



University of Colorado  
Boulder

# Bilateral and Contralateral OAE Suppression Testing in Tinnitus Patients

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## But Aren't OAEs Absent in Hearing Loss?



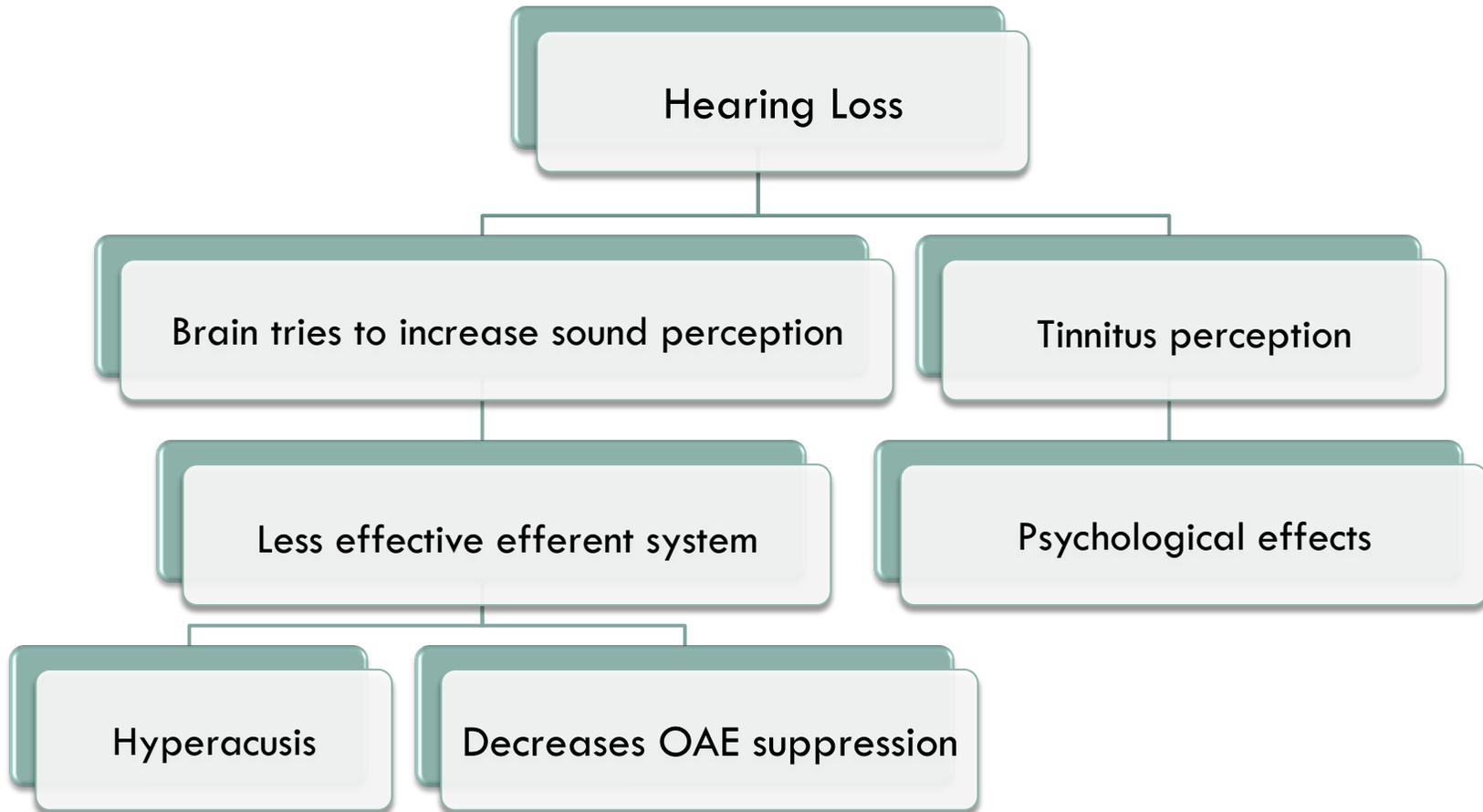
- OAEs typically thought of as an OHC measure
- OAEs tend to be absent with HTLs  $>20-30$  dB (but only at those frequencies effected)
- Blast injury cases often have low frequencies preserved, so OAEs often present there
- Contralateral suppression of OAE is a measure of the functioning of the efferent neural pathways; so highly relevant to tinnitus, esp blast injury & TBI
- Suppression effects can often be seen in the better hearing frequencies

# OAE Suppression in Normals

- When stimulated, the functioning OCB will cause inhibition of the auditory system (less movement of the OHC = less firing of the auditory nerve)
- OCB stimulation can occur by:
  - Electrically stimulating the OCB fibers
  - Applying contralateral, ipsilateral, or bilateral noise
  - This inhibition seems to play a role in hearing in noisy environments and protection against loud sounds

(Baran & Musiek, 2007; Berlin. Hood, Hurley, Wen, & Kemp, 1995)

# OAE Suppression & Tinnitus Model



# OAE Parameters

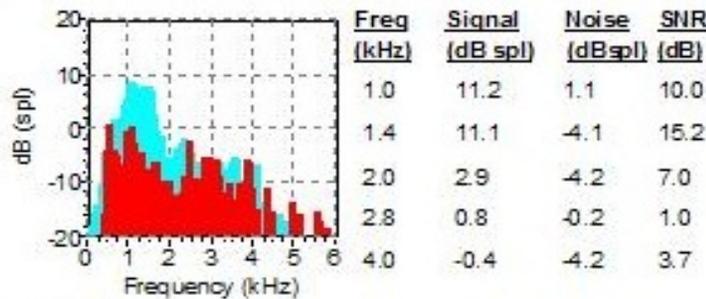
- DPOAE's abnormal in 68% of tn cases & 50% of non-tn, but TEOAE's abnormal in 70% of tn cases & 16% of non-tn (Granjeiro, et. al. 2008)
- Some tinnitus S's TEOAEs are even enhanced by contra noise (Riga, Papadas, Werner, & Dalchow 2007; Chéry-Croze, Collet, & Morgon 1993)
- Greater suppression of auditory nerve responses when using lower stimulation intensities
- The level of suppression inc's as the BBN suppressor level inc's
- The BBN suppressor should not elicit a contralateral acoustic stapedial reflex (mean ART for WN of 62dB in normals)
- Nearly all suppression studies have been on normal hearing patients with/without tinnitus

# Normal Suppression:

No noise:

With contralateral noise:

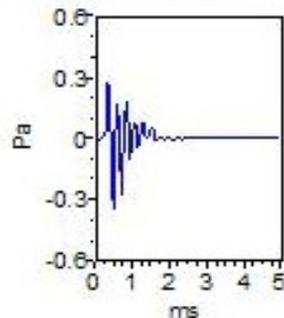
Half octave band OAE power



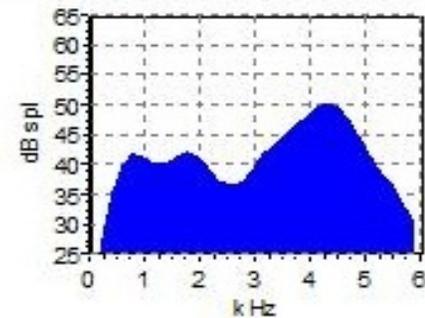
Test Summary

Total OAE response = 14.8dBspl Total Noise = 6.4dBspl

Checkfit stimulus



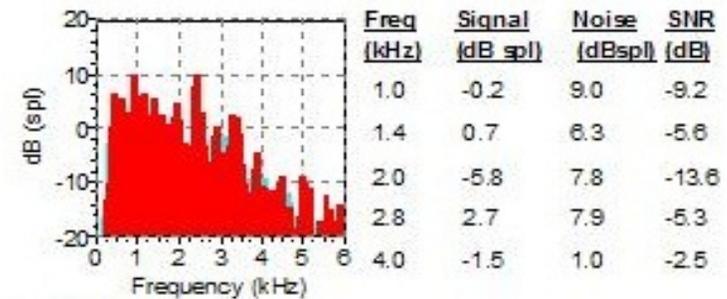
Ear canal response



Test Environment

NLo = 260 NHi = 0 Test time = 58s  
 RejLev = 53.1dBspl Repro = 87% Stim stab = 100%  
 Hardware = USBOAE Probe = Probe 1

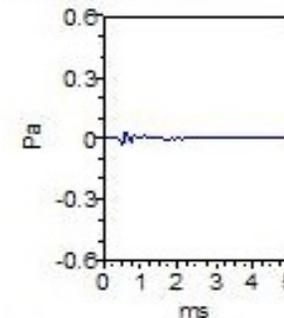
Half octave band OAE power



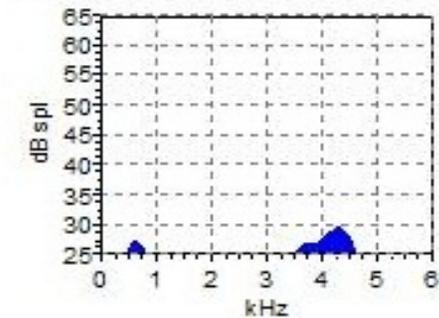
Test Summary

Total OAE response = -50.0dBspl Total Noise = 14.9dBspl

Checkfit stimulus



Ear canal response



Test Environment

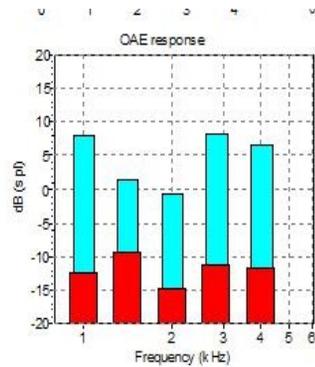
NLo = 260 NHi = 0 Test time = 58s  
 RejLev = 53.1dBspl Repro = 1% Stim stab = 100%  
 Hardware = USBOAE Probe = Probe 1

(37 year old female with normal hearing)

# No OAE Suppression (Tinnitus Case):

No noise:

With contralateral noise:



Nlo = 260      Resp = 13.0dB  
 NHi = 19      Noise = 0.8dB  
 RejLev = 6      Stim = 81.9dB  
 Test time = 72s

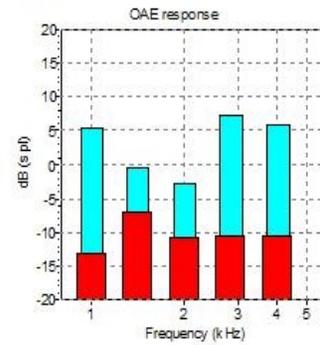
**Result** OAE detected  
**Mode** General Diagnostic  
**Decision** Unscored  
**Comments**

Half Octave Band Power			
Freq	SNR	Sig/Noise	
1.0kHz	20.2dB	7.9/-12.2dB	✓
1.4kHz	10.9dB	1.6/-9.3dB	✓
2.0kHz	14.1dB	-0.6/-14.7dB	✓
2.8kHz	19.6dB	8.3/-11.3dB	✓
4.0kHz	18.2dB	6.7/-11.6dB	✓

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Nlo = 260      Resp = 11.6dB  
 NHi = 2      Noise = 0.8dB  
 RejLev = 6      Stim = 83.1dB  
 Test time = 70s

**Result** OAE detected  
**Mode** General Diagnostic  
**Decision** Unscored  
**Comments**

Half Octave Band Power			
Freq	SNR	Sig/Noise	
1.0kHz	18.3dB	5.4/-12.9dB	✓
1.4kHz	6.4dB	-0.5/-6.9dB	✓
2.0kHz	8.1dB	-2.6/-10.7dB	✓
2.8kHz	17.9dB	7.5/-10.4dB	✓
4.0kHz	16.5dB	6.0/-10.5dB	✓

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(48 year-old female with high frequency hearing loss, tinnitus & hyperacusis)

# TBI/OAE in Military Patients

- Contra OAE suppression study on 49 Israeli soldiers
- 24 patients with TBI w/ auditory complaints, 10 TBI patients w/out & 15 normal controls
- "...the global amplitude of the TEOAE was significantly higher in TBI patients with auditory complaints compared to those without."

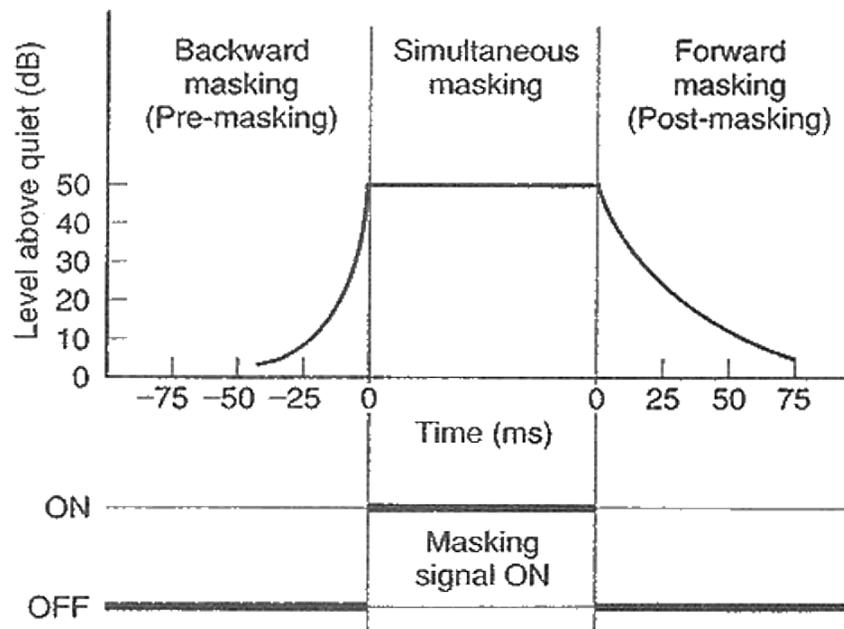
Attias, J., Zwecker-Lazar, I., Nageris, B., Keren, O., Groswasser, Z. (2005). Dysfunction of the auditory efferent system in patients with traumatic brain injuries with tinnitus and hyperacusis. *Journal of Basic and Clinical Physiology and Pharmacology*. 16(2-3), 117-26

# Background

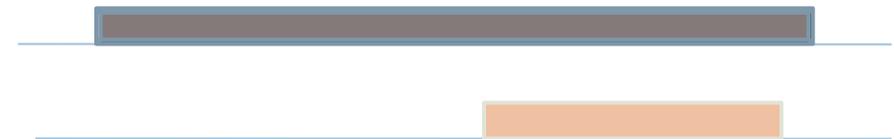


- Clinically viable objective measurements of tinnitus have been elusive
- Rather variable results for contra suppression of OAEs; greatly limited their clinical utility
- Bilateral OAE suppression is newly available commercially (two probes- each probe can give stimulus &/or record OAE)
  - ▣ Uses a forward masking paradigm to mask the OAE in both ears simultaneously
- Sig greater OAE suppression using bilateral noise than contralateral noise; in normal subjects (Berlin et al 1995)

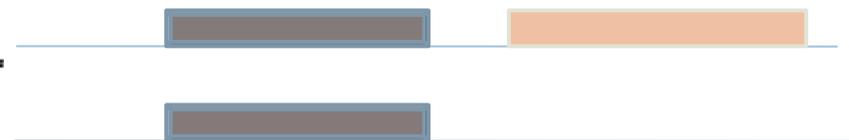
# Contralateral vs. Bilateral OAE Suppression



Contralateral (simultaneous masking)



Bilateral (forward masking)



Masking interval      Recording interval

Reference: Berlin, Hood, Hurley, Wen & Kemp, 1994;

Figure: [http://www.santafevisions.com/csf/html/lectures/019\\_timbre\\_II.htm](http://www.santafevisions.com/csf/html/lectures/019_timbre_II.htm)

# Rationale for OAE Suppression Study



- No published studies of bilateral OAE suppression in tinnitus patients
- Optimal testing parameters are unknown
- No studies could be found correlating several established measures of tinnitus with contra or bilateral OAE
- Hyperacusis is rarely measured objectively, so its correlation with OAE suppression also needs to be determined empirically

# Aims



- Compare the more rigorously validated measures of  $t_n$  with OAE suppression results
- Ascertain the role of hearing loss in viability of OAE Suppression
- More tightly control testing variables than prior studies in case that was contributing to variability
- Determine if Bilateral OAE suppression is more clinically viable than Contra suppression

# Method

- **Hearing evaluation:** Otoscopy, immittance testing, standard & high frequency audiometry (.25 –12.5 kHz)
- **Tinnitus evaluation:** Tinnitus Reaction Questionnaire, Neuromonics Assessment Form, Minimum Masking Levels, Pitch & Loudness Match, Loudness Discomfort Levels
- **OAE suppression:** A dual –probe IHS TEOAE system & Smart TROAE software
- Emissions at 1, 1.5, 2, 3, 4 kHz were tested bilaterally in the sound booth over 3 conditions:
  - ▣ 1- without noise,
  - ▣ 2- with Contralateral Broadband noise (BBN),
  - ▣ 3- with Binaural BBN using a forward-masking paradigm

# OAE Suppression Parameters

- Intensity = 65dB SPL
- Click Rate = 21 /sec
- Acquisition = Linear stimulation mode
- ISI (Contra & Binaural): 20 ms
- Duration (Contra & Binaural): 400 ms
- Suppressor type: Broad Band Noise (BBN)
- Suppressor level: 45 SL (relative to BBN threshold in MML)
- Sweeps: 512 (minimum, 1024 preferable)
- Kept probe placement constant (all in booth & use of dual probe system to keep placement unchanged)
- $\Delta$  in OAE amplitude criterion used =  $\geq 3$ dB suppression at each freq where emission was present (6dB SNR) without any contra or bilateral noise being used; i.e subtraction

# Statistical Analysis



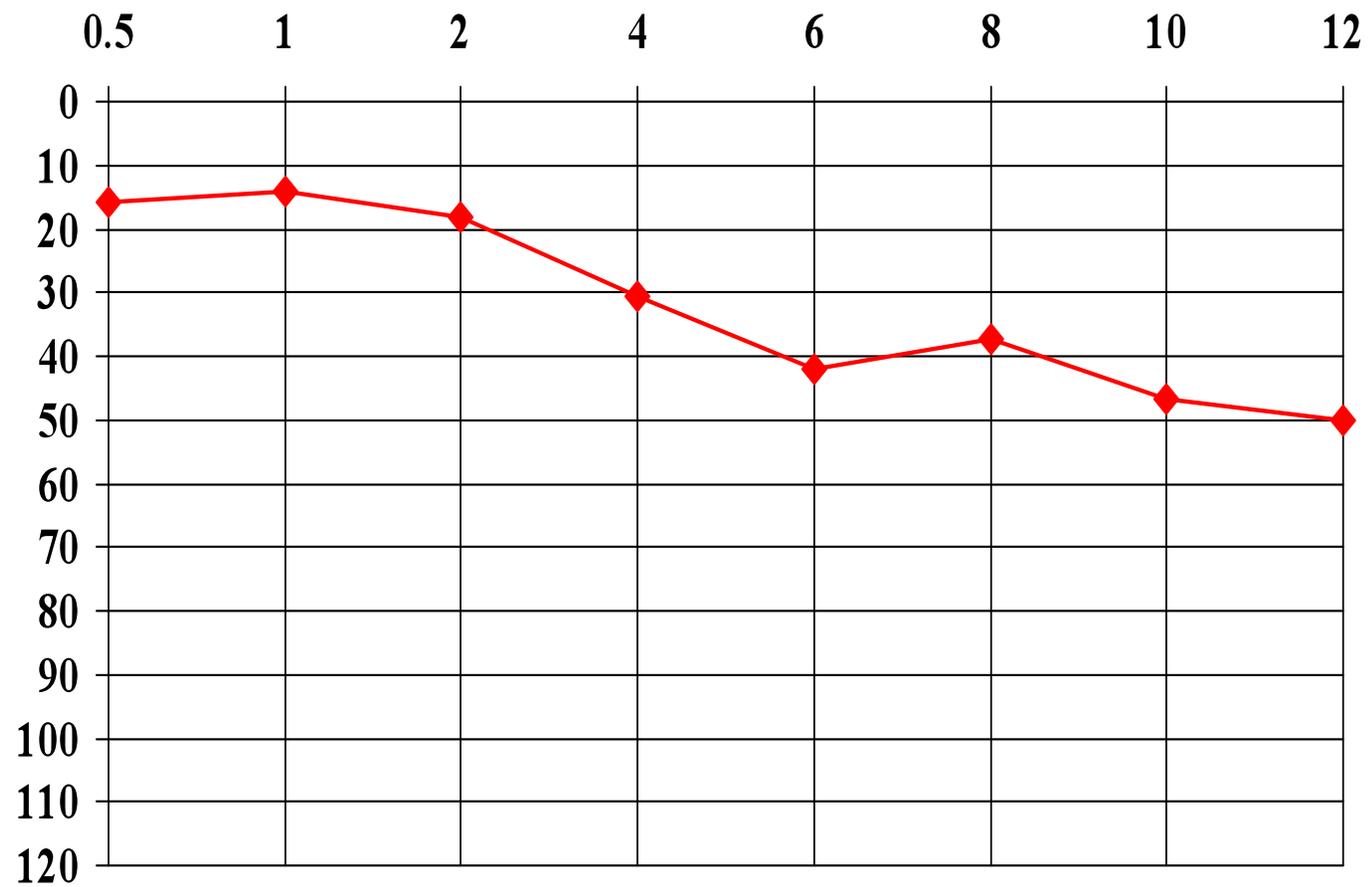
- Repeated bivariate correlations were used to correlate OAE suppression with tinnitus perception
- The variables related with tinnitus perception were; TRQ, awareness, disturbance, MMLs (BBN), LDLs & tinnitus loudness sensation level
- The analysis of suppression was conducted using repeated measures multivariate ANOVA with 3 factors;
  - contralateral & bilateral OAE suppression;
  - ear with greater and lesser tinnitus
  - frequency

# Subjects



- Twenty consecutive Tinnitus Clinic patients
- Eight then excluded because of absent TEOAEs
- Study thus is on 12 eligible patients
- Mean age 42 years (range 21-60)
- Eight male, four females
- Blast Injury status: two had recent acoustic blast injury, (another two had blast injury in past, but subsequent noise exposure)
- Traumatic Brain Injury status; two patients (one from acoustic blast injury, one from falling off a ladder)

# Mean Hearing Threshold Levels

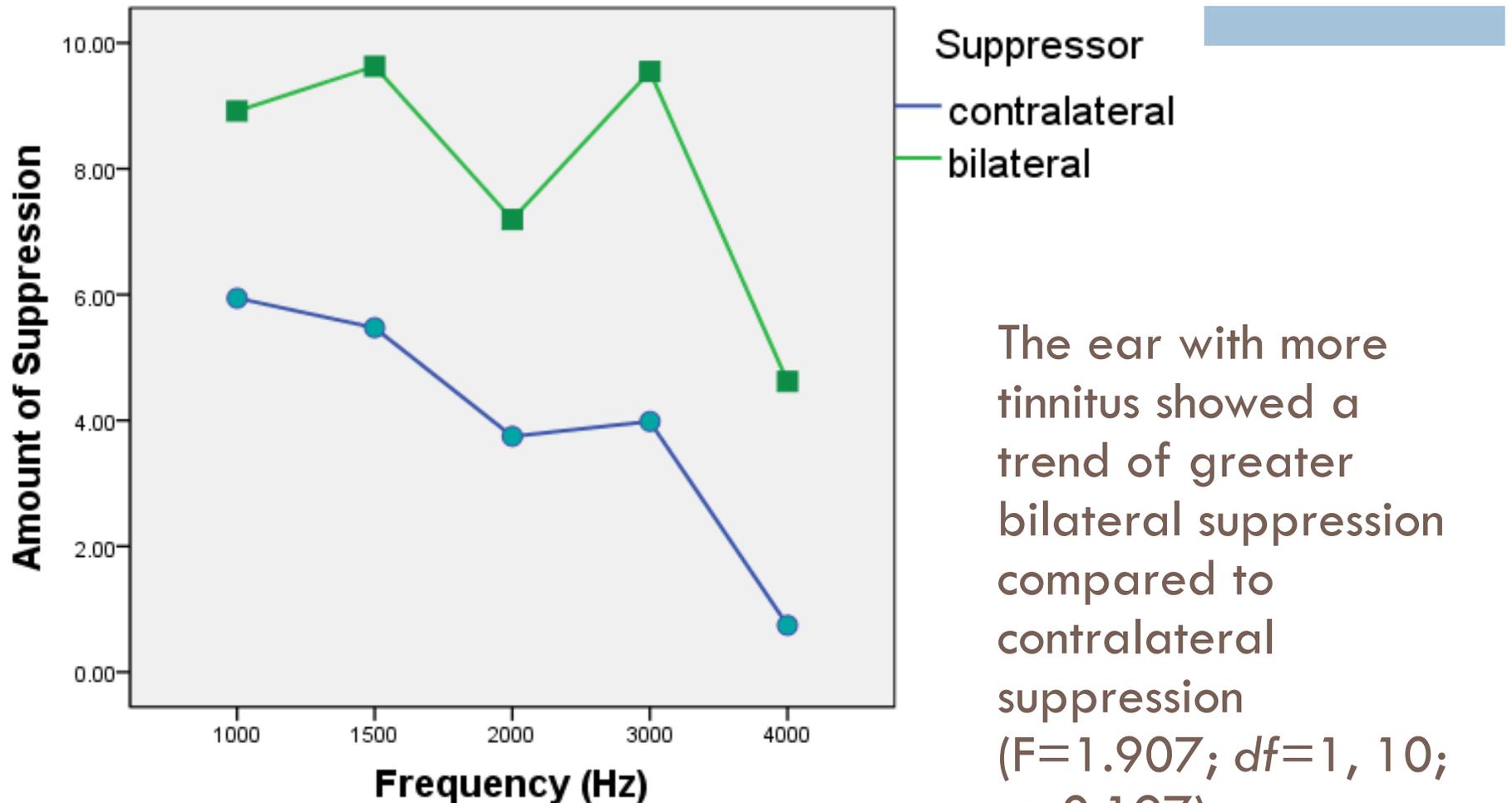


# Results



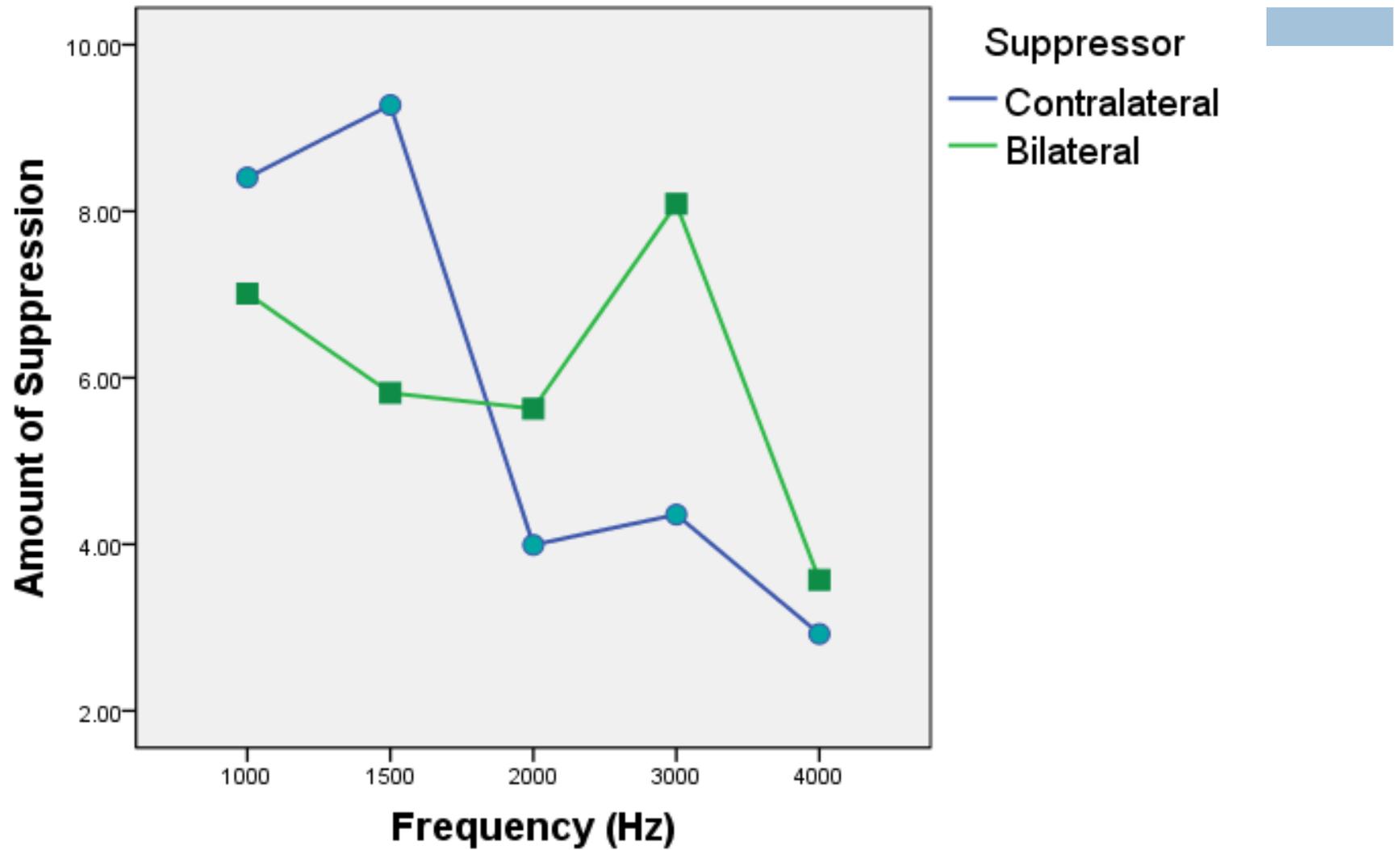
- Those with the most aberrant LDLs tended to be those with the greatest release from suppression (both contra & bilateral suppression)
- The analysis of the average suppression in each frequency bilaterally showed that in 8 out of 10 conditions OAE suppression was greater with bilateral noise
- (only 1000 & 1500 Hz in the right ear showed greater contralateral suppression)

# Ear with Greater Tinnitus

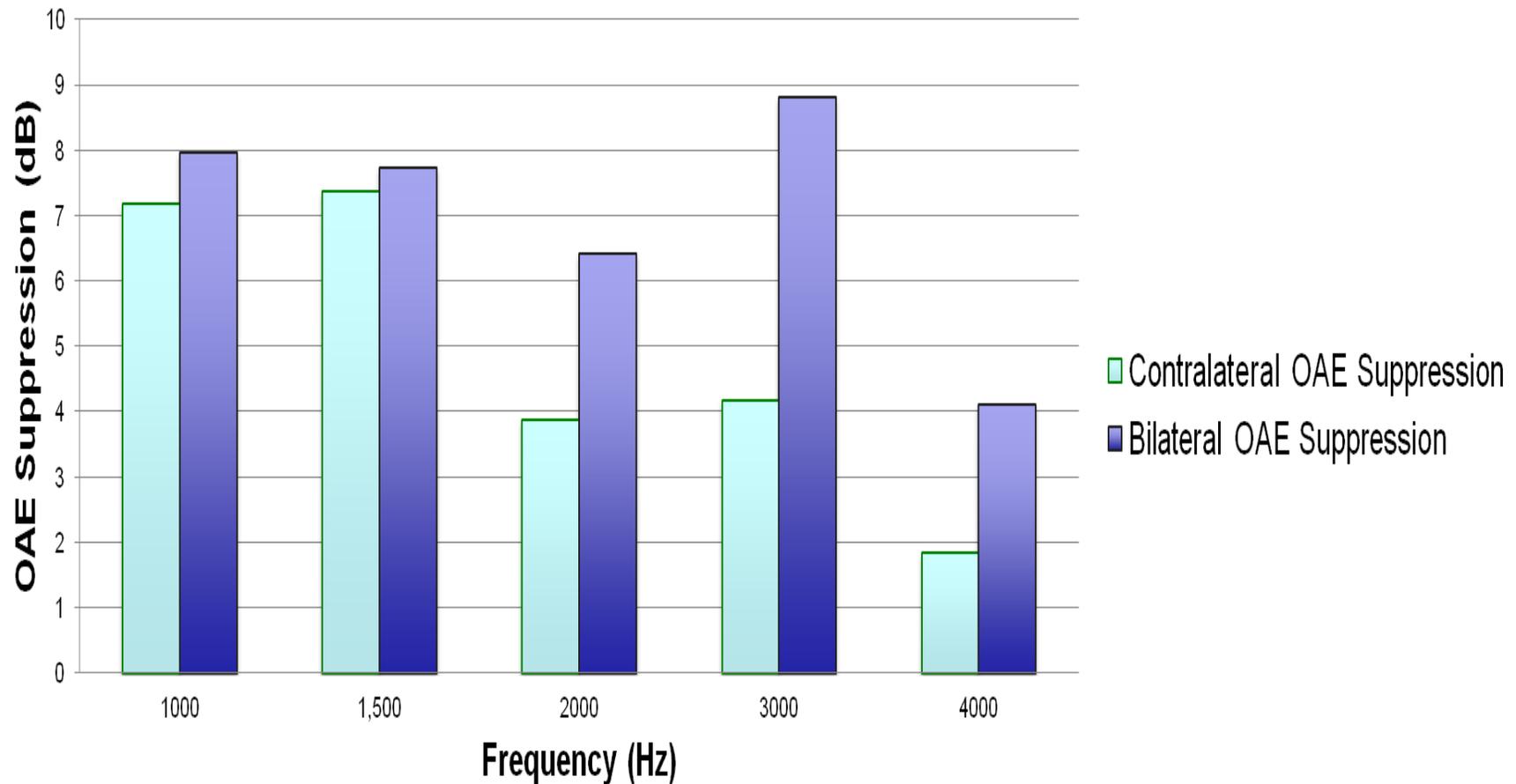


The ear with more tinnitus showed a trend of greater bilateral suppression compared to contralateral suppression ( $F=1.907$ ;  $df=1, 10$ ;  $p=0.197$ )

# Ear with Less Tinnitus

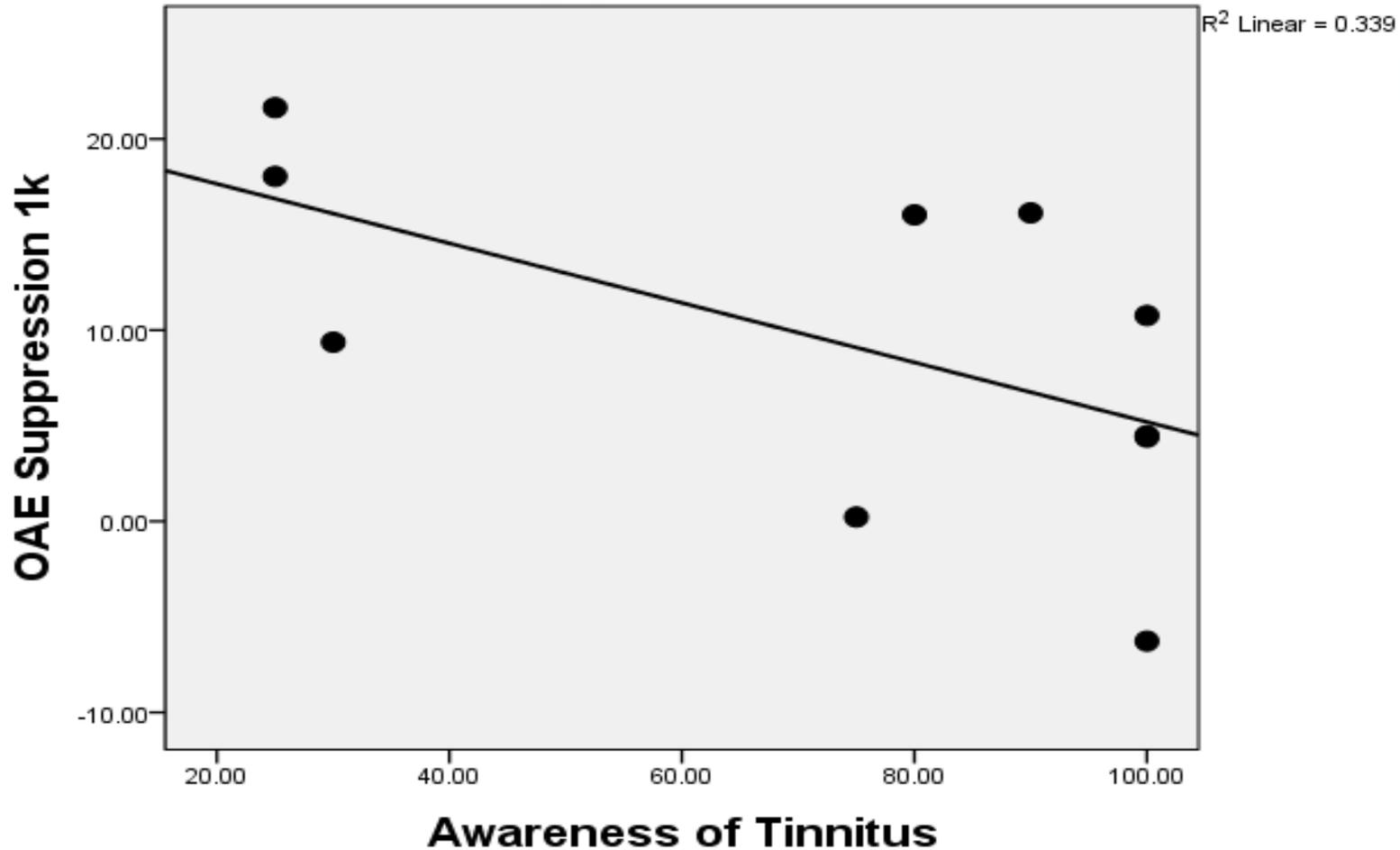


# Bilateral vs Contralateral Suppression Effect



OAE suppression was greater in the low freq's compared to the high freq's ( $F=14.619$ ;  $df= 4, 7$ ;  $p=0.002$ )

# Tinnitus awareness vs OAE suppression



Negative correlation between awareness of tinnitus and OAE suppression (1000 Hz  $r = -0.582$ ,  $p = 0.038$ )

# Conclusions



- These (preliminary findings) seem to agree with the current literature on OAE suppression, indicating that contralateral OAE suppression is decreased in the ear suffering from tinnitus when compared to the ear without or with lower tinnitus
- The present study uniquely found that;
  - Bilateral noise suppresses TEOAEs to a greater degree when compared to contralateral noise
  - Lower frequencies are more suppressed by bilateral and contralateral OAE suppression than higher frequencies

- 
- This data indicated that there is a clear correlation between the lack (or reduction) in OAE suppression, and the disturbance caused by subjective tinnitus and or hyperacusis
  - Consistent with both being mediated by efferent pathway 'dis-inhibition'
  - Indications that bilateral suppression may be a more reliable measure than contralateral; results might better correspond with patient reports and other objective measures

# Further Conclusions & the Future

- The correlation of psychometrical data w/ OAE suppression indicated that tinnitus awareness (% of the time) is corresponds with decreased suppression
- Appears to be a clinically viable objective measure
- Except when into hearing aid candidate range
- The low N at this stage of the study limits 'generalizability' of results
- Still very early days, but technique is quite promising
- The study is still ongoing and a larger number of subjects are needed to be able to confirm the current trends

# Acknowledgements



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