Novel personal noise dosimeters

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INTRODUCTION

Personal noise dosimeters have been used for decades as noise exposure measurement devices, constituting an important part of a program to protect workers for over exposure; however, they remain expensive and are not used as widely as would be beneficial. Our goal was to develop a new dosimeter that would be less expensive, easier to operate, and which would meet all EU regulatory requirements.The purpose of this paper is to evaluate and report on the current progress of this project.

METHODS

Frequency response test physical setup

Acoustic measurements were made in an anechoic chamber at either University College London's Ear Institute or London South Bank University. A calibrated Bruel and Kjaer (B&K) 4192 reference microphone (+/- 0.5 dB from 20 Hz to 20 kHz) was positioned 1 meter on axis from a single Samson Resolve A8 powered speaker (frequency range from 50 Hz - 20 kHz). The B&K reference microphone was angled 90 degrees to the incident plane wave and the soundBadge prototype's microphone was positioned 1 cm opposite the reference microphone (both were positioned at 90 degrees to the direction of travel of the acoustic plane wave in accordance with the manufacturer's suggested positioning).

Frequency response test stimuli and analysis

Custom Labview software was used to generate the sound stimulus and simultaneously capture responses from both the reference microphone and the soundBadge. Ten second bursts of frozen periodic random noise were used as the stimuli to avoid spectral splatter. The stimuli were generated by National Instruments (NI) 9263 16-bit ADC at 51,200 Hz and sent to the powered speaker at level of approximately 80 dB SPL, 100 bursts were presentations were made.

Responses from the reference microphone and the soundBadge taken after its analog microphone compensation filter or after its A and C-weighted filters were synchronously sampled by an NI-9234 24-bit DAC at a rate of 51,200 Hz and averaged. The frequency response of the soundBadge was assessed by taking the ratio of the Fourier transforms of the soundBadge to that of the reference microphone (Figure 1).

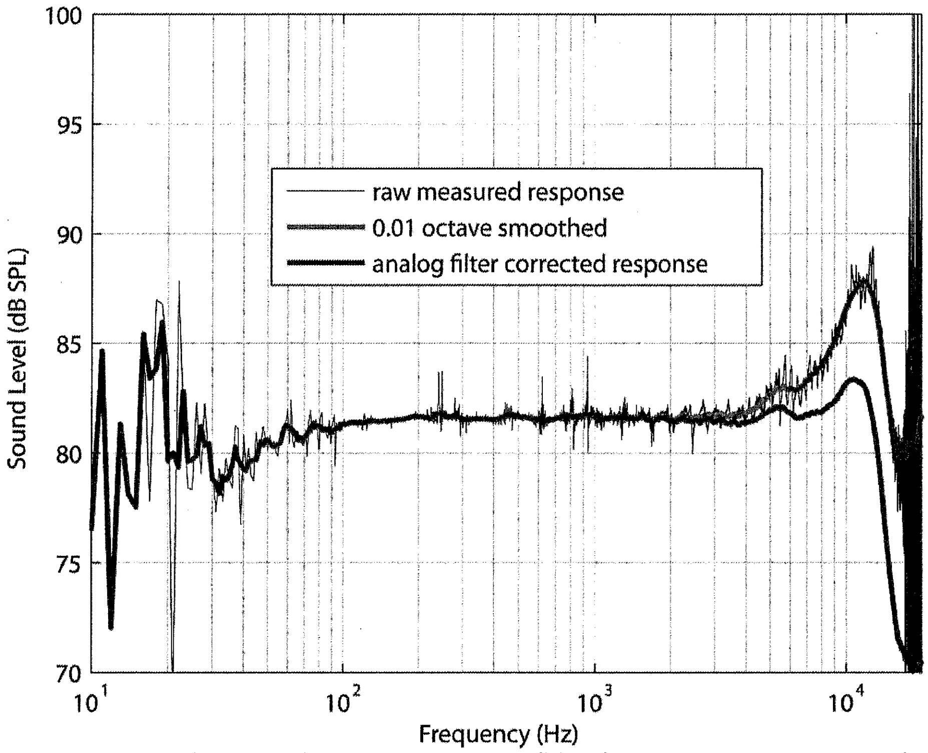

Figure 1: soundBadge raw microphone response (black), the smoothed response (red), and the response after processing by the device's analog correction filter (blue) shows the raw measured output reletive to the reference mic. This graph shows a relatively flat frequency response is achieved through an analog filter correction for the 12 kHz peak.

Simulation of industrial environment test physical setup

The overall performance of the prototype soundBadge was compared to 3 calibrated industry standard reference devices (a Rion NC-74 class I calibrator @ 1 kHz 94 dB SPL was used for sound level meter calibrations before each measurement). Two sound level meters (Norsonic NOR 140 Class 1 meter, and Norsonic NOR 132 Class 2 meter) and a Cirrus CR110A dosebadge were used for the comparison. A-weighted levels and noise dose measurements were made. All tests took place at London South Bank University either in the anechoic chamber, the acoustic and lighting laboratory, or the reverberation chamber. These locations comply with L_{Aeq} measurement requirements according to EU standards. Sound level meters were placed on a tripod at listening position of a worker. Dosimeters were worn (CR110A) or held (soundBadge) also at the listening position.

Simulation of industrial environment stimuli and analysis

Three noise types simulating a normal factory work environment were used: drilling, wood sanding and hammering metals. Measurements were timed to 2 minutes (120 s) apart from the Cirrus CR110A which has no display and whose recorded data was read at the end of all the sessions. A-levels were measured and dosages were calculated from these average equivalent A-weighted levels. Calculations were made according to the standard EU formulas (IEC 61252) after the assumption that these stimulated work noises would constitute 1 hour of an 8 hour work day.

RESULTS

Frequency response

Measured frequency response between 31.5 Hz to 8 kHz for A and C-weighting were within +/- 1.27 dB and +/- 0.9773 dB from the targets specified in EU regulations (IEC61252:2002-03 ; IEC61672-1:2002-05). The average deviation from the targets 31.5 Hz and 8 kHz were 0.3488 +/- 0.2855 and 0.3598 +/- 0.3271 for A and C weightings respectively. These were within class I weighting tolerances when measured at high levels (measurement was made at 81.5 dB SPL @ 1 kHz). Low frequency range limitations of the sound source prevented measuring below 30 Hz (see noise indicator bands on Figure 2). High frequency responses, between 8 kHz and 12.5 kHz, were within +/- 2.16 dB and +/- 2.22 dB of the target (Figure 2) and were also within class I specifications at (or presumably above) 80 dB SPL. Note that 80 dB SPL is the required lowest level a sound exposure meter must accurately measure according to EU specifications (IEC61252:2002-03).

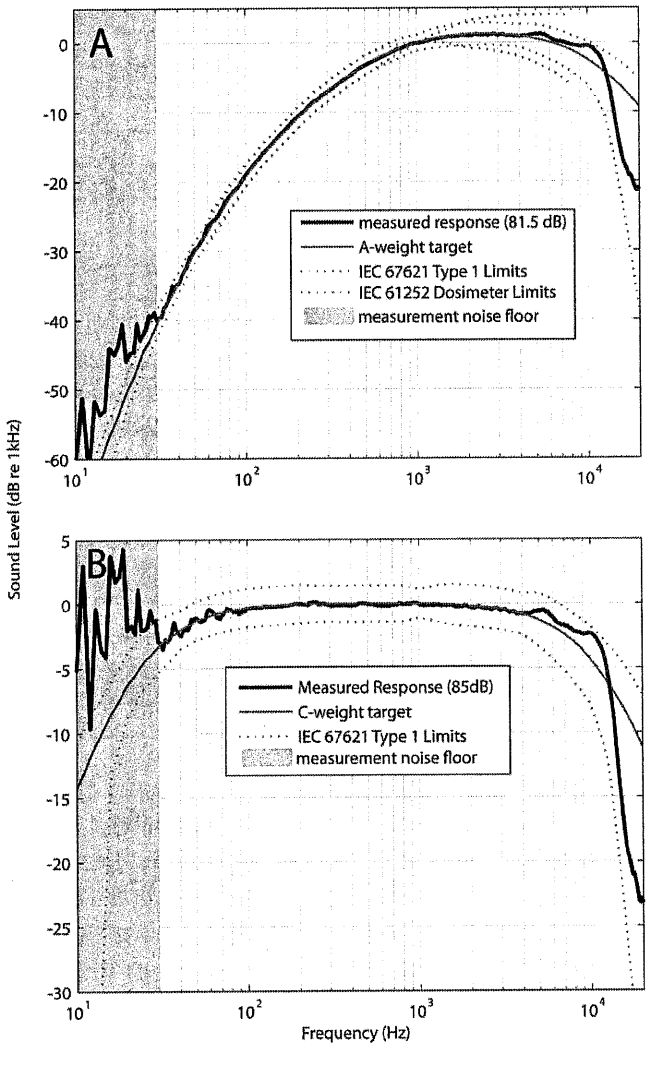

Figure 2: soundBadge frequency reponse measured after its analog A or C-weight analog filter (Panel A and Panel B respectively) compared to allowed EU regulatory limits shows the device performs within the required frequency weighting specification for noise dosimeters (as specified by IEC 61252 from 63 Hz to 8 kHz required) and is within Class I sound level meter tolerance from 30 Hz when measured at 81.5 dB SPL.

Simulation of industrial environments

Over the 3 locations and several simulated work environments the two calibrated sound level meters were within +/- 2 dB of each other when reporting equivalent A-weighted levels (NOR132 relative to NOR140 was within 0.9 dB to -2.0 dB, mean = 0.9167, std = 0.6274). The soundBadge prototype had A-weighted levels within +/- 2.9 dB of both sound level meters (relative to NOR140, min = -2.7 dB, max = 2.6 dB, mean = 1.2 dB, std = 1.15 dB; and relative to the NOR132, min = -2.9 dB, max = 2.0 dB, mean = 1.7 dB, std = 0.9 dB) (Table 1).

Table 1: Comparison of two sound level meters (a class I NOR140 and a class II NOR132) with the soundBadge prototype sound exposure meter for several simulated work environments (top of table). Representative measurements of the activities were made over 2 min durations and it was assumed that the work day would consist of 1 hour of this activity. In order to compare with CR110A the overall measurements were combined. All devices produced similar overall dose measurements and soundBadge was within 3 dB of the sound level meters for all measurements.

Environment	SOURCE	SLM Type	DURATION (sec)	SPL (dBA)	LAmax (dBA)	LEP,8h (dBA)	Noise Dose %
Office	Metal Filing	Nor 140	120	97.0	101.9	88.0	198.6
		Nor 132		99.0	102.7	90.0	315.2
		soundBadge		97.7	102.3	88.7	233.4
	Plastic Cutter	Nor 140		97.6	101.0	88.6	228.1
		Nor 132		98.8	101.2	89.8	301.0
		soundBadge		96.3	102.1	87.3	168.9
Reverb Chamber	Drilling Plastic	Nor 140		84.8	95.7	75.8	11.9
		Nor 132		83.9	95.4	74.9	9.6
		soundBadge		84.6	100.7	75.6	11.3
	Sanding Wood	Nor 140		89.8	92.9	80.8	37.6
		Nor 132		90.0	93.4	81.0	39.4
		soundBadge		87.1	95.1	78.1	20.2
	Hammering Metal	Nor 140		88.4	93.2	79.4	27.2
		Nor 132		89.0	94.9	80.0	31.3
		soundBadge		91.0	102.0	82.0	49.6
Anechoic Chamber	Hammering Metal	Nor 140		89.5	99.6	80.5	35.1
		Nor 132		90.1	97.0	81.1	40.3
		soundBadge		89.4	97.6	80.4	34.3
All	Through All	Nor 140	720	92.4	101.9	76.4	13.8
		Nor 132		93.5	102.7	77.5	17.6
		soundBadge		92.3	102.3	76.3	13.3
		CR110A	1758	87.8	121.1	75.7	11.5

Overall noise dose from the measured devices spanned a range of 11.5 % to 17.6 % (CR110A and NOR132). The soundBadge and the NOR140 were 13.8 and 13.3 % respectively. The CR110A required a separate reader and consequently the total time over which it was operated was used to calculate its dose, therefore the 11.5 % dose may have registered low due to the fact that this device was averaging sounds over a longer time. However, since the duration of time the CR110A spent in the loud sound environment was significant (720 seconds of the total 1,758 s spent averaging) those loud sounds dominated the average.

CONCLUSIONS

For sound level measurements above 80 dB SPL, the prototype soundBadge has a measured frequency weighting within EU sound level meter class I tolerance specifications for sounds between 30 Hz and 12.5 kHz. In simulated tests soundBadge produced accurate noise dose measurements comparable to CR110A and dosages calculated from both class 1 and class 2 sound level meters. It produced the closest agreement with the NOR140 class I reference meter for overall dosage.

REFERENCES

IEC61252 (2002-03). Electroacoustics-specification for personal soun dexposure meters. Geneva: International Electrotechnical Commission.

IEC61672-1 (2002-05). Electroacoustics-sound level meters. Geneva: International Electrotechnical Commission.

Modeling the incidence and prevalence of noise-induced hearing loss in New Zealand

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INTRODUCTION

Noise-induced hearing loss (NIHL) is recognised as a significant health and disability issue both in New Zealand (NZ) and worldwide. Noise exposure can lead to damage in the inner ear and loss of hearing ability, particularly to high frequency sounds; poor speech detection and discrimination; an inability to hear in background noise; and tinnitus. The impact on the individual varies but it can reduce employment options and cause social withdrawal, isolation and depression.

The World Health Organisation estimates that over 250 million people have significant hearing loss and that approximately 16 % of these cases result from excessive noise (Smith 2004). There is also a high economic cost; for example in Australia hearing impairment is estimated to cost $11.6b (1.6 % of GDP) annually and NIHL is thought to account for about 30 % of this cost (Access Economics Pty Ltd 2006). The Accident Compensation Corporation (ACC) in NZ reports a steady increase in the number of NIHL claims over recent years at an increasing cost for rehabilitation (Thorne et al. 2008).

Epidemiological data on NIHL has been collected using various methods including quantitative hearing assessment, self-reports (e.g. European Agency for Safety and Health at Work 2005), questionnaires (e.g. Palmer et al. 2000, 2001) and the number of people receiving compensation for NIHL (Thorne et al. 2008). Estimates of the incidence and prevalence of NIHL in different countries vary considerably. This variation is likely due to differences between the populations and their noise exposure, and includes: variations in the audiometric criteria for defining degree of hearing loss; differences in hearing conservation programs and use of personal hearing protection; and in criteria for attributing the proportion of hearing loss due to noise exposure rather than age or other disease. Based on the WHO definition for substantial or significant hearing loss (> ave 41 dB loss for 0.5, 1, 2 and 4 kHz), an estimated one sixth (16 %) of the population with hearing loss worldwide is attributable to occupational noise exposure (WHO 2002). This figure is corroborated by a USA assessment of the contribution of occupational noise exposure to total deafness rates, giving a range from 7 % in developed nations to 21 % in developing regions (Nelson et al. 2005). In the USA it is estimated that between 9 and 11 million people have NIHL and 30-40 million are at risk because they work in noisy environments (Crandell et al. 2004; NIDCD 2005). Hearing loss and tinnitus accounts for 10 % of the disabilities in the US armed services; the third highest disability (Humes et al. 2006).

In New Zealand it is difficult to identify exactly how many people are affected by NIHL and how many are at risk as there are very limited published data in this country. In 1984 the Department of Health estimated that about 50 % of adult hearing loss in NZ was due to noise (Hearing Report 1984). From 1992 to 1998, there were 2,411 validated cases of NIHL reported to the Notifiable Occupational Diseases System