FUNCTIOINING OF OLIVOCOCHLEAR BUNDLE

AND

SPEECH PERCEPTION IN NOISE: EFFECT OF AGE

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Registration No: 17AUD007

This Dissertation is submitted as part fulfilment

for the Degree of Master of Science in Audiology

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MANASAGANGOTHRI, MYSURU - 570 006

May, 2019

CERTIFICATE

This is to certify that this dissertation entitled **'Functioning of Olivocochlear bundle and Speech perception in noise: Effect of age'** is a bonafide work submitted as a part for the fulfilment for the degree of Master of Science (Audiology) of Chhandasi Shrikant Anarse, Registration Number: 17AUD007. This has been carried out under the guidance of the faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore

May, 2019

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DECLARATION

This is to certify that this dissertation entitled **'Functioning of Olivocochlear bundle and speech perception in noise: Effect of age'** is the result of my own study under the guidance of Dr. Ajith Kumar U, Professor of 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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May, 2019

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ABSTRACT

Aim: The main aim of the study will be to correlate the physiological measures of olivocochlear bundle (OCB) functioning with psychophysical measures of speech perception in presence of noise.

Objectives: To evaluate the contralateral suppression of Transient otoacoustic emission (TEOAE's) across the age groups, to evaluate the speech perception in noise (SPIN) scores in different SNRs (-5 dB SNR, -10 dB SNR and -15 dB SNR) and different conditions (Ipsilateral and contralateral (IC) condition and Ipsilateral Only (IO) condition) and to evaluate the functional relationship between SPIN scores and Contralateral suppression of TEOAE's across age groups.

Design: Sixty individuals divided into three groups Young normal hearing, Middle aged normal hearing and Elderly normal hearing in the age range of 15-24 years, 25-34 years and 35-45 years respectively. Participants in all the three groups had normal peripheral hearing acuity as assessed by pure tone audiometry, immittance and otoacoustic emissions. The medial olivocochlear bundle (MOCB) functioning was assessed via contralateral inhibition of transient evoked otoacoustic emissions (CS of TEOAE's). SPIN scores were evaluated in different SNRs (-5 dB SNR, -10 dB SNR and -15 dB SNR) and different conditions (IC and IO).

Results: Results revealed contralateral inhibition magnitudes did not differ significantly across different age groups. Speech perception scores were better in IC condition. Largest improvement was seen in YNH group with lowest SNR. Furthermore, Correlation analyses revealed no correlation MOCB functioning and speech perception in noise in all the age groups.

Conclusion: Contralateral white noise presentation helps in speech perception. This could be attributed to the functioning of the efferent system. However, the physiological evidence for the same is not present.

Key words: Contralateral suppression of Transient otoacoustic emission, Speech perception in noise, Medial olivocochlear bundle, efferent system, Young normal hearing, middle aged normal hearing, and Elderly normal hearing.

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Chapter 1

Introduction

Hearing is one of the most important and unique senses of all human beings. Sound picked up by the peripheral hearing system gets transferred via the afferent system to the higher auditory structures i.e. the auditory cortex for further refinement of auditory information. In addition to the afferent system, the presence of the efferent system works on modulating the auditory information. The olivocochlear bundle (OCB), which was first discovered by Rasmussen in the year 1946, is known to have a control over the peripheral receptor (cochlea) (Huffman & Henson Jr, 1990) or is known as the top to down control of the auditory system. The mammalian cochlea receives efferent input from both ipsilataeral and contralateral superior olivary complex. The medial olivocochlear bundle (MOCB) and lateral olivocochlear bundle (LOCB) are namely the two systems in the OCB which terminate in the outer hair cells and inner hair cells respectively. MOCB and LOCB also vary in the aspects of thickness and myelination (Warr & Guinan Jr, 1979). There are many differences in anatomy and physiology between MOCB and LOCB suggesting that they are functionally different systems and that these structures are known to be affected by inner ear stressors, e.g. noise, ototoxic drugs (Ciuman, 2010).

Many studies state that the OCB is known to protect the cochlea from loud sounds (Rajan, 1992). Noise protection, improvement in signal to noise ratio, mediation of selective attention, frequency selectivity by modification of the micromechanical properties of outer hair cells are some of the functions of the MOCB (Ciuman, 2010). Animals in whom the OCB had a lesion, exhibited significantly elevated thresholds for stimulus location in presence of background noise (May, Budelis, & Niparko, 2004).The OCB plays an inhibitory role by reducing activity of the outer hair cells, reduction in auditory nerve response, reduces basilar membrane movement along with otoacoustic emissions amplitude. Due to presence of crossed OCB, stimulation of ipsilateral side results in both ipsilateral and contralateral response (Ciuman, 2010). Some studies stated that the de-efferented ears amounted for more temporary threshold shifts and greater permanent shifts along with larger cochlear lesions of the outer hair cells suggesting that the efferent system influences the ear's ability to develop resistance to noise trauma (Zheng, Henderson, McFadden, & Hu, 1997). Other studies also state that MOCB has anti-masking function that helps adjusting to cochlear amplification along with peripheral signal detection in adverse listening environments (Bidelman & Bhagat, 2015) like speech perception in noise (SPIN).

However, some behavioural studies portray contradictory results. Study conducted by Scharf, Magnan, and Chays (1997) report no significant perceptual changes after MOCB sectioning in human vestibular neurectomy patients. They compared the performance of pre and post vestibuar neurectomy surgery and found no variation in the psychoacoustical measures like intensity discrimination, frequency selectivity, loudness adaptation and in the head localization (Scharf et al., 1997).

Influence of efferent system on SPIN is a phenomenon that is yet not completely understood. There are many factors that are known to modulate SPIN. Some of the factors suggested are phonological memory (Baddeley, 1992), signal to noise ratio (Kumar & Vanaja, 2004; Maruthy, Kumar, & Gnanateja, 2017), linguistic load (Anderson & Kalb, 1987; Miller, Heise, & Lighten, 1951) and speech intelligibility (Giraud et al., 1997). A few studies support an improvement in speech intelligibility, in presence of contralateral noise, because of activation of MOCB (Giraud et al., 1997). While a few others show contraindicative results (Mishra &

Lutman, 2014; Mukari & Mamat, 2008; Wagner, Frey, Heppelmann, Plontke, & Zenner, 2009). However these studies have many methodological differences, and are therefore it is difficult to compare. Also there are many other factors that have an effect on MOCB and SPIN. One such important factor is the stimuli used. The linguistic load of the material with which the speech testing is done also has an impact on the total correct scores (Miller et al., 1951). The more redundant the information, the more easy it is to decipher, even in the presence of noise. Along with this, the signal to noise ratio (SNR) of the stimuli also is a factor affecting the speech in noise scores. As the SNR improves the speech perception and intelligibility was shown to improve (Cheesman & Jamieson, 1996; Ellermeier & Hellbrück, 1998). Hence, the relationship between MOCB and SPIN may be modulated by the SNR.

Effect of age is another factor known to affect both MOCB reflex and Speech understanding in presence of noise, as well as their interaction. In case of children, as the age advances so does the development of the auditory processes thus resulting in an improvement in speech processing skills in the presence of noise (Verônica, Novelli, Carvalho, & Colella-santos, 2017). On the other hand, in case of elderly individuals, a deterioration of speech perception scores in presence of noise, despite of possessing normal peripheral hearing has been seen (Dubno, Horwitz, & Ahlstrom, 2002). Age related difficulties in understanding speech in presence of background noise may be related to functional decline of MOC efferent system. The decline in the SPIN scores could be attributed to the decline in the functioning of the MOCB with advancing age (Kim, Frisina, & Frisina, 2002; Kim, Frisina, & Frisina, 2006). Considering the various inconsistencies in the results of various studies stated and acknowledging the variables that affect the relationship between MOCB and SPIN, the study aims at evaluating the relationship between MOCB reflex and SPIN scores as a function of SNRs and age.

1.1. Need of the study

From review of literature it is evident that the effect of MOCB on SPIN is very inconsistent. It shows variation from positive correlation between contralateral suppression and SPIN results to absence of any correlation. Presence of contralateral noise is supposed to improve the speech perception due to the activation of the OCB. Contralateral noise causes stimulation of the MOCB that in turn increases the ability to detect and discriminate, thus enhancing speech perception in presence of contralateral noise (Kumar & Vanaja, 2004). Contralateral noise also improves the intensity discrimination. The activation of OCB may suppress the responses to a steady masker and decrease the adaptation effect. Thus, it indirectly increases the response of the auditory nerve fiber to stimulus (Kawase, Delgutte, & Liberman, 1993). While the reduction of speech identification scores in presence of ipsilateral noise has already been established, there is limited evidence regarding the relationship between speech perception in the presence of both ipsilateral and contralateral noise. If there is shift in speech identification scores that could have been caused due to the activation of OCB, then there should be a quantitative relationship between this shift and the strength of OCB feedback as measured by contralateral suppression of OAE. Therefore, this study aims at evaluating the correlation between psychoacoustical and physiological measures of OCB functioning.

1.2. Aim of the Study

The main aim of the study will be to correlate the physiological measures of OCB functioning with psychophysical measures of speech perception in presence of noise at different SNRs and age.

1.3. Objectives of the Study

1. To compare contralateral suppression of transient evoked otoacoustic emissions (TEOAE's) across three age groups i.e. 15 to 24 years, 25 to 34 years and 34 to 45 years.
2. To measure the SPIN scores using sentences at different SNR (across 0dB, -5dB, -10dB) in presence of ipsilateral only (IO) and ipsilateral + contralateral (IC) noise in YNH, MNH and ENH.
3. To evaluate the functional relationship between change in speech identification upon the addition of contralateral noise SPIN (with IO noise and with IC noise) and contralateral inhibition of TEOAE's in YNH, MNH and ENH.

Chapter 2

Review of literature

The afferent and efferent connections in the auditory system play a vital role in hearing in human beings. The olivicochlear bundle (OCB) which is basically the efferent system was first discovered by Rasmussen in the year 1946 and is known to have a control over the peripheral receptor (cochlea) by the central higher organs (Huffman & Henson Jr, 1990). It originates at the level of Superior olivary complex and terminates at the level of organ of corti in the cochlea (Warr & Guinan Jr, 1979). The medial olivocochlear bundle (MOCB) and lateral olivocochlear bundle (LOCB) are the two subsystems of the olivocochlear system (Guinan, 2006; Guinan, Warr, & Norris, 1983; Warr & Guinan Jr, 1979). Few structural and functional variations are evident in MOCB and LOCB. Structurally MOCB is known to have thick and myelinated fibres whereas LOCB has relatively thinner and unmyelinated fibres (Cooper & Guinan, 2006). Functionally, MOCB innervates the inner hair cells and LOCB innervates the outer hair cells (Cooper & Guinan, 2006). Also, MOCB accounts for larger contralateral projections than that of LOCB (Warr, Guinan, & White, 1986).

Various studies speak about the functions of the OCB, the MOCB which is the descending pathway has many functions in processing and fine tuning (modifying) the stimuli. Several other studies deal with exploring the anatomy, physiology and functioning of the MOCB (De Boer & Thornton, 2008; Cooper & Guinan, 2006; Maruthy et al., 2017; Murugasu & Russell, 1996; Rajan, 1992). Some of the functions hypothesized of MOCB are mentioned below

i. Protecting the cochlea from loud sounds (Patuzzi & Thompson, 1991; Rajan, 1992).

ii. Perceptual learning (De Boer & Thornton, 2008; Nobuo Suga, Xiao, Ma, & Ji, 2002)

iii. Inhibition of cochlear responses (Guinan, 2006; Murugasu & Russell, 1996)

iv. Perception in the presence of noise (Giraud et al., 1997; Kawase, Delgutte, & Liberman, 1993)

v. OCB aids in the control of masking (Liberman & Guinan, 1998).

vi. The MOC neurons are found to be sharply tuned to preserve tonotopic innervations (Liberman & Brown, 1986).

As mentioned earlier, one of the major functions of the MOCB is the inhibition of cochlear responses. This is achieved by activation the MOC which results in reduction of the cochlear amplifier gain (Guinan, 2006; Murugasu & Russell, 1996). The activation of the MOC results in reduction of the basilar membrane movement (Cooper & Guinan, 2006) which in total reduced the amplitude of the compound action potential (CAP) and enhances the cochlear microphonics (CM) (Delano, Elgueda, Hamame, & Robles, 2007).

2.1. Functions of MOCB

Although the existence of efferent system to the cochlea was discovered long ago by Rasmussen (1946) the functional role of these efferent innervations is not clear. MOCB is known to play role in various ways like act as protective system, perceptual learning, antimasking function that helps in perception in noise and perceptual learning. The complexity in of the efferent feedback system plays multiple roles in processing of signal.

2.1.1. Protective function. Hypothesis states that efferent system plays a role in protecting the cochlear from acoustic injury (Rajan, 1992) along with helping in antimasking (Liberman & Guinan, 1998). Various researches support that activation of the OCB, results in safeguarding or plays a role to protect the cochlea.

A study conducted by Prabhu, Divyashree, Neeraja, and Akhilandeshwari, (2016) to determine how contralateral broad band noise had an effect on acoustic reflex latency (ARL). They estimated the acoustic reflexes for 10 and 90% on-time and off-time with stimulation if the contralateral side with broadband noise. Test was conducted on 30 individuals having thresholds within the normal range. Results demonstrated a prolongation in latency for reflex on-time condition and latency reduced in reflex off-time. This reflex prolongation and reduction was evident for frequencies of 0.5, 1 and 2 kHz. This latency prolongation and reduction on contralateral stimulation attributes to the functioning of the efferent system in protecting cochlea. Thus, this changes in the acoustic reflex states that it can act as one of the tool to assess efferent system functioning.

Similar study by Wagner, Frey, Heppelmann, Plontke, and Zenner, (2008) conducted on animals namely guinea pig, cat and chinchilla that showed that MOCB exerts noise-protective effects on the cochlea. This was evaluated by estimating contralateral suppression of otoacoustic emission (CS of OAE’s). The study was conducted by measuring the Input/ Output functions of distortion product otoacoustic emission (DPOAE’s) in the presence and absence of contralateral stimulation. Results revealed good test-retest repeatability of contralateral suppression. Thus, suggesting it to be an appropriate measuring tool for contralateral suppression (Wagner et al., 2008).

Study by Buño (1978); Cody and Johnstone (1982) conducted study on guinea pigs. They provided the pigs with traumatizing noise condition in varying contralateral stimuli after anaesthetizing them. The study reported that presence of contralateral stimulation reduced the temporary threshold shift (TTS). The maximum reduction in TTS was seen in conditions where the spectral characteristic of noise and stimuli were similar. They also report the functioning of the efferent neurons to be frequency specific.

Patuzzi and Thompson (1991) conducted study on anesthetized guinea pigs and were categorized depending on the four different conditions exposed.

i. Traumatizing exposure (ipsilateral)
ii. Ipsilateral exposure and contralateral sound
iii. Ipsilateral exposure and MOC transection
iv. Ipsilateral exposure, contralateral sound and MOC transection

Animals were exposed to 115 dB SPL of a 10 kHz tone for duration of sixty seconds. A pre and post compound action potential thresholds were measured to evaluate the role of efferent system in protection from loud noise. All the potential thresholds were compared pre and post exposure. All the four different groups showed an evidence of elevated thresholds however, one group showed lesser amount of elevation of threshold. This group with lesser threshold shift was the one with contralateral sound presentation which portrays that the efferent system plays a protective role by presentation of contralateral sound.

However, study by Liberman (1991) showed contradictory results. The study performed a within subject comparison (across the two ears) to evaluate the protection offered by the efferent system in anesthetized cats. The middle ear muscles of these cats were severed for the experiment to eradicate the effect of middle ear reflex on the measurement. In one ear of all the cats the OCB was transected. Exposure to binaural intense pure tone stimuli was conducted to evaluate the amount of threshold shift. The results of the study revealed no significant effect between the two ears of a particular cat indicating that OCB did not play a role in protecting cochlea from loud sound exposure. The reason for this contradictory result could be attributed to the differences in species included in the study.

2.1.2. Perception in noise- Antimasking. Many studies report MOCB playing an important function in understanding of SPIN. However there are many factors that may affect the performance, considering this there is variability in the results acquired. Therefore, debate still persists between the correlation of SPIN and MOCB functions. Study carried out by Kawase et al., (1993) discussed the antimasking functions of MOCB conducted on anesthetized cats. They were exposed to tone burst stimuli in quiet and in presence of continuous noise. Results of the study revealed that there was a difference in score when stimuli presented in quiet and in presence of noise. In quiet condition, MOCB acts as being suppressive whereas, in presence of noise the response was enhanced.

A study was carried out by Winslow and Sachs (1988), by electrically stimulating the MOC fibres of cats. They evaluated the responses to brief tone stimuli in presence of noise with the help of micropipettes. Frequency around 8 kHz were considered for the study in both quiet and in presence of noise condition. Also, the stimuli presented with electrical simulation and without electrical stimulation of OCB. The results of the study revealed that on stimulation of OCB, reduction in discharge rates of the nerve fibers was evident. This decreases adaptation of the fiber, leading to saturation (which increases with increasing levels of noise). Thus, OCB stimulation restores dynamic ranges of nerve fibers to those seen in quiet, thus enhancing signal detection in the presence of noise.

Dewson, Wertheim, and Lynch (1968) carried out a study to evaluate functioning of MOCB on monkeys having olivocochlear lesions. The monkeys were also reported of having focussed cortical lesions. They were trained to discriminate changes in F2 in vowels. Testing was done in presence of low pass filtered noise. Results showed a change in tolerance value in whom the surgical sectioning was done. They showed lowering of the tolerance values. However, the results of this study cannot be generalized as the monkeys had other cortical lesions as well.

Giraud et al., (1997), conducted a study to evaluate the relationship between MOCB functions and Speech perception in presence of noise. They took two groups, one being normal hearing individual and others were neurectomized patients. They compared speech intelligibility among these two groups in SNRs varying from -20 dB to +25 dB. Stimuli used for the study was monosyllabic words from Fournier list. Results of the study showed improvement in speech in noise (SIN) scores in presence of contralateral noise only in healthy normal hearing individuals. This was absent in the neurectomized patients. Thus concluding that top down system i.e. the efferent system plays an anti-masking role in speech perception in noise.

Kumar and Vanaja (2004) studied the correlation of contralateral stimulation on speech perception and CS of TEOAE's. Ten normal hearing children were included in this study. Stimuli used was Speech identification test for Indian English speaking children (Rout, 1996). This stimuli was presented in presence of Broad Band Noise (BBN) of SNRs varying from -10 dB to +20 dB SNR. Testing carried out in 3 different conditions namely-

a. Quiet
b. Ipsilateral noise

c. Low level contralateral noise (30 dB SPL) Ipsilateral and Contralateral

Results of the study revealed on presentation of contralateral BBN noise, there was an enhancement in the scores of speech perception. In ipsilateral condition, SNRs of +10 dB and +15 dB showed enhanced scores which were found to correlate with magnitude of contralateral suppression of OAE. Thus, suggesting that MOCB plays a vital role in hearing in noise.

Maruthy, Kumar, and Gnanateja (2017) studied the correlation between efferent functioning and SPIN in two age population. One of the groups was labelled as younger normal and older normal hearing adults. Stimuli was taken from SIN-Kannada (Avinash, Meti, & Kumar, 2009). SNR50 was calculated. Results of study showed negative correlation between the CS of OAE magnitude and SIN in older normal hearing group. It was correlated with CS of TEOAE's (as a measure for MOCB functioning) and context dependent brainstem encoding of speech (as a measure of LOCB function). This trend was not seen in the younger group. They proposed that both MOCB and LOCB fine tunes the neural encoding of input speech and this is done independently.

Abdala, Dhar, Ahmadi, and Luo (2014) studied the associations of aging in MOC and SPIN. 118 individuals were considered for the study who was grouped into four groups namely teenagers, young adults, middle aged adults and old age individuals. CS of DPOAE was acquired as a measure of MOC functioning. Task for speech perception was consonant and vowel identification which was varied at different SNRs from -21 dB to +12 dB increasing in 3 dB steps. In addition, Hearing in noise test (HINT) was also evaluated and the plotting of the performance intensity function was done. Results of the study revealed that there was a presence of moderate correlation between speech scores and MOC reflex attained. The individuals who attained greater MOC reflex showed better performance on speech perception tasks as the greater MOC reflex enhanced transmission of place and manner cues (Abdala et al., 2014).

Rocha-muniz, Mota, Carvallo, and Schochat (2017) aimed at investigating the MOC efferent system functions in individuals with poor speech perceptions scores. They conducted TEOAE's with and without contralateral stimulation on 52 in age range of 6 years to 12 years. Children were grouped on basis of

i. Typically developing children (TD)
ii. Children who have poor speech in noise score (PSIN)
iii. Children who have poor speech in noise scores along with language impairment (PSIN + SLI)

Results of the study revealed PSIN group and the PSIN + SLI group acquired comparatively reduced otoacoustic emissions suppression than the TD group. Thus, suggesting a functional difference between the TD group and children with poor SIN and language impairment.

Kim et al., (2006), studied the relationship between MOC efferent system in speech perception and spatial release from masking (RFM) across different age groups. Individuals in the age range of 18 years to 75 years possessing thresholds within the normal hearing range were considered for the study. CS of DPOAE to measure the efferent system reflex and HINT to measure the speech perception in noise was administered. SNR50 was estimated for these individuals. HINT test was administered at different degree of azimuth to attain the RFM when speech and noise were spatially separated. Results of the study portray a reduction in the scores of speech perception in the presence of background noise. This decrement in the scores was attributed to the decline in the MOC efferent functioning. Higher frequency in the range of 4 kHz to 6 kHz is found to be correlated in speech processing in background noise which was affected in the elderly individuals. The spatial RFM was found to be correlated with the frequency range of 1 kHz to 2 kHz. Thus concluding that the MOC efferent system is characterized as a non-linear adaptive filter that is activated when speech processing in background noise condition such as a cocktail-party effect.

Bidelman and Bhagat (2015) examined the relationship between the CS of OAE and SPIN (Killion, Niquette, & Gudmundson, 2004). The test was performed at different SNRs ranging from 25 dB to 0 dB on normal hearing individuals. To evaluate the role of brainstem efferent activity in SIN perception ear specific CS of TEOAE's was measured. Along with this, a measure of MOC activation was evaluated that was known to be linked to auditory learning in noisy conditions. Results of the study revealed a negative correlation between the CS of OAE and SIN scores. Thus suggesting that at lower SNR individuals attained better speech recognition in noisy conditions. Further, they evaluated the relationship between the anti-masking function of the MOCB to the consonant-vowel (CV) discrimination in presence of broadband white noise at 10 dB SNR. CS of TEOAE's was also evaluated. Results of the study showed that poorer performance of CV discrimination in the presence of noise was seen in individuals having stronger OAE suppression. The results of this study were contradictory to the above mentioned studies and they reasoned it to be due to the acoustic properties of the signal and that the outcome was based on the correlation between the two.

Boer, Thornton, and Krumbholz (2012) conducted a study to correlate the measures of MOC activity and speech processing in noise. CS of OAE and CV discrimination was used as a measure of MOC function and speech perception in noise respectively. Results of the study portrayed a negative correlation between SPIN and CS of OAE's. The greater OAE suppression showed greater noise-masking effect thus affecting CV processing. The individuals having stronger OAE suppression showed poorer CV discrimination.

Similar study was conducted by Narne and Kalaiah (2018) showing an involvement of efferent system in hearing in noise. This was assessed in 20 adults within the age range of 8-28 years. Stimuli used for the study was Phonetically balanced sentences in Kannada (Avinash et al., 2009). They were presented in the presence of speech spectrum shaped noise and their scores were calculated. CS of TEOAE's was used as a measure for assessing the MOCB functioning. Results of the study revealed no significant relation between strength of MOC reflex at any level of stimulation and speech reception threshold in noise (Narne & Kalaiah, 2018).

Mukari and Mamat (2008) conducted a study having two main aims-

a. To compare the MOC functioning to the speech perception scores in noise and compare it between younger and elderly individuals.
b. To quantify the correlation between MOC reflex and speech perception in noise scores.

The study was conducted on MOCS functioning and SPIN. Measurements were taken in 20 young and 20 elderly individuals were considered for the study all having hearing thresholds in normative range. CS of DPOAE to assess MOC functions and HINT to assess speech perception in noise skills. Results of the study showed elderly population had lower high frequency suppression on frequencies from 3 kHz to 8 kHz and were found to perform poorly on HINT test as compared to the younger group. Study also revealed no correlation between the CS of OAE's and speech perception in noise. The reason for poor speech scores in presence of noise could be attributed to decline in the MOC functions with advancing age.

Thus, there is a considerable variation evaluating the MOC functions in humans.

2.1.3. Perceptual learning. Corticofugal pathway extends from the auditory cortex through the auditory pathway towards the subcortical nuclei. Through the efferent pathway of the OCB, the MOCB modulates the amplification gain. Thus, this corticofugal is thought to play a role in neuroplasticity that helps in perceptual learning.

Study to evaluate the function of OCB in perceptual learning was done by Xiao and Suga (2002). The descending (efferent) auditory system forms feedback loops that are known to improve the processing of the auditory signal in subcortical auditory nuclei. The study was conducted by electrically stimulating the cortical neurons through the corticofugal pathway and recording the cochlear micrphonics with electrodes placed in the cochlea. This study places emphasis on the fact that, the efferent or the corticofugal system modulates the cochlear hair cells; however the mechanism for this is yet unexplained.

The current study by Boer and Thornton (2008) evaluated the involvement of MOCB in perceptual learning throughout the auditory training. MOCB activity was monitored of normal hearing individuals throughout the training duration. The task conducted was on a consonant-vowel phoneme-in-noise discrimination. The results of the study reveal that there is a great amount of inter-individual variability amongst the performance and improvement. However, the MOCB activity showed subsequent amount of improvement after auditory training in comparison to the initial MOCB activity. Concluding the study, it was seen that MOCB-mediated listening stratergy facilitates speech in noise perception.

On presenting sound, small short changes that are specific to sound characteristics take place at the level subcortical auditory nuclei. Through conditioning and associative learning, these small changes are augmented in the auditory cortex (reorganizations takes place) and become more long term. The process is modulated by the descending auditory pathway. This modulation for reorganization of central auditory system is multi-parametric and occurs in frequency, time and amplitude domains (Suga et al., 2002). Thus, the corticofugal system plays a role in plasticity of the central auditory system (Suga, Gao, Zhang, Ma, & Olsen, 2000).

Similar study by Boer and Thornton (2008) was conducted to evaluate the involvement of the MOCB in perceptual learning after completion of auditory training in normal hearing individuals. A five day auditory training program on speech in noise (SIN) discrimination training was done. During the entire duration of training, a continuous uncorrelated broad band noise was presented to contralateral ear in order to activate the MOCB. Contralateral suppression of evoked OAE was administered on all patients after the completion of a training function. Results do the study revealed a significant behavioural improvement in phoneme in noise discrimination after the completion of training session. Weaker contralateral suppression is related to greater amount of improvement. A significant amount of improvement in MOCB activity was evident comparing pre and post training. This shows that the central auditory system is flexible and the descending feedback pathway has a role in long and short term plasticity. Similar results are evident in study done by Perrot, Micheyl, Khalfa, and Collet, 1999; Veuillet, Magnan, Ecalle, Thai-Van, and Collet, (2007).

2.2. Speech perception in noise

Thresholds in the normative range does not account for good speech perception in noise skills. Communication in the daily situations occurs in the presence of background noise. There are various processes and factors that may affect the SIN perception. Failure of which may be accounted either to inability to integrate the sensory information may be due to the neural and cognitive aspects of the stimuli. One of the major reasons for poor performance can be attributed to poor auditory processing skills in children and older individuals (Chermak & Musiek, 1997; Gates & Cooper, 1991)

Verônica, Novelli, Carvalho, and Colella-santos (2017) in their study found a developmental trend in acquisition of perception skills. Children within the age range of 8 years to 10 years were considered for the study. The individuals having any ear related problems or having a history of the same were excluded from the study. The study aimed at analysing the perception of speech in noise in school going children who are known to have poor school performance. Speech intelligibility was evaluated using the Brazilian hearing in noise test (HINT). Results of the study revealed that the children who had poor school performance had worst scores as compared to the children having good school performance. Also, when comparing age-wise 10 years old performed better as compared to the 8 years old. Whereas individuals in the age range of 9 years performed intermediately and had no significant difference when comparing to either 8 year or 10 year old.

Abdala et al., (2014), compared the difference in performance across teenagers, young adults, middle aged adults and elderly adults. Task involved was vowel and consonant identification and word in sentence identification in presence of noise. Results revealed deterioration or reduction in performance with advancing age. For individuals greater than 60 years of age, no correlation was found between speech scores and age in individuals.

Billings, Penman, McMillan, and Ellis (2015) compared the SPIN scores between the young normal hearing and older individuals. The older group was subdivided into older normal hearing (ONH) and older hearing impaired individuals (OHI). The hearing impaired individuals had severity ranging from mild to severe with sloping sensorineural hearing loss. Results portray the older individuals having comparatively lower scores as that of young normal hearing individuals. The next aim of this study was to determine the effect of SNR or signal level on speech perception. With the SNRs varying from -10 dB to 35 dB, results showed significant main effect seen in both the groups. Many studies took similar objectives and their findings were equivocal (Ellermeier & Hellbrück, 1998).

2.3. Effect of Age

Various studies have evaluated the effect of age on MOC reflex functioning. With advancing age, there is a decline in the functioning of the MOC (Kim et al., 2002). Study by Werff and Burns (2011) reports reduction in the neural efficiency in the elderly individuals that affects the transmission of signals. This was measured through speech evoked auditory brainstem response (Speech ABR) and results revealed older individuals having smaller amplitude and longer latencies as compared to young individuals. Studies have also shown that with advancing age there is a decline in the overall performance which could be attributed to the overall cognitive decline (Gordon-salant & Fitzgibbons, 2019). Various other studies also report of reduction in strength of MOC reflex as the age increases (Castor, Veuillet, Morgan, &

Collet, 1994; Kim, Frisina, & Frisina, 2002; Maruthy, Kumar, & Gnanateja, 2017; Mukari & Mamat, 2008).

Keppler et al., (2010) investigated the effect of aging and pure tone thresholds on EOAEs and efferent suppression due to aging. Individuals in the age range from 20 years to 79 years were included in the study having normal hearing or high frequency hearing loss caused due to presbycusis. Results revealed evoked otoacoustic emission (EOAE's) and efferent suppression were more strongly correlated with age than pure tone thresholds. This deterioration of OAE is mainly due to advancing age.

Castor et al., (1994), studied the TEOAE's and DPOAE's with and without CS. Young normal hearing and older individuals with some high frequency hearing loss were considered for the study. On comparing the normal young and older individuals, a reduction in amplitude of older individuals was evident as compared to young individuals. In case of DPOAEs, middle frequencies in the range of 2.83 kHz to 5.04 kHz were reduced. No significant effect of hearing loss on OAE was evident which was compared through threshold matched adults. Thus, they concluded that deterioration in MOC function could be related to age linked hearing loss.

Maruthy et al., (2017) evaluated relationship between SPIN and functioning of the efferent system along with the study of effect of age. 27 adults in age range of 18 years to 30 years, 29 older adults in the age range of 50 years to 65 years were included for the study. Results showed similar TEOAE's amplitude in quiet condition. However, when presented with contralateral white noise of 30 dB SL, the TEOAE's amplitude was found to be reduced in both the age groups. This reduction was found to be more in younger group than the older group.

Similar study was conducted by Kim et al., (2002), to find the influence of age on CS of DPOAE. 10 normal hearing individuals who were grouped into young, middle aged and elder group were considered for the study. Contralateral stimuli of 30 dB SL white noise were presented. A frequency specific analysis of CS was conducted and DPOAE amplitude was measured. The amplitude of suppression was found to be lower in middle aged and older age group. They concluded further stating that MOC decline starts before to the OHC dysfunction begins. The MOC function was found to be maintained best in frequencies ranging from 1 kHz to 2 kHz in individuals of all age groups.

Mukari and Mamath (2008) used CS of DPOAE to evaluate the efferent function across young normal hearing in the age range of 20 years to 30 years and older in the age range of 50 years to 60 years with thresholds within 25 dB Contralateral noise of 30 dB SL was presented for CS of DPOAE. Results found were that the younger group showed higher suppression in almost all frequencies comparing to the older group.

Few other studies show contradictory results, portraying no effect of age on efferent system. Study by Quaranta, Debole, and Di Girolamo, (2001) reports no significant differences in MOC functioning across younger and older individuals. Authors assessed CS of TEOAE's in participants ranging in age range of 20 years to 78 years which were divided into 5 groups. All the participants having thresholds within 25 dB HL were included in the study. A reduction in mean amplitude of CS was seen, although across group this was not significant.

Study by Abdala, Dhar, Ahmadi, and Luo (2014) investigated the MOC functioning across four different age groups namely teens, young adults, middle aged adults and elder adults. They measured CS of DPOAE and found a mild aging effect for the middle aged group for DPOAE frequencies under 1.5 kHz. However, in the elderly group, results showed a significantly higher amount of suppression than the other groups. The authors hypothesized the middle ear muscles playing a role in such an unexpected finding.

Chapter 3

Methodology

3.1. Participants

A total of 60 participants divided into three age groups participated in the study. The first group consisted of 20 participants in the age range of 15-24 years, and was labelled as young normal hearing adults (YNH) group. The second group consisted of 20 participants in the age range of 25-34 years and was labelled as middle aged normal hearing (MNH) group. The third group consisted of 20 participants in the age range of 35-45 years and was labelled as Elderly normal hearing (ENH) group. Prior to the commencement of the experiment all participants signed a written informed consent form. The study conformed to the ethical guidelines for bio-behavioural research involving human subjects, All India Institute of Speech and Hearing, Mysuru (Venkateshan, 2009).

3.1.1. Inclusion Criteria

- Participants of the YNH and MNH groups had thresholds within 15 dB HL at octave frequencies from 250 Hz to 8 kHz. Participants of ENH group had hearing thresholds within 15 dB HL at octave frequencies 250 Hz to 2 kHz and within 25 dB HL at 4 kHz and 8 kHz.
- All participants had 'A' type tympanogram (Jerger, 1970). All participants had ipsilateral and contralateral acoustic stapedial reflexes at normal sensation levels at 0.5 kHz and 1 kHz.
- All the participants had transient evoked otoacoustic emissions (TEOAE's) with global amplitude of 3dB or more for 65 dB SPL clicks.

- All the participants were native speakers of Kannada and had at least 10 years of formal education in Kannada language.

3.1.2. Exclusion Criteria

- Individuals having any history of noise exposure, use of ototoxic drugs or middle ear infections.
- Also, participants suffering from any neurological or cognitive dysfunction.
- SCAP questionnaire was used to exclude any participants from possible auditory processing disorder.

3.2. Equipment and Test Environment

The testing was carried out in a two room sound treated set up with adequate illumination and appropriate ventilation. The room specification followed during the testing were that of the ANSI S3.1-1999-R2013.

A calibrated dual-channel audiometer Inventis Piano (Corso Stati Uniti, Padova, Italy) was used for evaluating the hearing thresholds of the participant along with TDH 39 headphones and Radio Ear 71 bone vibrator (Middlefart, Denmark). Middle ear status was evaluated with a GSI Tympstar (Grason, Stadler, Minneapolis, USA). Both Tympanometry and Reflexometry were conducted to evaluate the middle ear status. To evaluate the outer hair cells functioning and level of inhibition, Otodynamics ILO V6 (Hatfield, Herts, United Kingdom) was used. Madsen Electronics Orbitter 9.2.2 Version 2 Clinical Audiometer (Tampa, Florida) was used to present noise to the contralateral ear during OAE presentation. Speech perception was conducted from Lenovo G50 i5 laptop using Sony MDR-ZX 110A On-Ear Stereo headphones.

3.3. Material

Stimuli were taken from the Sentence Identification Test (SIT) (Geetha, Kumar, Manjula, & Pavan, 2014). It consisted of 30 equivalent sentence lists, out of which 12 lists were considered for this study. Each sentence consisted of 4 keywords and each sentence list consisted of 10 such sentences. Therefore a total of 40 keywords were present in one list. The sentences were made using familiar words which were of equal difficulty level. All the sentences had a considerably low predictability level.

Stimuli for this study were created using the Adobe Audition software version 2.1.3. All the speech sentences present in a particular list were concatenated one next to the other and the silences between them were removed. The average RMS of these sentences was calculated. The presentation level for speech was maintained at 70 dB SPL which was calibrated using a Sound level meter (SLM) and Knowles Electronics Manikin for acoustic research (KEMAR). Keeping this RMS value as the baseline, the average RMS of the white noise was manipulated to ensure an overall SNRs of -5dB, -10dB and -15dB. These sentence materials at different SNRs were saved on to one of the stereo track in Adobe audition. This condition was referred to as 'ipsilateral only (IO)' – meaning participants heard the sentence material only in the presence of ipsilateral noise.

In the other track white noise was generated and was calibrated to produce same intensity as speech stimuli. This was achieved for each of the sentence list as required. This condition was referred to as 'ipsilateral+ contralateral (IC)' – meaning participants heard the sentences both in the presence of ipsilateral and contralaeral noise. The sentences were later aligned with a gap of 3 seconds between them. Participants listened to sentences in following conditions:

1. Two lists at -5 dB SNR (IO)
2. Two lists at -10 dB SNR (IO)
3. Two lists at -15 dB SNR (IO)
4. Two lists at -5 dB SNR + Contralateral noise (IC)
5. Two lists at -10 dB SNR + Contralateral noise (IC)
6. Two lists at -15 dB SNR + Contralateral noise (IC)

Thus a total of 12 lists were considered for the study. Lists were randomly chosen to be mixed with a particular mode of stimulation and a particular SNR. The difference between the IO and IC condition at each SNR was considered as the influence of activation of efferent auditory system.

3.4. Experimental Procedure

The procedure mainly consists of physiological and psycho-acoustical measures of olivocochlear bundle along with evaluating the normal functioning of auditory system.

3.4.1. Audiological evaluation. Thresholds at octave frequencies from 0.25 kHz to 8 kHz for air conduction mode and from 0.25 kHz to 4 kHz for bone Conduction mode were evaluated using modified Hughson and Westlake procedure (Carhart & Jerger, 1959). SRT (speech reception threshold), SIS (speech identification scores) and the UCL (uncomfortable levels) were assessed using standard procedures. Tympanometry and reflexometry was conducted to evaluate middle ear functioning. Tympanometry was conducted with a probe frequency of 226 Hz and acoustic reflex thresholds are obtained at 0.5 kHz and 1 kHz both ipsilaterally and contralaterally. Transient evoked Otoacoustic emissions were measured to assess the outer hair functioning by using the Otodynamics ILO V6 instrument by presenting 260 sweeps of non-linear clicks at 65 dB SPL (±0.5 dB).

Once the functioning of auditory system is confirmed as being normal, the physiological and psycho-acoustical measures were evaluated by measuring contralateral suppression of TEOAE's (CS of TEOAE's) and Speech in Noise (SPIN) scores.

***3.4.2. Contralateral inhibition of TEOAE*'s.** On seating the patients comfortably on the chair, a probe of the appropriate size in accordance to the ear canal size was inserted in the right ear. TEOAE's were measured for 260 linear clicks presented at 65 dB SPL (± 0.5 dB). The participants were instructed to reduce the movements during the testing. The participants were kept engrossed by either watching a muted video or reading a book during the entire duration of testing for contralateral inhibition of TEOAE's as it has been shown in literature that attention may influence contralateral inhibition (Ferber-Viart, Duclaux, Collet, & Guyonnard, 1995) . With the probe for OAE inserted in the right ear and an E-A-RTONE 5A insert earphone placed in the left ear. A 60 dB calibrated white noise was presented through insert earphones using the Orbiter 922 diagnostic audiometer to the left ear served as suppressor. Placement of probe and the insert earphone was kept undisturbed for the entire duration of testing. TEOAE's were recorded under quiet and contralateral noise conditions and the global amplitude values were noted down for both conditions. The amount of contralateral inhibition was evaluated by subtracting the global amplitude of TEOAE's without noise from with noise in the contralateral ear.

3.4.3. Speech perception in noise. The speech perception in noise test was conducted by using the sentences given in Sentence Identification Test (SIT) in Kannada (Geetha et al., 2014). Sentence list was assessed at 3 different SNRs namely -5dB SNR, -10dB SNR and -15dB SNR. Each SNR was assessed in two different conditions namely – Ipsilateral Only (IO) noise and both Ipsilateral and contralateral (IC) noise.

Two lists were presented per SNR. Participants were instructed to repeat the sentences verbatim. Verbal responses were recorded through Audacity Software version 2.1.3 for offline analysis. Scoring was done by a native Kannada speaker. A score of one was given for every correctly repeated keyword from the list and zero for incorrect repetition or partially correct response. The number of keywords correctly repeated was calculated for a particular list. Considering this, there was 2 lists for a particular condition, an average of the scores of the two lists were calculated.

3.5. Analyses

The parameters used for analyses were as mentioned below-

i. Differences in the magnitude of contralateral inhibition of TEOAE's between three groups 15-24 years, 25-34 years and 35-45 years using the univariate analysis of Variance (ANOVA).
ii. Difference between SPIN scores with only ipsilateral and with ipsilateral + contralateral noise in three different SNRs (-5 dB SNR, -10 dB SNR and -15 dB SNR) and 3 age groups (18-30 years, 31-42 years, 43-55 years) using Mixed analysis of variance (ANOVA).

iii. Correlation analysis between the SPIN scores and the amount of inhibition in all age groups using the Karl Pearsons's product moment correlation.

Chapter 4

Results

The results of the study are explained in accordance to the objectives, which are threefold. A total of 60 participants divided into three age groups participated in the study. Overall, the data followed normal distribution (based on Shapiro-Wilk's test) and hence parametric tests were used.

4.1 Effect of Age on Contralateral Inhibition of Transient Evoked Otoacoustic Emissions (TEOAE's)

The mean and SD of the magnitude of inhibition of otoacoustic emission (OAE's) across the different age groups are depicted in the Figure 4.1**.**

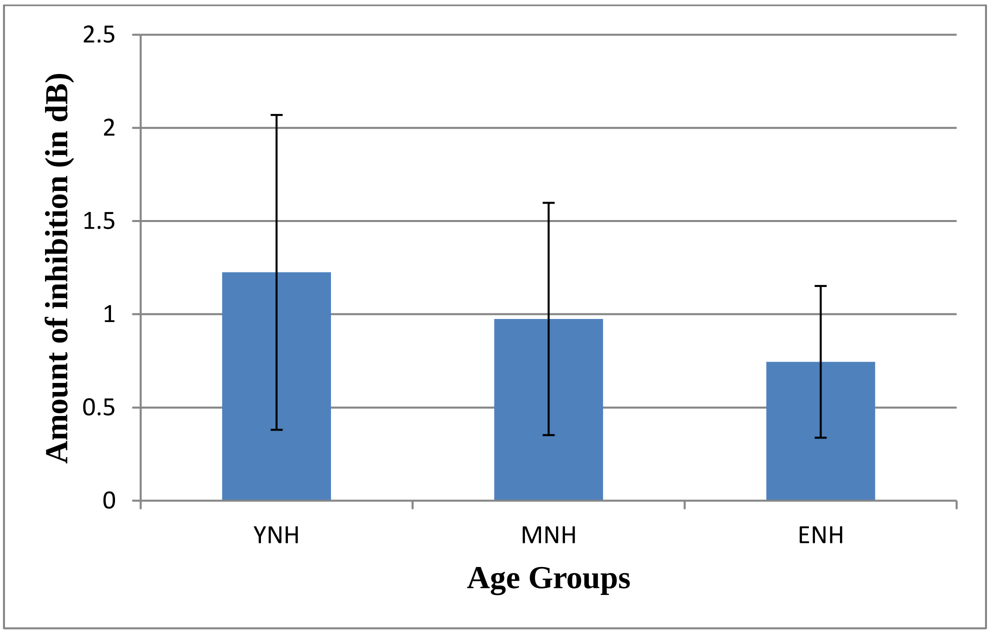

Figure 4.1. Magnitude of contralateral inhibition of TEOAE's as a function of age Young normal hearing individuals, Middle aged normal hearing individuals and Elderly normal hearing individuals denoted as YNH, MNH and ENH respectively.

As depicted in the Figure 4.1, magnitude of inhibition reduced with advancing age, albeit with high variability. To evaluate the significance of mean differences in inhibition amplitudes across different age groups one-way analysis of variance (ANOVA) was conducted. Results revealed no significant main effect of age on the amplitude of contralateral inhibition [$F (2, 57) = 2.728$, $p = 0.074$] of TEOAEs.

4.2 Effect of Age on Speech Perception in Noise

The SPIN scores were examined at -5 dB SNR, -10 dB SNR and -15 dB SNR and compared among the different age groups namely Young normal hearing (YNH), Middle aged normal hearing (MNH) and Elderly normal hearing (ENH). The Figure 4.2 depicts the differences in the number of words identified correctly under different SNRs with and without noise in the contralateral ear. Any value above zero indicates that addition of noise into contralateral ear improved the speech identification scores. From the Figure 4.2 it can be seen that improvement was maximum in YNH group at most negative SNR (-15 dB).

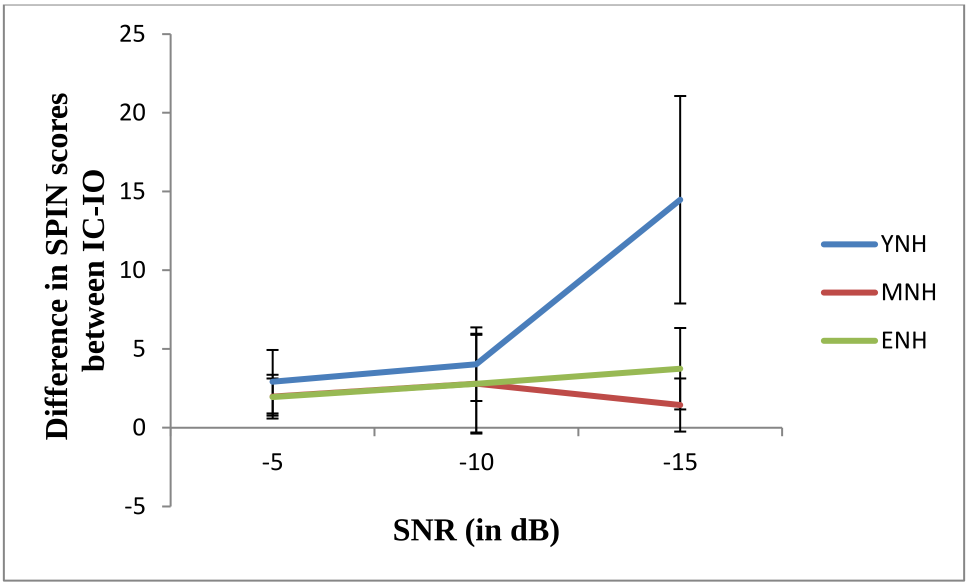

Figure 4.2: Mean and SD of differences in speech identification scores upon the addition of contralateral noise (Ipsilateral and Contralateral and Ipsilateral Only (IC-IO) condition) across different SNR as a function of age

To assess the statistical significance of differences a 3 (SNRs) X 3 (age group) mixed ANOVA was carried out with SNRs as within subject factor and age groups as between subject factor. Greenhouse-Geisser correction was used whenever assumptions of sphericity were violated. Results showed a significant main effect of SNRs [F (2, 114) = 28.25, $p<0.01$]. A significant main effect of age groups was also evident [F (2, 57) = 43.39, $p<0.01$]. In addition, a significant interaction between SNRs and groups was also found [F (4, 114) = 35.48, $p<0.01$]. As there was significant interaction between age groups and SNR follow-up one way univariate ANOVA was carried out at each SNRs separately to assess the effect of age on improvement in the speech identification scores upon the addition of contralateral noise. Table 4.2 depicts the results of univariate ANOVA at different SNRs.

Table 4.1: *Results of univariate ANOVA at different SNRs.*

	Degrees of freedom	F value	p value
-5 dB SNR	2, 57	2.510	0.090
-10 dB SNR	2, 57	12.75	< .001**
-15 dB SNR	2, 57	54.87	< .001**

**<.001- highly significantly different, *<0.05- Significantly different.

From the Table 4.1, it can be seen that there was a significant main effect of age on improvement in the speech identification scores upon the addition of contralateral acoustic stimuli only at -10 and -15 dB SNR. There was no significant effect of age at the SNR of -5 dB. To further assess the effects of age on improvement in speech identification scores, post hoc independent samples t tests (with Bonferroni's correction for multiple comparisons) were carried out between each age group at each SNRs. Table 4.3 shows the results of these independent samples t test.

Table 4.2: *Result shows 't' values of different comparisons.*

		YNH	MNH	ENH
- 5 dB SNR	**YNH**			
	MNH	-1.915		
	ENH	-1.965	-0.050	
-10 dB SNR	**YNH**			
	MNH	-1.352		
	ENH	3.538*	4.890**	
-15 dB SNR	**YNH**			
	MNH	-9.816**		
	ENH	-8.078**	1.738	

**<.001- highly significantly different, *<0.05- Significantly different.

From the Table 4.2 following observations can be made

1. YNH group benefited significantly more upon the addition of contralateral noise than ENH group at -10 dB and -15 dB SNR.
2. YNH group benefited significantly more upon the addition of contralateral noise than MNH group only at -15 dB SNR.

4.3 Relationship between Contralateral Inhibition of TEOAE's and SPIN Scores

To evaluate the relationship between contralateral inhibition of OAEs and improvement in speech identification scores upon the addition of contralateral noise Pearson's Product-Moment correlation analyses was performed between two variables. Table 4.3 shows Correlation coefficient 'r' between contralateral inhibition of OAE and improvement in speech identification scores upon the addition of contralateral noise. None of the correlation coefficients were significant.

Table 4.3: *Correlation coefficient 'r' CS of TEOAE's and improvement in SPIN scores.*

Group	-5 dB SNR	-10 dB SNR	-15 dB SNR
YNH	-0.238	0.342	-0.250
MNH	-0.153	0.091	0.184
ENH	-0.357	0.044	0.436

Chapter 4

Discussion

5. 1 Effect of Age on Contralateral Inhibition of TEOAE's

In order to evaluate the effect of age on contralateral inhibition of transient evoked otoacoustic emissions (CS of TEOAE's), TEOAE's with and without contralateral noise was examined across three age groups - Young Normal Hearing (YNH), Middle aged Normal Hearing (MNH) and Elderly Normal Hearing (ENH). Individuals in YNH group were between 15 years to 24 years, MNH group were between 25 years to 34 years and ENH group were between 35 years to 45 years. The mean of CS of TEOAE's was found to more in the YNH age group than MNH and ENH group. However, this difference was not statistically significant (p = 0.074).

Previously many investigators have evaluated the effect of age on contralateral inhibition of OAEs and results are equivocal. Parthasarathy (2001) assessed the contralateral inhibition of TEOAE's in participants between 20 and 79 years. They reported that inhibition amplitudes were significantly less only in participants above 60 years and inhibition magnitudes did not differ significantly between 20 to 59 years of age. Castor, Veuillet, Morgan, & Collet (1994) studied the effect of age on contralateral inhibition of TEOAE's and Distortion product otoacoustic emission (DPOAE's) amplitude across age ranging from 6-88 years. Their results indicated the amplitude of inhibition reduced in individuals only above 57 year of age. There were no significant differences in inhibition magnitudes till 57 years of age. Quaranta, Debole, & Di Girolamo, (2001) evaluated TEOAE's with and without contralateral white noise across the age range from 20 to 78 years. Their results showed that contralateral white noise inhibited the amplitudes of TEOAE’s but the amount of inhibition was not significantly different between young and elderly individuals. These studies indicate that significant age effects on contralateral inhibition of OAE’s are evident only above 60 years of age. As the upper age limit considered in the present study was 45 years there was no significant effect of age on the inhibition magnitudes.

Moreover, studies which have shown significant reduction in the olivocochlear reflex strength - measured through contralateral inhibition of OAE’s - have evidenced the same primarily for low frequencies. Abdala, Dhar, Ahmadi, & Luo, (2014) assessed the olivocochlear reflex strength through contralateral inhibition of distortion product OAE’s in Teen (13 years to 17 years), Young (19 years to 27 years), middle age (40 years to 58 years) and elderly (63 years to 73 years) individuals. Inhibition magnitudes were significantly less in both middle aged and elderly individuals compared young group only for frequencies below 1.5 kHz. As in the current study only global amplitudes were considered for the calculation of inhibition the age differences in inhibition magnitude may be masked by strong high frequency contributions.

5.2 Effect of Age on Speech Perception in Noise (SPIN).

The second objective of the study was to evaluate the effect of contralateral noise on SPIN scores in different SNRs namely -5 dB SNR, -10 dB SNR, -15 dB SNR across different age groups- YNH, MNH and ENH. The Results of the study revealed a significant effect of SNR on SPIN scores. Highest scores obtained for -5 dB SNR, followed by -10 dB SNR and poorest scores attained at -15 dB SNR. In addition, addition of the contralateral noise (IC) improved the SPIN scores at all SNRs. The improvement was maximum at -15 dB SNR in YNH group.

Kumar & Vanaja (2004) reports the effect of different SNRs on improvement in speech identification scores upon the addition of contralateral noise. Ten children with normal hearing and good academic performance were tested for Speech identification scores in different conditions (IC and IO). These scores were obtained at quiet, +10, +15 and +20 dB SNR values. Results of the study revealed enhanced scores with presence of contralateral stimuli. They reported maximum improvement in speech identification scores upon the addition of contralateral noise at lowest SNR.

In animal experiments it's been shown that feedback from the efferent pathway can enhance the auditory nerve action potentials by the decompression of the rate-level functions. The activation of the olivocochlear bundle may suppress the response to steady state masker and increases the responses to auditory stimulus (Kawase & Liberman, 1993). Activation of the efferent pathway is shown to increase the dynamic range of the auditory nerve fibres. The increased dynamic range of the auditory nerve may aid in coding the fluctuations in intensity better. Since variation in the intensity and frequency are major cue for speech perception, decompression of the rate level function of the auditory nerve might enhance speech understanding noise.

5.3 Relationship between CS of TEOAE's and SPIN Scores

The current study aimed at examining the relationship between the contralateral suppression of TEOAE's and improvement in speech identification scores upon the addition of contralateral scores. The results of the study showed no correlation between the MOC function and SPIN scores in all the age ranges.

In literature there is no consensus regarding relationship between olivocochlear bundle functioning and speech perception in noise. Several studies have reported a positive correlation between contralateral inhibition of OAEs and speech perception in noise (Giraud et al., 1997; Kumar & Vanaja, 2004; Maruthy et al., 2017). Kumar & Vanaja, (2004) reported a positive correlation between in improvement in speech identification scores and magnitude of contralateral inhibition of OAEs at poorer SNRs. Similarly, results are also reported by others (Giraud et al., 1997; Maruthy et al., 2017; Wagner, Frey, Heppelmann, Plontke, & Zenner, 2008).

However, some of the studies have found no significant association between speech in noise perception and olivocochlear bundle function. Narne & Kalaiah, (2018) assessed speech perception in noise using phonetically balanced sentences in Kannada (Avinash et al., 2009) in in 20 adults within the age range of 8-28 years. CS of TEOAE's was used as a measure for assessing the MOCB functioning. Results of the study revealed no significant relation between strength of MOC reflex and speech perception in noise (Narne & Kalaiah, 2018). Similarly, Mukari & Mamat, (2008) and Wagner et al., (2008) failed to evidence any relationship between contralateral inhibition and speech perception in noise.

On the other hand, some studies have also reported negative correlation between functioning of olivocochlear bundle function and hearing in noise. Bidelman & Bhagat (2015) found a negative correlation between the CS of OAE and SIN scores. Results of the study showed that poorer performance of CV discrimination in the presence of noise was seen in individuals having stronger OAE suppression. Similarly, Boer, Thornton, & Krumbholz (2012) conducted a study to correlate the measures of MOC activity and speech processing in noise and found a negative correlation between the two. However, it is difficult and out of the scope of this study to physiologically evaluate the functioning of the MOC system. In addition to this, most of the above mentioned studies have used monosyllables or words as their stimuli. However the current study used sentences which could have been a probable result for the differences in the findings.

Chapter 4

Summary and Conclusions

The main aim of the present study was to study the effect of age on function of efferent auditory pathway. The main objectives of this study were:

1. To compare contralateral suppression of transient evoked otoacoustic emissions (TEOAE's) across three age groups i.e. 18-30 years, 31 to 45 years and 45 to 55 years.
2. To measure the SPIN scores using sentences at different SNR (across 0dB, -5dB, -10dB) in presence of ipsilateral and ipsilateral + contralateral noise.
3. To evaluate the functional relationship between SPIN (with ipsilateral noise and with ipsilateral and contralateral noise) and contralateral inhibition of TEOAE's in YNH, MNH and ENH.

Sixty participants were included in the study. They were divided into three groups based on their age – the young normal hearing group (YNH- with age ranging between 15 – 24 years), middle aged normal hearing group (MNH in the age range of 25-34 years) and the elderly normal hearing group (ENH in the age range of 35-45 years). Participants included in all the three groups had normal peripheral hearing acuity assessed through pure tone audiometry, immittance and otoacoustic emissions. In order to evaluate the effect of age on contralateral inhibition of transient evoked otoacoustic emissions (CS of TEOAE's), TEOAE's with and without contralateral noise was measured. Results revealed no significant differences in the inhibition magnitude of TEOAEs across different age groups. The second objective of the study was to evaluate the effect of contralateral noise on SPIN scores in different SNRs namely -5 dB SNR, -10 dB SNR, -15 dB SNR across different age groups- YNH, MNH and ENH. Results showed that addition of contralateral white noise improved the SPIN scores in all age groups at all SNRs. However, the improvement was maximum in YNH group at -15 dB SNR (lowest SNR tested). Pearson's product moment correlation analyses revealed no significant correlations between contralateral inhibition magnitudes of TEOAE's and improvement in speech perception in noise scores at all the SNRs in all the age groups.

This study demonstrates that contralateral white noise aids in speech perception in noise. This augmentation in the speech in noise perception may be mediated through efferent auditory system or some other mechanism. This augmentation in speech identification scores is highest in young adults at lower signal to noise ratios. The exact physiological reasons for improvement in speech identification in noise upon the addition of contralateral noise are presently unclear.

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