Extending the frequency range for audiometry

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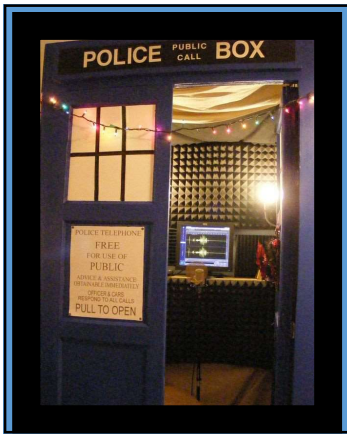
Outline - Goals

- Reasons to consider use of extended high frequency audiometry
- Describe the LiSN-S test and relation to high frequency hearing

Did you ever wonder why?

- Are sound isolation booths necessary?
- Why don't we test frequencies above 8 kHz?
- Why do we usually test speech understanding in quiet?
- If your car could travel at the speed of light, would the headlights still work?



Thinking outside the booth does not just mean thinking differently.

It means thinking *"are we too limited by our sound booths?"*

Why are sound booths needed?

- To test sound field thresholds for normal hearing people
- Controlled, but don't replicate the real world
- At a cost of $75k, they are a very expensive way to test threshold of normal hearing people
- Some people find booths to be claustrophobia-inducing at best
- Yet…much of our counseling happens in these same booths
- Is there a better, more efficient and patient-friendly way to test auditory threshold?

Which environment is better?

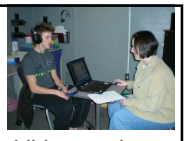
One Solution: Circumaural Earphones

- More comfortable for patients
- Easily placed by assistants
- Better sound isolation
- Avoids ear canal collapse
- Prevents low frequency leaks
- Fewer calibration issues (TM perforations)
- Allows extended high frequency testing

Speech in Noise Tests

- Still rarely used in audiologic assessment
- Yet…..hearing in noise is main patient complaint
- Patients with "normal hearing" may also complain of listening problems in noise
- Traditional speech recognition tests have ceiling effects, high variability and poor prediction of functional outcomes
- Adaptive tests in noise don't require sound booth, can simulate head related transfer function; better prediction of functional outcomes

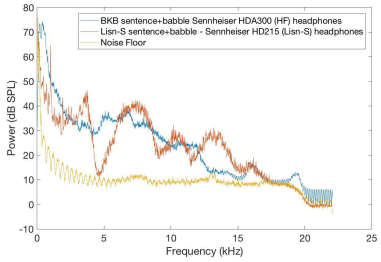
LiSN-S Test



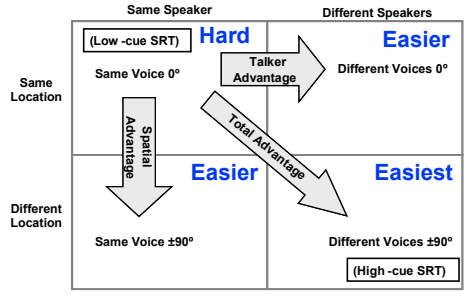
1. Adaptive speech-in-noise
2. Target: sentences (designed for children and adults)
3. Competing speech: looped children's stories
4. 3-D auditory environment under headphones

- Laptop computer
- Sound card
- Sennheiser HD 215 headphones

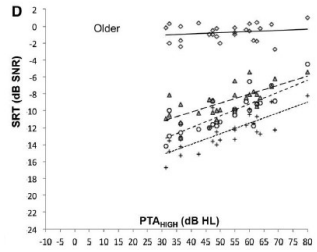
Spectrum of LiSN-S Sentence and Distractor Compared to BKB-Sin and Noise Floor



LISN-S SRT & Advantage Measures



Speech in Noise for Older Adults with Normal Hearing in Standard Frequencies but EHF Loss



Speech-in-Speech Listening on the LiSN-S Test by Older Adults With Good Audiograms Depends on Cognition and Hearing Acuity at High Frequencies

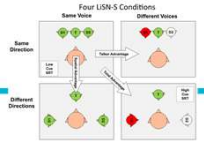
Besser….Pichora-Fuller, Ear Hear, 2015

Participants and Enrollment

- Prospective longitudinal study of children
  - Aged 6-12 years
  - LiD: n=51; Parent questionnaire (ECLiPS, Barry & Moore, 2014) and diagnosis by audiologist at Cincinnati Children's
  - TD: n=63; Typically developing, no listening problems on ECLiPS
  - Both groups: No major neurologic, cognitive or brain injury,
  - Normal hearing (<25 dB HL, .5-8 kHz), Otoscopy and tympanometry (226 Hz)

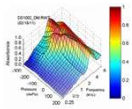
Behavioral Test Methods

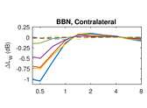
- Standard (.5-8 kHz) and extended high frequency threshold audiometry (10-16 kHz); bone conduction if threshold > 20 dB HL.
- NIH Cognition Toolbox (Weintraub et al. 2013, Neurology)
- SCAN-3 test of auditory processing skills (Keith, 2008)
- Listening in Spatialized Noise Test (LiSN-S, Cameron & Dillon, 2007)

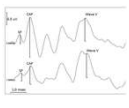


Physiologic Test Methods

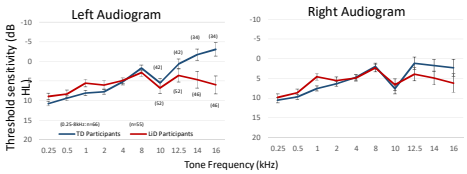
- Wideband tympanometry .25 to 8 kHz (Keefe et al., 2016, Hunter et al., 2016);
- Wideband acoustic reflex thresholds, ipsilateral and contralateral presentation; BBN and .5, 1, 2 kHz pure tone stimuli
- DPOAE using 65/55 dB SPL tone pairs 2-10 kHz
- ABR using clicks, recorded SP, CAP with gold foil ear canal electrodes







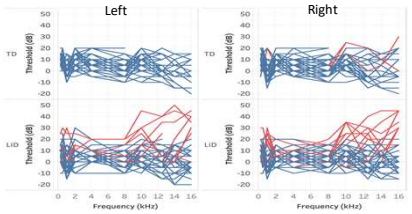
RESULTS: Standard and EHF Hearing Thresholds



TD - typically developing, LiD - listening difficulties
Mean ± SEM
* p < 0.05
** p < 0.01

RESULTS: Individual Standard and EHF Hearing

(1+ high freq threshold >20 dBHL)

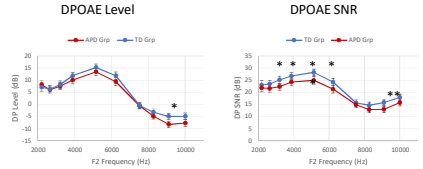


TD: 4/31 have abnormal HF hearing (13%)

LiD: 14/46 have abnormal HF hearing (30%)

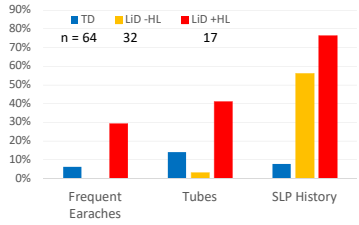
All children had 'normal hearing'. Children with LiD were more likely to have one or more threshold > 20 dB HL at frequencies 10 – 16 kHz.

RESULTS: Distortion Product Otoacoustic Emissions

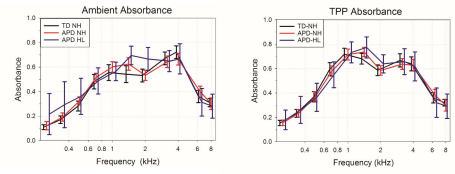


TD - typically developing, LiD - listening difficulties
Data points: mean ± SEM
* $p \leq 0.05$
** $p \leq 0.01$

Hearing loss associated with OM and PE tube history, speech/language therapy

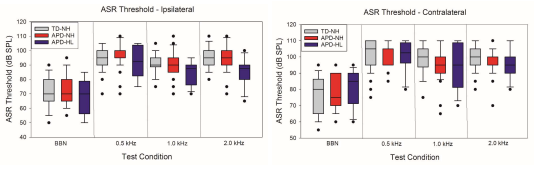


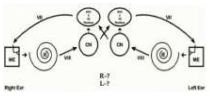
Wideband Tympanometry – Absorbance and Group Delay



TD - typically developing
APD - listening difficulties
Mean ± SEM
** $p < 0.01$

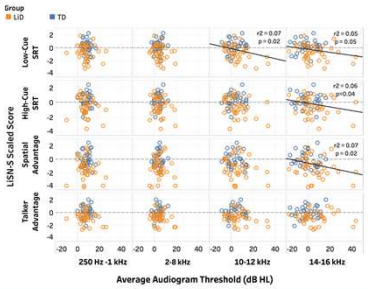
Wideband Acoustic Reflexes – Ipsilateral and Contralateral





Afferent and efferent pathways:
Middle ear > cochlea > cochlear nucleus > MN VII N > stapedial nerve > middle ear
Sensitive to HHL (Valearo et al., 2016)

LiSN-S Results versus Hearing Thresholds



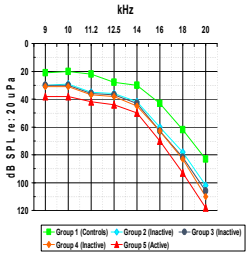
Hardest

Easiest

Easier

Easier

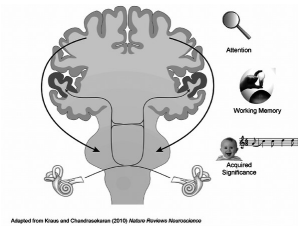
Previous Evidence of Extended High-Frequency Hearing Loss and OME: Prospective Study



Hunter et al., *Ear Hear* 1996

- EHF HL increased with frequency in children with OME aged 3-11 yr.
- EHF HL in OME directly related to # of tubes and frequency of OME episodes during follow-up
- Animal studies show RWM transmission of bacterial endotoxins and basilar OHC damage (Paparella, Morizono).

Multiple bottom up acuity, binaural processing and top down deficits?



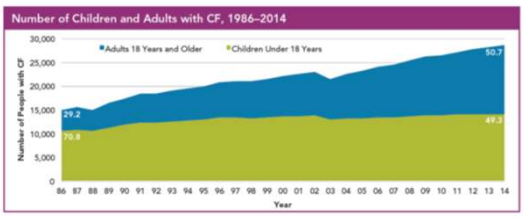
- Childhood Recurrent Otitis Media (Gravel et al.)
- Fluctuant conductive hearing loss – poorer phonetic mapping (Wallace et al)
- Speech-language delay – poorer prediction of semantic with loss of high frequency speech cues (Roberts et al.)
- Binaural processing cues – conductive hearing loss (Moore et al; Hall et al; Cameron & Dillon)
- Acuity in extended high frequencies (Hunter et al, Margolis et al)

Summary – EHF & LiD

- About 30% of children aged 6-12 years with listening difficulties (aka APD) have hearing loss above 8 kHz
- Hearing acuity above 8 kHz is related to some aspects of challenging speech perception in competing spatial conditions (shown in older adults: Besser et al., 2015)
- Hearing acuity above 8 kHz is related to a history of OME, PE tubes and speech-language difficulties
- Both top-down and bottom-up mechanisms should be considered in LiD or APD

Cystic Fibrosis and Hearing Loss Study

Increasing Lifespan of CF Patients

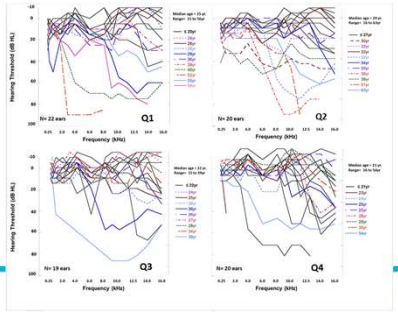


2014 Annual Report, CF Foundation

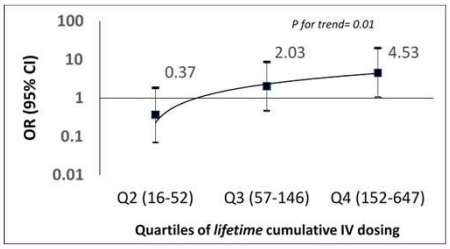
Background: CF and Hearing

- AG antibiotics are known to induce ototoxicity (hearing and balance problems).
- Prevention of hearing loss from intravenous (IV)-AG exposure in patients with CF uncertain, contributing to the lack of ototoxic monitoring in many CF clinics.
- The prevalence of hearing loss from AG treatment in adults with CF is about 47% compared to 11-18% in age-matched groups of adults without a history of CF or AG exposure.

Hearing in CF Patients 15-63 years old (Garinis et al., J Cystic Fibrosis, in press)



Odds ratios for association of cumulative IV dose for AG (± vancomycin) exposure (Garinis et al., J Cystic Fibrosis, in press)



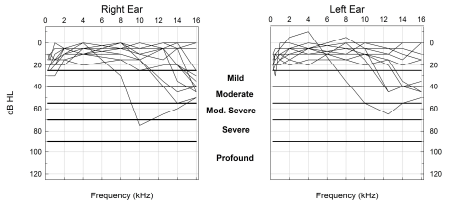
Test Protocol

- 21 CF participants (13 analyzed thus far)
- Mean age at test: 15.5 yrs (Range: 13-19 yrs)
- Tests completed over 1 or 2 days
  - Hearing and Balance Questionnaire
  - Audiometric Thresholds (standard and high frequency
  - Tympanometry and acoustic reflexes
  - Speech-in-Noise Testing
  - Clinical DPOAEs (2-10 kHz)
  - Chirp-evoked Otoacoustic Emissions (up to 16 kHz)
- Goal is to retest at every admission

Hearing and Balance Questionnaire

Questions	Parent Report	Patient Report
Concerns with Hearing	3/6 (50%)	3/12 (25%)
Tinnitus	2/6 (33%)	5/12 (42%)
Balance Issues	1/6	5/12 (42%)
History of OM	2/6	4/12 (33%)
PE Tubes	1/6	1/12
Childhood HL	0/6	1/12
Past Hearing Test	6/6	9/12

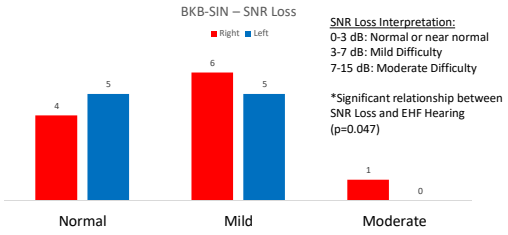
Audiometric Thresholds



Frequency Range	Right HL	Left HL	Percent HL Either Ear
0.25-8 kHz	4/13	2/13	30.7%
10-16 kHz	8/13	6/13	61.5%

- HF Audiometry not completed for CF1005
- 1 patient had middle ear conductive hearing loss

Speech-in Noise Function BKB-SIN



SNR Loss Interpretation:
0-3 dB: Normal or near normal
3-7 dB: Mild Difficulty
7-15 dB: Moderate Difficulty

*Significant relationship between SNR Loss and EHF Hearing (p=0.047)

Preliminary Findings

- The rate of hearing loss among teen IV-AG histories in the CCHMC cohort is high, especially for high frequency hearing.
- Based on previous reports, these hearing losses will increase over time into adulthood.
- The functional impact is hearing speech in noise, such as in the classroom.
- Expanded study is planned with R01 submission to NIH.

Questions?