To

MY FAMILY

EAR DIFFERENCE IN TEMPORARY THRESHOLD SHIFT FOR MONAURAL STIMULATION

REG.No.8610

An independent project submitted as part fulfilment
for First Year M.sc(Speech and Hearing) to the
University of Mysore,

MAY 1987

ALL INDIA INSTITUTE OF SPEECH AND HEARING: MYSORE-6

CERTIFICATE

This is to certify that the Independent Project entitled:

" EAR DIFFERENCE IN TEMPORARY THRESHOLD SHIFT FOR MONAURAL STIMULATION ".

is the bonafide work, done in part fulfilment for First Year M.sc(Speech and Hearing) of the student with Register No.8610.

Dr.M.Nithya seelan
Director,
All India Institute of
Speech and Hearing
Mysore - 570006.

CERTIFICATE

This is to certify that the Independent Project entitled:

"EAR DIFFERENCE IN TEMPORARY THRESHOLD SHIFT FOR MONAURAL STIMULATION"

has been prepared undear my supervision and guidance.

GUIDE

Dr.M.N. Vyasamurthy
Dept. of Audiology.

DECLARATION

This Independent Project entitled: "EAR DIFFERENCE IN TEMPORARY THRESHOLD SHIFT POR MONAURAL STIMULATION" is the result of my ova study undertaken under the guidance of Dr.M.N.Vyasamurthy, Department of Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any university for any other Diploma or Degree.

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MAY 1987.

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INTRODUCTION

It is a property of ail sensory systems that exposure to a stimulus of sufficient duration and intensity produces changes in the responsiveness of the system, some changes occur during the presentation of the stimulus and some are apparent after the end of the stimulus (Eg. Shift in thethreshold). such effects are much less marked in the auditory system than they are in the visual system although large threshold shifts are often observed after exposure to stimuli of very high intensity (Moore, 1977).

Temporary changes in auditory perception induced by acoustic stimulation have been studied by scientists only for the past 120 years (Ward, 1973). Victor Urbantschitsch (1881) discovered the phenomenon*

The decrease of sensitivity after exposure to acoustic stimulation has been called 'auditory adaptation*, 'auditory fatigue', 'acoustic trauma' and the more neutral 'temporary threshold shift' (Here after referred to as TTs). some investi-gators interchangeably use all the words except acoustic trauma, whereas some others discriminate among them (Ward, 1965).

Hood (1950, 1972) has distinguished between auditory adap-tation and auditory fatigue and has emphasized that these are two quite distinct processes. The essential feature of fatigue is that it 'results from the application of a stimulus which is usually considerably in excess of that required to sustain the normal physiological response of the receptor, and it is measured after the stimulus has been removed' (Hood, 1972). So, auditory fatigue is more properly referred to as post-stimulatory auditory fatigue and the measure used is called TTs (temporary threshold shift). The most common index of auditory fatigue is the TTS. Adaptation is a special case of fatigue (Harris and Rawnsley, 1953).

Brief exposures to intense noise can produce a temporary hearing loss or threshold shift, and after a period of rest the ear will regain its former sensitivity. A good example is the reduction of auditory sensitivity for several hours after completing a flight in a noisy airplane (Newby and Popelka 1985).

Hearing tests before and after noise exposure reveal the existence of TTS or the amount of reversible reduction in hearing sensitivity. A TTs is totally reversible when the noise ceases and sufficient time has elapsed for the ears to recover. (Lipscomb, 1974).

In the past few decades, a great deal of hearing research has been directed toward the phenomenon of auditory fatigue (Ward, 1963, 1973). This phenomenon has been studied most frequently with the TTS paradigm.

TTS is the most studied after effect of auditory stimulation (Babighian et al, 1975).

Definition of TTs:

TTS is defined as a reduction in hearing sensitivity resulting from exposure to noise* provided that thresholds return to pre-exposure levels with time (minutes, hours or days) after cessation of the aoise (Rintlemann et al 1972). The most appropriate TTS measurements are those actually obtained 2 minutes post exposure.

TTS refers simply to the transitory changes in hearing sensitivity induced by a fatiguing stimulus (Humes and Bees, 1978).

TTs is defined as the difference in the threshold of audibility measured before and after an individual has been exposed to sounds with known physical characteristics (corso, 1967). It is a transitory phenomena and the shift in threshold returns to its pre-exposure level in the absence of sound with in a matter of hours usually. Generally it is elevated or decreased sensitivity. To describe the amount of TTs produced by a particular exposure to sound, we specify the amount of threshold shift, that is present 2 minutes after the end of exposure (TTS_2).

Auditory fatigue is a temporary change in threshold sens-tivity following exposure to another auditory stimulus (Ward, 1963). The most common index for auditory fatigue is the TTS, which, indicates any post stimulatory shift in auditory thresh-old 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 pre- and post - threshold defines the severity of the fatigue (Elliott et al, 1970).

Need for measuring TTs:

There are 4 major ways to study the effects of exposure to intense sound on the ear.

1) measure the shifts in behavioural auditory thresholds.
2) measure the loss of cochlear and other related physiological potentials.
3) examine the organ of corti in the inner ear for anatomical injury.
4) examine the inner ear with histochemical or quantitative chemical methods for evidence of biochemical alterations (Benitz, et al, 1972).

Such experiments have been done primarily because we are interested to know about the permanent threshold shift (PTs) or noise induced hearing loss (here after referred to as NIHL).

According to Axelsson and Lindgren (1978), there are principally 4 different methods to establish a possible relationship between noise exposure and subsequent hearing loss. There are:-

1) determinations on the basis of sound level measurements and. their relations to established damage risk criteria.

2) histologically confirmed inner ear changes after exposure.
3) the finding of permanent sensory neural (SN) hearing loss after exposure, preferably including tests at extremely high frequencies.
4) the existence of temporary hearing loss after exposure.

The practical significance of TTS (according to Corso, 1987) is that numerous data have suggested that TTS is approximately linearly related to the permanent threshold shift induced by exposure to high levels of noise. Also,'damage risk criteria' (DRC) for noiae exposures may be specified for a criterion TTS.

Such recommendations vary according to the specific characteristics of the noise environment, but are derived from 3 basic postulatest-

1) TTs_2 is a consistent measure of the effects of a single day's exposure to noise.
2) All exposures that produce a given TTS_2- are considered equally hazardous.
3) There is a quantitative relation between TTS_2- and the permanent shift after 10 years of exposure.

In general, any exposure to sound which produces a TTS- that approaches or exceeds 40dB is capable of producing a permanent impairment in hearing sensitivity.

The study of TTs is of theoretical and practical interest to audiologists because.

1) The similarities between TTS, auditory adaptation and PTS indicate that the anatomical and physiopathological processes which underlie them may be differentiated only quantitatively (Derbyshire and Davis, 1935; Davis et al, 1950; Shimizee et al, 1967; Gisselsoa and sØrensen, 1959; SØrensen. 1959; Tonndorf et al, 1955).
2) TTS may be used effectively to study auditory fatigue and related phenomena, because in contrast to adaptation - it permits post stimulatory study, and in contrast to PTS - it does not pre suppose permanent damage.
3) TTS measures are among the important auditory tests performed to assess SN hearing less, and
4) A series of clinical studies on TTs have attempted to evaluate the predictability of NIHL and to state some damage risk criteria (Ward, 1970) (Babighian et al, 1975).

TTs can be used to predict the succeptibility of any individual to noise induced permanent threshold shift (NIPTS) (Newby and Popolka, 1985).

Of the several methods for identifying those noise exposures that are likely to cause permanent elevations of hearing thresholds, the one that is presently best accepted (Kryter, Ward, Miller and Eldredge, 1966) is based on the reasonable assumption that those noise exposures producing only slight TTs in a group of normal ears will produce only slight PTSs after many repetitions of the exposures (Botsford, 1971).

Temkin (1933) suggested that the measurement of the temporary change in hearing sensitivity following a brief and moderately intense acoustic over stimulation provided a simple and valid estimate of eventual PTS incurred from more severe exposures to loud sounds. That is why we measure TTs. Despite considerable research efforts, the relationship between TTs and PTS remains far from simple.

According to weissing (1968) 'Measurement of threshold shift represents an elegant method of obtaining information about the damaging effects of noise upon the ear'. The most recent clinical interest in the topic is derived from a suggestion that (Peyser, 1930 and Tempkin 1933) one might be able to predict individual susceptibility to permanent damage from high intensity sound by means of individual difference in the TTs produced by a much less intense exposure.

The reduction of auditory fatigue without the use of protective helmets can apparently be used as an objective way of evaluating their efficacy. Two studies, one in an industrial, the other in a laboratory environment showed that for the same noise the value of the helmets differed (Duclos, et al, 1984).

TTS can be used to study the efficacy of ear protective devices (EPD) or hearing protective devices (HPDs).

Factors affecting TTs:

The production of TTs is dependent on many factors. If a steady pure tone is used frequency intensity and duration are important. In case of noise, bandwidth, intensity and duration are important. If impulses are used rise time, number of impulses, rate of impulses. Peak intensity are important. The TTs producing stimulus is interrupted, then TTs produced is less when compared to the continuous stimulus.

There are 5 major factors which influence the size of the TTS:

1) exposure time or the duration of the fatiguing stimulus.
2) recovery time or the time between cessation of the fatiguing stimulus and the past exposure threshold.
3) exposure frequency or the frequency of the fatiguing stimulus.
4) exposure SPL or the intensity of the fatiguing stimulus.
5) Test frequency.

If the stimulus is intermittent, interruption rate and for impulses pulse repetition rate are also contributing factors.

Miscellaneous factors that affect TTS are interactive effects resting threshold, latent and residual effects, Vitamin-A, salt, oxygen, vibration, drugs and level of consciousness, sex, age, experience, articulation, acoustic reflex threshold, central factors, binaural versus monaural presentation of the stimulus etc.

The range of individual differences in the amount of TTs produced by specific exposure to pure tone. Noise etc. is quite large.

Ward (1973) hag described several types of TTS. Ultra short term TTs (residual masking), short-term TTs (Low level adaptation), sensitization or facilitation, ordinary TTs (physiological fatigue), long lasting TTs (Pathological fatigue - not complete by 16 hours).

Ear difference in auditory fatigue has been reported (Glorig and Rogers, 1965; Ward, 1967; Jerger, 1970; weiler, 1974).

The psychoacoustic literature on TTs provides little information about ear difference in TTs for monaural stimulation.

Several studies do, however, consider the comparability of monaural and binaural TTs exposures upon monotically measured TTS. There are studies on ITS due to low frequency versus high frequency, sex differences in TTs etc.

Statement of the problem:

The present study is aimed at studying if there is any ear difference in temporary threshold shift produced by monaural stimulation at equal intensity levels and for equal duration of exposure.

Hypothesis:

There is no significant ear difference in TTs produced by monaural stimulation at equal intensity levels and for equal duration of exposure.

Implications of the study:

1. It provides information regarding TTs for monaural stimulation.
2. It provides information about TTs at 2KHz for monaural stimulation.
3. It provides information regarding presence or absence of ear difference in TTs for monaural stimulation.

Limitations of the study:

1. The fatiguing frequency used was limited to the low frequency, i.e. 1KHz only.
2. Only a small population was tested.
3. The age range was limited.

Definitions of the terms used:

Temporary threshold shift (TTs): Refers to an elevation in the threshold of hearing which recovers gradually following the noise exposure.

TTS_0-: Temporary threshold shift measured as soon as the fatiguing stimulus is ceased.

TTS_1.: Temporary threshold shift obtained after 1 minute of exposure recovery time.

TTS_2: TTS measured after 2 minutes of recovery time.

Monaural stimulation:

when the stimulus of a particular frequency at a particular intensity is presented to one ear only.

Ear difference:- When normal hearing subjects are asked to recall or identify dichotically presented stimuli, they show a greater degree of accuracy for sounds presented to one ear over the other.

Here, ear difference means the difference between the amount af TTS seen in right ear and left ear when normal hearing subjects are exposed to pure tone of relatively high intensity monaurally.

Fatiguing frequency: The frequency at which the ear was exposed continuously to produce the fatigue.

Fatiguing stimulus: The acoustic stimulus used to produce auditory shift in threshold.

Test frequency: The frequency at which the thresholds were determined after the ear was exposed to fatiguing stimulus.

REVIEW OF LITERATURE

The problem of auditory fatigue is still vexed with uncertainity and controversy.The problem arises from the fact that so many of the relevant parameters are interactive so that experimental results are difficult to generalize however precisely determined they are (Ward, 1963).

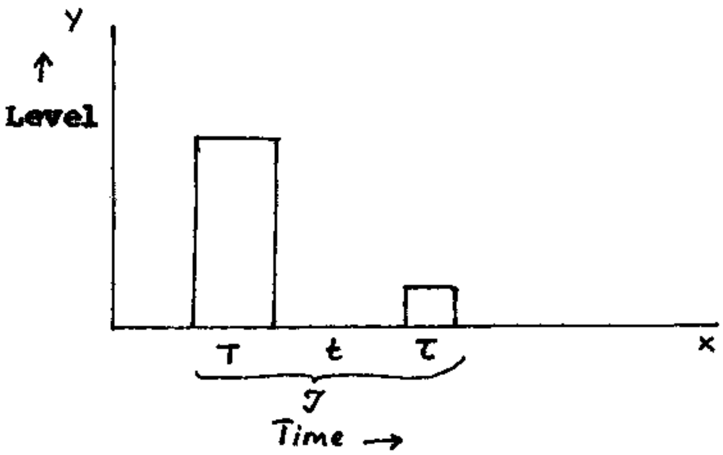
Auditory fatigue is one of a number of terms used to describe a temporary change (usually but not always, a decrease) in threshold sensitivity following exposure to another auditory stimulus. This is due to the appropriate neural elements either are temporarily incapable of being fired, or at least are refractory (require more energy before responding).

Auditory fatigue (AF) is a time linked process. AF grows with duration of exposure and disappears as a function of time since exposure.

The most common index for auditory fatigue is the TTS Which has generated a number of interesting investigations both experimental and clinical and perhaps been the most studied after effect of auditory stimulation.

Both the permanent and temporary effects of noise on the human auditory system are variable (Humes, 1980; Ward, 1973; Robinson, 1976) and this is true even when the physical characteristics of the noise exposure are held constant. This variability in noise effects implies that noise may interact with other variables to produce its effects on hearing.

The basic scheme for measurement of TTS:



T = duration of the fatiguing stimulus

t = duration of a pauce

T = duration of the test stimulus.

J = duration of the total test cycle.

A TTS arousing stimulus is presented for a period of time T. Then the test stimulus of duration T is presented at a time 't' after cessation of the TTS arousing stimulus.

Many studies have shown the relation of sound parameters such as duration, intensity level, repetition rate, acoustic spectrum etc. to TTS.

TTS decreases after termination of noise exposure. However, in many subjects, a substantial TTs could be found even after 25 minutes and more after termination of noise exposure. (Axelaaon and Lindgren, 1978). Recovery from TTs is faster at first and slower later. That is recovery from TTS is a linear function of the logarithm of time following the cessation of stimulation. But Luscher and Zwislocki (1949) and Rawnsley and Harris (19S2) reported that in short-t term TTS, the recovery seems to be linear in time rather than in the logarithm of time. Ward (1960) has shown that in the case of higher level exposures giving rise to TTS in the region above 40dB. The recovery process is no longer logarithmic with time, but occurs at a steady rate of about 0.012 dB/ minute (Tempest, 1985).

If the TTS_2 is less than about 40dB, complete recovery can be expected in about 16 hours.

Epstien and Schubert (1957) and others have shown that the log-time function for recovery is similarly obtained after stimulation by pure tones.

The recovery process is relatively independent of test frequency.

Production of TTS is dependent on many factors.

Pure tone produces more TTS than noise. Continuous exposure causes more TTS than intermittent exposures.

TTs is a linear function of the logarithm of exposure time (Ward et al 1950) i.e. TTS grows linearly with the logarithm of time (Hood, 1950). At low frequencies, the longer the noise is on, the more the reflex relaxes, so, the greater the effective level reaching the inner ear. The TTS increases as the exposure time increases.

No clear cut relationship between the amount of TTs and duration of exposure (from 0 to 250 minutes). (Axelsson and Lindgren (1978).

TTs generally grows with intensity of fatiguing stimulus. (Ward, 1963; Ward, 1965; Axelason and Lindgren, 1976; Moore, 1977).

Doy (1970) said that in the region of 30 minutes to 2 hours, noise bands yield approximately one more dB of TTS_2 per each dB increase in level.

Davis et al (1950) noticed that TTS observed for 130 dB SPL noiae was less than TTs for 120 dB SPL. His observation was confirmed by Trittipoe (1958), Miller (1958), and Ward (1962). The most likely explanation for this might be that the mode of vibration of the stapes may change at high levels, a change that is inturn produced by the maximum contraction of the middle ear muscles (Bekesy, 1949).

The frequency range in which TTs occurs depends on the stimulus. In case of broad band noise, the maximal TTS will be seen at 3000-6000Hz range where as in case of pure tones and narrow band noise maximum TTS is observed at a frequency higher than that of a TTS producing sound i.e. from 1/2 to 1 and 1½ octave higher (Ward, 1965). TTs apparently involves areas on the basilar membrane. At low produced at the stimulation maximum effect is produced at the stimulation frequency, less at adjacent frequency. With the increase in intensity, the high frequencies are more affected than the lower (Ward, 1963).

The range from 3000 to 6000Hz. is most susceptible to TTS (Rintlemann et al, 1972).

Mills et al (1983) found that maximum TTS observed for noise of 63, 125 and 250Hz (low frequencies) were in the frequency regions of better auditory sensitivity.

In general the higher the exposure frequency upto to 4-6Hz, the greater the TTS produced (Ward, 1963; Albert,1979). Greater TTs are produced by pure tones than by noise bands at frequencies below 2KHz, because noise is a better stimulus for sustained middle ear muscle contraction which protects the cochlea. Intermittent exposure produces fairly complex results. For high frequency sounds the amount of TTS produced is proportional to the total length of time of exposure. For intermittent low frequency sounds, the amount of TTS produced is leas because of the middle ear muscle activity. While the higher frequencies at and above, 3000CPS are resistant to TTS for only about 2 minutes 1000CPS shows no TTs upto approximately 15 minutes of noise exposure (Carso, 1967).

Ward (1966) said that TTs of a magnitude large enough to be readily noticed by a listener, often after only, 1 or 2 hours of exposure to pop music, should, however, serve as a warning to those affected by the possibility of damage of their hearing, if such exposure is repeated frequently.

'TTS' or 'auditory fatigue' being a vast area, the review of literature has been done only on some selected areas which are relevant to the present study.

Ear difference in TTS:

During the past few years, much attention has been devoted to the study of ear difference in the processing of auditory stimuli (Davis and Weiler, i978).

If the auditory tests consisting of melodies are presented dichotically, the score for the left ear is higher than that for the right, so, in nonverbal perception, tha role of right and left hemispheres is different than that of speech. (Kimurs, 1964y King and Kimura, 1972).

In 1970, spellacy and Blumstein reported data which suggested that when normal hearing, subjects are asked to recall or identify dichotically presented stimuli one ear was said to perform over the other. Other studies have shown that when the stimuli is long, the right ear become dominant (3hankweiler and studdert Kennedy, 1967; Kimura and Foeb, 1964). Left ear appears to be dominant ear when the stimuli are not complex language sounds (Kimura, 1964; Curry, 1967). When the input is nonverbal left ear is found to be superior in a dichotic listening task. (Kimura, 1964; 1967; Chaney and Webster, 1966; Bryden, 1967; Curry, 1967; 1968; Murphy and Venables, 1969; Gordon, 1970; Spellacy, 1970), and Right ear for verbal stimuli. These findings are said to reflect differential roles of the 2 hemispheres, since each hemisphere perceives better input from the contralateral ear (Kimura, 1967).

Ear difference in auditory fatigue has been reported by many investigators. On the other hand, some investigators did not observe any ear difference in TTS.

Waldron and McNee (1963) conducted a study to find out 'do the left and right ears of an individual experience the same degree of threshold shift and recover at the same degree when subjected to white noise of relatively high intensity levels'. Results indicated that the answer is in the negative.

Glorig and Rogers (1965) found that right ear was better in high frequencies and left ear in the low frequencies when TTS was measured after exposure to noise.

Ward (1967) pointed out that the same ear may also exhibit different susceptibilities to different frequency bands.

Ulrich and Pinheiro (1974) randomly selected 14 teenagers who were exposed to long hours of highly amplified live rock and roll sessions. They obtained the hearing thresholds of the subjects before and 30 minutes after each rock and roll session (250-8000 Hz frequency range) the sound pressure levels were ranging from 90-115dB at various positions around the stage. The loudest range of the spectral distributions was from 75Hz to 1200HZ with a slight peak between 300Hz to 600Hz. When the post-exposure thresholds for first and last sessions were statistically compared, the left ear showed a significant increase in TTs at 4KHz for the last session and a significant decrease in TTs at 500Hz and 1KHz. The right ear had significantly greater TTS at lKHz and at 4KHz for the last exposure with an increment in threshold shift apparent at all test frequencies.

Jerger's (1970) study showed similar differential effects in the TTs in the 2 ears of the performers.

Jerger and Jerger (1970) measured the auditory sensitivity of 2 groups of rock and roll musicians before and after (within one hour) the concert. They found that the pre- and post exposure sensitivity was fairly normal, but 14—15 years old musicians' post exposure audiogram showed substantial TTs at high frequencies especially in the left ear. Overall sound pressure level was 100-116 dB SPL.

Weiler et al (1974) investigated the hearing of teenagers who voluntarily exposed themselves to repeated session of loudly amplified pop music. Hearing thresholds were measured before and 30 minutes after exposure for 8 weekly sessions of rock and roll music with an average SPL (Sound Pressure Level) of 110dB to 115dB. Significant TTs were found in all subjects, especially high frequencies. The exposure had differential effects on the ears at the same test frequency.

The left ear Showed a significant increase in TTS at 4KHz for the last session and a significant decrease in TTs at 500Hz and 1KHz. The right ear had significantly greater TTs at 1KHz, and at 4KHz for the last exposure with an increment in threshold shift apparent at all test frequencies. The average TTS was greater at 250Hz and 500Hz in right ear. The left ear had more TTS that right ear at 1KHz and 2KHz and the right ear had more TTs at 4KHz and 8KHz than left ear. The projset followed the subjects through a series of weekly exposure to rock and roll music. Mean right ear TTs was greater for the final exposure at all frequencies, left ear TTS for the final session only at frequencies above 2 KHz.

There is no ear difference as far as TTS and its recovery are concerned (Bishnoi, 1975). He used 2KHz tone as fatiguing stimulus at 80dB and measured TTS at 4KHz.

Axelsson and Lindgren (1977) found a clear difference between the right ear and left ear in that the left ear was better in high frequencies.

Sreemathi (1981) studied ear difference in TTS at 1KHz and 4KHz (500Hz and 2KHz tone were used as fatiguing stimuli at 120 dB SPL) and found that there is no significant difference in TTS between left ear and right ear.

Gunja (1984) studied ear difference in TTs for binaural stimulation at equal intensity levels and for equal duration of exposure at 4KHz and 8KHz. Results showed that there were a significant differences in TTS_0 and TTS_2 at 4KHz and no significant differences between 2 ears at 8KHz. She explained the significant difference observed at 4KHz as it might be due to the influence of crossed olivo cochlear bundle. The action of the efferent auditory system appears to be more intense in the right ear than left ear during binaural stimulation as the subjects showed greater TTS in the right ear than the left ear. Gunja (1984) she explained the absence of ear difference at 8KHz in terms of Dayal's (1972) observation that the crossed olivo cochlear bundle has no effect on the adaptation mechanism at high frequencies.

Ulrich and Pinheiro (1974) tried to explain their finding i.e. in their study on TTs they found that the average TTs was greater at 250Hz and 500Hz in right ear. The left ear had more TTS than right ear at 1KHz and 2KHz and right ear had more TTS at 4KHz and 8KHz than the left ear. According to them 'it is difficult to determine the reason for such difference in suscep-tibility. One can hypothesize that the microscopic physical variations between the 2 ears in the positions or angle of the cochlear duct relative to the oval window could be responsible. Such a difference might cause the fluid pressure waves in the inner ear to stress the sensory structures at slightly different points'. In their study, while the mean right ear TTs was greater for the final exposure at all frequencies, left ear TTS for the final session was greater than after the 1st session only at frequencies above 2KHz. Part of the explanation for this result might be that the left ear suffered more initial TTS than the right ear in the low frequencies. The smaller TTS after final exposure might indicate that the inner ear had already undergone physiological changes so that lateral inhibition along the cochlear partition was affected, making hearing appear more sensitive to clinical testing. The mean left ear TTS at 1KHz was initially greater than that of right ear at the same frequency, with the higher frequencies in the mid lower basal turn of the cochlea greately depressed, the inner ear response to lower frequencies farther along the basilar membrane might have bean protected or leas inhibited by lateral inhibition.

In 1976 Weiler, Delast and Carmichael reported significant ear difference using a binaural, simultaneous dichotic adaptation technique. The right and left ears yielded 3 and 6dB of adaptation respectively to a 500Hz adapting tone at 60dB SPL.

Davis and Weiler (1978) found auditory adaptation in both the ears using monaural heterophonic balance technique. Left ear showed significantly low adaptation.

Binaural and monaural stimulation in TTs:

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 stimuli. (Hirsh,1958; Loeb and Riopelle, 1960; Ward, 1965; Karlovich et al, 1972; Karlovich et al, 1974).

Melnick (1967) measured monaural TTs following 2 minutes of exposure under 3 condition of presentations; monaural, binaurally in phase and binaurally out of phase by 180'. TTS was greater for monaural than binaural exposure conditions.

Guiot (1969) compared the TTss produced by exposure to pulsed monaural and pulsed alternate binaural high Intensity stimuli in 7 subjects/and found that all showed greater TTS for monaural exposures than for binaural except in 3 cases. He explained this interms of middle ear muscle activity.

Shivashankar (1976) studied the differences in TTS between monaural and binaural exposures to high frequency tones (2, 3, and 4KHz) at high intensity levels (126dB SPL) for equal duration of time. It was found that there was no significant difference in TTs between monaural and binaural exposure. This could be attributed to the action of hemolateral olivo cochlear bundle which might inhibit the responses of the higher centres, as crossed olivo eochlear bundle does not play a role in the adaptation mechanism at high frequency. (Dayal, 1972).

The TTS reduces in the presence of contralateral stimulation due to efferent action (Cody, and Johnstone, 1982, Sinha 1984). In coatralateral stimulation efferent action is present whereas in monaural stimulation no efferent action will be there. This might be a possible reason for reduced TTS for binaural stimulation.

Ward (1965) postulated that the acoustic reflex is stimulated by the loudness rather than by the energy of a signal and so decided that TTS ought to be leas for binaural stimulation than for monaural stimulation. He reasoned that the summed loudness would produce greater contraction of the middle ear muscles and thus would afford greater protection from any given high level of noise and this difference is more at lowest frequencies. He also suggested that the other influences might lead to a similar effect and listed efferent and cochleo - cochlear pathways as possibilities. Simmons' (1965) study on similar lines confirmed the liklihood that muscle contraction is the effective reason.

Sex differences in TTs: Studies of difference between males and females in temporary noise effects are scarce.

If one exposes normal hearing college students of both sexes to the same noise, the man and women dhow equal TTS (Ward, et al. 1959).

Several studies have shown that women have better hearing than men, even when the noise exposure has been equal in 2 groups (Kylin, 1960; Dieroff, 1961).

Loeb and Fletcher (1963) found no significant difference between males and females in amount of TTS at 4KHz, but discovered a greater amount of TTS in females at 2KHz which was statistically significant. From the middle ear muscle reflex activity studies Ward (1966) suggested that females have more efficient middle ear muscles than males. He observed that females 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. In contrast, shallop (1967) using impedance change as a dependant variable, did not find any difference between males and females, when the middle ear muscles were activated by a eontralateral acoustic stimulation.

Nerbonne and Hardick (1971), Karlovich et al (1972) also reported aa absence of the significance difference in TTS magnitude between males and females, however, the former reported a faster recovery rate in females.

Smitley and Rintleman (1971) did not demonstrate any differences between the man TTS in men and women in their study.

There is no difference either in the initial magnitude of TTS or in recovery from it in the male and female group (Bishnoi, 1975).

Axelsson and Lindgren (1978) reported that male listeners have a broader range of TTS affecting all frequencies from 1 to 8KHz while female listeners ere only affected at 3, 4 and 6KHz. At all frequencies males had more TTS than the females.

There is no significant difference between the male and female group with regard to the mean TTs at 2KHz and TTs at 4KHZ (Zakaria, 1980). sreemathi (1981) studied sex difference in TTS at 1KHz and 4KHz and found that there is no significance, difference in TTS between males and females.

Axelsson and Lindgren (1981) found frequency specific differences between males and females in TTS. Female discotheque patrone experienced more TTS at 3 and 4KHz than did males. Males exhibited TTS at all frequencies tested (l-8KHz) while females exhibited TTS only between 3 and 6KHz.

Chermak et al found gender difference in TTS measures with repeated noise exposure. Under these conditions of cumulative noise effects females revealed greater TTs at 4KHz than did the males. This difference may be due to hormonal differences (Dengerink et al 1984). Dengerink et al (1984) found that females using oral contraceptives showed greater TTs at 4KHz than males or females who do not use cral contraceptives. Difference in TTS between males and normally cycling females were not observed.

Petiot and Parrot (1984) did not find any significant sex differences in auditory fatigue at either 4KHz or 6KHz When TTS was induced by a 20 minutes exposure to continuous pink noise at 105 dS (a) transmitted through earphones. However, the mean recovery rate appeared to be higher in women than in men at both frequencies and it was significant at 6KHz.

There is no significant difference in TTS among males and females, however males showed greater amount of TTS as compared to females. There is no significant difference in rate of recovery among males and females, however females showed faster rate of recovery than males (Nigam, 1987).

Physiological correlates of TTS:

Many authors state that auditory fatigue is a peripheral or cochlear phenomena based on the result that very loud sounds produce histologically verifiable cochlear damage.

The basic mechanisms involved in auditory fatigue are moat probably associated with the organ of corti.

Very few studies have attempted to determine the underlying physiological basis of auditory fatigue (Ward. 1963).

Since TTS is usually frequency specific damage or malfunction must be confined to a certain area of the cochlear partition, since more effect is found at frequencies above the stimulus frequency than below it, the localized TTS process is certainly correlated with tne gross pattern of movement of the Basilar membrane (Bekesy, 1949).

Davis et al (1960) suggested that TTs effects are related to temporary damage to the organ of corti. Hood (1950) related some of his findings to equilibrium and some to place sad frequency theories of the action of cochlea. Rosenblith (1950) tried to formulated a theory regarding the mechanism of TTs. He suggested that TTs is explicable in terms of residual masking. This theory is supplemented by the work of Van Dishoek (1953),Miler (i958). Hallpike and Hood (1951) concluded that TTs is associated with subnormal functioning of organ of corti. Fodor (1942),Jerger (1955) etc. also indicated the importance of inner ear in mediating TTS. Hughes and Rosenblith (1957) have shown that recovery of the cochlear microphonics exhibits many similarities and recovery from TTs.

In auditory fatigue, there are many mechanical,electrical and chemical changes occur at or near the hair cells.

Wusteinfeld (1957) studied the size of the hair cells in the fatigued ears of guinea pigs. He found that with exposure to high frequency tones nuclei of hair cells in the basal region swelled to many time their normal volume and similarly for cells in the apical region following exposure to low frequency tones. This was true only for the outer hair cells, nuclei of the inner hair cells remained nearly unchanged. But Ward (1963) says that 'still, we do not know whether they are the basic causesfor fatigue or are simply epiphenomena'. Future research should confirm this.

Fatigue is connected with hair cell changes (Moore, 1977).

Tobias (1972) said that one of the physiologic responses to high noise stimulation is constriction of the Veins and arteries and so, the blood supply of the inner ear region also reduces. Lawrence et al (1967) concluded that the reduction of blood supply in the vicinity of the inner ear sensory cells may account for TTs, which of course may revert to permanent damage if the blood supply is cut off for long periods.

Legouix and Pierson (1981) suggested that there are mechanical, biochemicals, hydrodynamic processes involved in post stimulatory depression of cochlear potentials. Further, they stated that the locus of both temporary and permanent threshold fatigue or damage appears to be in the hair cells and their supporting cells in the basilar membrane.

Lawrence et al (1967), Hawkins (1971) suggested that TTS is due to the vasoconstriction of arteries and veins due to noise which inturn results in reduced blood supply to cochlea. In contrast, Perlman and Kimura (1962) did not observe any change in the capillaries in the apical part of the guinea pig cochlea during the presentation of low frequency tones. Moreover, various facts do not support a causal relation between vasoconstriction and injury to hair cells. Duvall et al (1974) reported that damage to the hair cells occur before the changes in the stria vascularis and Hawkins (1976) found strial edema and loss of suprastrial cells in Chinchillas while no alterations of the hair cells was detectable.

Another aspect of the biochemical changes that occur in the organ of corti under the 'influence of noise is the alteration of the ionic content of the fluids and of the hair cells. Misrahy et al (1958) suggested that the acoustic vibrations could induce modifications in the permeability of the reticular membrane; leaving potassium ions to leak out from scala media and block the hair cells and the nerve endings. Tasaki and Fernandez (1952) have shown that when the potassium content of perilymph is increased, cochlear responses are reversibly depressed. In addition to permeability changes, it is possible that active transports are also disturbed following noise exposures.

In 1963, Wernick and Tobias reported a central factor of auditory fatigue in humans. They showed that the TTs, from low or high level sound exposures, was more when the subject was given a mental task. The existence of a central influence on auditory fatigue was also observed by Rawson-Smith (1936), Fricke (1966), Smith and Loeb (1967) etc. However, reports by Ward and sweet (1963), Sell and stern (1964), Riach and Sheposh (1964), Capps and Collina (1965) have not been unanimous in support of the- Wernick and Tobias'(1963) results, some of these authors have pointed out that the degree and time course of TTs may be affected by the cochle to-cochlear or olivo cochlear auditory mechanisms. Recent reports indicate that the cochlea is perhaps not the only site of auditory fatigue (Babighian, 1972).

Babighian et al (1975) studied TTS in 8 Kangaroo rates based on evoked responses and single neuron responses. Their study revealed that there is a central involvement in auditory fatigue.

Price and Oatman (1967) call central factor in auditory fatigue as an artifact - 'The effect interpreted earlier as being the influence of a central factor seems to be procedural artifact'. Thus, the presence or absence of central factor in auditory fatigue is still unresolved.

Prom the review of literature on TTS, we can see that there is no pertinent literature available on ear difference in TTS for monaural stimulation at low frequencies and hence this study has been proposed to be undertaken with the hope that it might throw some light on this area.

METHODOLOGY

Subjects:

10 male subjects having normal hearing in the age range of 17-27 years were selected from the student population of All India Institute of Speech and Hearing, Mysore.

The subjects selected for the study, had no history of any ear discharge, sarache, tinnitus, giddiness,headache, brain damage or exposure to loud sounds.

All the subjects had hearing sensitivity within 20 dB HL (ANSI, 1969) in the frequencies 250Hz, 500H2, 1KHz, 2KHz, 4KHz, and 8KHz.

Instrument Used:

Grason-Staddler Audiometer (GSI-10) with TDH-50P earphones with supra aural cushions was used. The audiometer was calibrated according to the specifications given by ANSI (1969).

Test environment:

The study was carried out in an acoustically sound treated room at All India Institute of speech and Hearing. The ambient noise levels present in the test room was below the proposed maximum allowable noise levels.

Procedure:

All the subjects were screened at 20dB HL in the frequencies 250-8000Hz to find the presence or absence of a hearing loss in both the ears.

Thresholds were established for 2KHz for right ear at first using a pulsed tone (200/200). The subjects were exposured to 1KHz tone at 1OOdB HL in the right ear for 5 minutes.

*TTS was then determined in the right ear.

1) immediately after the cessation of the stimulus (TTS_0)
2) after one minute of recovery time (TTS_1).
3) After 2 minutes of recovery time (TTS_2).

A minimum of 24 hours rest period was given to each subject and the same procedure was repeated to obtain TTS_0, TTS_1 and TTS_2 ia the left ear.

The data was then analysed statistically using 'the Mann-Whitney U-test of significance.

*TTS = threshold at 2KHz after the exposure to pure tone for 5 minutes - threshold at 2KHz before the exposure to pure tone for 5 minutes.

RESULTS AND DISCUSSIONS

The results were analysed statistically using Mann-Whitney U test of significance. Tables i(a) and K b) show the temporary threshold shifts (TTS_0 ,TTS_1 ,TTS_2) at 2KHz in right ear and left ear respectively. The results show that majority {7 out of 10) of the subjects had higher thresholds and in the right ear that in the left ear at TTSL* VTS* and TTS-. One subject showed higher threshold^ in the left ear and two subjects showed equal thresholds in both the ears at TTS_0, TTS_1, TTS_2.

Tables 2(a), and 2(b), show mean and standard deviation for TTS_0, TTS_1, TTS_2 at 2KHz in the right and left ear respectively. No significant difference between the values has been observed in all 3 conditions.though the mean TTS values of right ear were more than those of left ear.

Table-3 gives the results of Mann-Whitney U test. If gives the values of U for TTS_0,TTS_1,TTS_2 measured at 2KHz. The results show that 'U' values for TTS_0,TTS_1,TTS_2- measured at 2KHz are greater than U values given in the table for the test of significance. The test says that if the U values is equal to or less than the value in the table. then the null hypothesis is rejected at that particular level of significance.

According to the results obtained from the study, the hypothesis! "There is no significant ear difference in TTS produced by monaural stimulation at equal intensity levels and for equal duration of exposure has been accepted at TTS measured at 2KHz.

Thus in the present study, no significant difference was observed in TTS at 2KHz between the right and left ears for monaural stimulation (1KHz) at equal intensity levels (100d8 HL) presented for equal duration of exposure (5 minutes).

The graphs show mean TTS_0, TTS_1 and TTS_2 in right ear and left ear at 2KHz Respectively.

Table-l(a): Temporary threshold shifts (TTS_0, TTS_1, TTS_2) at 2KHz in right ear (Fatiguing stimulus - 1KHz at 100dB)

subject / in aB	1	2	3	4	5	6	7	8	9	10
TTS_0	13	25	25	15	10	10	25	20	20	25
TTS_1	10	20	15	10	10	10	20	15	15	20
TTS_2	10	15	15	10	10	10	20	15	15	20

Table-1(b): Temporary threshold shifts (TTS_0, TTS_1. TTS_2) at 2KHz in left ear (Fatiguing stimulus - 1KHz).

subject / in dB	1	2	3	4	5	6	7	8	9	10
TTS_0	15	15	10	10	5	20	20	15	20	15
TTS_1	10	15	10	5	5	20	15	15	10	15
TTS_2	10	5	10	5	0	20	15	15	10	15

Table-2(a): Mean and standard deviation (S.D) of TTS_0 TTS_1 and TTS_2 at 2KHz in right ear.

	Mean	S.D.
TTS_0 in dB	19	6.15
TTS_1 in dB	14.5	4.38
TTS_2 in dB	14	3.94

Table-2(b): Mean and Standard deviation of TTS_0, TTS_1 and TTS_2 at 2KHz in left ear.

	Mean	S.D.
TT_0 in dB	14.5	4.97
TTS_1 in dB	12	4.63
TTS_2 in dB	10.5	5.99

Table-3: Showing the results of Mama-Whitney - U test. Value of U.

	TTS_0	TTS_1	TTS_2
1KHz. measured at 2KHz.	29	36.5	43

Table value at 0.05 level of significance C=27

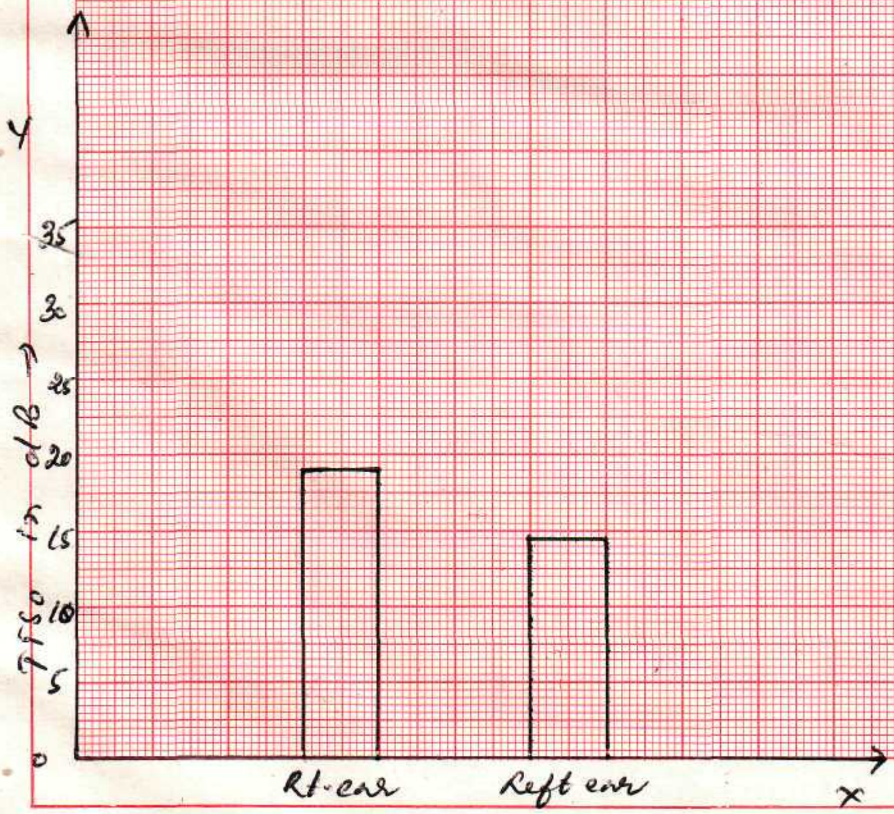
Table value at 0.01 level of significance -19

Discussions:

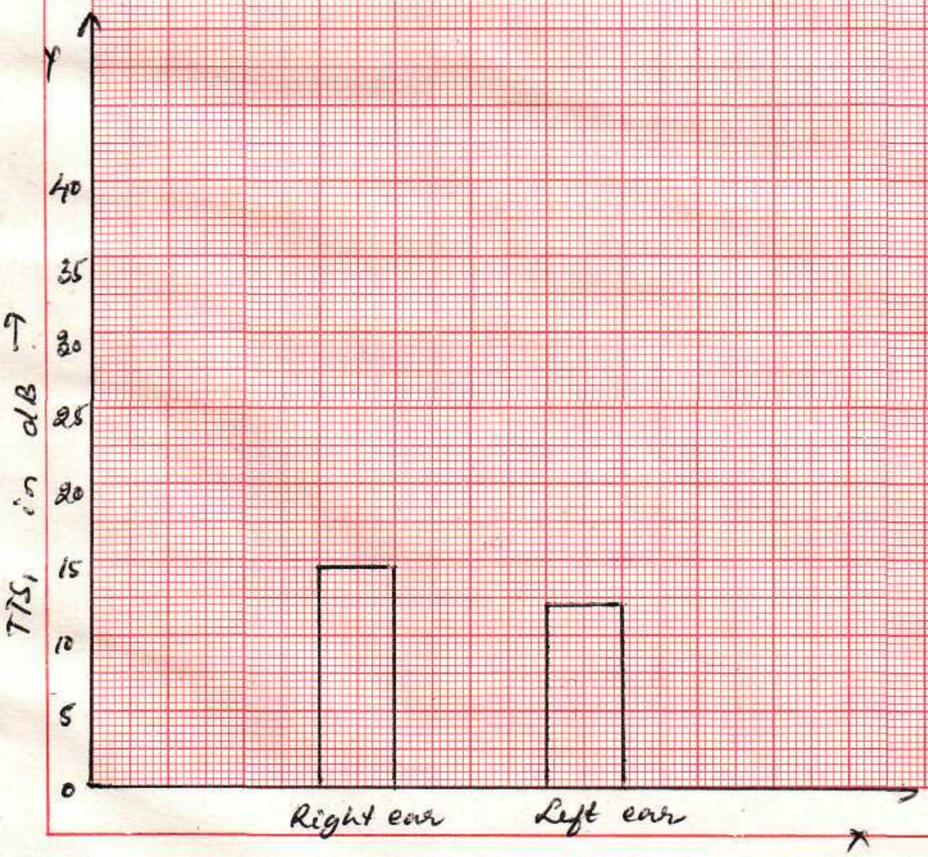
The present study shows that there is no significant difference in TTS at 2KHz between right and left ear for monaural stimulation using 1KHz pure tone at 100 dB HL presented for 5 minutes.

Ear difference in auditory fatigue has been studied by many authors. Glorig and Rogers (1965), Ward (1967), Jerger (1970), Ulrich and Pinheiro (1974), Jerger and Jerger (1970), Weiler et al (1974), Axelsson and Lindgren (1978), Gunja(1984) have reported significant ear difference in TTS. Whereas Waldron and McNee (1963) Bishnoi (1975), Sreemathi (1981), Gunja (1934) found no significant difference in TTs between the left ear and right ear.

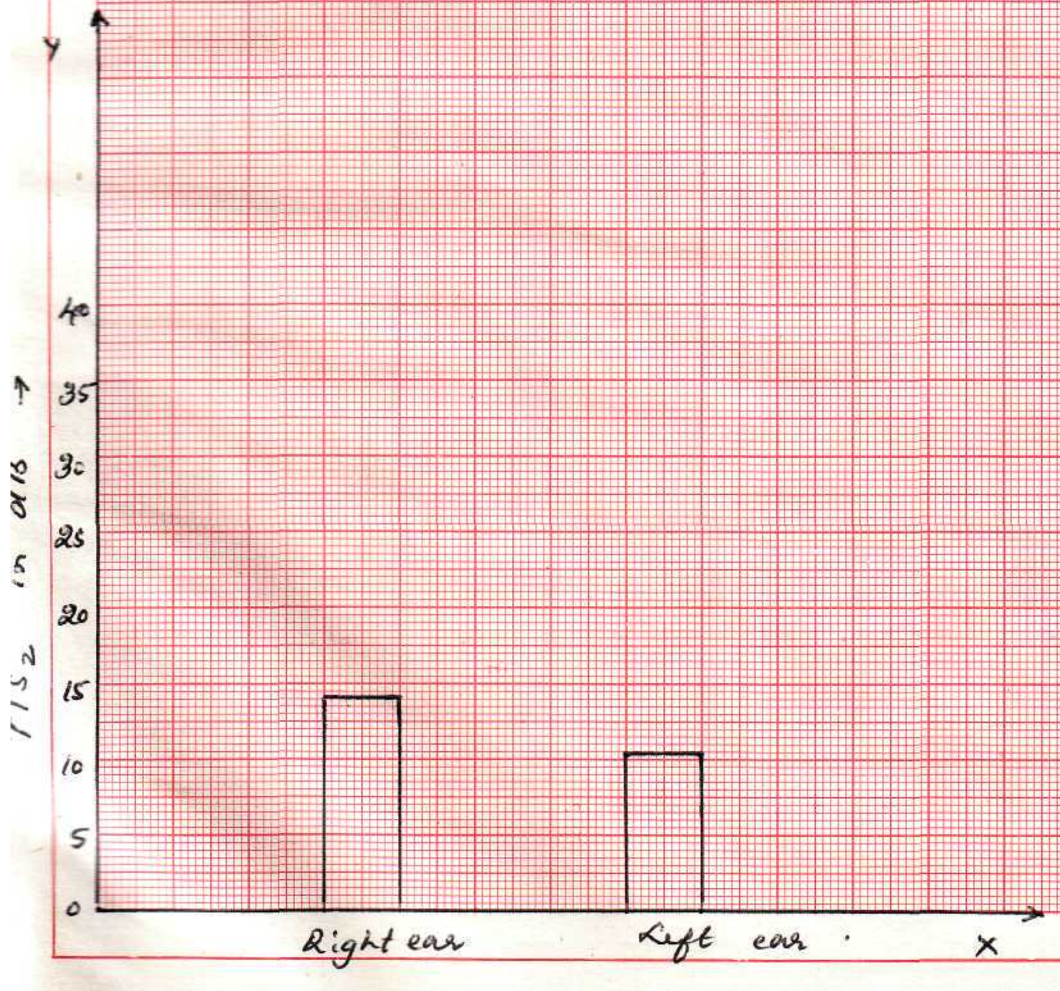
Mean TTS_0 in right ear & left ear at 2kHz.
(fatiguing stimulus is 1kHz tone at 100 dB HL
for 5 minutes.)



Mean TTS, in right ear & left ear at 2kHz.
(fatiguing stimulus is 1kHz tone at 100dBHL
for 5 minutes.)



Mean TTS_2 in right ear & left ear at 2 kHz.
(fatiguing stimulus is 1kHz tone at 100 dBHL for 5 minutes.)



TTS is considered as hair cell phenomena or due to temporary damage to organ of corti (Davis et al 1950; Corso, 1967; Hallpike and Hood, 1951 etc)the existence of a central influence on auditory fatigue has been observed by many authors (Rawson-smith, 1936; Wernick aad Tobias, 1963; Capps and Colline, 1965; Friche, 1966; Smith and Loeb, 1967 etc).

The present study agrees with the results of the studies conducted by Waldron and McNee (1963) Bishnoi (1975); sreemathi (1981) and others mentioned earlier.

SUMMARY AND CONCLUSIONS

The present study was aimed at investigating whether there is any significant ear difference in TTs for monaural stimulation at equal intensity level and for equal duration of time.

The GSI-10 audiometer with TDH-50P earphones with supra aural ear cushions calibrated according to the specifications given by AHSI, 1969 was used for the study. 10 normal male subjects were taken for the study. TTS_0, TTS_1 and TTS_2 were measured in the 10 subjects at 2KHz in the right ear and the left ear separately after they were being exposed to a fatiguing stimulus (1KHz at 100 dB HL) continuously for 5 minutes.

Conclusions:

l(a) There was no significant difference in TTS_0 at 2KHz between the right and left ears for monaural stimulation using 1KHz tone at 100d3 HL presented for 5 minutes continuous exposure.

(b) There was no significant difference in TTS_1 at 2KHz between the right and left ears for monaural stimulation using 1KHz tone at 100 dB HL presented for 5 minutes continuous exposure.

(c) There was no significant difference in TTS_2 at 2KHz between the right and left ears for monaural stimulation when 1KHz tone at 100dB HL presented for 5 minutes continuous exposure.

However, in all the 3 conditions majority of the subjects showed greater amount of TTS in the right ear though it was not statistically significant.

Recommendations for future research:-

1. Ear difference in TTs at frequencies other than 2KHz for monaural stimulations.
2. Ear difference in TTS for monaural stimulation in females at low frequencies.
3. Ear difference in TTs for monaural stimulation using narrow band noise in both the sexes.
4. Ear difference in TTS for monaural stimulation using broad band noise in both sexes.

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