Relationships Between Wideband Middle Ear Power Analysis and Distortion-Product Otoacoustic Emissions in Newborns

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Introduction & Aims

Wideband middle-ear immittance measures, such as power reflectance, transmittance, admittance and impedance represent passive, linear transmission properties of the outer and middle ear. Collectively, these measures are referred to as Middle Ear Power Analysis (MEPA), which can be measured in human ears with the HearID system (developed by Mimosa Acoustics, Champaign, IL). This system also measures distortion product otoacoustic emissions (DPOAE) with the same probe assembly.

Theoretically, a strong correlation between middle-ear transmission and DPOAE amplitude, as a function of frequency, would be expected due to forward and reverse transmission filtering by the middle and outer ear. In this study, we compared wideband reflectance with DPOAE responses in 252 ears of healthy newborns aged 1-3 days. The goal of this study was to characterize frequency relationships between MEPA and DPOAE and to determine if wideband immittance can predict OAE responses for specific frequencies.

(1) Does MEPA demonstrate a specific frequency-dependent relationship with OAE results?

(2) What is the optimal frequency range to quickly establish newborn middle-ear status?

Methods

• Healthy newborns (n=252 ears) aged 1-3 days received MEPA and DPOAE tests using the same probe assembly and ear tip within the same test session.

• Thirty-five newborns received a second, identical MEPA and DPOAE test within a few hours to a few days (the first measurement was used for normative analyses, and the subsequent measurements were used to consider changes in reflectance over time).

• HearID version R4 (Mimosa Acoustics, Inc., Champaign, Illinois) was used for the wideband MEPA and DPOAE measurements. The HearID system consists of a laptop-hosted DSP PC-card, connected to an ER-10C probe (Etymōtic Research, Elk Grove Village, Illinois) with a probe-adaptor cable, and a calibration cavity set. HearID R4 is a research tool and was under active development throughout the course of the study.

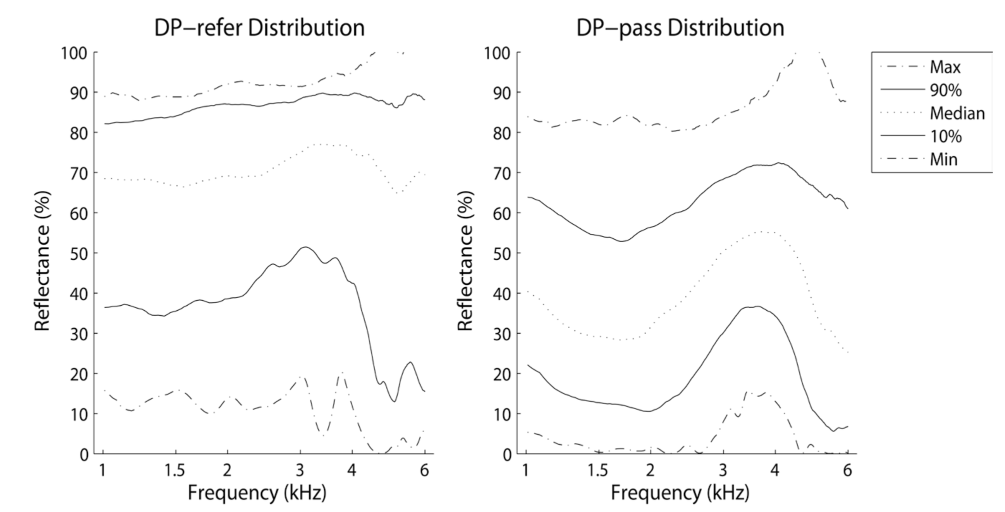
•Calibration was performed daily in the 4-cavity set and also in the ear prior to each measurement.

Methods (cont.)

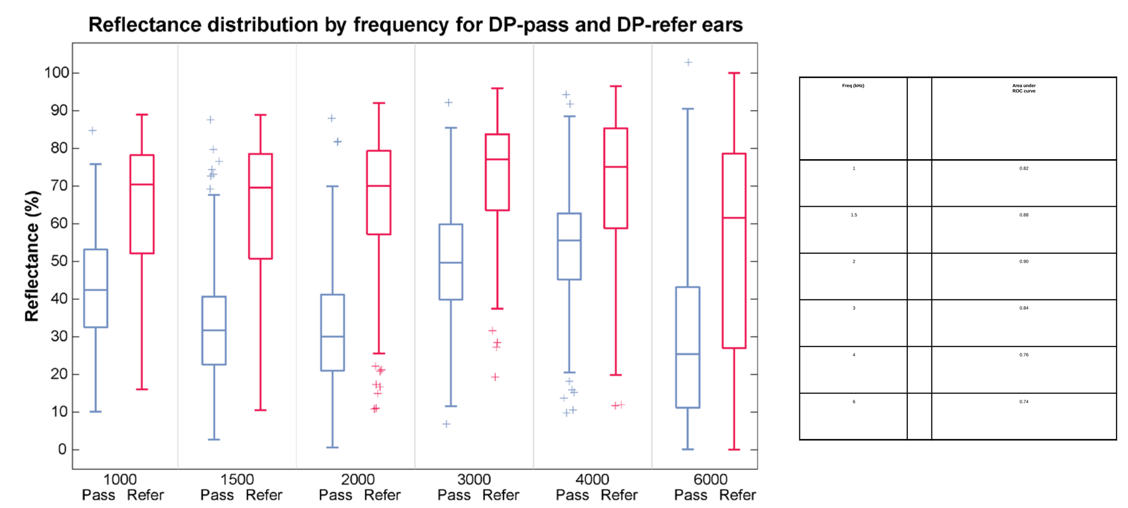
- The wideband MEPA chirp stimulus was output repeatedly at 60 dB SPL for 4 to 8 seconds (depending on stopping rules and noise levels), averaged, and analyzed within the frequency range of 0.2 to 6 kHz. For the tone stimuli, the previous chirp measurement was used as the in-the-ear calibration to adjust the output level for each tone. The 11-tone series was output simultaneously at frequencies 0.2, 0.3, 0.4, 0.6, 0.8, 1, 1.5, 2, 3, 4, and 6 kHz with total level at 60 dB SPL for 4 to 8 seconds (depending on stopping rules and noise levels) per tone.
- DPOAE were measured at $f2$=2, 3, 4 and 6 kHz. The $f2/f1$ ratio was 1.22, and the intensity levels of the primary tones were set at $f1/f2$ = 65/55 dB SPL at each frequency. The primary tones were output for up to 4 s, terminating early if the DPOAE had a sufficiently low noise level (< 0 dB SPL) and sufficiently high SNR (SNR >10 dB).
- For analyzing MEPA results, DP Pass/Refer status was used as a grouping variable. Overall Pass: at least 3 frequencies passed; Overall Refer: at least 2 frequencies referred.

Results

- Reflectance for chirp stimuli was significantly higher for ears that did not pass DPOAE, with the largest separation from 1.5 to 3 kHz.

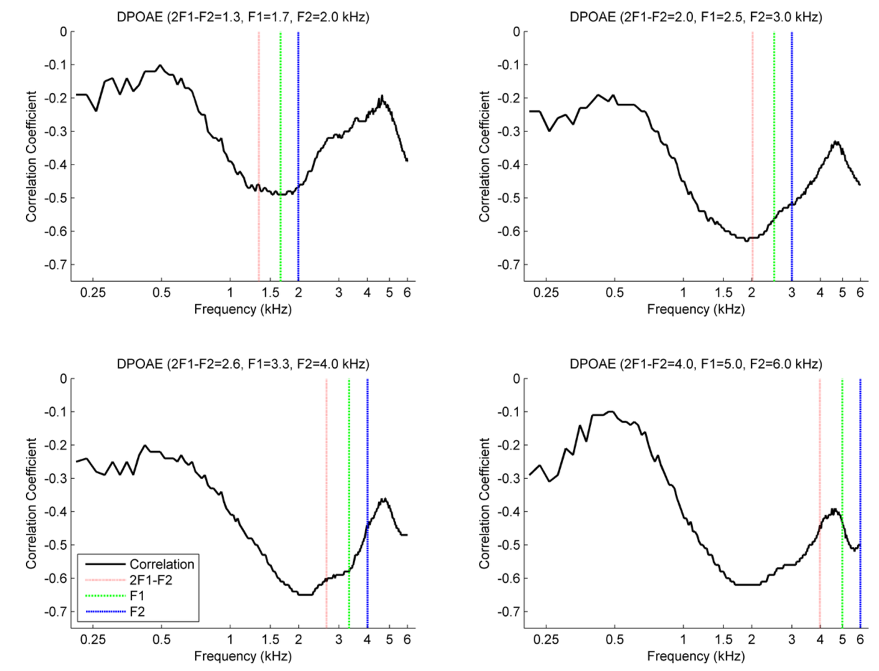


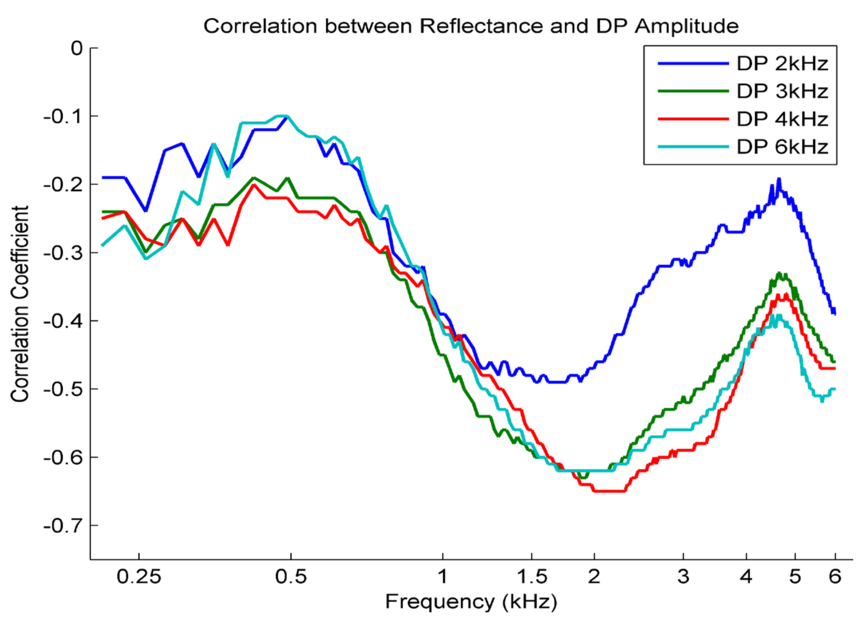
- Reflectance distributions for sine stimuli are illustrated below in box and whisker plots.



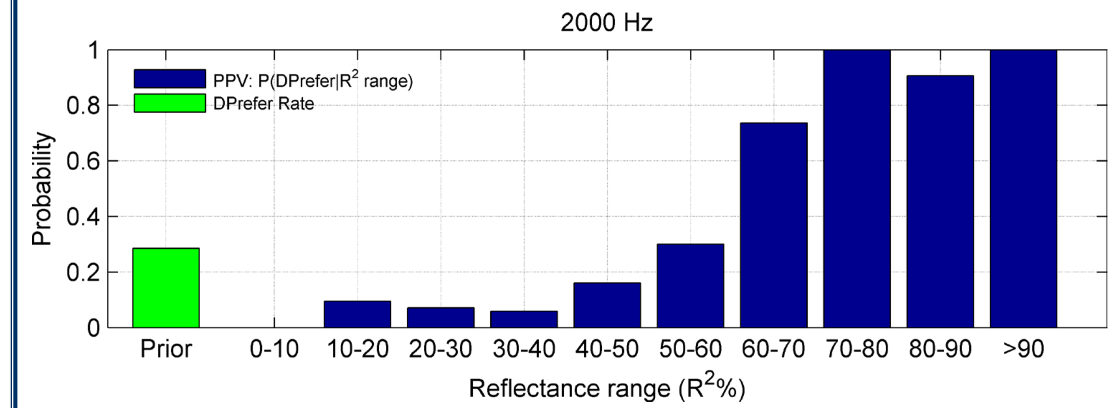
Results (cont.)

▪ DPOAE amplitude (separately for each DPOAE test frequency) was correlated against the reflectance (for chirp stimulus) as a function of frequency. We expected that maximum correlation would occur in the frequency regions containing F1, F2, and 2F1-F2 as those three frequencies need to pass through the middle-ear and return to the ear canal when measuring DPOAE. If reflectance was high at any of these frequencies, it would be expected that DPOAE amplitude would be adversely affected. The following graphs show instead that correlations are highest in a band around 1.5 to 2 kHz regardless of the DPOAE stimulus or response frequency.

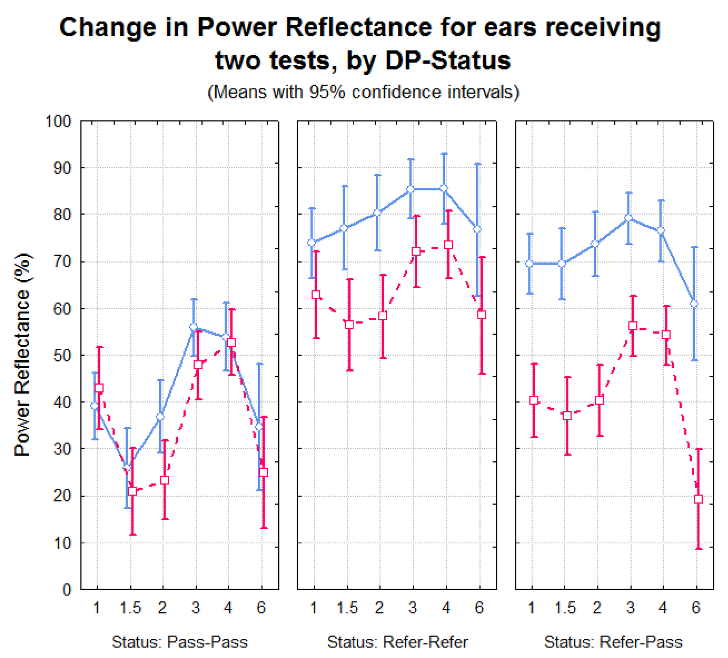




• The positive predictive value that an ear will refer on DPOAE screening based on the reflectance value at 2 kHz is shown below for 10% reflectance bins. The probability of an ear getting a DP refer, given a reflectance value between 60-70%, is 0.73. This probability increases to near certainty for higher reflectance values.



Results



Re-testing shows improvement is largest in the 1.5-2 kHz band, and related to pass versus refer changes in DPOAE screening, further demonstrating the dependence of DPOAE on middle ear transmission effects in the 1.5-2 kHz band.

Discussion/Conclusions

• Analyses consistently demonstrated that across the four DPOAE frequencies, whether measured as $f1$, $f2$ or $2f1$-$f2$, the strongest correlations with reflectance occurred around 1.5 to 2 kHz. Thus, there was not a specific frequency relationship between wideband reflectance and DPOAE responses in newborn ears.

•These frequency effects were not due to statistical properties, eg., noise floor levels, variability or floor/ceiling effects.

• Cochlear effects cannot be eliminated, but middle ear filtering appears to be the primary factor since the correlations mirrored the overall reflectance response.

• Further evidence for middle ear filter effects is in the change on re-test, showing greatest change in the 1.5-2 kHz range.

• The overall prediction of DPOAE pass status is strongest for the 1.5-2 kHz region, thus a brief screening test for middle-ear function in newborn ears could consist of a MEPA test using a single 2 kHz tone.

Acknowledgements

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