ROLE OF MEDIAL OLIVOCOCHLEAR BUNDLE ON THRESHOLD AND SUPRATHRESHOLD MEASURES OF SPEECH PERCEPTION IN NOISE

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CERTIFICATE

This is to certify that this dissertation entitled **'Role of Medial Olivocochlear Bundle on Threshold and Suprathreshold Measures of Speech Perception in Noise'** is a bonafide work submitted in part fulfillment for degree of Master of Science (Audiology) of the student Registration number: 18AUD020. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru
July, 2020

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CERTIFICATE

This is to certify that this dissertation entitled **'Role of Medial Olivocochlear Bundle on Threshold and Suprathreshold Measures of Speech Perception in Noise'** has been prepared under my supervision and guidance. It is also been certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled **'Role of Medial olivocochlear Bundle on Threshold and Suprathreshold Measures of Speech Perception in Noise'** is the result of my own study under the guidance of a faculty at All India Institute of Speech and Hearing, Mysuru, and has not been submitted to any other University for the award of any other Diploma or Degree.

Mysuru   Registration No: 18AUD020

July, 2020

Dedicated to all the things that have made me:

Almighty

My Family

My Teachers

My Friends

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter- 1

INTRODUCTION

Speech perception in noise (SPIN) is a complex process. The presence of noise challenges the individual's ability to understand speech and noisy backgrounds are inevitable in everyday listening. This challenge although is more for individuals with auditory disorders, normal hearing individuals are not exempted from it (Assmann & Summerfield, 2004; Neff & Green, 1987). Successful extraction of the target message in the noisy background is brought about by various means such as adaptation of nerve fibers to continuous noise, identification of the speech cues by the listener, and suppression by the efferent auditory system. The higher centers of the brain have a control mechanism over the peripheral auditory system known as 'Top–down' mechanism (Mishra & Lutman, 2014), wherein the cortex modulates the brainstem activity and the activity at the level of cochlea is controlled by the brainstem. This is done by the efferent feedback pathways. Currently, there is sufficient scientific evidence for role of the efferent system- especially the caudal efferents- in facilitating signal detection in noise. With the discovery of otoacoustic emissions (OAEs) and its suppression during contralateral stimulation, medial olivocochlear bundle (MOCB) has received immense importance.

The olivocochlear bundle forms the primary descending pathway that regulates cochlear function in the auditory system. They arise as a group of neurons from Superior olivary complex (SOC). Olivocochlear bundle makes bilateral connections to the cochlea as medial olivocochlear bundle (MOCB) and lateral olivocochlear bundle (LOCB). MOCB serves contralateral connections to the outer hair cells (OHCs) and its stimulation changes the micromechanics of OHCs resulting in reduced amplification of the incoming signal by the OHCs. Based on human and animal research, certain functions have been attributed to the medial olivocochlear bundle (MOCB). These include localization of sound sources (Ciuman, 2010), regulation of auditory attention (Mulders & Robertson, 2002), protection of cochlea against acoustic injury (Reiter & Liberman, 1995), and improved detection of acoustic signals in the presence of noise (Micheyl & Collet, 1996). These functions are executed by modulating the active mechanisms of cochlea, and any dysfunction along the pathway of MOC is likely to result in poor SPIN (May, Budelis, & Niparko, 2004), tinnitus generation (Prasher, Ryan, & Luxon, 1994) and increase in the incidence of hyperacusis (Ceranic, Prasher, Raglan, & Luxon, 1998).

The functioning of medial olivocochlear neurons has been extensively studied using contralateral suppression of otoacoustic emissions (CSOAEs) (Collet et al., 1990; Parthasarathy, 2001; Kumar & Vanaja, 2004; Wagner, Frey, Heppelmann, Plontke, & Zenner, 2008). The magnitude of CSOAEs is known to be in the range of 0.1 to 2.4 dB (Hood, Berlin, Hurley, Cecola, & Bell, 1996; Kalaiah, Nanchirakal, Kharmawphlang, & Noronah, 2017; Stuart & Cobb, 2015) and the suppression is frequency-specific in nature (Berlin, Hood, Cecola, Jackson, & Szabo, 1993).

The role of MOCB in regulating SPIN draws equivocal support from the literature. Evidence for the presence of facilitatory role of MOCB is found in patients who have undergone vestibular neurectomy (Giraud et al., 1997) as well as in normal hearing individuals (Giraud et al., 1997; Kumar & Vanaja, 2004; Maruthy, Kumar, & Gnanateja, 2017). In individuals with normal hearing, the magnitude of OAE suppression has been found to correlate with the SPIN scores. On the contrary, Wagner et al. (2008) reported absence of relation between speech reception threshold and contralateral suppression of OAEs (CSOAEs). Similarly, Mishra and Lutman (2014) did not find a correlation between magnitude of contralateral suppression and SPIN scores. In view of these contradictory findings, there is a definite need for more studies to probe the relationship between CSOAEs and SPIN in a group of individuals with normal hearing.

1.1 Justification for the Study

Review of literature reveals that the role MOCB in SPIN is a debatable issue. Its role on speech identification in particular is equivocally supported by the existing studies. One reason for such diverse findings is the complex mechanisms involved in speech identification. MOCB neurons when triggered, suppress the activity of outer hair cells, more so in the side bins. Such peripheral mechanisms may have a trivial role during the speech identification which involves complex auditory, linguistic and cognitive processes. On the contrary, in tasks such as signal detection that involve lesser auditory, linguistic and cognitive processes, the influence of MOCB-mediated changes in the peripheral mechanisms may show a consistent change. Therefore, the current study aimed to assess the effect of contralateral noise on speech detection threshold, speech recognition threshold and speech identification in a group of normal hearing adults. The findings of the study will help in understanding the role of MOCB in speech perception tasks of varying difficulty. This in turn will guide us in understanding whether involvement of more complex auditory, linguistic and cognitive processes during speech perception is likely to undermine the role of MOCB in speech perception in noise. The findings can address the existing lack of consensus about the role of MOCB in speech perception.

1.2 Aim of the Study

The aim of the study is to find the effect of efferent auditory function on speech perception in noise measured through SDT, SRT and SIS.

1.3 Objectives of the Study

1. To compare speech detection threshold in noise, with and without contralateral noise in normal hearing adults.

2. To compare speech recognition threshold in noise, with and without contralateral noise in normal hearing adults.

3. To compare speech identification scores in noise, with and without contralateral noise in normal hearing adults.

Chapter-2

REVIEW OF LITERATURE

Medial Olivocochlear bundle (MOCB) is the primary descending auditory pathway and modulates cochlear amplification through outer hair cells. The presence of olivocochlear bundle was first described by Rasmussen in 1946. MOCB is credited with regulation of functions such as speech perception in noise (SPIN). Therefore, any damage along this pathway is likely to result in poor SPIN scores (May, Budelis, & Niparko, 2004).

2.1 Anatomy and Physiology of Medial Olivocochlear Bundle

The olivocochlear bundle comprises of medial and lateral olivocochlear neurons. Medial olivocochlear neurons originate from medial superior olivary cochlear nucleus of superior olivary complex and terminate at outer hair cells (OHCs). The lateral olivocochlear neurons originate from lateral olivary cochlear nuclei and terminate at the dendrites of Type 1 cells of afferent nerve fibres beneath the inner hair cells (IHCs). MOC neurons have thick and myelinated axons, and 75% of them are mainly directed towards OHCs of the contralateral cochlea (Guinan, 1996; Terreros & Delano, 2015). The rest of the fibers are directed towards the ipsilateral OHCs. These fibers enter the Rosenthal's canal with the auditory nerve and the medial efferent fibres become unmyelinated as they leave the canal through habenula perforata. The lateral olivocochlear neurons, on the other hand possess thin and un-myelinated fibers throughout its course that mainly make synapses with ipsilateral auditory nerve dendrites just beneath cochlear inner hair cells and few of it cross to the contralateral side (Ciuman, 2010). It is because the efferent neurons follow a different course from brainstem to cochlea, it is possible to stimulate olivocochlear neurons independent of the ascending auditory pathway.

Sounds presented to one ear pass through the auditory afferent nerves terminating at the ipsilateral posterior ventral cochlear nucleus (PVCN), and stimulate the MOC interneurons. The MOC neurons in turn cross to the contralateral side and innervate the basolateral surface of OHCs on the contralateral side. Acetylcholine is the major neurotransmitter in MOC and LOC neurons. A few of the LOC neurons are also dopaminergic (Lopez-Poveda, 2018)

Apart from acoustic stimuli, the OCBs can also be activated using electrical stimulation. Animal studies (Winslow & Sachs, 1987; Guinan & Gifford, 1988) have shown that electrical shocks delivered with an electrode placed at the mid line of the fourth ventricle activates MOCB fibres. This causes a reduction in the amplitude of mechanical vibrations of the basilar membrane in response to moderate and low level sounds, and a reduction in the compound action potentials recorded from the auditory nerves (Galambos, 1956). This is similar to the response achieved by presenting noise in the contralateral ear in humans (Collet et al., 1990). Once the efferent neurons are activated, it increases the basolateral conductance of OHC membrane which hyperpolarizes the OHCs and reduces their electro-motility, thereby reducing the amplification by outer hair cells (Guinan, 2006).

The activity of efferent system can be monitored by transient evoked otoacoustic emissions (TEOAEs). TEOAEs are low level sounds generated from outer hair cells in response to brief stimuli such as clicks and tone bursts (Theodore & Sharon, 1991). TEOAEs can be suppressed by presenting BBN in the contralateral ear (Ganz, Spech, & Kevanishvili, 1997). It leads to the activation of auditory efferent system which suppresses the activity of OHCs and in turn TEOAE amplitude. Suppression magnitude is calculated by subtracting the OAE amplitude with CAS from that of the baseline recording of OAE without CAS. Maruthy (2002) studied contralateral suppression of TEOAEs on 32 normal hearing adult individuals with NBN centered at frequencies 1 kHz, 2 kHz, 3 kHz, 4 kHz and BBN. The results of his study showed that there is certain degree of specificity in the distribution of efferents across the basilar membrane as the greatest suppression was found at 1 and 2 kHz for 1 and 2 kHz NBN.

2.2 Factors affecting the Magnitude of TEOAE Suppression

Multiple factors are known to affect the suppression magnitude of TEOAEs. These include intensity of contralateral suppressor, type of the suppressor, age of the subject and gender of the subject.

Parthasarathy (2001) studied contralateral suppression of TEOAEs with increasing level of BBN in the contralateral ear. He recorded TEOAEs in 30 normal hearing individuals while presenting continuous BBN in the opposite ear at different intensities ranging from 40 to 70 dB SPL in 10 dB steps. There was an increase in the average magnitude of suppression of TEOAE amplitude from 0.5 to 3.5 dB with the increase in intensity of contralateral BBN. Bell, Berlin, Cecola, Hurley, and Hood (1996) measured efferent-mediated suppression effects in normal hearing individuals within the age range of 12 to 59 years. They measured response to linear clicks from 50 to 70 dB peak SPL in 5 dB steps. The contralateral noise was given at 10 dB above or below click level. They found an increase in suppression of TEOAEs with an improvement of mean suppression from 0.33 when the contra noise level was 10 dB below click level to 1.38 dB when the noise level was 10 dB above click level.

Similarly, Collet, Duclaux, Kemp, Morgon, Moulin, and Veuillet (1990) studied the suppression magnitude to linear clicks at 60 dB peak SPL while contralateral BBN was presented at intensities ranging from 0 to 50 dB SPL. They found no significant change in suppression when the noise levels were below 30 dB SPL. But there was an increase in mean suppression up to 3 dB when the suppression noise was changed from 30 to 50 dB SPL. Overall, the findings indicate that a trend in the increase in contralateral suppression was seen as the level of contralateral noise was increased.

Differences between genders in the suppression magnitude has also been reported in the earlier studies. Abdollahi and Lotfi (2011) studied the amplitude of TEOAEs and contralateral suppression in 60 young participants comprising 30 females and 30 males. They found that TEOAE average amplitude was greater in females than in males with an average mean amplitude of 24.98 dB for females and 20.96 dB for males. However, TEOAE suppression was significantly more in males (mean: 2.07 dB) than females (mean: 1.54 dB).

Across advancing age, contralateral suppression is shown to decrease attributable to degeneration in the efferent nervous system (Parathasarathy, 2001; Castor, Collet, Morgon, & Veuillet, 1994). Parthasarathy studied contralateral suppression in six different groups ranging in age from 20 to 79 years. The authors found that on increasing the contralateral noise levels from 40 to 70 dB SPL there was minimal increase in the average contralateral suppression of 0.9 dB for the age group between 60-79 years. The younger age group however had maximal contralateral suppression of 3.5 dB. The study showed a reduction in suppression magnitude with the increase in age.

Castor, Collet, Morgon, and Veuillet (1994) recorded TEOAEs with and without contralateral noise (30 dB SPL) in 60 normal hearing individuals within two age groups: between 20 and 39 years, and, between 70 and 88 years. They found smaller suppression in the older age group (mean 0.36 dB) compared to the younger age group (2.17 dB). However, the older age group had high frequency hearing loss and the difference in the contralateral suppression magnitude could not be attributed to age. Lisowska, Misiolek, Namyslowski, and Orecka (2018) found similar evidence for age effect on contralateral suppression of OAEs across three different age groups (10-25; 26-40; 41-60 years). There was a significant difference in the overall amplitude and suppression magnitude between the age group 41-60 and the other two younger groups. MOC effect was found to be weaker in the oldest group with mean suppression of 2.0 ± 1.1 dB, compared to two younger groups who had comparable mean MOC effect (10-25 years: 2.1±1.2 dB; 26-40 years: 2.05±1.1 dB). The aforementioned studies conform to the age-related decline in suppression magnitude related to the weakening of the efferent system with the aging.

There are also ear-differences observed in the contralateral suppression of OAEs. Kumar and Vanaja (2004) compared magnitude of suppression of TEOAEs between the two ears. The authors found an ear advantage for the right ear with greater suppression in the right ear (mean: 1.6 dB) compared to the left (mean: 0.86 dB). The findings were in agreement with the earlier reports by Khalfa, Micheyl, Veuillet, and Collet (1998), wherein they had found greater suppression in right ear.

Among various types of suppressors used, BBN is known to induce more suppression of TEOAEs than other frequency specific suppressors, as they stimulate larger number of neurons (Berlin et al., 1993; Komazec, Filipovic, & Milosevic, 2003). Komazec, et al. (2003) compared contralateral suppression of TEOAEs for BBN and puretones. BBN was found to induce more suppression compared to pure tones (Varghese, Zhu, & Frisina, 2005). Berlin et al. (1993) studied contralateral suppression on 11 normal hearing adults. They presented BBN, puretones and NBN centered at 250, 500, 1000, 2000 and 4000 Hz. They found that BBN was the strongest suppressor, followed by NBN. They also found puretones being the weakest suppressor. This is because BBN have energy concentration across a greater bandwidth, hence stimulates maximum region of SOC with greater number of MOCB fibres compared to frequency specific NBN or puretones.

Musical training have shown to improve modulate contralateral suppression magnitude. Ameen (2011) did an independent project wherein he divided a total of 60 participants into three groups based on their musical experience. First group, with 20 individuals and no musical experience (control group). Second group consisted of 20 individuals with experience in only listening to music on a regular basis (Listener group). Third group, with 20 individuals who practice vocal music formally (singer group). In all the participants, contralateral suppression of TEOAEs were performed and global SNR and SNR at 1, 2, 3, 4, 5 KHz were documented. Results of the study revealed there was a significant difference in the mean of the singer and control group as well as singer and the listener group (Group1 mean: 1.38±2.27; Group2 mean: 1.34±1.66; Group3 mean: 4.02±2.34). Hence, it was concluded that musical training can modulate the efferent inhibition.

2.3 Studies in Support of the Facilitatory Role of MOCB on SPIN

Numerous studies have shown evidence to support that activation of MOCB facilitates SPIN. Giraud et al. (1997) compared the bisyllabic word recognition scores in normal hearing and vestibular neurectomized patients in the presence of contralateral BBN. They found an anti-masking effect in normal hearing participants which resulted in an improvement of about 5–10% in the phoneme recognition rate in the presence of contralateral noise. Vestibular neurectomized patients however did not show such improvements in the de-efferented side. The authors explained this on the basis of two aspects. One, MOCB fibres could play a role in the spectral analysis, temporal analysis and intensity coding of acoustic speech signals which are affected in vestibular neurectomized patients. An alteration in the shape of tuning curves of auditory fibres was found after sectioning both crossed and uncrossed OC fibres in animals. Thus, degradation in spectral or temporal analysis could have resulted in lesser speech in noise intelligibility. The second, reduction in the amplitude of cochlear mechanisms due to efferent activation may partly account for the lesser speech-in-noise intelligibility as found in vestibular neurectomized patients (Giraud et al., 1997).

Kumar and Vanaja (2004) evaluated the effect of contralateral acoustic stimuli on speech perception with varied SNRs from +20 to +10 dB on ten normal hearing children. They found the presence of contralateral suppression at lower SNRs (+10 dB and +15 dB) but not at higher SNRs. Thus, their study found the possible role of MOCB in hearing in noise at lower SNRs.

A similar study was done using vowel discrimination task of /e/ and an /e/-like variant with a changed F2 frequency in quiet and in the presence of BBN on cats having bilaterally lesioned olivocochlear bundles (Hienz, Stiles, & May, 1998). The results showed that lesions in the olivocochlear systems of cats produce deficits in vowel discriminability in high levels of background noise. These findings were similar to those found by Dewson, Wertheim, and Lynch (1968) who worked on the ability of monkeys to discriminate among vowels in both quiet and noise following olivocochlear lesions. The authors found that, following surgical sectioning of the MOCB, the level of an intense background noise required to maintain a criterion level of performance was lower than the level required pre-surgically to maintain the same criterion performance. No such differences were found at lower noise levels. This behavioral study again supports the hypotheses of the possible role of OCB in improving stimulus discrimination in noise. However, results of Dewson et al. (1968) were criticized later because the monkeys in his study had cortical lesion.

Mertes, Johnson, and Dinger (2019) studied MOC reflex for speech recognition in noise in 30 normal-hearing young adults. The study showed differences in performance in speech perception tasks with and without contralateral noise. MOC reflex was assessed using contralateral inhibition of TEOAEs. SPIN was evaluated at different signal to noise ratios (SNRs) ranging from -12 to 0 dB (-12, -9, -6, -3, 0). Performance was significantly better with contralateral noise only at the lowest SNR (only at -12 dB). The results suggested that MOC reflex contributes to listening in low SNRs and the relationship between the MOC reflex and perception is highly dependent upon the task characteristics such as the speech material used and the competing signal used as noise.

2.4 Studies that do not show evidence for Facilitatory Role of MOCB in SPIN

There are ample evidences which do not support the facilitatory role of MOCB. Geller and Galambos (1956) cut the crossed OCB in two cats and found no change in behavioral threshold for tones of 300, 1500, and 5000 Hz in a background of noise. Differential thresholds concerning frequency and intensity discrimination were also determined for one animal, and discrimination performance was not affected. Trahiotis and Elliott (1970) studied behavioural measures such as pure tone audiometry, masking noise and temporary threshold shift following the surgery of olivocochlear bundle on cats. The results suggested no shift in pure tone average. This was expected, since signals far above the threshold are needed to activate efferent system, and hence it is not affected by OCB transection. However, the authors mentioned that there was no significant difference in the amount of masking noise needed and change in TTS for the control and experimental groups.

Marrufo-Pérez, Eustaquio-Martin and Lopez-Poveda (2018) suggested adaptation of nerve fibers to continuous noise as one of the mechanisms for improved speech intelligibility in noise. They showed that normal hearing individuals recognized more words monoaurally when presented with ipsilateral, contralateral, or bilateral noise when speech is given with a delay from the background noise i.e. when they were given some time to adapt to the noise. When studied on normal hearing and individuals with cochlear implants, there was an improvement in speech recognition threshold when speech was presented few milliseconds after the presentation of noise in both the groups. Since cochlear implanted individuals had affected MOCB, they attributed this improvement to mechanisms other than MOCB reflex. They concluded that mechanisms different from the

MOC reflex can produce adaptation to noise in word recognition which would result in improved speech perception in noise.

Yashaswini and Maruthy (2019) studied contralateral suppression of TEOAEs at different levels of contralateral suppressor and the effect of different levels of contra noise (40 dB, 50 dB, 60 dB SPL) on speech identification scores at various SNRs from 15 dB to 0 dB. They also evaluated SNR-50 with and without contralateral noise. They found no association between the magnitudes of suppression of TEOAE and SPIN scores at any SNRs between -10 to 0 dB. Neither was any correlation found between the activation of MOCB and improvement in perception of speech in noise, thereby contradicting the earlier studies. However, this inconsistency can be due to the subtle role of MOCB in regulating SPIN.

Chapter-3

METHODS

In the study, speech perception in noise in terms of SDT, SRT and SIS was determined with and without contralateral BBN in a group of normal hearing individuals. Contralateral noise was meant to stimulate the MOCB neurons and the consequence of it on speech perception in noise (SPIN) was experimentally investigated. A quasi-experimental research design with purposive sampling was used in the study. The details of the methods used are given in the subsequent sections.

3.1 Participants

Fourteen (all females) normal hearing adults participated in the study. Their age ranged between 18 and 30 years (mean age: 24.5years). They had puretone hearing thresholds within 15 dBHL at all the octave frequencies from 0.25 to 8 kHz. They had type ‘A’ tympanogram with present acoustic reflexes, indicating normal middle ear functioning. All the participants passed the screening test of auditory processing checklist for adults, SCAP-A (Vaidyanath & Yathiraj, 2014). They had presence of TEOAEs with an amplitude more than 10 dBSPL between 1 and 6 kHz. They also had presence of contralateral suppression of TEOAEs with more than 0.5 dB suppression magnitude, indicative of normal MOCB functioning. Informed consent was taken from all the participants prior to their inclusion in the study and the method conformed to the ethical guidelines stipulated for bio-behavioral research in humans (Venkatesan, 2009). All the participants were native speakers of Kannada.

3.2 Test Environment

The participants were tested in an audiometric room with noise level permissible as per ANSI S 3.1 (1991).

3.3 Test Materials used for Measures of Speech Perception

Bisyllabic word, /pa:pa/ was used as stimuli to estimate SDT. SRT was estimated using the standardized paired-word list available in Kannada developed in the department of Audiology at All India Institute of Speech and Hearing, Mysuru. These words had equal stress on both the syllables. SIS was estimated using the phonemically balanced word list in Kannada, developed by Yathiraj and Vijayalakshmi (2005). The word list consisted of four equivalent lists comprising twenty-five words each.

The pre-recorded materials were available for paired-words and phonemically balanced word list. However, the bisyllabic word /pa:pa/ used for SDT was not available in the prerecorded version and therefore was recorded for this study. An adult female speaker with normal speech-language abilities uttered the word into a unidirectional microphone kept at 10 cm distance from the mouth. The output of the microphone was fed into Adobe audition 3.0 software. The word was uttered five times (five samples) and the sample with best clarity, audibility and fidelity was selected for SDT testing.

Different ipsilateral speech-shaped noises were generated for SDT, SRT and SIS testing, depending on the phonetic corpus of the test material used. They were generated using Matlab (version 8.5). The stimuli were fed into Matlab which takes up different segments of the stimuli and mixes them together to form noise with the same frequency composition pertaining to the stimulus.

The speech materials and the respective speech-shaped noise were group normalized to -3dB using Adobe Audition 3.0 software. The stimuli were played in a personal computer and were delivered to the participant through a calibrated Inventis Piano audiometer having TDH-39 headphones.

BBN was used as a contralateral suppressor. It was generated using Adobe Audition 3.0 software. The sampling rate used was 44,100Hz with 16 bit resolution. The BBN was presented from a personal computer. Using a sound level meter, output of the computer was calibrated to deliver BBN at a specified level.

3.4 Test Procedure

3.4.1 Candidacy assessment

A detailed case history was taken from the participants aimed at ensuring no complaints of otological or neurological disorder. The candidacy assessment included pure tone audiometry, immittance evaluation, transient evoked otoacoustic emissions (TEOAEs) and SCAP-A.

Puretone thresholds were estimated using a calibrated Inventis Piano diagnostic audiometer. Both air and bone conduction thresholds were estimated using modified Hughson-Westlake procedure (Carhart & Jerger, 1959). The air conduction thresholds were obtained at octave frequencies between 250 Hz and 8 kHz, while bone conduction thresholds were estimated between 250 Hz and 4 kHz.

Immittance evaluation was carried out using a calibrated diagnostic GSI Tympstar immittance meter. Tympanogram and acoustic reflexes were recorded from both the ears using a probe tone of 226 Hz. Ipsilateral and contralateral acoustic reflex thresholds were recorded for pure tones of 0.5, 1, 2 and 4 kHz.

Screening checklist for Auditory Processing for adults (SCAP-A): The participants underwent a screening procedure using SCAP-A (Yathiraj & Vaidyanath, 2014) to screen out auditory processing disorder. It consists of 12 questions with a 2 point rating scale. Before the administration of objective tests, SCAP-A checklists were self-administered by the participants. All the participants had passed SCAP-A.

Transient evoked otoacoustic emissions (TEOAEs) for clicks were recorded using ILO-292 Echoport plus equipped with ILO (V6) software. The clicks were presented in linear stimulus paradigm at 70 dB SPL. SNR and amplitude of Otoacoustic emissions were documented at octave frequencies between 1 kHz and 6 kHz. Only those participants with TEOAE amplitude greater than 10 dB SPL and global SNR greater than 6 dB were considered in the study. Contralateral suppression was measured by the introduction of BBN to the opposite ear and participants with suppression magnitude greater than 0.5 dB were taken for further testing.

3.4.2 Experimental test procedure

This included four different measures: TEOAEs, SDT, SRT and SIS. The speech perception measures (SDT, SRT & SIS) and otoacoustic emissions were recorded only from the right ear of the participant, whereas continuous contralateral BBN was presented to the left ear.

Measure 1: Contralateral suppression of transient evoked otoacoustic emissions (TEOAEs): In each participant, two baseline recordings of TEOAEs were made without any contralateral noise, followed by one recording with contralateral acoustic stimulation (CAS). The TEOAEs were recorded using ILO-USB II equipped with the ILO 292 DP Echoport plus (V6) software suite. The participants were made to sit on a comfortable chair in a straight posture. They were instructed to stay quiet during the recording and avoid extraneous movements of the body. A probe with an appropriate ear tip was placed into the external auditory canal of the right ear. Position of the probe was adjusted till a flat stimulus spectrum was achieved across the frequency range. Clicks were presented in linear mode at 70 dB SPL. Responses to clicks were averaged over 260 sweeps. The frequency-specific amplitude and SNRs at octave and mid octaves between 1000 and 4000 Hz were noted down.

Contralateral BBN at 60 dB SPL was delivered using calibrated headphones connected to a personal laptop computer (Windows 8.1 Pro 64bit i3-core Dell). Only the recordings in which the stimulus stability was more than 90 percent and global SNR was more than 6 dB were considered for analysis. SNR was recorded to ensure that the change in amplitude of OAEs was due to the introduction of contralateral noise and not due to ambient noise. Furthermore, only those recordings with not more than 0.5 dB difference in global amplitude of TEOAEs between two baseline recordings were accepted. This was to ensure that the amplitude differences in the successive recordings was exclusively due to the presence of contralateral noise and not the inherent variations in cochlear mechanisms. The amplitude of TEOAEs at 1000, 1414, 2000, 2828, 4000 Hz were noted down. The magnitude of suppression was then calculated by subtracting the amplitude of OAEs in CAS conditions from that in second baseline recording.

Measure 2: Speech detection threshold with and without contralateral noise: Speech detection threshold (SDT) was estimated using the standardized procedure recommended by ASHA (1988). The stimulus intensity was varied at 1 dB. The speech stimuli and the corresponding ipsilateral speech noise was routed through channel 1 and channel 2 respectively of a calibrated audiometer, which was connected to a Windows 10 computer. The target stimuli were presented to the right ear. The contrlateral BBN was presented to the left ear through a calibrated headphones connected to a personal HP laptop computer (Figure 3.1).

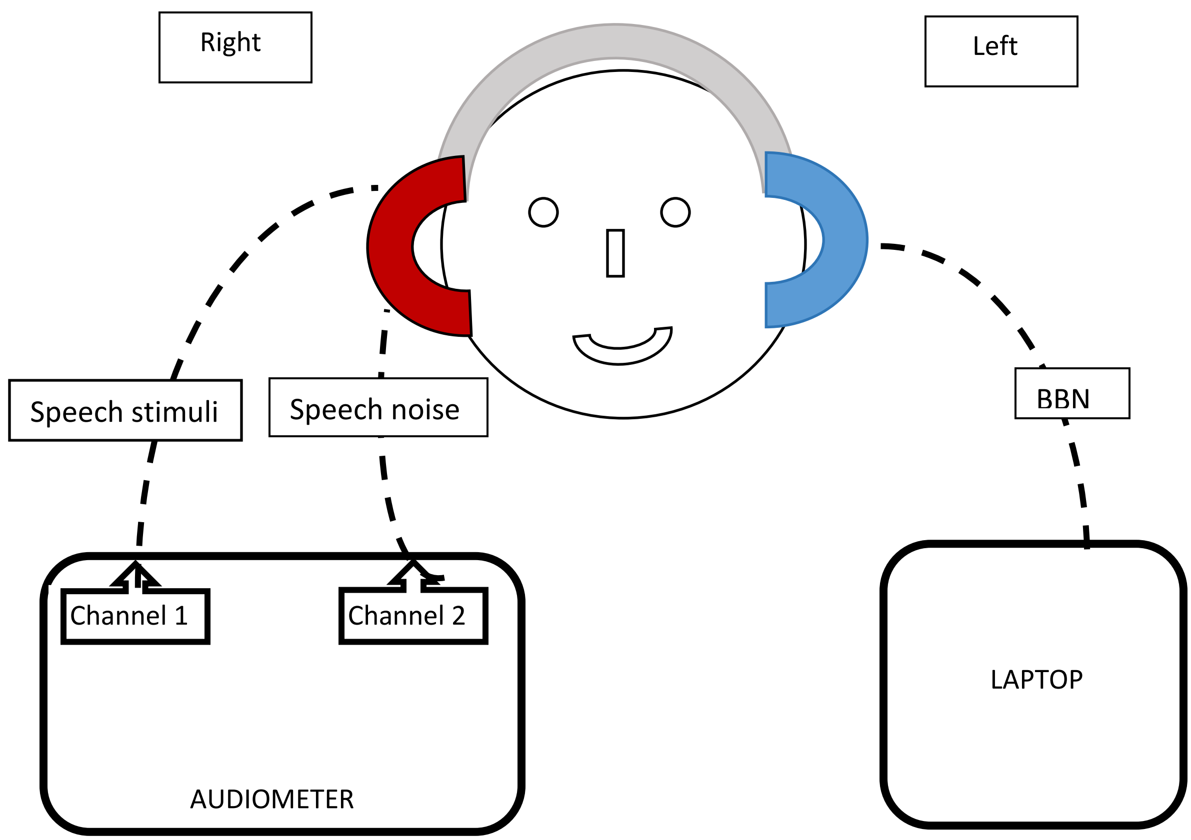

Figure 3.1: *Block diagram showing the test set-up used in the study to estimate measures of speech perception in noise (common for all) i.e. SDT, SRT and SIS.*

SDT was estimated in two conditions; first, SDT was estimated in the presence of ipsilateral speech-shaped noise presented at 10 dB SL (Ref: Noise detection threshold). In the second condition, SDT was estimated while a continuous BBN of 60 dB SPL was presented to the left ear along with ipsilateral speech-shaped noise at 10 dB SL and the SDT was again estimated. Similar procedure was followed to estimate SDT in noise at two more levels of presentation of ipsilateral speech-shaped noise i.e. at 20dBSL and 30dBSL (ref: NDT). At both these levels SDT was estimated with and without contralateral noise. The order of ipsilateral noise levels used was counter-balanced across participants.

Measure 3: Speech recognition threshold with and without contralateral noise: Recorded version of the standardized paired-word list in Kannada was played from a personal computer and was routed through TDH-39 headphones connected to a calibrated Inventis Piano audiometer. SRT in ipsilateral speech-shaped noise was estimated with and without contralateral BBN. Similar to SDT, three different intensities of ipsilateral speech-shaped noise were used: 10, 20 and 30 dB SL (ref: NDT). The contralateral BBN was presented at 60 dB SPL. The intensity of speech was varied in 1dB to estimate the SRT. This was meant to track even the small changes in SRT, if any, secondary to the presentation of contralateral noise. The participants were instructed to repeat the paired-words ignoring the noise. The minimum intensity in dB HL at which the participants could repeat 50% of the words correctly was noted down as SRT.

Measure 4: Speech identification scores with and without contralateral noise: Speech identification scores (SIS) was estimated at suprathreshold level of 40 dB SL (ref: SRT) using the recorded version of speech identification test. The stimuli were presented along with ipsilateral speech-shaped noise at -5 dB SNR. As a pilot attempt, SIS was estimated at -10, -5 and 0 dB SNR. However, floor effect was observed at -10 dB SNR while ceiling effect was observed at 0 dB SNR. Hence, -5 dB SNR was the chosen in this study.

A second SIS in ipsilateral speech noise (at -5 dB SNR) was estimated in the presence of continuous contralateral BBN to the left ear. Different word lists were used for estimating SIS with and without contralateral noise. The total number of correctly repeated words were recorded and SIS was estimated in percentage.

Chapter-4

RESULTS

The study tested the role of medial olivocochlear bundle (MOCB) in regulating threshold (speech detection & speech recognition) and supra threshold (speech identification scores) measures of speech perception in noise (SPIN). The measures of SPIN served as dependent variables while the activation of efferent auditory system through contralateral noise served as independent variable. The measures of SPIN with and without contralateral noise were compared to derive the role of efferent auditory system in regulating SPIN.

The individual data were tabulated in SPSS software (Version 20.0) and the group data were statistically compared. Owing to the small number of participants in the study (due to COVID-19 situation) and non-normal distribution of the data (derived from Shapiro-wilks test of normality), non-parametric tests were used. Results obtained in the study are reported under the following headings.

1) Comparison of SDT in noise with and without contralateral noise
2) Comparison of SRT in noise with and without contralateral noise
3) Comparison of SIS in noise with and without contralateral noise
4) Correlation between suppression magnitude and the change index of SDT, SRT and SIS

4.1 Comparison of SDT in Noise with and without Contralateral Noise

In each participant, SDT in ipsilateral noise was estimated. Three different levels of ipsilateral noise were used; 10 dB, 20 dB and 30 dB SL (ref: threshold of noise). SDTs in these three ipsilateral conditions were measured once without contralateral BBN and once with contralateral BBN. Table 4.1 gives the mean, median, and inter quartile range of SDT measured in all the six stimulus conditions. The median SDT was lower in the presence of contralateral noise in 10 dB SL and 30 dB SL ipsilateral conditions. On the contrary, median SDT was lower in the without contralateral noise condition compared to with contralateral noise condition at 20 dB SL ipsilateral speech noise condition. However, the results of Wilcoxon signed rank test (shown in Table 4.1) showed no significant difference ($p>0.05$) between with and without contralateral noise conditions. This was true at all the three ipsilateral noise levels.

Table 4.1: *Mean, median, and interquartile range of SDT in three ipsilateral noise conditions (10dBSL, 20dBSL & 30dBSL), with and without contralateral noise. Z and p values derived from Wilcoxon signed rank test are also shown*

Level of ipsilateral noise	Contra noise	Mean (dB HL)	Median (dB HL)	Interquartile range	/Z/	p
10 dB SL	Absent	1.86	3.00	5	0.319	0.749
	Present	2.00	2.00	5		
20 dB SL	Absent	9.86	10.00	5	1.006	0.314
	Present	9.64	10.50	5		
30 dB SL	Absent	19.50	20.00	6	1.628	0.103
	Present	18.79	19.50	7		

4.2 Comparison of SRT in Noise with and without Contralateral Noise

SRT was measured in the presence of three different levels of ipsilateral noise; 10 dB, 20 dB and 30 dB SL (ref: threshold of noise). SRT at each of these levels was measured once without and once with contralateral BBN. Table 4.2 gives the mean, median, and inter quartile range of SRT measured in different stimulus conditions. The median SRT was lower in the presence of contralateral noise in 20 dB SL and 30 dB SL ipsilateral noise conditions, while the median SRT remained same at 10 dB SL. The results of Wilcoxon signed rank test (Table 4.2) showed no significant difference ($p>0.05$) between with and without contralateral noise conditions at 10 and 30 dB SL ipsilateral noise conditions. But at 20 dB SL, SRT estimated with contralateral noise was significantly lower than that of without-noise condition ($p<0.05$).

Table 4.2: *Mean, median, and interquartile range of SRT in three ipsilateral noise conditions (10dBSL, 20dBSL & 30dBSL), with and without contralateral noise. Z and p values derived from Wilcoxon signed rank test are also shown*

Level of ipsilateral noise	Contra noise	Mean (dB HL)	Median (dB HL)	Range	/Z/	p
10 dB SL	Absent	13.14	13.00	8	1.135	0.256
	Present	12.43	13.00	6		
20 dB SL	Absent	20.86	20.50	6	2.368	0.018*
	Present	19.50	20.00	5		
30 dB SL	Absent	29.36	30.50	7	1.467	0.142
	Present	28.36	29.50	5		

4.3 Comparison of SIS in Noise with and without Contralateral Noise

In each participant, SIS at -5 dB SNR was measured once without and once with contralateral noise. Table 4.3 gives the mean, median, and inter quartile range of speech identification scores obtained in the two conditions. In the presence of contralateral noise, median SIS increased by 8%. But the results of Wilcoxon sign rank test (Table 4.3) showed that the change was not statistically significant.

Table 4.3: *Mean, median, and interquartile range of SIS at -5 dB SNR, with and without contralateral noise. Z and P value derived from Wilcoxon signed rank test are also shown*

Contra suppressor	Mean (dB HL)	Median (dB HL)	Interquartile range	/Z/	p
Absent	61.14	60.00	24	1.929	0.054
Present	67.71	68.00	16		

4.4 Correlation between suppression magnitude and the change index of SDT, SRT and SIS

Suppression magnitude of TEOAE of each participant was derived by subtracting the global TEOAE amplitude obtained with contralateral BBN from that of baseline global amplitude. Similarly, the change indices of SDT, SRT and SIS were determined by subtracting the SDT, SRT and SIS obtained without contralateral BBN from the corresponding scores obtained with contralateral noise. The association between suppression magnitudes and change indices were tested using Spearman rank correlation test. The results (Table 4.4) showed a significant negative correlation between suppression magnitude and change index of SRT at 20 dB SL ipsilateral noise. The correlation of suppression magnitudes with the SDT, SIS, and, SRT at other ipsilateral noise levels were not statistically significant. The scatter plot showing the relationship between the TEOAE suppression magnitude and the change index of SRT at 20 dB SL ipsilateral noise is shown in Figure 4.1.

Table 4.4: *Results of correlation between suppression magnitude of TEOAEs and the change indices of SDT, SRT and SIS*

Measure	Ipsilateral noise level	r	p
SDT	10 dB SL	0.270	0.351
	20 dB SL	-0.159	0.588
	30 dB SL	0.069	0.816
SRT	10 dB SL	0.011	0.969
	20 dB SL	-0.573*	0.032*
	30 dB SL	0.170	0.562
SIS	-5 dB SNR	0.358	0.209

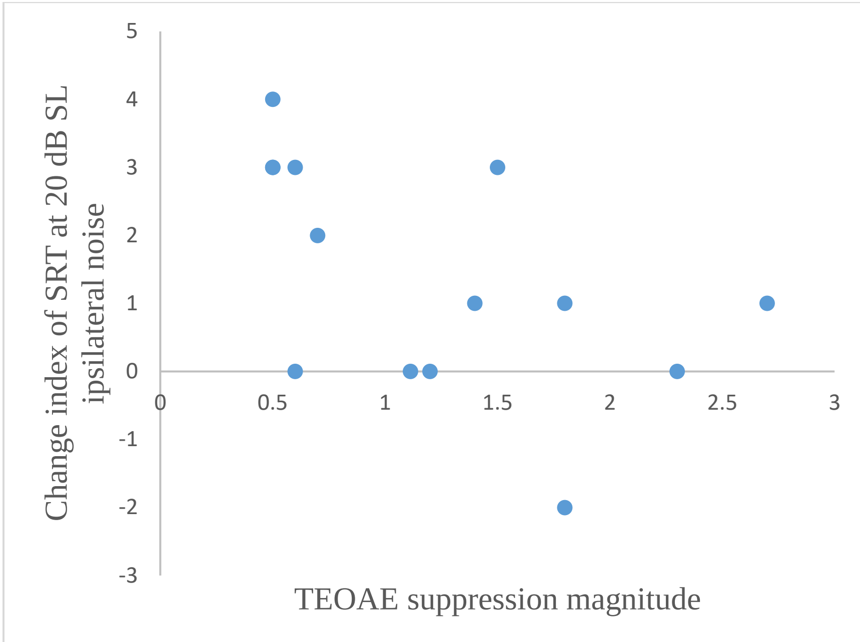

Figure 4.1: *Scatter plot showing the relationship between the TEOAE suppression magnitude and the change index of SRT at 20 dB SL ipsilateral noise.*

Chapter-5

DISCUSSION

The study investigated the effect of contralateral noise on speech detection threshold (SDT), speech recognition threshold (SRT) and speech identification scores (SIS) in the presence of noise. The relationship between magnitude of suppression and the change index of SDT, SRT and SIS in noise was also studied. Overall, the results show lack of evidence for facilitatory role of MOCB on measures of SPIN. The specific findings are discussed in the subsequent sections.

5.1 Role of MOCB in Regulating SDT in noise

No significant effect of contralateral noise was found in the perception of SDT in noise at any of the ipsilateral noise levels (10, 20 and 30 dB SL). This means that minimum intensity at which one can detect speech is not altered by the presence of contralateral noise. The presence of contralateral noise is known to stimulate MOCB (Maruthy & Yashashwini, 2019; Palmietto, 2017). Therefore, lack of significant difference in SDT in noise suggests that MCB does not regulate SDT in noise. The support for the same can be drawn from earlier studies (Geller & Galambos, 1960; May & McQuone, 1995). Geller and Galambos (1960) found no difference in behavioral thresholds in high level of background noise for speech frequencies when OCB of cats were cut. May and McQuone (1995) studied the intensity discrimination of 1 and 8 kHz pure tones on cats who were trained to signal the change in intensity in pure tones by releasing a response lever. Following the surgical lesion of OCB in cats, no significant lesioning effects were found for the discrimination of

1-kHz tones in noise but they exhibited consistent deficits in the discrimination of 8 kHz intensity changes in noise. However, cats with intact olivocochlear bundles displayed no change in discrimination after the surgical procedure.

On the contrary, Micheyl and Collet (1996) found an improvement in tone detection in background noise. Scharf, Magnan, and Chays (1996) studied psychoacoustical measures on 16 patients who underwent unilateral vestibular nurectomy. Contralateral noise was presented to stimulate the efferents of both the ears. There was a decrement in tone detection in noise when contralateral noise was introduced (30 dBSL) in healthy normal hearing ears whereas the detection thresholds for the operated ear with sectioned OCB was 2 dB higher at the same frequency. This indicate that the detection thresholds were higher for the vestibular neurectomized ear as a result of destruction of the efferents. Hence, MOCB might have a subtle role in regulating speech perception in noise.

5.2 Role of MOCB in Regulating SRT in noise

Effect of activation of efferent system was seen only for SRT in presence of ipsilateral noise at 20 dB SL. At other levels of ipsilateral noise, there was no significant improvement in median SRT. This may be due to the effect of MOCB is insignificant in very low level back ground noise such as 10 dB SL. It is only evident at optimum level of noise i.e. 20 dB SL. At 30 dB SL of ipsilateral noise masks the speech and MOCB’s role in regulating SPIN is too subtle to be evident at high level of noise. Wagner et al. (2018) had found no significant correlation between contralateral inhibition measured using DPOAEs and speech reception thresholds for sentences.

Comparison of findings in SDT and SRT indicates that MOCB has facilitatory role in speech recognition, but not in speech detection. SDT and SRT were chosen as two threshold measures of speech perception. The findings support that antimasking effect of MOCB reflex is helpful in improving speech recognition in noise.

5.3 Role of MOCB in Regulating SIS in Noise

No significant effect of contralateral noise was found in speech identification scores at -5 dBSNR. This was in contradiction to certain earlier studies (Boer & Thorton, 2008; Giraud et al., 1997; Kumar & Vanaja, 2004; Maruthy, Kumar, & Gnanateja, 2017) that found an improvement in SPIN on contralateral stimulation. Maruthy and Yashashwini (2017) found no significant effect of any level of contralateral noise (40,50,60 dB SPL) on syllable identification or SNR-50 across any SNRs (0,-5,-10) in 26 normal hearing individuals. However, the results in our study may be due to the subtle role of MOCB in regulating SPIN. The contradictory findings of our study may also be due to the lesser number of participants involved in this study. Further in depth research is needed with greater number of participants to generalize the findings.

5.4 Correlation between suppression magnitude of TEOAEs and SPIN

No significant correlation was found between suppression of TEOAEs and speech perception in noise for any of the parameters except SRT in noise at 20 dB SL. Change index of SRT at 20 dB ipsilateral noise negatively correlated with suppression magnitude. That is more the suppression magnitude, the change in SRT was less. Some of the earlier studies (Kumar & Vanaja, 2004; Mishra & Lutman, 2014; Maruthy, Kumar, & Gnanateja, 2017) also found SPIN to correlate with suppression magnitude. Micheyl and Collet (1996) found significant correlation between suppression magnitude and tone detection in noise at 2 kHz. They concluded, more the strength of efferents, more is the suppression and hence greater would be the improvement of tone detection in binaural noise. Support for absence of absence of correlation between change index of SDT and change index of SIS with the suppression magnitude can be drawn from earlier studies (Mertes et al., 2019; Wagner et al., 2008).

Overall, the findings suggest that MOCB has subtle influence on speech perception in noise that can be evidenced through only SRT in noise. The influence of MOCB, if any on SDT and SIS are not significant.

Chapter-6

SUMMARY AND CONCLUSIONS

The study aimed to investigate the effect of medial olivocochlear bundle (MOCB) stimulation on different speech perception measures. Contralateral suppression of transient evoked otoacoustic emissions (TEOAEs) being the functional measure of an intact efferent auditory pathway, correlation between suppression magnitude and improvement in SPIN scores (if any) was expected to indicate the role of MOCB in regulating speech perception in noise.

Fourteen normal hearing adults (18-30 years) participated in the study. Their candidacy for was ensured through a detailed case history, puretone audiometry, tympanometry, acoustic reflex thresholds, screening test for APD (SCAP-A), TEOAEs and contralateral suppression of TEOAEs. Only those participants with suppression magnitude of 0.5 or greater were considered for further experimental testing. Measures of speech perception were Speech detection threshold (SDT) in noise, speech recognition threshold (SRT) in noise and speech identification scores (SIS) in noise. SDT and SRT were estimated at three different levels of ipsilateral noise i.e. 10, 20 and 30 dB SL. SIS was determined at -5 dB SNR. All the measures were determined once without and once with contralateral broad band noise (BBN), presented at 60 dB SPL.

Based on the results of normality test and considering the small number of participants in the study, Wilcoxon signed rank test was used for pair-wise comparison of the measures obtained without and with BBN. Results of Wilcoxon signed rank test revealed no significant difference in SDT in noise at any of the ipsilateral noise levels (10, 20 & 30 dB SL). SIS in noise also did not differ between without and with contralateral BBN conditions. SRT in noise however showed a significant difference when the ipsilateral noise was 20 dBSL. In the presence of contralateral BBN, SRT obtained in 20 dBSL speech-shaped noise was significantly lower compared to that without contralateral BBN. There was no significant difference between SRT obtained without and with contralateral BBN, at 10 and 30 dBSL ipsilateral noise levels.

When the suppression magnitude and the change index of speech perception measures were correlated on Spearman's correlation test, there was no significant correlation found in any of the measures except for SRT at 20 dB SL. A negative correlation was found between suppression magnitude and change in SRT in 20 dB SL ipsilateral noise.

The findings of the study suggest lack of evidence for MOCB regulating SDT and SIS. Whereas MOCB appears to influence SRT in noise. The sample size in this study was not adequate for a strong inference. The sample size could not be increased due covid-19 situation in the country. Therefore, it is recommended that the same method may be followed to collect data from a larger sample for strong inference on the role of MOCB on threshold and suprathreshold measures of speech perception.

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