EVALUATION OF SUSCEPTIBILITY OF TTS IN MALES AND FEMALES IN RELATION TO LEFT-RIGHT EAR ASYMMETRY

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INTRODUCTION

After exposure to certain levels of noise, changes in hearing threshold can be permanently or temporarily observed. Both permanent and temporary hearing threshold changes have been shown to have an asymmetric affect on the right and left ears. Also, temporary reversible changes in threshold have been found to affect men and women differently.

Left-Right Asymmetry

Interaural hearing asymmetry has been analyzed in many studies of various populations with the conclusion that the right ear has slightly greater acuity than the left ear. Ward (1957), compared the median differences (left minus right) with two Wisconsin State Fair surveys and found median differences on the order of 2.4-3.4 dB between the two populations.

According to Glorig (1958) the average inferiority of the left ear of males from a normal population is on the order of 2.8 dB at 4 kHz. The left ears of women were inferior to right at an average of 0.4 dB. Kannan and Lipscomb (1974) compared right and left ear hearing thresholds at frequencies of 2-6 kHz in five studies of a normal population. They concluded that the left ear had statistically significantly higher thresholds than the right at all frequencies tested in males. Females showed no significant difference in hearing thresholds between the ears. Rudin, Rosenhall, and Svardsudd (1988) studied the between ear difference of 987 males age 50 to 60 years. At high frequencies, the left ear was poorer by an average of 3 dB.

Axelsson and Lindgren (1981) compared hearing thresholds between ears in 139 classical musicians exposed to occupational noise. They found that 88 musicians showed an asymmetry between ears greater than 15 dB at one frequency. They also found left ear to be worse in 52 of the 88 musicians, on the order of 3-5 dB poorer among the males and 1-5 dB poorer among the females. Pirila, Sorri, Jounio-Ervasti, Sipila, and Karjalainen (1991) also found the left ear to be on an average significantly worse than the right ear in populations exposed to occupational noise. In males, the left ear was twice as often the worse ear, and in females the corresponding ratio was 1.5.

One obvious reason for the left-right asymmetry found in normal and occupationally noise exposed populations is the use of firearms. Shooting posture requires hand preference when determining side of shooting. The majority of the population is right handed, leaving the left ear to be exposed to greater amounts of impulse noise. Chung, Mason, Gannon, and Willson (1983) studied the left-right differences of a population of occupationally noise exposed subject but excluded the shooters. The average median, or left minus right, was 2-2.5 dB in males and 1 dB in females at 4 kHz. Pirila, Jounio-Ervasti, and Sorri (1991) conducted a study on the effect of handedness on hearing threshold asymmetry of normal populations. He concluded that handedness is not responsible for the inferiority of hearing in the left ear at 4 kHz, as the left ear was poorer in both right and left handed populations. Pirila, Jounio-Ervasti, and Sorri (1991) and Axelsson and Lindgren (1981) do acknowledge that there may be a possible link between threshold asymmetry and handedness in special populations such as shooters and certain musicians.

The inferiority of the hearing threshold of the left ear at 4 kHz in various populations indicates that the left ear may be more susceptible to noise damage than the right ear. Pirila (1991) investigated the left-right asymmetry at 4 kHz in response to noise exposure of a normal population where shooters were excluded. Specifically, he compared the TTS of the left and right ears independently and experimentally confirmed that the TTS was on average greater in the left ear than in the right. From his study, and those of left ear hearing threshold inferiority at frequencies most susceptible to noise, he concluded that an asymmetry between ears may exist in susceptibility to noise damage.

Gender Effects

Ward (1966) measured TTS in normal hearing adults following exposure to low and high frequency noise. He hypothesized that differences in the fragility of the sensory structure on the basilar membrane existed. He found that significantly more TTS was observed in males after exposure to low frequency stimuli (700-1400 Hz bandwidth) and significantly more TTS was observed in women after exposure to high frequency stimuli (2800-5600 Hz bandwidth). There were no differences in TTS at the 1400-2800 Hz noise. Ward (1966) concluded that females have more efficient middle ear muscle systems. Strong contractions of the muscles to high intensity stimuli reduces low frequency transmission of sounds and enhances high frequency energy.

From the above cited studies of various populations, it is known that an ear asymmetry exists in regards to hearing (Ward, 1957, Glorig, 1958, Kannan & Lipscomb, 1974, Rudin, Rosenhall, & Svardsudd, 1988, Axelsson & Lindgren, 1981, Pirila, Sorri, & Jounio-Ervasti, et al., 1991, Chung et al., 1983, & Pirila, Jounio-Ervasti, & Sorri, 1991). Temporary hearing changes to high frequency noise, or TTS, has been found to be greater in women than in men (Ward, 1966). One investigator (Pirila, 1991) found that within a subject pool of men and women together a left-right asymmetry also exists in TTS. Little investigation has followed on the amounts of TTS created in each ear or its asymmetry, and therefore few published comparable data are available. An important question is if similar to hearing thresholds, an ear asymmetry actually exists in TTS when the subject's gender is taken into account. It is possible that the conclusion that more TTS is created in the left ear (Pirila, 1991) may have only been accurate because 11 of the 16 subjects were females.

This study investigated the effects of TTS with regard to gender as well as left and right ears independently.

METHODS

Subjects

Subjects consisted of ten males and ten females. Subject criteria included individuals: 1) 19-29 years of age, 2) who had not used firearms, 3) who had pure tone thresholds no greater than 15 dB HL in the range of 250-6000 Hz, 4) who did not have a difference in left and right ears greater than 10 dB at the above frequencies 5) with normal middle ear status. Each subject was paid a small fee for participating in this research project.

Stimulus Materials

Prior to noise exposure, air conduction pure tone thresholds at 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz were found using a Beltone 2000 audiometer with the left (blue) TDH-50P earphone and MX-41AR cushion. Following each one hour noise exposure period, pure tone hearing thresholds were obtained at 4000 Hz. Tympanometry was performed with a GSI 38 immittance system using a 226 Hz probe tone to screen for normal middle ear function.

A steady-state uniformly distributed white noise with a peak to peak amplitude of 5 volts was created by TDT (Tucker-Davis Technologies) model WG1 waveform generator. The noise stimuli was then sent through a 9 kHz low pass filter followed by a mixer. The white noise was then routed to an 8 Ohm output Symetrix power amplifier with the left and right channels locked to deliver the same stimuli to both ears. The signal was then sent to each pair of Sennheiser - HD 520II circumaural earphones with 300 Ohm inputs (see figure for output spectrum measured at earphones).

The stimuli was measured by a Micronta 22 - 175A true RMS voltmeter. 300 mV at each phone approximately equaled 91 dB SPL output for the white noise. Before each experiment the volume controls were set to supply approximately 300 mV at each pair of headphones. The actual measured variance at the headphones ranged from 89.6 - 93.3 dB SPL.

Acoustic calibration was completed on the left supraaural earphone used for threshold testing and each set of circumaural earphones used for listening. The left supraaural phone was coupled to a 6cc artificial ear coupler and each pair of circumaural phones were coupled to a flat plate coupler. The coupler was connected to a 1 inch microphone on a Bruel & Kjaer Type 2235 sound level meter.

Experimental Procedure

Subjects participated in one session that lasted approximately four hours. Tympanometry was completed to verify normal middle ear status. Each subject was assigned a subject number and then seated in the sound booth where their pure tone air conduction thresholds were found for each ear twice using only the blue earphone. The testing sequence designated for all subjects was to first put the blue phone on their right ear and to push the signal button when they hear the tone. Then the tester would enter the booth and switch the blue phone to be on the left ear and re-instruct the subject. This process was then repeated once more, yielding two threshold values for each ear at each of the testing frequencies and the average of the two was used as the pre-exposure threshold.

Two boxes containing directions were placed in the room. The first box was designated for females and the other for males. Each box contained five assignment directions for monitoring the right ear and five assignment directions for monitoring the left ear. After the subjects thresholds were obtained, each subject randomly drew a set of directions from the box corresponding to their gender. The subject's drawn directions were printed as follows:

"THESE ARE CONFIDENTIAL DIRECTIONS AND MUST ONLY BE READ OR KNOWN BY YOU. KEEP THEM FOLDED AND WITH YOU THROUGHOUT THE ENTIRE TEST SESSION. RE-READ THEM IF YOU FORGET WHAT TO DO NEXT. You will be listening to a noise in both ears for a total of four hours. While listening you may sleep, read, or watch videos. After each hour has passed, the tester will interrupt listening and remove the headphones. You will then be quickly escorted back to the sound booth where you will sit down in the chair. Next you will place the earphones on your head with the BLUE phone on the ear designated by your printed directions. Again, push the button only when you hear the tone. When the tester signals you, remove the phones and return to your original seat. The tester will place the listening phones on your head to begin another one hour listening session. IT IS VERY IMPORTANT THAT YOU FOLLOW THESE DIRECTIONS ALL FOUR TIMES THAT YOU ARE INTERRUPTED. After reading these directions, please sign your name and tear off the bottom portion at the perforated line and give it to the tester."

At the end of the testing the subject will put their subject number and name on the outside of their directions and leave them with the tester.

In some instances up to four subjects were scheduled per session. Each of the four were to begin listening to the stimuli at their designated time. Start times were separated by 15 minute time intervals. At the subject's start time the circumaural phones were placed on the subject with the right phone corresponding to the right ear. The white noise was then introduced binaurally. While listening the subjects were allowed to sleep, read, or watch videos. One hour after beginning exposure, subjects were interrupted and led to the sound booth. The door was closed and the subject was required to place the earphones on their head as specified by the directions they drew. The window in the sound room was covered to prevent tester bias. Threshold was found in descending 1 dB steps at 4000 Hz. Again, each subject responded by pushing a patient response button. The tester recorded the threshold of the unknown ear and the subject's number. Subjects removed the earphones before the examiner opened the door to the sound booth and the subject returned for the next period of noise exposure.

The earphones were turned around from the previous session to ensure the same amount of noise energy was delivered to both ears. The entire process was repeated after each hour of listening for each subject.

TTS Measurement

Prior to noise exposure each subjects thresholds were found twice for each ear. After all subjects had been run, each subjects' pre- and post-exposure threshold form was compared with their drawn instructions to identify both the sex of the subject and ear that had been monitored. Following the ear identification, an average was found for each subjects' two pre-exposure thresholds. The changes in threshold, or amount of TTS, was found simply by figuring the difference between the pre-exposure average and thresholds after four hours of noise exposure.

Data Analysis

Thresholds prior to exposure and following exposure were arranged in a table for each subject. Subjects were arranged into three factors of gender with levels being male and female, ear with levels being right and left, and time (pre and post exposure) resulting in eight groups: Male-Right-Pre, Male-Right-Post, Male-Left-Pre , Male-Left-Post, Female-Right-Pre , Female-Right-Post, Female-Left-Pre, and Female-Left-Post. A three-way ANOVA with repeated measures was completed to assess statistical significance of gender and ear across time as well as the interaction effects of each (see Table 1).

RESULTS

Results from the analysis indicate that the factors of gender [F(1,16)=.697, p=.42] (Figure 1) and ear [F(1,16)=.003, p=.96] (Figure 2) were not statistically significant, although the factor of time was significant [F(1,16)=24.435, p=.0001] (Figure 3).

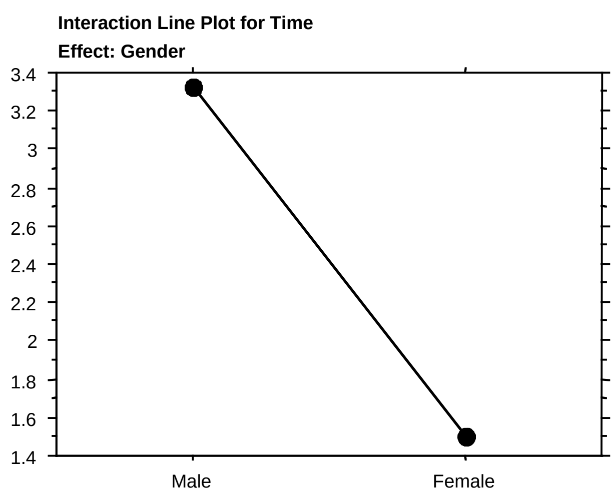

Figure 1. Mean change in threshold in dBHL over time for males and females (ear collapsed).

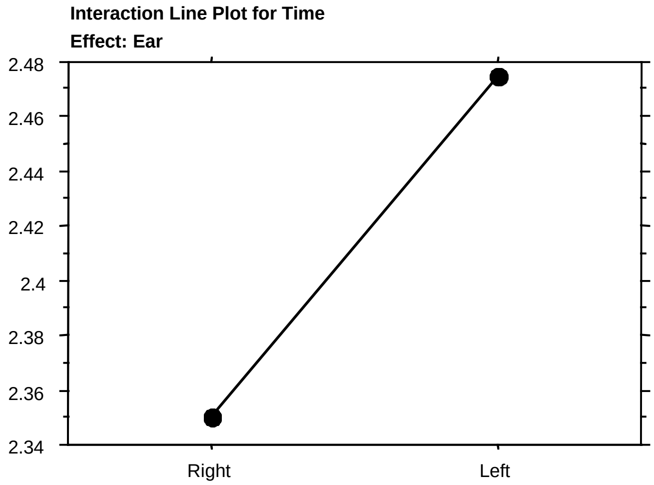

Figure 2. Mean change in threshold in dBHL over time for right and left ear (gender collapsed).

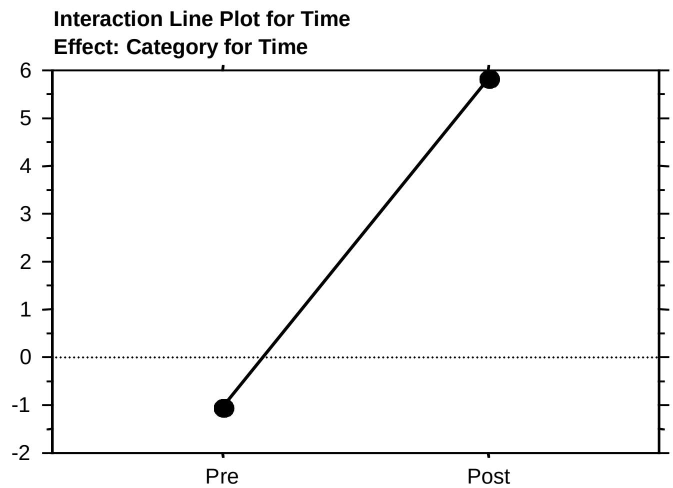

Figure 3. Average threshold in dBHL prior to and post exposure (gender and ear collapsed).

The interaction effects between gender and ear [F(1,16)=.314, p=.58] (Figure 4), time and gender [F(1,16) =.396, p=.54] (Figure 5), time and ear [F(1,16) =1.629, p=.22] (Figure 6), and time, gender, and ear [F(1,16)=.003, p=.96] (Figure 7) was also not significant.

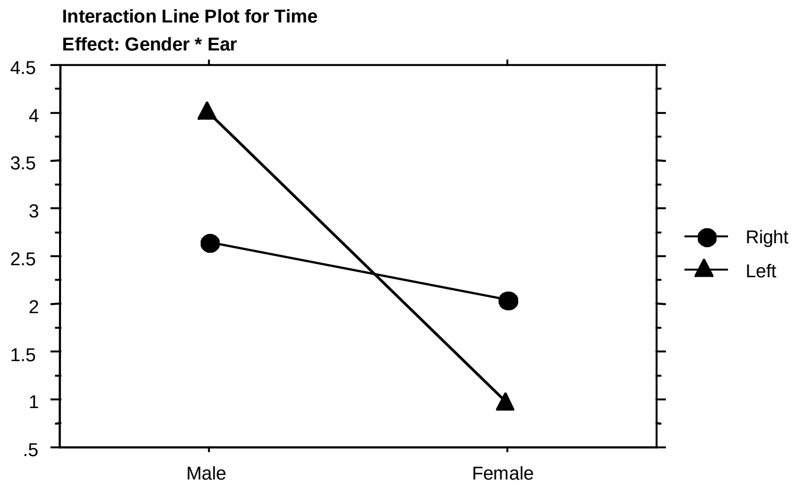

Figure 4. Mean change in threshold in dBHL over time.

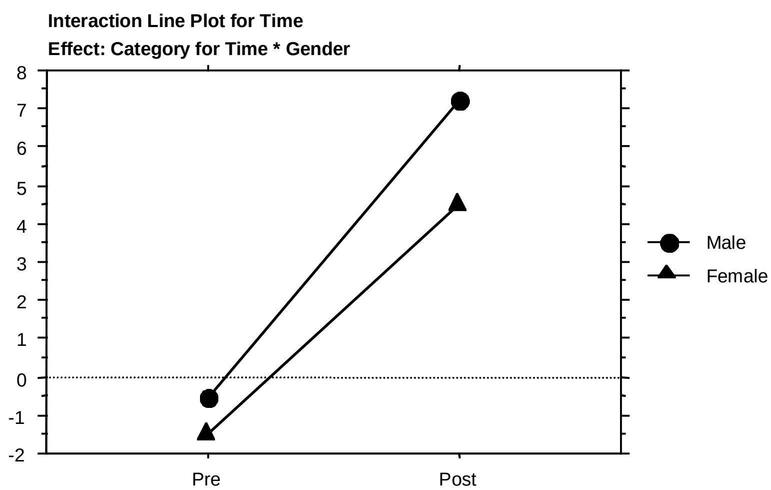

Figure 5. Average threshold in dBHL prior to and post exposure for males and females (ear collapsed).

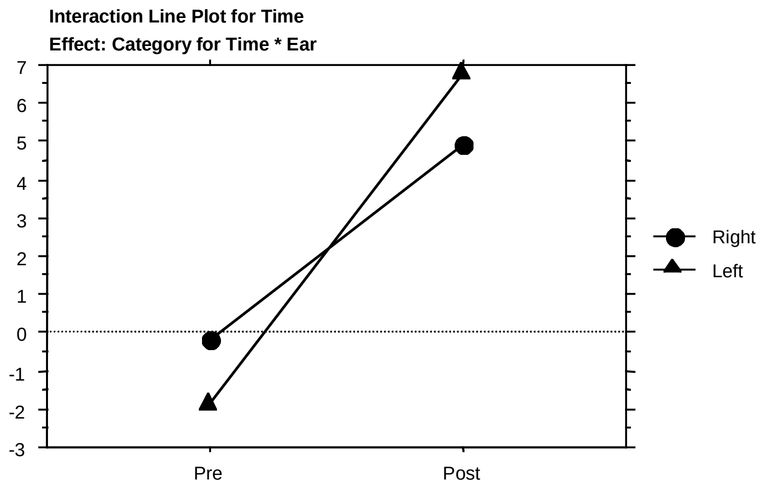

Figure 6. Average threshold in dBHL prior to and post exposure for right and left ears (gender collapsed).

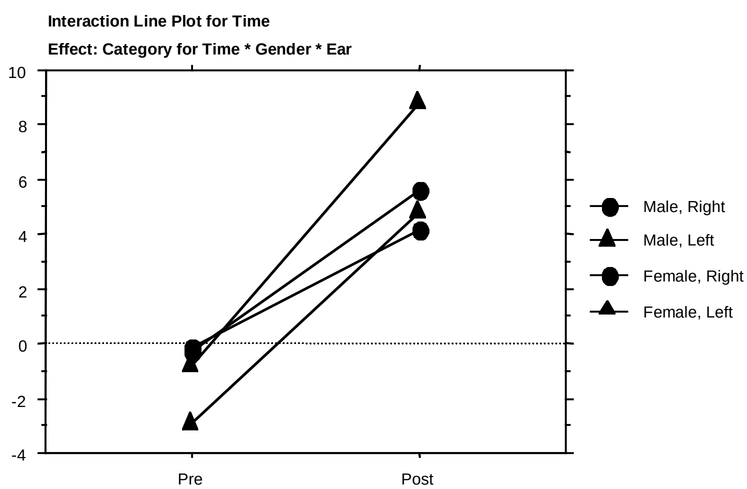

Figure 7. Average threshold in dBHL prior to and post exposure.

CONCLUSIONS

Asymmetrical TTS in regard to either gender or ear was not supported in this study. Although notable differences were present, statistical significance was not reached for these two factors. The data do show significant effects of time between pre and post exposure.

The results of this study, its contradiction to the only known similar past study (Pirila, 1991), along with the absence of other literature and published work on TTS asymmetry implies the need for future research. Numerous studies on factors affecting

TTS, such as smoking and caffeine intake of subjects being exposed to noise, could be monitored more closely.