### INTRODUCTION

Clinical applications of distortion product otoacoustic emissions (DPOAEs) include follow-up diagnostics after newborn screening (Janssen, 2013), assessment of loss of sensitivity and compression of the cochlear amplifier (Janssen and Müller, 2008), and monitoring of cochlear function due to noise exposure (Müller et al., 2010) or ototoxic drug administration (Janssen et al., 2000). To reduce test time, multiple DPOAEs (mDPOAEs) can be measured with multiple primary tone pairs presented simultaneously (Kim et al., 1997; Purcell et al., 2003). To avoid overlap of the traveling waves created by multiple primaries, their frequencies have to be at least one octave apart. When stimulating both ears contralateral DPOAE suppression can occur, especially for primary tone levels higher than 65 dB SPL.

# PURPOSE

The purpose of the study was to evaluate whether mDPOAE measurements can be done in both ears simultaneously without mutual influence of primary tone pairs in the ipsilateral and the contralateral ear.

# METHODS

Subjects: 20 adults (18 females, 2 males); age: 23 - 25 years.

Inclusion criteria: tympanogram within normal limits bilaterally and hearing thresholds  $\leq 15$  dB HL from 0.25 to 8 kHz bilaterally.

Data were collected using the Sentiero system (PATH medical GmbH, Germany) with the subjects seated in a sound-treated room;

DP-grams with  $f_2/f_1 = 1.2$  and  $f_2$  frequencies set at 1, 1.5, 2, 3, 4, 5, 6, and 8 kHz with  $L_1$  and  $L_2$  set at 65/65 and 57/45 dB SPL;

DP-grams collected using single- and multi-frequency presentations of the primaries for both monaural and binaural conditions.

Data with DPOAE levels < -5 dB SPL and SNR < 6 dB were excluded from the analyses.

Individual data were converted from levels (in dB SPL) to pressure values, averaged and the mean pressure results were transferred back to levels in dB SPL.

Mean DPOAE and noise levels collected with the single-frequency monaural paradigm (depicted by black diamonds and red triangles down, respectively, in all figures) were compared to those measured with other testing conditions as indicated in each figure. The asterisks indicate mean DPOAE levels that were significantly different based on the paired t-tests performed using IBM SPSS.

# PROTOCOLS OF DPOAE MEASUREMENTS AIMED AT REDUCING TEST TIME

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RESULTS



Study supported by Dean's Research Enhancement Award, College of Clinical and Rehabilitative Health Sciences, ETSU and by The Research Development Committee, ETSU (grant #15-012sm). Additional travel support provided by PATH medical GmbH.

In general, the binaural presentation of single-pair stimuli had subtle effects on DPOAE levels. The difference of 2 dB between mean DPOAE levels collected with binaural versus monaural presentations for  $f_2 = 1.5$  kHz and  $L_2 = 45$  dB SPL was the only one that reached statistical significance. All other data measured with the two paradigms were very consistent. Thus, the effects of contralateral inhibition created by binaural stimulations are negligible. Similar results for DPOAEs collected using the ILO Otodynamics Analyser 922 system at  $L_1 = 71$  and  $L_2 = 60$  dB SPL have been previously reported (Dziendziel, 2012, unpublished doctoral dissertation).

The effect of applying one additional pair of tones with an octave spacing on DPOAE levels was quite small, with the largest decrease of 1.3 dB for  $f_2 = 4$  kHz and  $L_2 = 65$  dB SPL. Slightly lower DPOAE levels obtained with the mDPOAE method than with single-pair stimulation may result from small mutual suppression of cochlear nonlinearities. The noise levels were elevated at 3 and 4 kHz in mDPOAEs measured at  $L_2 = 65 \text{ dB}$  SPL. Most likely those results are due to the frequency response of the transducers requiring quite different gains when mixing mid- and high-frequency stimuli.

**Could mDPOAE data be collected in both ears simultaneously?** In general, the mean DPOAE and noise levels collected with mDPOAE and binaural presentation conditions were highly reproducible when compared to those obtained with the singlefrequency monaural paradigm. Thus, multi-frequency and binaural measurements could be applied to reduce DPOAE testing time considerably. A protocol using automatic pass/refer criteria with a preset maximum measurement time for each data point and lowlevel primaries, e.g.,  $L_2 = 45$  dB SPL, is expected to be efficient, for example in patients with beginning cochlear hearing loss due to noise overexposure or ototoxic drug administration.

### DISCUSSION

### **Binaural presentation**

### The mDPOAE paradigm

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