Tinnitus status and spectral profile can be predicted from Audiogram and DPgram for a subset of subject

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Abstract:

We previously hypothesized that tinnitus is the result of a gain-adaptation mechanism that, when confronted with degraded peripheral input, increases neuronal gains such that spontaneous neuronal activity is perceived as a phantom sound. Following this hypothesis we predicted that the tinnitus percept can be determined for individual subjects from measures of their peripheral processing when obtained with sufficient frequency resolution. The aim of this ongoing study is therefore to find a correlation between the tinnitus percept with measures of peripheral processing on an individual subject basis. To asses peripheral processing, we measured Distortion Products Oto-Acoustic Emission (DPOAE) with high frequency resolution (160 points per octave) as well as band-noise audiograms (6 points per octave). The tinnitus percept was assessed using the well-established tinnitus-likeness test. This tests asks subjects to rate how much their tinnitus resembles a pure tone or tonal noise at various frequencies thus providing a 'tinnitus spectrum'. All measures were obtained in the frequency range of 1kHz to 10kHz. Preliminary results show that for a subset of subjects the tinnitus spectrum can indeed be predicted purely from these physiological measures (with $p<<0.05$). The observed correlation ($c=0.83 \pm 0.09$) of the estimated tinnitus spectrum with the observed likeness ratings is as good as can be expected given the subject's repeat-variability ($c=0.84 \pm 0.14$). The remaining subjects contrasted this group in that they had uniform audiograms and tended to give inconsistent likeness ratings ($c=0.13 \pm 0.15$). We conclude that for a subset of individuals, the subjective tinnitus percept can be traced back to objectively measurable hearing deficits. This suggests that for these subjects correcting the peripheral hearing deficit captured by these objective measures may alleviate their tinnitus percept, consistent with current attempts to treat tinnitus using custom-fit auditory stimulation.

Subjects and Procedures:

- 27 tinnitus subjects and 12 normal subjects were recruited for this experiment.
- DPOAE generator component using using continuous frequency sweep at various primary levels.
- Audiogram and tinnitus likeness test.

Computational Model:

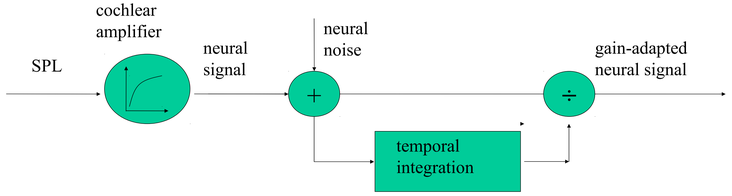

Fig1. Schematic showing the computational model

Model result consistent with data :

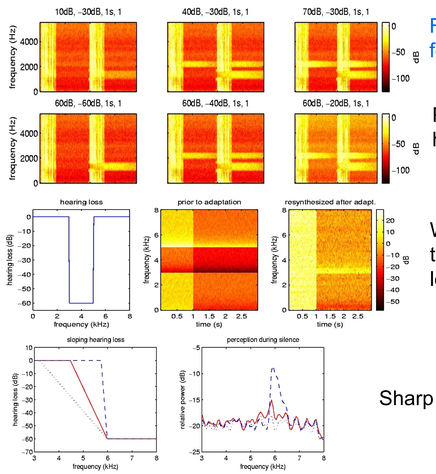

Fig 1. Model explains known features of Tinnitus:

Percept frequencies match the hearing loss frequencies.

When including lateral inhibition the predominant percept is at the lower edge of the hearing loss.

Sharp edges produce stronger percept.

Model prediction:

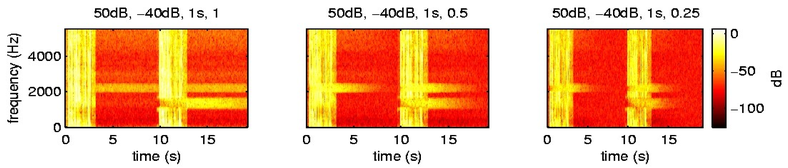

Fig 2. Effect of cochlea compression:

- Outer-hair cells in cochlea produce non-linear compression.
- Tinnitus correlates with reduced peripheral compression.
- In the model weak compression results in stronger tinnitus.

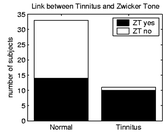

Fig 3. Zwicker tone correlates with tinnitus: A related phantom percept with short time constant (<1s) is the Zwicker tone. According to our model it should be equally affected by loss of compression. Indeed we confirmed previously that Tinnitus subjects are more likely to hear the Zwicker phantom percept. (Parra, Pearlmutter, 2007)

Model predictions:

1: Loss of peripheral compression is indicative of tinnitus status.
2: The precise properties of the tinnitus percept can be determined from thresholds and compression.

DPOAE, Audiogram and Tinnitus Likeness test:

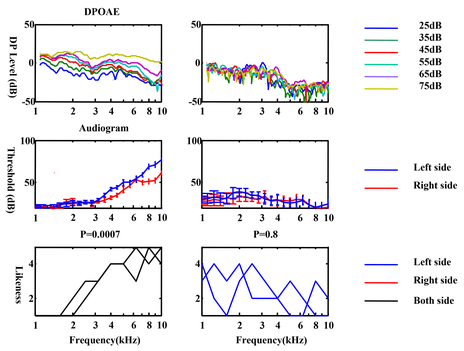

Fig 4. Example data: Recorded 27 tinnitus subjects and 12 normal subjects.

Top row shows DPOAE data.

Middle row shows audiogram results.

Bottom row shows likeness spectrum test.

Left column shows the results of one of reproducible subjects, right column shows one of the un-reproducible subjects.

Results and discussion:

I: DPOAE compression improves diagnosis of Tinnitus Status

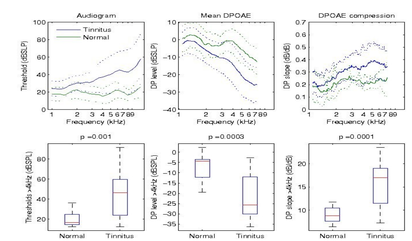

Fig 5. Audiogram and DPOAE significant difference with Tinnitus and Normal subjects

The left column shows the audiogram result. The middle column shows the mean DPOAE. The right column shows DPOAE compression.

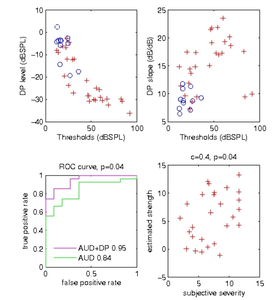

Fig 6. DPOAE improves diagnosis of Tinnitus Status

- Despite correlation DPOAE features and thresholds can be combined to estimate likelihood of tinnitus.
- DPOAE features provide significant information about tinnitus status over audiogram alone (p=0.04)
- Predicted tinnitus strength (log-likelihood) correlates with subjective tinnitus severity (p=0.04).

Why do some subjects with “normal” hearing have tinnitus?

Partial Answers:

(a) Loss of compression increases tinnitus percept (“missing link”).

(b) Tinnitus is not as severe as for subjects with strong loss.

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

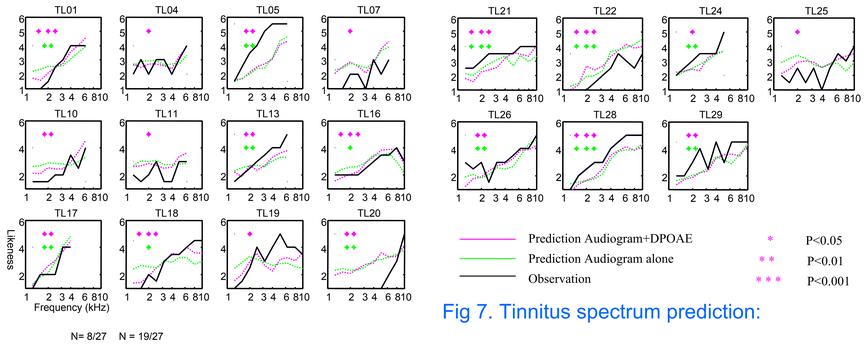

Fig 7. Tinnitus spectrum prediction:

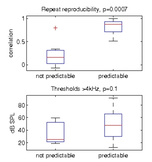

Fig 8. Subgroup of Tinnitus:

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

- Unpredictable subjects can not reproduce their subjective likeness ratings thus the subjective data may be “too noisy” to predict.
- Subjects may have less hearing loss.

Conclusion:

Gain adaptation model 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.

Theory also predicted:

1) Tinnitus subjects are more likely to hear the Zwicker tone.
2) DPOAE compression is diagnostic of tinnitus status, thus addressing one of the mysteries of Tinnitus.
3) Tinnitus spectrum can be predicted for most subjects when using DPOAE features in addition to audiogram.

References:

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