SEX DIFFERENCE IN AUDITORY FATIGUE

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RAVI NIGAM

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To

PAPPA, MUMMY,
BIPIN & SHUNNY

CERTIFICATE

This is to certify that the Independent Project entitled "SEX DIFFERENCE IN AUDITORY FATIGUE" is the bonafide work on part fulfillment for the Degree of Master of science (speech and Hearing) of the student with Register No.8609.

Dr.M.Nithya Seelan
Director,
All India Institute of Speech and Hearing, Mysore - 570 006.

CERTIFICATE

This is to certify that the Independent Project entitled "SEX DIFFERENCE IN AUDITORY FATIGUE* has been prepared under my supervision and guidance.

Dr.M.N.Vyasamurthy
GUIDE

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The writing of acknowledgements after completion of a research project is a pleasant task for two reasons. It signals the completion of the study, but more importantly, it provides an opportunity to express indebtedness to those who have contributed to its completion.

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DECLARATION

I hereby declare that this Independent Project entitled: "SEX DIFFERENCE IN AUDITORY FATIGUE" is the result of my own study 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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INTRODUCTION

The reduction in sensitivity following exposure to any stimulus of significant duration is a common functional characteristic of all sensory systems. For some system the sensation following exposure to stimulus may disappear completely (eg. gustatory and olfactory sense). For others there is merely a reduction in apparent magnitude or an increase threshold (eg. auditory sense). In all cases such changes are temporary changes as long as the stimulation does not exceed critical limits, which is the case of everyday life for most receptory system.

For a long time the problem of auditory fatigue has been vexed with uncertainty and controversy as many of the relevant parameters intract with each other.

Auditory fatigue is one of a number of terms used to describe a temporary change in threshold sensitivity following exposure to another auditory stimuli (Ward, 1963).

Auditory fatigue is a time linked process which not only grows with duration of exposure but also disappear, more or less swiftly as function of time since exposure (Ward, 1963).

The most common index for auditory fatigue is the temporary threshold shift (TTS) which indicates any post-stimulatory temporary shift in auditory threshold that recovers over time (ward, 1963).

It is usually estimated by first determining the normal threshold than 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 et al 1970).

TTS has received a great deal of experimental attention since Urbeantschitsch's (1881) discovery of phenomenon (Ward, 1973). TTS or post-stimulatory fatigue has generated a number of interesting investigation both experimental and clinical and perhaps been the most studied after effect of auditory stimulation.

The range of individual differences in the amount of TTS produced my specific exposure to pure tones, noise, or impulse is quite large. Since exposure that produce more TTS in group of ears also tend to result eventually in more average permanent loss, it has been assumed that individual ears displaying the least TTS from a given short exposure at moderate level will be the moat resistant to permanent loss from either prolonged exposure to moderate levels or short exposures at extreme levels (Ward, 1963). Therefore through various measurement of TTS one might be able to predict individual differences in susceptibility to permanent damage from high intensity sound by means of individual differences in the TTS produced by a much less intense exposure.

It is recognised that five primary factors influence the size of the TTS: (I) Recovery process, (2) Intensity of the fatiguing stimulus, (3) Frequency of the fatiguing stimulus, (4) Duration of the fatiguing exposure and (5) Test frequent.

The careful observations have shown that women have better hearing than men, even when the noise exposure has been equal in the two groups (Kylin, 1960; Dieroff, 1961). However if one exposes normal hearing college students of both sexes to the same noise, the men and women show equal TTS (Ward at al, 1959).

Fletcher and Loeb (1963) found no significant difference between males and females in amount of TTS at 4KHz but did discover a significantly greater amount of TTS in females at 2KHz.

From the middle ear muscle reflex activity studies, Ward (1966) suggested that females have more efficient middle ear muscle than males, on the basis of TTS data which revealed that females displayed less TTS than males when exposed to a low frequency band of noise. But when a high frequency noise was used, females showed greater TTS. Further Nerbonne and Hardick (1971), Karlovich et al, (1972) also reported an absence of the significance differences in TTS magnitudes between males and females; however the former reported a faster recovery rate in females.

Axelsson and Lindgren (1978) studied TTS after exposing subjects to pop music and reported that males showed more TTS than the females at all frequencies from 1-8 KHZ while females were only affected at 3, 4 and 6KHz.

Inspite of many studies, the controversy still exists that whether any sex difference exists in auditory fatigue. The present study was planned to find answers to the following questions:

1. Is there a difference in amount of TTS produced among males and females.

2. Is there a difference in recovery rate after cessation of fatiguing stimulus among males and females.

Statement of the problem:

The present study was aimed at studying whether there is any significant difference between TTS produced and rate of recovery among males and females in order to arrive at some conclusions regarding the sex differences in the auditory fatigue.

Hypothesis of the study:

The present study was undertaken to verify the following null hypothesis.

- There is no significant difference in TTS produced among males and females.
- There is no significant difference in rate of recovery after the cessation of fatiguing stimulus among males and females.

Brief Plan of the Study:

10 males and 10 females subject with normal hearing at 20dB HL with no history to exposure to intense sound were exposed to 100 dB SPI, pure tone at 2 KHz for 10 minutes. Pre exposure and Post exposure threshold were determined at 4KHz, one octave higher than the fatiguing frequency, TTS_0, TTS_1 and TTS_2 were determined for each subject and statistical analysis was done to find the significance between the amount of TTS and rate of recovery among two groups

Definitions of the terms used in the study:

1. Temporary threshold shift(TTS):Refers to an elevation in threshold of hearing which recovers gradually following the noise exposure.
2. TTS_0: Temporary threshold shift measured just after the cessation of fatiguing stimulus.
3. TTS_1 :Temporary threshold shift measured one minute after the cessation of fatiguing stimulus.
4. TTS_2: Temporary threshold shift measured two minutes after the cessation of fatiguing stimulus.
5. Fatiguing Frequency: The frequency at which the ear was exposed continuously to produce the fatigue.
6. Test Frequency: The frequency at which the thresholds were determined after the ear was exposed to fatiguing stimulus.
7. Recovery period: Time between the cessation of fatiguing stimulus and threshold determination.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The experimental literature on auditory fatigue is discouragingly large. As a matter of fact, in auditory fatigue the unsolved problems greatly out number the established facts. No attempt haa been made here to review the literature related to auditory fatigue, as the detailed review concerned with temporary threshold shift - the most common index for auditory fatigue, haa been discussed by many investigators. (Elliot,et al. 1970, Ward, 1973; Bishnoi, 1974; Sreemathi, 1980).

The present review of literature is discussed under two main topics;

1) General information and factors affecting auditory fatigue.
2) Auditory fatigue and sex differences.

Auditory fatigue is one of a number of terms used to describe a temporary change in threshold sensitivity following exposure to another auditory stimuli (Ward, 1973).

The most common index for auditory fatigue is the temporary threshold shift (TTS) which has been an important topic for experimentation and discussion for the past 120 years and has been generating a number of interesting investigation both experimental and clinical.

It has been confirmed by number of authors (Ward, Glorig and Sklar, 1959; Nixon and Glorig, 1961; Kryter, 1963) that the temporary threshold shift and permanent threshold shift are closely related and therefore as part of the public interest in hearing conservation in recent years, audiologists and others have investigated extensively the relationship between loud noise and hearing threshold shifts whether permanent (PTS) or temporary (TTS). Temporary threshold shift are often used to predict noise induced hearing loss (NIHL) and various susceptibility tests have been devised. However, relation of TTS and NIHL has not been consistently found.

Ward (1963) has condemned the several findings related to TTS, and has contributed extensively in the area of TTS, Following is a brief summary of the different findings reported in the available literature on TTS.

I. RECOVERY FROM TTS:

Recovery process from TTS seems to be dependent on fewer of the stimulus parametres than the growth process. Once a given TTS has been generated, it tends, by and large, to recover at a certain rate that depends very little on how the TTS was produced (Ward, et al. 1959b; Kylin, 1960). Furthermore, the recovery is usually exponential in form - faster at first, then slowing down. The recovery process is linear in the logarithm of time.

The most well-known exception to the rule that recovery is linear in log time is the so-called "bounce" phenomenon that sometime occurs in the first 2 min. of recovery. In this condition the TTS measured after one minute will be greater than the TTS measured after 30 seconds of recovery time.

A second exception to the uniformity of recovery of TTS is found when TTS_2 is too great. If the exposure has been so severe that TTS- at some frequency exceeds about 50dB, then recovery instead of being linear in log tine, proceeds linearly in time (Ward. 1960b).

The recovery process seems to be relatively independent of test frequency. That is if TTS_2 is 25 dB then TTS_{100} will be about 10dB, whether the test frequency is 500 Hz or 5000Hz.

GROWTH OF TTS:

The growth of TTS is dependent on many factors. All the parameters which are measureable can affect the growth of TTS. If a pure tone is used as fatiguing stimulus, then the frequency, intensity, and duration are important factors which can affect the growth of TTS. For continues noise, the level, band width, duration, and peak factors are the salient aspects. In case of impulses and explosions, the peak intensity, rise time, number of impulses and duration of exposure all determine the TTS produced. If the fatiguer is a combination of tones and noises and/or pulses, still other rules seems to apply. If the fatiguing stimulus is intermittent or has time - varying frequency characteristics, the TTS produced will be less than that produced by the same amount of energy in a steady exposure (Ward, 1963).

Furthermore, the parameters are, in many cases, interactive, like duration, intensity frequency etc. effect each other in complex manner. Also there are large inter-individual variationa(Ward, 1963).

FACTORS AFFECTIMG AUDITORY FATIGUE:

I. INTENSITY:

Generally TTS grows with intensity. The growth of TTS with intensity depends on all the other parameters. The growth ia linear but if one waits for the short term (R-l) process to disappear by measuring the TTS only after 2 min. or more, the growth of TTS with intensity becomes even more linear (Ward, 1963).

For recovery times less than a second and longer than 2 min. the TTS ia proportional to the amount by which the sound pressure level exceeds some base value; this base value is 75dB for octave band noise (ward, 1963).

The main exception to this rule that TTS increases with intensity occurs at vary high levels (Davis et al,1950). It was observed that a given exposure to 130dB SPL sometime produced less TTS than the same exposure at 125dB SPL. The moat likely explanation for this reversal is that the mode of vibration of the stapea may change at very high levels, a change that is in turn produced by the maximum contraction of the middle ear muscles (Bekesy, 1949).

At intensity levels around 80-120dB SPL, middle ear muscles comes into action and thus increase in the amount of energy reaching cochlea is not linear. This effect is seen move at low frequencies than at frequencies higher than 2KHz (Ward, 1963).

II. TEST FREQUENCY:

TTS involves areas, not points, on the basilar membrane. At low levels of stimulation, the maximum effect is produced at the stimulation frequency less at adjacent frequencies. As one raises the level, however this no longer is universally true, instead, higher frequencies are sometimes more affected than lower (ward, 1963).

Maximum TTS induced by exposure to intense sound often occurs at frequencies above the exposure frequency (Davis et al, 1950 ; Ward, 1962). In fact, it is not uncommon to observe no TTS at the exposure frequency even though the exposure was intense enough to produce 15-20dB of TTS at higher frequencies (Hirsh and Bilger, 1955).

Generally the maximum TTS observed is half octave to an octave above the stimulating frequency (Ward, 1963), but it is important not to be misled by this title; the TTS maximum may occur at any frequency above the exposure frequency (McFadden and Plattsmier, 1983).

McFadden and Plattsmier (1983) studied the TTS for several different test frequency following exposure to a 2500Hz tone. The intensity of the exposure tone was varied from 82 to 97dB SPL for 5 or 10 minutes duration. In each post-exposure session, TTS was followed for four test frequencies. In all cases TTS pattern moved upward in frequency as exposure intensity increased.

Most of the investigation on TTS have been concerned with effects produced by sounds in the frequency range of 500Hz to 4000Hz. studies which have used band of noise or pure tones, between 63Hz and 250Hz (Burdick et al,1977; Patterson et al,1977; and Mills et al,1983) suggest that the rules for TTS produced by mid- and high frequency sound apply to TTS produce by low frequency sounds with exception that whereas TTS is greatest half octave or one octave above the centre frequency or upper cut off frequency of the noise (Ward, 1962; Yamamoto et al,1970), TTS from low frequency sound is greatest in frequency region of best auditory sensitivity (500Hz - 4000Hz) which can be 3-5 octaves above the exposure frequency.

The above characteristics of TTS from pure tones are also true of TTS produced by noise (Ward, 1962).

III EXPOSURE FREQUENCY:

The higher the exposure frequency* atleast upto 4000Hz - 6000Hz, the greater the TTS produced. Further, the pure tones are assumed to be more dangerous than octave bands of noise (Anonymous, 1956). However, this was an assumption based on the critical band hypothesis (Kryter, 1950) that if a given amount of energy were concentrated within a single critical band, it would be more dangerous than if it were spread over several critical bands. Pure tones below 2000Hz produce more TTS than corresponding octave bands of noise when both are at the same intensity. But the effect is adequately explained by the difference in the ability of the two stimuli to produce sustained reflex arousal of the middle ear muscles. When a pure tone ia presented, the muscles, after an initial contraction, rapidly relax. However a noise produced a more sustained reaction presumably because of it's random nature, which continuously reasouses the reflex. Therefore, more energy reaches the cochlea under pure tone exposure conditions, and the reflex and not the critical band hypothesis is the determining factor (ward, 1962b).

At low frequencies pure tones are more dangerous than noise, not because of "concentrating energy in small area" but because of the aural reflex. However at, high frequencies, the noise may even produce more TTS than the corresponding center frequency pure tone (Vyasamurthy et al,1974). Smith and Loeb (1968) found that higher the exposure frequency more the time to recover.

IV. DURATION OF EXPOSURE:

The TTS grows linearly with the logrithm of time. But at lower frequencies, the situation is complicated by the action of the reflex. The longer the noise is on, the more the muscle relaxes and so the greater is the effective level reaching the inner ear, ao the TTS gets positively accelerated. (selters, 1962).

The increase in TTS with exposure time is found under almost all conditions. The main exception is reported by Bentzen (1953) for very short values of recovery time. His test tone was 20- or 30 msec, pulse of the same frequency as the exposure pulses with a delay pause of 50 msec. Under these conditions, the TTS from moderate levels was the same for all exposure durations from 0.25 to 2 seconds (Cited by Ward, 1963).

V. <u>INTERMITTENT EXPOSURE:</u>

When the exposure is intermittent or varies in level, the action of middle ear muscles becomes much more important because even a short rest will at least partially restore their contractile strength.

Ward et al, (1958) have shown the relation, that if during the total exposure time (T), the exposure stimulus is only on a Certain fraction (R) of the time, then the TTS produced will be only R times as great as that produced by a continues exposure at that level. This relation holds for burst - durations ranging from a quarter of a second (Rol, 1956) upto 2 minutes (selters and Ward, 1962). For noise bursts shorter than 0.2 sec. or longer than 2-3 minutes somewhat more TTS is produced than as the fraction rule would predict. Furthermore, the rule also breaks down for combination of very small on-fraction (0.1 or below) and very high intensities (above 110dB).

Another principle applicable to intermittent noise, is that while the level is below the "Critical Level" (the level that just fails to produce TTS lasting 2 minutes or longer) or base value, recovery proceeds. Just as fast as if the ear were in complete silence (Ward, 1960a).

The rules applicable to intermittent noise exposure are known as "on-fraction" "exposure-equivalent" and "equivalent continues". Ward at al,(1959a, b) have derived some equations, and one of such is in the following form:-

$TTS=K_1 (S-So) (\log T-K_2) + K_3$ where (S-So) is the average value of the amount by which level S exceeds the base value (negative values excluded), T is the exposure time, and K_1, K2 and K_3 are constants. However, this form of equation holds for (l) exposure durations of 10 minutes or more; (2) Recovery times of 2 minutes or longer; (3) Exposure frequency 2000Hz or greater; (4) SPLs below 125dB SPL; and (5) For intermittent exposure, burst duration of from 1/4 seconds to 2 minutes.

MISCELLANEOUS FACTORS AFFECTING TTS:

In addition to the parameters which have discussed, many other conditions might be relevant in determining the exact values of TTS. Some of them are as follows:-

1) Interactive effects:– The course of the fatigue process at one area of the basilar membrane is relatively independent of conditions existing at other areas. It has been shown that though two noises were producing TTS at their own respective regions on basilar membrane, neither had any effect on the other. (Ward, 1961a).

2) Hearing level or resting threshold:- TTS is inversely proportional to hearing level i.e. if thresholds are higher, TTS produced is less. If a person is suffering from pure conductive hearing loss,

then all the energy of the fatiguer will not reach cochlea and thus he will have lesser shift than a normal hearing person when both are exposed to equal amount of noise. Individual with pure sensory hearing loss also will show less TTS than normal individuals, but only because they have less to lose, as it were. The energy entering the cochlea of such a person is no different from the normal case. (Ward, 1963).

3) Vibration:- Morita (1953) reported that when 10 subjects were exposed to 100dB white noise for 30 minutes while simultaneously being vibrated, the TTS was greater than if the lOOdB noise acted alone. This might be due to lessened protective effect of middle ear muscle due to vibration.

Yokoyama et al,(1974) studied the changes in auditory sensitivity with vibration and vibration - plus - noise. There were no significance change in threshold sensitivity after exposure to vibration alone. Exposure to vibration and noise simultaneously caused greater threshold shifts and longer recovery time than exposure to noise alone. They suggested that the effects of the combined noise and vibration might be the results of some disturbances of physiological homeostasis or possible mechanical interactions with it's blood supply.

4) Latent and residual effects:- Noises which fail to produce a measurable TTS_2 do not enhance to a measurable degree the magnitude of TTS produced by a subsequent exposure. Thus latent effects of stimulation are unimportant (Ward, 1960a).

Harris (1955) showed presence of residual effects. He restimulated his subjects many times after the TTS due to previous exposure reached zero. He found increments in TTS in every subsequent exposure.

5) Vitamin-A:- In subjects having diet containing reasonable amount of Vitamin-A, administration of vitamin-A does not effect the TTS and it's recovery. It is possible but not demonstrated yet, that deficiency of vitamin-A might change the course of auditory fatigue (Ward. 1963).

6) Oxygen:- It is known that adequate oxygen is necessary for normal functioning. But excess of O_2 does not have any effect on course of fatigue as already demonstrated. Anoxia causing increased TTS has not been demonstrated in humans but it is already shown in guinea pigs. Reduction in cochlear microphonics was more when the animals were in 10% oxygen state throughout the experiment (38 minutes) thaa when they were in 10% oxygen atmosphere for only 5 minutes (Hirsh and Ward, 1952).

7) Salt:- Cook (1952) speculated that excessive use of ordinary salt may cause the ear to become waterlogged and not only produce endolymphatic hydrops but also increased TTS. But it is only a speculation and no experimental data have been obtained in this direction.

8) Drugs:- Drugs, especially myorelaxina have effect i.e. more TTS is seen because middle ear muscles will be inoperative.

Lehnhardt (1959) reported that administration of Myorelaxin resulted an increase in TTS at and below 3000Hz and a decrease at and above 4000Hz.

9) Iris-Pigmentation:- subjects with highly pigmented irises (brown) experience less TTS than those with leas pigmented irises (blue) and that those with green-grey pigmentation display intermediate amount of TTS. Tota and Bocci (1967) noted high correlation between the melanin content in the strio-vascularis and that found in pigmentation of iris; they contributed their TTS difference across eye colour to the protective effects of melanin. The results of Karlovich (1975). study, however, do not support the hypothesis that individual with highly pigmented irises (brown-eyed) are more resistent to auditory fatigue than those with less pigmentation of iris (blue eyed).

10) Level of consciousness and central factors!- Chernyak (1958) reported a study where it was found that less TTS to be produced by a given noise if the subjects was hypnotized and told that he was in silence. Wernick and Tobias (1963) reported that when subjects were required to do mental arithmatic during exposure to fatiguing stimuli, they exhibited greater TTS, than when they were required to do no task.

But different findings have also been reported. Ward and Sweet (1963) exposed 12 subjects to a 4000Hz tone at 100dB SPL for 3 minutes under 2 conditions, (a) sitting quietly and (b) adding columns of the figures. Pre and past exposure thresholds at 5-6KHz were determined with Bekesy audiometry using interrupted tones.

No significant differences in TTS were found at any time after exposure, in fact the greatest mean difference at any time waa in opposite direction. The TTS at 2 minutes 15 seconds was 14dB for revire conditions aad 12 dB for the mental task. It is concluded that the efferent system need not be involved to account for any aspect of auditory fatigue.

In an electrophysiological study, Babighisn (1975) exposed rats to continuous sound. A decrease in cochlear microphonics, action potentials and impulses from inferior colliculus was found, But reduction in impulses from inferior colliculus was more and it was concluded that central factors were involved.

12) Binaural and Monoaural Stimulation:

Hirsh (1958) studied the monoaural TTS following monoaural and binaural exposure under 3 experimental conditions to ascertain whether or not TTS depends upon whether one ear or both ears were exposed to sound. The result showed that the TTS for 1KHz tone is the same whether the ear was tested alone, or both ears simultaneously.

Ward (1965) compared the TTS following monoaural and binaural exposures to three different high intensity stimuli. The maximum effect occured at 2KHz where the binaural exposure gave less TTS as compared to monoaural exposure. This reduction is TTS was explained in terms of feedback loop and it was reported that with the increased input when the second ear is stimulated, the total activity of reflex centre also increased in middle ear muscle activity.

Melnick (1967) found that more TTS occured when the exposure signal was 180° out of phase in the experiment on the effect of two interaural phase conditions for binaural exposure on threshold shift.

Shivashankar (1976) has reported that there is no significant difference in TTS between monoaural and binaural exposure to high frequencies tones, especially at 3000Hz at TTS_2. This could be explained in the light of the assumption made by Dayal (1973) that the action of homolateral Olivo-cochlear bundle which might inhibit the responses of the higher centres* as cross edolivo-cochlear bundle does not play a role in adaptation mechanism at high frequency.

13) <u>TTS and Ear Difference</u>:- Right and Left ears of human beings are often shown to be having differential abilities to process auditory stimuli. similarly, ear difference in auditory fatigue hag been reported.

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

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

Jerger (1976) showed similar differential effects in the TTS in the 2 ears.

Weiler at al (1974) investigated the hearing of teenagers who voluntarily exposed themselves to repeated sessions 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 of 110dB to 115dB. Significant TTS were found in all subjects, especially in high frequencies. The exposure had differential effects on the 2 cases at the same test frequencies. The left ear showed a significant increase in TTS at 4KHz for the last session and a significant decrease in TTS at 500Hz and 1000Hz. The right ear had significantly greater TTS at 1000Hz and at 4000Hz for the last exposure with an increment in threshold shift apparent in all test frequencies. The average TTS was greater at 250Hz and 500Hz in the right ear. The left ear had more TTS than right ear at 1000Hz and 2000Hz and right ear had more TTS at 4000Hz and 8000Hz than the left ear. The project 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 about 2000Hz.

Axelson and Lindgren (1977) determined hearing thresholds in 83 pop musicians average exposure time of 9 years and average weekly exposure time of 18 hours. In the analysis of the whole population there was a clear difference between the right ear and left ear in that the left ear was better in high frequency.

According to Weiler (1964), the microscopic physical variation between the 2 ears 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 structure at slightly different point.

14) TTS and articulation;- TTS is reported to be less while subjects articulate during exposure.

Shearer and Simmons (1965) observed changes in acoustic impedance associated with moderate intensity whispering and vowel /a/ phonation. Acoustic impedance change preceded in initiation of apeech sound by 65 to 100msec. or at least coincided with speech output.

The occurrence of acoustic impedance slightly before speech output would indicate that the stapedius muscle under these circumstances is activated concurrently with a speech musculature (Metz, 1946). so the middle ear activity is part of neurological pattern in the production of speech.

Another change in peripheral auditory transmission system is alteration in the vibration pattern of the stapes which reduces the motion of cochlear fluids (Bekesy, 1960).

The effects of humming were studied on TTS from a 5 minutes 500Hz 118dB SPL Exposure. The experimental technique consisted of measuring hearing threshold at 700Hz before and after exposure, this exposure being accompanied by the performance of a specific activity such a humming. Results indicated that TTS from the exposure accompanied by humming was significantly less than TTS from exposure without any supplementary activity (Benguerel and McBay, 1972).

Ward (1963) implied that the middle ear muscle reflex shows less adaptation and more potential for reactivation When a change or intermittent acoustic stimuli is presented to the ear. so the articulation causes continues reactivation thus less energy reaches cochlea and thus less TTS is observed.

Shreemathi (1981) has studied the effect of articulation on auditory fatigue. Subjects were asked to read a passage in experimental condition. TTS in experimental condition was lesser than TTS in control situation in which subjects maintained silence. This effect was seen at 1000Hz but not at 4000Hz where middle ear reflex function is not effective.

AUDITORY FATIGUE AND SEX DIFFERENCES:

Hearing surveys invariably indicate that women have more sensitive hearing than men at high frequencies by the time they reach their 20's and that the difference increase with age.

Wisconsin State fair survey (1954) as a function of frequency and age decades show that no difference in hearing level between sexes in the 10 to 19 age group. The survey shows women have greater sensitivity. This implies that the differences that becomes apparent in older groups represent a more rapid decrement in hearing in men than in women, not an inherent initial difference in sensitivity.

The explanation that comes first to mind is that men are more exposed than women to auditory hazard such as industrial noise, gunfire, fireworks, sad blows on head. However, it is also reported that, even when male and female work side by side in a noisy industry, mea show a greater hearing loss than females - more apparently, then one would expect if the only difference in total exposure were sociocusic.

It is therefore reasonable in view of the characteristically greater resistance of women to diverse and debilitation in general, to ask if perhaps females are not simply less susceptible to hearing loss than male, other things being equal.

Now the trouble with industrial hearing loss data is that other things are not equal. Even when male and female workers work in same noise, female still get less average exposure than male: they take longer and more frequency rest periods and more sick leaves (Glorig, 1966). Furthermore, a process of selection may be acting a differential manner; the economic necessity for remaining on a noisy jobi s often greater for male than female,so the more susceptible famale may guit after a day or two, while the more susceptible male cannot.

An experiment was designed (Ward, 1959) to test the hypothesis that there is a difference between men and women in susceptibility to TTS. The TTS at 3000 and 4000Hz produced by a one hour exposure to a noise of 1200-2400Hz at 100dB SPL was measured on 30 normal hearing college students 15 men and 15 women. The TTS was again measured at the end of the exposure and also at 17.47 and 90 minutes after cessation of the noise. Women showed slightly less TTS than men, the differences were not significant. They concluded that no apparent sex linked.difference existed between males and females in the amount of TTs experienced or in the role of recovery from the exposure.

Fletcher and Loeb (1963) also investigated the relationship between sex and susceptibility to TTS, exposing 50 men and 50 women with normal hearing to 12 minute of a 1.2 - 2.4 KHz band of random noise at 110 dB SPL. They found no difference between males and females in the amount of TTS experienced at 4 KHz, but did discover a significant greater amount of TTS in the females at 2KHz.

Ward (1966) made various measurements of TTS from high intensity tones and noise were made on 24 males and 25 females young normal hearing adults. Significantly more TTS was produced in males by low frequency stimuli (below 1000Hz) and significantly less by high frequency stimuli (above 2800 Hz). No difference between sexes in TTS from low intensity (40dB SL) in auditory adaptation, in rate of recovery from a fixed value of TTS, or in TTS produced by impulse noise could be demonstrated. Male showed about 30% more TTS than female following low frequency (700Hz and below) exposure, about 30% less following high frequency exposure, with a neutral point at about 2000Hz. The female showed a greater diminution in TTS produced by intermittent noise relative to that from a continuous noise.

There data are constant with the hypothesis that female have more efficient middle ear muscle than male, provided that strong contraction of these muscles not only reduces the transmission of low frequency energy that also enhances the transmission of high frequency sounds (Ward, 1966).

No difference were observed in TTS from widely spaced impulses or low intensity tones, in auditory adaptation at 1000Hz or in rate of recovery from TTS of 20dB, 2 minutes after exposure. These results imply that there are no sex linked differences in the fragility of the sensory structure on the basilar membrane or serve in fatigability (Ward, 1966).

When exposure to 1400-2800Hz noise was effected via a loud-speaker that the subjects faced, rather than via earphones, the male showed more TTS than the female. Part of this effect can be acribed to the fact that men's external ears collect more sounds than women's being both larger and projecting farther from the head (Ward, 1966).

Ward (1966) based on the above results suggested that female should be placed in occupation with intense low frequency energy, while males should be working in intense high frequency noise.

Smitley and Rintelmon (1971) did not demonstrate any difference between the mean TTS in men and women in their study.

Nerbonne and Hardick (1971) exposed 10 men and 10 women to 110dB SPL of broad band noise on four separate occasions for 5 minutes. Each subjects threshold at 4000Hz was determined after 1, 9,19 and 29 minutes of recovery. Even though the 2 groups expe-rienced similar amounts of TTS immediately following exposure the females rate of recovery was more rapid, even when the initial amount of TTS was held constant for each sex.

Axelsson and Lindgren (1978) studied TTS after exposing subjects to pop music. Subjects were pop musicians and listeners. Both male and female listeners had a slight hearing loss 6000Hz prior to exposure. Male listeners have a broader range of TTS affecting all frequencies from 1-8 KHz, while female listeners were only affected at 3, 4, and 6KHz. At every frequency the male listeners showed more TTS than the female listeners. Axelsson and Lindgren speculated that male, listeners with a higher incidence of exposure to noise from different sources may have less reserve capacity of the sensory cells which is reflected in greater susceptibility to TTS.

METHODOLOGY

METHODOLOGY

Subjects:

Twenty subjects (10 males and 10 females) from the student population of All India Institute of Speech and Hearing, in the age range of 17 to 23 years, were selected for this study. The selection of subjects was done mainly on random basis.

The subjects were selected on the following criteria:

1. They should not have had any history of chronic ear discharge, tinnitus, ear ache, headache, giddiness exposure to loud noise or any other otologic complaints.
2. Hearing sensitivity within 20 dB HL (ANSI 1969) for the frequencies, 250Hz, 500Hz, 1KHz, 2KHz, 4KHz and 8KHz.

Instrument used:

GSI-10 Audiometer with TDH-50p earphone and P/N 510 Co 17-1 aural cushion was used. The audiometer was calibrated according to the specifications given by ANSI 1969, ISO 1975.

The equipment had built in time system from which the duration of stimulus and measurement after cessation of stimulus was done.

Test environment:

The study was carried out in acoustically sound treated room at the Department of Audiology, All India Institute of

Speech and Hearing, Mysore. The ambient noise level present in the test room were below the proposed maximum allowable noise level. Testing was done in a two-room situation.

Procedure:

All the subjects were screened at 20dB HL in the frequencies 250Hz, 500Hz, 1KHz, 2KHz, 4KHz and 8KHz to find the presence or absence of a hearing loss in both the ears.

Thresholds were established for the right ear at 4000Hz using Modified Hughson-Westlake procedure with pulsed tone.

Instructions:

"Now I will present a tone at high intensity in one of your ears continuously for 10 minutes. You don't have to respond to this tone by listing your finger. All you have to do is to keep quiet. Head movements of any sort should be avoided. Unnecessary clearing of your throat, coughing, yawning or swallowing and any excessive bodily movements should be avoided".

The reason for avoiding unnecessary movements was that these activities elicit middle ear muscle contraction (Djupesland, 1967).

Subjects were exposed to 2000Hz fatiguing frequency at 100 dBSPL in the test ear for 10 minutes.

TTS was determined at test frequency i.e. 4000Hz, one octave higher the fatiguing frequency:

I. Immediately after the cessation of the stimulus (TTS_0).

II. After one minute of recovery time (TTS_1).

III. After two minutes of recovery time (TTS_2).

The data obtained were subjected to relevant statistical analysis.

RESULTS

RESULTS

For each subject TTS_o, TTS_1 and TTS_2 was calculated. Table I_a and I_b shows the temporary threshold shift (TTS_0 TTS_1 and TTS_2) for males and females respectively.

Tables II_a and II_b show mean and standard deviation for TTS_0, TTS_1 and TTS_2 at 4KHz for males and females respectively. The mean TTS_0, TTS_1 and TTS_2 in males are 34.5dB (SD=7.8), 28dB (SD=7.8), and 25dB (SD=6.3) respectively, whereas in females these value are 30dB (SD=7.0), 22.5dB (SD=6.8) and 18dB (SD=5.5) respectively.

Tables III_a and III_b show the raw score for recovery at 4KHz (Fatiguing frequency 2KHz) at TTS_0 TTS_1, TTS_1-TTS_2 and TTS_0-TTS_2 in males and female respectively.

Tables IV_a and IV_b show the mean and standard deviation of recovery. The mean values of TTS_0-TTS_2, TTS_1-TTS_2 and TTS_0-TTS_2 are 6.5 dB (SD=2.2), 3.0dB (SD=3.2) and 9.5dB(SD=3.5) for males and 7.5dB (SD=3.9), 4.5dB (SD=1.7) and 12dB(SD=4.58) for females respectively. Result indicate that females have faster rate of recovery at all the three levels.

Tables V_a and V_b show the result of Mann-Whitney U Test.

It is evident from table V_a that TTS_0(U=36),TTS_1 (U=35)and TTS_2 (U=19)are not significant at 0.05 and 0.01 level of significance between the two groups i.e. males and females. However males show more TTS than females.

Observation from table V_b shows critical value of U for TTS_0-TTS_1, TTS_1-TTS_2 and TTS_0-TTS_2 as 45.5, 36, and 37.5 respectively which indicate that there is no significance difference between rate of recovery among males and females. However females shows faster rate of recovery than males (Table IV_b).

Table-I_a: Temporary threshold shifts (TTS_0+ TTS_1+ TTS_2) at 4KHz (Fatiguing stimulus - 2KHz) for males.

Subject	1	2	3	4	5	$	7	8	9	10
TTS_0 in dB	25	50	30	35	25	30	35	30	40	45
TTS_1 in dB	20	40	20	30	20	20	30	25	35	40
TTS_2 in dB	20	40	20	20	20	20	25	25	30	30

Table-I_b: Temporary threshold shifts (TTS_0, TrS_1, TTS_2) at 4KHz (fatiguing stimulus - 2KHz) for females.

Subject	1	2	3	4	5	6	7	8	9	10
TTS_0 in dB	20	30	25	25	35	35	40	40	30	20
TTS_1 in dB	20	25	20	10	25	20	30	35	25	15
TTS_2 in dB	15	15	15	10	20	15	25	30	20	15

Table-II$_a$: Mean and Standard Deviation of TTS_0, TTS_1 and TTS_2 at 4KHz (Fatiguing stimulus - 2KHz) in males.

	Mean	Standard Deviation
TTS_0 in dB	34.5	7.8
TTS_1 in dB	28	7.8
TTS_2 in dB	2S	6.3

Table-II$_b$: Mean and standard Deviation of TTS_0, TTS_1 and TTS_2 at 4 KHz (Fatiguing stimulus - 2KHz) in females.

	Mean	Standard Deviation
TTS_0 in dB	30	7.1
TTS_1 in dB	22.5	6.8
TTS_2 in dB	18	5.5

Table -III_a: Recovery at 4KHz (Fatiguing stimulus 2KHz) for males.

Subject	1	2	3	4	5	6	7	8	9	10
TTS_0 - TTS_1	5	10	10	5	5	10	5	5	5	5
TTS_1 – TTS_2	0	0	0	10	0	0	5	0	5	10
TTS_0 - TTS_2	5	10	10	15	5	10	10	5	10	15

Table -III_b: Recovery at 4 KHz (Fatiguing stimulus - 2KHz) for females.

Subjects	1	2	3	4	5	6	7	8	9	10
TTS_0 - TTS_1	0	5	5	15	10	15	10	5	5	5
TTS_1 – TTS_2	5	10	5	0	5	5	5	5	5	0
TTS_0 - TTS_2	5	15	10	15	15	20	15	10	10	5

Table-IV$_a$: Mean and Standard Deviation of recovery at 4KHz (Fatiguing Stimulus - 2KHz) in males.

	Mean	Standard Deviation
TTS_0 - TTS_1	6.5dB	2.2
TTS_1 – TTS_2	3.0dB	3.2
TTS_0 - TTS_2	9.5dB	3.5

Table-IV$_b$: Mean and Standard Deviation of Recovery at 4 KHz (Fatiguing stimulus - 2KHz) in females.

	Mean	Standard Deviation
TTS_0 – TTS_1	7.5dB	3.9
TTS_1 - TTS_2	4.5dB	1.7
TTS_0 - TTS_2	12db	4.5

Table-V_a : Critical values of U in the Maun-Whitney Test for TTS_0, TTS_1. and TTS_2

	TTS0	TTS1	TTS2
Measured at 4KHz(Fatiguing frequency 2KHz)	36	35	19
Significance	Absent	Absent	Absent

Table-V_b: Critical value of U in the Maun-Whitney Test for recovery.

	TTS_0-TTS_1	TTS_1–TTS_2	TTS_0–TTS_2
Measured at 4KHz(Fatigu-ing stimulus 2KHz)	45.5	36	37.5
Significance	Absent	Absent	Absent

Table value at 0.05 level = 27.

Table value at 0.01 level = 19.

DISCUSSION

DISCUSSION

Glorig et al (1957) pointed out that frequency and severity of hearing loss are significantly greater in male population than in female. One explanation offered for this fact has been that females may be, for unknown reasons lees susceptible to the damage caused by exposure to a given amount of intense noise.

The purpose of the present study was to examine the sex difference in auditory fatigue and rate of recovery following fatigue. 10 males and 10 females subject with no earlier exposure to intense noise were exposed to 100dB SPL pure tone at 2KHz for 10 minutes. TTS waa measured one octave higher than fatiguing frequency i.e. 4KHz with pulse tone.

The result of the present investigation clearly indicated that there is no significant sex difference in auditory fatigue at TTS_0, TTS_1 and TTS_2. However males shows more TTS than females. No significant difference was observed in rate of recovery among males and females, however females showed rapid rate of recovery than males.

The result of this investigation are in general agreement with the results of earlier studies which have been reported in the literature in an attempt to clarify the role which sex has, in susceptibility to TTS.

Ward et al (1959) exposed 15 males and 15 females with normal hearing to one hour of a 1200-2400HZ band of noise at 100dB SPL. Males showed slightly more TTS than females but the difference was not statistically significant. No significant difference was observed in the rate of recovery from the exposure.

Fletcher and Loeb (1963) also investigated the relationship between sex and susceptibility to TTS, exposing 50 man and 50 women with normal hearing to 12 minutes of 1200-2400Hz bend of random noise at 110dB SPL. They found no difference between males and females in the amount of TTs experienced at 4KHz, but did discover a significantly greater amount of TTS in females at 2KHz.

In another study by Ward (1966) employing 24 males and 25 females; the male showed approximately 30% more TTS after exposure to a low frequency fatiguing stimulus while they experienced about 30% less than females when exposed to a high frequency noise.

Nerbonne and Hardick (1971) exposed 10 men and 10 women to 110dB SPL of broad band noise and found no sex linked difference in amount of TTS, however females showed rapid rate of recovery.

Axelsson and Lindgren (1978) reported that males showed more TTS than female and speculated that male listener with a higher incidence of exposure to noise from different sources may have lass reserve capacity, of the sensory cells which is reflected in greater susceptibility to TTS.

Dengerink at al (1984) reported greater TTS in females with cutaneous vasodilation whereaa males showed less TTS with vasoconstriction for 110dB white noise for 5 minutes.

The results of present study support the finding of Ward et al (1959), Fletcher and Loed (1963) and Nerboane sad Hardick (1971), however there is some disagreement with the results of Ward (1966), Axelsson and Lindgren (1978) and Dengerink et al (1984) which may be due to methodological, small fluctuations in human performance due to sampling or measurement, or statistical differences between the investigations.

Moore (1982) pointed five major factors which influence the size of the TTS.

1) The time between cessation of the fatiguing stimulus and the post exposure threshold determination - called the recovery interval (RI).
2) The intensity of fatiguing stimulus.
3) The duration of the fatiguing stimulus.
4) The frequency of the fatiguing stimulus.
5) The frequency of the test stimulus.

Implications for future research:

The females more rapid rate of recovery suggests that an investigation of the recovery rates of the two sexes with different fatiguing agents composed of low, high and broad frequency energy be carried out in an attempt to further evaluate this process. If this difference is verified further, the fact that females recover more rapidly from TTS produced by signals with a broad frequency composition could explain partially why men seem to suffer more TTS and PTS in many industrial situation. Further it could be suggested that female should be placed in occupations with noisy conditions.

SUMMARY AND CONCLUSIONS

SUMMARY AMD CONCLUSIONS

The present study was aimed to test the following null hypothesis.

1) There is no significant difference in amount of TTS between males and females.
2) There is no significant difference in rate of recovery following cessation of stimulus among males and females.

10 males and 10 females subjects were given a exposure of 2KHz pure tone at 100dB SPL for 10 minutes. All subjects were having normal hearing at 250-8000Hz. They were screened at 20dB HL. Threshold were obtained at 4KHz for preexposure and post exposure. TTS_0, TTS_1 and TTS_2 were calculated for each subject. Maun-Whitney U test was used to examine the statistically significant difference between the two groups.

The findings of the present study are:

1) There is no significant difference in amount of TTS among males and females, however mean TTS was more for males than females.
2) There is no significant difference in rate of recovery among males and females, however females showed faster rate of recovery than males.

Limitations of study:

1) Small number of subjects were tested.
2) Only one frequency i.e. 2KHz was used as fatiguing stimulus

3) Only one intensity i.e. 1OOdB SPL was used as fatiguing stimulus.
4) Only one type of stimulus i.e. pure tone was used.

Recommendations for future research:

1) The same experiment can be carried out on large sample.
2) Sex difference should be studied at difference frequencies i.e. low and high with different levels of intensity as fatiguing stimulus.
3) Different stimuli i.e. pure tones and noise should be studied separately.
4) Physiological changes in males and females due to noise exposure should be studied with relation to TTS.

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