Dedicated to:

MY PARENTS AND SANDEEP

Study of the Relationship between the Acoustic Reflex Threshold and Threshold of Octave Masking

JAGADISH.A.

A Dissertation
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of the Requirements for the Degree
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CERTIFICATE

This is to certify that the dissertation entitled "A study of the relationship between Acoustic Reflex Threshold and Threshold of Octave Masking" is the *bona fide* work in part fulfilment for the Degree of M.sc. (Speech and Hearing), of the student with Register No.5

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CERTIFICATE

This is to certify that this dissertation has been prepared under my supervision and guidance.

(M.N.Vyasamurthy)
Guide

DECLARATION

This dissertation is the result of my own study undertaken under the guidance of Mr. M.N. Vyasamurthy, Lecturer in Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any University for any other Degree or Diploma.

Mysore Register No. 5

Date:

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CHAPTER I

INTRODUCTION

Psychoacoustic tasks could be used as new indices of susceptibility to noise-induced hearing loss, replacing traditional TTS-based susceptibility tests. Prior attempts to delineate "tough" from "tender" ears have relied on the use of Temporary Threshold Shift (TTS) as the measure of vulnerability (Ward 1973 b). If several correlates were identified, they could be used as a test battery for susceptibility testing. The value of the test battery approach in assessing human auditory function has been recognized for many years and may prove a more reliable approach to susceptibility testing.

The identification of psychoacoustic correlates of TTS may also provide new information about the areas of the auditory system involved in the fatigue process. A test battery comprised of psychoacoustic correlates of susceptibility may be useful in detecting minimal auditory dysfunction. It is generally accepted that the puretone audiogram is a poor indication of the histological status of the auditory system, especially of the Cochlea (Eldredge and Miller 1969, Ward and Duvall 1971, Lipscomb 1975).

If auditory pathway is to be identified before irreparable damage results in a puretone hearing loss, then new tests which are sensitive to subtle dysfunction must be used.

It was known since 1830 that there is individual differences in susceptibility to Temporary Threshold Shift (TTS) and Permanent Threshold Shift (PTS). Some investigators, have studied possible relationships between susceptibility to TTS and other psychoacoustic tasks. In 1954, Lawrence and Blanchard suggested that a psychoacoustic measures of cochlear nonlinearity, the aural overload test, might be a correlate of susceptibility to auditory fatigue. Later Humes and Schwdrtz (1977) supported the above findings.

The Threshold of Octave Masking (TOM) test is a tonal masking technique used to estimate the threshold of cochlear distortion or nonlinearity. It has been suggested as a substitute for measuring aural harmonic thresholds (Grimm and Bess 1973). Agreement between TOM and Threshold of aural overload tests has been established by clack and Bess (1969), Grimm and Bess (1973) and Nelson and Bilger (1974).

Humes, Schwartz and Bess (1977) found the relationship between TOM and TTS. There was a negative correlation between TOM and TTS. They strongly recommend TOM test as a well suited test for susceptibility.

There are many studies (Borg, 1968; Brasher et al., 1969; Coles, 1969; Zakrisson and Borg, 1974; Zakrisson et al., 1975) reported regarding the influence of the acoustic reflex (AR) on temporary threshold shift (TTS). The relation between TTS and AR exists because when reflex occurs there will be attenuation of low frequency sounds reaching the cochlea. As TTS is related to the intensity of the signal reaching the cochlea, the reduction in the intensity of the signal brought about by reflex action can be expected to result in less TTS.

Ward (1967) and Harris (1967) report that the amount of TTS can be a predictor for susceptibility to noise induced hearing loss or permanent threshold shift. On the basis of TTS many tests have been developed to identify subjects who are susceptible to noise induced hearing loss or PTS.

Johnson et al (1967), Miyakita et al (1978) have found relationship between the acoustic reflex threshold and susceptibility to noise induced hearing loss or permanent threshold shift. Anne Zachariah (1980) has found that the subjects who show greater TTS exhibits low acoustic reflex threshold and that subjects who show less temporary threshold exhibit high reflex thresholds. It is also reported that the subjects with low acoustic reflex threshold (tender ears) show greater TTS and greater magnitude of contraction of the stapedius muscle through the acoustic reflex and that subjects who exhibit high reflex threshold (tough ears) show less TTS and less magnitude of contraction of stapedius muscle.

There are studies regarding the relationship between TOM and TTS (Humes et al, 1977) and ART and TTS (Zachariah 1980). As there is no study regarding the relationship between TOM values and ART the present study was undertaken to find out the relationship between TOM values and ART.

Statement of the problem

The present study was undertaken to find out whether there is any significant relationship between TOM values and ART values in normal hearing subjects.

Null Hypothesis

"There is no significant correlation between TOM and ART in normal hearing subjects".

Sub-Hypothesis

"There is no significant difference between ART and acoustic reflex magnitude".

Brief plan of the study

The study consisted of two parts.

Part I: TOM values for 1 KHz and 2 KHz were found out using Beltone 200-C Clinical Audiometer, calibrated to ANSI (1969).

30 normal hearing subjects were tested using f_2 (1000 Hz and 2000 H_Z) and f_1 (500 Hz and 1000 Hz) at 10 dB SL, 15 dB SL, and 20 dB SL. TOM values were determined by slope-extrapolation method.

Part II: Madsen Z0 73 Impedance Bridge was used to find the acoustic reflex thresholds and magnitudes of the reflex. Acoustic reflex thresholds at 500 Hz, 1 KHz and 2 KHz were determined. Magnitudes of the reflex for tones viz., 500 Hz, 1000 Hz and 2000 Hz at 10 dB and 20 dB above the acoustic reflex thresholds were measured.

Definitions of the terms

TOM (Threshold of Octave Masking):

"The threshold of octave masking is that masker sensation level (SL) in dB where the initial threshold shift in f_2 occurs as established by a slope extrapolation procedure" (Olsen and Berry 1979).

Masker (f_1): A steady-state pure tones of 500 Hz and 1000 Hz were considered as the maskers in this study.

Masker (f_2): A pulsed 1000 Hz and 2000 Hz tones were considered as the masker in this study.

Slope Extrapolation: Slope extrapolation is a graphical method of finding TOM. Masker values are plotted in X-axis and Maskee values are plotted on Y-axis. The line joining the points are extended to cut the X-axis. The apoint of interception is taken as TOM value (see graph No. 1).

Aural Harmonics: "The ear generates overtones called aural harmonics (AHs), when the mechanisms within the cochlea are forced to vibrate beyond their capacity for simple proportionate response" (Wever and Lawrence 1954).

Acoustic Reflex Threshold (ART): This is defined as the minimum intensity of the auditory stimulus in dB hearing level (ANSI, 1969) at which a just noticeable deflection in the Balance Meter needle of Madsen ZO 73 acoustic impedance bridge was observed.

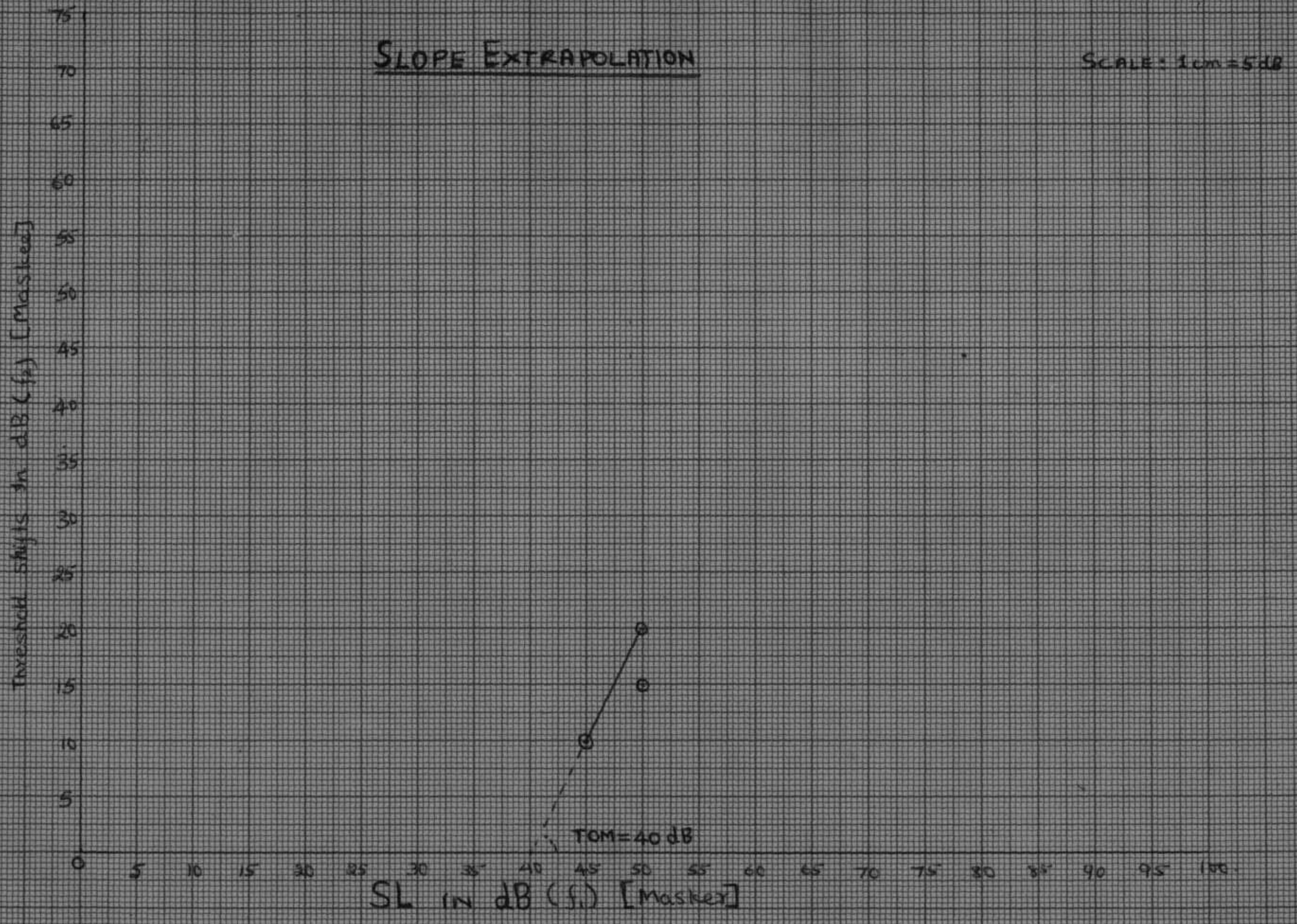
Noise induced hearing loss (NIHL): It is defined as the gradual decrease in sensitivity of hearing due to exposure to noise.

Individual susceptibility: It is the likelihood of a person to develop NIHL, if exposed to continuous excessive noise.

Permanent threshold shift (PTS): It is the post-stimulatory shift in auditory threshold that is permanent in nature.

Temporary Threshold Shift (TTS): This is defined as a behavioural decrease of auditory sensitivity expressed as a threshold elevation after exposure to continuous puretone or noise.

SLOPE EXTRAPOLATION



CHAPTER II

REVIEW OF LITERATURE

The present study is aimed at finding out the relationship between TOM values and ART values. Review of literature is discussed under the following headings:

1. The acoustic reflex
2. Acoustic reflex and TTS
3. Tests of susceptibility

1. The Acoustic Reflex

Puretones with an intensity level of 60 to 105 dB above the threshold of hearing produce impedance changes in both ears (Metz 1946, 1951, 1952, Jepsen 1951, 1955, Thomsen 1955 a, 1955 b, Evertsen et al 1958, Klockhoff 1961, Moller 1961, 1962; Terkildsen 1960 b, 1962; Dallos 1964, Djupesland et al 1966; Liden 1970, Jerger et al 1972, Hung & Dallos 1972; Borg 1972, Peterson & Liden 1972; Borg & Zakrissen 1974; Woodford et al 1975; Fria et al 1975; Yonovitz & Harries 1972, 1976 & Brask 1978).

Measurable inward movement of the tympanic membrane in connection with acoustic stimulation has been demonstrated and has been interpreted as the expression of an acoustically elicited tensor tympanic reflex (Mach & Kessel 1872, Fick

Cit Lucae 1874; Ostmann 1898; Kochler 1910, Mangold 1913, Nawata 1958, Weiss et al 1962; Hoist et al 1963 and Liden et al 1970). On the other hand Waar (1923), Luscher (1931) and Kobrak (1953) were unable to produce consistant visible reflex movements of the tympanic membrane by acoustic stimulation. Luscher's (1931) investigation shows that patients with facial nerve palsy and assumed stapedius muscle paralysis did not show the contraction of tensor tympanic muscle.

Observation of changes in the acoustic impedance of the ear in which the stapedius muscle is paralysed has been used to determine whether acoustic stimuli of high intensity might produce reflex contraction of the tenser tympani muscle. Jepsen (1955) studied unilateral stapedus muscle paralyzed cases and said that there was no contraction of tensor tympani on acoustic stimulation.

Electro-myographic studies (Solomon & Starr 1963; Djupesland 1965 and 1967) and Extra-tympanic monometry (Brask 1978) showed that acoustic stimuli usually lead bo reflex contraction of the stapedius muscle alone, while tensor tympani muscle contracts only when the sound is of much intensity or presented in such a way that it gives rise to a startle or a defensive reaction.

Pathways of the acoustic stapedius reflex

The neural network involved in the reflex action of the stapedius muscle during acoustic stimulation is not known in detail. However experimental studies in animals have shown that the pathways are located in the lower part of the brainstem (Hammerschlag 1899, 1902, Cajal 1909, Lorento 1933; Tsukamoto 1934; Rasmussen 1946 and Borg 1973).

Pathway of the Ipsilateral Stapedius Reflex

During acoustic stimulation electric impulses from the sensory cells in the cochlea are transmitted through the primary acoustic neuron to the ventral cochlear nucleus. The primary acoustic neurons constitute the acoustic nerve. The trophic centre for the second acoustic neuron is in the ventral cochlear nucleus. The majority of axons from the ventral cochlear nucleus pass through the trapezoid body to the medial part of the facial motor nucleus and from this nucleus the electric impulses are transmitted through the facial nerve to the ipsilateral stapedius muscle. In addition, some nerve fibers pass from the ventral cochlear nucleus through the trapezoid body to the ipsilateral medial superior olive. From this nucleus the electrical impulses are transmitted via a third neuron to the medial part of the ipsilateral facial motor nucleus. The ipsilateral stapedius reflex are thus consists of mainly three but to some extent four neurons.

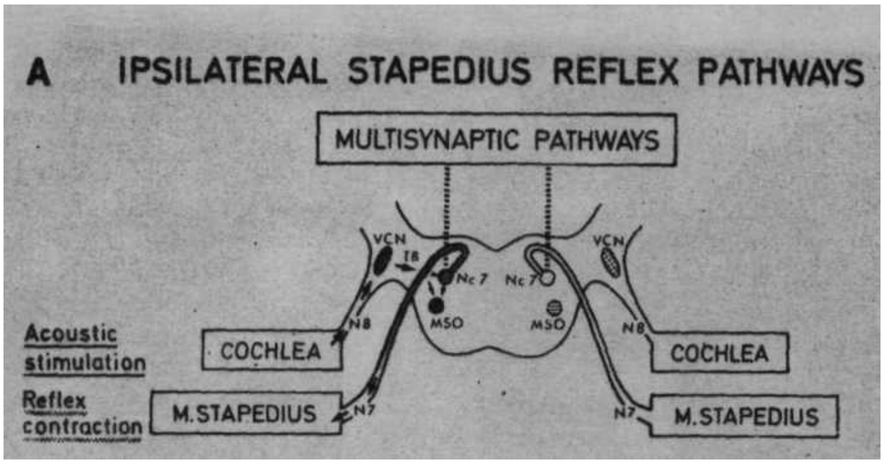


Fig.A: Schematic diagram over ipsi lateral stapedius reflex pathways based on experimental work in rabbits (Borg, 1973). N8, acoustic nerve, VCN, ventral cochlear nucleus TB, trapezoid body; MSO, medial superior olive, N7, facial nerve.

Pathway of the contra lateral stapedius reflex

The electrical impulses from the sensory cells in the cochlea pass via the primary acoustic neuron to the ventral cochlear nucleus the electric impulses are transmitted through a second neuron to the region of the Medial Superior Olive. A third neuron connects the medial superior olive to the medial part of the contra lateral facial motor nucleus. A fourth neuron transmits the electric impulses from the facial motor nucleus to the contra lateral stapedius muscle. Thus the ipsilateral stapedius reflex contains 3 and partly 4 neurons; the contra lateral reflex contains 4 neurons.

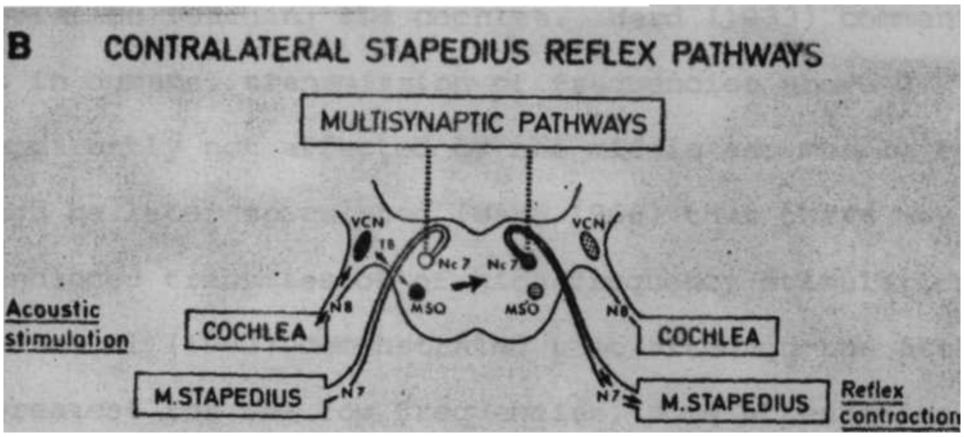


Fig.B: Schematic diagram over contralateral stapedius reflex based on experimental work in rabbits (Borg, 1973). N8, acoustic nerve; VCN, ventral cochlear nucleus, TB, trapezoid body; MSO, medial superior olive; N7, facial nerve

The acoustic stapedius reflex threshold is defined as the intensity in dB hearing level at which the reflex response can first be detected.

2. Acoustic Reflex and TTS

Luscher (1929) was the first to observe contraction of the stapedius muscle in man. He found that the upper and lower limits for the elicitation of the stapedius reflex were 14000 and 90 CPS respectively and demonstrated that the threshold of the reflex was lowest at about 2000 CPS.

Middle ear muscles are considered as protective in nature. They intense the impedance of the middle ear by contraction on stimulation, thus reducing the potentially harmful intense of its protection in situations where man is exposed to impulsive noises.

In a series of experiments concerned with TTS, Ward (1962) found that, a high frequency puretone and a high frequency band of noise of equal SPL produce equal amounts of TTS, a low frequency puretone produces more TTS than a low frequency band of noise. Ward hypothesized that the acoustic reflex was responsible for the difference between the TTS produced by the low frequency puretone and the low frequency noise.

Fletcher and King (1963) examined the susceptibility of stapedectomized and normal persons to noise induced TTS. The stapedectomized group did not exhibit greater TTS after noise exposure than did the normal group.

Hecker and Kryter (1965) found that subjects with a high exposure hearing level are less susceptible to TTS than subjects with normal hearing; and a strong reflex is associated with high rather than low pre-exposure hearing level.

It is known that the stapedius reflex attenuates the transmission through the middle ear of low frequency sounds by upto 20 dB (Borg, 1968; Brasher et al, 1969; Coles, 1969; Zakrisson and Borg, 1974; Zakrisson et al 1975; Zakrisson, 1975 etc.).

stimulation reaching the cochlea. Ward (1933) commented that in humans, transmission of frequencies above 2 K C/s is apparently not affected by the middle ear muscle reflex though he later speculated (Ward 1966) that there may possibly be enhanced transmission of high frequency stimulation. Reger et al (1963) demonstrated that although the attenuation is greatest for the low frequencies, some attenuation is provided for all frequencies, from 125-8000 Hz. This has important implication for reduction of TTS.

Terkildson (1960) exposed normal individuals and workers continuously to traumatic noise levels and examined them with respect to the threshold and the period of latency of the intra-aural muscle reflexes. Results were identical. The sensitivity of the reflex pattern to artificial pressures on the ear drum was investigated in all persons. In about 1/3 of them such a sensitivity was present, and two separate types could be established which were found to be closely correlated to the type of movement of the ear drum induced during such reflexes. The investigation seems to confirm the functional identity of the middle ear muscles.

Fletcher (1962) indicated that the reflex contraction of the muscles of the middle ear can provide limited protection of the ear from damage due to noise exposure. It may be feasible to artificially induce the reflex in order to take advantage of its protection in situations where man is exposed to impulsive noises.

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Borg (1968) investigated the influence on sound transmission through the middle ear as exerted by the acoustic stapedius muscle reflex in subjects with unilateral peripheral facial paralysis of short duration. Reflex activity in both ears were recorded simultaneously as a change in the acoustic impedance at 800 CPS. Bursts of puretones between 300 and 3000 CPS were used to elicit this reflex. Attenuation was found to be greater at frequencies below the resonant frequency of the middle ear (about 1000 CPS) than above. A puretone of 500 CPS (20 dB above reflex threshold), was attenuated 12-15 dB whereas a tone of 1450 CPS (16 dB above threshold) was attenuated 0-6 dB. After the recovery of the stapedius function, the excitation in the cochlea reached a maximal level (at 500 CPS, 115 dB SPL) which was lower than during palsy. The decrease in maximal excitation was interpreted as showing that a "perfect regularity" effect is exerted by the stapedius reflex in governing sound transmission through the middle ear when the reflex is near its maximal degree of activity.

J.G. Walkar (1972) reported TTS measurements on 11 subjects resulting from exposure to steady state noise, impulse noise and a combination of both. When a hazardous level of the steady-state noise was combined with various levels of Impulse noises there was a significant reduction in the measurement of TTS at 4 and 6 KHz.

Ward (1973) made it clear that the acoustic reflex plays an important role in limiting TTS at low frequencies.

Zakrisson and Borg (1974) found that when subject's with unilateral Bell's palsy and stapedius paralysis in one ear and normal stapedius reflex in the other were exposed to narrow band noise with the centre frequencies 0.5 and 2.0 KHz, there was significantly greater TTS in the affected ear than in the unaffected ear after the 0.5 KHz noise at and above 110 dB SPL. After the 2.0 KHz noise, there was no such difference. They concluded that the stapedius reflex in man may protect the ear against auditory fatigue, probably against permanent injury within the low frequency region.

Zakrisson et al (1975) concluded from their findings that the stapedius has a protective function against low frequency sound exposure and suggested that this protection might be extended to higher frequencies only when high frequency noise also contains low frequency components.

There has, however, been some questions concerning the effects of middle ear muscle contraction on transmission of higher frequencies. Enhancement of transmission for these frequencies has sometimes been found in animals, but Ward (1963) commented that in humans transmission of frequencies above 2 KHz is apparently not affected by the middle ear muscle reflex, though he later speculated (Ward, 1966) that there may possibly be enhanced transmission of high frequency stimulation. He based this speculation on TTS data which indicated that female subjects showed less TTS than males when exposed to a low-frequency band of noise, but when a high frequency noise was used, females displayed greater TTS; he thus proposed that females might have a more "efficient" middle ear muscle system than males. It must be noted that Shallop (1967) using impedance change as a dependent variable, did not observe significant differences between males and females in this respect.

A more direct assessment of the relationship between the acoustic reflex and TTS has been performed by measuring TTS in subjects with the absence of an acoustic reflex.

Mills and Lilly (1971) hypothesized that if the difference in TTS produced by noise and puretones was attributable to the effects of the acoustic reflex, then subjects without a reflex response should display an equivalent amount of TTS from either signal. They reported that both puretone and noise reflex activating signals produced nearly equivalent TTS in stapedectomized patients. For normal subjects, however, a 10 dB difference in TTS was observed between exposure conditions.

Data obtained from others (Ward, 1962 a; 1962 b; 1962 c; Karlvich et al, 1972, Ahaus and Ward, 1975) lend support to the supposition that the maintenance of acoustic reflex contraction is a contributing factor in the acquisition of TTS. Studies that have examined this relationship, however, have been restricted primarily to observing the influence of reflex activation on TTS by measuring the resultant TTS.

Karlovich et al (1977) speculate that acoustic reflex dynamics, particularly reflex relaxation, reflex adaptation and reflex temporal summation, probably are involved in producing the differential effect of contralateral noise on TTS.

Wiley and Karlovich (1978) concluded that the relations between TTS and acoustic-reflex dynamics are, however, complex and TTS reductions associated with acoustic-reflex activity will vary dependent on the spectral, intensive and temporal characteristick of the reflex-activating signals.

Miyakita et al (1978) measured the magnitude, threshold and latency of the acoustic reflex and the acoustic impedance of the middle ear with an electro-acoustic impedance bridge. Each of the results obtained shows large individual differences between 100 subjects. The reflex latency decreases with increasing stimulus level and a positive correlation was found between the reflex latency and the reflex threshold. From these results it is conceivable that a person having a high reflex threshold might be susceptible to sound with short rise time and short duration such as an impulsive noise because of its prolonged latency and small magnitude of the acoustic reflex. The authors concluded that the acoustic reflex threshold can be used as an indicator showing individual susceptibility to impulsive noise. The middle ear muscles contract more vigorously for binaural exposure than for monaural; thus producing more reduction in the transmission of the effective intensity at lower frequency stimulus components.

Shivashankar (1975) studied to find whether there is any significant difference in TTS between monaural and binaural exposures to high frequency tones at equal intensity levels for equal duration of time. His results indicated no significant difference in TTS between monaural and binaural exposures to high frequency tones, at equal intensity Levels for equal duration of time except for 3 KHz tone.

Hicker and Kryter (1965) found that subjects with a high exposure hearing level are less susceptible to TTS than subjects with normal hearing, and a strong reflex is associated with high rather than low pre-exposure hearing level.

Anne Z (1980) studied the relationship between the TTS and ART in a normal hearing population with regard to subjects susceptibility to NIHL. Her results indicate that subjects who show greater TTS have lower acoustic reflex thresholds and subjects who show less TTS exhibit higher acoustic reflex thresholds.

3. Tests of susceptibility

Meaning of susceptibility:

There are marked individual variations in the effects of noise on hearing and it has been generally called as individual differences in the susceptibility of ears to damage from exposure to noise. Investigators have long attempted to develop a measure which might delineate those persons most susceptible to hearing loss from high noise levels.

Ears cannot be sharply classified either as resistant or susceptible. Not only there are differences in the magnitude of TTS among individuals but there are also differences for a particular person.

Many references have been made in the literature to "tough ears" and "tender ears" referring to differences in degree of susceptibility. Because of the recognition of individual differences in susceptibility, considerable attention has been focussed on the problem of identifying those individuals who, when placed in a noisy environment, would be most susceptible to noise-induced hearing loss. The assumption has been that if such individuals could be identified, they could be assigned to less noisy environments, or at least could be provided with the best possible ear protection when they are working in noise.

Though much has been spoken about susceptibility, there is no precise definition putforth, "Susceptibility has just been described as a characteristic that determines relative resistance of that ear to both temporary and permanent change

a) from long or short exposures;
b) at high or low intensities;
c) to high or low frequency stimulation;
d) from tones, noises or impulses of any shape or spectrum; and
e) that is relatively invariant for an individual throughout his life span (Ward 1963).

Tests for detecting susceptibility of persons to noise-induced hearing loss

According to Newby, 1972, these tests can be grouped mainly into three groups: (1) tests based on TTS measures; and (2) tests based on aural harmonic distortion measures. The third group may include various other proposed tests with different rationales.

1. Tests based on TTS measures

Temkin (1933) suggested that the measurement of temporary change in hearing sensitivity following a brief and moderately intense acoustic over-stimulation provide a simple and valid estimate of eventual PTS incurred from more severe exposures to loud sound.

The method involves presenting a subject with a fatiguing stimulus that may be either a puretone or wideband noise. After a prescribed period of exposure to the fatiguing stimulus, the degree of shift of subjects threshold at some frequency (usually around 4 KHz) is measured immediately and after sometime following the cessation of the fatiguing stimulus.

Predictions of susceptibility are then made on the basis either the absolute amount of threshold shift observed, or the time required for subjects threshold at criterion (or test) frequency to return to normal, i.e., its pre-stimulation level. The individual who incurs the greatest amount of threshold to return to "normal" level, is then presumed to be the most susceptible to permanent irreversible hearing impairment if placed in a noisy environment for his working life.

The table shows some of such proposed tests for susceptibility:

PROPOSED SUSCEPTIBILITY TESTS INVOLVING TTS

Nos.	Report	Stimulus (KHz)	Level (dB)	Duration (Min.)	Recovery Time(Min.])	Test frequency(KHz
1	2	3	4	5	6	7
1	Peyser (1940)	0.25	80 HL	0.5	0.5	0.25
2	Wilson (1943)	0.25	80 HL	5	1	Octave of 0.25

1	2	3	4	5	6	7
3	Peyser (1943)	1	100 HL	3	0.25	1
4	Theilgaard (1949)	0.5;1; 2 & 4	100 HL	5	5	Half octave above Exp.
5	Theilgaard (1951)	100	100 HL	5	5	1.5
6	Tanner (1955)	1	100 HL	5	Immediately	1
7	Theilgaard, according to Greisen	1.5	100 HL	5	5	2
8	Wilsen (1944)	2	80 HL	8	1	Octave of 0.25
9	Harris (1954)	2	97 SPL	5	Parameter	4
10	Palva (1958)	2	30 SL	3	2	2
11	Van Dishock(1956)	2.5	100 HL	3	0.25	All(Sweep)
12	Greisen (1951)	3	80 & 90 HL	5	5	4
13	Jerger & Carhart (1956)	3	105 SPL	1	Parameter	4
14	Jerger & Carhart (1956)	3	100 SPL	1	Parameter	4.5
15	Wheeler (1950)	Noise	105 SPL	30	Parameter	2,4 & 6
16	Gallegher and Goodwind (1952)	Noise	115 HL	10	Immediately	2,4 & 6
17	Ruedi (1954)	Noise	Parameter	2	2	4
18	Falconnet et al (1955)	Noise	100 SPL	3	Parameter	3
19	Christiansen (1956)	Noise	105 HL	3	0.5, 15	4

1954) are forced to vibrate beyond their capacity for simple proportionate response. At the same time the fundamental signal also causes the ear to lose sensitivity for the higher frequencies. This spread of masking is presumably the reason aural harmonics are not heard as separate perceptual entities at moderate signal intensities even though their presence is detectable using special psychophysical procedure.

The most common of these procedures is the method of best-beat, based upon a suggestion by Wegel and Lane (1924). With this method, clinical investigators have measured the lowest intensity (in dB SL) of the puretone fundamental (f_1) required to mask the second aural harmonic (fAH) just detectable. This threshold of distortion has been related to inner ear pathology (Lawrence and Yantis 1956) bo the estimation of cochlear reserve in otosclerotic ears (Yantis and Magielski 1958) to the intelligibility of speech in patients with sensori-neural impairments (Yantis et al, 1966) and possibly even to the determination of susceptibility to acoustic trauma (Lawrence and Blanchard 1954, Capano, 1962.) In spite of its potential significance in hearing conservation and the diagnostic evaluation of hearing disorders, otologists and audiologists do not utilize the best-beat method as a regular clinical tool. The neglect may be due to certain practical as well as theoretical difficulties. One aspect of the later is the problem of masking at the octave interval and its complicating effect upon resultant measurements.

Clack (1967) using a different procedure has indicated that the amplitude of aural harmonic (FA_H) is below the perceptual threshold when the ear's distortion begins and grows at a rate equal to or less than the masked threshold for intensities below 70 dB SL. This suggests that the aural harmonic levels, by the best-beat method, might be essentially equivalent to the masked threshold measured in the immediate frequency vicinity of the aural harmonic (FA_H).

To test this hypothesis, two separate experiments were carried out. In the first, the threshold of masking and the aural harmonic threshold levels were obtained from the sample of normal ears. The second experiment compares the masking thresholds from a group of sensorineural impaired listeners to the aural harmonic thresholds obtained by previous clinical investigators using the best-beat method.

After conducting the experiment Clack and Bess (1969) conclude as follows:

In the first experiment, the threshold of masking (TOM) was shown to be equivalent to the aural harmonic threshold level in normal ears. The second experiment reveals that even when the ear is impaired by sensorineural disease processes, the TOM is affected in the same way as the aural harmonics threshold. It appears that the results of both experiments provide support for the contention that the best-beat method and the tone-on-tone masking procedure measure essentially the same phenomenon.

Grimm and Bess (1973) suggested threshold of octave masking test (TOM) as a substitute for measuring aural harmonic thresholds. The results have shown that the TOM test will differentiate subjects with cochlear involvement from normal hearing subjects at all three Mr (Masker) frequencies (500 Hz, 1000 Hz and 2000 Hz). In addition, the test has demonstrated excellent test-retest reliability.

The following table reads harmonic thresholds and TOM values.

Table

Mean aural harmonic threshold reported by three previous investigators and mean threshold of octave masking value obtained by Grimm and Bess (1973)

		500 Hz	1000 Hz	2000 Hz
Harmonic Thresholds				
Lawrence and Yantis (1956)	Normal		52 dB	57 dB
	SN		17 dB	23 dB
Yantis, Millin and Shapiro (1966)	Normal	47 dB	53 dB	50 dB
	SN	28 dB	30 dB	28 dB

Contd.

		500 Hz	1000 Hz	2000 Hz
Ophein and Flottorp (1955)	Normal	42 dB		-
	SN	10 dB	-	
TOM values				
Grimm and Bess (1973)	Normal	44 dB	53 dB	56 dB
	SN	16 dB	28 dB	16 dB

Olsen and Berry (1979) administered TOM test to normal hearing and sensori-neural impaired listeners at four test frequencies: 500 Hz; 1000 Hz; 2000 Hz; 4000 Hz. The TOM value was found to be inversely proportional to the degree of hearing loss at the masker frequency. Results indicate that the TOM is capable of distinguishing subjects with sensorineural involvement from those with normal hearing. Examination of the slope of octave masking revealed that once the influence of hearing loss is overcome at higher intensities, the sensori-neural ear performs essentially the same as the normal ear in a tone-on-tone masking test.

Humes (1978) has reviewed the application of the aural overload test to temporary threshold shift, susceptibility to noise induced hearing loss, speech discrimination, site of lesion testing and auditory recruitment. It is rather tempting to infer that since aural overload and TOM values occur at approximately equivalent sensation levels, the tests have mutual-applicability to the areas discussed by Humes.

3. Other Tests

Johnnsen et al (1967) suggested that the acoustic reflex can be used to evaluate an individual's ear susceptibility. Furthermore, the subjects with poor acoustic reflexes showed extensive temporary loss of hearing after exposure to noise. They concluded that apparently some people can keep their good hearing longer than others because they have a good middle ear reflex.

In search of alternative and/or additions to the conventional TTS procedure Humes and Bess (1978) designed a study to examine individual differences among various psychophysical measures that have been suggested previously as potential predictions of TTS and auditory fatigue.

They adopted the following tests:

1. Aural overload test (Lawrence and Blanchard 1954)

2. Loudness discomfort level (LDL), Hood (1968) had suggested that LDL may be related to the amount of post stimulatory fatigue, an individual incurs.

LDL was measured in accordance with Mergon et al (1974) at frequencies 0.5, 1, 2 and 4 KHz. Then TTS at 0.75 and 3 KHz recorded from 0 to 3 min. Post exposure following 3 min. exposures to 0.5 and 2 KHz puretones at 100 dB SPL.

3. Critical Intensity (CI) procedure was conceived originally by Ruedi (1954) and later used by Ward (1965-1968). In the traditional CI paradigms the subject was exposed to a fatiguing stimulus which increased successively in level until a criterion amount of TTS was observed. In the former investigations by Ruedi (1954) and Ward (1965-68), the only time intervening between successive exposures was that required for threshold determination. That is no recovery period was employed.

A modified procedure was adopted by Humes and Bess. Their procedure was to determine the CI at which maximum TTS shifts upwards in frequency from the exposure frequency to one half octave above the exposure frequency and they allowed recovery periods between exposure levels.

To assess susceptibility to TTS they used Broad Band noise and puretones of high and low frequencies.

The findings of their study suggest that the aural overload test and the CI procedure possess sufficient sensitivity to underlying individual differences in TTS.

Mustain and Schoeny (1980) conducted a study on 56 normal hearing subjects to explore psychoacoustic correlates of susceptibility to auditory fatigue.

The following auditory fatigue tests were given:

1. The high frequency test consisted of a 3 minutes exposure to a 110 dB SPL of 2000 Hz puretone with TTS measured at 4 KHz.

2. The low frequency test consisted of a 3 minutes exposure to a 115 dB SPL of 500 Hz puretone and TTS measured at 1 KHz.

Amount of TTS and TTS recovery time were compared with performance on a test battery consisting of:

a) masking level difference test
b) Brief tone audiometry
c) Speech discrimination in noise
and
d) Threshold of octave masking test

The results of this study suggest a relationship between susceptibility to auditory fatigue and TOM. This relationship is not surprising in view of the demonstrated correlation between TOM test results and threshold of aural over load and in view of the relationship between aural over load and TTS which has been demonstrated physiologically and psychoacoustically.

Humes et al reported a -ve correlation between TOM test results for a 4 KHz masker and amount of TTS and 4 KHz following a 5 min. exposure to BBN at 110 dB SPL.

Their study also suggests a relationship between amount of TTS and BTS. The implication here is that persons showing larger amount of TTS tend to have flattened threshold duration functions for selected frequencies.

Speech discrimination and MLD's failed to show any consistent relationship to any of the high or low frequency test variables.

Need and characteristics of a good test of susceptibility for NIHL:

As the noise and NIHL have been increasing in their magnitude day by day, considerable attention is needed on the control of noise and prevention of NIHL. One of the ways, is to protect the susceptible ears/persons from the damage or exposure to noise, and for this an adequate test, to identify the susceptibility is highly needed. Different tests have been proposed so far, and a good test should have the following characteristics (Summerfield et al 1958):

1. The equipment to be employed should be "simple" and "rugged";

2. it must be sufficiently uncomplicated so that subjects and relatively naive testers can perform the test without

difficulty;

3. the test must not consume more time for its administration;

4. it must be both valid and reliable; and

5. the test results must be immediately classifiable into degree of susceptibility that are meaningful to industrial personnel who have to assign employees to specific tasks.

Distribution of susceptibility

It would be convenient, if individuals were grouped into two categories - those with ears particularly susceptible to TTS and those minimally susceptible. Further, if this susceptibility reflected accurately the response of the ear to years of daily exposure to occupational noise, great benefit would accrue in the ability to identify those with ears liable to damage by noise. Unfortunately, first of these two possibilities does not appear to be true, and the second while apparently valid for groups of persons is not yet known to be true for individuals (Burus 1968).

Ward (1965) reviewed the concept of susceptibility to hearing loss following continuous exposure and concluded that susceptibility was normally distributed in a population. Summerfield et al (1958) suggested that if susceptibility to

NIHL ia distributed normally throughout the population then the number of highly susceptible ears will be only a very small proportion of the population. And if this is in fact the case, than research efforts might better be spent in learning how to achieve better protection of the hearing of the much larger number of workers who are moderately susceptible to NIHL.

Bishnoi (1975) conducted a study which aimed to study the distributional pattern of individual susceptibility to noise induced hearing loss in Indian population. He used wilson's test to determine the degree of susceptibillty. His major findings were that:

1. the temporary threshold shift scores are distributed normally over a range of 0 to 30 dB.

2. TTS_2 of 10 dB is a better index of the degree of susceptibility to TTS.

3. No differences were noticed between (a) males and females (b) normal hearing and impaired hearing subjects sad (c) no ear difference; and

4. there exists a negative correlation between TTS and resting thresholds

The above review of literature clearly reveals that there is not a single study carried out to ascertain whether there is any correlation between TOM and ART in the same subjects although both the psychoacoustic measures are linked to susceptibility to noise induced hearing loss.

The present study was undertaken to study whether there is any significant correlation between ART and TOM values in the same normal subjects.

CHAPTER III

METHODOLOGY

1. Subjects: Thirty normal hearing (20 dB HL ANSI 1969) subjects in the age range of 16-26 years (males 10 and females 20) were selected for this study.

Only one ear of each subject was tested. Selection of the ear (right or left) was done randomly.

The subjects were selected on the following criteria:

1. They should not have had any history of chronic ear discharge, tinnitus, giddiness, earache or any other otologic complaints.

2. Hearing sensitivity should be within normal limits, i.e., within 20 dB HL (ANSI 1969) in the frequencies from 250 Hz to 8 KHz.

II. Equipment: The following equipment were used.

(a) Beltone 200-C dual channel clinical audiometer
(b) Madsen ZO 73 impedance bridge

Brief description of the equipment:

(a) Beltone 2OO-C audiometer: Using channel one, it was passible to present the following tones:

125 Hz, 250 Hz, 500 Hz, 756 Hz, 1000 Hz, 1500 Hz, 2000 Hz, 3000 Hz, 4000 Hz, 6000 Hz and 8000 Hz.

Using channel two it was possible to present the following tones:

500 Hz, 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz and 6000 Hz.

Frequency accuracy of the audiometer was ± 3% and SPL accuracy of ± 3 dB at all frequencies. TDH-49 earphones with MX–41/AR cushions were used. The audiometer was calibrated in accordance with the specifications given by ANSI 1969. Calibration was exercised using an artificial ear B&K4152, a condenser microphone B&K 4132 and a sound level meter B&K 2203 with an octave filter set B&K 1613. The output values of the earphones at 70 dB HTL are given in the appendix.

Madsen ZO 73 impedance bridge

Monometer: is a part of the air pressure system and shows the actual air pressure in the ear canal, it covers the range from +300 m/m to -600 m/m of water.

Compliance scale: The compliance can be read directly from the scale in equivalent cc or in acoustics ohms.

Balance meter: When the meter is in balance, SPL in the ear canal is 85 dB. Deflection to the right indicates lower compliance and deflection to the left, higher compliance.

Sensitivity: In position 'O' the balance meter and the 220 Hz probe tone are discontinued. In position 1-4 the probe tone is on, the sensitivity increases through position 1,2,3 and 4.

Stimulus: Meter deflection shows when stimulus is on.

Hearing level: Regulates stimulus intensity in 5 dB steps from 40 dB to 125 dB.

Frequency: 250 Hz, 500 Hz, 1 KHz, 2 KHz and 4 KHz tones can be presented.

This bridge was calibrated using the standard procedures as mentioned in the manual of the impedance bridge.

III. Test environment: The experiment was carried out in sound treated rooms at the Audiology Department, All India Institute of Speech and Hearing, Mysore.

The ambient noise levels were below the proposed maximum allowable noise levels (Hirschorn, M. 1971) for audiometer calibrated to ANSI 1969.

IV. Procedure: Part No. I

To find out TOM values the following procedure was used.

Puretone AC thresholds for all subjects were determined by using Hughson-Weslake procedure.

The subjects were instructed for TOM test as follows:

"first you hear a pulse tone in quiet. Whenever you hear the pulsed tone, you are requested to indicate by flikering your finger. Later you will be hearing two tones or wobbulating tones in the same ear. When you hear two tones or wobbulating tones, you are required to indicate by showing two fingers. The moment you fail to hear the wobbulation, i.e., the moment you hear the wobbulation changing into a continuous tone, indicate it by raising only one finger".

Subjects were given some practice trials so as to make them familiar with pulsed tone and wobbulation before collecting the actual data.

Threshold for pulsed 1000 Hz (f_2) tone in quiet was obtained. Later 500 Hz (f_1) tone was introduced into the same ear at O dB HL. Intensity of f_1 (500 Hz) was increased in 5 dB steps, until the pulsed tone was masked. Later, intensities of f_1 (500 Hz) tone required to mask the pulsed tone presented at 10 dB SL, 15 dB SL and 20 dB SL were determined and corresponding shifts were noted.

Similarly threshold for pulsed 2000 Hz (f_2) in quiet was determined and a continuous 1000 Hz (f_1) tone was introduced to the same ear and corresponding shifts were noted.

The threshold of octave masking (TOM) was calculated by plotting the threshold shifts in f_2 (1000 Hz and 2000 Hz) as a function of intensity level of f_1 (500 Hz and 1000 Hz) as shown in the graph (See the graph next page). A line of best fit was drawn through the data points representing the 10 dB, 15 dB and 20 dB threshold shifts. The function was extended to intercept the f_1 intensity level axis. The point of intercept is considered the threshold of octave masking (TOM).

Thus TOM values for 1 KHz and 2 KHz were determined. Slope extrapolation procedure was used.

Part II: (a) To measure ART the following procedure was used.

(i) The impedance bridge was checked for calibration

(ii) The earphone was placed on the ear for which TOM values were found out, e.g., if a subject's 'Rt' ear was tested for TOM test, then the earphone of the impedance bridge was placed on the 'Rt' ear of the subject during ART measurement.

(iii) Probe tip was inserted to the opposite ear with a suitable ear tip and air-tight sealing was obtained.

SLOPE EXTRAPOLATION

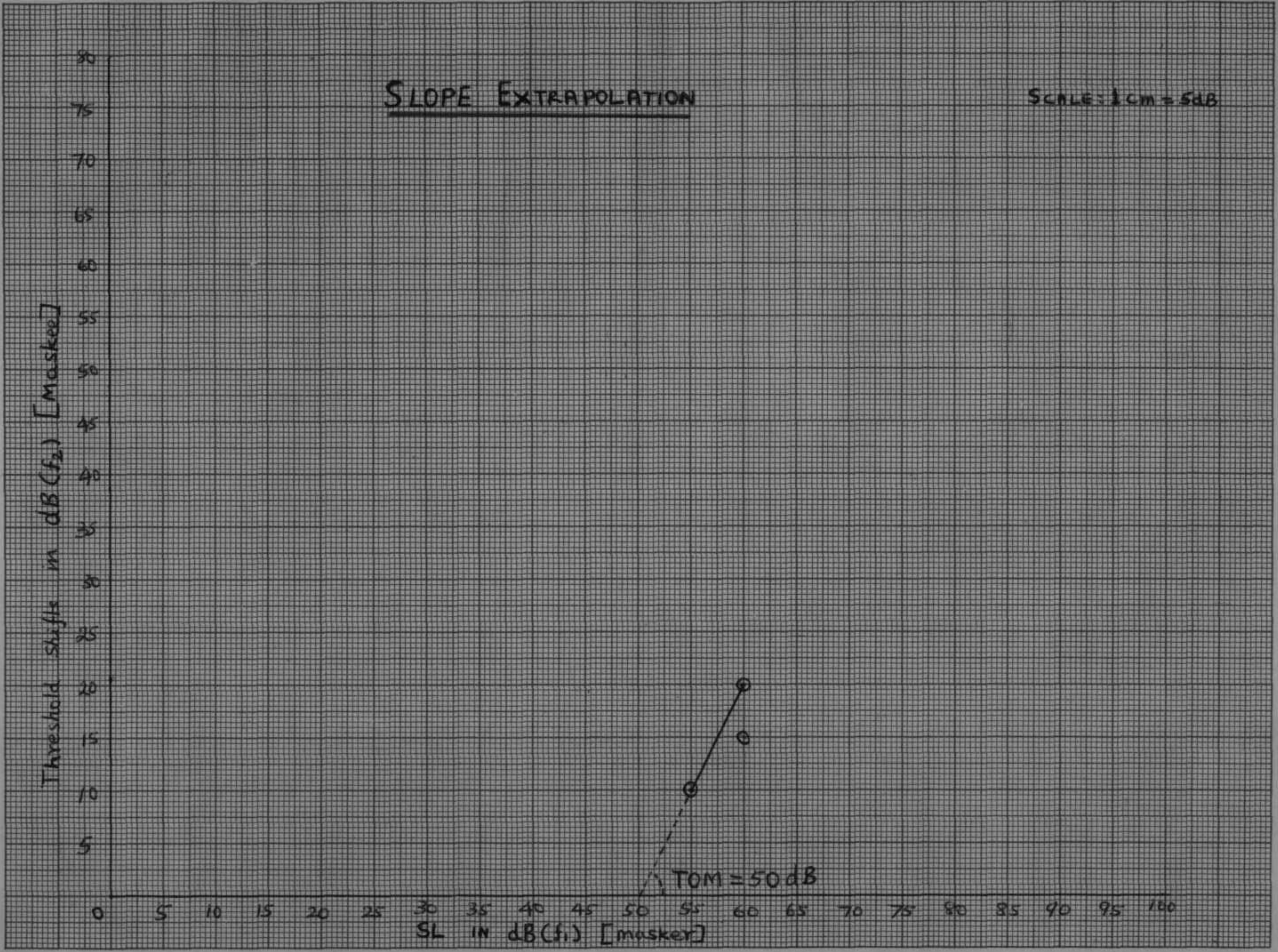

Table 2 shows Mean, Standard Deviation and Range of TOM values

Masker Frequency	Mean (dB)	S.D.	Range (dB)
1 KHz	53.73	5.80	37-64
2 KHz	57.53	3.64	50-64

Table 3 shows Mean, Standard Deviation and Range of ART values

Frequency	Mean (dB)	S.D.	Range (dB)
500 Hz	83.66	3.78	80-95
1 KHz	84.83	5.25	80-105
2 KHz	92.50	6.02	80-105

Table 4 shows correlation between TOM and ART values

	ART 1 KHz	ART 2 KHz
TOM 1 KHz	0.65	-0.25
TOM 2 KHz	0.07	0.88

r: 0.361 and 0.463 are required for significance at .05 and .01 level (df = 28).

SLOPE EXTRAPOLATION

(iv) The middle ear pressure was determined by varying the air pressure from -200 to +200 mm of water. The ear canal pressure corresponding to the peak of the tympanogram was noted down as the middle ear pressure, i.e., the pressure at which compliance was maximum.

(v) Frequency knob was set to 500 Hz and intensity knob was set at a confortable level and the presentation button was gently pressed. Minimum intensity of the stimulus which produced noticeable deflection of the meter needle was noted and this level was recorded as ART.

(vi) Similarly the acoustic reflex thresholds at 1000 Hz and 2000 Hz were determined.

(b) To measure the magnitude of reflex:

Steps from (i) to (iv) of the experiment II were carried out.

Later, the frequency knob was set at 500 Hz and the intensity knob was adjusted to 10 dB above the ART value. The compliance scale was manipulated in such a way the balance meter read "1" (lower scale of the balance meter). Then the presentation button was gently pressed - corresponding deflection in the balance meter was recorded.

Using the above procedure, magnitude of reflex was determined at 20 dB above ART for 500 Hz tone.

Similarly for 1 KHz and 2 KHz tones at 10 dB and 20 dB above ART, magnitude of the reflex were determined.

All the subjects were tested in the above manner.

V. Intra-subject Reliability

A sample of ten subjects, randomly selected from the total group, was tested for intra-subject reliability. Each subject from this group was retested using the same procedures.

Test-retest reliability was found using the product moment coefficient of correlation.

The data were analyzed using appropriate statistical methods.

CHAPTER IV

RESULTS AND DISCUSSION

The results of the present study are discussed under the following headings:

1. The relationship between TOM and ART

2. Comparison of the results of TOM values with the results of the previous studies

3. The relationship between ART and magnitude of reflex.

1. The relationship between TOM and ART

Table 1 shows TOM, ART and magnitude of reflex values at different frequencies for 30 normal subjects with mean and standard deviation.

Table 1: TOM, ART and Magnitude of Reflex values at different frequencies

Sub-jects	TOM		ART			Magnitude of Reflex at 10 dB SL			Magnitude of Reflex at 20 dB SL		
	1 KHz	2 KHz	500Hz	1 KHz	2 KHz	500 Hz	1 KHz	2 KHz	500 Hz	1 KHz	2 KHz
1	60	60	90	90	95	5	5	5.5	6.5	6.5	5.5
2	58	55	80	80	90	5	4	4	6	5.5	5.5
3	60	50	90	90	85	6	4	7.5	9	5	8.5
4	61	60	85	90	95	4	6	6	6	8	7.5
5	55	60	80	80	95	6	7	4.5	8	8	5
6	58	62	85	90	95	3.5	4	6	4.5	6	7.5
7	56	53	80	80	85	3.5	7	8	7.5	8.5	10
8	50	50	80	80	85	4	4.5	7	6	6	8.5
9	50	56	85	85	90	5	6	8	8	8	8.5
10	60	56	90	90	90	6	6	3.5	9	8	4
11	58	51	85	85	80	3	3.5	5	4	4	5.5
12	S3	60	80	80	85	4.5	4.5	5	5.5	5.5	
13	52	58	85	85	90	5	5	8	6	5.5	9
14	52	60	80	85	100	8	7.5	4.5	10	9.5	6.5
15	58	55	85	90	95	4	5	6	6	6	8
16	56	58	85	80	95	4.5	6	7.5	7	9	9
17	64	60	95	105	95	2.5	2.5	2.5	2.5	3	2.5
18	48	54	80	80	90	3	4.5	3.5	4	6	4.5
19	53	60	80	85	95	3.5	4	4	5.5	5.5	4.5
20	53	58	85	85	90	4	4	3	4.5	4.5	5
21	50	63	80	80	105	4.5	4	5.5	6.5	5.5	6.5
22	39	62	80	80	105	3.5	4	2.5	5.5	6	7.5
23	52	64	85	85	100	3.5	3.5	6.5	6.5	8.5	8
24	47	58	85	80	90	5.5	6	3	7.5	9.5	4.5
25	55	56	80	85	90	2.5	3	5.5	3	4	6.5
26	37	60	85	80	100	5.5	4.5	6	6.5	6	9
27	50	54	80	85	85	5	5.5	5.5	7	9.5	6.5
28	57	60	85	85	100	3.5	5.5	6.5	5	6	9.5
29	54	57	80	85	90	6	7.5	4.5	8.5	4	5.5
30	56	56	85	85	90	4	3.5	6	6.5	6.5	7
Mean	53.73	57.53	83.66	84.83	92.50	4.45	4.90	5.35	6.26	6.45	6.71
SD	5.8	3.64	3.78	5.25	6.02	1.12	1.30	1.62	1.79	1.81	1.85

Table 2 shows Mean, Standard Deviation and Range of TOM values

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	ART 1 KHz	ART 2 KHz
TOM 1 KHz	0.65	-0.25
TOM 2 KHz	0.07	0.88

r: 0.361 and 0.463 are required for significance at .05 and .01 level (df = 28).

From the results it is evident that there is a positive correlation between TOM and ART values at the respective frequencies. From the results, it cam be concluded that the null hypothesis "There is no significant relationship between TOM values and ART values in normal hearing subjects" can be rejected. Table 4 also shows that the correlation between ART at 1 KHz and TOM at 2 KHz was not significant . Similarly, the correlation between ART at 2 KHz and TOM at 1 KHz was not significant. This implies that correlation between TOM and ART values can be expected at respective frequencies only.

Thus the results prove that there is relationship between TOM and ART. Since TOM value is used as an indicator for susceptibility to noise induced hearing loss, on the same lines ART can also be used as an indicator for susceptibility to noise induced hearing loss. As ART is an objective measure, perhaps, it may be convenient to rely on ART for detecting individuals who are susceptible to noise induced hearing loss instead of TOM value. More over, determining TOM value requires a special provision in the dual channel audiometer for presenting two different tones through the same earphone. In most of the dual channel audiometer, this facility is not available.

2. Comparison of the results of TOM values with the results of the previous studies

Table 5 shows Mean and SD of TOM values reported by Grimm and Bess; Olsen and Berry and the present investigator

Subjects	Masker frequency (Hz)	
Normal Hearing	1000 Hz	2000 Hz
Grimm and Bess:		
Mean	53	56
Standard Deviation	6.0	7.8
Olsen and Berry:		
Mean	55	60
Standard Deviation	4.3	5.0
Present study:		
Mean	54	58
Standard Deviation	5.8	3.64

Grimm and Bess (1973) and Olsen and Berry (1979) reported TOM values of 53 dB and 55 dB at 1 KHz in normals respectively. At 2 KHz the two studies showed TOM values of 56 and 60 dB. The present study reveals Mean TOM values of 54 and 58 dB at 1 KHz and 2 KHz respectively.

3. The relationship between ART and magnitude of reflex

Table 6 shows Mean, Standard Deviation and range of magnitude of reflex values at 10 dB SL and at 20 dB SL (Balance Meter reading of ZO 73 arbitrary units)

	10 dB SL			20 dB SL		
Frequency	Mean	S.D.	Range	Mean	S.D.	Range
500 Hz	4.45	1.21	2.5-8.0	6.26	1.79	2.5-10
1 KHz	4.90	1.30	2.5-7.5	6.45	1.81	3.0-9.5
2 KHz	5.35	1.62	2.5-8.0	6.71	1.85	2.5-10

Table 7 shows the correlation between ART and magnitude of reflex values

	ART 1 KHz	ART 2 KHz
Magnitude of Reflex (10 dB SL)	-0.22	-0.16
Magnitue of Reflex (20 dB SL)	-0.25	-0.03

As expected, the results of the present study showed that ART and magnitude of reflex were negatively correlated, i.e., in an individual, if ART is low, magnitude of reflex will be more and vice versa. The results of the present study agree with the results obtained by Anne (1980).

Since there is positive correlation between ART and TOM it can be inferred that magnitude of reflex can also be used as an indicator for detecting the individuals who are susceptible to noise induced hearing loss. It appears that subjects who exhibit low acoustic reflex threshold may also show greater magnitude of reflex and also show lower TOM values.

In the above discussion, it may be stated that the subjects who show greater magnitude of reflex, lower reflex threshold and lower TOM values may be considered as susceptible to noise induced hearing loss as the three measurements are related to each other.

Since measurement of ART and magnitude of reflex are objective in nature and also that they are less time consuming, these measurements may be preferred to TOM value.

Test-retest reliability

The test-retest reliability was established for:

1) TOM at 1 KHz and 2 KHz

2) ART at 500 Hz, 1 KHz and 2 KHz

3) Magnitude of Reflex for 500 Hz, 1 KHz and 2 KHz at 10 dB SL and 20 dB SL. The results of test-retest measurements for 10 normals are given in Table 8.

Table 8: TOM, ART and Magnitude of Reflex Test-Retest values at different frequencies

Sub-jects	TOM		ART			Magnitude of Reflex at 10 dB SL			Magnitude of Reflex at 20 dB SL		
	1 KHz	2 KHz	500Hz	1 KHz	2 KHz	500 Hz	1 KHz	2 KHz	500 Hz	1 KHz	2 KHz
1 - TS	60	60	90	90	95	5	5	5.5	6.5	6.5	5.5
RTS	60	60	85	90	90	4.5	5	5.5	6	6.5	5
2 - TS	61	60	85	85	90	4	6	6	6	8	7.5
RTS	60	60	85	80	95	5	5.5	6.5	6	7.5	7
3 - TS	56	53	80	80	80	3.5	7	8	7.5	8.5	10
RTS	57	54	85	85	90	4	6.5	7.5	7.5	8	10
4 - TS	60	56	90	90	90	6	6	3.5	9	8	4
RTS	58	54	85	85	95	5	6.5	4	10	8.5	4.5
5 - TS	52	58	85	85	90	5	5	8	6	5.5	9
RTS	53	58	90	85	90	5	5,5	8.5	6.5	5.5	9.5
6 - TS	56	58	85	80	95	4.5	6	7.5	7	9	9
RTS	54	56	85	85	95	4	6	7	7	9.5	9
7 - TS	53	60	80	85	95	3.5	4	4	5.5	5.5	4.5
RTS	52	60	85	85	100	4	4.5	4	5	5	4
8 - TS	39	62	80	80	105	3.5	4	2.5	5.5	6	7.5
RTS	40	60	80	80	105	3	4	3	5.5	5.5	7
9 - TS	55	56	80	85	90	2.5	3	5.5	3	4	6.5
RTS	53	54	80	85	95	3	3.5	5	3.5	4.5	6.5
10 - TS	57	54	85	85	100	3.5	5.5	6.5	5	6	9.5
RTS	53	54	80	85	105	4	4.5	6	5.5	5.5	10

TS = Test Scores; RTS = Retest Scores

Table 9 shows Mean, Standard Deviation and Correlation between test and retest data for TOM

	1 KHz (dB)	2 KHz (dB)
Test:		
Mean	54.9	57.7
S.D.	6.00	2.75
Retest:		
Mean	54.0	57.0
S.D.	5.47	2.72
r	0.96	0.92

r of 0.632 required for significance at the 5% level (df = 8)

As it is clearly indicated by the table there is significant correlation between test and retest results.

Table 10 shows Mean, Standard Deviation and Correlation between test and retest data for ART

		500 Hz	1 KHz	2 KHz
Test	:Mean	84.0	85.0	93.0
	S.D.	3.74	3.53	6.33
Retest	:Mean	84.0	84.5	96.0
	S.D.	3.0	2.69	5.38
r		0.36	0.50	0.79

r of 0.632 required for significance at the 5% level (df = 8).

There is highly significant correlation between test-retest results for 2 KHz. However, the test and retest results at 1 KHz and 0.5 KHz show no significant correlation.

Since retesting was done after a month, it is quite possible that the middle ear pressure changes might have contributed to the different ART values obtained during retesting,

Table 11 shows Mean, Standard Deviation and Correlation between test-retest data for magnitude of reflex at 10 dB SL and 20 dB SL (Balance Meter reading of ZO 73 arbitrary units)

	10 dB SL			20 dB SL		
	500 Hz	1 KHz	2 KHz	500 Hz	1 KHz	2 KHz
Test:						
Mean	4.1	5.15	5.7	6.1	6.7	7.3
S.D.	0.96	1.1	1.82	1.51	1.51	2.01
Retest:						
Mean	4.15	5.15	5.7	6.25c	6.6	7.25
S.D.	0.70	1.1	1.71	1.63	1.58	2.17
r	0.80	0.96	0.96	0.96	0.97	0.98

r of 0.632 required for significance at the 5% level (df = 8)

The results of test retest scores for magnitude of reflex show significant correlation (5% level).

CHAPTER V

SUMMARY AND CONCLUSIONS

The value of the test battery approach in assessing human auditory function has been recognised for many years and may prove a more reliable approach to susceptibility testing. If several correlates were identified, they could be used as a test battery for susceptibility to noise induced hearing loss. Psychoacoustic tasks could be used as a new indices of susceptibility to noise-induced hearing loss, replacing traditional TTS-based susceptibility tests. The identification of psychoacoustic correlates of TTS may also provide new information about the areas of the auditory system involved in the fatigue process and it may also be useful in detecting minimal auditory dysfunction. (Eldrege and Miller 1969, Ward and Durall 1971, Lipscomb 1975).

Individual differences for susceptibility to TTS and PTS was known since 1830. Some investigators have studied possible relationships between susceptibility to TTS and other psychoacoustic tasks. Lawrence and Blanchard (1959) suggested that a psychoacoustic measures of Cochlear non-linearity, the aural overload test, might be a correlate of susceptibility to auditory fatigue. Grimm and Bess (1973) suggested Threshold of Octave Masking (TOM) test, which is a tonal masking technique used to estimate the threshold of cochlear distortion or non-linearity as a substitute test for measuring aural harmonic thresholds. Clack and Bess (1969), Grimm and Bess (1973) and Nelson and Bilger (1974) have found close agreement between TOM and threshold of aural overload tests.

Humes, Schwartz and Bess (1977) found the relationship between TOM and TTS. There was a negative correlation between TOM and TTS. They strongly recommended TDM tests as a well suited test for susceptibility.

Borg (1968), Brasher et al (1969), Coles (1969), Zakrisson and Borg (1974), Zakrisson et al (1975) reported the influence of the acoustic reflex (AR) on TTS.

The relation between TTS and ART exists because when reflex occurs there will be attenuation of low frequency sounds reaching the cochlea. As TTS is related to the intensity of the signal reaching the cochlea, the reduction in the intensity of the signal brought about by reflex action can be expected to result in less TTS. On the basis of TTS, many tests have been developed to identify subjects who are susceptible to noise induced hearing loss or PTS.

Johnson et al (1967), Miyakita et al (1978) have found relationship between the acoustic reflex threshold and susceptibility to noise induced hearing loss or PTS. Anne Zachariah (1980) has found that the subjects who show greater TTS exhibits low acoustic reflex threshold and that subjects who show less temporary threshold exhibit high reflex thresholds. It is also reported that the subjects with low acoustic reflex threshold (tender ear) show greater TTS and greater magnitude of contraction of the stapedius muscle through the acoustic reflex and that subjects who exhibit high reflex threshold (tough ears) show less TTS and less magnitude of contraction of stapedius muscle.

There are studies regarding the relationship between TOM and TTS (Humes et al 1977) and ART and TTS (Anne Zachariah 1980). The present study was undertaken to find out the relationship between TOM values and ART.

Thirty normal hearing subjects in the age range of 16-26 years were selected for this study. Only one ear of the subject was selected. Selection of the ear (right or left) was done randomly.

The experiment was carried out in sound treated rooms at the Audiology Department, AIISH, Mysore. The ambient noise levels were below the proposed maximum allowable noise levels (Hirschorn 1971).

The study consisted of two parts.

Part 1: In this part, TOM values for 1 KHz and 2 KHz were found. Beltone 200-C dual channel clinical audiometer was used for this purpose.

Threshold for pulsed 1OOO Hz (f_2) tone in quiet was obtained. Later 500 Hz (f_1) tone was introduced into the same ear. Intensity of f_1 (500 Hz) was increased in 5 dB steps, until the pulsed tone was masked. Next, intensities of f_1 (500 Hz) tone required to mask the pulsed tone presented at 10 dB SL, 15 dB SL and 20 dB SL were determined and corresponding shifts were noted. Similarly threshold for pulsed 2000 Hz (f_2) in quiet was determined and a continuous 1000 Hz (f1) tone was introduced to the same ear and corresponding shifts were noted as above. The threshold of octave masking (TOM) was calculated by plotting the threshold shifts f_2(1000 Hz and 2000 Hz) as a function of intensity level of f_1 (500 Hz and 1000 Hz) as shown in the graph No. 2. A line of best fit was drawn through the data points representing 10 dB, 15 dB and 20 dB threshold shifts. The function was extended to intercept the f_1 intensity level axis. The point of intercept was considered Threshold of Octave Masking (TOM). Thus TOM values for 1 KHz and 2 KHz were determined using slope extrapolation method.

Part 2: (a) To measure ART ZO 73 impedance bridge was used. Impedance bridge was checked for calibration. Earphone was placed on the ear for which TOM values were found. Probe tip was inserted to the opposite ear with a suitable eartip and air tight sealing was obtained. Middle ear pressure was determined, i.e., the pressure at which there was maximum compliance was seen.

Frequency knob was set to 500 Hz and intensity knob was set at comfortable level and the presentation button was gently pressed. Minimum intensity of the stimulus which produced noticeable deflection of the meter needle was noted and this level was recorded as ART. Similarly acoustic reflex thresholds at 1000 Hz and 2000 Hz were measured.

(b) To measure the magnitude of reflex:

Same procedure in part II (a) was followed upto getting middle ear pressure. Next step was to set the frequency knob to 500 Hz and the intensity knob was adjusted to 10 dB above the ART value. The compliance scale was manipulated in such a way the balance meter read '1' (lower scale of the Balance meter). Then the presentation button was gently pressed and corresponding deflection in the balance meter was recorded using the above procedure, magnitude of reflex was determined at 20 dB above ART for 500 Hz tone.

Similarly magnitude of reflex was determined for 1 KHz and 2 KHz tones at 10 dB and 20 dB above ART. All subjects were tested in the same manner.

To find out the intra-subject reliability a sample of 10 subjects randomly selected from the total group was re-tested using the same procedure mentioned above. The data were analysed statistically.

The following conclusions are made from the study:

1. There is significant correlation between ART at 1 KHz and TOM at 1 KHz.

2. There exists a good correlation between ART at 2 KHz and TOM at 2 KHz.

3. It appears that the relationship between TOM and ART is frequency dependent.

4. Subjects who show lower ART exhibit low TOM values and subjects who show higher ART exhibit higher TOM values.

5. There exists a negative correlation between ART and magnitude of reflex.

6. Subjects who show lower ART and lower TOM yield larger magnitude of reflex.

7. Subjects who show higher ART and higher TOM yield smaller magnitude of reflex.

8. On the whole, the analysis of the data reveals that subjects with lower TOM have lower ART and higher magnitude of reflex. Lower TOM, lower ART and higher magnitude of reflex may be suggestive of susceptibility to noise induced hearing loss.

9. ART and magnitude of reflex thresholds being more objective tests, these can be employed in finding out the subjects who are susceptible to NIHL.

Limitation of the study

The inherent limitation of susceptibility tests applies to this study also.

Recommendations

1. It would be worthwhile if the present study is carried out on a large sample of normal subjects.

2. To establish the relationship between TOM values and "Fatigability of reflex".

3. To establish the relationship between TOM values and TTS on Indian population.

4. A study may be undertaken to verify whether low TOM values, lower ART, "greater fatigability of reflex" and greater TTS go together in a subject or not.

5. It would be worthwhile to have a longitudinal study on industrial workers, by making use of all the above mentioned susceptibility tests to establish the validity.

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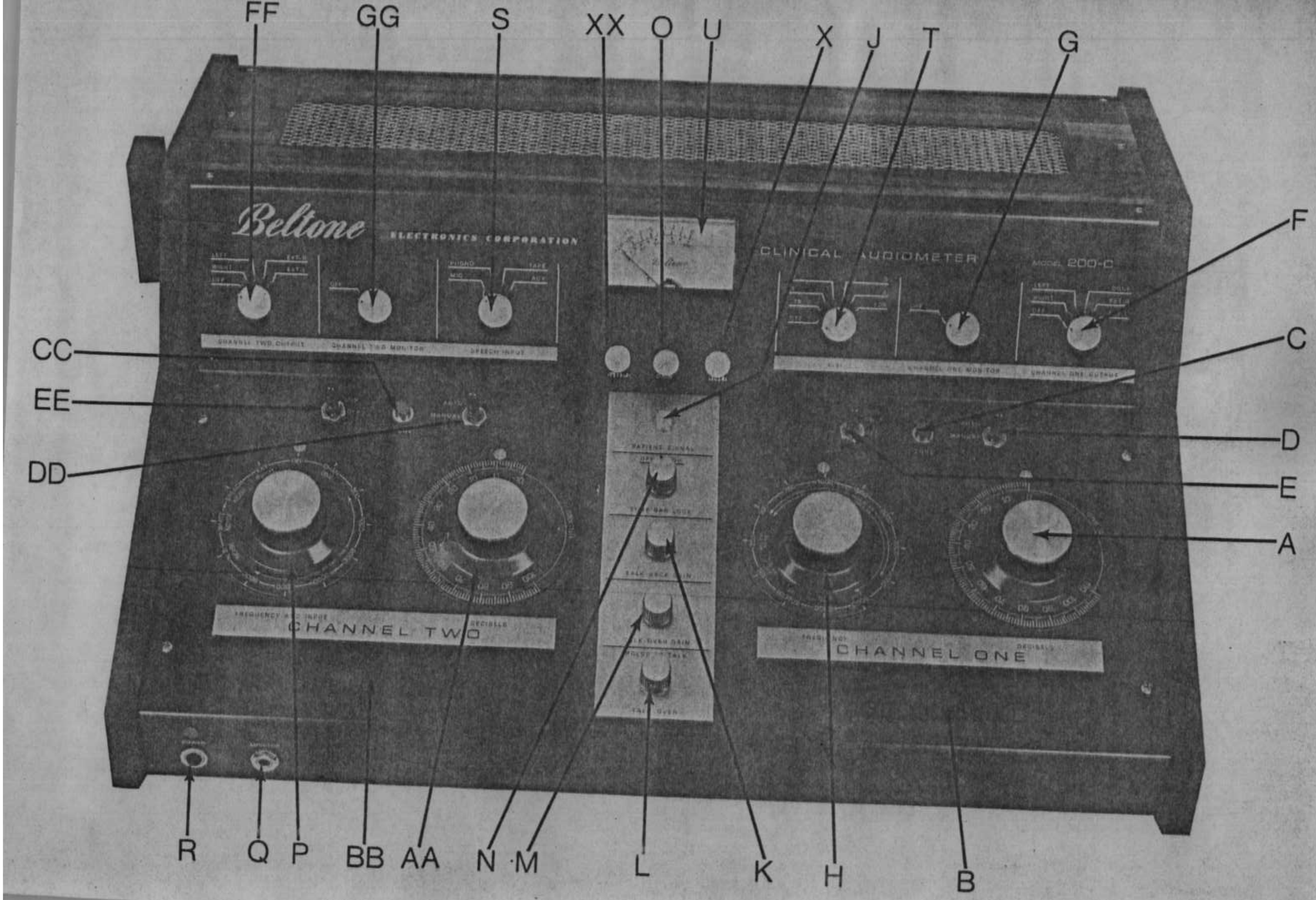

FIGURE 2.1 ILLUSTRATION OPERATING CONTROLS

FRONT PANEL INDICATORS: CONTROL KNOBS OF BELTONE 200 C

(A), (A-A) - Output Attenuators

(B), (B-B) - Tone Interrupter

(C), (C-C) = Tone 'on' lamp

(F), (F-F) - Output Selector

(J) - Patient signal lamp

(E), (E-E) - Tone Reversing Switch

(D), (D-D) - Automatic/Manual Switch

(G), (G-G) - Monitor Control

(T) - SISI (short Increment sensitivity Index)

(S) - Speech Unit

(U) - VU meter

(N) - Tone Bar Lock

(L) - Talk-over switch

(M) - Talk-over gain

(O) - VU meter selector switch

(X) - Channel one VU meter gain control

(XX) - Channel two VU meter gain control

(K) - Talk-Back gain

(R) - Power switch

(H) - Frequency/Speech selector

(P) - Frequency/Masking/input selector

APPENDIX

Output values for R&L Settings at 70 dB HT&

Channel one											
Frequency required	125	250	500	750	1000	1500	2000	3000	4000	6000	6000
Frequency Actual Hz	126	250	498	747	998	1491	1989	2985	3983	5971	7934
dBSPL Red Phone 70 HTL (R)	116.5	96.2	83	78	77	77	81	80	81	84	80.7
dBSPL Blue Phone 70 HTL (L)	116.8	95.5	83	78.1	77.2	77.1	81	80.9	80.3	85.2	81.4
Channel Two											
Frequency Actual Hz			502		1002		2003	3008	4010	6009	
dBSPL Red Phone 70 HTL (R)			83.0		77.0		81.0	80.0	81.0	84.0	
dBSPL Blue Phone 70 HTL (L)			83.0		77.1		81.0	81.0	81.2	85.0	

Sound Pressure level in dB Ref. 20. micro Pa
ANSI-69 Threshold values for TDH - 49
Earphones in Mx-41 / AC Cushions

Obtained values

Frequency in Hz	250	500	750	1000	2000	3000	4000	6000	8000
dB SPL	26.5	13.5	8.5	7.5	11.0	9.5	10.5	13.5	13.0

Maximum allowable background Sound Pressure Levels in dB for no masking above the zero hearing loss setting on a standard audiometer (Decibles re 0.0002 Microbar). The proposed standard data were developed by subtracting the difference between ASA and ISO reference threshold values from the ASA background noise.

Audiometric Test	Octave Band Sound-Pressure level (dB)	
Frequency (Hz)	Octaves	Proposed Standard
125	75/150	31
250	150/300	25
500	300/600	26
1000	600/1200	30
2000	1200/2400	38
4000	2400/4800	51
6000	4800/9600	51
8000	4800/9600	56