DPOAEs in the Clinic

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Learning Outcomes

Participants will learn:
1. how to interpret DPOAE results
2. how to make the most effective measurements of DPOAEs in the clinic
3. why DPOAEs are complicated

The ear receives sound… and makes sound

Sounds coming out of an ear

Otoacoustic emissions

Lots of commercially available systems to measure otoacoustic emissions...

GSI Corti
IHS Smart OAE
Interacoustics
Mimosa Acoustics

Otoacoustic emissions used in….

Newborn hearing screening
Site of lesion evaluation in adults

1948 Thomas Gold
- Fluid in the cochlea produces viscous forces in the cochlea that are too great for passive tuning to provide for frequency selectivity in humans
- Cochlea must have a mechanism to counteract these viscous forces
1976 David Kemp

Looked for sound coming out of ear... and finds it
Termed “otoacoustic emissions”

1980 to 1988
- Literature dominated by descriptive articles, normative data
- 1988 ILO88, first commercial system to measure OAEs, released.
- 1988 to present The search is on to relate otoacoustic emissions to hearing thresholds
  - Emphasis is on OAEs categorized in terms of type of stimulus used to evoke OAEs

DPOAEs re HTL have been examined with the focus being on obtaining largest amplitude DPOAE
- Use f2/f1 = 1.2
  - Use L2/L1 = -10 dB
- For input-output function, L2/L1 not fixed
  - See Kummer et al 1998
    - L1 = 0.4L2 + 39 dB
- What is the rationale behind this approach?

From 210 subjects, Gorga et al. 1996.
Age range 7 to 86 years (mean 39).
Normal ears: solid line
Hearing impaired ears: dashed line
From the figure, for f2 = 1.4 to 8 kHz, a DPOAE amplitude greater than 5 dB SPL represents normal cochlear function
DPOAEs are a by-product of cochlear mechanical amplification. Large amplitude DPOAEs are consistent with normal cochlear function.

DPOAE threshold vs hearing threshold

From 210 subjects, Gorga et al. 1996 JASA 100(2), 968-977


DPOAE threshold (dB SPL)

Hearing threshold (dB HL)
To evoke a DPOAE requires the simultaneous presentation of two tones
- (i) Nonlinear interaction
- (ii) Other side of nonlinearity is suppression, so get two-tone suppression
- Ideally we want to maximize (i) while minimizing (ii)
**what is a good S/N?**

- **DPOAE**
  - Noise at the frequency of the DPOAE adds vectorially to the DPOAE, the phase of the noise wrt to the DPOAE resulting in anything from constructive to destructive interference. For a noise that is 50% of the amplitude of the DPOAE, the variability in the amplitude of the DPOAE due to the noise can be up to 10 dB.
  - A 15 dB S/N provides a DPOAE amplitude that is relatively unaffected by noise

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**Probe assembly in ear canal**

Is sound pressure the same at these two positions?

- ER2
- ER2

**Voltage to speakers:**

- should it be constant?
- or
- should it be altered based on microphone measurement?

**Microphone measures level**

- of stimuli and OAEs in ear canal at position of microphone (not at eardrum)

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**Location of microphone relative to eardrum:**

- what is the impact on stimulus level at the eardrum?

- Standing wave in ear canal

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**Troubleshooting**

- **Check your OAEs**
  - No change → good
  - Changed
    - How is it changed?
      - No OAE
      - Could you hear stimulus?
      - Yes → problem with microphone
      - No → problem with speaker
      - Reduced OAE
      - Check speaker ports for wax/condensation
      - Check connections for speaker/s and microphone

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**Artifact rejection**

- Designed to eliminate high noise trials
  - Movement of jaw, swallowing etc.
- Set based on acquiring data in reasonable time period while maximizing S/N
- Most applicable to obtaining OAEs from small children

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**Two sources of 2f<sub>1</sub>-f<sub>2</sub> OAE**

- Source of DPOAE
- Source of OAE
2f₁-f₂ OAE has amplitude microstructure


Human 2f₁-f₂ OAE I/O functions are complex


Clinically measured DP-gram

Using IHS System

Clinically measured DP-gram

- DPOAE a sum of two components
  - Arise from two different places, f₂ and 2f₁-f₂
  - Arise from two different mechanisms
  - Phase of DP place component stimulus level dependent
    - Vector sum is then stimulus level dependent
  - Vary stimulus level, vary fine structure (peaks and dips in spectrum)
  - For a stimulus ratio of 1.2, the nonlinear component from f₂ expected to dominate
    - Amplitude of f₂ component is then average across spectrum

DP-gram

- Three stimulus levels
  - 75/65
  - 65/55
  - 55/45
  - f₂/f₁ = 1.2
**DPOAE amplitude versus f2/f1**

- As \( f_2/f_1 \rightarrow 1 \), DP place component dominates
- As \( f_2/f_1 > 1 \), DP nonlinear component dominates (some disagreement re this)

Lukashkin and Russell (2001)

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**Presbycusis**

- Most common type of hearing loss in adults
- High frequency loss, progresses with age
- DPOAEs can be used to probe etiology

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**DPOAE I/O functions**

Model fits to data reveal contribution of OHC loss versus drop in endocochlear potential (EP)

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**Conclusion**

- OAEs represent an important part of the test battery to assess auditory status and evaluate site of lesion.
- DPOAEs provide objective monitoring of auditory status