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EFFECTS OF EXPOSURE TO INTENSE LOW FREQUENCY TONES ON HEARING AND PERFORMANCE

by

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and
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Bureau of Medicine and Surgery, Navy Department
Research Work Unit MF12.524.004-9012D.06

Released by:

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SUBMARINE MEDICAL RESEARCH LABORATORY
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SUMMARY PAGE

THE PROBLEM

To assess the effects of intense low frequency sound on crew members.

FINDINGS

Ships' compartments resounding with low frequency tones in the 70 to 300 Hertz range at Sound Pressure Levels of about 113 dB would be habitable. Meaningful sensory processing tasks could be performed in such compartments without serious degradation. Most crew members would not incur large hearing losses from such exposures.

APPLICATION

These findings contribute to the generalization of noise exposure standards incorporated in the Navy's Hearing Conservation Program and are directly applicable to the assessment of the habitability of specific ships' compartments.

ADMINISTRATIVE INFORMATION

This investigation was conducted as a part of Bureau of Medicine and Surgery Research Work Unit MF12.524.004-9012D—Physiological Psychology of the Ear Under Stress. The present report is No. 6 on this work unit. The manuscript was approved for publication on 26 January 1970, and designated as Submarine Medical Research Laboratory Report No. 610.

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ABSTRACT

Groups of men were exposed for a twenty-four hour period to either 70 Hertz tones at 112.8 ± 10 dB re .0002 dynes/cm^2 or 300 Hertz tones at 113.4 ± 3 dB re .0002 dynes/cm^2. During the exposure, performance on a sensory-motor task ("RATER") was tested periodically, and auditory threshold shifts were measured. No decrement in RATER performance was noted for either group. Temporary Threshold Shifts were moderate except for one subject. The general behavior of the groups and statements made during informal interviews indicated that similar exposure conditions would be well tolerated on a routine basis.

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I. INTRODUCTION

Crew members aboard Naval vessels are sometimes exposed to intense tonal stimulation emanating from on-board machinery and equipment. The nature of the missions of naval craft is such that exposure to these stimuli may be nearly continuous around the clock in living, as well as working spaces. Consequently, conventional industrial standards of acceptable noise levels, which are limited to bands of noise and to a maximum exposure of eight hours per day, are not always applicable. Such considerations prompted a study by Harris[1] on the effects of 60 hrs exposure to pure tone pulses at 3500 Hertz (Hz) a frequency which lies within the region of maximal auditory sensitivity. For the conditions employed (5% duty cycle, 250 msec pulse length) Harris concluded that maximum permissible exposure Sound Pressure Level (SPL) would be some level less than 100 decibels (dB)*.

However, at very low frequencies an SPL of 100 dB may be as little as 50 dB above threshold level although loudness levels may be comparable. It is not clear how tolerance limits based upon research with high frequency signals should apply to lower frequency tones. Accordingly, it was decided to subject volunteers to intense low frequency tones for a 24-hr period and to observe any resulting Temporary Threshold Shifts (TTS) and performance decrements.

II. METHOD

Subjects for this work were 12 Naval enlisted personnel awaiting assignment to Submarine School. All men had passed audiometric screening tests administered within a week prior to their participation in the experiment. All were in their late teens or early twenties. They were exposed in two groups of six men each, one group receiving 300 Hz signals, the second group 70 Hz.

The exposures were administered in a concrete reverberation chamber of about 7500 cu. ft. Six matresses and other bedding were provided. All meals were served in the chamber. Essentially, the men were confined for a 24-hr period. However, the selected duty cycle was such that the men could leave the chamber for periods of up to five minutes at frequent intervals. Thus, they were not physically or socially isolated from the outside world. Reading material was provided and the men were free to amuse themselves as they pleased. Most men read or wrote letters when not sleeping or eating. Most of the time was spent on the mattresses.

Stimuli were delivered through six Altec "Voice of the Theatre" speakers, each speaker driven by a 75-watt Altec Amplifier. Sinusoids were passed through a Grason-Stadler Electronic Switch controlled by modular programming equipment to the amplifiers. Tones were "on" for five minutes and "off" for five minutes. During the "off" periods, subjects were free to leave the room to smoke or visit the head.

The SPL delivered to the room was as high as possible with the sound system used. As a consequence, distortion appeared to increase above usual levels. At a 5% distortion level, distortion products were about 26 dB below total output level. If the total level were 120 dB SPL then the distortion products would have a level of about 94 dB SPL. The distribution of this energy, then, becomes very important since if the distortion were primarily due to a single prominent harmonic, a secondary fatiguing stimulus would be present. In a reverberant room the relative strength of a given harmonic varies from place to place as a function of the modal structure of the room. Therefore, wave analyses were conducted at seven selected locations in the chamber using a General Radio model 1900-A Wave Analyzer and type 1521-B Graphic Level Recorder. Output levels were adjusted so that the mean level of any single harmonic was 90 dB or less. The resulting exposure levels were 113.4±3

*All Sound Pressure Levels in this report are with reference to 2.0×10^{-4} microbar.

dB at 300 Hz and 112.8±10 dB at 70 Hz. Distortion levels were estimated to be about 12% with most of the energy distributed over the lower harmonics.

Prior to exposure all men were tested individually with a standard audiometer and were trained to perform on the RATER. The RATER is a device which presents four stimulus patterns (circle, square, etc.) in random sequences. The subject responds by depressing one of four buttons each being associated with a particular pattern. Various measures of performance accuracy and response rate are yielded by the device. A full description of the RATER and some reliability and validation data are given by Parker.[2] The device presumably measures changes in performance due to the influence of stressors. Performance on the RATER was measured every two hours during the exposures. During exposure to 300 Hz, the subjects were also examined audiometrically every two hours. For the 70 Hz condition audiometric examinations preceded and followed the 24-hour exposure.

III. RESULTS AND DISCUSSION

RATER data are plotted in Figure 1. Trial 1 is the pre-exposure run following training. Ten hours elapsed between Trials 7 and 8, during which time subjects slept. It may be seen that prior to exposure the two groups were comparable in terms of total responses emitted (T), but differed on Correct Responses (C) and Error (E) scores, the Hz group being superior performers. On subsequent trials in the 70 Hz group, T and C increased while E declined in step-wise fashion from initial levels. For the 300 Hz group, T and E dropped dramatically from Trial 1 to Trial 2 whereas C improved. On Trials 6 and 7, T and C were improved over Trial 2 performance. The differences between the groups on T and C are obvious and profound. It is to be noted, however, that error scores for the 300 Hz group are consistently lower than for the 70 Hz group.

It would be difficult to conclude from these data that exposure duration had a degrading effect on performance since both groups generally improved throughout the day. There is a suggestion that had the experiment continued, a decrement would be observed at least in the 300 Hz group since their performance does seem to decline following Trial 7. However, performance on Trials 8 and 9 for this group is at least as good by all criteria as it was on Trial 2.

Nor can one conclude that the 300 Hz condition produced a decrement in performance over the 70 Hz condition. For this to be so, the groups would have to be demonstrably comparable. In fact, they are not. Figure 2 is a plot of the data in Figure 1 in terms of present correct responses on each trial. It is seen that by this criterion the 300 Hz group is superior to the 70 Hz group from Trial 2 onward. The testing was done such that all members of each group could observe the other members' performances. In fact, on some trials the men recorded their peers' scores. In this situation it is likely that group performance norms were established which the members attempted to meet. The instructions to both groups apparently were effective in establishing rather high initial response rates. The 70 Hz group apparently maintained high output rate as a group value throughout the session even at the expense of accuracy. That is, it seems that this group was willing to tolerate a lower accuracy level (High E) in order to maximize T and C. The 300 Hz group may have valued accuracy (Low E) over high response rate T and C. From Trial 2 onward, the median performance of this group never fell below 95% correct, whereas the 70 Hz group never exceeded this level. It is interesting to note in passing that of these two strategies, i.e., maximizing Correct Responses vs minimizing Errors, the former seemed to produce the greatest absolute increment in performance.

Median and Maximum Temporary Threshold Shifts at the end of the 70 Hz exposure are listed in Table I. All thresholds returned to within 5 dB of pre-exposure levels within a few hours.

The results of the thresold measurements during and following the 300 Hz exposure condition are plotted in Figure 3. Generally, the maximum shifts observed occurred at 500 Hz. Mean TTS peaked at the 6-hr exposure

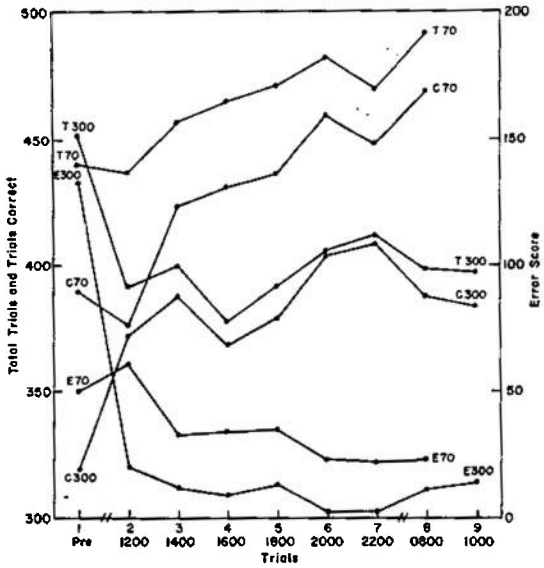

Fig. 1. Performance on RATER over a 24-hour period while exposed to intense low frequency tones. Graphs are for Mean Total Responses Emitted (T), Total Correct (C) and Total Errors (E) on each trial for each exposure condition (300=300 Hertz, 70=70 Hertz). Error Scores (E) are to be read from the right hand scale, (T) and (C) from the left. Note: The lower scale on the abscissa designates the time of day for each trial.

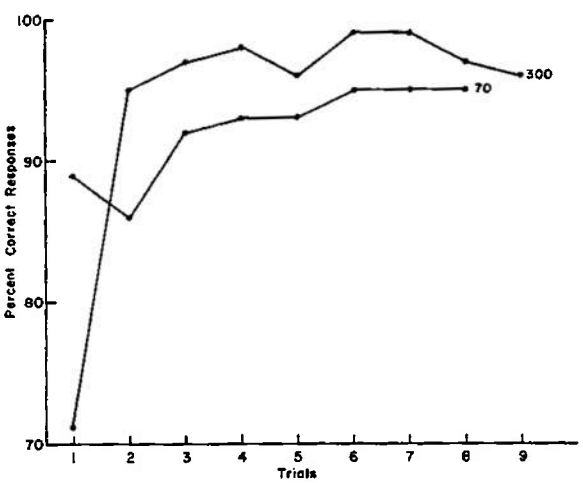

Fig. 2. Percent Correct Responses for each group.

period and then generally declined throughout the remainder of the exposure. The 24-hr data represent the first post-exposure measurements and occurred as little as 5 minutes after the exposure to as much as 30 minutes after the exposure with the average time being about 15 minutes. It appears that some recovery had already occurred. At the 3-hr post-exposure period the Median TTS had dropped to 5 dB (Mean=6.25 dB).

TABLE I

Temporary Threshold Shifts Observed Following About 25 Hours Exposure at 70 Hz at an SPL of 112.8±10 dB.

	FREQUENCY						
	125	250	500	1000	2000	4000	8000
Median Shift	5	5	7.5	0	5	0	2.5
Maximum Shift	15	10	10	10	10	10	20

One man in the 300 Hz group suffered a 15 to 20 dB shift at 250 and 500 Hz during the first three hours of exposure. His shifts remained at that level at 250 Hz throughout the 24-hr period. At 500 Hz TTS grew to 25 and 30 dB in the left and right ear respectively by the 12th hr, but by morning (the 22nd hr) had not grown further. Following termination of the exposure, recovery proceeded slowly. Three days following the exposure, there remained a 10 dB shift in the right ear at 250 Hz. Six days following the exposure there was no shift remaining.

The TTS data generally indicate that the exposure conditions used in this study are not hazardous to the ear. There may be some individuals, however, for whom this is not the case.

During the exposure conditions, informal interviews were held with the subjects. None complained of the noise as being painful or unbearable. All men indicated that they could put up with the noise for extended periods on a cruise. None were observed at any time to attempt to shut out the noise with pillows. The only adverse effects were startle which occurred with the onset of the first few blasts and some initial apprehensions concerning the effects of the exposure. Within an hour or two some men in both groups fell asleep. All men ate well at all three meals which were served in the chamber. The spirits of all men seemed to remain rather high. They were at all times cooperative and assisted in collecting some of the RATER data. They all

made a point of returning to the exposure chamber promptly after having left for any reason.

IV. CONCLUSIONS

The exposure conditions utilized in this study do not produce serious decrements in the performance of tasks similar to RATER and are not hazardous to the ear of the gen-

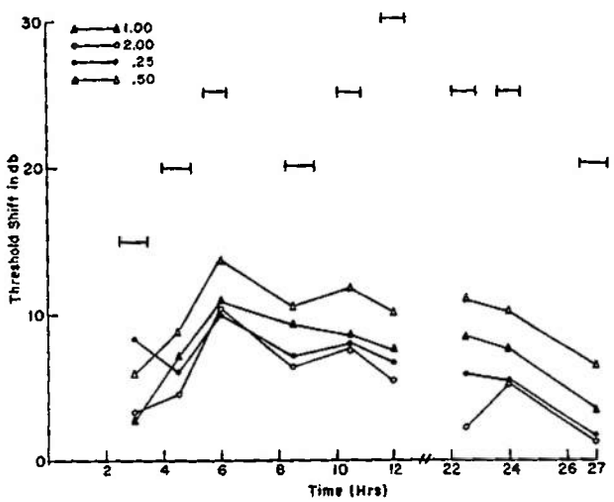

Fig. 3. Mean Temporary Threshold Shifts produced during 24 hours exposure to 300 Hz tones at 50% duty cycle. Bars indicate maximum observed TTS at 500 Hz.

eral population. Ships' compartments resounding with single tones in the frequency and intensity range of the conditions used in this study (70 to 300 Hz at about 113 dB SPL), would be habitable. Similar tones would not, in and of themselves, constitute a negative morale factor.

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13. ABSTRACT

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