improvement of the speech perception abilities in the presence of noise.

Zeng, Martino, Soli, & Linthicum (1999) evaluated the effectiveness of the efferent system in auditory perception in individuals who had undergone vestibular neurectomy. They considered six subjects with vestibular neurectomy who had mild to moderate hearing loss. The performance of the ear that underwent the surgical procedure was compared with the normal ear's performance for different tests like: pure tone intensity discrimination in quiet and during forward masking, detection and intensity discrimination of brief tones at onset and steady state of a diotic broadband noise and sentence recognition in noise. The results of pure tone thresholds, intensity discrimination in quiet and recovery from forward masking were reported to be normal. It was found that vestibular neurectomy worsened the intensity discrimination in noise in the steady state condition and not in the onset condition. These results suggest that the efferent system is involved in the auditory perception in noise.

Efferent System and Attention

Giard, Fort, Mouchetant-Rostaing & Pernier (2000) used a different stimulus paradigm to check the effect of attention on evoked otoacoustic emissions (EOAEs). He presented tone-pips of 1 kHz and 2 kHz at 15 dB SL to opposite ears. The auditory attention task was to listen to tone pips of 1 kHz in one ear and to ignore the 2 kHz tone-pips in the other ear while responding to target tone-pips which are at a higher intensity than the other two. The intensity of the target stimuli was varied subject wise so as to achieve 70-80% detection rate. The EOAEs were obtained for two conditions: (1) when the subject attended to the 1 and 2 kHz tone-pips and when the subject ignored the 1 and 2 kHz tone-pips. He found that the amplitude of the EOAEs were reduced, even though the effect was small, when the 1 and 2 kHz tone-pips were ignored as compared to the attended condition.

Maison, Michely & Collet (2001) evaluated the effect of focused auditory attention on the cochlear micro-mechanics in humans. They measured EOAE for a tone-in-noise detection task. Otoacoustic emissions were elicited by tones of 1 kHz and 2 kHz in the ipsilateral ear during which the subject had to detect probe tones at a given frequency in background noise in the contralateral ear. It was hypothesized that frequency-specific activation of the efferents in the contralateral ear will be depicted as frequency specific variations in EOAE amplitude in the ipsilateral ear. The subjects were made to count the number of tones. It was seen that the EOAE amplitude suppression increased corresponding to the tone frequency. The results revealed that a huge efferent system activation was seen at the frequencies corresponding to which auditory attention was paid. The study hence concludes that the efferent system is stimulated by contralateral stimulation and plays a role in selective auditory attention.

A study by Meric & Collet (1992) tested the effect of auditory and visual attention on evoked otoacoustic emissions. They found that there was a significant effect of visual attention on the EOAEs with a general decrement of 0.35 dB.

Froehlich, Collet & Morgon (1993) conducted a study to determine the effect of visual and auditory task on the cochlea using transient evoked otoacoustic emissions

(TEOAEs). It was seen that the TEOAE amplitude reduced during visual and auditory attention task for all the 13 subjects who underwent testing. For the visual attention task, the TEOAE amplitude was found to reduce mainly in the 960 Hz to 1920 Hz range whereas for the auditory task this reduction was seen in the frequency range of 1920 Hz to 2880 Hz. They concluded that selective attention which happens through the medial olivocochlear system, modifies the micro-mechanical properties of the cochlea. Also the visual and auditory attention acts on different areas of the cochlea.

De Boer & Thornton (2007) studied the effect of subject task on contralateral suppression of click evoked otoacoustic emissions (CEOAEs). They tried to see if the tasks performed by the subjects during the recording have an effect on the contralateral suppression. The suppression of the CEOAEs was carried out under four different task conditions: (1) no task, (2) passive visual attention task, (3) active visual attention task and (4) active auditory attention task. The otoacoustic emissions (OAEs) were evoked with 50 and 60 dB SPL clicks. The passive visual task included the subject watching a DVD with subtitles and the active visual task required the subject to respond to visually presented sums. The active auditory task demanded the subjects to detect tone pips in the OAE evoking click train. A major effect of the subject task was found on the change in CEOAE input-output slope due to contralateral noise. This showed a smaller amount of suppression during the active auditory task compared to the no-task condition. There was no significant difference in suppression between the no-task condition and the two non-auditory tasks. This suggests that the main effect of task reflects a specific effect of auditory attention. This study suggests that the MOCB activity is inhibited by top-down influences when selective attention is given to the ear receiving the stimulus.

In contrast there are few studies which have reported that there is no effect of auditory as well as visual attention on the strength of the EOAEs.

Avan & Bonfils (1992) tried to determine the relation between attention and cochlear micro-mechanics. They took twenty normal subjects and measured distortion product OAEs and stimulus frequency OAEs between 1 and 4 kHz in the presence and absence of a visual attention task. In the visual attention task, two alphabets "O" and "Q" were randomly given on a computer screen at a rate of 2/s for 5 minutes and the subjects were asked to count the number of occurrences of the alphabet "Q". The EOAE responses were measured before the task, during the task as well as after the task. The recordings before and after the visual task were carried out in darkness. No significant changes in the EOAEs were observed in this study. They concluded that selective attention had negligible effect on the peripheral system.

Michie, LePage, Solowiji, Haller, & Terry (1996) evaluated the relationship between evoked otoacoustic emissions and selective attention. They conducted a series of six experiments using tone-pip EOAEs. In each of the experiment, EOAEs were generated by 1 or 2 kHz tone-pips for both the attended and unattended conditions. In experiments 1-4, a non-linear stimulus difference method was used to record EOAEs. In experiments 1-5, 1 and 2 kHz tone -pips were given to the same ear and the difficult level of the task was varied to ensure that adequate amount of attention was being given to the task and/or contralateral noise was presented. In experiment 6 the 1 and 2 kHz stimuli were given to the opposite ears. They reported that there were no attention effects on cochlear mechanics in any of the above mentioned experimental conditions.

Scharf, Magnan, & Chays (1994, 1997) conducted behavioral evaluations on patients who had undergone vestibular neurectomy. The hearing loss in the subjects did not exceed a mild degree. The normal ear and the surgery ear were compared for a series of psychoacoustic functions like: a) detection of tones, b) intensity discrimination, c) frequency selectivity, d)loudness adaptation, e) frequency discrimination in tonal series, and f) in-head lateralization. The findings of the subjects were normal in all of the measures. The only abnormal finding was that the subjects could detect signals at irrelevant frequencies. This finding was attributed to impaired ability to maintain attention in the required frequency area. It was concluded that this reduced ability was due to the absence of a functioning olivocochlear system (OC) system and hence they conclude that OC system helps in selective attention.

In literature there are mainly two views regarding the relationship between the olivocochlear system and attention. The first view states that OCB functioning takes place in an inter modal attentional mechanism where the peripheral responses are inhibited while a visual attention task is carried out (Maison, Michely & Collet, 2001). There are few studies which report of responses of neurons in cochlear nucleus changing with visual stimulation in awake cats (Hernandez-Peòn, Scherrer & Jouvet, 1956) and also recording at round window of awake cats reduced due to visual attention task (Glenn & Oatman, 1977; Oatman, 1971, 1976; Oatman & Anderson, 1977, 1980).

According to the second view, the OCB activation suppresses the peripheral auditory activity to enhance the information in the other regions. This view was supported from studies showing that the amplitude of EOAE at a given frequency may differ depending on whether this frequency is the target of auditory attention. The EOAEs were smaller when the stimulus used to elicit them was ignored as compared to when attention was given to the stimulus (Giard, Collet, Bouchet, & Pernier, 1994).

Hence literature has shown that EOAE amplitudes reduce when subjects are engaged in a visual task and that the vice-versa can also happen. The findings which are in support of the hypothesis that EOAE amplitudes reduce under attentional control strongly suggested the existence of a top-down attentional control mechanism operating through centrifugal projections to the cochlea (probably through the medial efferent system). However, the procedures (comparison of the EOAE amplitudes between a passive listening condition and an active task) did not reveal whether the observed effects were due to a genuine effect of selective attention or to a change in nonspecific arousal during task performance.

Hence there is a need for further studies to elucidate the effect of a selective attention task on the contralateral suppression of otoacoustic emissions.

CHAPTER 3 - METHOD

This study was carried out to determine the effect of attention, both auditory and visual, on the contralateral inhibition of distortion product otoacoustic emissions (DPOAEs)

Participants

Thirty adults (15 females and 15 males) between the age ranges of 18-25 years participated in the study. All the participants in the study had hearing thresholds within 15 dB HL at octave frequencies between 250 Hz to 8000 Hz and 'A' type tympanograms (static acoustic admittance between 0.5 to 1.75mmho and peak pressure between +60 to -100 daPa) in both ears. All the participants included in the study had bilateral acoustic reflex thresholds above 60 dB SPL for click stimuli and DPOAEs with 6 dB SNR for frequencies between 1000 Hz and 8000 Hz. Participants with any known otological or neurological problems were not included in the study. All tests were conducted in an acoustically treated room. The participants were compensated for their time with refreshments.

Equipment

A calibrated two channel Grason-Stadler Incorporation (GSI-61) diagnostic audiometer with Telephonics TDH 50P supra-aural headphones housed with EC054 ear cushions was used for air-conduction threshold estimation, speech audiometry and for finding out uncomfortable level for all the participants. Radio ear B-71 bone vibrator connected with the same audiometer was used for bone-conduction threshold estimation.

Calibrated Grason-Stadler Incorporation Tympstar middle ear analyzer with default probe assembly and contralateral insert earphones was used for conducting tympanometry and reflexometry. Calibrated Otoacoustic Emission Analyzer ADS+DP2000 from the Mimosa Acoustics/ Etymotic Research, was used for measuring DPOAEs and to measure contralateral inhibition of DPOAEs. DPOAE stimulus was delivered via a calibrated Etymotic ER 10-C insert earphone. The Etymotic ER10C probe consist of two miniature transducers for emitting acoustic stimuli, and a low-noise microphone to record sound in the ear canal. A laptop connected to ER-2 insert earphones with foam ear tips were used for delivering the contralateral stimuli.

Stimulus Description

DPOAE stimulus.

A computer based DPOAE analyzer (Cubedis /ER10-C instrumentation, Mimosa Acoustics/ Etymotic Research, USA) was used to record DPOAEs. DPOAEs were recorded with the f_2/f_1 ratio of 1.20 and intensities of two primaries were L_1/L_2 = 65/55 dB SPL. The DPOAEs were measured from 1000 Hz to 8000 Hz* with 50 points per octave resolution. DPOAEs were measured at a total of 151 frequencies (individual frequency pairs on which DPOAEs were measured are given in *Appendix A).

The instrument generated two pure tones digitally which were delivered through the transducer ER10C into the external ear canal. The output tones are scaled so that the pressure in the ear canal is maintained at a constant SPL. The sounds in the ear canal are picked up by the low-noise microphone and passed to the A/D converter in the Audio processing unit. Software in the DSP simultaneously averages the responses in real time in order to average out the noise.

Prior to measurement of the DPOAE, the instrument performs in the ear calibration. In calibration a chirp stimulus is given as the output from each of the ER10C probe channels twice with a pause between each. The pressure frequency responses in the ear canal are measured and displayed. The transfer function displays the signal output in dB SPL per volt RMS as a function of frequency. The frequency range of the calibration window reflects the frequency band of the protocol being used. Two curves are obtained for each ear, one for each channel. The shape of the curves changes with the size and shape of the ear canal and the ear tip insertion depth. An error message will appear in cases of high background noise, probe blockage or if any other measurement problems are detected. For each channel, the repeated calibration is matched with the initial calibration to assess the reproducibility. During the 1 second pause between the two calibration chirps, the noise floor is estimated. This noise floor is also plotted in the DP-gram.

Stimuli for contralateral inhibition.

Stimuli for contralateral inhibition consisted of:

1. White noise presented at 60 dB SPL
2. Words presented in noise at 0 dB SNR. English words** taken from three lexical categories with forty words from each category making an overall of 120 words (** Appendix B) were mixed with white noise at a signal to noise ratio of 0 dB

SNR. These words were given to 5 individuals and they were asked to classify it according to the categories that they could associate it with, to make sure that the words could be reliably categorized. These words were then randomized using a random number generator function in Microsoft Excel. The words were recorded in Adobe Audition 3 in a sound treated room. This recording was mixed with white noise at 0 dB SNR using Matlab software.

3. Time reversed version of the same stimuli. In the time reversed version, the stimuli is reversed from right to left so that it is played backwards and this was created using Adobe Audition 3.

Contralateral stimuli were presented through ER2C insert earphones. The earphones were connected to a USB sound wave 7.1 audio adapter which was connected to a Dell laptop. The output of the laptop was routed through a calibrated audiometer and stimuli were presented at an overall intensity of 60 dB SPL.

Test environment

The testing was carried out in a sound treated room with noise levels within the permissible limits (ANSI S 3.1; 1991).

Procedure

Basic audiological evaluation.

1. Pure-tone thresholds were obtained using modified version of Hughson and Westlake procedure (Carhart &Jerger, 1959) at octave frequencies between 250 Hz to

8000 Hz for air conduction using calibrated TDH-50 P headphones and between 250 Hz to 4000 Hz for bone conduction using calibrated B-71 bone conduction vibrator.

2. Ascending method was used to determine participant's uncomfortable level for both ears using speech stimuli that was presented through headphones.

3. Immittance audiometry was carried out with a probe tone frequency of 226 Hz. Ipsilateral and contralateral acoustic reflexes thresholds were measured for clicks.

Results of these measures were used in the subject selection as described above.

Contralateral inhibition of DPOAE.

DPOAEs amplitudes were measured using the stimulus and acquisition parameters described above. Before starting any measurement, an in-the-ear calibration was done. This was done for both the ears for all the conditions. This calibration evaluates the fitting of the probe in the ear canal, assesses the proper functioning of the system and ensures that the signal levels are at the accurate levels at the microphone across all the testing frequencies and hence this permits repeatable measurements over time.

After the in the ear calibration baseline DPOAE assessment was carried between 1 kHz and 8 kHz at 50 points/octave resolution. The testing was done from high to low frequencies. The measurement at each frequency point involves delivering two primary pure tones *f1* and *f2* at 65 and 55 dB SPL with an f_2/f_1 ratio of 1.2. The signal duration increases from 4 seconds at 4 and 6 kHz to 6 seconds at 3 kHz, to 8 seconds at 2 kHz to counteract the higher noise floor seen at lower frequencies. The sounds in the ear canal are received by the microphone and sent to the computer for analysis.

After the base line measurement, DPOAE amplitudes were measured again in presence of:

a. 60 dB SPL white noise which was routed through a calibrated audiometer using button type masking insert to the contralateral ear.

b. An auditory identification task wherein the participants were made to listen to English words mixed with white noise at 0 dB SNR presented to the contralateral ear. The subjects were made to listen to these words and were asked to write down the words that they could identify as falling in a specific lexical category e.g. animals, common objects. The written responses were then verified to make sure that the subjects had identified at least 85% of the words correctly. This was done to ensure that they were engaged in the auditory attention task. Participants who received less than 85% scores were discarded from the study.

c. Time reversed version of the previously mentioned stimuli (b), presented to the contralateral ear.

d. Stimuli described in 'c' presented to the contralateral ear along with the visual identification task. Visual identification task was carried out using Paradigm software. Here the participants were given a symmetry judgment task. In this task the participants were shown two pictures on a laptop screen and they were asked to press a particular arrow to denote whether the pictures were symmetrical or not.

The probe was not removed between these measurements unless the system indicated that the probe fit was altered.

CHAPTER 4 - RESULTS

Primary aim of the study was evaluate the effect of attention on contralateral inhibition of otoacoustic emissions (OAEs). For this purpose distortion product otoacoustic emissions (DPOAEs) were measured in with and without contralateral acoustic stimuli (CAS). Contralateral acoustic stimuli used were a) white noise, b) words in noise c) time reversed words in noise.

Baseline DPOAE Measurement

DPOAEs were analyzed for peaks in the fine structure according to guide lines provided by Abdala, Mishra & Williams (2008). Example of the DPOAE data from a representative participant is shown in Figure 4.1 and 4.2. Figure 4.11 shows original DPOAE recording. In Figure 4.1 distinct fine structure of the DPOAEs can be seen with peaks and trough. Figure 4.2 shows the smoothed DPOAE fine structure for the same participant. For smoothing of the data, every three successive data points were averaged to calculate the noise floor and DPOAE amplitude. Data points where signal to noise ratio was less than 6 dB was excluded from the analysis. From this data, peak or the maximum in the fine structure was measured. For the purpose of DPOAE peak identification 1000 Hz to 8000 Hz frequency range was divided to 1/3 octave bands. Maximum or peaks were identified as DPOAE frequencies with maximum amplitude in every 1/3 octave band. Thus, a total of 9 peaks in the DPOAEs were identified for each participant. Figure 4.3 shows the frequencies and amplitude of DPOAEs at peaks for the participant with a fine structure depicted in Figure 4.1. Inhibition magnitudes were measured at these peak/maximum frequencies in all subsequent conditions.

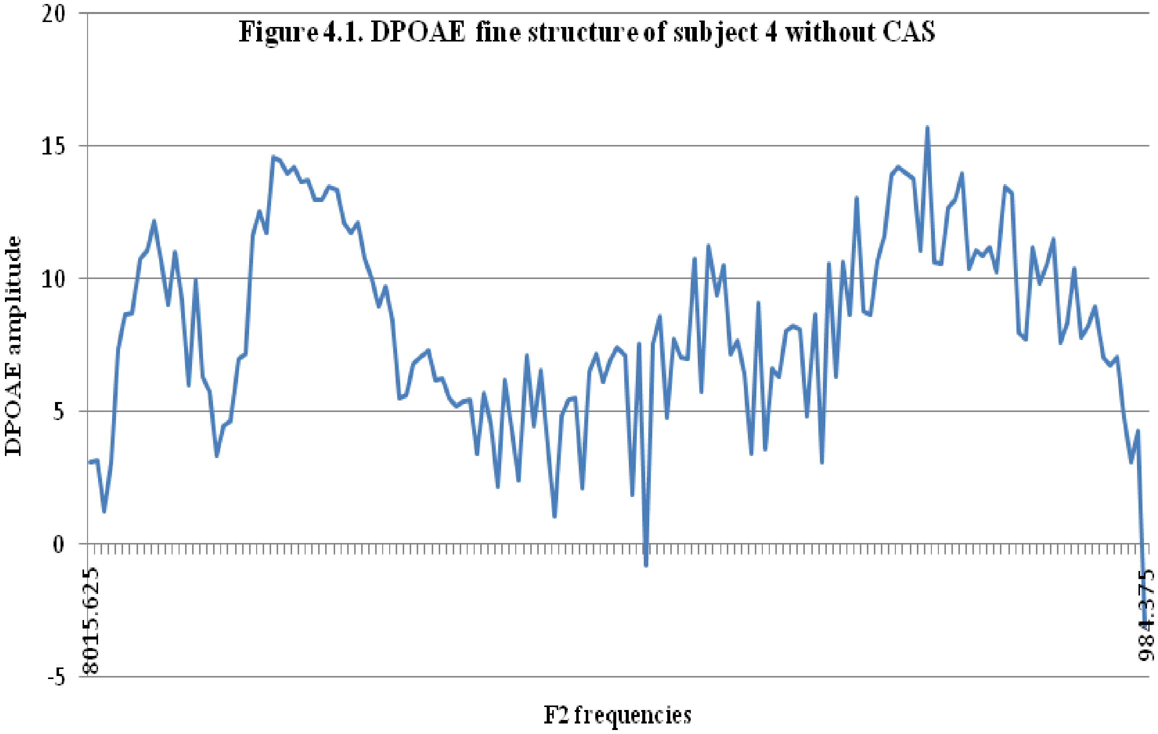

Figure 4.1: The figure represents the DPOAE fine structure for subject 4 in the absence of any contralateral acoustic stimulation (CAS). The peaks and dips are represented by the points with the highest and lowest amplitudes. The x-axis denotes the 151 f2 frequencies and the y-axis represents the DPOAE amplitudes corresponding to each f2.

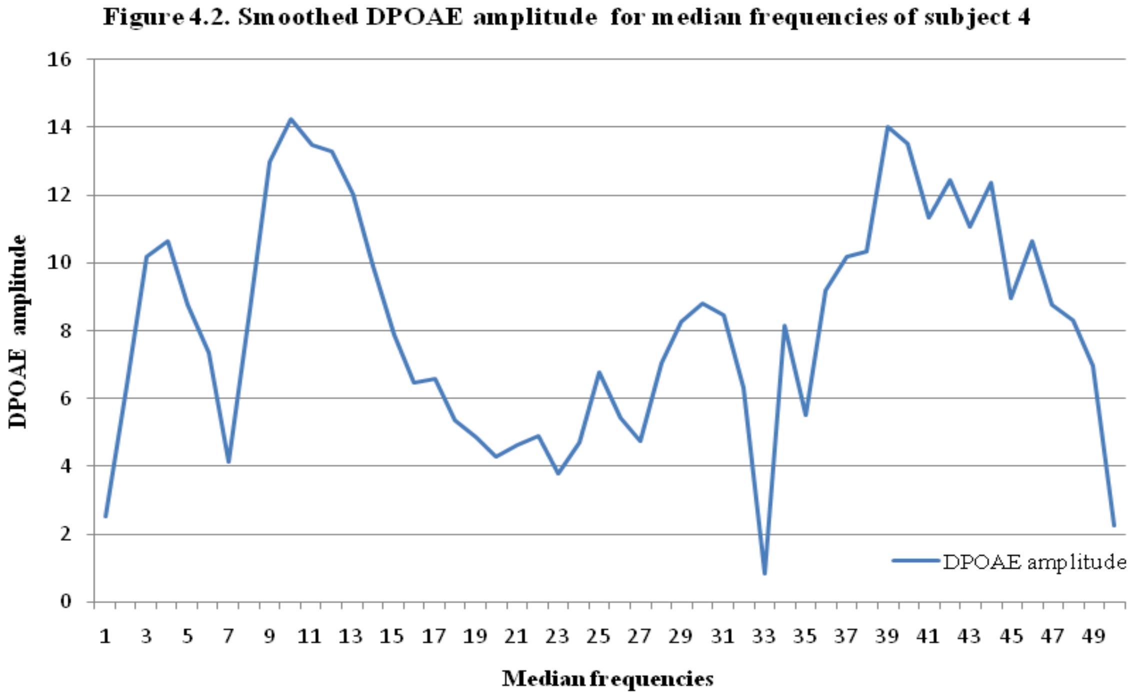

Figure 4.2: The figure represents the DPOAE amplitude corresponding to the median averages of the frequencies. The x-axis represents the 50 median frequencies and the y-axis represents the amplitude of the DPOAE corresponding to these frequencies.

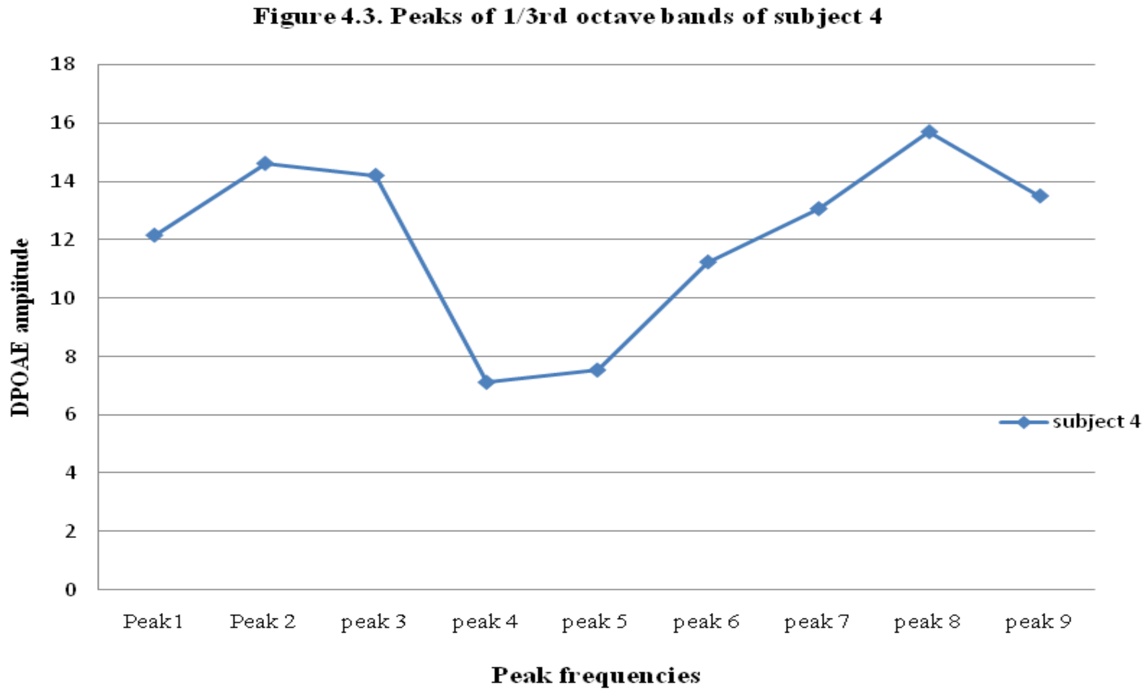

Figure 4.3: The figure represents the peaks of the 1/3rd octave bands for subject 4. The x-axis represents the data of the peaks from 1-9 and the y-axis represents the DPOAE amplitudes corresponding to the respective peak frequency.

DPOAE with Contralateral Acoustic Stimulus (CAS)

After the base line DPOAE measurements DPOAEs were measured again with different contralateral acoustic stimulus and attention conditions. DPOAE inhibition amplitudes were calculated as the difference between the DPOAE amplitudes at peak frequencies in base line condition and DPOAE amplitudes with different contralateral acoustic stimulus.

Figure 4.4 shows the DPOAE inhibition magnitudes across peaks in the fine structure when participants listened a) white noise in the contralateral ear b) words presented at a signal to noise ratio of 0 DB SNR in the contralateral ear (auditory attention condition) c) time reversed version of stimulus in condition “b” and d) same stimulus as in “c” while performing a visual attention task. From the figure it can be inferred that inhibition magnitudes did not differ much between different conditions. Repeated measures of analysis of variance (RMANOVA)was carried out to assess the significance of difference between the mean inhibition magnitudes across different conditions. Results showed that there was no significant main effect of experimental condition on inhibition magnitudes [$F(3, 87) = 0.296$, $p > 0.05$].

Figure 4.4.DPOAE values for different attention conditions of subject 4

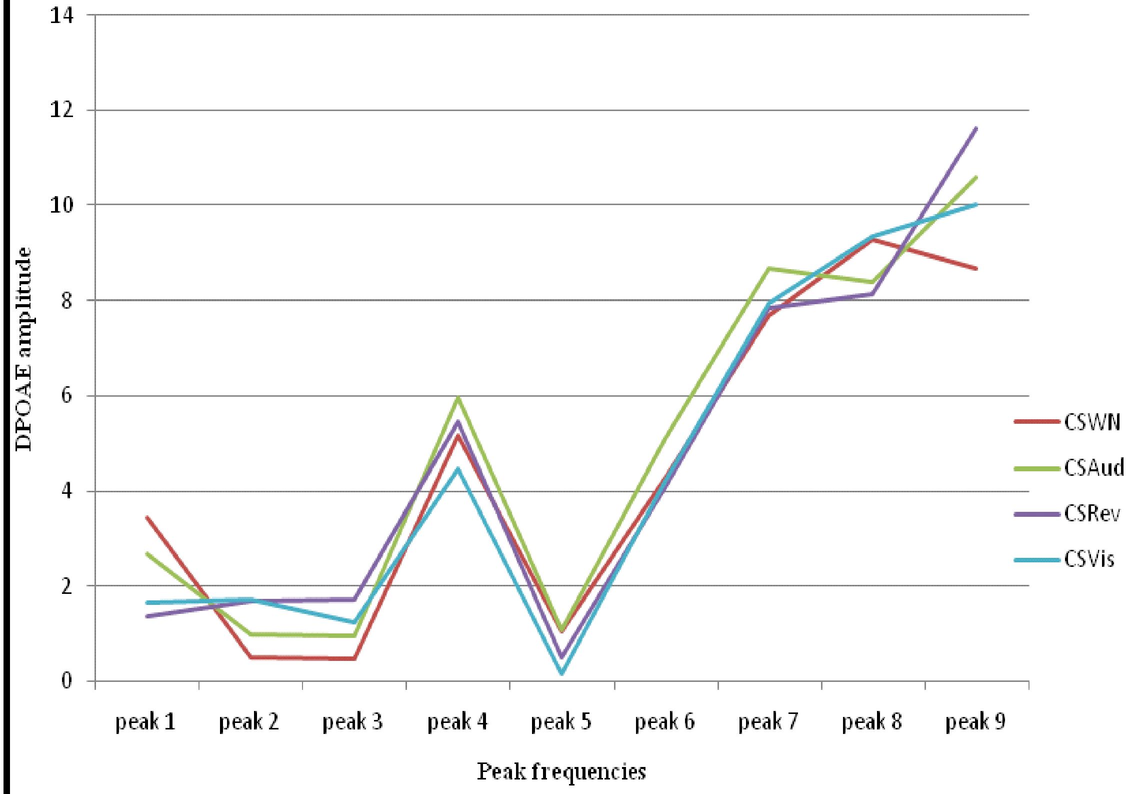

Figure 4.4: The figure represents the peak DPOAE values for the four conditions: 1) **CSWN**: contralateral suppression in white noise, 2) **CSAud**: contralateral suppression in the presence of an auditory attention task, 3) **CSRev**: contralateral suppression in the absence of auditory attention, 4) **CSVis**: contralateral suppression in the presence of a visual attention task. The x-axis represents the peak frequencies and the y-axis represents the DPOAE amplitudes corresponding to the peak frequencies for subject 4.

CHAPTER 5 - DISCUSSION

The present study was carried out to investigate the role of the efferent system in selective attention. The study measured the magnitude of contralateral inhibition at peaks in the fine structure of the DPOAE in 30 normal hearing individuals when they were paying attention to contralateral stimuli and not paying attention to contralateral stimuli. Results showed that attention did not alter the magnitude of contralateral inhibition.

Effects of attention on physiological measures of auditory systems are equivocal. Many authors have studied the effect of visual attention on auditory responses (Hernandez-Peon, 1957; Picton & Hillyard, 1974; Oatman, 1976; Lukas, 1980, 1981; Brix, 1984; Papanicolaou et al., 1986; Puei et al., 1988; Froehlich et al., 1990). These experiments have shown that cochlear potentials, cochlear nucleus potentials, auditory brain stem potentials, auditory middle latency responses and auditory late latency responses vary with the visual attention. Lukas (1980) evaluated the effect of auditory attention and visual attention on auditory brain stem responses. Participants were asked to count tone pips presented binaurally as an auditory attention task or count the alphabets flashed on a screen as a visual attention task. The results revealed that the auditory brain stem response showed reduced wave V amplitude during the visual attention task. The author attributed this finding to the action of the medial olivocochlear system and stated that during visual attention irrelevant auditory stimulus will be attenuated in the auditory system.

After the discovery of otoacoustic emissions, measuring the inhibition in the amplitudes of the otoacoustic emissions upon the presentation of contralateral acoustic stimuli became the standard procedure to evaluate the functioning of the efferent system. The amplitude of the DPOAEs changes when a contralateral noise is presented. This is termed as contralateral inhibition of OAEs. When distortion product otoacoustic emissions (DPOAEs) are recorded with high frequency resolution, they exhibits a pseudo-periodic variation in levels, which is characterized by the peaks (maxima) and dips (minima) as a function of frequency and is referred to as fine structure. Similar peaks and dips were also observed in the DPOAEs in our participants (Figure 4.1). This peaks and dips in the DPOAE gram are thought to be because of constructive and destructive interference between two different sources involved in DPOAE generation. The first source is located at the region of overlap of traveling waves of f_1 and f_2 and is caused by inter modulation distortion. The second source is located at the characteristic frequency region of DPOAE and is generated due to linear reflection. Thus, the ear canal DPOAE is a composite signal comprised of a nonlinear distortion component and a linear reflection component. Previous investigations have shown that inhibition of DPOAE amplitude upon the contralateral acoustic stimulation was more stable at peaks in the fine structure (Deeter, Abel, Calandruccio & Dhar, 2009; Muller, Janssen, Heppelmann & Wagner, 2005; Lisowska et al., 2002). Therefore, in the present study DPOAE inhibition amplitudes were measured only at peaks in the DPOAE fine structure.

Many studies have reported that the magnitude of contralateral inhibition of OAEs change when an auditory or a visual attention task is given simultaneously. These changes have been attributed to the top-down control of the medial efferent system under attentional paradigms. Maison et al (1999) reported an increase in the amount of contralateral inhibition when attention was given to tones presented in contralateral broadband noise as compared to a no attention condition. The inhibition was found to be enhanced only for those DP frequencies whose frequencies matched with that of the embedded tones. Garinis, Glattke and Cone (2011) compared the magnitude of contralateral inhibition in quiet and while participants paid attention to words presented in noise in the contralateral ear. Their results indicated that magnitude of contralateral inhibition of OAEs were significantly more when attention was paid to auditory signal. But Harkrider & Bowers (2009) reported that when participants paid attention, either to the contralateral stimuli (broadband noise), the OAE evoking stimuli (click) or the ipsilateral stimuli there was a significant reduction of contralateral inhibition (0.4-0.5 dB).

However on the contrary, several investigators failed to evidence any relationship between efferent function and attention (Avan & Bonfils, 1992; Michie, LePage, Solowiji, Haller, & Terry, 1996; Scharf, Magnan, & Chays, 1994, 1997). Avan & Bonfils (1992) conducted a study to determine the relation between attention and cochlear micro-mechanics. They measured distortion product OAEs and stimulus frequency OAEs between 1 and 4 kHz in the presence and absence of a visual attention task. The evoked otoacoustic emission (EOAE) responses were measured before the task, during the task as well as after the task revealed that there were no significant changes in the EOAEs. They concluded that selective attention had negligible effect on the peripheral system. Michie et al (1996) conducted a series of six experiments on normal hearing subjects to evaluate the role of cochlear efferent system on attention. In the first experiment, 1 & 2 kHz signals were provided and the subjects were asked to press a button corresponding to particular stimuli. EOAEs were recorded for this condition. The second experiment was similar to the first experiment. In the third experiment the subjects were made to do the same task along with simultaneous presentation of contralateral broadband noise. The authors did not observe any effect of focused auditory attention on the contralateral inhibition. The fourth experiment was similar to the previous experiments but it was more difficult where intensity of the standard and target stimulus was varied. Here also no effect of attention was observed on the contralateral inhibition. In experiment five, single tone pips of either 1 or 2kHz were presented as the target stimuli and this was presented at a lower than the standard stimuli. This task condition was more difficult for the subjects, but in spite of that no effect of attention was observed on the contralateral inhibition. In the last experimental condition, sixth, tone pips of different frequencies were provided to both the ears and the subjects were made to respond to the ones that were higher in intensity. As of before there was no significant attention effect o contralateral suppression. Hence the authors concluded that there were no significant effects of attention on the inhibition of EOAEs.

Direct conclusion cannot be inferred from all these studies as all of the studies varied in many aspects. The discrepancies reported in all these studies could be due to the methodological differences like: a) type of OAE measured, b) type of attention evaluated (auditory v/s visual), c) direction of attention, d)level of the contralateral suppressor stimuli, e) the attention task (auditory/visual), f) frequencies tested (Harkrider & Bowers, 2009).

Results of the present study also showed that there was no significant effect of attention on inhibition of OAEs. This probably may be due to

1. The auditory attention task used in this study was categorization (a closed set task) and not identification. This task may not be auditorily very taxing to participants and hence failed to observe any changes in the inhibition magnitudes of OAEs
2. Contralateral inhibition of OAEs is mainly mediated by olivocochlear bundle, which originates from superior olivary complex (SOC). Attention is a more central phenomenon involving cortical structures. The cortical efferent neurons do not directly innervate the cochlear structures. Though, SOC receives the cortical efferent input these inputs are sparse and may not change the cochlear activity significantly. In fact, it may be hypothesized that measuring the changes in OAE amplitudes evaluated the functioning of only caudal efferent system (OCB) and is not a good reflection of cortical efferent activity. Therefore, to evaluate the more centrally modulated functions of the efferent system better physiological measure should be evolved.

CHAPTER 6 – SUMMARY AND CONCLUSION

The aim of the study was to investigate the effect of attention on contralateral inhibition of distortion product otoacoustic emissions (DPOAEs).

The objectives of the study were: (a) To measure the magnitude of contralateral inhibition of DPOAEs when participant actively categorized the words presented in white noise stimulus at 0dB signal to noise ratio to the contralateral ear, (b) To measure the magnitude of contralateral inhibition of DPOAEs when the contralateral acoustic stimulus is same as above but time reversed, (c) To measure the magnitude of contralateral inhibition of DPOAEs when the contralateral acoustic stimulus is time reversed and participant performs a visual symmetry judgment task.

The study was carried out on 30 normal hearing participants (15 females and 15 males) in the age range of 18-25 yrs. Participants with any known otological or neurological problems were not included in the study. The participants underwent pure tone audiometry and their thresholds were estimated to be within the normal limits. Immittance testing was also carried out and they had normal tympanograms with acoustic reflex threshold within the normal limits. A baseline DPOAE measurement was also carried out for all the subjects. After the baseline assessment, contralateral inhibition of DPOAEs was carried out in four conditions: (a) with white noise as the contralateral acoustic stimulus, (b) contralateral inhibition in the presence of an auditory attention task, (c) contralateral inhibition in the presence of a visual attention task, and (d) a no-attention condition. DPOAEs were analyzed for peaks in the fine structure according to guide lines provided by Abdala, Mishra & Williams (2008). In first step DPOAE fine structure was smoothened by calculating the median average for very three successive data points for both noise floor and DPOAE amplitude. Data points where signal to noise ratio was less than 6 dB was excluded from the analysis. From this data, peak or the maximum in the fine structure was measured. For the purpose of DPOAE peak identification 1000 Hz to 8000 Hz frequency range was divided to 1/3 octave bands. Maximum or peaks were identified as DPOAE frequencies with maximum amplitude in every 1/3 octave band. Thus, a total of 9 peaks in the DPOAEs were identified for each participant. Inhibition magnitudes were measured at these peak/maximum frequencies in all subsequent conditions.

A two-way Repeated Measures Analysis of Variance was carried out to determine the effect of the four conditions on the contralateral inhibition of DPOAEs. The results revealed that there was no significant main effect of the different conditions on the contralateral inhibition of DPOAEs. This may be because the auditory attention task used in this study was categorization (a closed set task) and not identification. This task may not be auditorily very taxing to participants and hence failed to observe any changes in the inhibition magnitudes of OAEs.

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APPENDIX A*

List of frequencies

The f1 and f2 frequencies that were used in this study for the DPOAE measurements are mentioned here. These are in the f1/f2 ratio of 1.2. The frequencies range from 1 kHz to 8 kHz.

Sl. No.	F1	F2
1.	6656.25	8015.63
2.	6562.5	7875
3.	6468.75	7781.25
4.	6375	7687.5
5.	6328.13	7546.88
6.	6234.38	7453.13
7.	6140.63	7359.38
8.	6046.88	7265.63
9.	5953.13	7171.88
10.	5906.25	7078.13
11.	5812.5	6984.38
12.	5718.75	6890.63
13.	5625	6796.88
14.	5578.13	6703.13

15.	5484.38	6609.38
16.	5437.5	6515.63
17.	5343.75	6421.88
18.	5250	6328.13
19.	5203.13	6234.38
20.	5109.38	6140.63
21.	5062.5	6046.88
22.	4968.75	6000
23.	4921.88	5906.25
24.	4828.13	5812.5
25.	4781.25	5718.75
26.	4734.38	5671.88
27.	4640.63	5578.13
28.	4593.75	5484.38
29.	4500	5437.5
30.	4453.13	5343.75
31.	4406.25	5296.88
32.	4359.38	5203.13
33.	4265.63	5156.25
34.	4218.75	5062.5
35.	4171.88	5015.63
36.	4125	4921.88
37.	4031.25	4875

38.	3984.38	4781.25
39.	3937.5	4734.38
40.	3890.63	4640.63
41.	3843.75	4593.75
42.	3796.88	4546.88
43.	3703.13	4453.13
44.	3656.25	4406.25
45.	3609.38	4359.38
46.	3562.5	4265.63
47.	3515.63	4218.75
48.	3468.75	4171.88
49.	3421.88	4125
50.	3375	4078.13
51.	3328.13	3984.38
52.	3281.25	3937.5
53.	3234.38	3890.63
54.	3187.5	3843.75
55.	3140.63	3796.88
56.	3093.75	3750
57.	3046.88	3703.13
58.	3046.88	3609.38
59.	3000	3562.5
60.	2953.13	3515.63

61.	2906.25	3468.75
62.	2859.38	3421.88
63.	2812.5	3375
64.	2765.63	3328.13
65.	2765.63	3281.25
66.	2718.75	3234.38
67.	2671.88	3187.5
68.	2625	3140.63
69.	2578.13	3093.75
70.	2578.13	3093.75
71.	2531.25	3046.88
72.	2484.38	3000
73.	2437.5	2953.13
74.	2437.5	2906.25
75.	2390.63	2859.38
76.	2343.75	2812.5
77.	2343.75	2812.5
78.	2296.88	2765.63
79.	2250	2718.75
80.	2250	2671.88
81.	2203.13	2625
82.	2156.25	2625
83.	2156.25	2578.13

84.	2109.38	2531.25
85.	2062.5	2484.38
86.	2062.5	2484.38
87.	2015.63	2437.5
88.	2015.63	2390.63
89.	1968.75	2343.75
90.	1921.88	2343.75
91.	1921.88	2296.88
92.	1875	2250
93.	1875	2250
94.	1828.13	2203.13
95.	1828.13	2156.25
96.	1781.25	2156.25
97.	1781.25	2109.38
98.	1734.38	2062.5
99.	1734.38	2062.5
100.	1687.5	2015.63
101.	1687.5	2015.63
102.	1640.63	1968.75
103.	1640.63	1921.88
104.	1593.75	1921.88
105.	1593.75	1875
106.	1546.88	1875

107.	1546.88	1828.13
108.	1500	1828.13
109.	1500	1781.25
110.	1453.13	1781.25
111.	1453.13	1734.38
112.	1453.13	1734.38
113.	1406.25	1687.5
114.	1406.25	1687.5
115.	1359.38	1640.63
116.	1359.38	1640.63
117.	1312.5	1593.75
118.	1312.5	1593.75
119.	1312.5	1546.88
120.	1265.63	1546.88
121.	1265.63	1500
122.	1265.63	1500
123.	1218.75	1453.13
124.	1218.75	1453.13
125.	1171.88	1453.13
126.	1171.88	1406.25
127.	1171.88	1406.25
128.	1125	1359.38
129.	1125	1359.38

130.	1125	1359.38
131.	1078.13	1312.5
132.	1078.13	1312.5
133.	1078.13	1265.63
134.	1078.13	1265.63
135.	1031.25	1265.63
136.	1031.25	1218.75
137.	1031.25	1218.75
138.	984.375	1218.75
139.	984.375	1171.88
140.	984.375	1171.88
141.	937.5	1171.88
142.	937.5	1125
143.	937.5	1125
144.	937.5	1125
145.	890.625	1078.13
146.	890.625	1078.13
147.	890.625	1078.13
148.	890.625	1031.25
149.	843.75	1031.25
150.	843.75	1031.25
151.	843.75	984.375

APPENDIX B **

Word list

This appendix provides the list of the English words used as the contralateral acoustic stimulus for conducting inhibition measurements. These words were taken from three lexical categories: animals, common objects and abstract words. Forty words were taken from each category and they were randomized to create this list. These words were mixed with white noise at 0dB signal to noise ratio. The list was made in such a way that there was 4s interstimulus interval for the participants to write their responses. The overall duration of the stimulus was 10minutes.

Sl. No	Randomized words
1.	Lion
2.	Plate
3.	Dream
4.	Hippopotamus
5.	Kettle
6.	Glass
7.	Tiger
8.	Spoon

9. Giraffe
10. Happy
11. Spicy
12. Smoke
13. Zebra
14. Sad
15. Cup
16. Cloud
17. Camel
18. Fork
19. Energy
20. Yak
21. Truth
22. Sleep
23. Hyena
24. Beautiful
25. Donkey
26. Mug
27. Bowl

28. Monkey
29. Table
30. Deer
31. Dirty
32. Horse
33. Chair
34. Clock
35. Big
36. Boar
37. Small
38. Curtain
39. Bear
40. Cushion
41. Summer
42. Leopard
43. West
44. Rhinoceros
45. Carpet
46. Cupboard

47. East

48. Pig

49. Long

50. Mattress

51. Sheep

52. Cooler

53. Pen

54. Jaguar

55. Short

56. Book

57. Vulture

58. Near

59. Wolf

60. North

61. Fan

62. Bucket

63. Cheetah

64. South

65. Bottle

66. Chimpanzee
67. Dog
68. Far
69. Phone
70. Tall
71. TV
72. Broom
73. Cat
74. Thin
75. Snake
76. Shark
77. Mirror
78. Short
79. Jump
80. Snail
81. Jug
82. Cry
83. Alligator
84. Run

85. Pencil
86. Towel
87. Spider
88. Sweep
89. Squirrel
90. Box
91. Climb
92. Mouse
93. Pillow
94. Pot
95. Whale
96. Sit
97. Bull
98. Blender
99. Lamp
100. Crab
101. Stand
102. Buffalo
103. Pull

104.	Knife
105.	Dolphin
106.	Push
107.	Desk
108.	Scissors
109.	Eagle
110.	Clean
111.	Fox
112.	Coin
113.	Spread
114.	Paper
115.	Panda
116.	Wash
117.	Gorilla
118.	Brush
119.	Wind
120.	Card
121.	Stove