RELATIONSHIP BETWEEN CONTRALATERAL INHIBITION OF OTOACOUSTIC EMISSIONS AND SPEECH PERCEPTION IN NOISE: EFFECT OF MASKER

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Registration No: 17AUD008

This Dissertation is submitted as part fulfilment

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MAY, 2019

CERTIFICATE

This is to certify that this dissertation entitled '**Relationship between contralateral inhibition of otoacoustic emissions and speech perception in noise: effect of masker'** is a bonafide work submitted as a part for the fulfillment for the degree of Master of Science (Audiology) of the student Registration Number: 17AUD008. 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 **‘Relationship between contralateral inhibition of otoacoustic emissions and speech perception in noise: effect of masker’** 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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ABSTRACT

The main aim of this study was to elucidate the relationship of contralateral inhibition of transient evoked otoacoustic emissions (TEOAE) with speech perception in noise (SPIN) across different testing factors. 60 participants volunteered for the study. The participants of the study were divided into three groups based on their age – the young normal hearing group (YNH- with age ranging between 18 – 29 years), middle aged normal hearing group (MNH between 30-44 years) and the elderly normal hearing group (ENH with age ranging between 45-5 years). Participants in all the three groups had normal peripheral hearing acuity as assessed by pure tone audiometry, immittance and otoacoustic emissions. The SNR 50 scores were obtained in the presence of six different types of maskers, namely- white noise, speech spectrum noise, two speaker babble, eight speaker babble, reversed two speaker babble and reversed eight speaker babble. The medial olivocochlear bundle (MOCB) functioning was assessed via contralateral inhibition of transient evoked otoacoustic emissions. Results showed that contralateral inhibition magnitudes differed significantly between YNH Vs ENH and YNH Vs MNH, while there was no significant difference observed for MNH Vs ENH. The SNR 50 scores also showed significant difference between YNH and ENH for all maskers excluding reversed babble. Furthermore, correlation analyses suggested that there was no relationship between MOCB functioning and speech perception in noise across all types of maskers and age groups.

Key words:Medial Olivocochlear Bundle, Speech perception in Noise, Otoacoustic emission, Age, Maskers

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Chapter 1

Introduction

The ear is one of the most important and exceptionally sensitive organs for humans as it collects acoustic energy, controls and projects it onto an array of around 3000 sensory hair cells. All of the information from the peripheral receptor organ is carried to the central auditory structures for analysis by means of afferent auditory pathways. The higher organs, in turn, can manipulate the peripheral receptor, by means of the efferent auditory system. This is made possible by distinct feedback loops that can be identified by their terminations. The efferent innervations of cochlea in mammals are provided by the olivocochlear bundle, which consists of two fundamental groups of neurons (Rasmussen, 1946). These groups are the lateral olivocochlear (LOC) bundle and the medial olivocochlear bundle (MOC) bundle (Guinan Jr, Warr, & Norris, 1983). Both the LOC and MOC arise from the superior olivary complex (SOC). The thin, unmyelinated axons of LOC project to the ipsilateral cochlea and terminate on the afferent (type I) fibers of the inner hair cells (IHC's). The neurons of MOC have comparatively thicker, myelinated axons that project predominantly to the contralateral cochlea, terminating on the cell bodies of outer hair cells (OHC).

Several possible functions of auditory efferent stimulation have been elucidated by previous researchers. They are as follows:

- An improvement in understanding of speech in presence of noise by way of anti-masking. MOC stimulation may restore some auditory nerve fibre sensitivity by adjustment of IHC and auditory nerve fibre dynamic ranges

(Micheyl & Collet, 1996; Jacobson, Kim, Romney, Zhu, & Frisina, 2003; Winslow & Sachs, 1987).

- Maintaining the cochlea in an optimal electromechanical state for acoustic signal processing by reducing OHC amplitude variability (Johnstone, Patuzzi, & Yates, 1986; Maison, Micheyl, Chays, & Collet, 1997).
- Protection of cochlea from acoustic trauma by reducing OHC activity and hence provides a temporary threshold shift for short duration high-intensity stimulation to high frequencies (above approximately 8 kHz) (Liberman, Epstein, Cleveland, Wang, & Maison, 2016; Maison & Liberman, 2000).

Speech perception in the presence of noise (SPIN) is a complex phenomenon and the mechanisms underlying it are still not completely understood. The role of MOC bundle has also been implicated in speech understanding in the presence of noise in several studies (Kumar & Vanaja, 2004; Maruthy, Kumar, & Gnanateja, 2017). There are studies contradicting these findings as well, especially on the role of MOC bundle in speech perception in noise (Mishra & Lutman, 2014; Mukari & Mamat, 2008; Wagner, Frey, Heppelmann, Plontke, & Zenner, 2009). However, there are many methodological differences among these studies which make it difficult to compare them.

Studies report that the speech in noise scores vary with the type of speech stimulus that has been used for testing (Anderson & Kalb, 1987; Miller, Heise, & Lighten, 1951). Several studies examining the effects of competing speech and non-speech maskers have reported that masking from one competing talker or amplitude-modulated noise results in less masking than steady-state noise (Carhart, Tillman, & Greetis, 1969a; Carhart, Tillman, & Greetis, 1969b; Speaks, Karmen, & Benitez, 1967). But when the competing speech acquires a more continuous character by the addition of more talkers, the masking effect comes closer to that of steady-state noise (Carhart et al., 1969a; Gordon-Salant & Wightman, 1983).

Hence, it is clear that the relationship between MOCB functioning and SPIN are ambiguous. Therefore in the present study relationship between MOCB reflex and speech in noise was examined using six different types of maskers in young, middle and older individuals with normal hearing.

Need for the study

The review of the existing literature reveals that differences across the maskers used for SPIN have differential effects on the speech perception (Carhart, Tillman, & Greetis, 1969a; Carhart, Tillman, & Greetis, 1969b). The role of MOCB in speech perception in noise has also been reported (Kumar & Vanaja, 2004; Maruthy, Kumar, & Gnanateja, 2017). However, there is a lack of information on the relationship between SPIN performance using different type of maskers and the MOCB functioning. Also, it would be interesting to study how this relationship varies across age in normal hearing individuals. Hence the present study is taken up to investigate the effect of age and type of maskers on correlation between contralateral inhibition of OAE and SPIN. The findings of such a study would help in better understanding of behavioral performance in SPIN and the underlying neural mechanisms across age groups.

Aim of the study

The aim of the study was to draw a functional relationship between the speech in noise performance across different masking conditions and contralateral inhibition of oto-acoustic emissions (OAE).

Objectives of the study

- To compare contralateral inhibition of transient evoked oto-acoustic emissions (TEOAE) in normal hearing young adults (YNH), adults in the middle aged group with normal hearing sensitivity (MNH) and elderly normal hearing individuals (ENH)
- To measure SNR-50 in presence of different types of maskers in YNH, MNH and ENH
- To assess the relationship between SPIN (in different masker conditions) and contralateral inhibition of TEOAE across the three groups

Chapter 2

Review of Literature

The olivocochlear efferent neurons originate in the brainstem and terminate in the organ of corti, allowing the central nervous system to have effect on the operation of cochlea(Huffman & Henson, 1990).The physiological role of these auditory efferent fibres is still ambiguous. Many authors have studied role of medial olivocochlear bundle (MOCB) functioning by stimulating it electrically or acoustically to check on its inhibitory effects over auditory periphery (Micheyl, Perrot, & Collet, 1997). Following this, it was thought that OCB may play a role in the protection of cochlea from over-stimulation (Hildesheimer, Makai, Muchnik, & Rubinstein, 1990). Apart from the protective role, this inhibitory function could also lead to an improvement in coding of signals in presence of background noise (Liberman, 1988) indicating an antimasking role for OCB (Micheyl et al., 1997)

Studies relevant to the present research are being reviewed under the following headings:

2.1. Effect of age on contralateral inhibition of TEOAE

2.2. Effect of age and maskers on speech perception in noise

2.3. Relationship between contralateral inhibition of TEOAE’s and SPIN

2.1. Effect of Age on Contralateral Inhibition of TEOAE

From the findings of existing studies it is clear that as age increases, there is an overall decline in performance by the individual, including general cognitive decline (Gordon-Salant & Fitzgibbons, 1997). Studies have also reported decreased neural efficiency in older individuals with normal hearing sensitivity by measuring speech evoked auditory brainstem responses (Werff & Burns, 2011). Results of studies on effect of age on MOCB reflex are ambiguous. Some of the studies have shown that as the age increases, the MOC reflex gets weakened(Castor, Veuillet, Morgan, & Collet, 1994; Kim, Frisina, & Frisina, 2002; Maruthy, Kumar, & Gnanateja, 2017; Mukari & Mamat, 2008).

Castor et al. (1994) recorded transient evoked otoacoustic emissions (TEOAE) and distortion product otoacoustic emissions (DPOAE) with and without contralateral stimulation (at 30 dB SL) in young normal hearing group and older group with some high frequency hearing loss (between 70 – 88 years). The authors found lesser reduction in amplitude of TEOAE in the older group after contralateral stimulation. In DPOAE, this reduction was predominantly in the middle frequency region (2.83 to 5.04 kHz). To check the influence of hearing loss on this effect, the authors compared the older individuals with threshold matched young adults, and the difference was not found to be significant. They conclude that the deterioration in the function could be related to the age linked hearing loss.

The study by Kim et al. (2002) checked how age influences MOC function by measuring the contralateral inhibition (CI) of DPOAE on ten normal hearing individuals divided into young, middle and old groups each. White noise (at 30 dB SL) was used as the contralateral stimuli. The authors carried out a frequency specific analysis of the inhibition obtained with the contralateral noise in the DPOAE amplitude. Inhibition magnitudes were significantly lower in the middle aged and older group. They conclude that MOC decline starts prior to the OHC dysfunction. The MOC is function is found to be maintained best at 1-2 kHz in individuals of all age groups. Mukari and Mamat (2008) also used CI DPOAE to check efferent function across young normal hearing (20-30 years) and older (50-60 years with thresholds within 25 dB) adults, along with other objectives of their study. 30 dB SL was the presentation level of the contralateral noise for CI DPOAE. It was found that the younger group had higher inhibition in almost all frequencies.

Parthasarathy (2001) checked age effects of contralateral inhibition of TEOAE and reported the magnitude of inhibition reduced with the increasing age. In their study, subjects between 20 and 79 years were divided systematically into six-decade age groups. However, reduction in the inhibition amplitude was pronounced only in the two groups with mean age greater than 60 years. In these groups, a rapid decline in the amplitude of inhibition was noticed when compared to the other younger groups.

Maruthy et al. (2017) in their study checked the functional relationship between perception in presence of noise and efferent system functioning across two age groups on the MOC system. Their participants included 27 adults in the age range of 18-30 and 29 older adults with age ranging between 50-65 years. Both the groups had similar TEOAE amplitude in quiet. Contralateral white noise was presented at 30 dB SL and TEOAE measured again. The reduction in amplitude was noted. The reduction in amplitude was found to be more in the younger group than in the other group.

Some studies also indicate no effect of age on magnitude of inhibition amplitudes between younger and older individuals' in MOC functioning (Quaranta, Debole, & Girolamo, 2001). In their study, the authors assessed contralateral inhibition of TEOAE in participants with age varying from 20 to 78 years. All participants had thresholds within 25 dB HL. They found a reduction in mean amplitude of inhibition, though it was found to be non-significant across the groups.

2.2. Speech Perception in Noise

The presence of unrelated auditory information (other talkers, environmental noises) presents a major challenge to listening to speech. Understanding speech in the presence of noise requires interplay of sensory information, and linguistic and cognitive developmental factors. One of the reasons for poor performance in such situation has been attributed to poor auditory processing skills in children and elderly population (Chermak & Musiek, 1997; Gates & Cooper, 1991)

A developmental trend has been observed in performance of children in speech in noise test. Several studies have supported age-related development in speech in noise abilities utilizing paradigms that present signals in the presence of noise, where the levels of both the signal and noise are adjusted accordingly to attain distinct signal-to-noise ratios. Investigations of speech perception under varying signal-to-noise ratios using sentences with either high or low contextual cues revealed that, older children performed better than younger children in the high context conditions, due to their extended knowledge of language rules, thus confirming speech in noise improvement with age. A similar study, including children aged 5–11 years and young adults, also supports age improvements in speech in noise recognition (Fallon, Trehub, & Schneider, 2002).

Research evidence indicates that speech perception abilities also deteriorate with aging. Kalikow, Stevens, and Elliott (1977) reported that the perception of sentences in the presence of noise at SNRs of +10, +5, 0 and -5 dB was much poorer in individuals of older ages than younger age. In another study, (Jain, 2016) compared perception of speech in presence of noise across different age groups and the results show that SNR-50 deteriorates significantly after 40 years of age. Also, the best scores were seen in the age range of 20-29.11 years.

In another experiment, Abdala, Dhar, Ahmadi, and Luo (2014) also compared the difference in performance across teenagers, young adults, middle aged adults and older adults in a task involving vowel, consonant and word in sentence identification in the presence of noise. They found deterioration in performance with increase in age. They also found that there was no correlation between speech scores and age in individuals greater than 60 years of age.

Carhart, Johnson, and Goodman (1975) obtained masked threshold for spondees in (1) steady state speech spectrum noise, (2) speech spectrum noise modulated by seven talker combinations, and (3) the seven talker combinations. These combinations were 1, 2, 3, 16, 32, 64, and 128 voices speaking continuous discourse. The long term spectra of all maskers were equalized to a common level by averaging their intensity disparities across the 20 AI bands that contribute to intelligibility. The results showed that, greater masking effects were there in case of combination of talkers than modulated noise due to perceptual masking.

Rosen, Souza, Ekelund, and Majeed (2013) measured speech recognition at two fixed signal-to-noise ratios in 16 different backgrounds for normal hearing adults. The results indicated that for a given number of talkers, natural speech was always the most effective masker. The greatest changes in performance occurred as the number of talkers in the maskers increased from 1 to 2 or 4 and also extent of masking was more for the masker type which was more close to target.

(Simpson & Cooke, 2005) measured consonant identification rates for vowel-consonant-vowel tokens with N-talker babble noise and babble-modulated noise for an extensive range of N, at a fixed signal-to-noise ratio. The results showed that greatest IM is observed for the lowest number of speakers in the babble and progressively reduces with increasing number of speakers in the babble in a non-monotonic fashion.

Speech perception abilities are even observed to be much better in temporally modulated noise compared to steady state noise (Festen & Plomp, 1990; Jin & Nelson, 2010). However, speech is always observed to produce greater masking effects than noises; a phenomenon referred to as ‘perceptual masking’ by Carhart (Carhart, Tillman, & Greetis, 1969b).

Rhebergen, Versfeld, and Dreschler (2005) found speech reception threshold with intelligible and unintelligible interfering speech played normally and time-reversed. With Dutch listeners, Swedish reversed interfering speech gave a rise in SRT of 2.3 dB compared with the Swedish interfering speech played normally. The difference can be attributed to differences in forward masking. Dutch time-reversed interfering speech gave a decrease in SRT of 4.3 dB compared to intelligible Dutch interfering speech. This study hence reported that time-reversed babble is also as effective as babble. This finding is the result of both a release from informational masking and an increase in forward masking. Therefore, the amount of informational masking is larger than 4.3 dB and, if one assumes similar differences in forward masking for Dutch and Swedish speech, may amount to 6.6 dB.

Gordon-Salant and Fitzgibbons (1997) examined the contribution of cognitive aspects on age related changes in speech perception by measuring the effects of recall task, speech rate, and presence of contextual cues on recognition performance by young and elderly listeners. Stimuli were low and high context sentences from the R-SPIN test presented at normal and slowed speech rates in noise. Elderly listeners demonstrated poorer performance than younger listeners on the sentence recall task, but not on the word recall task, indicating that added memory demands have a detrimental effect on elderly listeners' performance. Slowing of speech rate did not have a differential effect on performance of young and elderly listeners.

2.3. Relationship between Contralateral Inhibition of TEOAE's and SPIN

Winslow and Sachs (1988) did electrical stimulation of MOC fibers in cats. They studied responses to brief tone stimuli in the presence of noise using micropipettes. For analysis, base frequency near 8 kHz (no phase locking) were taken in quiet and background noise condition with and without electrical stimulation of OCB. The authors found that when OCB was stimulated, there was a reduction in the discharge rates of the nerve fibers. This decreases adaptation of the fiber, leading to saturation (which increases with increasing levels of noise). Therefore, OCB stimulation restores dynamic ranges of nerve fibers to those seen in quiet, thus enhancing signal detection in the presence of noise.

Few studies discussing the antimasking function of MOCB was carried out by Kawase, Delgutte, and Liberman (1993). The study was carried out on anesthetized or decerebrate cats and single nerve response to tone burst stimuli in quiet and continuous noise was checked. They conclude that there's a difference in response and function of OCB in quiet and noise conditions. In quiet, the MOCB majorly gives a suppressive response, whereas, in noise, the response to transient stimuli is enhanced.

In another study, the authors explored the presence of efferent involvement in understanding signals in the presence of noise (SNR's varying from -20 dB to +25 dB) in humans. They compared the speech intelligibility in noise using monosyllabic words from Fournier list in healthy individuals and vestibular neurectomized patients. They found that there was an improvement in the SIN scores in conditions with contralateral noise in the healthy participants which was almost nil in the neurectomized patients. The study concluded that the efferent system plays an anti-masking role in speech perception in noise (Giraud et al., 1997)

Kumar and Vanaja (2004) attempted to correlate effect of contralateral acoustic stimuli on speech perception and CS of TEOAE. The participant group included ten normal hearing children. The authors used speech identification test for Indian English speaking children in the presence of BBN at +10, +15 and +20 dB SNRs in the ipsilateral ear. Testing was done in different conditions such as quiet, various ipsilateral noise conditions, low level contralateral noise (30 dB SL) and both ipsilateral BBN and contralateral low level BBN. They found that contralateral stimulus enhanced speech perception at ipsilateral SNR's of +10 dB and +15 dB, which correlated with the magnitude of CS of OAE. The result suggests the possible role of MOCB in hearing in noise.

Muchnika et al. (2004) investigated the inhibition effect of TEOAE in APD children. The study groups included 15 APD children aged 8–13 years associated with learning disabilities and 15 controls. The inhibition effect of TEOAE was evaluated by comparing the TEOAE levels with and without contralateral acoustic stimulation. A significantly reduced inhibition effect of TEOAE was exhibited in the APD group, when compared to the controls. This study is also suggestive of role played by MOCB in difficult listening conditions

Boer, Thornton, and Krumbholz (2011) measured MOCB activity using contralateral inhibition of otoacoustic emissions, and consonant-vowel (CV) discrimination in presence of broadband Gaussian noise at an SNR of 10 dB. Their findings revealed a detrimental effect of MOCB induced reduction in cochlear gain on speech-in-noise processing and thus conflict with some previous studies that have found a beneficial effect (Giraud et al., 1997; Kumar & Vanaja, 2004).

In another set of studies, no correlations have been found across the two phenomena, like the one by Mukari and Mamat (2008). In their experiment, they compared medial efferent system functioning (assessed through CS of DPOAE) in SIN perception (through HINT) in younger and older individuals. Even though they found age related reduction in DPOAE amplitude and SIN performance, it wasn't assigned to MOCB functioning. These findings are reported in other studies as well (Wagner et al., 2009). These authors found no statistically significant relation between SIN intelligibility and CS of DPOAE.

Likewise, Mishra, and Lutman (2014), checked the MOC unmasking effects in normal hearing listeners. The four alternative auditory feature test (Foster & Haggard, 1987) in the presence of steady noise filtered to be similar to that of the long term average speech spectrum of the target word was administered on 18 adults (18-30 years). They could not find any significant relations between magnitude of inhibition in these individuals and their speech perception in noise.

Maruthy, Kumar, and Gnanateja (2017) recorded context-dependent brainstem encoding as an index of rostral efferent function and contralateral inhibition of otoacoustic emissions as an index of caudal efferent function in groups with good and poor speech perception in noise. These efferent mechanisms were analyzed for their relationship with each other and with speech perception in noise. Their results revealed that the two efferent mechanisms did not show any functional relationship. But both the mechanisms function with the same purpose of fine tuning the afferent input and enhancing understanding of speech in adverse listening conditions.

In a study by Narne and Kalaiah (2018), involvement of efferent system in hearing in noise was assessed in 20 adults (between 18-28 years). Phonetically balanced sentences in Kannada (Avinash, Meti, & Kumar, 2009) in the presence of speech spectrum shaped noise was administered on the participants. CS of TEOAE was used as a measure for assessing the MOCB functioning. It was found that there was no significant relation between strength of MOC reflex at any level of stimulation and speech reception threshold in noise.

Chapter 3

Methods

The study aimed at examining the effect of different type of maskers on Speech Perception in Noise (SPIN) and its correlation between Contralateral Inhibition of Transient Evoked Otoacoustic Emissions (CI-TEOAE) across age groups. The specific objectives of the study were: (a) to compare magnitude of inhibition of OAEs in normal hearing young adults (YNH), adults in the middle aged group with normal hearing sensitivity (MNH) and elderly normal hearing individuals (ENH) (b) To measure SNR-50 in presence of different types of maskers in YNH, MNH and ENH (c) To assess the relationship between SPIN (in different masker conditions) and contralateral inhibition of TEOAE across the three groups. The method followed in the study is discussed in the following sections.

3.1. Participants

A total of 60 participants volunteered for the study. The participants recruited for the study were native speakers of Kannada, a south Indian language, spoken mainly in the state of Karnataka. The participants in the study were divided into three groups based on their age. The first group consisted of young normal hearing adults (YNH) (n= 20) in the age range of 18-29 years. The second group (n = 20) included middle aged participants (MNH) with age ranging between 30-44 years and the third group (n =20) covered elderly normal hearing (ENH) individuals in the age range of 45-55 years. A structured interview was carried out to ascertain that none of the participants had any history of middle ear pathology, noise exposure, ototoxic drug usage etc. Through the interview it was also ascertained that none of the participants had any gross neurological or cognitive dysfunction.

3.1.1. Inclusion criteria. The participants of the study in YNH and MNH had thresholds within 15 dB HL at octave frequencies from 250 Hz to 4 kHz. Participants in ENH group had thresholds within 15 dB HL at octave frequencies from 0.25 kHz to 2 kHz and within 25dBHL at 4 kHz. All participants showed ipsilateral and contralateral acoustic stapedial reflex thresholds at normal levels at 0.5 kHz and 1 kHz. All the participants had 3 dB or more global transient evoked otoacoustic emission (TEOAE) for 65 dB SPL clicks. All participants were native speakers of Kannada. A written informed consent was taken from all participants prior to the commencement of the experiment. Study adhered to ethical guidelines as per the “ethical guidelines for Bio-behavioural research at All India Institute of Speech and Hearing, Mysore” (Basavaraj & Venkatesan, 2009)

3.2. Equipment and Test Environment

The testing was carried out in a sound treated, double room set up with appropriate lighting and ventilation. The participants were made to sit comfortably on a chair and instructions were given in their native language.

A calibrated dual channel, diagnostic audiometer – Inventis Piano with TDH 39 headphones (Corso Stati Uniti, Padova, Italy) and Radio Ear B71 bone vibrator (Middlefart, Denmark) was used for the evaluation of hearing status of the participant. A calibrated GSI Tympstar (Grason-Stadler, Minneapolis, USA) middle ear analyzer with default probe assembly was used to check for the middle ear status (both tympanometry and reflexometry). Otoacoustic emissions and its inhibition were recorded and analyzed using ILO V6 (Otodynamics) OAE software (Hatfield, Herts, United Kingdom). Madsen Electronics Orbitter 922 Version 2 Clinical Audiometer (Tampa, Florida) was used to present white noise for recording inhibition of otoacoustic emissions. For the speech perception in noise test, recorded speech material was delivered through calibrated Sennheiser HD 380 pro headphones connected to an hp 14 Core i3 Laptop.

3.3. Procedure

3.3.1. Basic audiological evaluation. Pure tone Audiometry was carried out using modified Hughson and Westlake procedure (Carhart & Jerger, 1959). Hearing thresholds were measured at octave frequencies between 0.25 kHz to 8 kHz for air conduction and between 0.25 kHz to 4 kHz for bone conduction. Speech reception threshold, speech identification scores and the uncomfortable levels were assessed using standard procedures. For tympanometry, probe frequency of 226 Hz was be used. Acoustic reflex threshold was obtained at 0.5 kHz and 1 kHz ipsilaterally and contralaterally.

3.3.2. Contralateral inhibition of TEOAE. The participants were seated comfortably on a chair and a probe of appropriate size was inserted in to the ear canal of the right ear. The probe tube calibration test was run and it was ensured that the values at each frequency were 65dB +/- 2dB at 1 kHz and 2 kHz and +/- 3dB at 4 kHz. Otoscopic examination of the subject’s ear canals was performed prior to testing in order to avoid invalid or incomplete results due to presence of wax in the ear canal. The probe was secured to the clothing by using the shirt clip on remote probe. The subjects were instructed to remain still and quiet while the test was performed. In the left ear, an E-A-RTONE 5A insert earphone connected to an OB922 clinical audiometer was placed. TEOAEs were obtained for 260 linear clicks presented at 65 dB SPL (±0.5 dB). After this recording 60 dB SPL of calibrated white noise was presented to left ear through the insert ear phones and TEOAEs were recorded again using the same protocol mentioned above. Magnitude of contralateral inhibition was measured as the difference in global TEOAE amplitude with and without noise in the contra lateral ear.

3.3.3. Speech perception in noise

Preparation of stimuli. Twelve lists from Kannada sentence identification test by (Geetha, Kumar, Manjula, & Pavan, 2014) were used for estimating the signal to noise ratio required for 50% correct identification (SNR-50). Each list contained 10 sentences, with each sentence having 4 keywords. Therefore, there were a total of 40 keywords per list. The sentences were made of familiar words of equal difficulty level. All the sentences have low predictability level. Four different types of maskers were used for the study – babble, reversed babble, speech spectrum noise (SSN) and white noise. Among the speech babble there were two speaker babble and eight speaker babble. For the recording of multi-talker babble, native speakers of Kannada were asked to read out segments from a Kannada newspaper for 5 minutes. Later, to obtain speech babble, 3.5 minutes section of this recording was taken. All the talkers' recording was done separately in a sound treated room. Microphone was placed firmly at a distance of 10 cm from the mouth of the speaker. Recording was carried out using the Adobe Audition 3.0 software installed in a personal computer, connected to a MOTU MICROBOOK II external sound card interface at a sampling frequency of 44.1 kHz. Post recording, all the individual tracks were first amplitude (RMS) normalised and then mixed to obtain the "speech babble". This mixed babble was then time inversed to obtain the "reverse-babble" masker. "Speech spectrum noise" with the spectral shape similar to that of speech babble was generated using a custom Matlab script Gnanateja (2017). The maskers (babble, time reversed babble, white noise and speech shaped noise) were mixed at different SNRs. The mixing of the maskers and the sentences at different SNRs was done using a custom Matlab function Gnanateja (2017). Two lists were used for each of the masker conditions. Within the list SNR for each of the 10 sentences in the list was progressively reduced from +10 to -8 dB in steps of 2 dB in case of speech babble and speech noise. In the condition of white noise masker the SNR varied from 0 to -14 dB in steps of 2 dB. The reason for the same is due to its poor masking effects on speech content.

Procedure. The stimuli were delivered through calibrated Sennheiser HD 380 pro headphones connected to an hp Laptop. Output of the headphones was calibrated with help of KEMAR. The presentation level for speech was maintained at 70 dB SPL. The participants' task was to repeat the sentences heard verbatim while ignoring the background maskers. The lists used for the different masker conditions were randomized across the participants as well the order of sentences presented within a list were randomized to ensure there are no order effects.

Verbal responses were obtained from the participants and the responses were recorded using Smart Recorder App in an Android phone for offline analyses. A score of one was given for every correct response (key words of sentences) and zero for any incorrect or partially correct response. The total number of correctly repeated key words in each lists were identified and the SNR-50 was calculated using the Spearman-Karber equation given by Finney and Tattersfield (1952);

Speech recognition threshold (SNR-50) = i +1/2(d)-(d)(#correct)/(W)

where, 'i' is the initial presentation level (0 dB in case of white noise and +8 dB for other maskers),'d' is the attenuation/decrement step size (2 dB), 'W' is key words per decrement (4 in this case) and '#correct' is the total number of correct key words repeated by the participants. As there were two lists for each masker condition, SNR-50 was calculated separately for these two lists. Later, their average score was obtained, which was considered as the actual SNR 50 for that particular masker condition.

3.4. Analyses

The parameters analyzed were

i. Comparing the amplitude of contralateral inhibition of TEOAE across the three groups through univariate analysis of variance.

ii. Difference between SNR-50 across the different maskers (speech noise, two speaker babble,8 speaker babble, white noise, reversed two speaker babble &reversed 8 speaker babbles) in different age groups and any interactions between them through Repeated Measures ANOVA.

iii. Relationship between inhibition magnitude of TEOAEs and SNR-50 using Pearson's Product-Moment correlation analyses.

Chapter 4

Results

The objectives of this study were to assess the effect of age on contralateral inhibition of otoacoustic emissions (CIOAE), speech perception in noise and relationship between the two. The results are discussed under these respective headings. The study included 60 participants, who were divided into three groups based on the age. Overall data followed normality on Shapiro-Wilks test and hence parametric tests were used.

4.1. Effect of Age on Contralateral Inhibition of TEOAE

Figure 4.1 represents the mean and one standard deviation (denoted by error bars) of inhibition of transient evoked otoacoustic emissions (TEOAE) amplitudes across three age groups (young, middle and elderly normal hearing individuals – YNH, MNH and ENH respectively).

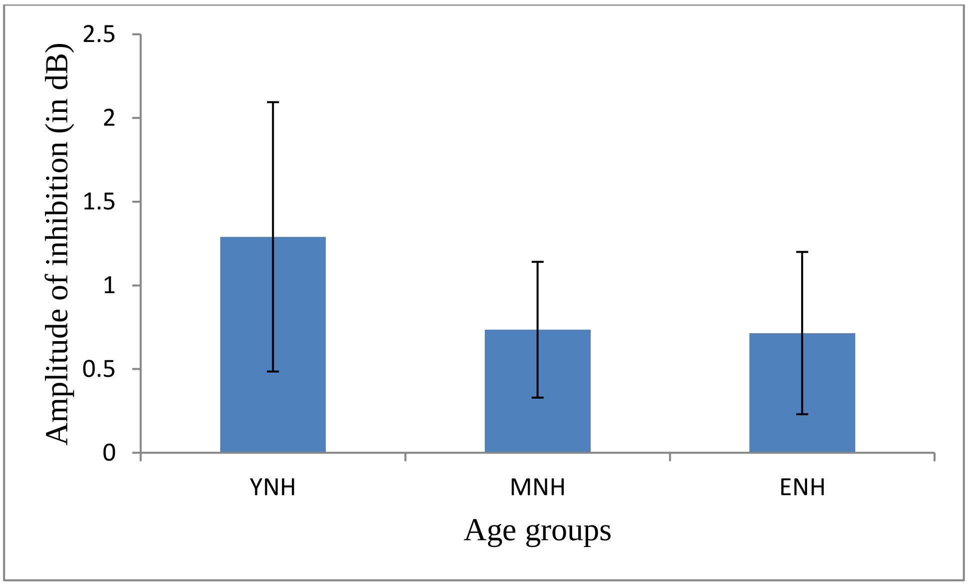

Figure 4.1: Contralateral inhibition of TEOAE as a function of age

From Figure 4.1 it can be seen that YNH group had higher inhibition of TEOAEs compared to MNH and ENH. To check the statistical significance of these differences, a univariate analysis of variance (ANOVA) with inhibition amplitude as the dependent variable and groups as between subject factor was run. Results revealed significant main effect of age on inhibition amplitude [F (2, 57) = 6.105, $p = 0.004$, $\eta^2 = 0.176$]. Follow-up post hoc test using Bonferroni corrections for multiple comparisons indicated that the mean inhibition for YNH (M=1.29, SD=0.784) group was significantly higher compared to MNH (M=0.406, SD=0.735) and ENH (M=0.485, SD=0.715). However, there was no statistically significant difference in mean inhibition amplitudes of MNH and YNH groups.

4.2. Effect of Age on Speech Perception in Noise

SNR-50 values were compared across the three groups – YNH, MNH and ENH for different types of maskers. Figure 4.2 depicts the mean and one standard deviation of SNR-50 for sentences in the presence of different types of maskers across three groups.

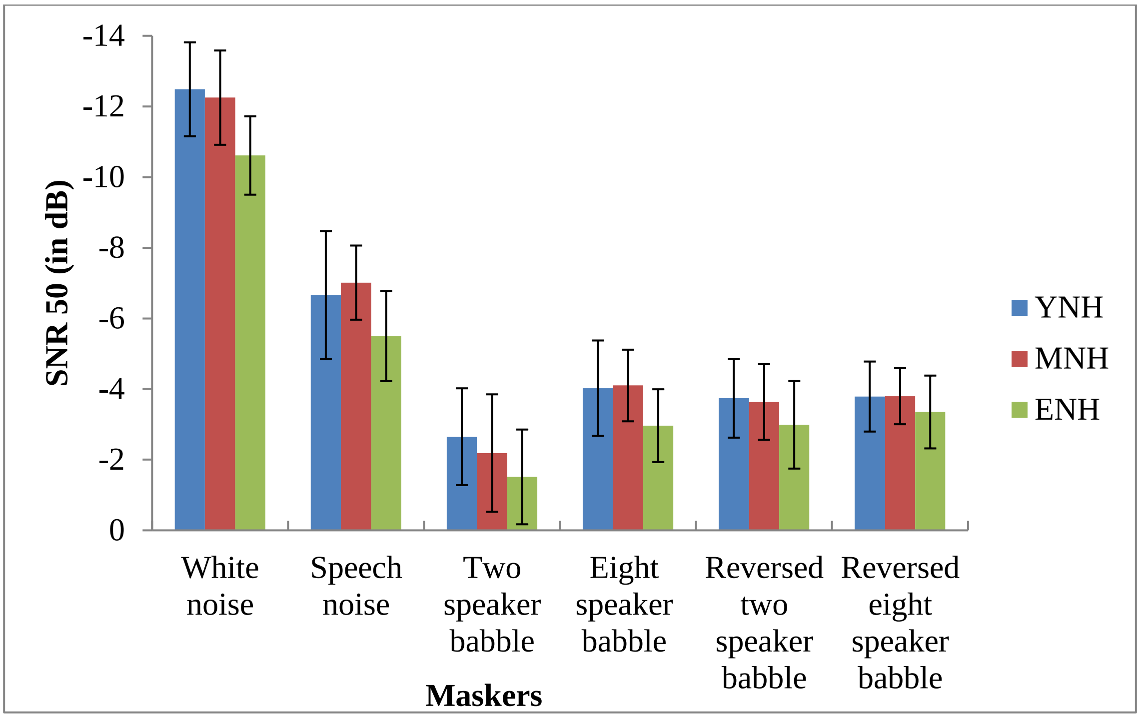

Figure 4.2: Mean and SD of SNR 50 for maskers as a function of age

From Figure 4.2 it can be seen YNH group had better SNR-50 compared to other two groups for all maskers. Among different type of maskers white noise had better SNR-50 compared to babble and reverse babble in all the three groups. Furthermore, two-speaker babble had poor SNR-50 compared to all other maskers in all three age group. To evaluate the statistical significance of these observations a Repeated measures ANOVA was done with different types of maskers as within the subject factor and age groups as between the subject factor. Results showed a significant main effect of age [F (2, 57) = 7.177, p = 0.002] and maskers [F (5,285) = 1162.7, p <0.001] on SNR-50. Interaction between maskers and age was also significant [F (10,285) =2.885, p=0.002]. As interaction was significant follow-up univariate ANOVA was carried out for each masker conditions to assess the effects of age on SNR-50. Results of Univariate ANOVA are shown in table 4.1. Results revealed significant main effect of age for white noise [F (2, 57) = 13.08, p <0.001], speech spectrum noise [*F* (2, 57) =6.257, *p*=0.003], two speaker babble [*F* (2, 57) = 3.049, *p* =0.05] and eight speaker babble [*F* (2, 57) =6.208, *p* =0.004]. Table 4.2 shows the post-hoc tests adjusted with Bonferronie's corrections for multiple comparisons. From the Table 4.2 following observations can be made:

- There was a significant difference between YNH Vs ENH for all types of maskers excluding reversed two speaker and reversed eight speaker babble
- There was no significant difference between any groups for reversed two speaker and reversed eight speaker babble
- There was significant difference between MNH Vs ENH only for white noise and speech spectrum noise

Table 4.1: *ANOVA table for each masker condition*

Type of masker	**Degrees of freedom**	**F value**	**p value**
White noise	2, 57	13.08	<0.001**
Speech noise	2, 57	6.257	0.003*
Two speaker babble	2, 57	3.049	0.05*
Eight speaker babble	2, 57	6.208	0.004*
Reversed two speaker babble	2, 57	2.536	0.088
Reversed eight speaker babble	2, 57	1.471	0.238

Note: ** indicates highly significant difference (p<0.001)

*indicates significant difference (p<0.05)

Table 4.2: *Post hoc tests*

Maskers	**Groups**	**T**	**P**
White noise	YNH- MNH	0.595	1
	YNH-ENH	4.696	<0.001**
	MNH-ENH	4.101	<0.001**
Speech spectrum noise	YNH- MNH	-0.782	1.000
	YNH-ENH	2.597	0.036 *
	MNH-ENH	3.379	0.004*
Two speaker babble	YNH- MNH	0.998	0.967
	YNH-ENH	2.455	0.051 *
	MNH-ENH	1.457	0.452
Eight speaker babble	YNH- MNH	-0.208	1.000
	YNH-ENH	2.942	0.014*
	MNH-ENH	3.150	0.008
Reversed two speaker babble	YNH- MNH	0.277	1.000
	YNH-ENH	2.074	0.128
	MNH-ENH	1.797	0.233
Reversed eight speaker babble	YNH- MNH	-0.042	1.000
	YNH-ENH	1.464	0.446
	MNH-ENH	1.506	0.413

Note: ** indicates high significant difference (p<0.001)

*indicates significant difference (p<0.05)

4.3. Relationship between Contralateral Inhibition of TEOAE and SNR-50

For this objective, Pearson's Product-Moment correlation analyses were done between contralateral inhibition of TEOAE magnitudes and SNR-50 for each masker condition for all the age groups. Table 4.3 shows the correlation coefficient 'r'.

Table 4.3: *Correlation between contralateral inhibition of TEOAE magnitudes and speech perception in noise scores*

Maskers	**YNH**	**MNH**	**ENH**
White noise	0.251	0.197	-0.114
Speech spectrum noise	0.102	0.091	0.040
Two speaker babble	0.295	0.190	0.029
Eight speaker babble	0.380	0.230	0.062
Reversed two speaker babble	0.273	-0.091	0.265
Reversed eight speaker babble	0.201	-0.031	0.214

From the Table 4.3 it can be seen that there was no statistically significant correlation between SNR 50 and magnitude of inhibition for all the age groups across different types of maskers.

Chapter 5

Discussion

5.1. Effect of Age on Contralateral Inhibition of TEOAE

To examine the effect of age on contralateral inhibition of transient evoked otoacoustic emissions (CI-TEOAE), TEOAE was measured in individuals belonging to three age groups – young normal hearing (YNH), middle aged normal hearing (MNH) and elderly normal hearing (ENH) individuals and the inhibition amplitude was compared. The mean of CI-TEOAE was found to be significantly more in the YNH group, when compared to MNH and ENH groups.

There are a few studies reported in literature which has looked for CI-TEOAE with reference to age. Findings of the present investigation is in agreement with that of Maruthy, Kumar, & Gnanateja (2017). In their study, the authors assessed the CI-TEOAEs using similar protocol of the current study in two groups of individuals; young and older adults respectively. The results of their study indicated a negative correlation of inhibition amplitude with respect to age. This means that as the age advanced inhibition amplitudes reduced. Similar results are reported by other investigators as well. Parthasarathy (2001) checked age effects of CI-TEOAE across different age group (from 20-79 years) and reported that the magnitude of inhibition reduced with the increasing age. In their study, subjects between 20 and 79 years were divided systematically into six-decade age groups, five subjects per group. However, reduction in the inhibition amplitude was pronounced only in the two groups with mean age greater than 60 years. In these groups, a rapid decline in the amplitude of inhibition was noticed when compared to the other younger groups. In the current study also, the effect of age on magnitudes of inhibition were observed. There were marked difference between inhibition amplitudes for YNH Vs MNH and YNH Vs ENH. Also, it can be observed that there was almost no difference in the mean inhibition amplitude for MNH Vs ENH. Hence, we can elucidate that the magnitude of inhibition for TEOAEs starts deteriorating from the MNH age range (30-45 years) itself. There are a few other studies which also report of a decline in medial olivocochlear (MOC) functioning as age progresses (Castor et al., 1994; Kim et al., 2002).

In the study by Quaranta, Debole, and Di Girolamo (2001) recorded TEOAE's with and without contralateral acoustic stimulation for 52 subjects in the age ranging from 20-78 years. The subjects were divided into five groups. The results of this study indicated no effect of age on magnitude of inhibition amplitudes between five groups contradictory to the present study. Reasons for these differences in the results are not known.

5.2. Effect of Age on Speech Perception in Noise

The next objective of the study was to compare the speech perception in noise (SPIN) scores assessed using different types of maskers (white noise, speech spectrum noise, two speaker babble, eight speaker babble, reversed two speaker babble and reversed eight speaker babble) across different age groups. The results of the study showed that there is a significant effect of age on SPIN scores. The SPIN scores were significantly poorer in the ENH group, compared to YNH group. This is in consensus with other studies as well (Abdala et al., 2014; Billings, Penman, McMillan, & Ellis, 2015). (Abdala et al., 2014) found a decrease in speech scores with increasing age up till 60 years of age, beyond which they found no decline. (Billings, Penman, McMillan, & Ellis, 2015) found the SNR-50 to be poorest in older individuals with hearing impairment, followed by older normal hearing group and then the young normal hearing group.

The results of the present study also indicated that, all three groups performed best in presence of white noise masker and poor in presence of two speaker babble. This finding is in consensus with other investigators (Bronkhorst, 2000; Carhart, Johnson, & Goodman, 1975; Hoen et al., 2007; Lu, Daneman, & Schneider, 2016). It's been reported that the perception of speech in the background of speech is more difficult than in the presence of non-speech backgrounds such as speech spectrum noise or white noise. Furthermore, when speech babble is used as the masker, the intelligibility of the masker depends on the number of speakers in the babble (Rosen, Souza, Ekelund, & Majeed, 2013; Simpson & Cooke, 2005). Typically, the intelligibility of the babble is greatest when the number of speakers in the babble is low (2 or 3 speaker babbles). These babbles have clear audibility of individual words, phrases or even sentences, and are thus loaded with lexical information. This type of masking is called informational masking (IM). However, babbles become progressively less intelligible and more noise like with increasing number of speakers in the babble. Improvements in speech perception with increasing number of speakers have been reported by other studies as well (Boulenger, Hoen, Ferragne, Pellegrino, & Meunier, 2010; Hoen et al., 2007). Research has also shown that IM can also be elicited by maskers which are close to the features of babble, such as time-reversed babbles (Arai, 2010); Rhebergen, Versfeld, & Dreschler, 2005). Therefore, time reversed babble contributes to greater masking effects than speech spectrum noise or white noise. The reason could be due to the acoustic phonetic information still preserved in the reversed babble, while the semantic information is lost.

Other studies reported that older adults have special difficulty reproducing the last word of sentences heard with a background of multitalker babble, as tested by Speech Perception in Noise (SPIN) test (Kalikow et al., 1977). In that test, older adults generally require a higher signal-to-noise (S/N) ratio than young adults (Pichora-Fuller, Schneider, & Daneman, 1995). Researches on comprehension of written texts has shown that irrelevant speech impairs reading performance more than non speech noise, apparently because of its semantic content (Martin, Wogalter, & Forlano, 1988). Thus, difficulties in listening with background noise may be caused not only by acoustic masking of the target speech but also by informational interference that occurs when words are heard with a background that includes intelligible speech Carhart et al., 1969b) Although this is generally true throughout adulthood, older adults may be even more susceptible than young adults to informational interference (Carhart & Nicholls, 1971)

5.3. Relationship between Contralateral Inhibition of TEOAE and SPIN scores

The study also aimed to examine the relationship between CI-TEOAEs and SPIN by considering various factors (age and type of masker) that may affect the findings. There was no correlation found between SPIN and MOCB functioning across age groups and types of maskers.

The findings of current study are in consensus with that of Mukari and Mamat (2008) where the authors did not find relationship between DPOAE inhibition magnitudes and speech perception in noise. The lack of correlation between contralateral TEAOE inhibition magnitudes and speech perception in noise revealed in this study could be due to several reasons. Firstly, poorer speech perception in noise experienced by the older group may be related to other factors other than the olivocochlear functioning, such as a deterioration in cognitive functioning, which includes reduced working memory capacity (Gordon-Salant & Fitzgibbons, 1997). (Wagner et al., 2009) also reported no correlation between MOCB functioning and speech in noise performance.

Boer, Thornton, and Krumbholz (2011) indicated that reflexive MOC activation is not always beneficial to speech-in-noise processing. Their findings in fact suggested a detrimental effect of MOC induced reduction in cochlear gain on speech-in-noise processing and thus conflict with some previous studies that have found a beneficial effect (Kumar & Vanaja, 2004).

Maruthy, Kumar, and Gnanateja (2017) studied the functional relationship between the efferent auditory system and speech perception in noise. The findings from their study demonstrated correlation between MOCB functioning and speech in noise intelligibility. This finding was not in consensus with the present study.

Other studies like Banai (2005) have also contradicted the findings of present study. In this study the authors have described a link between phonological processing in the brainstem and measures of speech understanding and literacy in children with language-based learning problems, who show specific difficulties with speech-in-noise perception. In this population, intensive auditory training has been shown to reduce noise degradation of neural responses to speech sounds in the brainstem as well as increases in MOCB activity (Veuillet, Magnan, Ecalle, Thai-Van, & Collet, 2007), concomitant with improvement in speech perception. The reasons for these contradictory results may be due to differences in the participants and methods between studies.

Chapter 6

Summary and Conclusions

The medial olivocochlear bundle (MOCB) decreases the gain of the cochlear amplifier through reflexive activation by sound. Physiological results indicate that MOCB-induced reduction in cochlear gain can improve the understanding of speech in presence of background noise. Some previous studies indicate that this "antimasking" effect of the MOC system plays a role in speech-in-noise perception. However, there were also studies which showed that MOCB may not always necessarily help in enhancing speech intelligibility in presence of noise. This study aimed to draw a functional relationship between the speech in noise performance across different masking conditions and contralateral inhibition of oto-acoustic emissions (OAE). The participants of the study were divided into three groups based on their age – the young normal hearing group (YNH- with age ranging between 18 – 29 years), middle aged normal hearing group (MNH in the age range of 30-44 years) and the elderly normal hearing group (ENH – with age ranging between 45-55 years). Participants in all the three groups had normal peripheral hearing sensitivity as assessed by pure tone audiometry, immittance and otoacoustic emissions. Contralateral inhibition of TEOAE was calculated as the difference in the global click evoked TEOAE amplitude with and without 65 dB white noise in the contralateral ear. Twelve lists from Kannada sentence identification test by Geetha, Kumar, Manjula, and Pavan (2014) were used for estimating the signal to noise ratio required for 50% correct identification (SNR-50). Four different types of maskers were used for the study – babble, reversed babble, speech spectrum noise (SSN) and white noise. Among the speech babble there were two speaker babble and eight speaker babble. The maskers were mixed with sentences at different SNRs using a custom Matlab function.The presentation level for speech was maintained at 70 dB SPL.

Results revealed that the mean inhibition for YNH group was significantly higher compared to MNH and ENH. The SPIN scores were significantly poorer in the ENH group, compared to YNH group in all types of maskers. Pearson’s product moment correlation analyses revealed no correlation between contralateral inhibition magnitudes of TEOAEs and speech perception in noise across different maskers. This suggests that the MOCB does not always play a role in enhancing the understanding of speech in presence of noise.

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