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CONSIDERATIONS REGARDING THE LABORATORY MEASUREMENT OF HEARING PROTECTOR ATTENUATION

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INTRODUCTION

Probably the most noteworthy feature of a hearing protection device (HPD) in the mind of the typical prospective purchaser is the attenuation data associated with that device. In the U.S. this situation has been exacerbated to some extent by the emergence of the Noise Reduction Rating (NRR), a single number rating based upon the overall average laboratory mean attenuation ($\bar{x}$) less a two standard deviation (σ) correction. Some buyers use the NRR as their sole purchasing criterion, even ascribing critical importance to differences of only 1 dB between the rating for two devices. The purpose of this report is to suggest some of the factors that affect the laboratory measurement of HPD attenuation, so that the significance of small differences may be placed in the proper perspective. All of the data in this report were developed according to ASA STD 1-1975.

LABORATORY SELECTION

The only laboratory round robin experiment on HPD attenuation that has been reported, was organized by the U.S. Environmental Protection Agency (EPA). Seven U.S. labs directly participated in the program, and an eighth lab, a facility responsible for greater than 80% of the U.S. manufacturers' reported data, was included by virtue of the fact that all of the HPDs evaluated in the round robin had test reports from that laboratory on file with the EPA. Four HPDs were evaluated. The labs, protectors, "experimenter fit instructions," and the results, have been previously described [1]. Recently a ninth lab, located in Britain, was commissioned to participate using the identical protectors and protocol [2], except the electro-acoustic parameters were in accord with BS 5108-1974.

The NRRs are listed in Table I and representative data are presented in Figures 1a and 1b. The inclusion of the lab #9 results, provide further confirmation of the previous observations of Berger, et al. [1]: a)significant variation exists among labs, b)except for lab #8, which was the one responsible for the labeled data, no lab was able to reproduce the manufacturers' labeled NRRs, c) application of any one set of lab data to a real world environment for the purposes of predicting an estimated protected noise exposure is a tenuous proposition.

SUBJECT SELECTION

Almost without exception, U.S. data are based upon the testing of 10 subjects with 3 replications per subject. The data in Table II demonstrate a severe case of the effects that one particularly hard to fit subject can have on the data for a commercial earmuff: an average reduction in $\overline{x}$ of 1.1 dB, and an average increase in σ of 1.3 dB. This resulted in an NRR that was reduced by 4.6 dB compared to that found using an alternative easier-to-fit subject.

SAMPLE SELECTION

Reported attenuation data for earmuffs are normally based upon one or two representative samples being submitted to the test laboratory. However, for earplugs, the laboratory uses either one or multiple pairs per subject, depending upon whether the device is reusable or disposable. To investigate if this creates a bias in favor of earmuffs, ten samples each of five different models of earmuffs were purchased. Each set of ten earmuffs was composed of samples obtained from two different sources. Two complete attenuation tests (over-head position) were conducted for each HPD using one group of ten subjects; one time using a single sample for all subjects, and the other time using one sample for each subject.

For four of the earmuffs the one vs. ten sample tests were statistically indistinguishable, but for the fifth device (metal headband with liquid cushions) the $\overline{x}$s for the 10 sample test were statistically lower at 125 and 250 Hz ($P < .01$, $df = 58$), and also at 2 kHz ($P < .05$) as shown in Figure 2. Combined with increased s, this resulted in an NRR that was reduced by 5.1 dB. For the fifth device, the standard deviation of the variation in headband force across the ten samples, was 12% of the mean force, compared with 6 - 9% for the other four products.

FITTING TECHNIQUE

A typical premolded vinyl earplug (V-51R) was chosen to evaluate the importance of fitting techniques. Testing according to ASA STD-1 requires the presentation of broad band noise (60 - 70 dB) to assist in optimal adjustment while fitting the device. Attenuation was evaluated both with and without this noise (Figure 3). Although the

Table I - NRR's from nine laboratories

Lab. No.	Medisprint V-51R	Tasco T-100 (Under Chin)	MSA MX-IV (Under Chin)	E-A-R* Plug
1	13.2	5.4	-3.9	21.7
2	13.2	8.4	1.4	27.9
3	13.3	8.4	20.6	22.2
4	12.9	9.3	7.5	22.8
5	19.4	10.5	12.7	25.8
6	14.4	10.6	17.7	28.1
7	21.7	13.4	11.1	28.1
8*	24.4	16.7	23.3	34.3
9	7.4	7.0	9.1	19.0
Mean	15.5	9.9	11.1	25.6
Range	17.0	11.3	27.2	15.3
Std.Dev.	5.3	3.4	8.0	4.6

*This lab did not directly participate - see text.

Table II - Effect of one hard-to-fit subject on test data

		Frequency (Hz)									
		125	250	500	1k	2k	3.15k	4k	6.3k	8k	NRR
A	$\bar{x}$	10.3	14.5	21.9	28.7	33.7	41.5	38.4	35.8	33.9	14.9
	s	3.8	4.4	5.0	4.6	3.2	2.9	2.6	6.9	7.9	
B	$\bar{x}$	10.6	15.9	23.4	30.9	34.6	42.1	39.1	37.5	35.7	19.5
	s	2.8	7.9	3.9	2.2	2.6	3.9	2.6	4.8	6.1	

A - with hard-to-fit subject
B - hard-to-fit subject replaced by easier-to-fit subject

Figure 1a - Data from 9 labs for a V-51R earplug.

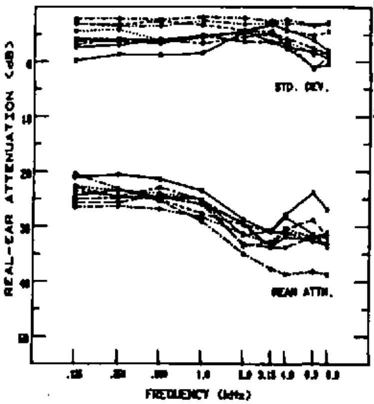


Figure 1b - Data from 9 labs for a semi-aural device.

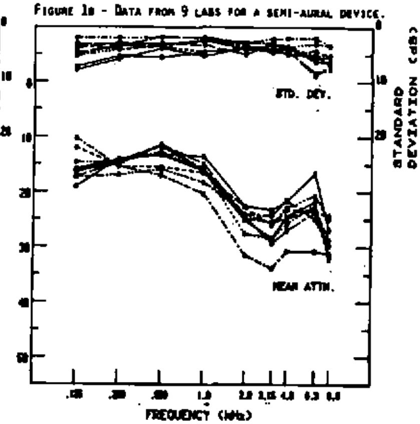


Figure 2 - Effect of samples on attenuation.

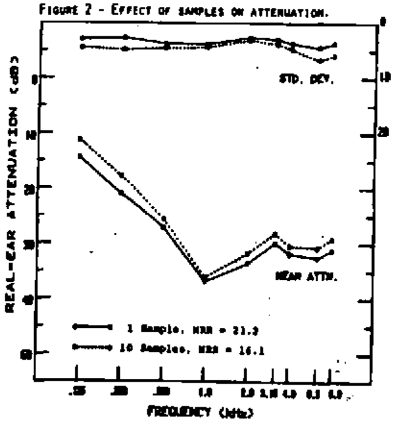
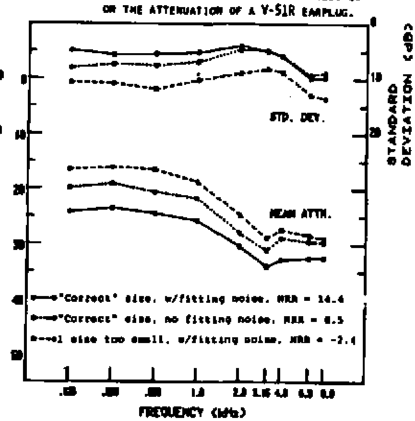


Figure 3 - Effect of sizing and fitting procedures on the attenuation of a V-51R earplug.



variances were not signifcantly different ($P < .05$) based on an F-test, the means were different (t-test, $P < .05$, df = 58) at all frequencies except 6 and 8 kHz. Three of the ten subjects had more trouble getting a good fit without the noise. For additional details see Berger [3].

SIZING TECHNIQUE

The importance of selecting the correctly sized premolded insert was evaluated using a V-51R (5-sized device). Each subject was tested with the "correct size," as well as a plug that was one size smaller and one that was one size larger. Fitting noise was used for these tests. The larger size yielded results that were not statistically different from the "correct" size, but the smaller size yielded noticeably reduced protection values for 6 of the 10 subjects. The σs doubled and the $\bar{x}$s were significantly reduced except at 6 and 8 kHz (see Figure 3).

DURATION OF USE

Another factor unaddressed in standard laboratory procedures is whether or not HPDs can maintain their position and/or seal during an extended use period. Three different reports [3, 4, 5] have examined this problem and demonstrated that certain premolded and fiberglass earplugs do work loose with time, whereas the foam and custom molded earplugs that were evaluated, did not.

CONCLUSION

A number of parameters including the selection of the hearing protector test laboratory can significantly affect the attenuation values that will be reported for particular products. Therefore these data must be viewed with caution, especially when the user intends to estimate effective protection for particular noise exposure conditions.

REFERENCES

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