PILOT STUDY ON INDIVIDUAL DOSE-RESPONSE RELATIONSHIP EVALUATED THROUGH OTOACOUSTIC EMISSION MEASUREMENTS IN CONTROLLED NOISE EXPOSURE: INFLUENCE OF CIRCADIAN RHYTHM

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1 Introduction

Over 22 million of North American workers are exposed everyday to noise exposure doses that may induce hearing loss [1]. Even if they use hearing protection devices (HPD) in order to limit their exposure, but the protection is limited since the HPDs may not be correctly fitted nor worn at all times. As a result, Noise Induced Hearing Loss (NIHL) remains one of the biggest cause of invalidity and indemnity in North America [1, 2].

Health and safety practitioners in the workplace periodically perform audiometric measurements to monitor the workers' hearing levels. These measurements are conducted on too long intervals and usually after the hearing damage has appeared, and do not prevent the occupational hearing loss. Therefore, a system able to simultaneously record and process the noise characteristics to calculate the cumulative dose and measure the resulting hearing fatigue continuously, possibly through distortion-product otoacoustic emission (DPOAE), might enable better prevention of NIHL.

Objective

In an attempt to monitor hearing status changes, an experiment was conducted on human subjects in controlled noise exposure conditions measuring pure-tone audiometry (PTA) hearing threshold levels (HTL), stapedial and medial olivocochlear reflexes in addition to continuous otoacoustic emissions monitoring.

The objective of this paper is to consider the possible effects of the circadian rhythm on the hearing health monitoring measurements. The effects of the time of day (TOD) on pre/post exposure comparisons is studied for subjective tests such as the PTA and also for objective measurements such as the stapedial and medial olivocochlear reflex thresholds as well as otoacoustic emissions. Ideally the circadian rhythm should have a minimal effect on the differences between pre (morning) and post (afternoon) noise exposure measurements in order to distinguish true variations caused by the noise exposure. Eventually a thorough analysis of the aggregated results will be conducted in an extensive study to evaluate the true effects of noise exposure on hearing health.

2 Potential effects of circadian rhythm on subjective and objective hearing tests

To detect changes due to noise exposure during their work shift, workers would be tested at the beginning of the work day, in the morning, and at the end of their work day in the afternoon. Workers' focus can be influenced by the TOD possibly affecting the subjective hearing measurements. The metabolic activity of cells involved in the hearing system, such as the cochlea's hair cells, may also depend on the TOD and therefore a difference between morning and afternoon measurements may be related to this activity instead of other factors such as noise exposure.

2.1 Potential effects on pure-tone audiometry

In Ezzatian's study [3] a gap detection test was used to assess the hearing ability of the listeners, a method similar to classic audiometry, it considers the time of detection instead of the HTL. Such measurement gives a good indication whether the participant is wide awake or sleepy. Such participant status could influence the delay to answer to audiometric stimuli and might result in the participant not answering to his true HTL if the audiometry is performed too fast. Although the status of the participants can influence the outcome of subjective hearing tests, it seems that the effects of TOD are not large enough to influence performance in the typical testing conditions as Ezzatian reported in [3].

2.2 Potential effects on stapedial reflex

At the time of writing, no study was found specifically on the effects of TOD on stapedial reflex thresholds. However, the study from Venet [4] addressed the effects of noise exposure on the efferent reflex (ER) and therefore Venet recorded measurements in the morning and the afternoon. Although it is not clear according to Guinan [5] whether Venet [4] is measuring a mixture of medial olivocochlear (MOC) reflex and middle-ear muscle (MEM) activity or simply the MEM activity alone, there is an observable change of about 1-2 dB average in ER threshold levels for the control group, not exposed to noise, which could be attributed to the effects of TOD.

2.3 Time of Day effects on DPOAEs

In spite of the results from the studies on circadian rhythm effects [3], the study from Cacace [6] revealed that an effect of the TOD on DPOAEs could be detected. To detect such effects, Cacace processed time variations in DPOAE levels with a discrete fourier transform (DFT) before analyzing the data with an ANOVA to eliminate phase differences in the changes between subjects and simply look at the frequency of the changes. Although this TOD effect is statistically significant, it is not large enough to influence the test interpretations in standard laboratory test conditions [6].

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3 Experiment description

For the experiment, 9 volunteers had to pass a hearing screening test starting with an otoscopic examination, followed by a standard DPOAE test and a classic PTA test. Subjects were exposed on three different days for the following noise conditions: Industrial, Constant, Quiet. On the days of the hearing status monitoring measurements, they first went through the pre-exposure tests, which consisted in a manual PTA, stapedial reflex measurements with tympanometry and medial olivocochlear reflex by contralateral suppression (CAS) DPOAEs test. The subjects were also tested for DPOAEs after the calibration of the DPOAE stimuli signals, right before the noise exposure. Once the noise exposure started, every 15 minutes a new DPOAE measurement of about 5 minutes duration was performed with a designed system [7], or a reference system. The noise exposure was recorded with a sound level meter positioned in the room close to the test subjects' ears. A noise level around 85 dB(A) was set so that the resulting exposure inside the HPD protected ear canal was about 70 dB(A), slightly below the average MEM reflex threshold. After the 4-hours noise exposure the subjects went through the post-exposure tests which were the same as the pre-exposure tests with the addition of a DPOAE test in silent condition at the beginning of this test sequence.

4 Preliminary experimental results

4.1 Pure-tone audiometry

Measured differences between pre and post-exposure PTA HTLs are on average within an audiometer step (5 dB(HL)). Surprisingly, better hearing or in other words a lower HTL in post-exposure levels (e.g. paired Wilcoxon test mean of differences $= 4.44$ dB(HL), $p < 0.05$ for Industrial noise conditions at 3 kHz), was measured in the afternoon whether the subject was exposed to noise or not.

4.2 Stapedial reflex

No significant changes in acoustic reflex thresholds (ART) were observed for the Quiet conditions (e.g. mean of differences $= -3.13$ dB(SPL), $p > 0.1$ at 4 kHz), although the average is negative in contrast with averages for Impulsive and Constant constant conditions (e.g. mean of differences $= 2.22$ dB(SPL), $p > 0.1$ at 2 kHz for Constant noise conditions), indicating elevated ART for post-exposure where ART are slightly decreased after a regular Quiet day. This might indicate some minor effect of the circadian rhythm as reported by [6] and non significant effects of noise exposure with the current statistics approach.

4.3 DPOAEs

In general, the measured difference between afternoon and morning DPOAE measurements for the Quiet conditions are within 1 dB (e.g. mean of differences $= 0.84$ dB(SPL), p ¡ 0.05 at 4382 Hz), a magnitude similar to what is found in [6]. Therefore, the effects of TOD would be smaller and of opposite sign compared to the envisioned noise induced changes of possibly < -2 dB(SPL).

5 Discussion

Previous studies [3, 4, 6] along with the current preliminary results indicate that the influence of the circadian rhythm, if present, is relatively small and should not influence the test interpretations for standard laboratory conditions. Other factors might affect the results for subjective and objective hearing tests, such as the learning factor for subjective tests where a decrease in average HTL of 1-2 dB(HL) could be observed for PTA in the post-exposure measurements [8].

6 Conclusions

In summary, circadian rhythm effects on hearing tests are not large enough to influence the interpretation of the results in standard test conditions. Other factors might have a bigger effect and therefore should be considered first. It is not necessary to correct for this TOD effect for the upcoming extensive study of the DPOAE level variations over the test day.

Acknowledgements

Annelies Bockstael gratefully acknowledges the support of the Research Foundation-Flanders (FWO). Vincent Nadon is especially grateful to the IRSST, the Quebec occupational health and safety research institute, for its support for the project as well as the technical support from the EERS-ÉTS industrial research chair in in-ear technologies.

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