Hearing Protectors Fit-Testing Using Smartphones: Preliminary Data

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1 Introduction

Hearing protection devices (HPD) are -too- often the first line of protection for industrial workers against the risk of noise-induced hearing loss. But the efficiency of HPD is dramatically affected by workers' ability to properly fit them and get a sufficient amount of attenuation over the total duration of their exposure to high levels of noise [1]. Fit-testing systems have been developed over the years to assist workers in fitting their HPD and to estimate the amount of attenuation offered by such HPDs [2]. These systems are often expensive, require trained personnel and end-up being used only once in a while to assess if a given worker is properly protected. A possible fast and lightweight alternative is explored here where the user can self administer a simple auditory test using a smartphone or tablet.

2 Proposed Fit-Testing Method

To quickly estimate the amount of attenuation provided by any given HPD on any given individual, a tablet/smartphone app has been developed. The app features an audio stimulus generator to generate loud tones over the tablet embedded loudspeakers, a graphical user interface where the user can report the count of audio stimuli perceived, and an attenuation prediction algorithm able to estimate the overall attenuation of the HPD under test, only knowing its type. The proposed approach relies on a supra-threshold method where sequence of 1 kHz-centered narrowband stimuli are played in decreasing levels with steps of 5 dB (see Fig. 1 for timeplot of the exact stimuli used). The subject simply counts the number of bursts perceived before stimuli become inaudible in two conditions: with open ears and with both ears occluded with the HPD under evaluation

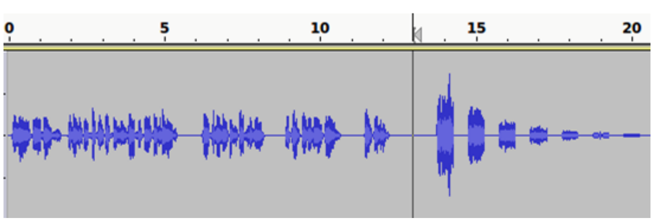

Figure 1: Timeplot of the audio stimuli consisting in a 12-second explanation followed by the test sequence (only 7 of the 15 bursts are visible here).

2.1 Experimental Setup

The proposed method has been developped in laboratory on a dozen test subjects with normal hearing. Each test subject is seated in an audiometric booth equipped for REAT measurement following ANSI S12.6 standard [3]. The tablet running the app and generating the stimuli is held in a fixed location at ear level with the 2 miniature speakers of the tablet facing the subject, as seen in Fig. 2, at a sound pressure level -not controlled but fixed in both open and occluded condition- that reaches up to 75 dB. Four experimental steps are then performed: First, the REAT open threshold is measured, using the Bekesy method with audiometric stimuli presented in a so-called "free field" condition through the booth loudspeakers. Second, the tablet is used to generate the 1 kHz audio stimuli and the subject counts the number of bursts perceived before becoming inaudible. The earplugs under evaluation are then fitted on both ears by the subjects themselves with only the help of a broadband "fitting noise". Third, the REAT occluded thresholds are measured. Fourth, the tablet generates the same audio sequence as in the open condition but increased by 5 dB to slightly overcome the earplug attenuation; that offset value beeing later accounted for in the calculation of the tablet measured attenuation. This whole sequence is repeated a second time for every subject, with a total of 6 subjects tested for the premolded earplugs and 11 subjects tested for the roll-down foamplug.

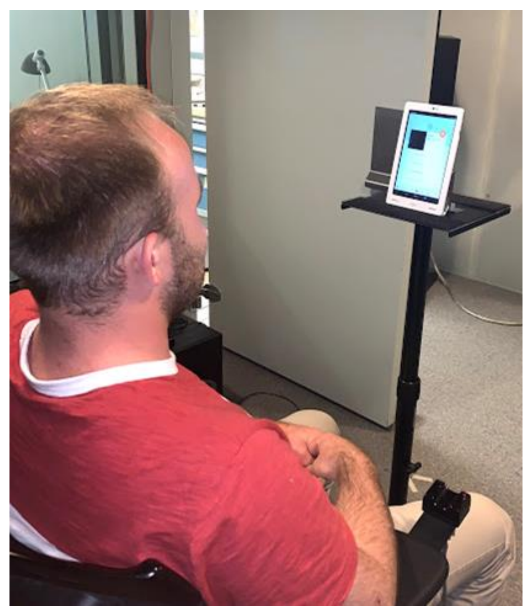

Figure 2: Photography of the test subject seated in the audiometric booth equipped for REAT measurements, clearly showing the tablet used to generate the audio stimuli.

2.2 Computation of Attenuation Values

The two counts values are entered within the app to compute an estimate of the overall HPD attenuation at 1 kHz, by multiplying by 5 dB the difference between the counted stimuli in open and occluded conditions and adding the 5 dB offset. This resulting value is then compared to the binaural

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REAT attenuation. The REAT is reported at every octave-band form 125 Hz to 8 kHz and an overall attenuation can also be reorted. This overall attenuation is computed using the "octave band method" [1] as an C-A overall attenuation, hence represents the average difference between the C-weighted overall sound pressure level and the A-weighted overall sound pressure level attenuated by the HPD using a broadband pink noise spectrum.

3 Preliminary Results

3.1 Comparison between REAT and Tablet Measured Attenuation Values

The measured attenuation values using REAT and using the tablet are compared in Fig. 3 and 4. for both the roll-down foamplug and premolded earplug. They show that while the REAT values obtained at 1 kHz (red diamonds) are poorly predicted, the overall REAT attenuation values (blue squares) are better correlated with the attenuation measured at 1 kHz with the tablet.

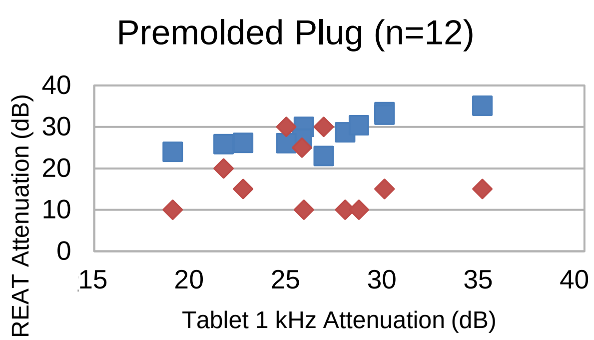

Figure 3: Scaterplot of REAT values obtained at 1 kHz (red diamonds) and overall (blue squares) as a function of attenuation measured at 1 kHz with the tablet for 2 trials of premolded plugs on 6 subjects.

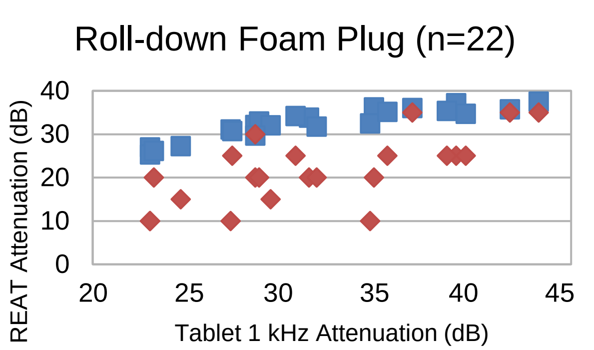

Figure 4: Scaterplot of REAT values obtained at 1 kHz (red diamonds) and overall (blue squares) as a function of attenuation measured at 1 kHz with the tablet for 2 trials of roll-down foam plugs on 11 subjects.

By comparing Fig. 3 and Fig. 4, it can also be seen that the overall REAT attenuation appears to be better correlated with 1 kHz tablet measurement for the roll-down foam plug than for the premolded earplug

4 Discussion

The data obtained suggest that a polynomial regression, using the best fit (in a least-squares sense) method, could be used to link the overall C-A attenuation measured using REAT to the attenuation measured with the tablet at 1 kHz. This regression could later be used as a predictive model, and should probably be a function of the type of HPD tested (roll-down foam, premolded, formable, push-to-fit, custom molded, and even semi-inserts and earmuffs). The reasons why the regression obtained is not a linear should also be investigated, exploring dynamic range limitation, noise floor ceilings, etc. It could also be tempting to add extra tones at lower frequencies in the tablet stimuli burst, in order to better predict the overall attenuation [4]. Nevertheless, it should also be remembered that the level of the stimuli being uncontrolled (but kept identical in both open and occluded condition) only the 1 kHz band will remain unaffected by the dynamic compression of the human hearing as expressed by the equal-loudness contours.

5 Conclusion

This very preliminary study suggests that a simple measurement made using only a tablet or smartphone generating 1 kHz tonal bursts could possibly predict overall attenuation of foamplugs with a limited degree of accuracy but sufficient for general use. Further research is now needed to validate a robust polynomial regression model using a large number of subjects and HPD models.

Acknowledgments

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