Estimates of human cochlear tuning derived from DPOAE reflection-component delays

Abdala, Carolina; Guérit, François; Luo, Ping; Shera, Christopher A.

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INTRODUCTION

Cochlear delay and cochlear tuning are linked through filter theory, which holds that sharper tuning requires longer delays. Likewise, cochlear delays have been linked to reflection source DPOAE delays via the theory of coherent reflection (Zweig and Shera, 1995). Reflection-source emissions tend to be poorly resolved from backscattering. Only energy off of microscopic irregularities along the cochlea, i.e., stimulus-frequency and dish-shaped OAEs, and the reflection component of the DPOAE. Anesthesia between these DPOAE delays has been identified in several species (Shera et al., 2002; Oversehn and Shera, 2003). However, estimating tuning derived from DPOAE delays measured in humans are sharper than tuning recorded in other mammals, leading to some skepticism about the proposed relationships (Siegel et al., 2005; Ruggero and Temchin, 2005, 2007).

Here we apply delays derived from the reflection component of the 2f0, DPOAE to estimate tuning in humans using a species-invariant tuning ratio which defines the correlation of cochlear tuning and estimation errors (Shera et al., 2010). Our objectives is to explore non-invasive methods for obtaining estimates of cochlear tuning and generating preliminary tuning estimates for age groups representing seven decades of human lifespan.

METHODS

Subjects - 186 subjects: 15 premature (mean = 34 wks PCA) and 30 term newborns; 19-month-old infants, 26 teens (13-15 yrs), 43 young adults (20-30 yrs), 21 middle-aged (40-57 yrs) and 32 older adults (68-75 yrs).

DPOAEs (2f0)2/f0, swept logarithmically at 8 stc to capture frequencies from 0.4- to 24 kHz for DPOAEs from 4-8 kHz; 65 (5)-80 (5) dB SPL, f0/f1 = 1.22. Least-squares fit method used to estimate DPOAE level and phase from averages of 6 to 8 sweeps.

Inverse FFT - MATLAB-based software was adapted to measure DPOAE distortion and reflection-component based on their respective phase-sensitive delays. DPOAEs and FFT software developed by C. Talmadge, adapted by F. L. Suey and A. D. Dhar, 2012.

Losses - Simple models of linear and nonlinear least squares regression are fitted to localized subsets of the data and adjacent fits are plotted to create the overall fit. Losses fits were conducted using two strategies: energy weighting and peak picking (Shera and Bergevin, 2012).

I. Calculating Delays

A. DPOAE level (black) and noise (gray).

B. DPOAE level versus frequency (F) and phase-sensitive delay and (C) Nio, delay in periods.

C. -DPOAE level delayed in periods Nio. Only data points shown in red were used in estimating the delay fit.

II. Modeling Delay Trend

A. Parameters estimated from energy-weighted delay data are shown. "Mean of EW and PP" refers to energy-weighted delay data or data restricted to peaks in energy-weighting and peak-picking fits.

B. Parameters estimated from energy-weighted delay data are shown. "Mean of EW and PP" refers to energy-weighted delay data or data restricted to peaks in energy-weighting and peak-picking fits.

III. Estimating Tuning

A. Typical tuning function fits to (CF/CFa|b) as a function of frequency.

B. Typical tuning function fits to (CF/CFa|b) as a function of frequency.

CONCLUSIONS

(1) Consistent with past work (Shera and Berges, 2012), our results suggest that passing a frequency filter structure contains the most important information for estimating delay trends.

(2) The loss peaks based on energy weighting and peak picking usually agree and have generally overlapping CI. Slight differences are restricted to the ends of the frequency range.

(3) Consistent with theory (Shera and Guinan, 1999) and empirical observation (Sterhag and Shera, 2002), all delays derived from the DPOAE reflection component are similar to SFOAE delays. Differences were likely due to methodological factors.

(4) The bend in the DPOAE R delay function was centered around 1 kHz, marking the putative apical-basal transition and a deviation from approximate cochlear scaling. This bend frequency matches nicely with SFOAE delay data.

(5) Our tuning estimates are similar to SFOAE-based estimates. Shera et al. (2010) reported mean Qm values ranging from 11 to 19 over a comparable frequency range, these are slightly higher values than those found here (9.7 to 16). Tuning generally becomes sharper with increasing frequency, most notably in the young-adult group, which had an extended frequency range.

(6) Methylation

a) Infants generally had high Qm values, consistent with sharp DPOAE suppression tuning curves (Adabble, A. et al., 2008). The small decrease in the preschool group in the young-adult group. This decrease was not significant.

b) Only adults show a decrease in tuning around 3 kHz. This may reflect degradation in tuning with age. However, this decrease was not significantly different from controls.

c) The bend frequency marking the apical-basal transition (and deviations from cochlear scaling) does not vary with age; this is consistent with studies of cochlear scaling based on distortion emissions (Adabble and Dhar, 2012).

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SFOAE delays in humans provide estimates of cochlear tuning (Shera et al., 2010). Our results suggest that the reflection component of the DPOAE can provide comparable delay data for tuning estimates. Here, loss fits to either energy-weighted delay data or data restricted to peaks in fine structure captured the underlying delay trends, and produced measures of human tuning that are similar to previous reports using reflection-source emissions.

REFERENCES

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