EARLY DETECTION OF NOISE-INDUCED COCHLEAR DAMAGE

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Introduction Otoacoustic emissions (OAEs) are acoustic signals which can be registered in the ear canal by means of low noise microphones. They are a consequence of the inner ear activity. In fact, from a micro-mechanical point of view, the inner ear behaves like an active, non linear amplification system which injects power in the cochlear outer cells to amplify sounds near to the perception threshold. The idea that OAEs can be used to perform an early detection of inner ear functionality loss has been fascinating the researchers for a long time. In this work we show that this idea is strongly supported by theoretical considerations and experimental evidence. It is well-known that the amplitude of the OAEs is related to the effectiveness of the active feedback mechanism, which is transmitted by the outer hair cells (OHCs), and that the evoked OAE signals are dominated by the contribution of the spectral components for which the cochlear amplifier is most effective (spontaneous or long-lasting OAEs) (Sisto and Moleti, 2001). It is also well-known that the OHCs are the first part of the auditory system to be damaged by noise. Thus it is quite obvious to predict that mild cochlear damage due to the early effects of noise exposure could be detected by using OAE measurements. Hall and Lutman (1999) have shown that OAEs are indeed more sensitive than standard audiometry in a range of mild hearing loss, by taking into account the sensitivity and test-retest fluctuations of both techniques. In this work we show that transient evoked OAE (TEOAE) parameters can effectively discriminate between populations of exposed and non-exposed to noise.

Methods Otoacoustic emissions evoked by transient stimulus (TEOAE) data have been analysed relative to a population of 61 young male subjects (age ranging from 18 to 25 years). The ears were classified, according to a standard wide band audiometric test, in 3 classes: 1) ears of subjects not exposed to noise and bilaterally normal hearing (78 ears from 39 subjects), 2) audiometrically normal ears of subjects affected by unilateral high frequency ($f > 3$kHz) hearing loss (22 ears from 22 subjects), 3) hypo-acoustic ears of the same last subjects. Hearing loss was in all cases related to previous training with fire arms within the Army. Pure tone audiograms were recorded in an acoustically shielded room. The audiometric test frequencies were 0.25, 0.5, 1, 2, 3, 4, 6, and 8 kHz. The examined ear was conventionally defined 'normal' if no threshold shift large than 20dB was found over the whole frequency range. For threshold shift larger than 20dB in any audiometric range f 3 kHz, the ear was defined 'high frequency impaired'. TEOAE recordings were obtained using the standard ILO-96 System in the "non linear" mode of acquisition. The statistical distributions of the set of OAEs parameters chosen as candidates for early detection of ear damage (global and spectral reproducibility, global and spectral response amplitude, global and spectral signal to noise ratio and spectral latency) were analysed in this population of ears. The TEOAE recordings were processed off-line by a dedicated software developed in LabVIEW (National Instruments). A time-frequency analysis was performed on the TEOAE registration by means of a standard wavelet technique (Tognola et al., 1997). For 10 frequency bands, the time at which the absolute value of the wavelet coefficient reaches its maximum was evaluated for each registration. This time was identified as the time that the spectral component of the

travelling wave needs to reach its tonotopic site and to be reflected back. We refer to this time as the 'spectral latency'.

Results As regards the whole set of parameters analyzed, a statistically significant difference was found between classes 1) an 2). This difference largely exceeds the differences existing between classes 2) and 3). This fact suggests that the noise exposure, which was responsible of the unilateral hearing loss in the ear closer to the noise source, also caused a sub-clinical, from the audiometric point of view, damage in the audiometrically normal ear. Thus, the OAE technique seems to be able to early detect such a kind of sub-clinical damage. In other words, the audiometrically normal ears of subjects affected by a unilateral hearing loss result more similar, as regards the OAEs parameters, to hearing impaired ears than to the ears of bilaterally normal subjects. As shown in Table I, statistically significant differences, expressed by the probability of the student's t-test, can be evidenced between classes 1) and 2) by using parameters of the global TEOAEs response (reproducibility and amplitude), but much more significant differences can be found using the corresponding spectral parameters. As regards the spectral latency, an analogue result can be found, as shown in Table II.

		Global	0.8 kHz	1.0 kHz	1.25 kHz	1.6 kHz	2.0 kHz	2.5 kHz	3.2 kHz	4.0 kHz
Repro	P_{1-2}	0.0218	ns	ns	ns	ns	0.0093	0.0005	0.0018	0.0017
	P_{2-3}	Ns	ns	ns	ns	ns	ns	ns	ns	0.01
Ampl.	P_{1-2}	0.010	ns	ns	ns	0.0082	0.0122	0.0003	0.0035	0.0048
	P_{2-3}	Ns	ns	ns	ns	ns	ns	ns	0.0366	ns
SNR	P_{1-2}	0.0152	ns	ns	ns	0.023	0.009	0.001	0.004	0.002
	P_{2-3}	Ns	ns	ns	ns	ns	ns	ns	0.05	ns

Table 1: Statistical comparison of the global and spectral OAE parameters distributions, between classes 1) and 2) and between classes 2) and 3).

Latency (ms)	0.5 kHz	1 kHz	1.5 kHz	2 kHz	2.5 kHz	3 kHz	3.5 kHz	4 kHz	4.5 kHz	5 kHz
Class1	10.7	10.3	8.7	6.9	5.7	5.2	5	4.7	4.7	5
Class 2	10.8	10.4	8.9	7.2	7	7.2	5.6	5.3	5.9	6.9
Class 3	11.1	10.9	9.4	8.1	9.2	7.3	9.4	6.9	7.9	8.4
P_{1-2}	ns	Ns	ns	ns	0.0002	0.0267	ns	ns	ns	ns
P_{2-3}	ns	Ns	ns	ns	0.0383	ns	0.0047	ns	ns	ns

Table 2: Spectral latencies for the three classes of ears and statistical comparison of the spectral latencies distributions, between classes 1) and 2) and between classes 2) and 3).

Conclusions OAE parameters are indeed effective indicators for statistical discrimination of populations exposed and non-exposed to noise. A strong effort is needed now to show that it is possible to find an indicator, based on one or more OAE parameters, providing a reliable indication of sub-clinical cochlear damage on a single subject.

References

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