#687  Distortion Product Otoacoustic Emissions (DPOAE) Behavior and Growth Rate in Tinnitus Subjects with Normal Audiograms

Leah Acker, Christopher Shera, and Jennifer Melcher, Eaton-Peabody Laboratory, Massachusetts Eye and Ear Infirmary, Speech and Hearing Bioscience and Technology Program, Harvard-MIT Division of Health Sciences and Technology

1. Introduction

While most people with tinnitus have elevated hearing thresholds, the correspondence between tinnitus and hearing loss is far from perfect (Fowler, 1944, 1965; Heller and Bergman, 1953). People with normal thresholds can have tinnitus, and people with identical thresholds in each ear can have unilateral tinnitus. This imperfect correspondence might result because some people have tinnitus that arises solely from central nervous system pathology. However, it is also possible that some forms of tinnitus arise from peripheral auditory pathology that does not alter thresholds. The present study begins to explore the latter possibility by comparing the DPOAEs of people with tinnitus and normal audiograms to those of audiometrically-matched control subjects without tinnitus. While previous studies have compared the DPOAEs of tinnitus and non-tinnitus subjects with normal audiograms (Gouveris et al., 2005; Ozimek et al., 2006; Job et al., 2007), the present study is different in its examination of individual subject data, as well as group averages. Our preliminary findings suggest the DPOAEs of audiometrically-normal tinnitus subjects are, on average, abnormal, but that the abnormality may be present in only a subset of people with tinnitus.

2. Methods

- **Subjects**: Recruited through the Tinnitus Clinic at the Massachusetts Eye and Ear Infirmary, newspaper ads, or personal contacts.
- **All subjects had normal thresholds.**
  - Thresholds were 25 dB HL at all tested frequencies from 125 Hz to 8 kHz. Conventional pure-tone audiometry was used.
- **Matching between tinnitus and non-tinnitus groups**
  - Mean audiograms for the tinnitus and non-tinnitus groups differed by 7 dB or less at any given frequency (Figure 1).
  - The age range was similar for the tinnitus and non-tinnitus groups (Figure 2). Mean ages were 41.8 ± 12.8 years (tinnitus), 47.5 ± 13.1 years (non-tinnitus).
  - All but one of the tinnitus subjects and 3 of the non-tinnitus subjects were male.
- **Tinnitus characteristics**
  - 7 of the 8 tinnitus subjects had tinnitus localized to both ears or in the head (four “on both sides,” one “on one side,” and two “on both ears” or “on both sides”). The remaining subject had tinnitus localized to the left ear.
  - Tinnitus descriptions included: “ringing,” “humming,” “buzzing,” “hearing,” “pulsing tone.”
  - Scores on the Tinnitus Reaction Questionnaire of Wilson et al. (1991) ranged from 0 to 47.
- **Assessment of sound tolerance**
  - Loudness growth was measured using a broadband stimulus and the method of Coz et al. (1997).
  - Subjects who demonstrated 105 dB SPL or less to “uncomfortable” loudness (loudness discomfort level, LDL) were classified as having reduced sound tolerance (i.e., hypersensitivity).
  - In a larger dataset of LDL and dynamic range (LDL minus threshold data), a cluster analysis identified 105 dB as a natural threshold point in the data.
- **DPOAE measurements**
  - DPOAEs were measured at 500 Hz ≤ f ≤ 8 kHz, with 1/2 octave spacing.
  - The DPOAEs were measured for 500 Hz ≤ f ≤ 8 kHz, with 1 octave spacing.
  - The reference intensity was 60 dB SPL.
- **DPOAE calculations**
  - The mean DPOAE magnitude was calculated for each frequency.
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  - The slope of the fit line was considered the “growth” of the DPOAE at a given frequency.

3. DPOAE differences between tinnitus and non-tinnitus groups

Differences in DPOAE Magnitude and Growth

Figure 3 shows mean DPOAE magnitudes and their standard errors at F2 levels of 40 and 60 dB SPL for both tinnitus and non-tinnitus groups. Although the qualitative pattern is similar in the two groups there are statistically significant differences in certain frequency ranges. For example, a 3-factor ANOVA (tinnitus × age x audiogram) finds significant main effects of tinnitus in the 2-3 kHz region at F2 = 40 dB SPL (p < 0.001) and above 3 kHz at 60 dB SPL (p < 0.05). Figure 4 shows that significant differences in DPOAE growth rate are also apparent in the mid-frequency range (p < 0.001 between 1.2 and 3 kHz). These differences result from what appears to be a more pronounced magnitude “dip” in the tinnitus group near 2-3 kHz. Panel 4 examines the dip more closely in individual subjects.

Differences in DPOAE Growth

The growth rate of DPOAEs, averaged across subjects, tended to be greater in tinnitus subjects as compared to non-tinnitus subjects (Figure 4). The trend is apparent between F2 = 1 and 3 kHz. There was a significant difference between the tinnitus and non-tinnitus subjects between F2 = 1.2 kHz and F2 = 3 kHz (p = 0.0003). This effect was more significant then either the effects of age or audiogram.

4. DPOAE differences among individual tinnitus subjects

In individual data, a clear “dip” in DPOAE magnitude was only seen in tinnitus subjects.

The DPOAE “dip” had no consistent counterpart in the audiograms.

Only some tinnitus ears showed a “dip” in DPOAE magnitude.

5. Discussion

The present study extends previous reports of abnormal DPOAE magnitude in people with normal audiograms and tinnitus in two main ways:

1. It brings to light a previously unexplored trend that may have been present in the data of at least three of the previous studies: a dip in DPOAE magnitude in tinnitus, but not in non-tinnitus subjects, with normal thresholds (Mitchell et al., 1999; Gouveris et al., 2005; Job et al., 2007).

2. The present data show that the dip apparent in average data is not an artifact of the averaging, but present in individual - and to different degrees in different people.

While not emphasized here, there was also a tendency for DPOAE magnitude to grow abnormally with stimulus level in tinnitus subjects, as previously described by Janssen et al. (1998). This aspect of the data warrants follow-up.

Examining individual data to discern different types of tinnitus

The approach of the present study differs from the majority of DPOAE studies of tinnitus in its examination of individual data (panel 4), as well as average data (panel 3). (Mitchell et al., 1998 is one of the few DPOAE tinnitus studies examining individuals.) Examining individual data in any physiological investigation of tinnitus (OAE, imaging, evoked potentials) may be crucial for identifying different physiological forms of tinnitus to the extent they exist (Levine, 2006).

Do outer hair cells play a direct role in some types of tinnitus?

The abnormalities of DPOAE magnitude seen in some of the tinnitus subjects we studied may indicate a direct role for the outer hair cells in tinnitus. Alternately, outer hair cell malfunction, as indicated by DPOAE abnormalities, may not play a causative role in tinnitus, but instead coincide with other pathologies undetected in threshold measurements but resulting in tinnitus (e.g., loss of normally high-threshold spiral ganglion cells, malfunction of tectorial membrane feedback).

6. Conclusions

- **Tinnitus subjects with normal thresholds show DPOAE abnormalities, including a “dip” in DPOAE magnitude vs. F2 that has no consistent counterpart in the audiograms.**

- **The “dip” in DPOAE magnitude was present in the individual data of only a subset of tinnitus subjects.**

- **Our results, while preliminary, illustrate the potential importance of examining individual data in any physiological investigation of tinnitus.**

- **DPOAE may prove useful in distinguishing different physiological types of tinnitus.**

Citations


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