TEST SUBJECT NUMBERS AND THE PERFORMANCE OF HEARING PROTECTORS

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Abstract

Current Australian requirements for the attenuation testing of hearing protectors call for a minimum of sixteen test subjects for ear muffs and twenty for earplugs. However, sometimes because of the nature of the device under test the variance of the test results can be quite large. In fact, at some frequencies the standard deviation of the test result can be larger than the mean attenuation. Since the parameter used for the calculation of the overall performance of a hearing protector is a direct function of the mean attenuation minus the standard deviation, (ā – SD), a large standard deviation can have a significant negative impact on the final performance indicator. It can result in an apparent 'amplification' of the test sound. While the suppliers of hearing protectors wish to minimise test costs by using a minimum number of test subjects, it may be of benefit to increase the number of test subjects in order to determine the "true" attenuation performance.

Introduction

The subjective rating of hearing protectors can be a very vigorously debated topic. The two extreme sides of the debate range from those who would like to see a hearing protector rating that gives a clear indication of the attenuating capabilities of the device when it is used in the correct manner by competent persons. On the other side of the argument are those who would like to see hearing protectors given a rating that reflects the minimum attenuation that could be expected from <u>any</u> user. The middle ground wishes to see a realistic attenuation rating that could be expected to be obtained by the majority of users in typical workplaces [1 - 4].

Currently the rating system recommended for use in Australia and New Zealand is the Classification System as outlined in AS/NZS 1269.3: 1998 [5,6]. The Classification System is, in fact, based on the previously (and still) used SLC_{80} rating developed in the 1970s by Waugh [7]. The Classification system was introduced in order to make the whole process of selecting hearing protectors more simple for the end user [6].

Hearing Protector Testing

In Australia hearing protector testing is carried out in accordance with the requirements of AS/NZS 1270:2002 Acoustics – Hearing protectors [8] which include mechanical and acoustic test procedures. The acoustic testing is carried out using a procedure now commonly referred to as 'the subject-fit method'. Basically, in this process individual test subjects are selected on the basis of them being relatively inexperienced in the use and fitting of hearing protectors. Also the experimenter or tester is not allowed to interfere in the selection or fitting of the device. Only the instructions that are normally provided by the supplier of the device may be used by the test subject. Currently this test method is given as an option in the American Standard [9] and is in the process of consideration for ISO adoption [10].

Acoustical testing is carried out using 'pink' noise of one third octave band width at octave band centre frequencies for occluded and unoccluded ears. A minimum of sixteen subjects are used for ear muffs and twenty for ear plugs. This results in a set of seven mean attenuations and their respective standard deviations at the octave band centre frequencies. The SLC_{80} value is then calculated as per AS/NZS 1270 [8].

How many test subjects?

Statistically, the more subjects that can be tested (larger sample size) the more the results are likely to represent the total population. However, time and financial considerations invariably lead to a limit to the number of test subjects. Attempting to state definitively the number of test subjects that will give the representative attenuation for any test device is particularly difficult.

The performance of any particular device may vary widely from its fellows for many reasons, even to the extent that this may result in a non-normal attenuation distribution [11]. For example, an analysis of the results of ear plugs tested at the National Acoustic Laboratories (NAL) over the last few years shows that the mean of the standard deviation of the attenuation at seven octave band centre frequencies for 14 earplugs was 7.7 dB, with a standard deviation of 2.4 dB. For 72 ear muffs tested, the mean standard deviation was 4.1 dB, with a standard deviation of 1.3 dB. Thus ear muffs can be expected to perform more uniformly than ear plugs and hence the test numbers required are less for ear muffs than ear plugs.

Table 1 shows the minimum number of test subjects required for reliable test results given the mean standard deviation, a 95% confidence interval of either 3 or 6 dB and a power of either 0.50 or 0.80. A power of 0.8 means that there is a probability of 0.20 of making a Type II error (ie the probability of retaining a false claim). For statistics involving 'behavioural' activities it is usual to use a power of 0.80 [12].

Table 1. Minimum number of test subjects required for various combinations of confidence interval and statistical power.

Device	Mean SD	95% CI	Power	# test subjects
Muffs	4.1 dB	+/- 3 dB	0.5	8
			0.8	15
		+/-1.5 dB	0.5	29
			0.8	59
Plugs	7.7 dB	+/- 3 dB	0.5	26
			0.8	52
		+/-1.5 dB	0.5	102
			0.8	207

As the figures in Table 1 show, particularly in the case of ear plugs, the test subject numbers grow very rapidly the smaller the confidence interval and the greater the power. This is a direct result of the relatively large value in the mean standard deviation.

Test Results

Fortunately actual hearing protector attenuation test results do not seem to be as 'bad' as the above theoretical figures would suggest. Figures 1 and 2 show the convergence of the mean attenuation and standard deviation respectively for a commercially available ear muff.

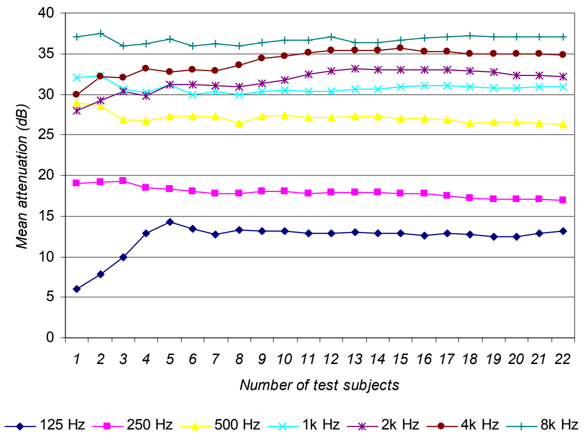

Figure 1
The convergence of the mean attenuation for increasing number of subjects for an example ear muff

The mean value has converged to a steady value by around 12 test subjects while the standard deviation is within one dB before the required number of 16 test subjects is reached.

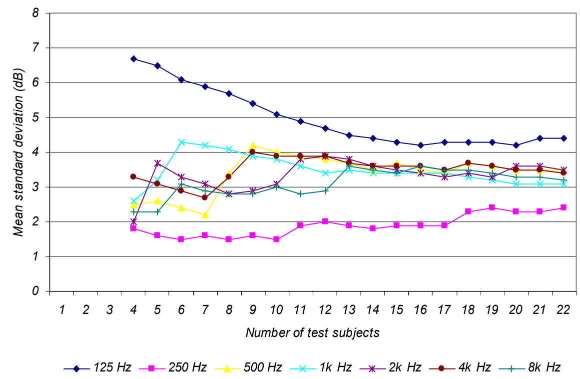

Figure2
The convergence of the standard deviation for increasing number of test subjects for the example ear muff presented in Figure 1

Figures 3 and 4 give similar results for a commercially available ear plug. As can be clearly seen both the mean and standard deviation do converge with a reasonable numbers of test subjects.

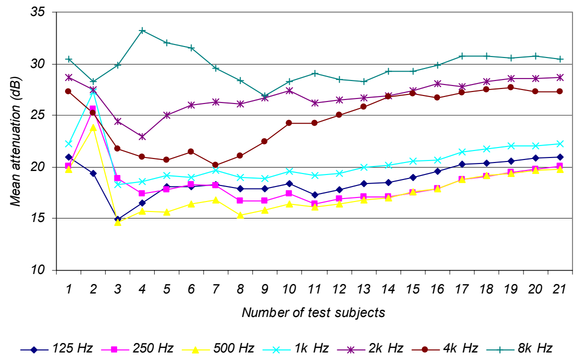

Figure 3
The convergence of the mean attenuation for increasing number of subjects for an example ear plug

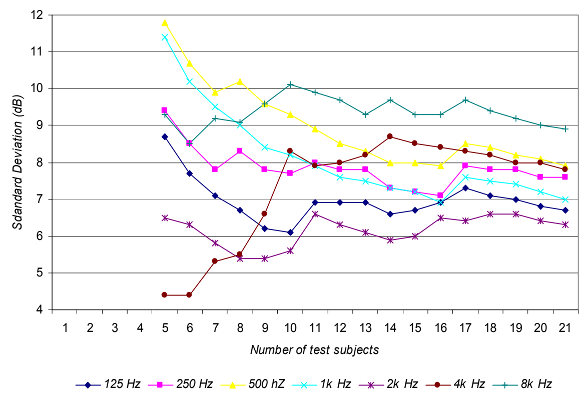

Figure 4
The convergence of the standard deviation for increasing number of test subjects for the example ear plug presented in Figure 3

However it should be remembered that these two randomly chosen devices may be much better behaved when compared to some other products on the market. For example, another ear plug with test results included in the above sample of 14 devices, had standard deviations that varied across the seven octave bands from 8.2 to 14.8 dB. With a range of values this large the rate of convergence of the mean attenuation and standard deviation could be expected to be much less rapid.

Obviously the larger average standard deviation is the main contributing factor to the larger number of test subjects required for the testing of ear plugs. This could be countered by better education in ear plug use [13] and/or an overall better design. It has been anecdotally observed that some ear plug designs do not perform uniformly as well for all test subjects compared to other designs. This is not to say that they do not perform satisfactorily for some individuals. Further research is being carried out in this area.

Conclusion

When considering the appropriate number of test subjects to include in a test series and, more importantly, what number of test subjects to recommend for inclusion in a test standard, allowance will need to be provided for hearing protectors that do not behave as well as the two devices presented above as examples.

Much more testing will need to be carried out so that the number of test subjects recommended as the 'correct number' to include in testing standards, for example the next revision of AS/NZS 1270 [8], so that allowance can be made for all possible devices.

References

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