FUNCTIONING OF OLIVOCOCHLEAR BUNDLE

AND

SPEECH PERCEPTION IN NOISE

(REGISTER NO. M 9901)

A dissertation submitted in part fulfillment of the second year
M.Sc (Speech and Hearing), University of Mysore, Mysore

ALL INDIA INSTITUTE OF SPEECH AND HEARING
MANASAGANGOTHRI, MYSORE-570 006

MAY 2001

Dedicated to

My Dear

Parents

&

Teachers

Certificate

This is to certify that the Dissertation entitled *"Functioning of Olivocochlear Bundle & Speech Perception in noise"* is the bonafide work done in part fulfillment of the degree of Master of Science (Speech and Hearing) of the student (Register No. M 9901).

Director
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May 2001

Certificate

This is to certify that the Dissertation entitled *"Functioning of Olivocochlear Bundle & Speech Perception in noise"* has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other University for the award of any Diploma or Degree.

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I hereby declare that this Dissertation entitled *"Functioning of Olivocochlear Bundle & Speech Perception in noise"* is the result of my own study under the guidance of Ms. C. S. Vanaja, Lecturer in Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any other University for the award of any Diploma or Degree.

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CONTENTS

PAGE NO.

References

CHAPTER I

INTRODUCTION

In humans, the role of ear is extremely important. It is one of the most important links in speech chain, which enables proper communication. All the information from peripheral receptor organ is carried to the central organ, the brain for analysis, by means of afferent auditory pathway. The higher organs have control over the peripheral receptor, the cochlea, by means of efferent feed back pathways (Huffman & Henson, 1990). The mammalian cochlea receives efferent innervation from both ipsilateral and contralateral superior olivory complex. The olivocochlear bundle (OCB) is composed by two separate systems the medial olivocochlear projections which terminates primarily on to outer hair cells and lateral olivocochlear bundle which project primarily to inner hair cells (Warr and Guinan, 1979).

Although the existence of efferent innervation to the mammalian cochlea was described more than 50 years ago (Rassmussen. 1946 cited in Sahley, Nodar and Musiek (1997) the functional role of these fibers remain unclear. Hypothesis that have been proposed over the years, include the following:

1) OCB helps to protect the cochlea from acoustic injury (Rajan, 1992).
2) OCB aids in the control of masking (Liberman & Guinan. 1999).

It has been established that in animals, activity of medial olivocochlear bundle (MOCB) contributes to enhance the encoding of signals in noise. (Dewson, 1968 cited in Sahley, Nodar and Musiek, 1997; Winslow and Sachs, 1988; Kawase and Liberman, 1993, Kawase, Delgurte and Liberman, 1993; May and Mequone, 1995).

However, behavioral studies on humans uestibular neurectomes) have given contradictory results. Scharf, Magnan and Chay (1997) failed to evidence significant perceptual changes after MOCB section, except for frequency selective auditory attention. On the other hand, improvement in threshold detection and intensity discrimination *of* tones in noise in the presence of MOCB activity has been observed by other investigators {Micheyl and Collet, 1996; Micheyl, Perrot & Collet 19971 Zeng, Linermann. Soli and Linthicum (1994) reported that MOCB activity improved the perception of speech sounds in noise. Girand et al. (1997) also reported that in normal hearing subjects, activity of MOCB evoked through contralateral noise enhanced the speech-in-noise intelligibility. This improvement was not seen in vestibular neurectomised patients.

Functioning of the OCB can be tested noninvasively in humans through contralateral suppression of otoacoutic emissions (OAEs) (Collet et al. 1990). Contralateral suppression of OAEs refers to a reduction in amplitude of OAEs upon stimulation of the contralateral ear. This effect is attributed to alteration of cochlear micromechanics by MOCB which can be activated by contralateral acoustic stimulation (Buno, 1978 cited in Maison, Micheyl and Collet, 1999). This contralateral suppressive effect has also been reported for acoustic reflex (Ajith Kumar, 2000). This can be used to monitor the OCB functioning at high stimulus levels.

It can be inferred from the role of efferent system that, efferent dysfunction may be manifested as impaired ability to focus attention in the frequency domain, and perception and discrimination of tone and speech in noisy background. Children with learning disability have some of these dysfunctions such as difficulty in selective attention (Willeford & Burleigh. 1985) and poor speech understanding in presence of noise (Murdoch. 1994). So it can be hypothesized that there might be efferent dysfunction in these children.

Aim of the study: The main aim of the study was to correlate the physiologic measures of OCB functioning to psychophysical measures of speech perception in noise. The rationale underlying the study was, if as suggested by physiological data, activation of OCB leads to improved speech perception in noise, then speech identification scores (SIS) measured in presence of background noise should be improved by contralateral noise as it will excite the olivocochlear fibers projecting into the test ear. To investigate this preliminary hypothesis, first part of the study was devoted to measure SIS in BBN, successively in absence and presence of noise in the contralateral ear. If this shift in SIS is actually caused by OCB activation, then there should be a quantitative relationship between this shift and OCB feed back strength as measured by contralateral suppression of OAE and acoustic reflex. Therefore, the second part of the study investigated relationship between these two effects. Thus, the aims of the study were as follows:

1. Effect of contralateral acoustic stimuli on SIS in normal children and children with learning disorder.
2. To compare the functioning of OCB in normals and children with learning disorder using physiological measures.
3. To find the correlation between psychoacoustic and physiological measures of OCB.

Need **for the study:** There is lack of literature on the functional role of OCB in hearing. The psychoacoustic studies on patients with vestibular neurectomy have given contradictory results. Based on a pilot investigation, Veuillet, Bazin and Collet (1999, cited in Veuillet, Khalf and Collet, 1999) suggested that there is an association between contralateral suppression of evoked otoacoustic emissions (EOAE) and learning impairment. Further studies are required to substantiate these results and to see whether SIS can be predicted from amount of EOAE suppression in children. Understanding of possible physiological role of OCB ultimately may provide benefit to the following groups:

(a) Children experiencing auditory perceptual difficulties in noisy classroom with only minimal degree of peripheral impairment.

(b) Elderly individuals with presbycusis experiencing difficulty in understanding speech in the presence of noise (perceptual difficulties in communicating in noise).

(c) Children and adults with central auditory processing disorder.

CHAPTER II

REVIEW OF LITERATURE

The olivocochlear efferent neurons originate in the brainstem and terminate in the organ of corti, thereby allowing the central nervous system to influence the operation of the cochlea (Huffman & Henson, 1990). The functional role of these auditory efferent fibers is still a matter of debate. Following the early demonstrations that electrical or acoustical stimulation of olivocochlear bundle (OCB) elicit inhibitory effects over auditory penpherv (Fex, 1959, cited in Micheyl, Perrot and Collet, 1997; Galambose. 1956, cited in Micheyl, Perrot and Collet, 1997; Wiederhold, 1970), it was thought that OCB may play a role in the protection of cochlea from over stimulation (Cody & Johnstone, 1982; Rajan, 1988a, 1988b). Besides the protective role, this inhibitory function could lead to an improvement in coding of signals embeded in noise (Liberman, 1988), suggesting an antimasking role for OCB (Nieder & Nieder, 1970 cited in Micheyl, Perrot and Collet, 1997; Kawase & Liberman 1993; Kawase, Delgutte and Liberman, 1993). The following methods have been used to study the antimasking effect of OCB:

1) Electrical stimulation of OCB
2) Acoustical stimulation of OCB
3) Transection of OCB

Electrical stimulation of OCB: Electrical shocks delivered to the OCB at the floor of 4 ventricle decreases the compound action potential recorded at the round window (Galambose, 1956, cited in MicheyL Perrot and Collet, 1997) and raise the thresholds of single auditory nerve fibers to tones at their characteristic frequency (Guinan and Gifford, 1988). These suppressive effects of OCB activation were observed when clicks or tone bursts are presented in quiet. If, however, stimuli were presented along with ipsilateral continuous masking noise, shock evoked OCB activity increased the amplitude of click evoked compound action potential (Kawase and Liberman. 1993).

Dolan and Nultal (1988) also obtained similar results. They measured the magnitude of compound action potential as a function of intensity for tone burst in the following three conditions:

1) In the presence of masking noise.
2) With electrical stimulation of crossed olivocochlear bundle (COCB)
3) Combination of masking noise and electrical stimulation of COCB.

The results showed that electrical stimulation of COCB reduced the compound action potential (CAP) magnitude for low to moderate intensity tone bursts. In the presence of masking noise, there was a reduction in CAP amplitude for tone burst by 5-10 dB. The electrical stimulation of COCB along with the masking noise enhanced the CAP magnitude for signals of high intensities. Recordings from single auditory nerve fibers also showed similar results. Winslow and Sachs (1987) studied the effect of electrical stimulation of COCB on auditory nerve responses to tones in noise. They recorded the auditory nerve responses to tones of varying level presented simultaneously in the presence of fixed broadband noise with and without stimulation of the COCB. In the absence of the COCB stimulation, monotonic increase in noise level produced monotonic increase in noise driven response rate of auditory nerve fibers. They hypothesized that as a result of adaptation, the increase in noise rate produced monotonic decrease in saturation discharge rate. At high noise levels, these compressive effects may eliminate the auditory nerve responses to tones. The COCB stimulation counteracts the compressive effects produced by noise. COCB stimulation acts by reducing discharge rate in response to background noise. This reduction of noise driven rate, in turn decrease adaptation, which leads to an increase in saturation discharge rate, i.e., in the presence of background noise COCB stimulation produces upward shift of dynamic range.

Thus, a review of literature suggests that in the presence of background noise, electrical stimulation of OCB enhances the compound action potential, auditory nerve fibers response rate, and increases the dynamic range for brief tones.

Acoustical stimulation of OCB: Suppressive effects similar to that seen with electrical stimulation of COCB have been demonstrated when sound was presented to the contralateral cochlea (Liberman, 1988). In anesthetized cats, addition of contralateral sound raised ipsilateral thresholds by up to 12dB, roughly one half of maximal shock evoked suppression (Guinan and Gifford, 1988). Kawase and Liberman (1993) studied the antimasking effects of olivocochlear reflex in cats by comparing compound action potential to masked tones with and without contralateral noise. The amplitudes of CAP to masked tones increased when contralateral noise was presented at moderate sound pressure level. The entire contralateral noise enhancement disappeared when the OCB was cut. Enhancement effects of contralateral noise could be seen in both simultaneous and forward masking paradigms. Enhancement ' which was largest for high frequency tone pips (8-16 kHz), could be demonstrated for a wide range of tone pip levels and ipsilateral masker level. Responses of single auditory nerve fibers to tone burst in the presence of continuous masking noise could be increased by addition of contralateral noise. The contralateral noise increased the maximum discharge rates to the masked tone bursts whereas decreased the rates to the ipsilateral masker. The largest antimasking effects were seen for fibers with characteristic frequency between 6 to 8 kHz and for masker levels up to 20dB above the threshold.

The results of physiological studies of antimasking effects were also supported by behavioural findings. Micheyl and Collet (1996) investigated the involvement, of auditory efferents in hearing-in-noise in humans. OCB function was assessed in terms of contralateral attenuation of evoked OAE i.e., the reduction of click evoked OAE (CEOAE) amplitude elicited by a 30dB SL contralateral broadband noise (BBN). The detection thresholds for 1 and 2 kHz tone pips embedded in 50 dB SPL BBN were measured. EOAEs were measured in the same ear with and without contralateral BBN of 30 dB SPL. The result indicated that the contralateral attenuation of EOAEs correlated significantly with detection threshold for 2 kHz tone pip embedded in noise. It also correlated with shift in threshold at 1 and 2 kHz induced by contralateral acoustic stimulation.

It has been reported that OCB activation improves the discrimination of signals in presence of background noise. Micheyl et al. (1997) measured intensity difference limens in quiet in the presence of ipsilateral, contralateral and dichotic noise. OCB functioning was assessed through the contralateral suppression of EOAEs. Intensity difference limens measured in the presence of ipsilateral noise, were reduced when the contralateral noise was added. This shift in difference limens, for intensity showed a significant correlation with contralateral suppression of EOAE.

Transection of OCB: Another way of studying the functional role of OCB is to examine the behaviour before and after the transection of OCB in animals or in vestibular neurectomised patients. Dewson (1968, cited in Sahley, Nodar. Musiek, 1997) reported that midline efferent transection significantly impaired the recognition of 300 ms duration vowels presented at 70 dB SPL in low band pass noise in animals. It was necessary to reduce the intensity of noise by 15 dB in order to match preoperative performance levels. In the absence of background noise, however, there was no difference. Other investigators have reported that the frequency resolution was affected after transecting the OCB (Capps and Ades, 1968, cited in Sahley, Nodar, Musiek, 1997). It has been reported that the transection of OCB did not alter the pure tone thresholds (Igarashi, Alford. Nakai and Gordon, 1972), perceptual signal to noise ratios. (Igarashi, Alford, Gordon, Nakai, 1974), pure tone frequency discrimination at 8 kHz and ambient visual intensity discrimination under intense noise (Igarashi, Cranford, Nakai and Alford, 1979). But visual detection task in the presence of ambient BBN was impaired after the transection of COCB (Igarashi, Cranford, Nakai and Alford, 1977).

More recently, same approach was used in human subjects who have undergone vestibular neurectomy (Scharf, Magnan & Chay, 1997). They studied 16 patients who had undergone vestibular neurectomy, during which the olivocochlear bundle was severed. The results revealed that there was no change in detection of tonal signals, intensity discrimination, frequency selectivity, loudness adaptation, and frequency discrimination within a tonal series and in the head localization. The results were similar m both quiet and in noise. The only change observed after the vestibular neurectomy was that patients detected signals at unexpected frequencies better than before. This change suggested an impaired ability to focus attention in frequency domain. In contrast to this, other investigators have reported poorer speech perception in noise in vestibular neurectomized patients. Girand et al. (1997) investigated speech perception in noise in vestibular neurectomized patients and in normals. In normals, contraiateral noise improved speech intelligibility in noise and this was correlated with magnitude of contraiateral suppression of OAE. This improvement was almost absent in de-efferented ears of vestibular neurectomized patients. Similarly, Zeng et al. (1994) reported that pure tone intensity discrimination and speech perception in noise deteriorated significantly after vestibular neurectomy in a few subjects. They attributed this variability to the fact that not all the efferents were severed in even subject during vestibular neurectomy. Thus, these results suggest that olivocochlear efferents play an antimasking role in speech perception in noisy environments.

Physiological basis of masking and anti-masking

Liberman and Guinan, (1999) reviewed the physiological basis of masking; and antimaskins. According to them, a sinele auditory' nerve fiber

(ANF) responds to sound by increasing the rate at which it produces the action potential. Since ANFs can discharge spontaneously in the absence of applied sounds, a response actually constitutes an increase in action potential rate above the background rate. The shaded "tuning curve" in the Fig. 1 defines the response area for that ANF to tones presented in a quite background. Any frequency-intensity level combinations within the response area will cause this fiber to increase its discharge rate. Addition of noise can raise the thresholds of ANF in two ways viz., "excitatory masking" and "suppressive masking".

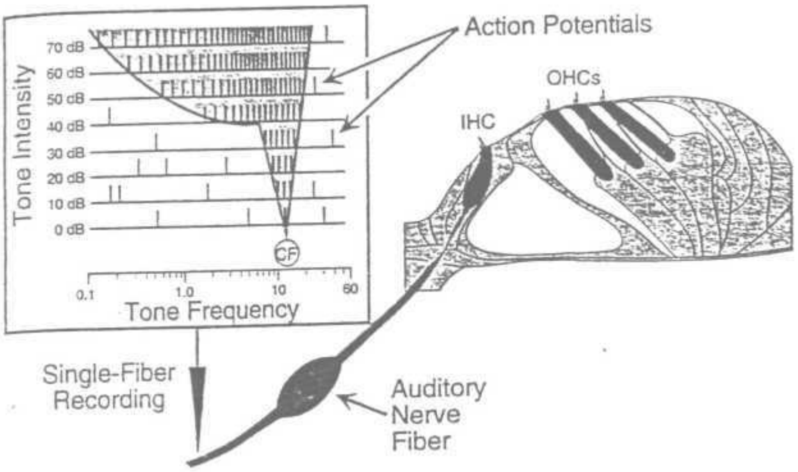


FIG. 1. TUNING CURVE OF A SINGLE AUDITORY NERVE FIBRE TO TONES PRESENTED IN A QUIET BACKGROUND.

SOURCE : LIBERMAN AND GUINAN (1999)

Excitatory masking is the effect of high frequency noise 'masker' on the response of the high characteristic frequency fiber to a signal as illustrated in Fig.2.

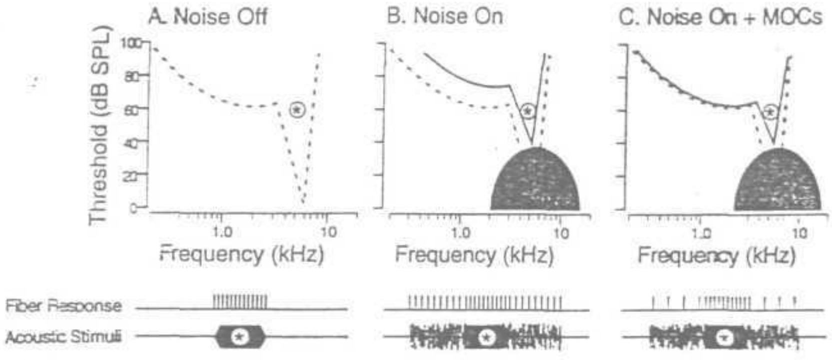


FIG. 2 ANTI-MASKING EFFECTS OF THE MOCB REFLEX

SOURCE : LIBERMAN AND GUINAN (1999) .

In the absence of noise, the signal (schematized by the asterisk) is within the fiber's response area (broken line) i.e., in the absence of noise, the fiber responds to the signal by increasing its discharge rate. However, the noise band also contains energy at frequencies and levels to which the fiber responds. Thus when the noise is presented, the fiber responds to noise and this raises the fiber's threshold to tones (solid line), so that the signal no longer elicits a response when noise is on. This 'excitatory masking' occurs for two reasons. First, the excitation of the fiber by the steady noise is like increasing its background discharge rate. This effect has been called line-busy effect. The second reason is that ANFs becomes fatigued by continuous stimulation by noise and when fatigued they are less responsive to additional transient signal. The phenomenon of suppressive masking is because of effects of low frequency noise band on the responses of same- high characteristic frequency

(CF) fiber to the same high frequency signal. The high CF fiber does not respond to the low frequency noise band; however because of nonlinearity in the inner ear, the sound energy placed just below fibers response area elevates the thresholds near CF.

Activation of OCB, either electrically or acoustically, decreases the steady responses to noise or increases the responses to transient signal, as shown in Fig. 2. So. the resultant increment in the response is easier to detect, and ability to discriminate suprathreshold stimuli in noise will be improved. The OCB suppress the noise more effectively than the signal because noise is continuous and signal is transient. OCB reflex acts to minimize the responses to long lasting stimuli while maximizing the response to novel stimuli.

Clinical relevance of efferent auditory pathway:

Functioning of OCB in humans has been studied primarily through contralateral suppression of EOAE. Clinical testing of OCB is helpful in identification of retrocochlear pathology and auditory neuropathy. It also aids in better understanding of CAPD in children and adults. Studies carried out on functioning of OCB in clinical population can be categorized as follows:

Studies on patients with cochlear and retrocochlear pathology: The amplitude of contralateral suppressive effect obtained in patients with cochlear pathology do not differ significantly from values obtained on control subjects

(Collet, et al. 1992). In patients with retrocochlear pathology contralateral suppression effect on EOAE is reduced or absent on the tumor side (Prasher, Ryan and Luxon, 1994). It is also observed that on the unaffected side of cerebropontine angle tumors, greater abnormalities of suppression were recorded even when auditory brainstem response (ABR) and acoustic reflex measurements were normal. The contralateral suppressive effect is reported to be absent in patients with auditory neuropathy (Starr, Picton, Sininger, Hood and Berlin, 1996).

Tinnitus: EOAEs in ears with tinnitus have been found to show less suppression by contralateral acoustic stimulus compared to ears presenting similar hearing loss but without tinnitus (Veuillct, Collet and Morgan, 1992 cited in Veuillet, Khalf and Collet, 1999). Contralateral suppression of DPOAE at the frequency of tinnitus is reported to be abnormal in patients with tinnitus at least in one ear (Chery-Croze, Truy, Morgon, 1994). Differences in variability in EOAE contralateral suppression between tinnitus and normal groups have also been reported (Graham and Hazell, 1994).

Learning Disorder: Studies on learning disordered children have shown that they perform poorer than normals in the presence of noise. Chermak. Vanhof, and Bendcl (1989) reported that word identification performance at +12.5 dB signal to noise ratio was significantly poorer in learning disordered children than normals. Archana (2000) tested speech perception in noise at +10 dB

SNR in learning disabled. All the subjects showed bilaterally reduced scores indicating auditory closure deficits. These children can be hypothesized to have OCB dysfiinctioning. The results obtained on learning disordered children are cogent with a significant reduction in MOC functioning only in the right ear (Veuillet et al. 1999). Such a pilot investigation suggests that there appears to be some association between contralateral suppression of click evoked otoacoustic emissions (CEOAE) and learning disorder. It has also been reported that children with learning disability show an abnormality in selective attention, memory and auditory perceptual skills (Willeford and Burleigh. 1985; Murdoch, 1994).

To conclude, both electrical and acoustical stimulation of OCB results in improved perception in noise. But studies done on vestibular neurectomy in which OCB is presumed to be cut have given contradictory results. Early studies done on monkeys (Dewson, 1968, cited in Sahley, Nodar, Musiek, 1997) showed that olivocochlear bundle helps in speech perception in noise. In humans, studies done using nonspeech materials have shown that auditory perception improved by OCB stimulation (Micheyl and Collet, 1996). It can also be hypothesized that a group of children and adults with learning disorder may have dysfunctions of OCB. Studying the OCB functioning in these children helps in better understanding of functional role of efferent auditory pathway in hearing and may facilitate the treatment procedures.

CHAPTER III

.METHODOLOGY

This study was undertaken to evaluate the functioning of OCB in normal subjects and children with learning disorder.

A. **Subjects:** Subjects were divided into two groups:

Group 1: Consisted of 10 subjects in the age range of 10-12 years diagnosed as learning disorder on the basis of early reading skills (Rac and Potter, 1981). Indian norms given by Loomba (1995) was used for the diagnosis.

Group 2: 10 children with normal scores on early reading skills, matched for age and gender served as control group.

All the subjects had normal hearing i.e., thresholds no more than 15 dB HL at octave frequencies between 250 Hz to 8 kHz and normal results on immittance evaluation. Subjects with any history of otologic or neurologic disorders were not included in the study.

B. **Equipment:** (i) Psychoacoustic experiment: Two channel clinical audiometer, Madson OB 822 with TDH-39 headphones housed in MX-41/AR ear cushion with audio cups were used for air conduction threshold measurements. Speech stimulus was presented through the audiometer using two channel cassette deck (Philips AW 606). Broad band noise fed through the insert receiver of a calibrated audiometer, GSI-16, was used as contralateral acoustic stimuli (CAS) to activate the efferent system.

ii) Physiologic experiment: A calibrated immittance meter, GSI-33 middle ear analyser (version-2) was used to assess the middle ear functioning of the subjects as well as contralateral suppression of acoustic reflex. Biologic scout plus otoacoustic emission analyser was used to measure the amplitudes of transient otoacoustic omission (TEOAE) and contralateral suppression of OAE. Board band noise fed through insert receiver of a calibrated audiometer, Madson electronics OB 822, was used as contralateral acoustic stimuli to activate the efferent system.

C. **Material:** The speech stimuli consisted of 2 half lists of speech identification test developed by Rout (1996) for Indian English speaking children. The material was recorded by Yathiraj (2000). Two randomized sets were recorded for each list A calibration tone was recorded at the beginning of each list.

D. Test **environment:** Pure tone audiometry and speech identification test was carried out in a double-doored sound treated room with adequate illumination. OAE and acoustic reflex measurements were carried out in a quiet environment.

E. Procedure: All the subjects were screened for hearing loss and middle ear dysfunction, subjects who met the criteria specified earlier were selected for the study.

(i) Psychoacoustic experiment: Speech identification score was obtained at 50 dB HL in quiet and with a signal to noise ratio of+10, +15 and +20 dB. This was carried out in the presence and absence of contralateral BBN at 30 dB SL (re: threshold of noise). Verbal responses were obtained from the subjects.

(ii) Physiological experiment: TEOAEs evoked by clicks presented at 70 dB SPL were recorded. The probe with a foam tip was positioned in the external ear canal and adjusted to give a flat stimulus spectrum across the frequency range. The responses of 256 sweeps were averaged to obtain the standard nonlinear click emissions and amplitudes of TEOAE were measured. The OAEs were also recorded in the presence of contralateral BBN at 30 dB SL (re: threshold of noise). Care was taken to ensure that the position of the probe was not altered. The difference of 0.5 dB between the two conditions was considered to be significant.

Suppression of acoustic reflex was used to evaluate the OCB feedback at higher intensities. Acoustic reflex threshold was obtained at 1 kHz using 226 Hz probe tone. Reflex activating stimuli was presented at 10 dB SL with respect to acoustic reflex threshold and amplitude of reflex was measured in terms of equivalent volumes. BBN was presented to the contralateral ear at 30 dB SL and reflex amplitudes at 10 dB SL (ref: ART) was measured again. A difference of .01 ml between two conditions was considered as significant.

The data obtained was tabulated and suitable statistical analysis was carried out to investigate the aims of the study.

CHAPTER IV

RESULTS

The data obtained from normal subjects and learning disordered children were analysed to investigate the following:

1) Effect of contralateral acoustic stimulation (CAS) on speech identification scores (SIS) in normal subjects and subjects with learning disorder.
2) Compare the physiological measures of olivocochlear bundle (OCB) in normal subjects and learning disordered.
3) Correlation between shift in SIS induced by CAS and physiological measures of OCB.

Effect of CAS on speech identification scores:

Control group: Table 1 and Table 2 shows the mean and standard deviations (SD) of SIS in right and left ear respectively, at different conditions, in the presence and absence of CAS. Paired t test was carried out to check if the difference between the mean scores is statistically significant. Results revealed that SIS in both ears improved significantly (P<05) in the presence of contralateral noise when the signal to noise ratios (SNR) in ipsilateral ear was + 10 dB and + 15 dB. Presence of CAS reduced the SIS in right ear at + 20 dB signal to noise ratio and in quiet in both the ears. However, this reduction was not statistically significant. These results, that is, the mean SIS, in presence and absence of CAS are also represented in Figure 1 and 2, for right and left ear respectively.

Table I: Mean SIS, SD and t values for right ear with and without CAS.

Conditions		Mean	SD	t values
Quiet	Without CAS	23.8 (95.2)	1.3	.625
	With CAS	23.5 (94.0)	1.6	
+ 10dB	Without CAS	1.9(7.6)	2.6	2.16*
	With CAS	4.2(16.8)	2.4	
+ 15dB	Without CAS	6.3 (25.2)	3.4	2.84**
	With CAS	9. (36.0)	3.7	
+ 20dB	Without CAS	12 (48.0)	3.7	.5
	With CAS	11.8(47.2)	4.4	

* P < .05
** P<.01
Values in ( ) indicate percent correct scores.

Table 2: Mean SIS, SD and t values for left ear with and without contralateral BBN.

Conditions		Mean	SD	t values
Quiet	Without CAS	24.3 (972)	.67	1.635
	With CAS	23.5 (94.0)	1.8	
+ 10dB	Without CAS	9(3.6)	1.2	6.846***
	With CAS	4.7(18.8)	2.6	
+ 15 dB	Without CAS	7.2 (28.8)	3.8	2.6*
	With CAS	9.6 (38.4)	4.9	
+ 20dB	Without CAS	13.6(54.4)	6.18	.485
	With CAS	14 (56.0)	5.4	

***P<.0001
* P<.05
Values in ( ) indicate percent correct scores.

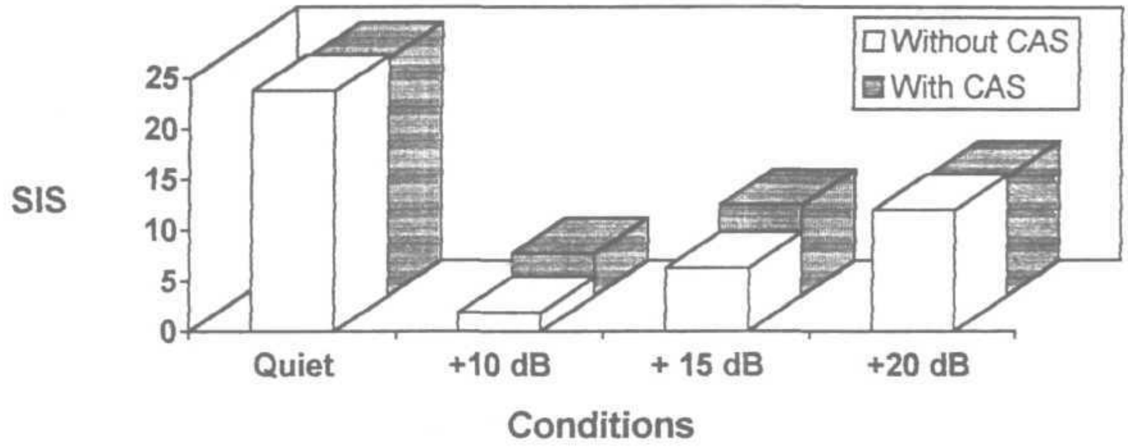


Fig.1. Mean SIS for right right in normal subjects with and without CAS.

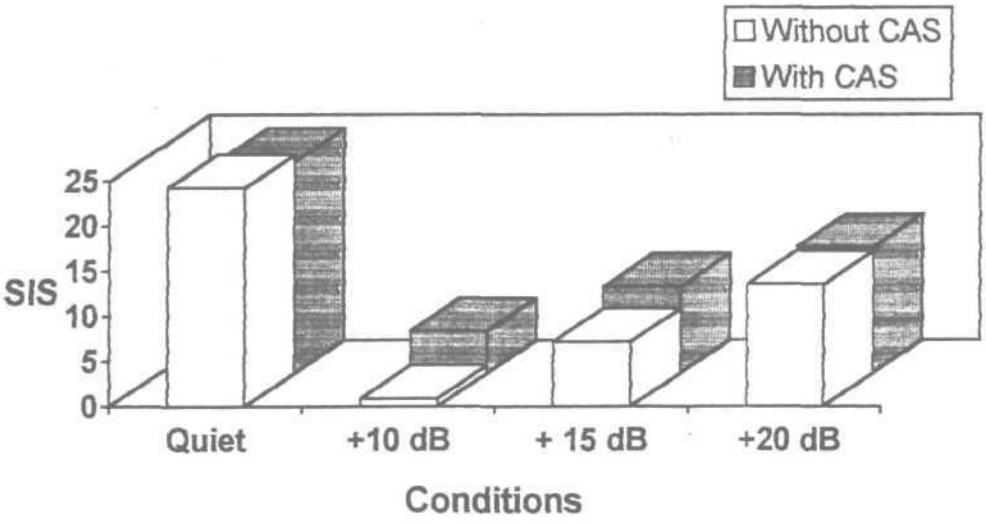


Fig.2. Mean SIS for left ear in normal subjects with and without CAS.

Experimental group: Mean and SD of SIS in right and left ear of subjects with LD are shown in Tables 3 and 4 respectively. The results of paired t test showed that except at +10 dB SNR and in quiet, for left ear, the addition of contralateral noise did not improve SIS significantly in children with LD. Inspection of individual data showed that the improvement seen in quiet and at +10 dB SNR in the left ear was because of the data from a single subject. When this subject was excluded from the analysis, there was no statistically significant difference in SIS with and without CAS.

Table 3: Mean, SD and t values of SIS for right ear in children with learning disorder with and without CAS.

Conditions		Mean	SD	t values
Quiet	Without CAS	20.3(812)	2.62	1.55
	With CAS	21.5(86.0)	2.5	
+ 10dB	Without CAS	0.6 (2.4)	1.07	1.00
	With CAS	0.4(1.6)	0.69	
+ 15dB	Without CAS	3.7(14.8)	2.4	.337
	With CAS	3.5(14.0)	1.9	
+ 20dB	Without CAS	7.8(31.2)	2.5	1.32
	With CAS	8.6 (33.4)	1.8	

Values in ( ) indicate percent correct scores.

Table 4: Mean, SD and t values of SIS for left ear in children with learning disorder with and without CAS.

Conditions		Mean	SD	t values
Quiet	Without CAS	19.6(78.4)	2.9	1.91*
	With CAS	21.4(86.6)	2.3	
+ 10dB	Without CAS	0.5 (2.0)	0.84	1.00
	With CAS	0.8 (3.2)	1_ 1.03	
+ 15dB	Without CAS	2(8)	1.94	1.97*
	With CAS	1.7(6.8)	1.8	
+ 20dB	Without CAS	4.9(19.6)	3.41	1.102
	With CAS	7.7 (30.8)	2.4	

* P < .05

Values in ( ) indicate percent correct scores.

The mean SIS, with and without CAS, is depicted in bar diagrams in Figure 3 and 4.

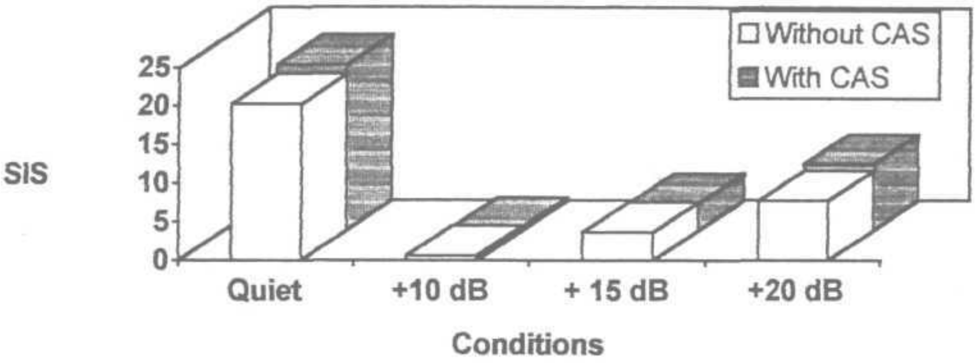


Fig.3. Mean SIS for right ear in children with learning disorder with and without CAS.

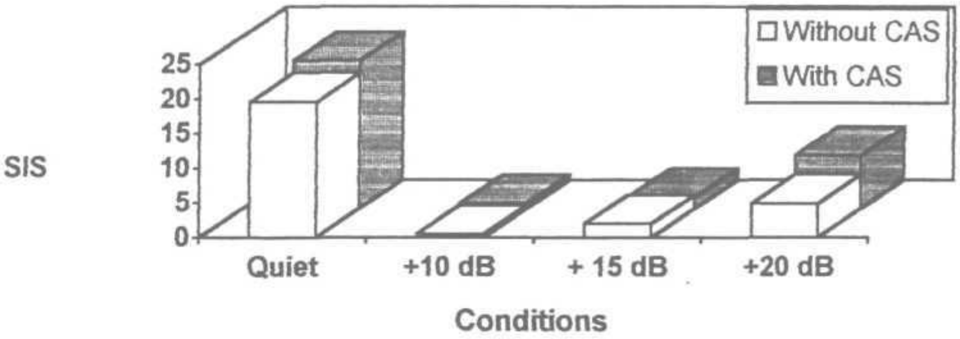


Fig. 4. Mean SIS for left ear in children with learning disorder with and without CAS.

Right ear Vs left ear: To evaluate the ear advantage mean shift in SIS in right ear upon contralateral stimulation was compared to that of left ear. Table 5 and 6 shows the mean shift in SIS (SIS with CAS *minus* SIS without CAS) for right and left ear in normal and LD subjects respectively. The results of paired t test are also included in the Table. Except at +10 dB SNR, in normal subjects, there was no statistical significant difference in mean shift between right and left ear. Children with LD did not show any difference in shift in SIS between two ears.

Table 5: Mean, SD and t values for shift in SIS in normals.

Conditions		Mean	SD	t values
Quiet	Right ear	-.2 (0.8)	1.47	.343
	Left ear	-.8(3.2)	1.5	
+ 10dB	Right ear	2.3 (9.2)	1.63	2.016**
	Left ear	3.8(15.2)	1.75	
+ 15dB	Right ear	3.3(13.2)	2.02	.45
	Left ear	2.4 (9.6)	2.91	
+ 20dB	Right ear	.2 *(0.8)*	1.3	.892
	Left ear	**4(1.6)**	2.54	

**P<.01
Values in ( ) indicate percent correct scores.

Table 6: Mean, SD and t values for shift in SIS for LD children

Conditions		Mean	SD	t values
Quiet	Right ear	1.2(4.8)	2.44	.5
	Left ear	1.8(7.2)	2.97	
+ 10dB	Right ear	-.2 (-.8)	.63	1.36
	Left ear	-.3 (-1.2)	.99	
+ 15dB	Right ear	-2 (-.8)	1.87	.1
	Left ear	-.3 (-1.2)	.63	
+ 20dB	Right ear	.8(3.2)	1.9	1.55
	Left ear	2.8(11.2)	2.93	

Values in ( ) indicate percent correct scores

Physiological measures of OCB: These included contralateral suppression of TEOAE and acoustic reflex amplitudes. As shown in the Table 7, contralateral noise reduced the amplitudes of acoustic reflex and OAE in normal subjects. The suppressive effect for OAE was more in the right ear while acoustic reflex amplitudes reduced equally in both the ears.In contrast, in children with LD (Table 8), contralateral noise did not alter the amplitudes of OAE and acoustic reflex in right ear, whereas it reduced the amplitude slightly in left ear. This suppressive effect in the left ear was less when compared to age and gender matched normal subjects. Representative samples of OAE amplitudes in the presence and absence of contralateral noise for normal subjects and children with LD are shows in Figure 5a, 5b and 6a, 6b. Because of technical problem, contralateral suppression of OAE was measured only in eight subjects in both the groups.

Table 7: Contralateral suppression of OAE and acoustic reflex
in normal subjects.

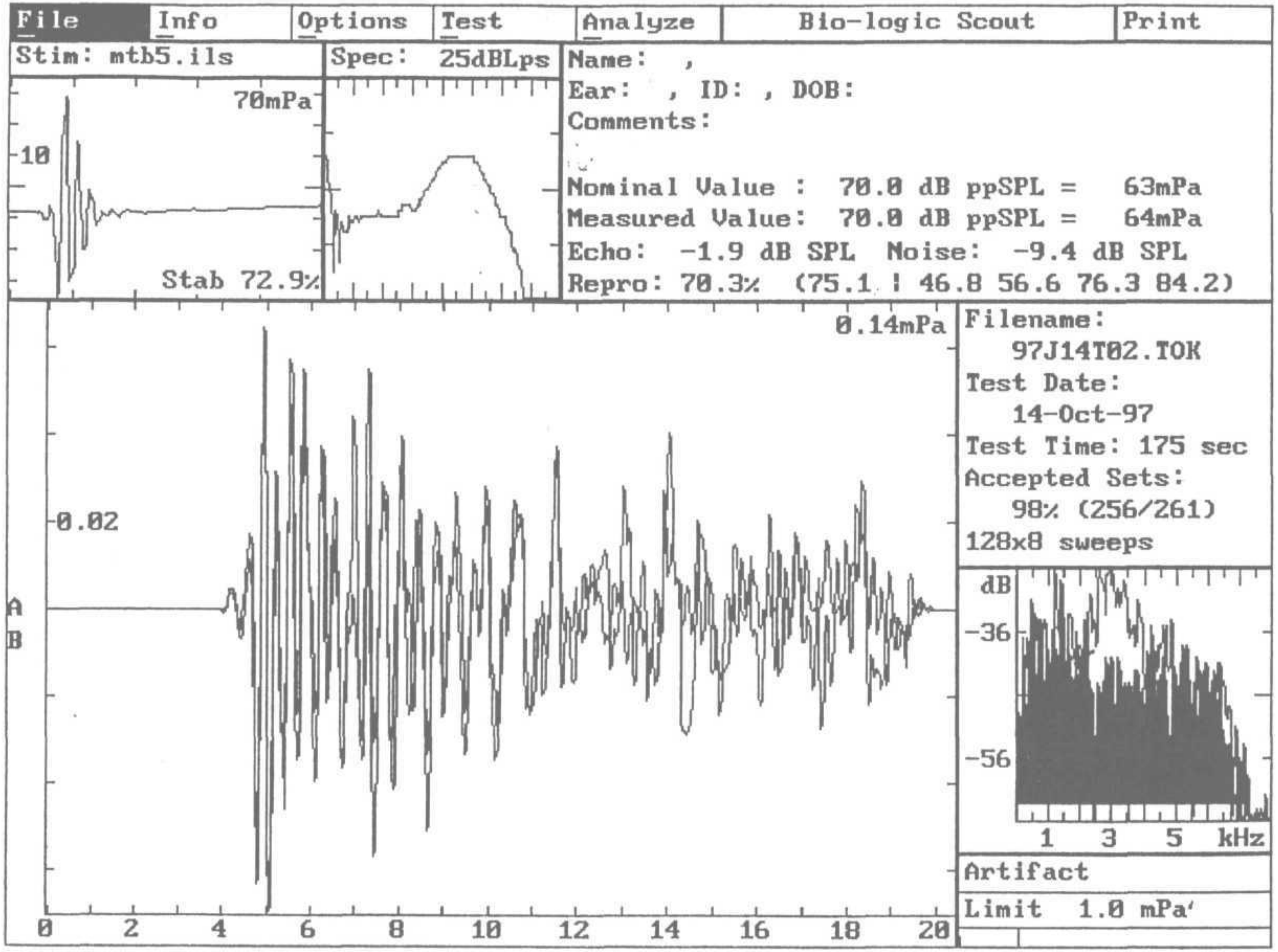
1	Ear	Mean	SD
Contralateral suppression ofOAE	Right ear	1.6	.85
	Left ear	.87	*.69*
Contralateral suppression of acoustic reflex	Right ear	.03	1.25
	Left ear	.032	1.35

Table 8: Contralateral suppression of OAE and acoustic reflex in children with LD.

	Ear	Mean	SD
Contralateral suppression of OAE	Right ear	.15	.92
	Left ear	.53	.5
Contralateral suppression of acoustic reflex	Right ear	.003	8.23
	Left ear	.013	1.159

Relation between physiologic measure of OCB and speech perception in noise:

Correlation analysis was performed with contralaterally induced shift in TEOAE as the independent variable and shift in SIS as the dependent variable. For this, Pearson's product-moment correlation was calculated for the combined data of control and experimental group. Similarly correlation coefficient between contralateral suppression of AR and shift in SIS was also calculated. As shown in the Table 9, psychoacoustic measures of OCB at + 10 dB and +15 dB SNR showed statistically significant positive correlation (P< .001) with the physiological measure. No significant correlation was observed when SIS in quiet and + 20 dB SNR was considered.



Stim: mtb5.ils

Spec: 25dBLps

Name: ,

Ear: , ID: , DOB:

Comments:

Nominal Value : 70.0 dB ppSPL = 63mPa

Measured Value: 70.0 dB ppSPL = 64mPa

Echo: -1.9 dB SPL Noise: -9.4 dB SPL

Repro: 70.3% (75.1 ¦ 46.8 56.6 76.3 84.2)

Filename:
97J14T02.TOK

Test Date:
14-Oct-97

Test Time: 175 sec

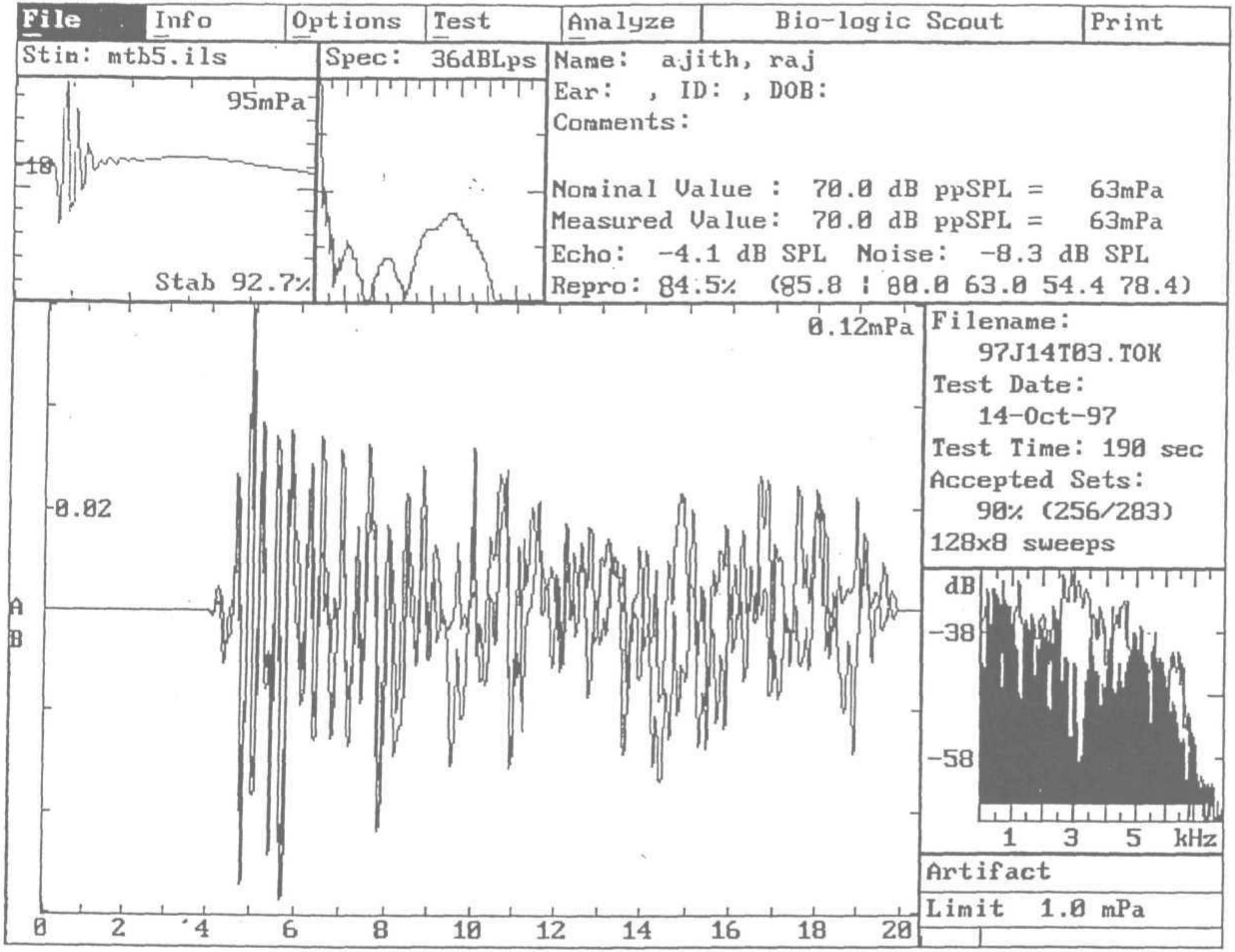
Accepted Sets:
98% (256/261)

128x8 sweeps

Artifact

Limit 1.0 mPa

FIG. 5a. TEOAE RESPONSE WITHOUT CONTRALATERAL ACOUSTIC STIMULUS IN NORMAL SUBJECT



Stim: mtb5.ils
Spec: 36dBLps
Stab 92.7%

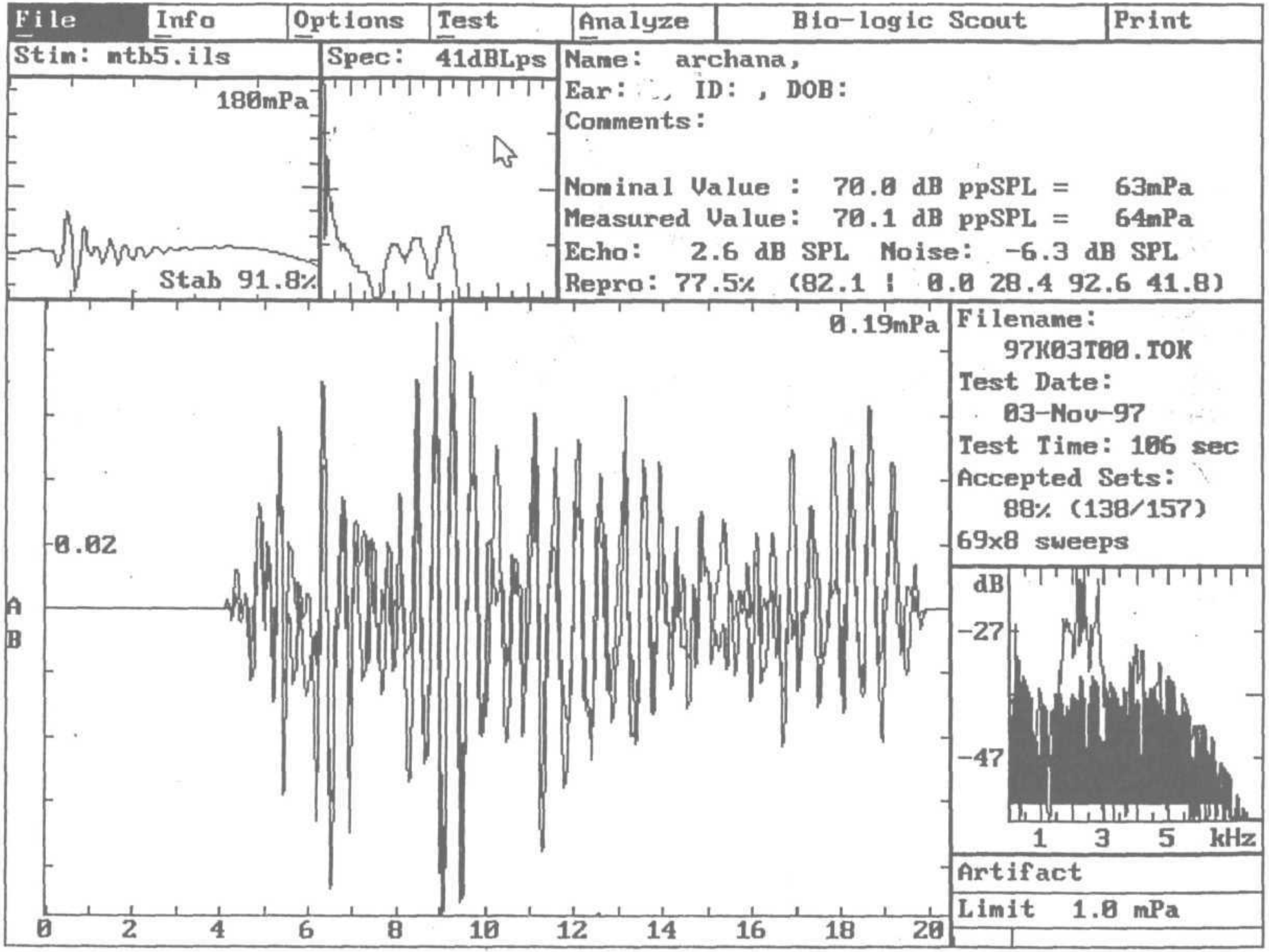
Name: ajith, raj
Ear: , ID: , DOB:
Comments:

Nominal Value : 70.0 dB ppSPL = 63mPa
Measured Value: 70.0 dB ppSPL = 63mPa
Echo: -4.1 dB SPL Noise: -8.3 dB SPL
Repro: 84.5% (85.8 | 80.0 63.0 54.4 78.4)

Filename:
97J14T03.TOK
Test Date:
14-Oct-97
Test Time: 190 sec
Accepted Sets:
90% (256/283)
128x8 sweeps

Artifact
Limit 1.0 mPa

FIG. 5b. TEOAE RESPONSE WITH CONTRALATERAL ACOUSTIC STIMULUS IN NORMAL SUBJECT



Stim: mtb5.ils

Spec: 41dBLps

Name: archana,

Ear: , ID: , DOB:

Comments:

Nominal Value : 70.0 dB ppSPL = 63mPa

Measured Value: 70.1 dB ppSPL = 64mPa

Echo: 2.6 dB SPL Noise: -6.3 dB SPL

Repro: 77.5% (82.1 ¦ 0.0 28.4 92.6 41.8)

Filename:
97K03T00.TOK

Test Date:
03-Nov-97

Test Time: 106 sec

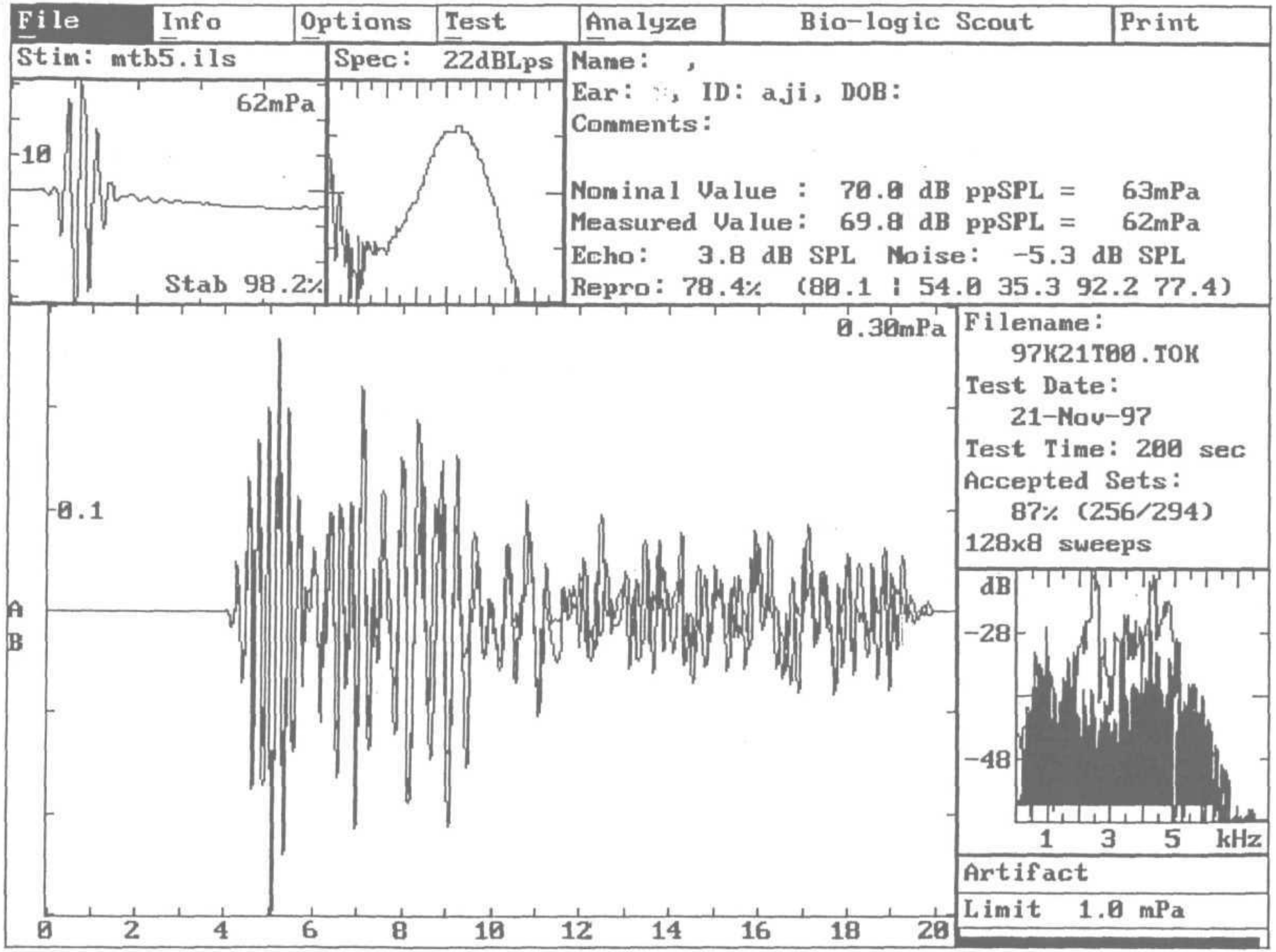
Accepted Sets:
88% (138/157)

69x8 sweeps

Artifact

Limit 1.0 mPa

FIG. 6a TEOAE RESPONSE WITHOUT CONTRALATERAL ACOUSTIC STIMULUS IN A CHILD WITH LD.



Stim: mtb5.ils

Spec: 22dBLps

Stab 98.2%

Name: ,

Ear: , ID: aji, DOB:

Comments:

Nominal Value : 70.0 dB ppSPL = 63mPa

Measured Value: 69.8 dB ppSPL = 62mPa

Echo: 3.8 dB SPL Noise: -5.3 dB SPL

Repro: 78.4% (80.1 | 54.0 35.3 92.2 77.4)

Filename:
97K21T00.TOK

Test Date:
21-Nov-97

Test Time: 200 sec

Accepted Sets:
87% (256/294)

128x8 sweeps

Artifact

Limit 1.0 mPa

FIG. 6b TEOAE RESPONSE WITH CONTRALATERAL ACOUSTIC STIMULUS IN A CHILD WITH LD.

Table 9: Correlation between physiologic and psychoacoustic measures.

	Quiet	+ 10dB	+ 15 dB	+ 20dB
Contralateral suppression of OAE and shift in SIS	-.03	.48	.5	-.23
Contralateral suppression of acoustic reflex and shift in SIS	.1	.53	.512	-.08

A strong positive correlation was obtained between contralateral suppression of OAE and acoustic reflex (r=.78). The results of present study in context of earlier literature are discussed in the next chapter.

CHAPTER V

DISCUSSION

Results of this study indicate that in normal subjects contralateral noise improved the speech identification scores (SIS) at +10 dB, and +15 dB signal to noise ratio (SNR), but this effect was absent in children with learning disorder (LD). The shift in the SIS observed upon the presentation of contralateral noise showed a significant correlation with contralateral suppression of transient evoked otoacoustic emission (TEOAE) and acoustic reflex amplitude.

SIS in presence of contralateral noise; Contralateral noise improved speech perception in the presence of noise when the SNR was +10 dB and +15 dB in normal subjects. It can be hypothesized that the contralateral noise stimulated the medial olivocochlear bundle (MOCB), which increased the detection and discrimination of signals in noise, thereby enhancing the speech perception in presence of ipsilateral noise. It is well established that efferent system is activated during contralateral acoustic stimulation (CAS) (Buno, 1978, cited in Maison, Micheyl and Collet, 1999). Stimulation of MOCB aids in the perception of signals in presence of noise. Micheyl et al. (1997) reported that stimulation of MOCB through contralaleral noise improved intensity discrimination in presence of ipsilateral noise. Girand et al. (1977) and Dewson (1968, cited in Sahley, Nodar and Musiek, 1997) suggested that olivocochlear bundle (OCB) helps in speech perception in noise. Neurophysiological studies also have shown that OCB stimulation enhances the auditory nerve fibers (ANFs) responses to brief tones in presence of noise (Winslow and Sachs, 1988; Kawase and Liberman, 1993).

The feedback suppression of MOCB pathway can have enhancing effects on ANFs responses by the decompression of rate level functions. In the presence of noise, ANF response adapts to steady masker and an adapted ANF is less responsive than an unadapted one (Smith, 1977). Such compression in the rate-level functions affects the coding of changes in the stimulus parameters. The activation of OCB may suppress the responses to steady masker and decreases the adaptation effect. Thus it indirectly increases the ANF response to stimulus (Kawase and Liberman, 1993). Reducing the ANF discharge rate at low stimulus levels, the OCB could elicit a decompression of rate level functions, thereby partly restoring the sensitivity of ANFs to changes in stimulation level in background noise (Winslow and Sachs, 1988). Since variation in intensity and frequency are the major cues for speech perception this decompressive effect will enhance the SIS. The observation of the present study also supports the hypothesis that, MOCB enhances signal coding in noise not because the signal is narrow band and noise is wide band, rather because the noise is constant while signal is time varying.

The improvement in SIS in the presence of contralateral noise was seen only when ipsilateral SNR was +10 dB and +15 dB. In fact, in quiet and at +20 dB SNR, presentation of the BBN to contralateral ear decreased the SIS. This observation is consistent with the hypothesis that OCB activity helps in signal detection only in presence of ipsilateral noise (Girand et al. 1997). In quiet or if the ipsilateral noise is less intense, CAS might suppress the ANF responses to speech as well as noise.

In contrast to normal subjects, children with learning disorder did not show any improvement in SIS in the presence of contralateral noise. This indicates the possibility of abnormality in MOCB functioning in children with learning disorder. It has been reported that children with learning disorder have difficulty in understanding speech in presence of noise (Murdoch, 1994). This difficulty may be due to decreased strength of olivocochlear feed back.

Physiological measures of functioning of OCB:

Results of physiologic experiments revealed that normal subjects showed contralateral suppression in both the ears, but children with learning disorder showed contralateral suppression only in the left ear. Also, the magnitude of suppression in children with learning disorder was lesser than that of normal children. These results again suggest abnormal functioning of

MOCB in children with learning disorder. Similar results were also reported by Veuillet et al. (1999, cited in Veuillet, Khalf and Collet, 1999).

Ear effects: To evaluate the ear advantage, changes in SIS, OAE and acoustic reflex amplitudes in right ear upon contralateral stimulation was compared with that of left ear. Not much difference was observed between two ears for shift in SIS and acoustic reflex amplitudes in both normal and learning disordered subjects. But OAE showed consistently more suppression in right ear when compared to left in normal subjects. Similar results were reported by Khalfa, Micheyl, Veuillet and Collet (1998). They demonstrated that TEOAE input/output function increased more in right ear in presence of contralateral noise. They concluded that medial olivocochlear bundle is more effective in the right than in the left ear. This asymmetry between two ears reinforces the notion of peripheral auditory lateralization. It was also observed that children with learning disorder showed contralateral suppression for OAE and acoustic reflex in the left ear but not in the right ear. This shows that in children with learning disorder, MOCB is functioning slightly better in the left ear when compared to right ear. Analysis of results of individual subjects revealed that none of the children with learning disorder showed suppression in right ear, while five out of eight showed suppression in left ear, for OAE measures. Similarly for acoustic reflex amplitude, none of learning disordered children showed suppression in right ear and six out often showed reduction in acoustic reflex amplitude in the left ear upon presentation of the contralateral noise. It is well established that children with learning disorder have disturbed cerebral dominance (Oglehorpe, 1996). These results indicate that children with learning disorder may have disturbed lateralization even at the level of brainstem.

Relation between the physiologic and psycho-acoustic measures of OCB:

Shifts in SIS at +10 dB and + 15 dB SNR observed upon the addition of contralateral noise correlated with contralateral suppression of TEOAE and acoustic reflex amplitudes. On the basis of the various arguments put forward in previous studies to demonstrate an involvement of MOCB in the contralateral attenuation of EOAE and acoustic reflex amplitude (Collet et al. 1990 and Ajith Kumar, 2000), the observed correlation between contralateral effects on SIS and contralateral attenuation suggests that OCB reflex constitutes one of the physiological mechanisms, which augments the speech perception in noise. This is supported by physiological and animal experiments (Kawase and Liberman, 1993) and data from vestibular neurectomised patients (Girand et al. 1997; Zeng, Liberman, Soli and Linthicum, 1994).

It is a well known fact that a statistical relationship between two variables does not necessarily imply an underlying causal link between them. This is one of limitations faced when noninvasive measures are used to investigate the physiological bases of perceptual phenomenon in humans. However, the observed results of this study is in agreement with the electrophysiological data in animals, supporting the causal link between MOCB activity and speech perception in noise. An important observation in the present study that supports the interpretation of SIS shift induced by contralateral noise is due to OCB interaural functioning, this shift correlated, with physiological measures of OCB only at + 10 dB and + 15 dB SNR. This condition specific relationship in the present results is in close agreement with physiologic data, which clearly indicate that OCB enhances the encoding of signals, by opposing the background noise (Winslow and Sachs, 1988).

Thus, the results of the present study confirm the hypothesis, MOCB functioning is important for speech perception in noise, thereby suggesting a possible role of cochlear efferent fibers in hearing. Both psychoacoustic and physiological measures of OCB, showed impaired functioning of descending auditory pathway in learning disordered children, which may increase their difficulty in hearing in noise. The psychoacoustic measures can be used to evaluate the efferent auditory pathways, where it is not possible to record OAEs.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Although the existence of efferent innervations to the mammalian cochlea was described more than 50 years age (Rasmussen, 1946, cited in Shalcy, Nodar and Musick, 1997), the functional role of these fibers remain unclear. It has been demonstrated that in animals, activity of medial olivocochlear bundle (MOCB) enhances the encoding of signals in noise (Dewson, 1968, cited in Shaley, Nodar and Musiek, 1997). However, behavioural studies on humans (on vestibular neurectomees) have given very contradictory results (Sharf, Magnon, Chay, 1997). Very few studies have evaluated the functional role of MOCB in humans. Hence, the present study was a step in **this** direction and aimed at investigating the following:

1. Effect of contralateral acoustic stimuli on speech identification scores (SIS) in normal children and children with learning disorder.
2. To compare the functioning of olivocochlear bundle (OCB) in normal and learning disorder children using physiological measures
3. To find the correlation between psychoacoustic and physiological measures of OCB.

In the present study, two groups of subjects were tested. Group I consisted of 10 subjects with learning disorder in the age range of 10-12 years.

Group II was formed by 10, age and gender matched normal subjects. SIS were measured across the four conditions, quiet, +10 dB, +15 dB and +20 dB signal to noise ratio, with and without contralateral noise. Two physiological measures of OCB, contralateral suppression of otoacoustic emissions and acoustic reflex, were also measured.

Following conclusions were drawn from the study:

(a) Contralateral noise significantly improved the SIS at +10 dB and +15 dB SNR in normal subjects but not in children with learning disorder.

(b) The shift in SIS at +10 dB and +15 dB SNR showed a positive correlation with both the physiological measures of OCB. This condition specific positive correlation indicates the involvement of OCB in speech perception in noise.

(c) Normal subjects showed stronger OCB feed back in right ear indicating peripheral laterality. In contrast, subjects with learning disorder showed no suppression in right ear and reduced suppression in left ear on both the physiological measures. This indicates that disturbed lateraiity exists even at the lower level in children with learning disorder.

Thus, the results of the present study reinforces the hypothesis that the efferent system augments speech perception in noise. The finding that this anti-masking effect may not be present in children with LD opens the door to further research on functioning of OCB in those complaining of difficulty in hearing-in-noise. The study also emphasizes the need to include assessment of OCB functioning in the test battery approach, especially while evaluating those with difficulty in hearing-in-noise.

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