Repeatability of DPOAEs and their vulnerability to over-exposure

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Introduction

Over-exposure to noise is considered to be one of the main causes of hair cell damage and can result in temporary and permanent hearing threshold shifts. The detection of hearing loss is presently based on the results from pure-tone audiometry, but otoacoustic emissions (OAEs) are becoming an alternative measurement for screening and monitoring of cochlear changes. The origin of OAEs is in the cochlea. Mechanical energy produced by the outer hair cells (OHCs) propagates backward along the basilar membrane towards the stapes, thus OAEs reflect a leakage of energy from a non-linear, bio-mechanical process based on activity of OHCs. OAEs are measured by inserting a sensitive, low-noise microphone/ ear speaker assembly non-invasively into the external ear canal that stimulates the ear acoustically.

Measurements of OAEs before and after acoustical exposure suggest that OAEs are a more sensitive measure than pure-tone audiometry and therefore might be a measure for the early identification of hearing loss (Hotz *et al.* [1] and Lucertini *et al.* [2]). Moderate exposure that gives rise to temporary threshold shift (TTS) has been shown to alter the amplitude or frequency composition of OAEs (Sutton [3]). Temporary effects on OAEs may have implications for the clinical interpretation of OAEs from permanently noise-damaged ears.

The purpose of this study is to investigate the vulnerability of distortion product OAEs (DPOAEs) to acoustical over-exposure, to investigate which method is more vulnerable to sound exposure and to compare time- and frequency specific characteristics of the two methods. The long-term purpose is to find DPOAE characteristics that indicate the early stage of a hearing loss.

Methods and materials

Test design

In a pre-experiment, the test/ retest repeatability of the measurement procedure itself is tested in order to determine whether changes in DPOAEs reflect functional changes in the cochlea rather than measurement error. Both the repeatability of measurements with probe reinsertion and without probe reinsertion are tested. In the main experiment the changes of DPOAEs after sound exposure are observed by measuring DPOAEs with certain time intervals. In order to have smaller intervals between the measurements, the subjects are divided into 2 groups with differing measuring times.

Test subjects

In the study 16 test subjects participated. The subjects were divided into 2 groups, the 2 groups differing in their measurement times after the exposure. Both groups consist of each 4 males and 4 females. The subjects of Group 1 are aged between 20 and 26 (mean = 23.5). Group 2 subjects are aged between 22 and 28 (mean = 24,6). In Group 1 5 left ears and 3 right ears were tested, in group 2 4 right and 4 left ears. All subjects filled out a questionnaire about exposure and ear disease history. An otoscopy was performed and if necessary the test subjects were asked to clean their ears with cotton swabs. All subjects had their haring tested for both ears using pure-tone audiometry. 13 subjects had pure-tone thresholds equal to or better than 20 dB HL at 1/2 octave intervals from 250 to 4000 Hz. Three subjects had high frequency hearing loss higher than 20 dB HL.

General measurement procedures

During the entire test, the subjects were seated in a double-walled, sound-isolated audiometry chamber at the Department of Acoustics at Aalborg University. That room complies with the background noise requirements stated in ISO-8253-1: 1989.

Pure-tone audiometry

The pure-tone audiometry was performed with a custom-built audiometer, using Sennheiser HDA 200 headphones and the ascending method that complies with the norms for automatic audiometries (ISO-8253-1: 1989). The system was calibrated using the B&K type 4153 artificial ear according to IEC-60318-1: 1992 and IEC-60318-2: 1992. During the test the operator was situated in a control room next to the audiometry room, having contact to the test subjects via intercom and being able to observe the subject via a camera.

DPOAE measurement

For the DPOAE measurements the commercially available ILO96 research system from Otodynamics was used. DPOAEs at 2*f1-f2 were measured with primary levels of L1 = 65 dB and L2 = 45 dB. The ratio of the primary frequencies was set to 1.2. Eight DPOAEs per octave, with f2 running from 708 to 6165 Hz, were recorded. One DPOAE measurement consists of one sweep, i.e. the primary tones run from the lowest to the highest frequency once. The measurement for one pair of tones consists of 16 averages of 80 ms, corresponding to 1.280 sec. The recording of one sweep consisting of 26 frequencies takes approximately 40 sec. During the measurement the subjects were seated comfortably in an armchair. The subjects were asked to sit as quiet as possible, not to breathe too heavily and to avoid swallowing during the 40 sec of each DPOAE measurement.

Exposure

Via headphones, one ear of each subject was exposed to a 1 kHz tone, lasting for 3 minutes at an equivalent threshold SPL of 105.5 dB. For the Sennheiser HDA 200 headphones this corresponds to a sensation level of 100 dB (ISO-389-8: 2001). The corresponding equivalent free-field level is 102 dB and the A-weighted SPL 102 dB(A). This corresponds to an exposure level of 80 dB normalized to an 8 hour working day (ISO-1999:1990). In the test instructions, the subject was told to interrupt the experiment if he or she felt uncomfortable with the exposure.

Procedure

In the beginning of the test, the subjects were asked to listen to the sound that would be used as the “exposure” very shortly in order to let them decide whether they wanted to participate in the test or not. Thereafter, the subjects had both ears tested with pure-tone audiometry. For each subject one ear was randomly chosen for further investigations and an otoscopy performed. After the test preparations, four DPOAEs were recorded with removing and replacing the probe after each measurement. Four DPOAEs were measured without removing the probe. The subjects were then exposed, and six DPOAEs were measured in certain intervals after the exposure. In group 1 the sweep centre time was at 1:20 (min:sec), 3:20, 5:20, 10:20, 15:20 and 20:20 minutes after the exposure, in group 2 the sweep centre times were at 2, 4, 6, 12.30, 17:30 and 22:30 minutes after the exposure.

Results

Repeatability

Figure 1 shows the mean DPOAE, averaged over all repetitions and all test subjects as well as one standard deviation (SD) of the repetition. The SD is relatively high in the low frequency region below 1 kHz, where the DPOAE has its lowest levels. Above 1 kHz the SD is around 1 to 2 dB for all frequencies. The SD of the measurements with probe reinsertion is only slightly higher than without probe reinsertion; comparison of the 2 measurements with an ANOVA test shows no significant difference between probe reinsertion and no probe reinsertion measurements (p=0.90).

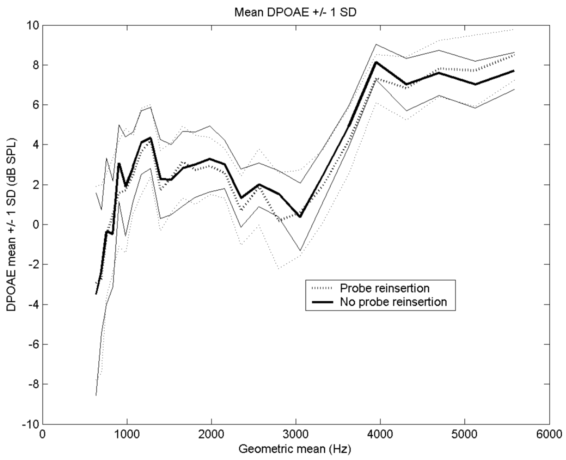

Figure 1: Repeatability of DPOAEs of all test subjects

In figure 2 the mean DPOAEs over frequency are plotted for each subject. The subjects are sorted after increasing DPOAE level. There is a large inter-subject difference in mean DPOAE level and in SD of the repeated measurements and a tendency that subjects with higher emission levels have lower SDs (R = -0.84).

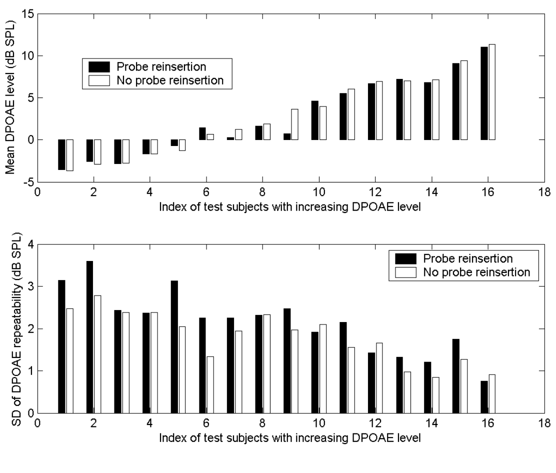

Figure 2: DPOAE mean emission levels and SDs of repeatability for individual test subjects; the data are sorted according to increasing mean DPOAE without probe reinsertion

Vulnerability to over-exposure

To analyse the DPOAE shift after the exposure and its recovery, the first and the last measurement after the exposure are illustrated for each group (figure 3). In addition, the pre-exposure measurement is plotted as a reference. By comparing the two pre-exposure DPOAEs, there seems to be a large difference between the 2 groups. Group 1 has higher emission levels and larger DPOAE shifts than group 2. When analysing the pre-exposure data of the 2 groups, group 1 has a mean emission level of 3.9 dB whereas group 2 has a mean emission level of 2.0 dB. Though no significant difference was found with an ANOVA (p=0.45).

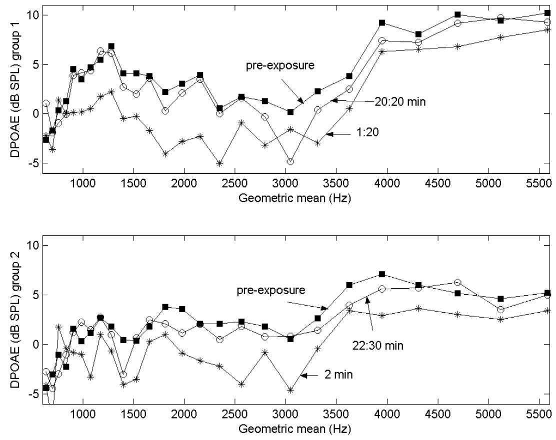

Figure 3: DPOAE shift after over-exposure for the 2 groups

When looking at the DPOAE shift in frequency, it can be seen that DPOAEs are affected in the entire measured frequency range. This is in contrast to the the "½ octave shift" characteristic of TTS, where the maximum TTS for narrow band exposures centred at frequencies above 250 Hz is known to occur at approximately ½ octave above the centre frequency of the stimulation.

In order to study the time course of DPOAE recovery, more test subjects are required in order to avoid group differences. Further analysis should include a comparison with TTS recovery under the same exposure conditions and an individual analysis of the DPOAE shift.

Acknowledgements

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Literature

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