TO MY MOTHER

POORNA RAJ

Temporary Threshold Shifts Following Monaural and Binaural Exposure to High Frequency Pure-Tones

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A Dissertation
Presented to
The University of Mysore

In Partial Fulfillment
of the Requirements for the Degree
Master of Science in Speech and Hearing

by
Nagaraja Rao Shivashankar

May 1976

TEMPORARY THRESHOLD SHIFTS FOLLOWING MONAURAL AND BINAURAL EXPOSURE TO HIGH FREQUENCY PURE-TONES

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CERTIFICATE

This is to certify that the dissertation entitled "TTS FOLLOWING MONAURAL AND BINAURAL EXPOSURES TO HIGH FREQUENCY PURE_TONES" is the bona fide work in part fulfilment for the Degree of M.Sc. (Speech and Hearing), carrying 100 marks, of the student with Register No.65.

Director
All India Institute
of Speech & Hearing
Mysore 570006

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 & Hearing, Mysore, and has not been submitted earlier at any University for any other degree or diploma.

Mysore

Dated: 01.05.1976 Register No. 65

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CHAPTER I

INTRODUCTION

The problem of auditory fatigue is still riddled with uncertainty and controversy as many of the relevant parameters interact with each other.

The most common index for auditory fatigue is the Temporary Threshold Shift (TTS), Which indicates any post stimulatory shift in auditory threshold that recovers over time (Ward, 1963).

It is usually estimated by first determining the normal threshold, then exposing the ears to fatiguing stimulus, and finally finding the post-exposure threshold. The difference between the pre- and post-exposure thresholds defines the severity of the fatigue (Donald M. Elliott et al, 1970).

It is recognised that five primary factors influence the size of the TTS:

1) Recovery process, 2) Intensity of the fatiguing stimulus, 3) Frequency of the fatiguing stimulus, 4) Duration of the fatiguing exposure, and 5) Test frequency.

The Action of middle ear muscles have been used to explain the results of various studies on TTS (Ward, 1962, 1962a, 1962b, 1965, 1970; Ward et al, 1958. 1959a, 1959b, 1961b; Morita, 1958; Murray and Reid, 1946; Lehnhardt, 1959; The ilgaard, 1951; Trittipoe, 1958; Miller, 1958; Sokolovski, 1973; Fletcher, et al, 1960; Loeb, et al, 1960, 1965;

Benguerel, et al, 1972; Vysamurthy, 1973; Hirsh, 1958; William F. Prather, 1961; Kerlovich, et al, 1972, 1974; Zakrissan, 1974). Of these studies only Hirsh (1958), Loeb, et al (1960) William F. Prather (1961), Ward (1965), and Kerlovich, et al, (1972, 1974) seemed to be concerned with TTS following monaural and binaural exposures.

Ward (1965) has observed that during bingural exposure, the middle ear muscles contracts more vigorously and that thereby less energy reaches the cochlea. This explanation is valid as long as the exposure stimulus is of a low frequency (below 2 KHz) as the attenuation of sound by the action of middle ear muscle is restricted to the low frequencies only (Ward, 1973; Gunn, 1973; Morgan and Dirks, 1975).

Data on monaural versus binaural high frequency exposures are not available. It will be interesting to know the effect of monaural versus binaural high frequency exposure at same levels, as the influence of the middle ear muscles in attenuating the sound energy reaching the cochlea is restricted to the low frequencies only. The action of the middle ear.

Muscles may not provide an adequate explanation to any discrepancy which might be noticed in the TTS produced by monaural and binaural exposure to high frequency.

Statement of the Problem

The present study is aimed at studying whether there is any significant difference in the TTS produced by monaural and binaural exposure to high frequency tones at equal intensity levels and for equal duration of exposure.

The following null hypothesis is proposed:

There is no significant difference in TTS produced by monaural versus binaural exposure to high frequency at equal intensity levels for equal duration of exposure.

Brief Plan of the Study

Madsen clinical audiometer (Model BO70) calibrated to ANSI (1969) specifications was used in this study.

TTS for monaural versus binaural exposure was measured in thirty normal subjects. These subjects were divided into three groups G1, G2, G3, and were fatigued by three different frequencies 2 KHz, 3 and 4 KHz respectively at equal intensity levels continuously for 15 minutes in both monaural and binaural conditions. TTS at the fatiguing frequency was measured immediately after the cessation of the stimulus, after 1 minute of recovery time and after 2 minutes of recovery time. TTS after 3 minutes at one step beyond the fatiguing frequency and TTS after 4 minutes at two steps beyond the fatiguing frequency was also measured.

Limitations of the Study

1) The fatiguing frequencies used were limited to the higher frequencies 2KHz, 3KHz and 4KHz only.

2) TTS immediately after the cessation of the stimulus was not measured in the test frequencies other than

the fatiguing frequency.

Definitions of the terms

Fatiguing Frequency	:	The frequency at which the exposed continuously to produce the fatigue.
Fatiguing stimulus	:	The acoustic stimulus used to produce auditory shift in threshold. Tones at different frequencies at 110 dB HL was used as the fatiguing stimulus.
Recovery Time	:	The time period from the cessation of the fatiguing Stimulus to the measurement of the post-stimulatory threshold.
Temporary Threshold	:	Any post-stimulatory shift auditory threshold that Recovers over time.
Test Frequency	:	The frequency at which the thresholds were determined after the ear was exposed to fatiguing stimulus.

CHAPTER II

REVIEW OF LITERATURE

The temporary threshold shift or auditory fatigue has been an important topic for experimentation and discussion for the past 120 years and has been generating a number of interesting investigations both experimental and clinical.

The present review of literature is limited only to the effect of TTS on monaural versus binaural exposures; as the detailed review concerned with TTS has been discussed by many investigators (Elliot, et al, 1970; Ward, 1973; and Bishnoi, 1974).

Dichotic exposure to certain acoustic stimuli at high intensity levels results in reduced post-exposure threshold shift (TTS) relative to monotie exposure to the same ctimuli (hirsh, 1958; Leeb and Riopelle, 1960; Ward, 1965; Kerlovich, et al, 1972; and Kerlovich, et al, 1974).

Hirsh (1958) studied monaural TTS following monaural and binaural exposures under three experimental conditions to ascertain whether or not it depends upon whether one ear or both ears were exposed to sound. In the first condition, TTS for 1000 cps tone for 1-minute exposure was measured after the ear was exposed to the same frequency at 20, 80 or 100 dB SL, both in monaural and binaural conditions. Both the ears of each of ten listeners were used. IN the second condition, TTS was measured at 1400 cps after 1-minute of exposure to 1000 cps tone at 100 dB SL. Both the ears of each of ten listeners were used. In the third condition. TTS was measured at 4000 cps after 3-minute exposure to a white noise (100 - 6000 cps) at 110 dB overall SPL. Four subjects out of nine used in the first condition were again used in this condition.

The results showed that, “the TTS for 1000 cps is the same whether the tested ear alone or both ears simultaneously are exposed to a 1000 cps tone at 20, 80, or 100 dB SL. ”It was also found that, “there is no difference in the initial part of the recovery curve for 1400 cps after exposure to 1000 cps at 100 dB SL, but the diphasic recovery curve or ‘bounce’ is clear only after monaural, not after binaural.” He also observed that, “TTS for 4000 cps after a 3-minute exposure to white noise at 110 dB SPL also shows little or no difference between monaural and binaural exposure.” He reports, “the less susceptible ears show more TTS after a binaural exposure than after a monaural exposure, while the more susceptible ears show less TTS after the binaural exposure.” He then concludes that, “In general there appears to be little difference between a binaural and monaural exposure so far as the TTS in the average ear is concerned. What difference there may be suggests that a binaural exposure has less of a fatiguing effect than monaural exposure. Furthermore in those conditions of pure tone exposure, where one would expect to see a ‘bounce’ in the recovery curve the binaural exposure appears to reduce markedly or eliminate the bounce. Whatever the mechanism is that produces this second rise in the threshold about 2 minutes after certain kinds of exposure, its activity appears to be suppressed by stimulations of both ears.”

Ward (1965) in his study, compared the TTS following monaural and binaural exposures to three different high intensity stimuli in 49 listeners. 24 male and 25 female young normal hearing adults were tested weekly for a period of about six moths. Pre – and Post-exposure thresholds were determined in three different experimental conditions.

The experimental procedures as described by Ward are given here.

Experiment 1

"On weeks 14 and 15, the listeners were exposed for 3 minutes to a 1400 cps tone at 115 dB SPL. Half of the listeners were exposed monaurally (right ear first) on the 14^{th} week, binaurally on the 15^{th}, with the other half getting the reverse order. Following the binaural exposures, the threshold at 1400 cps in the right ear was tracked for 1 minute. Beginning at 1 minute post-exposure, the following test sequence was followed (20 sec. Each): 1.4 (Kc/Sec) LE, 1.4RE, 2.0 Le, 2.8 LE, 2.8RE, 4.0 RE, 4.0 LE. The series after monaural exposure followed the same sequence, except that intermediate frequencies (1.7, 2.4, 3.3, 4.7 Kc/Sec) were tracked on the exposed ear, replacing tests on the contralateral ear. Then by means of generalized recovery curves based on the entire 21 weeks of testing the TTS measured at each point was converted to TTS2."

The result showed, " although the differences between the binaural and monaural shifts are not large, the level of statistical significance at 2 and 2.8 kc/sec. exceeds 0.0001 (chi-square). The maximum effect occurs at 2 Kc/sec, where the binaural exposure gave 4.1 dB less TTS (a reduction of 21%)." Ward explains this reduction in TTS terms of feedback 100p and further reports, "With the increased input when the second ear is stimulated, the total activity of the reflex center also increases, and this produces an increase in middle-ear-muscle activity, which produces a reduction in the effective intensity of the input, so that the total activity in the reflex center must be somewhat less then twice as much as that under monaural stimulation, even if there were simple summation."

Experiment 2

In this experiment an octave of noise (700-1400 cps) at 120 dB SPL was used instead of pure tone, for 3 minutes. The experiment was carried out as follows: "On either week 16 or 17 each listener was exposed to the noise monaurally (again right ear first). On the other week, half of the listeners were exposed to binaural noise, and half received a dichotic exposure; noise in the right ear but a 120 dB 1400 cps tone in the left ear. TTS was calculated as before."

The result shows that, 3 minutes of monaural exposure produces an average TTS of 10.5 dB, whereas that of binaural exposure is on the average of 6.1 dB, thus producing a reduction of 42% indicating that it is significant at the level of 0.001. It was also observed that, " the 120 dB tone in the other ear reduces the noise-induced TTS2 at 2 kc/sec to 7.4 db, a reduction of 30% (p=0.01) showing once more that, although a pure tone does not arouse the reflex to the same extent as a noise of the same level, its contribution to reflex arousal is far from negligible."

Experiment 3

"A final comparison between monaural and binaural stimulation involved a 3-minute exposure to a composite noise designed to generate moderate but not excessive values of TTS2 from 1 to 8 kc/sec. This noise was generated by mixing three octave bands: 700-1400cps at 125 dB SPL, 1400-2800at 116, and 2800-5600 at 110 dB. On week 21 all listeners were given binaural exposures, and then on week 22 the left ears were exposed monaurally (the right ears were used in a different experiment altogether)."

The result shows that, "the average reduction of TTS2 (both males and females) from monaural to binaural amounted to abut 40% a 1.4 and 2 kc/Sec ($p<0.001$), 25% at 2.8 kc/sec($p=0.01$), 12% at 4 kc/sec, and 6% at 5.6 kc/sec (not significant)."

Ward has thus concluded, "TTS studies employing monaural exposures are not directly applicable in the development of damage-risk criteria where the working assumption is that the permanent losses from a given noise are proportional to (or at least cannot exceed) the TTS, and therefore that equal-risk criteria will correspond to equal-TTS contours. If these contours are based on monaural exposures, then they will tend to be overprotective, in general, for real-life binaural exposures, especially at low frequencies."

Ward, on the basis of the results of the above experiments, has critized the study of Hirsh (1958). "Although Hirsh found a significant difference in TTS at 1400 cps following monaural and binaural 1-minute exposure to a

1000 cps tone at 100 dB SPL, as would be expected, the difference at 4 kc/sec following a 30minute exposure to white noise at 110 dB SPL was not appreciable.” Ward further explains this: “ A white noise stimulus and a 4 kc/sec test frequency, however, happens to be a combination that will not reveal the difference between monaural and binaural exposures. White noise has a spectrum with a downward slope of only 0 dB/Oct, therefore, after the effectiveness of the lows has been diminished by the middle ear muscles, most of the TTS produced at 4 kc/sec will be a result of the energy in the 2.5 to 3 Kc/Sec range, which is unaffected by the strength of the reflex contraction.”

The above study reveals that, 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. Ward explains this as, “ the contraction of the middle ear muscles depends on the overall loudness of the stimulus, and this contraction reduces the effective intensity of the stimulus components below 2 kc/sec, thus reducing the TTS produced by the se components. These results may be relevant to the so-called “boilermaker’s notch”; a permanent hearing loss whose maximum occurs at about 4 kc/sec. This tonal gap is produced by steady and by impact noises, by noises with both rising and falling spectral shapes. One reason for this particular maximum is that the auditory system has resonances in the 2-3 kc/sec range, so that energy in this region is enhanced. Thus, since auditory fatigue is greatest half an octave above the exposure frequency, the most TTS is to be expected to occur at about 4 kc/sec. However, the differential effect of the middle ear muscles may also contribute to the phenomenon. Even a noise with much greater energy in the 700- to 1400-cps band than in higher bands produces the must effect at 4 kc/sec, more so for binaural than for monaural exposure." He further reports that, "this occurs because the greater the overall intensity, the greater the reduction in effective intensity of the lower-frequency components relative to that of high frequencies. Thus the maximum effect would be expected to occur ½ 1 octave above the lowest frequency that is unaffected by the middle ear muscles – that is, again at 3 or 4 kc/sec."

Kerlovich, et al. (1972) studied the TTS reduction as a function of contralateral noise level, and found that, "the TTS gonerated by 1000 Hz stimulus is systematically reduced as the level of pulsed contralateral noise is increased from 70 to 115 dB SPL. This increase in contralateral noise level created, increased contraction of the stapedius muscle which resulted in attenuation of the 1000Hz exposure stimulus. Thus the data supports the idea that the stapedius muscle reflex is graded in response to acoustic stimulation."

Randolph and Gardner (1973) studied the "Interaural phased effect in binaural TTS". 17 normal hearing subjects were exposed binaurally for 3 minutes to a 0.5 kc/sec tone at 100 dB SPL. TTS for the same tone was subsequently tracked binaurally for 5 minutes. Significantly greater TTS (of the order of 3 dB) was observed from "homophasic" condition where the exposure and test tones were of like phase relationship at the two ears then for " antiphasic" conditions where the exposure and test tones respectively differed in interaural phase by 180'. They concluded that, interaural phase of an intense exposure stimulus thus influenced the subsequent binaurally determined TTS.

In a recent study carried out by Kerlovich, et al. (1974) on “the spectral and temporal parameters of contralateral signals altering TTS” indicated the reduction in TTS in the condition involving contralateral signals.

The study was carried out with nine young adults having bilateral hearing sensitivity no poorer than 20 dB HTL (ANSI 1969) for the frequency range of 250 to 6000 Hz. Each subject had an acoustic reflex for broad band noise and for a 4000 Hz tone; reflex thresholds for each subject were elicited with signals whose intensities were less than those used in the experiment. Each subject was exposed for three minutes to a 1000 Hz tone at 110 dB SPL. Either a 4000 Hz tone at 105 dB SPL or a broad band noise at 100 dB SPL was presented to eh contralateral ear during exposure. Four different temporal patterns were used for each contralateral signal: (1) continuous, (2) 18 seconds on /18 seconds off, (3) 1.8 seconds on/1.8 seconds off, and (4)0.18 seconds off. A control condition consisting of the absence of the contralateral stimulation also was used. Pre- and post-exposure thresholds for the test ear were tracked at a signal one half octave above the exposure frequency. Resultant data indicated that reduction in TTS was greatest for conditions involving rapidly pulsed (1.8 and 0.18 seconds on -off) contralateral signals. Finally they concluded that the acoustic reflex probably manifests less adaptation in response to rapid stimulus repetition rates (1.8 and 0.18 seconds on-off condition) and relatively more adaptation to sustained or slowly pulsed stimuli (continuous and 18 seconds conditions).

It is quite confirmative from the present review of literature that TTS following binaural stimulation at low frequencies (below 2 KHz) shows less TTS than that from the monaural stimulation.

There is no pertinent literature available on TTS following monaural versus binaural stimulation at high frequencies and hence this study has been proposed to be undertaken with the hope that it might throw some light on this area.

CHAPTER III

Subjects

Thirty normal hearing subjects from the student population of All India Institute of Speech and Hearing, Mysore, in the age range of 17 to 23 years were selected for this study.

The subjects were selected on the following criteria:

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

2) Hearing sensitivity should be within 20 dB Hl (Iso 1964), in the frequencies 250 Hz, 500 Hz, 1 KHz, 2KHz, 3 KHZ, 4 KHz, 6 KHz and 8 KHz and the sensitivity difference between the ears in the tested frequency should not exceed 5 dB.

Equipment

Madsen dual channel clinical audiometer, Model 0B 70, with TDH_39 earphone and circum aural cushion No.MX_41/AR was used. The audiometer was calibrated in accordance with the specifications given by ANSI 1969. Weekely check-up for the calibration was exercised using an artificial ear B & K 4152, 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 60 db HL are given in the Appendix I.

Test Environment

The experiment was carried out in an acoustically treated room at the All India Institute of Speech and Hearing. The ambient noise levels present in the test room were below the proposed maximum allowable noise levels (Hirschorn, M., 1971) for audiometer calibrated to ISO 1964 (See Appendix II).

Procedure

All the subjects were first tested for the presence or absence of acoustic reflex in both the ears using Madson acoustic bridge 2072. The details are given in Appendix III.

Two experiments were carried out: Experiment I concerned with monaural exposure and Experiment II concerned with binaural exposure.

Experiment I

All the thirty normal subjects were divided into there equal groups, namely, G1, G2 and 03 each consisting of ten subjects.

The detailed step by step procedure is as follows:

Group 1

i) Thresholds were established for 2 KH_2, 3 KH_Z and 4 KH_Z and 4 KH_Z for both the ears separately

ii) Five of the ten subjects were exposed to 2 KH_Z tone at 126 dB SPL in right ear for 15 minutes continuously while other five of them had the same tone in the left ear for the same duration of time

iii) TTS was determined at 2 KH_Z at, (a) immediately after the cessation of the stimulus (TTS_O), (b) after 1 minute of recovery time (TTS_1), (c) after 2 minutes of recovery time (TTS_2). TTS for 3 KH_Z and 4 KH_Z were also measured after 3 minutes and 4 minutes of recovery time respectively.

<u>Group 2</u>

(i) Thresholds were established at 3 KH_2, 4 KH_Z and 6 KH_Z for both the ears separately

(ii) Five of the ten subjects were exposed to 3 KH_Z tone at 127 dB SPL in right ear for 15 minutes continuously while other five of them had the same tone in the left ear for the same duration of time

(iii) TTS was determined at 3 KH_Z at, (a) immediately after the cessation of the stimulus (TTS_O), (b) after 1 minute of recovery time (TTS_1), (c) after 2 minutes of recovery time (TTS_2). TTS for 4 KH_Z and 6 KH_Z were also measured after 3 minutes and 4 minutes of recovery time respectively.

Group 3

(i) Thresholds were established at 4 KH_2, 6 KH_Z and 8 KH_Z for both the ears separately

(ii) Five of the ten subjects were exposed to 4 KH_Z tone at 126 dB SPL in right ear for 15 minutes continuously while other five of them had the same tone in the left ear for the same duration of time

(iii) TTS was determined at 4 KH_Z at, (a) immediately after the cessation of the stimulus (TTS_O), (b) after 1 minute of recovery time (TTS_1), (c) after 2 minutes of recovery time (TTS_2). TTS for 6 KH_Z and 8 KH_Z were also measured after 3 minutes and 4 minutes of recovery time respectively.

Table 1 gives the pattern of presentation of the test frequencies and fatiguing frequency for different groups and Table 2 shows the test frequencies at different recovery times for different groups.

Experiment II

A recovery period of minimum of one week was allowed for each subject before the second experiment was carried out. The same procedure as explained in the Experiment I were used but with a difference that the fatiguing tone was presented binaurally and the thresholds were determined in the ear which was used for monaural exposure (Experiment I).

.Table 1 showing the pattern of presentation of the test frequencies, fatiguing frequency, number of subjects and number of ears tested for different groups

Groups	RE	LE	Total No. of Subj-ects tested	FF		TF		
				KHz	KHz	KHz	KHz	KHz
1	5	5	10	2	2	2	3	4
2	5	5	10	3	3	3	4	6
3	5	5	10	4	4	4	6	8

B = Binaural

FF = Fatiguing Frequency

LE = Left Ear

M = Monaural

RE = Right Ear

TF = Test Frequencies

Table 1 showing the fatiguing frequency and test frequencies in KH_Z at different recovery times for different groups

Groups	FF	TF				
		T0	T1	T2	T3	T4
1	2	2	2	2	3	4
2	3	3	3	3	4	6
3	4	4	4	4	6	8

FF = Fatiguing Frequency

TF = Test Frequencies

T_O = Threshold after the Cessation of the stimulus

T_1 = Threshold after the recovery time of 1 minute

T_2 = Threshold after the recovery time of 2 minutes

T_3 = Threshold after the recovery time of 3 minutes

T_4 = Threshold after the recovery time of 4 minutes

Intra –subject reliability

A sample of 5 subjects were selected from the total group and was retested in the similar way using the procedures as described in the earlier two experiments for intra-subject reliability. A minimum gap of 20-30 days were given between test retest sessions.

The data were analysed statistically using Wilcoxon Matched Pair Signed Ranks test.

CHAPTER IV

RESULTS AND DISCUSSION

Earlier studies of Hirsch (1958), Ward (1965), Kerlovich, et al. (1971) and Kerlovich, et al. (1973) revealed that binaural exposures showed less TTS than monaural exposures at low-frequencies. Ward (1965) explained this reduction in TTS on the basis of middle ear muscles activity and the action of olivo-cochlear efferent bundle and cochleo-cochlear pathways.

According to Ward (1973), acoustic reflex hypothesis is restricted to low frequencies (below 2 KH_Z) only. In addition to reflex hypothesis, he also referred the reduction in TTS observed after binaural exposure at low frequencies to the inhibitory action of the olivo-cochlear efferent bundle and cochleo-cochlear pathways:

It is very interesting to know at this point whether there is any significant difference in TTS between monaural and binaural exposures to high frequencies at equal intensity levels for equal duration of time, as the reflex hypothesis and also the inhibitory effect is referred to low frequencies.

In the light of the test findings the results of the present study have been analyzed and discussed.

Results

The results were analyzed statistically using Wilcoxon

Matched Pair Signed Ranks test. Table 3 gives the Mean and Standard Deviation for all the three groups – G_1, G_2 and G_3. Table 4 gives the T values at 0.05 level of significance for all the three groups at different recovery times.

The results showed that, except the T value at 3 KH_Z, in G_1 at TTS_3, all the other values are greater than the T values given in the references table for Wilcoxon Matched Pair Signed Ranks test (Appendix IV).

According to the test explanation, the hypothesis: "There is no significant difference in TTS between monaural and binaural exposures to high frequencies at equal intensity levels for equal duration of time", has been accepted, except for 3 KH_Z in group G_1 at TTS_3.

The T value observed at 3 KH_Z for G_1 at TTS_3 is found to be equal to the T value given in the reference table, and the value being 4. As per the test explanation, the hypothesis has to be rejected. But it is not fair enough to either accept or to reject the hypothesis as the score falls exactly on the border line. Therefore further investigations are essential to establish the validity of the test results at this frequency.

Table 3 showing the Mean and Standard Deviation for all the three groups – G_1, G_2 and G_3

Groups		Mean					Standard Deviation				
		TTS_0	TTS_1	TTS_2	TTS_3	TTS_4	TTS_0	TTS_1	TTS_2	TTS_3	TTS_4
G_1	M	56.0	46.5	44.0	53.0	44.5	13.60	12.03	11.97	6.32	5.99
	B	57.5	49.0	44.0	49.0	40.0	11.37	3.70	13.70	8.43	9.13
G_2	M	54.5	43.5	36.0	49.0	42.5	19.07	17.65	16.47	9.90	6.77
	B	54.0	43.5	38.0	49.0	41.5	18.23	19.44	18.14	10.22	13.95
G_3	M	43.5	32.0	29.5	44.5	43.0	21.35	17.03	15.54	10.12	11.11
	B	42.0	33.5	28.0	44.0	36.5	23.12	19.01	16.70	12.47	11.56

Key: G1 = 2 KHZ (FF), TTS_0, TTS_1, TTS_2 at 2 KH_Z, TTS_3 and TTS_4 at 3 KH_Z 4 KH_Z (TF) respectively.

G2 = 3 KH_Z (FF), TTS_0, TTS_1, TTS_2 at 3 KH_Z, TTS_3 and TTS_4 at 4 KH_Z 6 KH_Z (TF) respectively.

G3 = 4 KH_Z (FF), TTS_0, TTS_1, TTS_2 at 4 KH_Z, TTS_3 and TTS_4 at 6 KH_Z 8 KH_Z (TF) respectively.

Table 4 showing the T value for the three groups – G_1, G_2 and G_3 – at different recovery times

Groups	TTS_0	TTS_1	TTS_2	TTS_3	TTS_4
G_1	2.5	7.5	13.0	4.0	10.0
G_2	10.5	13.0	16.5	6.0	6.0
G_3	23.5	15.5	13.0	19.5	10.0

Key: G1 = 2 KHZ (FF), TTS_0, TTS_1, TTS_2 at 2 KH_Z, TTS_3 and TTS_4 at 3 KH_Z 4 KH_Z (TF) respectively.

G2 = 3 KH_Z (FF), TTS_0, TTS_1, TTS_2 at 3 KH_Z, TTS_3 and TTS_4 at 4 KH_Z 6 KH_Z (TF) respectively.

G3 = 4 KH_Z (FF), TTS_0, TTS_1, TTS_2 at 4 KH_Z, TTS_3 and TTS_4 at 6 KH_Z 8 KH_Z (TF) respectively.

(T value at 0.05 level of significance)

Thus, the present study reveals no significant difference in TTS between monaural and binaural exposures to high frequency tones at equal intensity levels for equal duration of time.

As far as reliability is concerned, the retest results were found to be in agreement with the test results. Test and retest results are given in Appendix V.

Discussion

The present study reveals that there is no significant difference in TTS between monaural and binaural exposures to high frequency tones at equal intensity levels for equal duration of time.

Studies of Hirsch (1958), Ward (1965), Kerlovich, et al. (1972), and Kerlovich, et al. (1974) showed that TTS produced by binaural exposure to low frequencies found to be less than the TTS produced by the monaural exposure. According to Ward (1965), the acoustic reflex hypothesis is restricted to low frequencies only, and during binaural exposure middle ear muscles contract more vigorously than monaural exposure, thus reduces the energy reaching the cochlea, producing less TTS. In addition to acoustic reflex hypothesis, he also considers the action of olivo-cochlear bundle and cochleo-cochlear pathways to account for the reduction in TTS after binaural exposures to low frequencies.

Galambos (1956) has observed that olivo-cochlerar inhibitory effects reduces the magnitude of the whole nerve response. The magnitude of the inhibitory effects is about

15-20dB reduction in the strength of the acoustic click (Desmedt, 1962). Kiang (1963) reports the reduction in rate of firing with simultaneous presentation of two acoustic signals. Rupert, et al. (1963) report an immediate reduction in the spontaneous rate of response upon acoustic stimulation and also a reduction with a long time-course of onset and recovery. They also noted that, this inhibitory effects were not limited to one frequency. Nomoto, et al. (1964) reported stimulus dependencies for short latency inhibitory effects. They found that, inhibitory effects were only for high-frequency units and failed to detect any such effects for units with characteristic frequencies of 1 KH_Z or less. Strong signals are required.

Ward (1965) reports that, "the acoustic reflex hypothesis is not the only possible explanation for the monaural-binaural differences. One could jump on the current bandwagon and call on the olivo-cochlear effect bundle and cochleo-cochlear pathways to account for the results." Ward gives this explanation for the differences observed at low frequencies. As the present study was restricted to high frequencies, one cannot expect the action of middle ear muscles, as it is restricted to low frequencies only, and hence one could expect a high value of TTS during binaural exposures. But the present study reveals no significant difference in TTS between the monaural and binaural exposures to high frequency tones at equal intensity levels for equal duration of time. This result could be attributed to the inhibitory action of the efferent system. Dayal (1973) reports the action of crossed olivo-cochlear bundle (COCB) at high frequencies and revealed that, the COCB is not responsible for adaptation at high frequencies as he still could find some inhibitory responses even when COCB was cut. He assumes that, homolateral olivo-cochlear bundle may play a role in the adaptation mechanism at high frequencies.

The result of the present study can now be explained in the light of the assumption made by Dayal (1973) on the action of homolateral olive-cochlear bundle. As COCB is not responsible for the inhibitory effects at high frequencies. This no significant difference in TTS between the monaural and binaural exposures to high frequency tones at equal intensity levels for equal duration of time, revealed from this study could be due to the action of homolateral olivo-cochlear bundle, which might suppress the responses reaching the higher centres.

CHAPTER V

SUMMARY AND CONCLUSIONS

TTS at low frequencies following monaural and binaural exposures have revealed that, TTS following binaural exposures is less than the TTS following monaural exposures (Hirsh, 1958; Ward, 1965; Kerlovich, et al. 1972; Kerlovich, et al. 1974). This difference in TTS was explained on the basis of the middle ear muscles activity which is restricted to low frequencies only (below 2 KH_z). During binaural exposure, the middle ear muscles contract more vigorously and reduce the energy reaching the cochlea, thereby there will be reduction in TTS during binaural exposures. In addition to the acoustic reflex action Ward (1965) considers the action of olivo-cochlear bundle and cochlec cochlear pathways to be present during binaural exposures at low frequencies. Dayal (1973) reports the action of crossed-olivo-cochlear bundle (COCB) at high frequencies and revealed that, the COCB is not responsible for adaptation at high frequencies as he still could find some inhibitory responses even when COCB was cut. He assumes that, homolateral olivo-cochlear bundle may play a role in the adaptation mechanism at high frequencies.

The present study was an attempt to investigate 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.

Madson dual channel clinical audiometer Model 0B 70 calibrated to ANSI (1969) specifications was used in this study. TTS for monaural and binaural exposures was measured in thirty normal subjects. These subjects were divided into three groups G_1, G_2 and G_3 and were exposed to three different frequencies 2 KH_Z, 3 KH_Z and 4 KH_Z respectively at equal intensity levels in both monaural and binaural conditions, continuously for 15 minutes. TTS at the fatiguing frequency was measured immediately after the cessation of the stimulus (TTS_0), after 1 minute of recovery time (TTS_1) and after 2 minutes of recovery time (TTS_2). TTS after 3 minutes of recovery time (TTS_3) was measured one step beyond the fatiguing frequency and TTS after 4 minutes of recovery time (TTS_4) was also measured two steps beyond the fatiguing frequency.

Conclusions

It was found that there was 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 KH_Z at TTS_3 (fatiguing frequency being 2 KH_Z tone). As the T value at this frequency was equal to the table value, it is difficult to accept the hypothesis or reject the hypothesis. Further research data at this frequency is very much essential.

No significant difference in TTS following monaural and binaural exposures to high frequency tones at equal intensity levels, for equal duration of time could be attributed to the action of homolateral olivo-cochlear bundle.

It is reasonable if one would expect a high value of TTS during binaural exposures to high frequencies, as the acoustic reflex hypothesis is restricted to low frequencies only (Ward, 1973). But the results of the present study are in contrary to the expectation. The results show that there is no significant difference in TTS between monaural and binaural exposures to high frequency tones at equal intensity levels for equal duration of time. This result could be attributed to the action of homolateral olivo-cochlear bundle which might inhibit the responses of the higher centers, as crossed olivo-cochlear bundle (COCB) does not play a role in the adaptation mechanism at high frequencies (Dayal, 1973).

More research data is warranted on these lines.

It is quite evident from the present study that the results support the acoustic reflex hypothesis, as TTS during binaural exposures to high frequency tones was not less than the TTS produced for monaural exposures to high frequency tones at equal intensity levels for equal duration of time.

Recommendations

1) Studies pertaining to TTS_3 at 3 KH_Z after monaural and binaural exposures to 2 KH_Z tone at equal intensity levels for equal duration of time can be undertaken to verify the results obtained in the present study.

2) It may be worth while to study whether there is any significant difference in the recovery process after monaural and binaural exposures to high frequencies.

3) TTS at a fixed recovery interval after monaural and binaural exposures to a particular frequency can be studied at different test frequencies in the same

subjects.

4) It may be worth while to study the monaural versus binaural TTS for high frequency noise exposures.

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APPENDICES

LIST OF APPENDICES

APPENDIX I

Output values for L, R and L+R settings at 60dB HL

Frequencies used	L	R	L+R	Expected value
2 KH_Z	77	77	77	69
3 KH_Z	77	77	77	70
4 KH_Z	76	76	77	69.5
6 KH_Z	81	82	81	75.5
8 KH_Z	76	77	76	73

(Audiometer calibrated to ANSI 1969)

Key: L = Left earphone

R = Right earphone

L+R = Left and right earphones

APPENDIX II

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 the ASA and ISO Reference Threshold Values from the ASA Background Noise

Audiometric Test Frequency (c/s)	Octave Band Sound - Pressure Level (dB)	
	Octaves	Proposed Standard
125	75/750	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

APPENDIX III

Table showing the acoustic reflex thresholds of both the ears for all the subjects

Subject		Frequency in H_Z			
		500	1000	2000	4000
1	R	100	100	100	100
	L	95	100	100	100
2	R	80	80	80	95
	L	85	85	90	95
3	R	95	95	100	105
	L	105	105	120	125
4	R	95	95	95	95
	L	90	90	90	95
5	R	95	95	95	95
	L	95	95	95	95
6	R	85	85	85	85
	L	100	105	105	120
7	R	90	90	105	125
	L	95	95	95	95
8	R	95	95	95	95
	L	95	95	95	95
9	R	95	95	95	95
	L	85	85	85	85

Subject		Frequency in H_Z			
		500	1000	2000	4000
10	R	105	105	105	105
	L	100	100	100	100
11	R	–	–	–	–
	L	115	115	115	115
12	R	90	95	100	100
	L	85	85	90	105
13	R	90	90	90	95
	L	95	95	95	95
14	R	95	100	110	120
	L	95	95	105	115
15	R	90	90	90	110
	L	90	95	90	110
16	R	90	95	95	*
	L	90	95	95	100
17	R	90	90	90	110
	L	90	95	100	110
18	R	90	85	90	100
	L	85	85	90	95
19	R	90	90	95	95
	L	90	95	100	105
20	R	90	90	90	100
	L	90	95	95	100

Subject		Frequency in H_z			
		500	1000	2000	4000
21	R	95	95	95	100
	L	90	90	95	105
22	R	90	90	95	100
	L	90	95	9500	105
23	R	85	85	85	95
	L	85	85	90	95
24	R	75	75	80	95
	L	595	75	85	95
25	R	75	90	95	95
	L	85	90	95	105
26	R	85	90	95	105
	L	85	90	95	105
27	R	90	90	90	90
	L	90	95	95	*
28	R	85	90	105	*
	L	100	9500	100	100
29	R	90	95	100	110
	L	90	100	100	105
30	R	85	85	90	95
	L	85	90	95	100

Key: R = Right Ear

L = Left Ear

Note: * NO reflex

- Air tight sealing could not be obtaine

APPENDIX IV

Table of Critical Values of T in the Wilcoxon Matched-Pairs Signed-Ranks Test*

N	Level of significance for one-tailed test		
	0.025	0.01	.005
	Level of significance for Two-tailed test		
	.05	.02	.01
6	0	-	-
7	2	0	-
8	4	2	0
9	6	3	2
10	8	5	3
11	11	7	5
12	14	10	7
13	17	13	10
14	21	16	13
15	25	20	16
16	30	24	20
17	35	28	23
18	40	33	28
19	46	38	32
20	52	43	38
21	59	49	43
22	66	56	49
23	73	62	55
24	81	69	61
25	89	77	68

* Adapted from Table I of Wilcoxon, F. 1949. Some rapid approximate statistical procedures. New York: American Company, p. 13 - Taken from Sidney Siegel, Nonparametric Statistics for the behavioral sciences. (McGraw-Bill Kogakusha, Ltd. 1956) p. 354, Table G.

APPENDIX V

TEST-RETEST Results of the 5 subjects tested for RELIABILITY

Tables 1, 2, 3, 4 and 5 show the TEST-RETEST Results of the Subjects A, B, C, D and E respectively of the Groups G_1, G_2 and G_3.

Abbreviations used in the Tables

B = Binaural

D_R = Difference between monaural and binaural shifts of the Test Results

Dr = Difference between monaural and binaural shifts of the Re-test Results

Dr−D_R = Difference between the differences of Test and Re-test Results

FF = Fatiguing Frequency

TF = Test Frequency

M = Monaural

Table 1 showing the Test-Retest Results of the Subject A of the Group G_1

(FF = 2 KH_Z, TF = 3 KH_z & K KH_Z)

	TEST		Dr	RE-TEST		Dr	DT - DE
	M	B		M	B		
TTS_0	40	60	-20	65	60	5	-25
TTS_1	35	45	-10	50	60	-10	0
TTS_2	30	40	0	55	50	5	-5
TTS_3	50	45	5	50	40	10	-5
TTS_4	35	30	5	45	30	15	-10

Key : TTS_0, TTS_1, TTS_2 at 2 KH_Z, TTS_3 and TTS_4 at 3 KH_Z 4 KH_Z respectively

Table 2 showing the Test-Retest Results of the Subject B of the Group G_1

(FF = 2 KH_Z, TF = 3 KH_z & 4 KH_Z)

	TEST		Dr	RE-TEST		Dr	DT - DE
	M	B		M	B		
TTS_0	60	60	0	55	55	0	0
TTS_1	55	55	0	50	50	0	0
TTS_2	55	45	10	55	45	10	0
TTS_3	45	45	0	40	40	0	0
TTS_4	45	25	20	45	25	20	0

Key : TTS_0, TTS_1, TTS_2 at 2 KH_Z, TTS_3 and TTS_4 at 3 KH_Z 4 KH_Z respectively

Table 3 showing the Test-Retest Results of the Subject C of the Group G_1

(FF = 3 KH_Z, TF = 4 KH_z & 6 KH_Z)

	TEST		Dr	RE-TEST		Dr	DT - DR
	M	B		M	B		
TTS_0	55	50	5	65	60	5	0
TTS_1	50	50	0	55	55	0	0
TTS_2	45	45	0	50	50	0	0
TTS_3	55	55	0	55	55	0	0
TTS_4	45	35	10	40	30	10	0

Key : TTS_0, TTS_1, TTS_2 at 3 KH_Z, TTS_3 and TTS_4 at 4 KH_Z 6 KH_Z respectively

Table 4 showing the Test-Retest Results of the Subject D of the Group G_2

($FF = 3\ KH_Z$, $TF = 4\ KH_z$ & $6\ KH_Z$)

	TEST		DT	RE-TEST		Dr	DT - DR
	M	B		M	B		
TTS_0	60	50	10	65	55	10	0
TTS_1	45	30	15	45	30	15	0
TTS_2	40	25	15	45	35	10	5
TTS_3	35	25	10	35	30	5	5
TTS_4	30	30	0	25	25	0	0

Key : TTS_0, TTS_1, TTS_2 at $3\ KH_Z$, TTS_3 and TTS_4 at $4\ KH_Z$ $6\ KH_Z$ respectively

Table 5 showing the Test-Retest Results of the Subject E of the Group G_3

(FF = 4 KH_Z, TF = 6 KH_z & 8 KH_Z)

	TEST		DT	RE-TEST		Dr	DT - DR
	M	B		M	B		
TTS_0	45	35	10	45	30	15	-5
TTS_1	40	30	10	30	20	10	0
TTS_2	40	30	10	25	20	5	5
TTS_3	60	50	10	50	40	10	0
TTS_4	35	30	5	45	40	5	0

Key : TTS_0, TTS_1, TTS_2 at 4 KH_Z, TTS_3 and TTS_4 at 6 KH_Z 8 KH_Z respectively

APPENDIX VI

Reference Threshold Levels for the Earphone,
Telephonics TDH-39

Frequency, H_Z	Reference Threshold Levels re 0.0002 Microbar, dB
	Telephonics TDH-39
125	45
250	25.5
500	11.5
1000	7
1500	6.5
2000	9
3000	10
4000	9.5
6000	15.5
8000	13