Impaired cochlear function correlates with the presence of tinnitus and its estimated spectral profile

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Abstract: The presence of tinnitus often coincides with hearing loss. It has been argued that reduced peripheral input leads to frequency-specific increase in neuronal gains resulting in tinnitus-related hyperactivity. Following this gain-adaptation hypothesis, impaired cochlear function should be predictive of the presence and spectral characteristics of tinnitus. To assess cochlear function, perceptual thresholds and distortion product otoacoustic emissions (DPOAEs) were measured with high frequency resolution for subjects with tinnitus and non-tinnitus control subjects (N=29 and N=18) with and without hearing loss. Subjects with tinnitus also provided a `tinnitus likeness spectrum' by rating the similarity of their tinnitus to tones at various frequencies. On average, subjects with tinnitus had elevated thresholds, reduced DPOAE, and increased slope of the DPOAE input-output function in the range from 4 to 10 kHz. These measures were strongly correlated and were equally predictive of the presence of tinnitus. Subjects with a pronounced edge to their hearing loss profile were very likely to have tinnitus. In the group average, the tinnitus likeness spectrum was correlated with perceptual thresholds (r=0.98, p<0.01), confirming previous reports. For 19 of 29 of subjects, perceptual thresholds were correlated with the tinnitus likeness ratings across frequencies and this correlation was significantly improved when low input-level DPOAE were included as an additional variable (r=0.83+/-0.09, N = 19). Thus, cochlear function is strongly associated with the tinnitus percept and measures of cochlear function using DPOAEs provide additional diagnostic information over perceptual thresholds alone.

Subjects and Procedures:

- 29 tinnitus subjects and 18 normal subjects were recruited for this experiment.
- DPOAE generator component using continuous frequency sweep at various primary levels to exclude later DPOAE components which produce DPOAE fine structure (Long 2008).
- Tinnitus likeness rating (Roberts 2008) and detailed behavioral thresholds were also collected.

DPOAE, Audiogram and Tinnitus Likeness test:

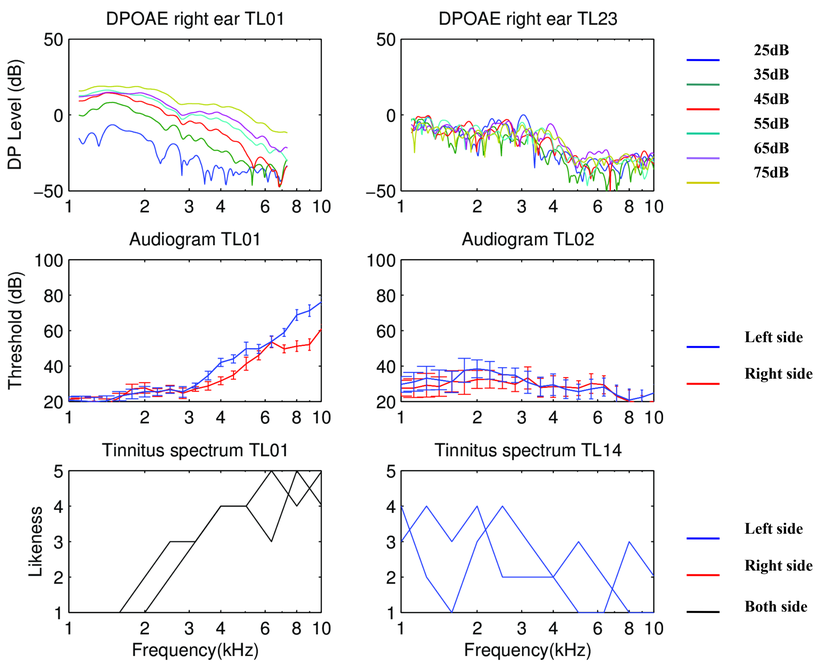


Fig 1. Example data:

DPOAE and Audiogram for a

TII (Left): Subject that gives reproducible tinnitus likeness ratings.

TI (Right): subject that can not give reproducible likeness ratings.

TIII: For some subjects only one likeness rating spectrum was obtained

Results and discussion:

I: DPOAE level and slope diagnostic of presence of Tinnitus

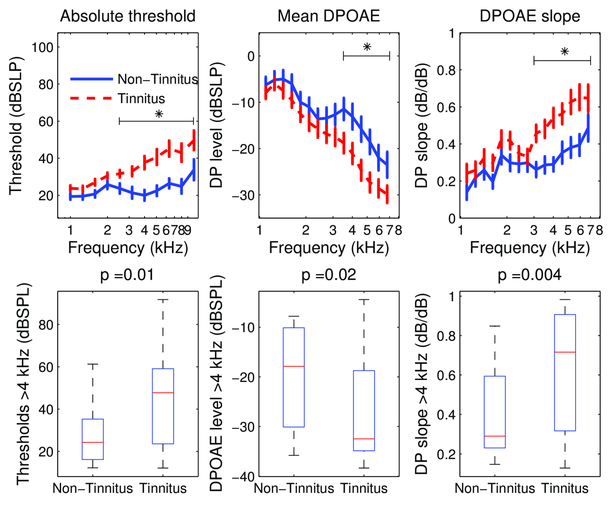


Fig 2. Audiogram and DPOAE: Significant difference between Tinnitus and Normal subjects

First row: The left column shows the audiogram result. The middle column shows the mean DPOAE. The right column shows slope of DPOAE input/output functions.

Second row: Same data as above averaged for frequencies above 4kHz.

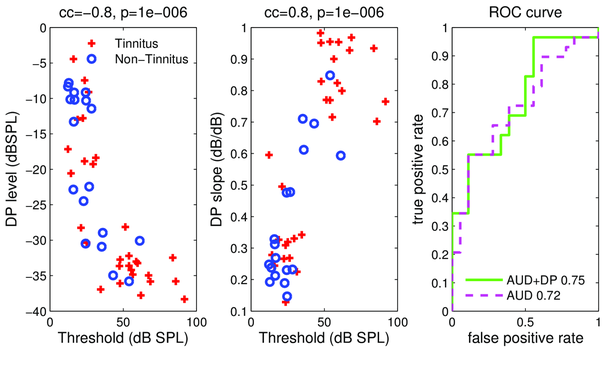
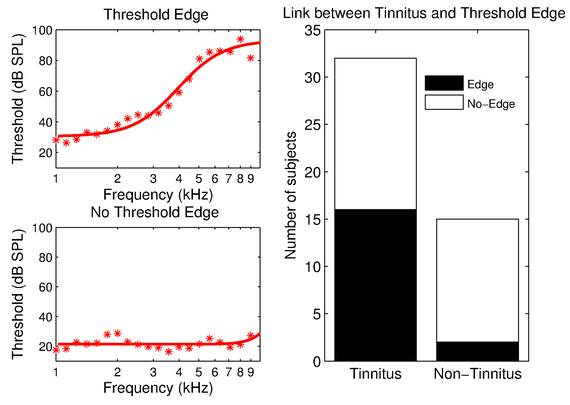


Fig 3. DPOAE does not improve prediction of presence of tinnitus in this sample

- DPOAE slope and level were strongly correlated.
- Audiogram and DPOAE (above 4KHz) were equally predictive of presence or absence of tinnitus in a given subject.

II: Audiogram Edge predictive of the presence of tinnitus



III: Tinnitus Likeness Spectrum can be predicted from cochlear function on 2/3 of subjects

$$L = 0.007\ dB^{-1} I^{*} - 0.05 dB^{-1} I_{DP} + 0.09 dI_{DP} + 1.53$$

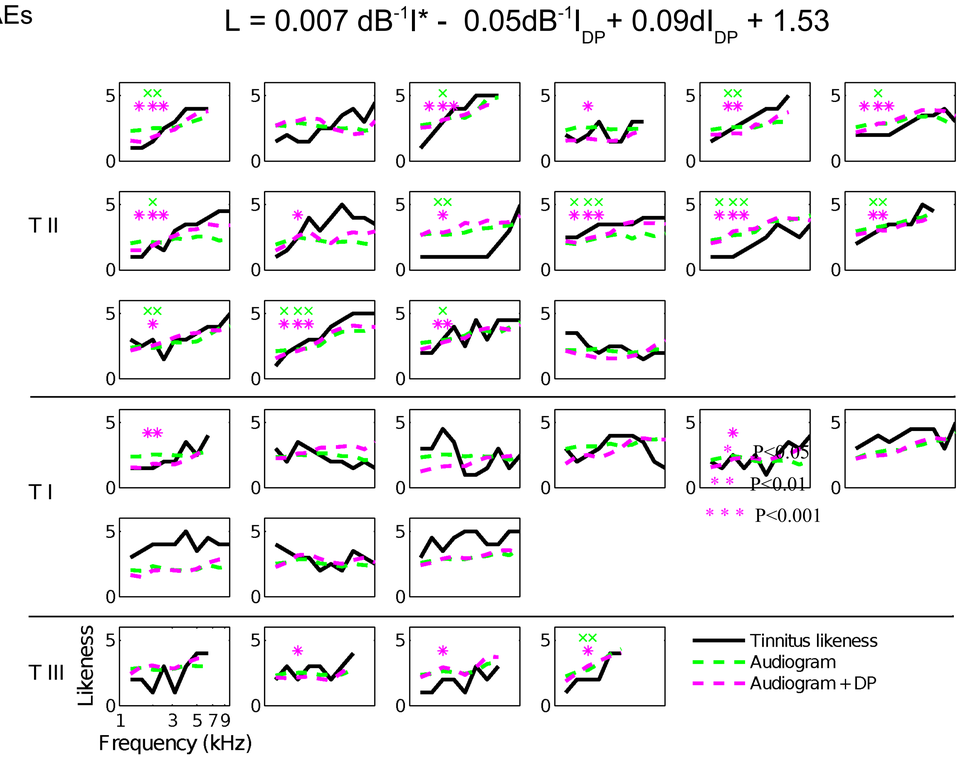


Fig 5. Tinnitus spectrum prediction:

- Previous reports show likeness spectrum correlated with audiograms in the group average.
- Spectrum of tinnitus could be predicted with audiogram and DOPAE for each individual subject.
- This correlation was significantly improved with DOPAE.

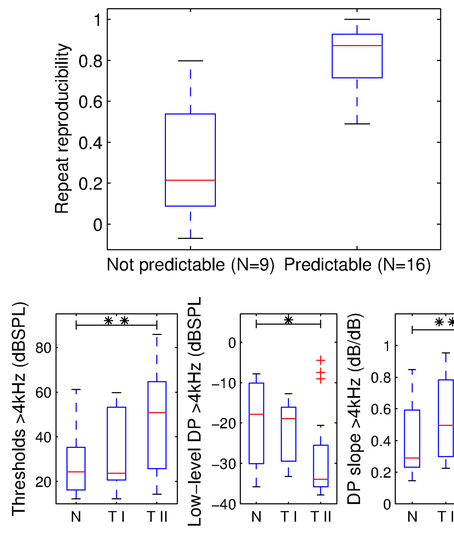


Fig 6. Predictable subgroup of tinnitus subjects:

Why are some subjects “predictable” from their peripheral hearing deficits and others not?

- Unpredictable subjects cannot reproduce their subjective likeness ratings thus the subjective data may be too noisy to predict.
- Subjects that were not able to give reproducible tinnitus spectrum had less hearing loss.

Conclusion:

Gain adaptation model (Parra 2007) explains known properties of Tinnitus:

1) Associated with hearing loss.
2) Effect predominant at floor of loss-edge.
3) Effect strongest for sharp loss-edge.

Gain Adaptation model also predicted :

1) Tinnitus subjects are more likely to hear the Zwicker tone.
2) Tinnitus predicted better when using DPOAE together with audiogram.

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