NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

SUBMARINE BASE, GROTON, CONN.

REPORT NUMBER 888

THE EFFECTS OF EARPLUGS AND EARMUFFS ON PITCH DISCRIMINATION IN NOISE

by

John E. Kerivan

Naval Medical Research and Development Command
Research Work Unit MF51.524.023-2002

Released by:

R. A. Margulies, CDR, MC, USN
Commanding Officer
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SUMMARY PAGE

THE PROBLEM

To determine whether the wearing of earplugs or earmuffs may lead to reduced performance in the perception of relatively minor acoustic cues in equipment maintenance and trouble-shooting.

FINDINGS

A job sample was simulated of detecting changes of ± 10% in frequency in octave-band noises, centered either at 500 or 2000 Hz, embedded in typical submarine engineroom noise at S/N of 0, -3, or -6 dB, with open ear canals or when wearing a standard earplug or earmuff. The effect of the protective devices was always to degrade performance, the more so for the earmuffs (e.g., at -6 dB S/N at 2000 Hz, the probability of a correct response fell off from 78% in the open-ear condition to 62% with the earmuff, where 50% represents chance). For this particular job sample, the personal protective devices did indeed lead to reduced performance.

APPLICATIONS

For the guidance of Industrial Health Technicians who must advise workers in the Navy's Hearing Conservation Program on the use of personal hearing protective devices, and for those responsible for the design and procurement of such devices.

ADMINISTRATIVE INFORMATION

This investigation was conducted as part of Naval Medical Research and Development Command Research Work Unit Number MF51.524.023-2002 - "The Effects of Ear Protective Devices on the Auditory Performance of Equipment Operators in High-level Noise Environments." The present report was submitted for review in January 1979, approved for publication on 23 January 1979 and designated NavSubMedRschLab Report No. 888.

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ABSTRACT

Earplugs and earmuffs are often not worn in hazardous noise because of workers' conviction that they do or at least may impair their perception of relatively slight acoustic cues important in trouble-shooting. A job sample was arranged of discrimination of a ± 10% pitch change in an octave band of noise centered either at 500 or 2000 Hz. The signals were embedded in a typical submarine engineroom noise, at each of three S/N ratios. Judgments were made by four trained adults either in an unfiltered (i.e., open-ear) condition or through a multifilter circuit simulating the insertion loss either of a typical earplug or a typical earmuff. S/N was constant across each open-ear vs earplug vs earmuff comparison. Performance was of course degraded at more unfavorable S/N, and was always worse at 2000 Hz. Primarily, performance was always worse for the earplug than for the open-ear condition, and still worse (by up to 25%) for the earmuff condition. It is clear that for this particular job sample the wearing of plugs, and especially of muffs, does indeed distort the spectral cues upon which excellent performance depends.

THE EFFECTS OF EARPLUGS AND EARMUFFS ON PITCH DISCRIMINATION IN NOISE

INTRODUCTION

The use of earplugs or earmuffs by workers in high noise areas is one temporary solution to a noise hazard. The primary function of the device is to reduce the level of noise to within acceptable limits. However, the reauirements for the use of hearing protectors include the continued use of auditory cues; these requirements have been identified over the years. Fortunately, some of them are amenable to experimental investigation.

In a recent editorial, Miller (1) identified three general problem areas in the use of ear protective devices. One of these described the incidence of changes in the perceived sound quality of noises in various environments when workers wear plugs or muffs. This comes as no surprise to one who routinely wears such devices. What might come as a surprise to those who do not is that certain job-related duties can be seriously impaired when ear protective devices are worn (2).

In a survey of naval engineroom personnel (3) it was found that many workers were using personal hearing protection only part of their exposure time in loud noise. One complaint registered by a majority of these individuals was that when plugs or muffs were used, the workers were less efficient at monitoring discrete frequencies or narrow bands of noise which could critically affect the operation of the engines. An alternative position has been presented by Miller (1) which states ". . . tests show that one can hear more clearly and more distinctly the different identifying sounds within the whole mixture of noise when the sounds are heard at a lower level." Perhaps the statement of Miller should be qualified with the assumption that in those cases the plug or muff will have reduced the level of noise equally at all frequencies within the range of interest. As shown in a recent DHEW publication (4) marked differences in the sound attenuation characteristics of all ear plugs and earmuffs exist across a frequency range of 125 Hz to 8 kHz.

It is possible that some tradeoffs are present between the selective attenuation characteristics of plugs and muffs and their overall reduction of noise levels that would enable workers to listen more effectively. However, this would be based on other factors as well, such as the hearing sensitivity of the individual worker, and his hearing acuity. Due to the nature of this problem a study has been conducted which evaluated the ability of trained listeners to discriminate differences in the pitch of bands of noise that were embedded in a background of engineroom noise.

METHOD

Stimulus Generation.

The noises were created by passing the output of a GenRad 1390B white noise generator to two A.P. 270-4 variable frequency filters. One-octave nominal bandwidths were created at .5, .55, 2.0, and 2.2 kHz center frequencies. The cutoff slopes were 24 dB/octave. The outputs from the filters were led to separate channels of a Scully two-channel tape recorder. This master tape was then re-recorded onto an Ampex AG-500 recorder using a GenRad 1925 third-octave-band multifilter to shape the noise to simulate the attenuation characteristics of a V-51R earplug or a David Clark 9AN/2 earmuff. There was also a non-filtered control condition.

In a similar fashion the background noise tape was recorded using the GenRad 1390-B noise generator with the GenRad 1925 multifilter to shape the noise for the long-term-averaged spectrum of submarine engine-room noise (5). This was re-recorded for the earplug or earmuff conditions with the appropriate attenuation characteristics built in. The physical characteristics of the signals and of the background noise were later verified using a GenRad 1523-P4 wave analyzer.

Test Procedure.

Four normal-hearing adults judged the difference in pitch between two 1-sec octave-band noise separated in frequency by 10% and in time by 0.5 sec. Subjects responded within 2 sec by pushing buttons appropriately coded on a response box. They were trained prior to data collection and ran on the experiment for approximately 6 hours each. Rest periods were given during experimental sessions. Subjects judged the pitch differences between .5 vs .55 kHz in one set of conditions, and 2.0 vs 2.2 kHz in another set. They were also asked to judge differences between items recorded in identical conditions. Comparisons were never made between a plug and a muff, only between plug vs plug, or muff vs muff.

All tests were embedded in noise at 0, -3, and -6 dB re background levels. The background effective SPL was always 70 dB (A). These levels were constantly monitored with a Hewlett-Packard 3400 A RMS VTVM. The tapes were played to the subjects on Ampex AG-500 recorders. Background and signal levels were mixed with an Ampex AM-10 mixer. Sennheiser HO 424 earphones were used diotically to deliver the stimuli. Grason Stadler 1200 series experimental equipment controlled the stimulus generation and recorded subjects' responses. Figure 1 illustrates the equipment configured to deliver the test.

RESULTS AND DISCUSSION

Physical Measures.

All stimulus and background tapes were analyzed through the headphones with the Bruel & Kjaer 2203 sound level meter and 1613 octave filter. The headphones were fitted to a Zwislocki artificial ear. Table 1 shows the difference in signal levels re background levels for the various conditions.

Product-moment correlations ($r = .92$) between the level difference of signal and background at the various conditions, vs pitch discrimination performance in each condition (plug, muff, control) indicated that as the masking levels changed within the nominal bandwidths of interest the pitch discrimination changed accordingly.

In an actual environment with broad-band frequency composition, there may well be instances in which a high-frequency modulation exerts by remote masking an effect on a lower-frequency signal. In these present data, however, we were masking and testing at one and the same frequency region, in which remote masking could hardly have been operating.

Perceptual Measures.

Over 10,000 responses were collected and utilized in an analysis of variance for a repeated measures design. The effects of reducing the S/N were clearly to reduce the pitch discrimination performance ($F = 77.7$; $p < .001$) (see Ref. (6)). Likewise, a significant difference in pitch discrimination occurred as a result of the simulated-device conditions ($F = 7.9$; $p < .001$). The interaction of S/N with the various plug or muff conditions also showed a significant difference below the $P = .001$ level, $F = 40$.

As depicted in Figure 2 the pitch discrimination for the control was best followed by the earplug and then by the earmuff. Performance in percent-correct responses fell off as much as 25% from the unfiltered to the earmuff condition.

Overall performance at the 2-kHz band was worse than at the .5-kHz band. Reasons for this include (a) differences in effective masking, (b) width of band, and (c) the particular choice of frequency differences for comparison. No doubt differences in masking were the dominant factor here. The overall intensities for the signal conditions were equated. Thus, absolute levels were maintained and only relative differences between signal and background could affect performance. As shown in Table 1 the levels in the 2-kHz band were up to 15 dB less intense in the muff as compared to the plug at .5 kHz. Once again, the correlation between these level differences and the pitch performance was quite high.

RECOMMENDATIONS

The object of any hearing conservation program is the protection of a worker's hearing. The importance of the goal of adequate hearing protection is not questioned. However, the ability of the worker to perform the job while wearing protective devices is also to be considered. One simple approach to personalized hearing protection should account not only for the noise hazard but also the auditory requirements of the job and the worker's hearing acuity at distinguishing slight acoustic changes. Efforts should be directed to identifying the frequency bands of interest, and the sort of acoustic changes within those bands which must be discriminated, which can significantly affect the job performance of a worker who must rely on audition for trouble-shooting and general equipment maintenance. These efforts might provide solutions to the problems and encourage workers to wear their hearing protective devices <u>all</u> the time instead of only part of the time.

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Table 1

The relative level differences at the 0 dB S/N conditions with the selective attenuation characteristics of the earplugs and earmuffs based on the background levels as measured through headphones.

	RELATIVE SIGNAL LEVELS (dB SPL re. 20 μPa.)						
.5 kHz. Conditions	125 Hz.	250 Hz.	500 Hz.	1 kHz.	2 kHz.	4 kHz.	8 kHz.
V-51-R	-48	-25	-3	-32	-59	N.M.	N.M.
9 AN/2	-45	-29	-10	-45	-66	N.M.	N.M.
Open Ear	-18	-15	0	-22	-48	N.M.	N.M.
2 kHz. Conditions							
V-51-R	-29	-7	0	-6	-9	-17	-28
9 AN/2	-26	0	-3	-12	-18	-3	-17
Open Ear	N.M.	-60	-48	-13	0	-10	-26

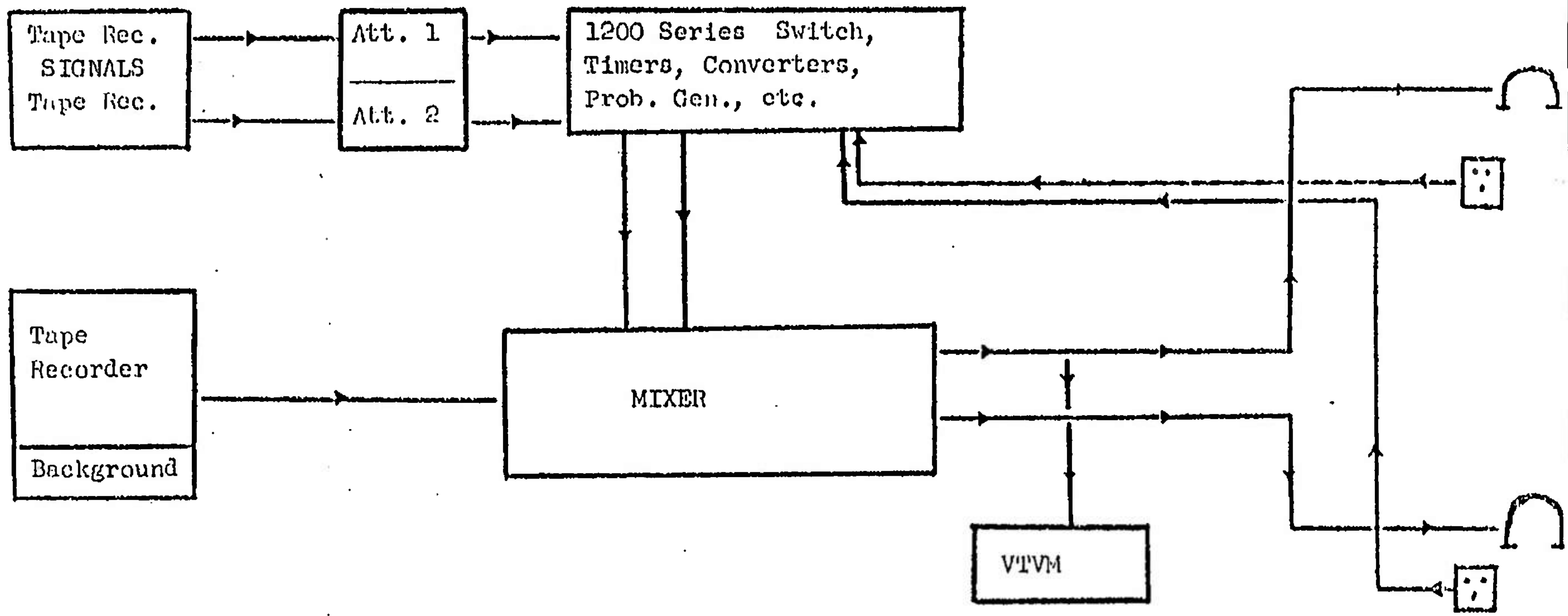

Figure 1. Test equipment configured to deliver the test stimuli.

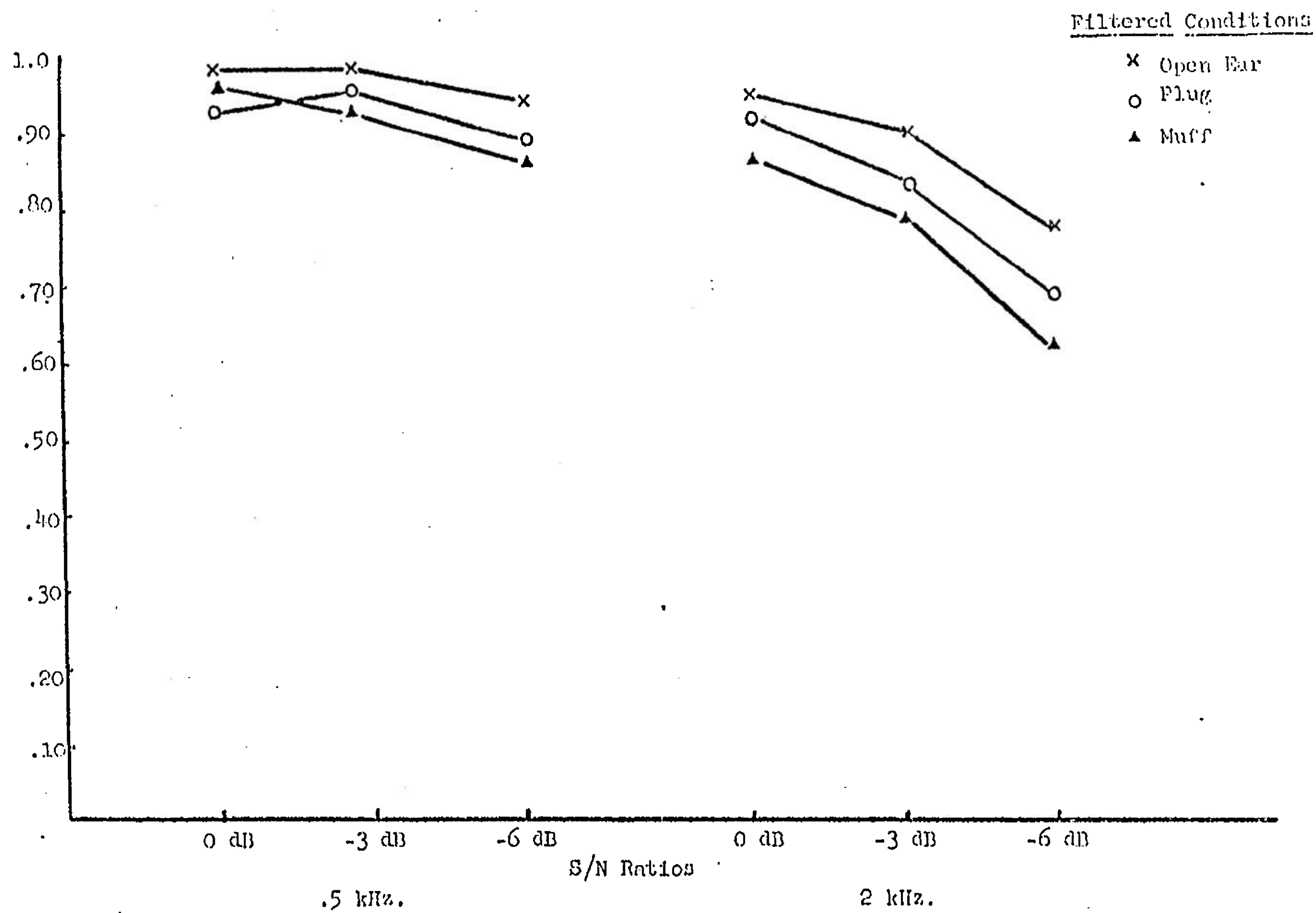

Figure 2: Mean proportion correct for four S's judging a 10% pitch shift in Octave noise bands across plug-muff conditions as a function of S/N ratio.

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