Proceedings of The Institute of Acoustics 3C19

THE EFFECTS OF NOISE EXPOSURE ON THE DETECTION OF WARNING SOUNDS

M W SAVILL

ARMY PERSONNEL RESEARCH ESTABLISHMENT FARNBOROUGH HAMPSHIRE

Introduction

The effects of exposure to intense noise on hearing sensitivity have been extensively studied (Kryter 1970, Burns 1968), and it is generally agreed that repeated exposures will cause a loss in hearing acuity. Elwood and Forrest 1976 consider that the effect can best be described as a temporary loss in hearing sensitivity with an accompanying permanent loss which may accumulate with repeated exposures.

An examination of the frequency spectra of certain types of warning sounds (particularly those made by the movement of personnel in a military environment) showed most of the energy to be concentrated at high frequencies; it is at these frequencies that temporary hearing losses have often been observed. This suggested that a temporary hearing loss could present a significant problem to the soldier who is trying to detect the presence of personnel by the sounds of their movement. A series of experiments have been conducted to investigate the effects of noise-induced hearing losses on the detection of warning sounds particularly in a quiet background. The primary objectives of the experiments were:-

i to devise a technique to measure warning sound thresholds and to evaluate its repeatibility

ii to measure the temporary threshold shifts, for several warning sounds, induced by an exposure to intense continuous noise

iii to investigate the existence of a correlation between pure tone and warning sound thresholds.

Methods

The subjects sat in a small audiometric booth and used an automatic, discrete frequency, Bekesy type audiometer, which had been modified to enable an external signal to be substituted for the internally generated sine wave. This allowed automatic measurement of the threshold of an external signal (for example a warning sound) with a similar accuracy to that of a normal audiogram. The seven sounds used in these experiments were chosen for both their military relevance and frequency content. The sounds were: a snapping twig, a footfall in gravel, clicking stones, and the vocal commands "fire", "stop", "go" and "halt". Each sound was repeated once per second, using tape loops, for a period of thirty seconds. The subject completed the audiogram using the normal method of indicating when he could hear the sound.

In the initial experiment the subjects (twelve soldiers, mean age 26.3 years) listened under monaural headphone conditions. There were four separate test days. On the first and fourth days the subjects completed either a normal (pure tone) or a warning sound audiogram, followed after a 22 minute rest period, by the other type of audiogram. Thus the subjects completed both types of audiogram twice, allowing a preliminary estimate of the repeatibility of the technique. The order in which the audiograms were undertaken was alternated to give a balanced experimental design and also to reduce the magnitude of any learning effects.

On the second and third days both types of audiogram were carried out before and after a 22 minute exposure to noise at a level of 103.5 dBA (that of an Armoured Personnel Carrier running on a metalled road). This noise was relayed into the audiometric booth via two Tannoy Devon loudspeakers. The effects of this noise exposure (corresponding to a Leq of 90 dBA) on the hearing sensitivity, both for pure tones and for warning sounds were assessed.

In the second experiment a different group of twelve subjects completed both types of audiogram under free field listening conditions in a small anechoic room. The acoustic stimuli were the same warning sounds as before but third octave bands of noise were used instead of pure tones. The audiograms were undertaken before and immediately after a 22 minute exposure to the recorded APC noise at a level of 100 dBA. The tests were also conducted before and after a 22 minute rest period. The tests were undertaken in a random order.

Results

The results from the first experiment are detailed below. The data from eleven subjects were used to derive the mean results, as one subject could not give consistent audiograms under the experimental conditions. The results from the second experiment have yet to be fully analysed but a preliminary investigation shows a similar pattern of results.

a Repeatibility

The data obtained on the first and fourth days were compared to ensure that the hearing sensitivity of the group had not altered during the experiment. Analysis, using Student's t-test, of the mean results for seven pure tones, with each ear considered separately (14 cases) showed only one situation in which the mean difference was significantly different from zero (at the 5% level). Similar analysis for the warning sound data showed only three cases, out of fourteen, where the mean differences were significantly different from zero at the 5% level. The mean detection levels for warning sounds were consistently lower on the second test occasion which, although not statistically significant, suggested a practice effect.

b Temporary threshold shifts

Interpretation of the data from this part of the experiment is difficult because of the limitations in measuring a time varying shift in hearing sensitivity. In these experiments the thresholds for different sounds were measured at different times post exposure. The mean temporary threshold shifts are summarised in Tables 1 and 2.

c Correlations

Price and Hodge 1976, have developed a predictive model which takes into account the spectral and temporal distribution of various sounds of military importance and also the sensitivity of the ears detecting them. This method is based on a critical band analysis of the sounds and a 200 msec integration period.

This method is impractical under normal circumstances thus it was decided to investigate the existence of a correlation between warning sound threshold and the threshold at the predominant frequency within the warning sound (or its nearest audiometric equivalent). Using a least squares method to obtain the best fit straight line the correlation coefficients of the individual data points when fitted to the line ranged from 0.85 to 0.93, thus suggesting a good degree of correlation.

Conclusions

The results indicate that it is possible to measure warning sound threshold with the same accuracy as that achieved in pure tone audiometry and if sufficient practice is given then similar repeatibility may be achieved.

The tests carried out on the second and third test occasions show that a 22 minute exposure to APC noise at a level of 103.5 dBA can cause a mean threshold shift of up to 6 dB for certain types of warning sound (measured 5 minutes post exposure). This loss in sensitivity for the warning sounds can be considered as a reduction in detection distance, under normal conditions a 6 dB loss is equivalent to a halving of detection distance.

The results hold out little hope that it will be possible to predict an individual's warning sound TTS from a known noise exposure, although it may be possible to achieve this for groups of subjects. It is proposed to extend this study to include the measurement of the effects of temporary threshold shifts on the localisation of various warning sounds.

References

1 K D KRYTER 1970 Academic Press The effects of noise on man.
2 W BURNS 1968 John Murray, London Noise and Man.
3 M A ELWOOD and M R FORREST 1976 Report 5/76 Army Personnel Research Establishment, Farnborough. The effects of noise on hearing : Part II, Continuous noise.
4 G R PRICE and D C HODGE 1976 Technical Memorandum 35-76 US Army Human Engineering Laboratory, Aberdeen Proving Ground, Maryland. Combat sound detection : 1 Monaural listening in quiet.

TABLE 1 Mean warning sound TTS measured at various times after a 22 minute exposure to APC noise at a level of 103.5 dBA.

	Left ear			Right ear		
Sound	Mean (dB)	SD	Time (mins)	Mean (dB)	SD	Time (mins)
"Fire"	2.3	5.6	0.25	3.4	6.0	3.75
"Stop"	-0.6	4.7	0.75	3.8	5.4	4.25
Snapping twig	1.8	5.7	1.25	5.8	7.9	4.75
Footfall in gravel	4.6	3.9	1.75	5.2	6.0	5.25
Clicking stones	5.8	6.5	2.25	6.1	6.1	5.75
"Go"	3.6	5.7	2.75	5.5	3.4	6.25
"Halt"	3.6	5.8	3.25	1.8	4.7	6.75

TABLE 2 Mean pure tone TTS measured at various times after a 22 minute exposure to APC noise at a level of 103.5 dBA.

	Left ear			Right ear		
Frequency (kHz)	Mean (dB)	SD	Time (mins)	Mean (dB)	SD	Time (mins)
0.5	3.3	5.2	0.25	4.8	6.5	3.75
1.0	2.2	3.4	0.75	5.2	4.4	4.25
2.0	5.7	6.9	1.25	8.4	5.2	4.75
3.0	11.7	6.9	1.75	9.3	6.1	5.25
4.0	7.8	8.2	2.25	10.7	7.3	5.75
6.0	2.8	8.3	2.75	7.6	7.8	6.25
8.0	-2.7	7.4	3.25	8.4	6.2	6.75