HEARING PROTECTOR TESTING AND INDIVIDUAL VARIABILITY

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ABSTRACT: Consistency of test procedures is extremely important when certifying products for both safety purposes and Australian Standard requirements. The results presented in this study demonstrated that using the subject-fit methodology as specified in *Australian New Zealand Standard AS/NZS 1270: 2002, Acoustics – Hearing protectors*, hearing protector attenuation can be reliably measured to within 0.1 dB. A small learning effect was observed with a reduction in the standard deviation from 3.7 dB in the initial fit to 2.7 dB at the final presentation.

1. INTRODUCTION

The test procedures used to determine the acoustic attenuation are a major discussion point at international meetings of those involved with setting hearing protector test standards. This involves the use of experienced compared to inexperienced test subjects in conjunction with experimenter assisted-fit or to subject-fit test methods. New Zealand and Australia strongly adhere to the inexperienced subject or 'subject-fit' methodology [1] while the majority of researchers in North America and Europe hold to experienced test subject - experimenter assisted methodologies [2, 3]. For those North American ("*Method B – subject fit*", see [2]) and European researchers who do favour a subject-fit, a method has been agreed and published as ISO/TS 4869 – 5: 2006(E) [4]. However, the subject-fit methodology is only presented as an optional procedure and the vast majority of jurisdictions still prefer the use of the experimenter assisted-fit technique.

The main reason for the vigorous discussion is due to measurements demonstrating the wide difference in the attenuation that can be experienced between laboratory testing and testing in the field [5] and criticism of NRR data which significantly overestimate hearing protector performance in the workplace [6]. (Note: NRR is a single number hearing protector rating scheme used primarily in the USA.) This difference arises because, when using experienced test subjects, the maximum attenuation of the device can be found through the reduction or minimisation of human factors that may possibly be introduced by inexperienced users. The test method allows experimenters to assist with the fitting of the device thus maximising performance.

This contrasts to the inexperienced subject-fit method where the object is to determine attenuation that could most reasonably be expected to be found to apply for the majority of typical users. The requirement of the Australian/New Zealand Standard, paragraph 4.3.1.3 [1], for a test subject to be inexperienced is defined in the following way:

"Subjects may participate in measurements of the attenuation of up to twelve hearing protectors, with a maximum limit of five pairs of earplugs, after which they will be ineligible for further participation."

Further the subject-fit method only permits the test subject to utilise information normally supplied with the device by the manufacturers, suppliers or distributors with or on the packaging. The subject-fit method is sometimes incorrectly called the naïve subject fit method.

This dichotomy can be understood from the manufacturers' and distributors' point of view as they wish to advertise what their particular product can achieve with respect to other products on the market. Thus they tend to favour the experimenter assisted method as it almost always provides a higher attenuation value. On the other hand, those supporting the subject-fit perspective wish to emphasise realistically achievable outcomes for typical end users, primarily in the workplace.

The work described here examines the personal variability in hearing protector attenuation arising through variation in fit/re-fit for one particular ear muff using the inexperienced subject-fit methodology. This variation in ear muff fit represents the intrapersonal variation – the variation for one subject. Indications from the lack of literature indicate that this has not been measured for either the experimenter assisted fit or the subject-fit methodologies. Interpersonal variation, that variation between subjects for fitting the same protector, is the standard deviation obtained during the normal test procedure.

2. METHOD

The particular hearing protector selected for this study was a common brand of ear muff readily available on the New Zealand and Australian market. When originally tested in accordance with the applicable test standard [1], the SLC_{80}[1] was 30 dB and the *mi*SLC_{80} [7, 8] was also 30 dB. The device was again tested several months later under the requirements of the test standard [1] in conjunction with several other hearing protectors. This test involves subjects having their hearing threshold measured in a diffuse field with both occluded and un-occluded ears (i.e. wearing and not wearing the hearing protectors respectively). The difference between the occluded and un-occluded hearing threshold levels provided the attenuation information.

[1] SLC_{80} or Sound Level Conversion is the Australian single number rating figure for the attenuation (dB) of hearing protectors representing the attenuation that can be expected to be achieved by approximately 80% of users.

There were 20 normal hearing test subjects selected, as per the requirements of the standard, to participate in a fit followed by a re-fit attenuation test along with a mixture of several other devices. The test subjects were not informed that one of the devices under test was to undergo repeat testing so, unless they particularly recognised the device when presented the second time, they were undertaking a blind test. The time between test and retest was typically about forty minutes.

The order of presentation of the devices was counterbalanced as described in Appendix C of the standard [1] in order to minimise any possible learning effect. With this in mind, naturally, each time the device of interest was first presented this instance was taken as the 'test' condition while the second presentation was taken as the 'retest' condition.

The statistical analysis of the results was carried out using the commercial software packages Excel© and Statistica©.

3. RESULTS

A summary of the results are presented graphically in Figure 1 and numerically in Table 1. These show, for comparison, the overall test results for the test and retest treated as a single population, the results of the first test and the results of the retest.

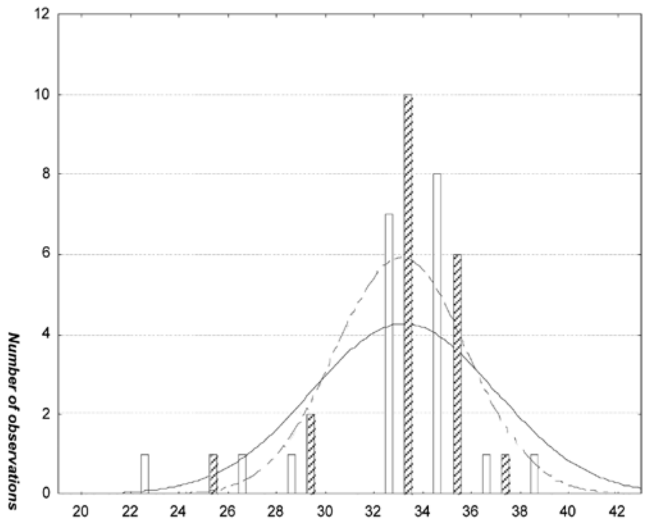

Figure 1. The histogram shows the distribution of attenuation results original test unshaded, retest shaded. The curves show normal distributions having the same mean and standard deviation, continuous for test and dashed for retest.

Parameter	*Overall (dB)*	*Test (dB)*	*Retest (dB)*	*Difference (dB)*
SLC_{80}	29.9	29.6	30.2	+ 0.6
Mean standard deviation	4.1	4.3	3.8	- 0.5
miSLC	33.1	33.1	33.0	- 0.1
i - standard deviation	3.2	3.7	2.7	- 1.0
$miSLC_{80}$	29.9	29.4	30.3	+ 0.9

Table 1. Differences in performance from test – retest results

The mean difference of the test retest attenuation (*mi*SLC) was - 0.1 dB with a standard deviation of 2 dB and the standard error reduced from 0.83 dB to 0.60 dB. A t-test for dependent samples indicated that there was no significant difference between the test and retest results ($p = 0.83$).

4. DISCUSSION

There was no statistically significant difference between the test and retest results. The difference in the mean attenuation (*mi*SLC) between test and retest was 0.1 dB. The standard deviation for the retest presentation was reduced to 2.7 dB from 3.7 dB in the original test presentation. Consequently the $miSLC_{80}$ increased from 29.4 dB to 30.3 dB as the $miSLC_{80}$ is the *mi*SLC minus the standard deviation.

The standard deviation of the test minus the retest difference in attenuation was calculated to be 2.0 dB. This represents the variation in ear muff fit arising due to personal factors or intrapersonal variations – variations from time-to-time when an individual uses the same protector. As mentioned in the introduction the interpersonal variation – variations arising from different individuals fitting the same hearing protector - is the standard deviation that results from normal hearing protector testing, 3.2 dB from the above results. These relative values are as would be expected, ie that the differences between people each fitting the same model of ear muff would be greater than a single individual refitting the same ear muff. More simply intrapersonal variation would be expected to be greater than interpersonal variation.

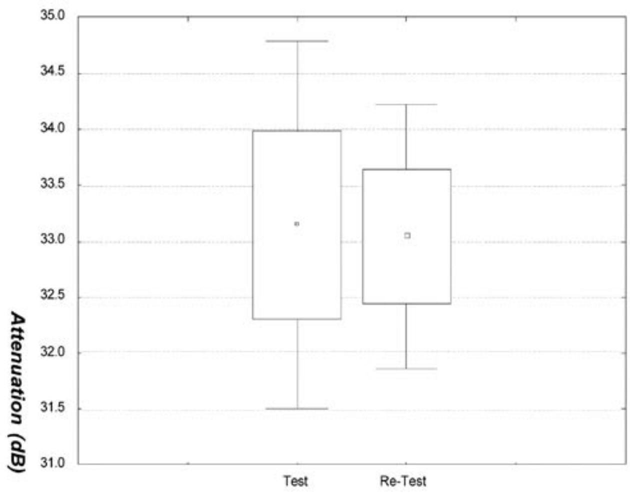

Figure 2. Test - retest results for comparison. The box shows the mean ± one standard deviation while the bars show the mean ± 1.96 standard deviations.

The decrease in standard deviation between test and retest, illustrated in Figure 2, implies the existence of a small learning effect gained from using several devices in sequence. This means that while the same mean attenuation can be expected to be achieved by users, the consistency of fit will normally improve with refit or practice, reflected by a reduction in the standard deviation.

This decrease in the standard deviation is important as it is reflected through the use of the single number performance figures SLC_{80} and $miSLC_{80}$ which use the mean attenuation minus one standard deviation figures included in their calculation. For example, with the above device the SLC_{80} increased from 29.6 dB on the initial test to 30.2 dB upon retest. Similarly the $miSLC_{80}$ increased from 29.4 dB to 30.4 dB reflecting the decrease in standard deviation.

5. CONCLUSION

The results of this work indicate that the consistency of test retest attenuation results for ear muffs is excellent and supports the current subject-fit testing procedures in use. There is a small learning effect indicated between test and retest presentations. The results also provided a value for the within-subject variation in device fit/refit with a standard deviation of 2 dB compared to the overall between-subject standard deviation of 3.2 dB.

6. REFERENCES

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