THE 41st ANNUAL

G. PAUL MOORE SYMPOSIUM

presents:

Gail Whitelaw, Ph.D.

"Beyond the Audiogram Hearing Disorders (HD) parts 1 and 2: Auditory Processing Considerations in Children and Auditory Issues in Concussion/Traumatic Brain Injury"

Jill Firszt, Ph.D.

"Effects of Unilateral Hearing Loss: From the Brain to Behavior"

February 5th, 2019

Emerson Alumni Hall

University of Florida

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National Student Speech Language and Hearing Association

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Department of Speech, Language & Hearing Sciences

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Dear Symposium Attendee,

The faculty, students, and staff of the Department of Speech, Language, and Hearing Sciences at the University of Florida extend a very warm welcome to all of our attendees at the 2019 G. Paul Moore Symposium. We hope you will find that this year's Symposium is intellectually stimulating and that it provides you with a great opportunity to network with both your colleagues and the many talented undergraduate and graduate students in our program.

This year marks the 41st annual G. Paul Moore Symposium. The event is named in honor of Dr. G. Paul Moore, a long-time professor at the University of Florida who made many outstanding contributions to the field of speech-language pathology. The University of Florida's National Student Speech Language Hearing Association (NSSLHA) has coordinated this event to continually honor Dr. Moore for these vital contributions. We thank Dr. Moore's family for their continuing support of this important educational activity.

This year we are very pleased to have four excellent presenters, each of whom are well-known nationally and internationally for their contributions in communication sciences and disorders. We welcome Dr. Gail Whitelaw from Ohio State University who will be presenting on auditory processing disorder in children. We also welcome Dr. Jill Firszt from Washington University at St. Louis, who will be presenting on the effects of unilateral hearing loss. In addition to these two speakers, we will also have a collaborative lecture from Dr. Ann Marie Orlando and speech pathologist Katie Roark from the University of Florida. They will be co-presenting on Autism and complex communication. We are pleased to have you join us for this year's edition of the Symposium.

Sincerely,

Cara Duncan & Emily McHugh
G. Paul Moore Symposium Directors
National Student Speech Language Hearing Association

Lori-Ann Ferraro, M.A., CCC-SLP
Director of Clinical Education
University of Florida Department of Speech, Language, and Hearing Sciences

Beyond the Audiogram: Auditory Processing Considerations in Children Part 1

2019 G. Paul Moore Symposium
The University of Florida

Gail M. Whitelaw, Ph.D.
The Ohio State University

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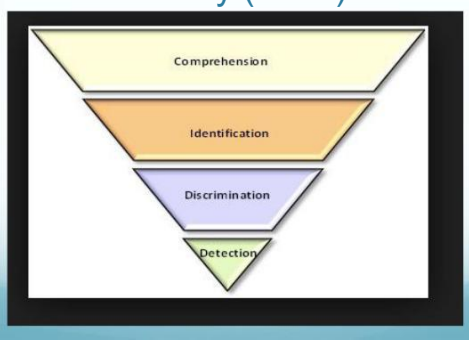
Erber's Hierarchy (1992)



The scenario

- A 9 year old child is referred to your clinic with concerns about hearing and listening. She has passed hearing screenings at school. She has difficulty with hearing in noisy environments. The teachers have completed a behavioral questionnaire (Screening Inventory for Targeting Educational Risk—SIFTER) and indicate significant concerns about listening skills.
  - Hoof beats and horses: Perform hearing evaluation and the results are "normal"
  - Now what?

Redefine "hearing"

- World Health Organization challenges us to see hearing as "functional" communication
- We are learning more about issues like "hidden hearing loss", auditory neuropathy, APD in those populations that provide evidence (e.g. Walter Reed, National Center for Rehabilitative Auditory Research, The Ohio State University)
- The role of audiology (what is outdated…word lists with the word "laud"; the WIPI, degrees of hearing loss—the list

Hoof beats and Zebras

- How to move off the beaten path?
- Looking for subtleties, looking for "functional" hearing difficulties
- Years of information on auditory processing disorder
- How to address these issues with school aged children

What is "functional" hearing loss

- The times, they are a'changing: Will we change with them?
- Hewett, D. (2018) Audiometry and Its Discontents. *Hearing Review 25*(1), 20-23.
- The pure tone audiometer was developed in 1879
- Pure tone audiometer considered today to be the "gold standard"

What is "functional" hearing loss

- Carl Crandell and colleagues pointed out that pure tone audiometry was unable to reliably predict the issue that most older patients present with—difficulty hearing in typical environments were competition is present
  - Recommended that speech in noise testing should be a standard of care
- 30 years later, pure tone audiometry still "king"

Role of the auditory system

The auditory system must prepare for the adaptive demands faced by a listener, including processing variations in the speech of individual speakers, grasp auditory information presented in less than optimal listening environments, and comprehending information of varying degrees of linguistic complexity.

To summarize: Must be fast and flexible!!!

What is "functional" hearing loss

- Human hearing is constantly shifting
- Complex
- Pure tone audiometry is of little use in cases where patients present with auditory disorders of listening in noise, etc. May call them auditory processing disorder but addresses their "functional" abilities in the real world

Another APD mantra…

- The auditory system is based on redundancy (built into the system) and predictability (built into the system and from experience)

What is "functional" hearing loss

- Although pure tone results will likely be a "gold standard" it will not be THE "gold standard" in the future
- Need to look at binaural/dichotic listening issues

The question is…

How to best tax the auditory system?

The Auditory System

- Auditory processing disorders on a continuum of hearing disorders
- How are "functional issues" addressed?
  - HD or hearing difficulties
  - Where are we in the process of measuring auditory behaviors?

Evidence for APD as a disorder?
Fear of the "controversy"

"…the quality and quantity of scientific evidence is sufficient to support the existence of APD as a diagnostic entity to guide the diagnosis and assessment of the disorder and to inform the development of more customized, deficit focused treatment and management plans"

ASHA, 2005

(Central) Auditory Processing Disorders Defined:

A breakdown in auditory abilities resulting in diminished learning (e.g. comprehension) through hearing, **even though though peripheral hearing sensitivity is normal**

Auditory processing disorders

- As idiosyncratic as the individuals they affect
- Most do not have origins identifiable at the structural level (rare)
- Brains are individualized and whether APD is developmental or acquired, central auditory nervous system pathology does not respect functional neurological boundaries
- Speaks to the need to customize the recommendations and treatment plan
  - Phillips, 2002

Auditory processing disorders

However, (C)APD may lead to or be associated with difficulties in higher order language, learning, and communication functions. Although (C)APD may coexist with other disorders (e.g., attention deficit hyperactivity disorder [ADHD], language impairment, and learning disability), it is not the result of these other disorders. (ASHA, 2005)

Evidence for APD as a disorder?

American Academy of Audiology. (2010). Clinical practice guidelines. Guidelines for the Diagnosis, Treatment and Management of Children and Adults with Central Auditory Processing Disorder. Retrieved from www.audiology.org/resources

DeBonis, D.A. (2015). It is Time to Rethink Central Auditory Processing Disorder Protocols for School-Aged Children. *American Journal of Audiology. 24*(6), 124-136.

- Anything new? Not really…many very old references?
- What is new? Focus on cognition
  - The good: The ear is a window to the brain
    - Hearing aid manufacturers have gone hog wild…untreated hearing loss can contribute to dementia/Alzheimer disease
  - The bad: It's been oversold

All children, by virtue of childhood, require a more favorable listening environment than adults:

Developmental aspect of audition that go beyond detection of sound (refer back to Erber!)

Article by DeBonis

- Generalized hearing issues
  - Parental/teacher concern: The value of hearing screening in school
- #1 indicator of hearing loss: Parental concern
  - You have a role here: All kids that have a hearing evaluation should have speech in noise testing (his "generalized listening issues")
  - Best test for this is the Bamford Kowel Bench-Speech–In-Noise (BKB-SIN): Well normed and takes a very short time to administer
- Language is related to cognition and attention, and same concerns are raised.

Developmental aspect of audition that go beyond detection of sound (refer back to Erber!)

Creating a welcoming environment to educate parents and professionals about typical auditory development

Move away from "the audiogram says"

Hot topic at the moment

- Interprofessional Education (IPE) and Interprofessional Practice (IPP)
- Auditory processing has always been best addressed by multidisciplinary/interdisciplinary team that might include audiologist, speech-language pathologist, physician, occupational therapist, psychologist, neuropsychologist, among others

Beyond the audiogram

- Article on "Hidden Hearing Loss" in the ASHA Leader summer, 2017
  - Hidden hearing loss are described as the patient who can "ace" a standard hearing test but describe a struggle to hear in a noisy room

Beyond the audiogram

- 'Hidden hearing loss' more "sexy" term
  - Cochlear synaptopathy
    - Prevalent in an animal model
    - In humans, associated with difficulty understanding speech in noisy environments (with "normal" audiogram)

The Auditory System: The earbone and brainbone have always been connected

- Peripheral
  - Communication difficulties related to hearing loss
  - Conductive (OE/ME)
  - Cochlear (IE)
  - Retrocochlear (VIII nerve)
  - Usually more overt types of difficulties
- Central
  - Usually demonstrate no hearing loss via conventional audiometry
  - Subtle problem with "auditory process"
  - Perceptual difficulty

Updated info on hidden hearing loss—hot of the presses!

- Dr. Daniel Rasetshwane; Boys Town National Research Hospital
- American Auditory Society Meeting, March 2018
- Suprathershold difficulties despite "normal" audiogram; missed by conventional audiometry
- Damage to low spontaneous rate fibers in the auditory system
  - Electrophysiology may provide significant information

Roles of the Central Auditory Nervous System

- "Processing" rapid signals
- Gating (aspects of the efferent auditory system)
- Alerting to incoming information

Beyond the audiogram

- Audiogram tells the story of hearing in quiet, it's detection
- On the cusp of learning more about HHL
- Is this a type of APD?
- What should our role be in this area?

Roles of the Central Auditory Nervous System

- Communication between the two hemispheres of the brain
- Coordinating or "teaming" between the two ears--they work as a unit (audiologists refer to this as dichotic listening)

Central Auditory Processes Are Mechanisms and Processes Responsible for the Following Behaviors (note: these are functional behaviors):

- Sound localization
  - Early behavior
  - Role in hearing in background noise
- Auditory discrimination
  - Gross and fine differences in sounds, including phonemes

Central Auditory Processes Are Mechanisms and Processes Responsible for the Following Behaviors: (Con't)

- Auditory performance decrements with degraded acoustic signal
  - Speakers that speak a dialect which differs from that of the listener

(ASHA, 1996)

Central Auditory Processes Are Mechanisms and Processes Responsible for the Following Behaviors (con't):

- Temporal aspects of audition, including:
  - Temporal resolution, temporal masking,
  - Temporal integration, and temporal ordering
  - Timing is important in terms of reading, auditory memory, sequencing, etc.

Central Auditory Processing Disorders Can Be Defined As:

- Observed deficiency in one or more behaviors noted in the ASHA consensus statement
- Can be auditory specific (e.g. a disorder of the coding and transformation of auditory input for perception) or part of a larger general information processing deficits

Central Auditory Processes Are Mechanisms and Processes Responsible for the Following Behaviors: (Con't)

- Auditory performance decrements with competing acoustic signals
  - Listening in the presence of background noise

Central Auditory Processing Disorders Can Be Defined As:

- Two different areas that are "abnormal"

(based on normative data of the test), based on American Academy of Audiology position statement

Etiologies of APD

- Delay in development
- Disorder of the central auditory nervous system
- "Cerebral morphologic abnormalities" (CMA)--issues of wiring
- Contrast with learning styles

Auditory Processing and the Impact on Language Impairment

- Early descriptions of auditory perceptual difficulties
  - Impairment in phoneme recognition and discrimination
  - Defective capacity for storing speech message
  - Impairment in processing speech at "normal" rates

Auditory Processing and Language Development

- Interaction of child with the environment
- Auditory systems well designed to process speech
- Learning to "hear" one's native language begins early

Assessment of Auditory Processing Disorders

Auditory Processing and Language Development (con't)

- Language development is highly dependent on the auditory system
- Two systems are also independent (Sloan, 2000)

Brief history of assessment

- 1950s: Italian physicians made observation on people with confirmed brain lesions in the temporal lobe--reported difficulty listening in background noise
  - Normal audiogram
  - When auditory system was taxed, they demonstrated considerable breakdown

Brief history of assessment (con't)

- Observation made that some kids looked like these adults
  - Generalized use of these tests
  - Idea of taxing the auditory system is good--audiogram doesn't tell the story
  - Lack of recognition that comparing a developing child auditory system to disordered adult brain--BAD
  - Since 1970s--emphasis on appropriate kid materials

Audiologists unique qualifications to assess auditory processing skills…

- All auditory processing assessment is designed to "tax" the auditory system
- History of APD testing and all the ideas addressed above help to tax the auditory system
- The issue of language—varying linguistic load

Who labels the child?

- Auditory processing assessment and management is in the scope of practice of AUDIOLOGY
  - Cannot relegate or abdicate this responsibility to other professions (popular to use the term "auditory processing disorder")
  - The "bowel-ear" connection
  - A test like the TAPS is NOT an auditory processing test…addresses all the other things that DeBonis "complains" about

Considerations

- The "audience"
  - APD diagnosis related to the educational setting
  - APD diagnosis as part of a "medical model"

Audiologists unique qualifications to assess auditory processing skills…

- Can control listening environment
- Can control stimulus presentation
- Area of expertise is hearing/listening

Assessment begins with screening at time of request for appointment

- In call to set up appointment, establish the following:
  - Age of the child (most literature suggests age 7 is earliest age for formal APD assessment)

Assessment begins with screening at time of request for appointment

- Value of assessment younger than 7 years of age if parent has concerns—role of the audiologist, however this assessment focuses on hearing/listening skills and not formal assessment of APD
  - Speech in Noise testing; ASA (Auditory Skills Analysis for 3-7-year olds)
  - Identify peripheral hearing loss!
  - Tremendous variability in listening behavior for younger children
- Auditory system development issues

Authentic assessment

- Screening tools completed by school personnel
  - SIFTER
  - CHAPs
  - Fishers Auditory Problems Checklist
    - Available at the Educational Audiology Association at http://www.edaud.org/

Pre-appointment screening

- In call to set up appointment, establish the following:
  - Cognitive ability of the child
    - Criteria of normal cognitive abilities
    - Performance/verbal split
    - Criteria for learning disabilities (scatter)
    - Language bias of IQ testing
    - Referral source

At this point, screening and…

- Determine not necessary and make referral (SLP, Psychological, etc.)
  - Well connected network…strong basis for cross referrals
- Determine further assessment is indicated and provide it yourself or refer to an audiologist who does this testing

Pre-appointment screening

- In call to set up appointment, establish the following:
  - Other diagnoses
    - Autism spectrum disorders
      - Growing population
      - Role of the audiologist
      - Diagnosed as "APD" by others
        - Opportunity to set the record straight; global sensory disorder

Prior to APD assessment…

- Must have an audiologic evaluation; must establish NORMAL hearing for a child
  - What does this mean? 15 dB HL for all frequencies (known as the "low fence"
- However, audiogram only tells part of the story
- Speech in noise testing…Bramford-Kowel-Bench-Speech in Noise test (BKB-SIN)

Test materials available for APD assessment in children: brief overview

- SCAN-3 (Psychological Corporation)
  - Normed 5 years-11.11
  - Screening and Diagnostic subtests:
    - Filtered Words
    - Auditory Figure-Ground
    - Competing Words
    - Competing Sentences
    - Time compressed sentences
- SCAN-3: Normed for adolescents and adults

Evidence

- **Looking at the evidence:**
  - **"The concept of CAPD as a unique diagnostic entity that should be assessed and treated in school-aged children continues to engender controversy." (DeBonis, 2015)**
  - **Research is "stagnating"? (Cowan, Rosen, and Moore, 2009) or not—Auditory processing research at Acoustical Society Meeting in Indianapolis in 2014**

Test materials available for APD assessment in children (con't)

- Pattern perception skills (Pitch pattern sequence and Duration pattern sequence)
- GIN (Gaps in Noise)
- Multiple Auditory Processing Assessment Version 2 (MAPA-2)

Management of APD

Acoustic Pioneer

- Feather Squadron
- http://acousticpioneer.com/

The management myth

- **There is no such thing as an auditory processing disorder**
- **It can't be "cured"**
- **We do the same thing for everyone so what's the point of doing an assessment or developing a management plan: List of APD recommendations**

What doesn't work

- Doing nothing
- Preprinted list of recommendations
- Preferential seating: Please stop recommending this as a "fix" for auditory processing and hearing loss
  - Has no evidence that it changes the acoustic environment for the child (see Leavitt & Flexer, 1991)
  - May have other types of benefits such as logistical access to the teacher and/or visual access

Management issues:

- Person centered
- Context centered

What doesn't work

- Acoustical "modifications" in the classroom
  - The tenet of if it's not measured, it doesn't happen
    - Tennis balls on the bottom of chairs
    - Use of soundfield FM in the classroom
- FM system as a panacea for all

Key for all aspects of management and treatment

- Increase predictability
- Increase redundancy

Linking assessment to management and treatment

- Compensatory strategies
- Improving the acoustic environment
- Direct intervention

Treatment and management of APD has happened for years…

- It is called aural habilitation/rehabilitation
- Supports the supposition that auditory processing disorders are on the continuum of functional listening disorders that are defined by the term "hearing loss"
  - Concept of hidden hearing loss
  - The patients I work with who are more "hard of hearing" than those with "impaired hearing" on an audiogram

Some tenets to address with APD management

- Best evaluated and treated in an interdisciplinary team setting
- APD likely as overlap with other types of disorders
  - Must address functional listening deficits regardless of the etiology
  - Co-morbidity exists for all issues related to hearing
- Can be separate disorder and one that audiologists "own" (one of the comments often made is that APD cannot be assessed clearly…looks like ADHD, however research supports that this is not accurate; Chermak and colleagues)
- Low incidence disorder: Estimates around 3% (2-5% are cited frequently) of the school aged population

Evidence based auditory training

- Treatment should include the following components: (Smith et al, 2009)
  - Exercises continuously adjust difficulty to user performance to maintain a predetermined percent correct rate
  - Correct trials rewarded: Points, animations, etc.
  - Exercises had stimuli that address the range of auditory/acoustic of interest (e.g. listening in noise, temporal processing, etc.)

What we know from auditory plasticity in children

- The central auditory system is "…highly plastic in early childhood" (Cardon, Campbell, and Sharma, 2012)
- First year of life has the greatest promise in plasticity of the cortex is during the first year of life (e.g. success of early intervention)
- Because the cortex is highly plastic, intervention can produce significant positive effects and outcomes
- At least two factors need to be considered: 1) timing of intervention and 2) type of input or stimulus to be used

Evidence based auditory training

- Treatment should include the following components: (Smith et al, 2009)
  - Training component exaggerates the target for listening—contrasts!
    - Goal is to drive plasticity and increase effectiveness of how the stimuli engage
  - Exaggeration gradually removed to create "real world" listening situation
  - Work consistently on the exercises (daily), which is monitored

What we know from auditory plasticity

- Historically, we know that children who lack stimulation of the auditory system due to peripheral hearing loss have hearing loss demonstrate negative cortical changes (Gordon et al, 2011).
- Most audiologists do not assess APD until age 7; often not identified until much older than that
  - Parental concern often much younger
  - Using plasticity evidence to rethink the timeframe of diagnosis in children
    - Need for evidence based testing and treatment that incorporates information about neural plasticity

Treatment

- **Brain can recognize treatment to better meet auditory processing demands: Posit Science; Lumnosity**
- **Plasticity depends on activity and stimulation…intervention must be initiated in a timely manner**
- **Organized and progressively challenging**
- **Building a better auditory system!**

Compensatory strategies

Rephrasing/repeating

- Repetition is good but only if acoustically better presentation than the first presentation (how does one do that…reduce distance, increase the volume, use of clear speech…allows child to be able to fill in missing information)
- Rephrasing: Can be used if information is added that will clarify the original misunderstanding (e.g. vocabulary not familiar to the child)

Building a team

- Support from intervention specialists, speech-language pathologists, teachers of the hearing impaired, etc.: it's all about the team
- Develop understanding of child's strengths and weaknesses
- Encourage child to use visual cues
- Assist child in recognizing "easy" and "difficult" listening situations
- Teacher strategy development

Auditory fatigue

- Recognize that listening is fatiguing
- Schedule "listening" activities early in the day
- Alternate "listening" activities with those that require less listening
- Provide a quiet place to do work
- Opportunities for physical activity to reduce stress and improve attention
- Current research with focus on listening fatigue and stress in students with hearing loss

Teacher strategy development

- Teacher strategy development:
  - Impact of rate of speech on comprehension
    - "Clear speech" techniques (Payton, Uchanski, Braida, 1994)
  - Understand signal-to-noise-ratio and facilitate ways to enhance it
- Use of visual and other modality cues

Technology tools

- **Speech to text options**
  - **Smartpens**
    - Livescribe pen
- http://www.livescribe.com/en-us/smartpen/
  - **CPRINT/CC**
  - **Recording lectures**
    - Front Row to Go Soundfield system with Lesson capture
  - **Guided notes, Powerpoints,etc.**
    - Who is responsible?

An evidence based listening environment

Impact of poor acoustics

- Reduction in speech perception
- Reduction in academic achievement
- Decrease in attention
- Decrease in reading ability
- Reduction of "on-task" behavior
- Reduction in psychosocial behaviors (Crandall and Smaldino, 2000)

Hearing in noise

- The ability for CANS development to support processing of complex auditory signals, such listening to speech in a room with a variable noise background, has a complicated developmental progression and extends well into adolescence (Sharma, Kraus, McGee, Nicole, 1997).

Evidence: Acoustical standard for classrooms (ANSI)

- Reverberation=less than .4 sec
- Background noise=35 dB of less
- Signal to noise ratio=+10 or greater
- Value of "sound study"
- Value of HVAC consult
- Value of classroom treatment

Hearing in noise

- Johnson (2000) revealed that the more complex the noise listening situation (e.g. addition of reverberation, decrease in linguistic redundancy) of stimulus tasks resulted in a longer developmental trend for speech in noise performance
- The typical child in school requires a +6 dB SNR
- The "high risk listener" (Johnson, 2000) requires a +12-+20 dB

Listening technology options

- FM/Other assistive technology
  - Classroom
  - Personal
- Hearing aids

CADS:Technology and APD

- FM/DM (digital modulation) is not necessary the primary or only recommendation
- Depends on the type of APD, educational setting, etc.
- Benefits of sound field amplification for ALL has been well documented, much less on addressing personal FM technology for children with APD
  - Soundfield types of systems may not have a significant enough SNR to address individual children with APD
  - Again, need to measure it: BKB-SIN testing as part of assessment AND while trying systems
  - CADS: Classroom Audio Distribution Systems: http://www.audiologyonline.com/articles/20q-classroom-acoustics-and-audio-12285

Current options

- Ear level devices specifically designed for those with normal peripheral hearing acuity
  - Phonak Focus (compatible with Roger Pen, Roger inspiro, Clip Mic)
  - Option Amigo Star receiver with T30-31 transmitter

Considerations with FM technology

- Authentic assessment
  - Specific observations
  - Use of a questionnaire, such as the *Listening Inventory for Education (LIFE-R)* (Anderson, Smaldino, and Spangler, 2011)
  - http://lifer.successforkidswithhearingloss.com
  - http://lifer.successforkidswithhearingloss.com
- Transparent system—not providing "amplification" per se, but signal-to-noise ratio enhancement only

Phonak Focus

Personal FM technology

- Superior Signal-to-noise ratio
- Quality of Sound: Clean, digital, dynamic
- Ease of use
- Fit: Easy to use but someone at school must be comfortable with a hearing aid type of device (e.g. removing wax from the tubing) for school aged kids
- Options of receiver

Oticon Amigo Star

Hearing aids

- Have used in some children and many teens and adults with incredible success
  - Dodgeball accident
  - Softball patient
- Caution fitting normal hearing acuity
  - Medical clearance: Discuss with physician
  - Real ear measures
  - More "authentic assessment"
  - Data about listening in noise: Set it up in the booth
  - Kuk (2011)

Direct therapeutic approaches

Hearing aids

- FM options are expanded when hearing aids are used
  - Can use FM receiver directly through hearing aid
  - Bluetooth connections
  - Use streaming device (Oticon Streamer, Widex FM Dex, Phonak ComPilot)
  - Possibility of improved hearing/listening with hearing aids only (Oticon Opn)



Listening/auditory training

- Recent evidence supports the impact of training on neural plasticity and in turn on functional auditory behaviors.
- Phillips (2003) points out changes in the auditory cortex, representing the neuroplasticity of the system, as a result of behavioral training, have been well documented in animal models.
- Thompson (2000) describes how treatment/therapy enhances the "representational plasticity" of the CANS, resulting in the ability to engage new neural networks post-treatment.

All technology requires training

- Evidence that when people know what they are doing, outcomes are better ☺
- Audiologist should be the one who leads this
- Who provides batteries, domes, etc. for kids at school

Specifics about this type of auditory training

- **All research, however, points to the need for stimulation or treatment to be :**
  - **Varied**
  - **Challenging**
  - **and developmentally appropriate in order to capitalize on the experience-dependent neuroplasticity available in the auditory system (e.g. McCall and Plemons ,2001).**
- **Significant implications for developing auditory processing skills in young children and to remediate auditory processing disorders in both children and adults**

Specifics about this type of auditory training

- Historically, many of the therapeutic approaches designed to address auditory processing disorders in children, such as completing pre-printed worksheets, have not capitalized on current knowledge of neuromaturation and neuroplasticity.
- May be benefit from this as an informal auditory training to "prime" for the formal auditory training

Formal Auditory training programs: "The beginning"

- Earobics: Earobics.com
  - Addresses range of skills, those noted in ASHA position statement
  - However, product NOW focuses on reading skill development
  - Home and Center based versions

Specifics about this type of auditory training

- This is the early stages of development of such programs, as is noted with the Fast ForWord program (Tallal, Miller, Bedi, Byma, Wang, Nagarajan, Schreiner, Jenkins, and Merzenich, 1998) and in dichotic listening therapy (Musiek, Shinn, and Hare, 2002), as these programs as a foundation for remediation and auditory training programs
  - ADAPTIVE—can change with the learning and document this change
- Acoustically enhanced
  - Evidence-based

Angel Sound

- http://angelsound.tigerspeech.com/
- Free, interactive listening rehabilitative program
- Research from House Ear Institute

Formal Auditory training programs: "The beginning"

- Fast ForWord (Tallal and colleagues)
  - Children with specific language impairment/CAPD have difficulty processing brief acoustic events that occur in rapid succession (e.g. running speech) (Sloan, 1998)
  - Adaptive, computer based, CENTER based (time)
- Controversial but established some of the issues that need to be addressed

Listening and Communication Enhancement (LACE)

- Listening and Communication Enhancement (LACE) program (developed by Robert Sweetow, Ph.D, distributed by Neurotone http://www.neurotone.com/)
  - Initially developed to address listening deficits in adults with peripheral hearing loss
  - Have used effectively with children and teens

Read My Quips

- http://www.sensesynergy.com/
- Designed by Harry Levitt, PhD.
- Focus is on speech comprehension, with average improvement of 30%

Acoustic Pioneer

- Test battery administered as an App on iPad by an audiologist
- Age 5 thru adults
- Testing is "Feather Squadronhttp://acousticpioneer.com/assessmentap p.html
- Treatment program associated with Feather Squadron: Auditory training games(http://acousticpioneer.com/auditorytraininggames1. html)

LisN and learn

- http://capd.nal.gov.au/lisn-learn-about.shtml
- Addresses speech in noise and dichotic listening
- National Acoustics Lab
- Use for students who have deficits with the LisN-S test
- Skills that are addressed: Localization; 3 dimensional listening
- Unique way to both test and address APD: new generation of tests and treatment with strong evidence base

Acoustic Pioneer

- Auditory training games
  - Zoo Caper Sky Scraper: Dichotic listening training
  - Insane Airplane: Tonal processing

Hear builder

- http://www.hearbuilder.com/get-hearbuilder/
  - Phonological Awareness
  - Auditory Memory
  - Sequencing
  - Following directions
- Top down approach
- Functional issues and augment to APD but not likely to address specific auditory processing skills
- Has some of the components of an evidence based listening program

Capdots

- http://capdots.com/
- 3 levels based on age and skills

What we're learning about auditory training…

- BioMark was the beginning—electroacoustic assessment and trained to this
  - Nina Kraus' lab/Northwestern University
  - http://www.brainvolts.northwestern.edu/projects/music/index.php
- The role of music performance in auditory processing

References

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Managing/Treating APD

- Empirical question of effectiveness of treatment regimes for APD
  - All learning involves plastic changes in the brain, thus newer training strategies are not unique
  - What may make them "special" is the effectiveness with which they can target an impaired process
  - This link may be as individual as individual listeners
    - Phillips, 2002

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BEYOND THE AUDIOGRAM PART 2: MILD TRAUMATIC BRAIN INJURY AND CONCUSSION

2019 G. Paul Moore Symposium

The University of Florida
Gail M. Whitelaw, Ph.D.
The Ohio State University
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Infusing audiology into the "real world"—diffusing the fear of Over-the-Counter hearing aids

- The Audiology Project (TAP)
  - http://www.theaudiologyproject.com
  - Current focus on hearing/balance issues for people with diabetes
  - "promoting the audiological medical management of hearing and balance"

What to expect in this session

- **At the end of this session, you will be able to:**
- **Describe the characteristics of concussion and TBI related to hearing/balance/listening**
- **List patient characteristics and the interdisciplinary team needed to support this population**
- **Develop a test battery for assessing this population: tie into pediatric issues related to mTBI and concussion**
- **Discuss audiologic management of patients with concussion/TBI**

My opportunity: Ohio Health's Traumatic Brain Injury Group

- "I need you"
- The "survivor's" story

Philosophy to guide this session

Making audiology essential!

- Lives of patients and their families
- Expanding our reach beyond "the usual suspects"
  - Physiatry (Physical Med and Rehab or PM&R)
  - Optometry
  - Neuropsychology
  - Neurology
- Addressing Interprofessional Practice (IPP) and Interprofessional Education (IPE): Superior patient care and leadership for our profession
- Understand that many children (and adults) have poor/no follow-up from head injury/concussion

"Old school" approach for audiologists related to head injury

- Limited role
- Limited interest
- Most often related to MVA (motor vehicle accidents)
- Mostly overlooked children: MILD concussion

Temporal bone fractures

- Ulrich 1926: Two classifications: Longitudinal and transverse
- Recent classifications look at the otic capsule (whether it is "spared" or involved).
- Simplicity of Ulrich system addresses why it is still used

Temporal bone fractures

- Transverse
  - 20%
  - Cochlear and vestibular structures are usually destroyed
  - profound sensorineural hearing loss
  - Severe ablative vertigo which reduces to an unsteady feeling in 3-6 months
  - Nystagmus visible, usually beating away from the fracture site

Temporal bone fractures

- Longitudinal:
  - 80%
  - tympanic membrane laceration
  - hemotympanum
  - ossicular chain disruption that produces conductive hearing loss (may have sensorineural hearing loss)
  - facial nerve paralysis (20%)
  - otorhinorrhea consisting of cerebral spinal fluid (CSF) is common but usually temporary
  - Vertigo can occur but is not related to the severity of the fracture.

Temporal bone fractures

- Combined
- The role of the audiologist in working with this patient population
- March, A.R. et al (2017): Temporal bone fractures. Otolaryngology and Facial Plastic Surgery. Medscape November 21, 2017.

Case 1: Being hit literally with "a ton of bricks"

- 5th grade girl in a MVA
- First concern was her life
- Bedside audio: Conductive hearing loss, thought to be longitudinal fracture, etc.
- "Recovered"
- 5-6 months after her MVA, back in our department
- Difficulty hearing in noise, could not hear in school
- Issues and dx. Consistent with auditory processing disorder

MVAs and the role of airbags being deployed

- Thought to be established that airbags being deployed results in auditory issues
  - Hearing loss
  - Impact noise exposure?
  - Tinnitus
- Role for audiologists (and not being an accident chaser!)
- Yaremchuk, K. and Dobie,R. A. (2001) Otologic injuries from airbag deployment. Otolaryngology—head and neck surgery. 125(3), 130-133.

Current thoughts on concussion/traumatic brain injury

- Focus of popular press
  - Chronic Traumatic Encephalopathy (CTE) with head injury in athletes, most specifically NFL players
    - Certainly going to be more research in this area, not a particularly strong area for audiologists at this time
  - Concussion: Growing interests since it's either a growing population or there is better recognition of concussions
- Is there a disconnect?

Scope of the issue

- 1.7-2.8 million Americans experience a TBI per year
- Falls leading cause in children under 4 and in adults over 65 years
  - Role of audiologist in fall prevention is significant since falls that result in TBI's are the falls that result in death for older adults
  - Over the span of six years (2007–2013), rates of TBI-related emergency department visits increased by 47%

Current thoughts on concussion/traumatic brain injury

- Is there a difference between concussion and TBI?
  - Concussion is thought to be mild, often attributed to an accident in sports
  - Traumatic brain injury is more "severe", "medical" such as a with a MVA
  - Not necessarily a correlation between reported difficulty and "degree" or physical findings
  - Functional deficits or biochemical changes in the brain

Scope of the issue

- In children 14 and younger
  - 640,000 emergency department visits per year
  - 18,000 hospitalizations
    - Taylor et al (20017)
- 20% of teens active in contact sports had a least 1 concussion
  - 6% are diagnosed with more than one concussion
    - Journal of the American Medical Association (2017)

Current thoughts on concussion/traumatic brain injury

- Concussions are traumatic brain injuries that can result from a bump, blow, or jolt to the head
  - Concussion symptoms may range from mild to severe
  - People who experience a concussion may lose consciousness, but generally this is not the case
  - Often like Lay's potato chips "no one can have just one"
  - TBI/concussions can affect children and adults differently
  - Effects can last a lifetime
  - Considerable misinformation with the "typical" person, which can include healthcare professionals and educators

Scope of the issue

➢ Hearing loss and tinnitus are the two most prevalent service connected disabilities in veterans in the United States

- Blasts/explosions that result in concussion/TBI, noise exposure (a new thought on "hidden hearing loss"), ototoxic chemicals
- Theodoroff, S.M., Lewis, M.S., Folmer, R.L., Henry, J.A., & Carlson, K.F. (2015) Hearing Impairment and Tinnitus: Prevalence, Risk Factors, and Outcomes in US Service Members and Veterans Deployed to the Iraq and Afghanistan Wars. Epidemiology Reviews, 37 (1), 71-85.

Post concussive syndrome (PCS)

- Can last for weeks, months, and years
- Headaches, dizziness, tinnitus, visual perceptual issues, auditory perceptual issues, anxiety, depression, short-term memory issues, among other symptoms
- Synergy among these issues
- Must be on the "look out"—listen carefully to patients
- Standard of care is cognitive rest, up to a year following the concussion/TBI

Boston Marathon Case: Adult case with general implications

- 32 year old woman who was survivor of Boston Marathon bombing
- Seven audiologic evaluations
- Main complaint "can't hear in noise"
- She couldn't hear in noise
- Hearing aids, aural rehabilitation, language therapy

Current references in concussion

- Centers for Disease Control report on TBI
- Taylor, CA, Bell JM, Breding, M.S., and Xu, Z. (2017) Traumatic Brain injury-related emergency department visits, hospitalizations, and deaths: US 2007-2013. MMWR Surveillance Summaries, 66.
- Concussion Surveillance System: https://www.cdc.gov/traumaticbraininjury/ncss/index.html

Case history information

- Subtle but significant
- Often have a "normal" audiogram: This means normal detection thresholds
- Hearing in less than optimal situations
- Speed of processing much slowed
- Tinnitus that interferes with listening/concentration/attention
- Sound tolerance issues (e.g. hyperacusis)

CONCUSSION/TBI AND THE AUDITORY SYSTEM

Research in auditory/vestibular symptoms in concussion/TBI

- Significant number of articles
- Conflicts in findings: Similar to every other area in concussion/TBI
- What we do as audiologists? Listen/be available/be aware/don't base it all on the audiogram
- "Head trauma may or may not involve the auditory system; however, when it is involved it is critical to make this determination." (Musiek, Baran, & Shinn 2004)
- How do we as audiologists challenge ("tax") the auditory system

Presentation of hearing/listening/balance issues following a TBI

- As noted previously, addressing temporal lobe fractures (may be a short term issue or a tip of an iceberg)
- Patients with "minor" head injuries most often demonstrate mild and moderate sensorineural hearing loss (Bergemalm & Borg, 2001)
- Some losses improve and some progress
- Delayed onset of hearing loss in some patients

(Bergemalm, P.O. & Borg, E. (2001) Long -term objective and subjective audiologic consequences of closed head injury. *Acta Otolaryngology*, 121: 724-734.)

Presentation of hearing/listening/balance issues following a TBI

- Evidence of impaired auditory function
  - Self-report is the strongest, however evident in both behavioral and electrophysiologic data, too

Gallum, F.J., Papesh, M.A.& Lewis, M.S. (2017). Hearing complaints among veterans following traumatic brain injury. Brain Injury, 31(9), 1183-1187.

Presentation of hearing/listening/balance issues following a TBI

- Changes in electrophysiologic results due to results of primary injury and secondary issues (contusion, hemorrhage, diffuse axonal injury)
  - May not be detected based on imaging techniques
  - Demonstrated deficits in attention and may be detected on electrophysiologic measures

(Musiek, F.E., Baran, J.A., & Shinn, J. (2004) Assessment and Remediation of an Auditory Processing Disorder Associated with Head Injury. *Journal of the American Academy of Audiology, 15*, 117-132.)

Assessment

- Detailed case history
- "Authentic assessment"
  - CHAPS questionnaire (see next page)
  - COSI
  - Your choice of "favorite" questionnaire that addresses communication function
  - World Health Organization:
    - Functional impact: Being able to communicate with others
    - Social and emotional impact: significant impact on everyday life, causing feelings of loneliness, isolation, and frustration.

Presentation of hearing/listening/balance issues following a TBI

- Concussion/TBI can result in auditory processing disorders
  - Concussions related to sport injury resulted in auditory disorders (temporal processing, dichotic listening) (Tureon et al (2011) Auditory Processing after Sport-Related Concussions. Ear and Hearing, 32(5), 667-670)
  - Dichotic listening: Some research demonstrates right ear advantage (REA)
  - Two ears were built to work together as a team, particularly after age 12-14 years
  - Some patients report that their "hearing" is better in one ear than the other, despite normal detection thresholds

Assessment

- Tymps and AR
- DPOAEs
- Conventional pure tone audiometry
- Speech audiometry
- Speech in noise
  - BKB SIN (5-14 years)
  - QSIN (adaptive)
  - R-SPIN (predictability)
  - Others—what you like and why you find it effective

Assessment

- Auditory processing/listening assessment
  - SCAN-3 (appropriate age level)
  - Gaps in Noise (temporal processing)
  - MAPA (Multiple Auditory Processing Assessment-2)
  - Frequency Pattern/Duration Pattern
  - Find ways to "tax" the auditory system
- Tinnitus/hyperacusis
  - Pitch match
  - Loudness match
  - Loudness discomfort

Vestibular rehabilitation

- Physical therapists that support concussion patient needs
- Driving issues is huge issue for many that have had concussion
  - MVA
  - Non-MVA
  - Physical therapist input
  - Driving simulator
    http://drivesim.osu.edu/

Vestibular/Balance issues

- Significant number of people who have had concussion who have vestibular issues
- Assessment and need for vestibular rehabilitation (evidence of significant improvement)
  - Alsalaheen, Bara A. et al (2010) Vestibular Rehabilitation for Dizziness and Balance Disorders After Concussion. Journal of Neurologic Physical Therapy. 34(2) 87-93.

Management/treatment

- School based intervention
  - Interdisciplinary team
  - Addressing executive function and the role of hearing/listening
  - Brain rest often recommended by neurologists
  - Common comment: "Well, you look fine"
  - Development of an IEP (may be classified as Other Health Impaired) or 504 plan
    The role of the audiologist as an advocate

Vestibular/Balance issues

- Vestibular Rehabilitation and concussion course
- Evidence based concussion certification workshop
- American Institute of Balance https://www.dizzy.com/product-category/workshops/

Management/treatment

- Hearing aids to address functional issues (the next talk)
- Digitally modulated/frequency modulated system
- Aural rehabilitation:
  - Listening and Communication Enhancement (https://www.lacelistening.com/)
  - Angel Sound (http://angelsound.tigerspeech.com/)
  - Read My Quips (http://www.sensesynergy.com/readmyquips)

Management/treatment

- Aural rehabilitation:
  - Dichotic listening programs
    - DIID (Dichotic Interaural Intensity Difference training: Musiek https://journals.lww.com/thehearingjournal/Citation/2004/07000/The_DIID__A_new_treatment_for_APD.11.aspx)
    - Capdots (http://capdots.com/)
- Metacognitive training
- Language therapy (partnership with us)
  - Top down approach

Summary

- Concussion and TBI is large patient population and growing
- Educate your "team": Physical Medicine, Emergency physicians, optometrists, physical therapists, speech/language pathologists
- Listen to the patient, their family, and their school team: functional concerns
- Provide full assessment
- Address treatment/management issues
- Fulfilling to address needs of patients and their fami

Who pays and how?

- Cash
- Automobile insurance in MVA
- School based support
- 3rd party
  - Bureau of Worker's Compensation
  - Bureau of Vocational Rehab—may be helpful in teens
    - No consistency

      Firefighter payment

Hidden hearing loss: The future

- Will change opportunity for audiology and all we've talked about in the past few hours

Effects of Unilateral Hearing Loss: From the Brain to Behavior

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Director, Cochlear Implant Program

Washington University in St. Louis
School of Medicine

G. Paul Moore Symposium
Gainesville, FL
February 5, 2019

Disclosures

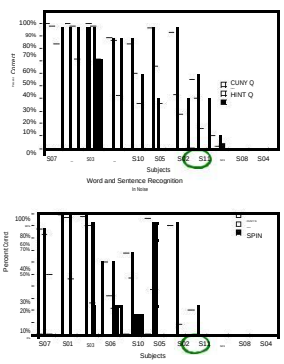
- Financial:
  - Employed by WUSM—salary
  - NIH (research funds)
  - Cochlear Americas, Advanced Bionics (consulting relationship and audiology advisory board member, research funds)

Overview of Presentation

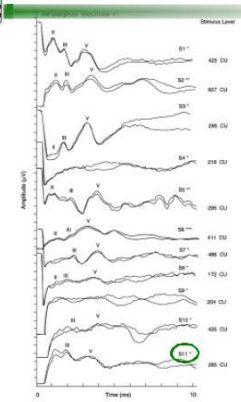
- Case Study
- Unilateral Hearing Loss (UHL)
  - Adults, Children
- Effects of UHL from listener perspective
- Primary focus today: Speech recognition in noise and Localization
- Variables: Length of deafness & Age at onset
- Imaging study-Speech in noise

Individual Subject (S11)

- Hearing history
  - Mumps age 7 yrs, profound HL (LE)
  - Acoustic neuroma age 47, profound HL (RE)
  - 1 mo later, CI in LE, the ear without direct peripheral stimulation for 40 years

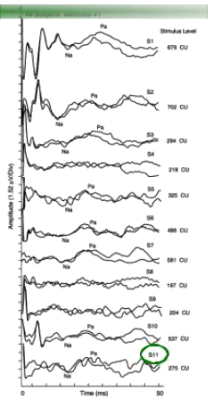


Firszt et al, 2002



EABR
El #1
100% of DR
All subjects

Firszt et al, 2002



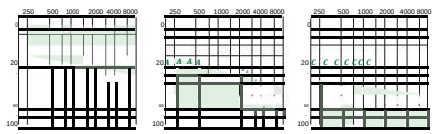
EMLR
El #1
100% of DR
All subjects

Firszt et al, 2002

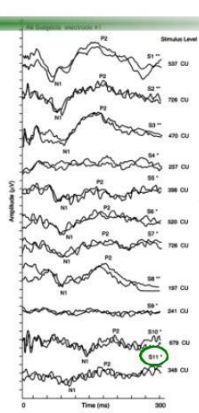
Studies underway at WUSM/SLCH

We are studying several patient populations with varied asymmetry between ears

- All have one deaf ear, rely on one better ear
- All are unilateral listeners



Better Ear	Normal or Near-normal hearing	Some hearing loss Uses amplification	Uses Cochlear implant
Poor Ear	Severe to profound hearing loss	Severe to profound hearing loss	Severe to profound hearing loss



El N1-P2
El #1
100% of DR
All subjects

Firszt et al, 2002

We Hear with Our Brain, Not Just Our Ears

- Contrast of
  - Bilateral normal hearing
  - Bilateral hearing loss
  - Unilateral hearing loss

Individual Subject (S11)

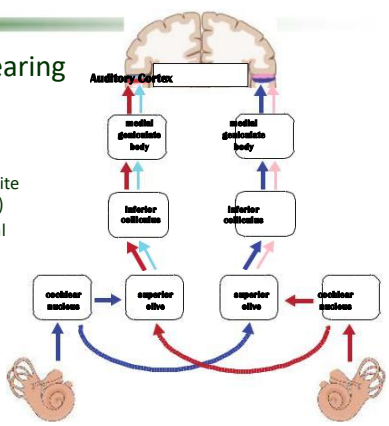
- Did having sound in one ear help to maintain the opposite poor ear for a good outcome?
- Was having hearing in both ears until age 7 and establishing binaural pathways the main reason?

Normal Hearing

Results in

- Stronger contralateral activation (opposite side) (dark colors)
- Weaker ipsilateral activation (same side) (light colors)

(Wolpaw & Henry, 1977; Shtyrov et al 1999)

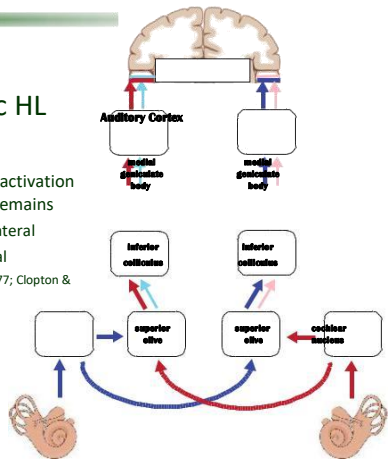


Symmetric HL

Results in

- Reduced overall activation
- Similar balance remains
  - Stronger contralateral
  - Weaker ipsilateral

(Silverman & Clopton, 1977; Clopton & Siverman, 1977)



Unilateral Hearing Loss (UHL) Study in Adults

Purpose:

- Quantify auditory deficits in adults with UHL
- Need to quantify when considering treatment
- Identify sources of variability in outcomes
- Compare results with NH bilateral listeners
- Compare results with NH unilateral listeners
- Introduce the condition of UHL acutely

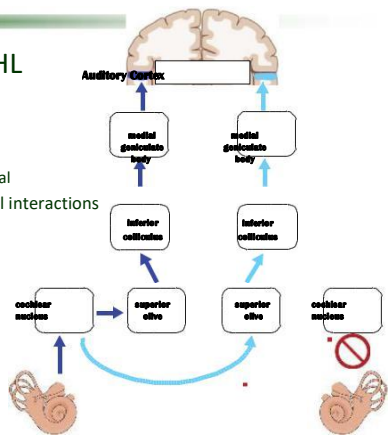
Firszt JB, Reeder RM, Holden LK. Unilateral hearing loss: Understanding speech recognition and localization variability - implications for cochlear implant candidacy. Ear Hear, 2017, 38:159-173.

Unilateral HL

Results in

- Loss of balance
- Stronger ipsilateral
- Altered binaural interactions
- Creates aural Dominance

(Kral et al 2013, Tillein et al 2016)



UHL Study – Demographics

Mean (SD) Range	Age (years)	*PTA (dB HL) from .25-8 kHz (tested ears)*	*PTA (dB HL) from .25-8 kHz in deaf ear*	Age Onset SPHL (years)	Length of Deafness (years)
UHL (n=26)	49.1 (12.9) 25 - 71	13.2 (7.1) 0.0 – 29.3	110.2 (10.5) 78.3 – 121.3+	27.3 (22.7) 0 - 61	21.9 (21.8) <1 - 72
NH - Plugged (n=25)	48.8 (13.7) 22 - 71	11.8 (11.8) 3.0 – 23.1	NA	NA	NA
NH - Bilateral (n=23)	49.7 (11.6) 22 - 67	12.2 (12.2) 2.5 – 26.1	NA	NA	NA

Firszt et al, 2017

UHL Adults

UHL Study

Test Protocol addressed two known deficits

- Listening in noise
- Localization

HINT Sentences in Restaurant Noise R-Space™

- 8 loudspeakers surround the listener
- Sentences--front
- Restaurant noise from all loudspeakers
- Adaptive measure: Noise at 60 dB SPL, speech level is varied
- Participants repeat the sentence
- SNR-50 score (SNR for 50% correct)

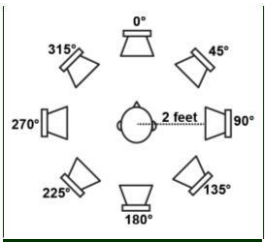
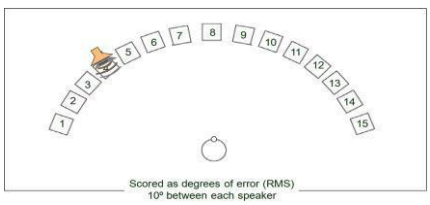


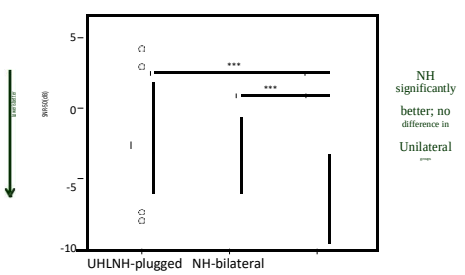
Illustration from Revit et al, 2002

Localization Methods

- Identify loudspeaker location
- Localization ability was scored as degrees of error (RMS) between source loudspeaker and participant response (0°= perfect localization)

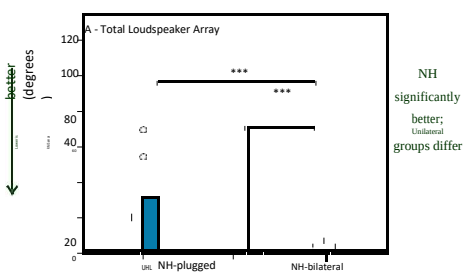


HINT Sentences in R-Space



Firszt et al, 2017

Localization

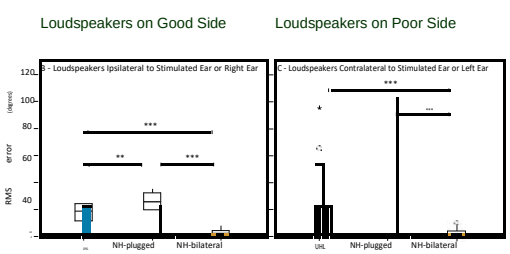


Firszt et al, 2017

Localization Methods

- CNC words (100) presented randomly via loudspeaker array
- 15 speakers; 10 active, 5 inactive
- 140 degree arc, speakers 10 degrees apart
- Roved at 60 dB SPL (+/- 3 dB)
- Asked to identify speaker location

Localization Based on Side of Presentation



Firszt et al, 2017

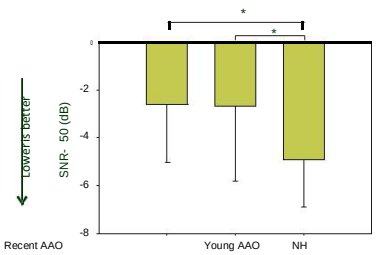
Result

- NH considerably better than either unilateral group—need NH norms for all measures
- UHL affected localization differently than listening in noise

— Localization better for UHL than NH-plugged

— R space results show no differences between unilateral groups

HINT Sentence in R-Space by Age atOnset



Firszt et al, 2017

Effects of Experience with UHL

Among the UHL participants:

- 9 had recent onset of SPHL (onset within 3 yrs of study)

— **Recent AAO**

- 8 had childhood onset of SPHL (onset by 3 yrs of age)

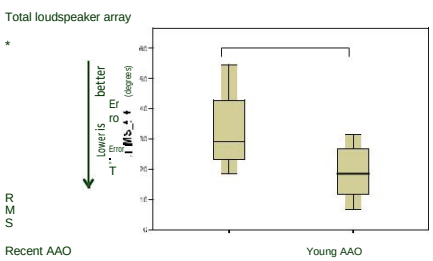
— **Young AAO**

Result

- Localization better for Young AAO versus Recent AAO

— Those with early onset of SPHL in one ear appear to have learned strategies to improve localization but this did not transfer to speech understanding in noise

Localization by Age at Onset



Firszt et al, 2017

Localization Training – UHL Adults

Can Training Improve Localization Ability?

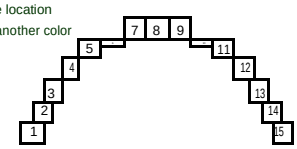
- Pilot study, 11 adults with UHL
- Pre and post-training assessments using words, and spectral and temporal sounds
- Attended 5 training sessions

– At least 3 days but no more than 1 week between sessions
– Spectral and temporal sounds; feedback provided
– 4 training runs at each session; 75 presentations per run
– Level of cuing graduated from very specific to none

Firszt et al, 2015, Hear Res

Training Activity

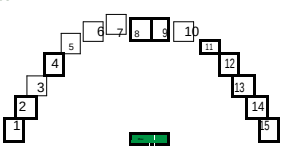
- Participant indicates the source loudspeaker
- Actual source location indicated by another color change



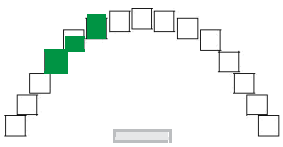
Training session #1, 100% of presentations were cued
Training session #2, 90% of presentations were cued

Training Activity

Participant presses "Play"



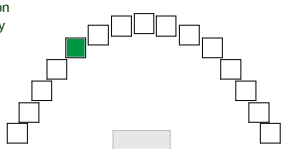
Training Activity



Training session #3, sets of 3 adjacent loudspeakers were cued and cues were present for 90% of the presentations

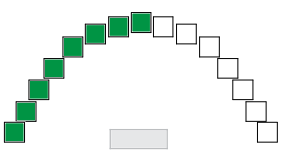
Training Activity

1 second color change for cued loudspeaker location followed by auditory presentation



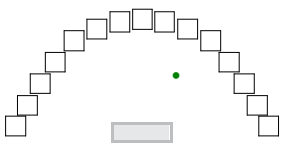
Training session #4, the side of presentation was cued and cues were present for 90% of the presentations

Training Activity



Training Activity

- Group mean RMS error scores improved for all stimuli
-
-



Training session #5, no cues were provided

Firszt et al, 2015, Hear Res

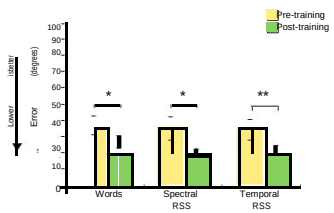
Localization Training Results Summary

Those with poorest RMS scores prior to training improved the most, those with the best RMS scores pre-training improved the least

Future work

- Are some individuals predisposed to have better localization or to benefit more from training?
- What is the impact of better ear hearing, hearing history?
- Does training generalize to everyday situations?

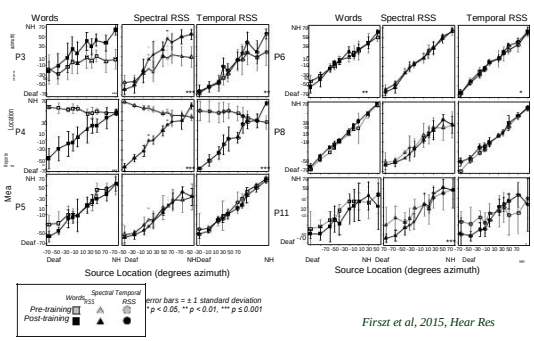
Pre- and Post-Training Results



Error bars = +/- 1 SEM

UHL Children

Localization Training



Firszt et al, 2015, Hear Res

Introduction

- Aims of pediatric study:
  - Identify abilities of children with UHL on measures that address known deficits, and quantify deficits on these measures
  - Investigate sources of variability
  - Compare performance and variability to NH peers

Reeder RM, Cadieux J, Firszt JB. Quantification of speech-in-noise and sound localization abilities in children with unilateral hearing loss and comparison to normal hearing peers. Audiol Neurotol, 2015, 20:31-37.

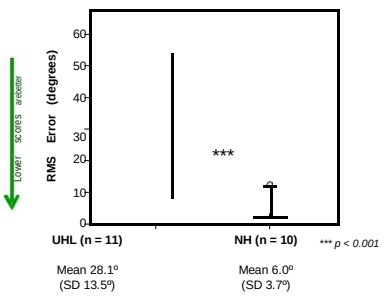
UHL Children and NH Matches

Mean (Range)	Age at Test (years)	Unaided FF PTA (dB HL) Poorer Ear	Better Ear	Age SPHL Onset (years)	Length of Deafness (years)
UHL (n = 20)	12.0 (6.9 – 16.3)	100.8 (61 – 120+)	6.6 (-2 – 20)	1.0 (0.0 – 7.9)	9.7 (0.3 – 15.3)

Mean (Range)	Age at Test (years)	Unaided FF PTA (dB HL) Right Ear	Left Ear
NH (n = 20)	12.0 (7.5 – 17.8)	4.2 (0 - 17)	4.9 (-1– 16)

Reeder et al, Audiol Neurotol, 2015

Localization



Mean NH Adults = 3 degrees

Reeder et al, Audiol Neurotol, 2015

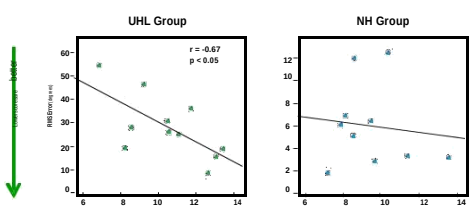
UHL Children and NH Matches

Mean (Range)	Age at Test (years)	Unaided FF PTA (dB HL) Poorer Ear	Better Ear	Age SPHL Onset (years)	Length of Deafness (years)
UHL (n = 20)	12.0 (6.9 – 16.3)	100.8 (61 – 120+)	6.6 (-2 – 20)	1.0 (0.0 – 7.9)	9.7 (0.3 – 15.3)
UHL (n = 11)	10.5 (6.9 – 13.4)	95.2 (61 – 120+)	5.9 (-2 – 20)	1.3 (0.0 – 7.9)	8.2 (0.3 – 12.1)

Mean (Range)	Age at Test (years)	Unaided FF PTA (dB HL) Right Ear	Left Ear
NH (n = 20)	12.0 (7.5 – 17.8)	4.2 (0 - 17)	4.9 (-1– 16)
NH (n = 10)	10.4 (7.5 – 15.5)	4.4 (0 – 17)	4.7 (-1 – 12)

Reeder et al, Audiol Neurotol, 2015

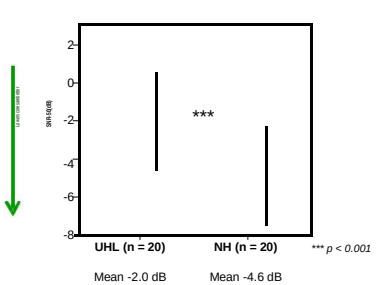
Correlations: RMS Error and Age



Age correlated with localization ability/scores for UHL only

Reeder et al, 2015

R-Space

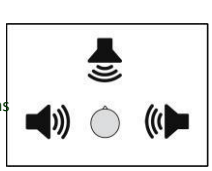


Mean NH Adults = -5 dB

Reeder et al, Audiol Neurotol, 2015

Adaptive SRT Methods

- Spondees (two syllable words with equal stress) from front loudspeaker
- Noise from 3 locations
  - Front, 90 degrees to right, 90 degrees to left
- Noise of 3 types
  - Male talker, Female talker, Multi-talker
- Results in 9 SRTs in Noise plus 1 SRT in Quiet



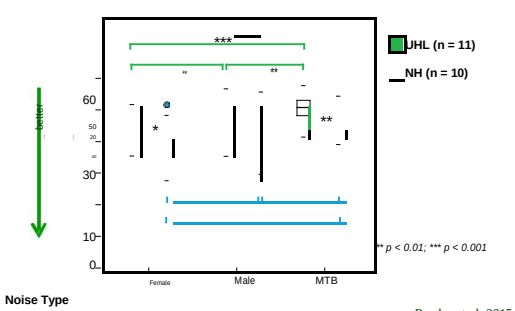
Adaptive SRT Methods

- 4 alternative, forced-choice adaptive task
- Using picture format, child identifies word
- For each spondee word presentation, background is randomized—either quiet or one of the 3 talkers—adds uncertainty to the listening task

Result

- Results poorer for UHL than NH - most measures
- Considerable variability on all measures with UHL
  - Some UHL children had scores within the range of NH children
- Localization – older children performed better, had more experience. No relation to listening in noise

Adaptive SRT in Noise by Noise Type

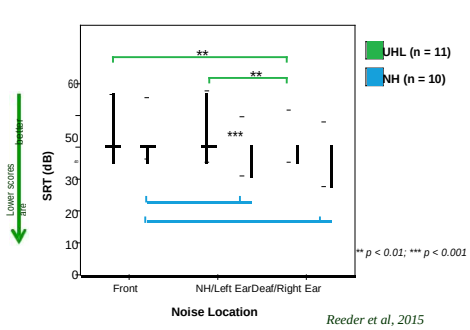


Reeder et al, 2015

Issues to Consider

- If we assume UHL deprives binaural processes, and we need bilateral input…
  - We do recommend bilateral HAs, bilateral CIs, and bimodal (HA+CI) at young ages
- We know from sequential CIs, bilateral input is needed in a timely manner—can't wait too long
- If younger is better, how do we identify deficits early? How do we determine recommendations for treatment? And how do we measure benefit?

Adaptive SRT in Noise by Noise Location



Reeder et al, 2015

Issues to Consider

- If not all children have a deficit, how to identify those that do
- Maybe all children have a deficit and we need different measures
- Those with performance comparable to NH peers, how are they doing it? Using other resources? Greater cognitive load? Some other work around?

Issues to Consider

- There will still be deficits with a CI
- Is there the potential to decrease performance?
- If so, who is at risk for poorer performance?
- Children with UHL have a higher risk of cochlear anomalies. Etiology plays a big role.
- Many unanswered questions…

Speech, Spatial and Qualities of Hearing Scale (SSQ)

- 49-item questionnaire designed to evaluate the effects of hearing loss in terms of function
- Uses a 10-point scale (0-10), where "0" indicates great difficulty and "10" indicates no difficulty
- Questions divided into 3 Domains: Speech, Spatial, and Qualities, or divided into 10 Subscales

(Gatehouse and Noble 2004)

Listener Perspective

How do adults with unilateral hearing perceive their hearing and communication abilities?

Dwyer NY, Firszt JB, Reeder RM. Effects of unilateral input and mode of hearing in the better ear: self-reported performance using the Speech, Spatial and Qualities of Hearing Scale. Ear Hear, 2014, 35:126-136.

Ten Subscale Analysis

Gatehouse and Akeroyd (2006)

SiQ = speech in quiet
SiN = speech in noise
SiSCont = speech in speech contexts
MultStream = multiple speech stream processing/switching

Speech Domain

Loc = localization
DisMov = distance and movement

Spatial Domain

SegSnds = segregation of sounds
IdSnd = identification of sound and objects
Qlty = sound quality and naturalness
Eff = listening effort

Qualities Domain

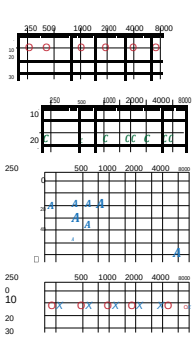
Participants

UHL group (n=30) **One deaf ear**
- Mean PTA 13 dB HL (0 - 27 dB HL)
- Mean age 51 yrs (25 - 76 yrs)

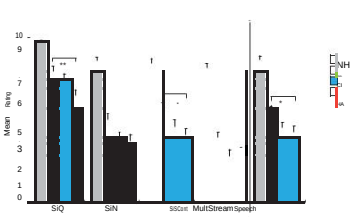
CI group (n=20) **One deaf ear**
- Mean PTA 20 dB HL w/CI (13 - 33 dB HL)
- Mean age 53 yrs (33 - 75 yrs)

HA group (n=16) **One deaf ear**
- Mean PTA 40 dB HL w/HA (29 - 52 dB HL)
- Mean age 60 yrs (26 - 77 yrs)

NH group (n=21)
- Mean bilat PTA 10 dB HL (4 - 23 dB HL)
- Mean age 50 yrs (27 - 73 yrs)



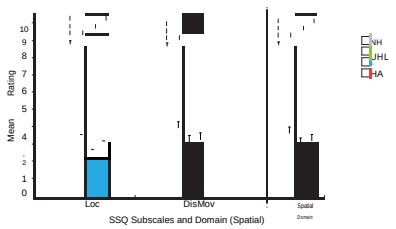
Results – Speech



** p < 0.05, ** p < 0.01, *** p < 0.001*

Dwyer et al, Ear Hear, 2014

Results – Spatial Hearing



** p < 0.05, ** p < 0.01, *** p < 0.001*

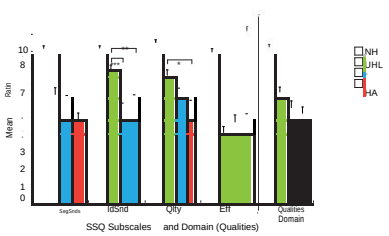
Dwyer et al, Ear Hear, 2014

Parent Perspective

How do parents rate the abilities of their children with UHL when listening in everyday situations?

Reeder et al, 2015, Audiol Neurotol

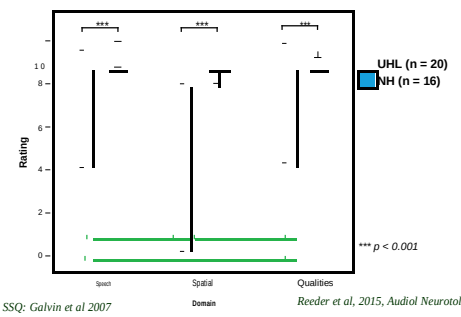
Results – Qualities of Hearing



** p < 0.05, ** p < 0.01, *** p < 0.001*

Dwyer et al, Ear Hear, 2014

(Pediatric) Speech, Spatial, and Qualities of Hearing Scale (SSQ)



Pediatric SSQ: Galvin et al 2007

Reeder et al, 2015, Audiol Neurotol

Result

- The 3 groups with one deaf ear, did not differ in their perceived hearing disability for 6 of 10 subscales
- In other words, NH in only one ear was as disabling as listening with a unilateral CI or a unilateral HA
- Adults reliant on a single ear, irrespective of the mode of hearing, report difficulties in many aspects of everyday listening and communication

Result

- Parents ratings for UHL significantly poorer than ratings of children with NH
- Among UHL children, Qualities ratings highest (7.2), followed by Speech (6.2) and then Spatial (4.3)
  - Similar pattern to that of UHL Adults (Qualities 6.5, Speech 5.5, Spatial 3.6)
- Parents report their children have difficulties in real-world environments
- Need to assess children directly

Overall Summary

- UHL poorer than NH-Adults and children
- Tremendous variability, some score within NH range
- Experience helps with localization but not listening in noise

— Adults with acute UHL vs UHL; UHL Adults Young AAO vs Recent AAO, Older UHL children

— Others with similar reports *(Slattery & Middlebrooks, 1994, Rothpletz et al 2012)*

— Different mechanisms involved

Introduction

- Variability is also seen *(Arndt et al 2011; Dillon et al 2017; Finke et al 2017; Firszt et al 2012, 2018; Hansen et al 2013)* among UHLs who receive a CI in the poor ear

—For the CI ear alone

—For the bimodal condition (NH + CI)

- Some show benefit when compared to their pre-implant performance whereas others show little to no benefit
- Greater understanding of variability will inform expectations, candidacy criteria, and treatment

Brain imaging study of speech in noise: UHL Adults

Introduction-Current Study

- Variability among UHLs may partially stem from auditory factors but also from cognitive processing needed for real-world listening
- UHLs may engage different brain networks than NH when processing speech which may explain variability among UHLs
- Little is known about the cognitive processes used by UHL for understanding speech in challenging environments

Introduction

- There is considerable individual variability in performance outcomes
- For both speech in noise and localization tasks, some show fair accuracy and may fall within the range of NH peers, whereas others do not *(Firszt et al 2015, 2017; Slattery & Middlebrooks, 1994; Rothpletz et al 2012; Van Wanrooij & Van Opstal 2004)*
- Explanations for this variability are not defined at this time

Objective-Current Study

- In NH, comprehension of speech depends on left lateralized cortical language areas
- In NH, semantic context helps speech understanding in noise
- Current study objective: Determine whether UHL engage cortical areas differently compared to NH when listening to degraded speech

Participant Demographics

- NH = 12, UHL = 12 (all RE deaf)
- Age and gender matched
  - NH = Mean 48 yrs, UHL = 47 yrs
- Hearing thresholds (PTA)
  - NH = 10 dB HL, UHL (LE) = 11 dB HL
- UHL
  - Poor ear (RE) = 111 dB HL
  - AAO = 30 yrs (range 0-51)
  - LOD = 16 yrs (range 3-49)

Methods

- fMRI study
- Siemens 3 T TRIO scanner
- Sparse imaging paradigm-present stimuli in silent intervals before volume acquisition, record peak amplitude of the BOLD response
  - Stimuli 4BW, 8BW, 16BW
  - Imaging task-Indicated whether last word was predictable based on sentence semantics
- During scanning, 60 sentence trials per run, 5 runs
  - Each run, 2 blocks of 10 sentences at 4BW, 8BW, 16 BW

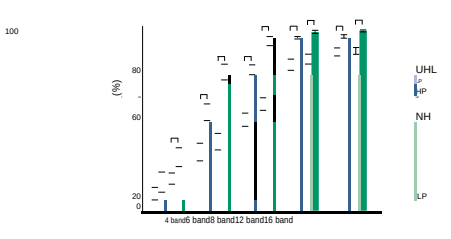
Methods

- Participants listened to Revised SPIN sentences
- Sentences varied in predictability and intelligibility
  - High and Low Predictability
    - High: Raise the flag up the pole
    - Low: Bob considered the pole
  - Intelligibility degraded with noise vocoding *(Shannon et al 1995)*
    - 4BW (least), 6BW, 8BW (moderate), 12BW, 16BW (most)
  - Behavioral task-Identified last word of each sentence

Methods

- In plane resolution was 4 x 4 mm (64 x 64 matrix, FOV = 256 x 256)
- Statistical analysis
  - Anatomical and functional criteria predefined each area based on Glasser et al 2016
  - Calculated percent signal change/z scores
  - Parametric stats using 2 x 2 x 3 mixed ANOVA (Group x Intelligibility x Predictability), Bonferroni corrected

Behavioral Task-Performance Accuracy



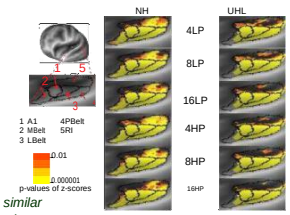
NH > UHL p = 0.005
HP > LP p < 0.001

Intelligibility effect p < 0.001

Predictions

- We predicted there would be effects in regions responsible for top-down semantic and cognitive processes, especially in the left hemisphere *(Obleser et al 2007; Peelle 2012, Specht 2014)*
- We expected semantic region differences between NH and UHL in areas of inferior frontal cortex (IFC), inferior parietal cortex (IPC) *(Binder et al 2009; Jefferies 2013; Obleser et al 2007, 2011; Peelle et al 2010, 2012)*
- Semantic regions might show group differences relative to intelligibility effects

Early Auditory Cortex

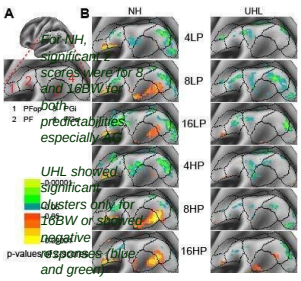


Compared to NH, UHL activity was fairly uniform for primary auditory cortex

Only significant differences were in the Mbelt area

Overall, results suggest similar lower level acoustic processing

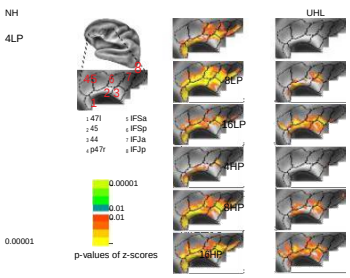
Inferior Parietal Cortex (IPC)



For NH, significant scores were for 8 and 16BW for both predictabilities, especially 2nd

UHL showed significant clusters only for 16BW or showed negative responses (blue and green)

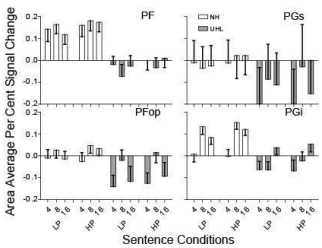
Inferior Frontal Cortex (IFC)



NH had highly significant z scores (colored yellow), greatest for 8BW

UHL had no IFC areas for 4BW but did for 8 and 16 BW

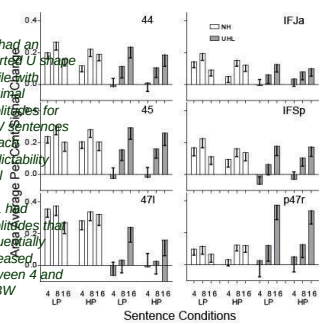
Inferior Parietal Cortex (IPC)



NH had mostly positive response amplitudes

UHL had negative responses at all BW and predictability levels

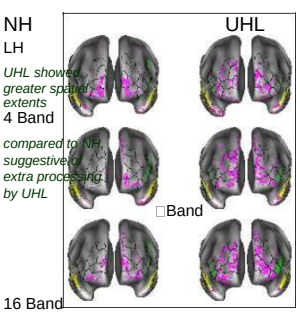
Inferior Frontal Cortex (IFC)



NH had an inverted U shape profile with maximal amplitudes for 8BW sentences at each predictability level

UHL had amplitudes that sequentially increased between 4 and 16 BW

Dorsolateral Prefrontal Cortex (DLPFC)



UHL showed greater spatial extents compared to NH, suggestive of extra processing by UHL bilaterally,

Conclusions

- In UHL, increased activity in IFC only occurred when sentences were highly intelligible whereas NH increased with less intelligible sentences
- In UHL, activity was reduced in key semantic processing areas (IFC, AG) compared to NH
- In UHL, increased DLPFC activity may assist to extract semantic information when speech is less intelligible

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- Emily Czerniejewski, MA
- Andrea Gregg, MA
- Meghan Hunt, MA
- Bernadette Rakszawski, AuD
- Janet Vance, AuD

Conclusions

- Imaging studies may also reveal differences not apparent in behavior (listeners have similar performance but use different brain networks)
- Future studies will address:
  - Brain networks used by UHL vs NH for speech in noise
  - Differences in brain networks for Congenital vs Later Onset UHL
  - Whether individual differences in brain networks relate to individual differences in speech understanding

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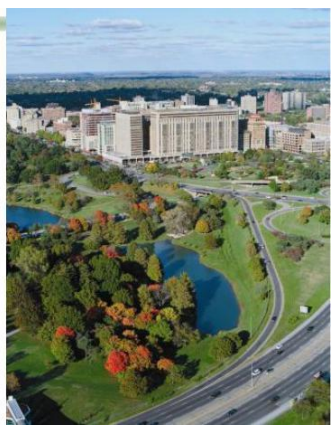


Acknowledgements

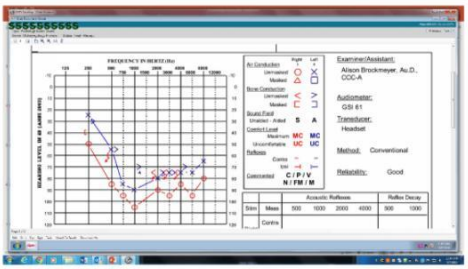
- NIH/National Institute on Deafness and Other Communication Disorders
  - R01 DC009010
- We thank our participants for their time and commitment to our studies
- We thank our colleagues

Asymmetric Hearing Loss and Cochlear Implantation: Results From Studies of Speech Recognition, Localization and Perceived Abilities

Jill B. Firszt, Ph.D.
Professor, Department of Otolaryngology
Director, Cochlear Implant Program
Washington University in St. Louis School of Medicine

G. Paul Moore Symposium
Gainesville, FL
February 5, 2019

CI Candidate, Circa 2018



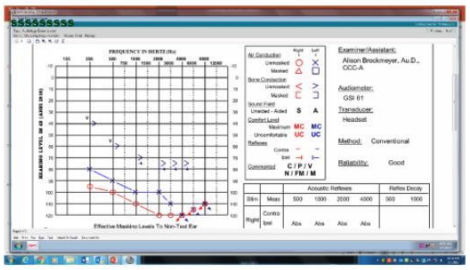
Overview of Presentation

- Asymmetric Hearing Loss with CI
  - Adults, Children
- Multi-center Clinical Trial for AHL
- AHL with CI and Substantial Contralateral Hearing
- Primary focus: Speech recognition in noise and Localization
- Variables: Length of deafness & Age at onset

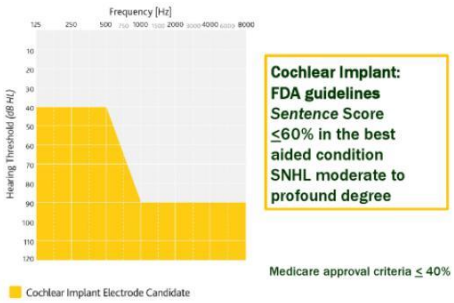
FDA Guidelines

	Advanced Bionics	Cochlear Corp.	Med-El
FDA	• Bilateral severe to profound SNHL • ≤ 50% on open-set sentences	• Bilateral moderate to profound SNHL • ≤ 50% sentence recognition in ear to be implanted & ≤ 60% in opposite ear	• Bilateral severe to profound SNHL • ≤ 40% on open-set sentences

CI Candidate, Circa 1998



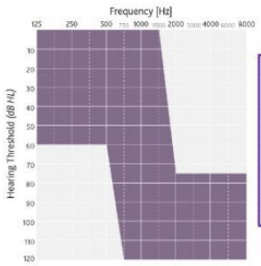
Cochlear Implant Candidacy



Cochlear Implant: FDA guidelines *Sentence* Score ≤60% in the best aided condition SNHL moderate to profound degree

Medicare approval criteria ≤ 40%

Electric Acoustic Candidacy



FDA Guidelines
Ear to be Implanted:
Aided *word* score ≤60%
Normal to moderate SNHL in low frequencies & sloping to severe-profound in high frequencies
***small difference in FDA guidelines for Cochlear and Med-El**
***not Medicare accepted criteria**

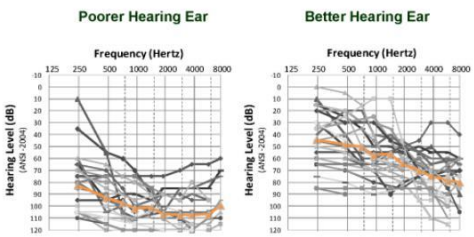
Group Demographics Postlingual Participants (n = 20)

- HA use
  - Better ear -- All wore a HA
  - Poor ear
    - 11/20 had never worn a HA
    - 9/20 had worn a HA for some time
      - Only 3/9 were wearing a HA at the time of implantation

Asymmetric Adults: Treatment with CIs

Early Study

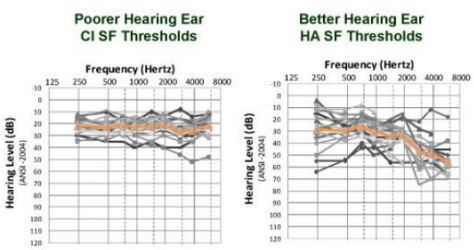
Unaided Hearing Thresholds



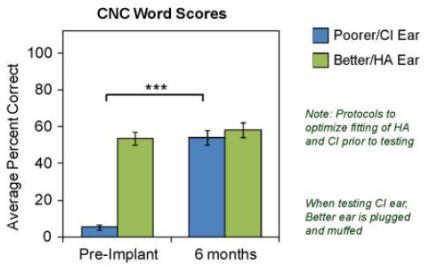
Study in Adults with Asymmetric Hearing Loss

- All have:
- One poorer ear that meets CI criteria, the poorer ear is implanted
- One better ear that uses a hearing aid (HA)
- N = 24
  - 20 = Postlingual
  - 4 = Prelingual

Implanted/Aided Sound-field Thresholds



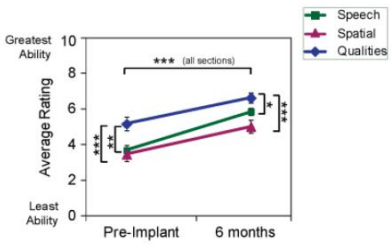
Speech Recognition-Postlingual (n=20)



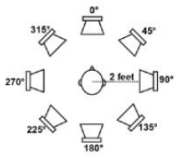
Note: Protocols to optimize fitting of HA and CI prior to testing

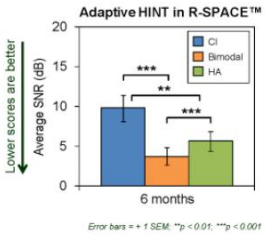
When testing CI ear, Better ear is plugged and muffed

SSQ (n=20)



Adaptive HINT in Restaurant Noise: R-Space (n=20)



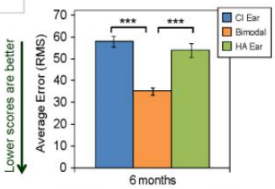


Mean NH Adults = -5 dB

Adult Asymmetric Hearing Loss Study

- How does <u>age at onset, length of deafness & use of a hearing aid</u> in the poorer ear affect outcomes with a CI?
  - Speech Recognition in Quiet
  - Speech Recognition in Noise
  - Localization

Localization (n=20)



Mean NH Adults = 3 degrees

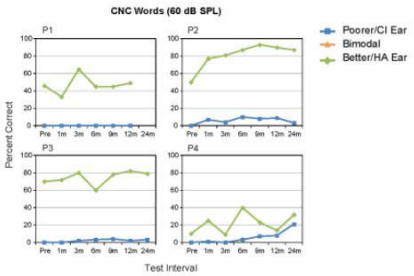
Individual Demographics Pre/perilingual Participants

	AAI	Etiology	AAO HL (P/B)	Age Began HA Use (P/B)	Duration SPHL CI Ear
P1	28	High Fever	3 / 3	Never / 3	25
P2	28	Unknown/EVA	birth / 23	Never / 28	23
P3	26	Meningitis	7m / 7m	Never / 1	25
P4	43	Unknown	birth / birth	3** / 3	40

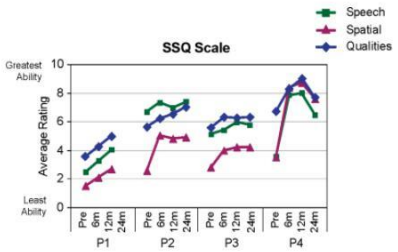
Firszt et al 2012, Ear Hear

*** Stopped wearing HA in poor ear 10 years prior to CI*

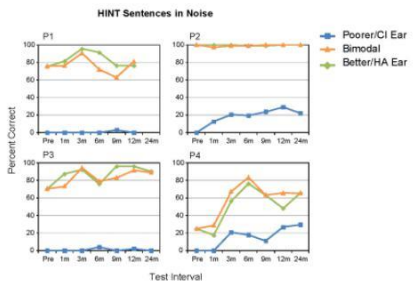
Pre-Lingual Results: CNC Words



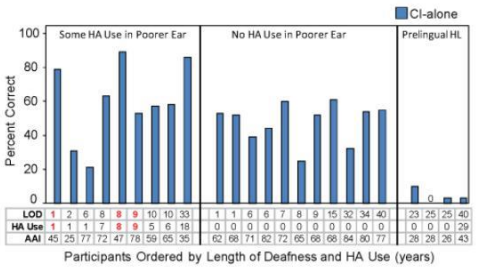
Pre-Lingual Results: SSQ



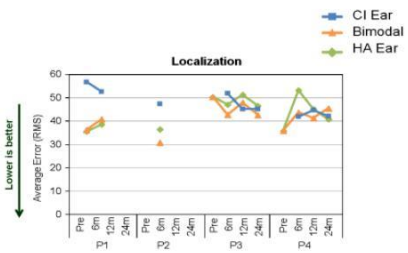
Pre-Lingual Results: HINT Sentences



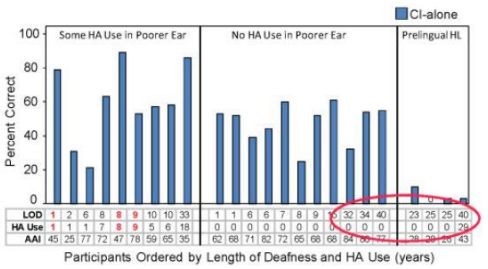
CNC Word Scores-CI Ear



Pre-Lingual Results: Localization



CNC Word Scores-CI Ear



CNC Word Scores Each Ear

Participants

- 5 children/teens with asymmetric hearing loss (ages 10-19 years)
- P1 - P3: more favorable hearing history with more CI experience
- P4 & P5: profound SNHL in the poorer ear from birth, were never aided in that ear, and have only 6 mos CI experience

Cadieux J, Firszt JB, Reeder RM. Cochlear implantation in non-traditional candidates: preliminary results in adolescents with asymmetric hearing loss. Otol Neurotol, 2013, 34:408-415.

Result

- All postlingual participants had open-set speech recognition in the CI ear, even those with long periods of deafness (32-40 yrs) and no HA use
- The prelingual participants had little speech recognition with similar lengths of deafness, but early age at onset

Demographic Information

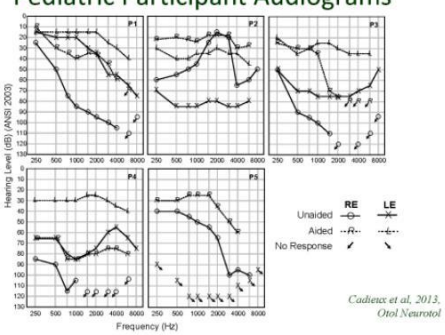
	Age (y)	Etiology	AAO SPHL (P)	Age Began HA Use (P/B)	AAI (P)	Length CI Use (y:m)
P1	11	EVA	8	4 / 4	8	3;2
P2	10	Unknown	Birth	2 / 2	5	5;2
P3	19	Unknown	4	4 / 4	14	5;4
P4	12	EVA	Birth	Never / 4	12	0;6
P5	15	Unknown	Birth	Never / 4	15	0;6

Cadieux et al, 2013, Otol Neurotol

Asymmetric Children: Treatment with CIs

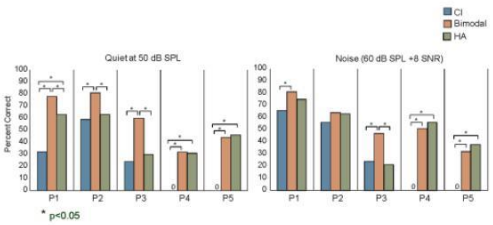
Pilot Study

Pediatric Participant Audiograms



Cadieux et al, 2013, Otol Neurotol

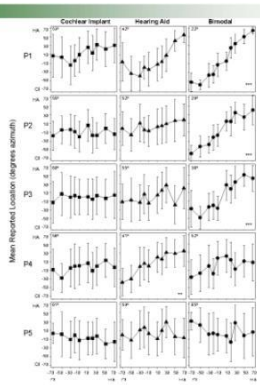
CNC Words in Quiet and Noise



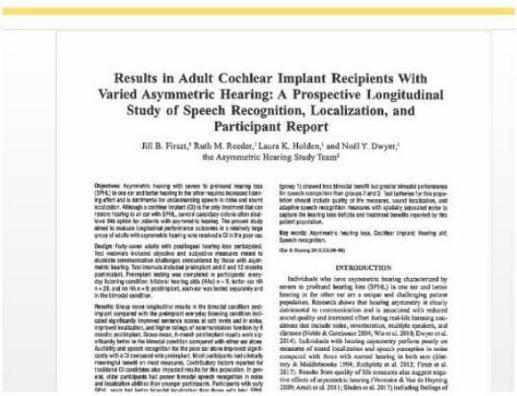
Cadieux et al, 2013, Otol Neurotol

Asymmetric Adults: Treatment with CIs

Recent Study



Cadieux et al, 2013, Otol Neurotol



Results in Adult Cochlear Implant Recipients With Varied Asymmetric Hearing: A Prospective Longitudinal Study of Speech Recognition, Localization, and Participant Report

Jill B. Firszt,[1] Ruth M. Reeder,[1] Laura K. Holden,[1] and Noël Y. Dwyer,[1] the Asymmetric Hearing Study Team[2]

INTRODUCTION

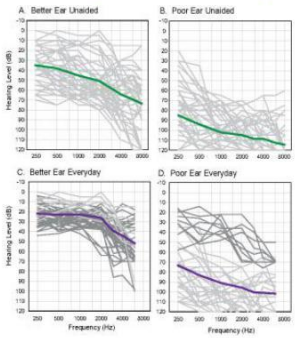
Result

- Some children with AHL show significant benefit from CI in the poorer ear
- Effects of congenital AHL requires further investigation
- Consider the implications of unilateral input, when this occurs early in life, and whether hearing abilities in the poor ear can be accessed later, or whether binaural abilities can be achieved

47 Participants

Demographic Information	Range	Mean	SD
Age at CI	25-83 yrs	63 yrs	15 yrs
Duration Poor Ear SPHL	1-49 yrs	15 yrs	14 yrs
Onset of Poor Ear SPHL	2-76 yrs	48 yrs	19 yrs
Pre-CI 3fPTA Poor Ear	67- NR dB HL	100 dB HL	16 dB HL
Pre-CI CNC Word Score Poor Ear	0-23%	4.0%	6.0%
Pre-CI 3fPTA Better Ear	0-70 dB HL	44 dB HL	20 dB HL
Pre-CI CNC Word Score Better Ear	26-100%	71%	21%

Hearing Profile for 47 Participants

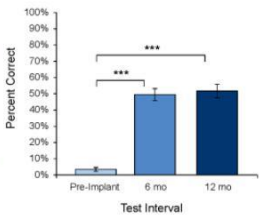


Pre-CI - Everyday Listening Condition
- 29 used a HA in better-ear
- 9 used bilateral HAs
- 9 used no HA in either ear

Firszt et al 2018, Ear Hear

Poor Ear Alone Results CNC Words

- Significant improvement pre-CI to 6-mos post-CI
- No additional improvement between 6 & 12 mos
- Same pattern of results for all speech recognition measures



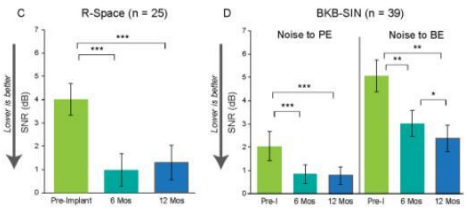
Firszt et al 2018, Ear Hear

*$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$
error bars = ±1 SEM

Test Conditions & Schedule

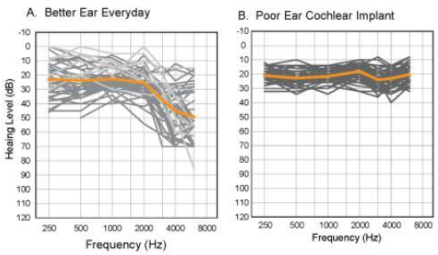
- Longitudinal study: Pre-CI, 3, 6, 9, 12 and 24 mo. Today showing 6 and 12 mo data.
- Pre-CI
  - 1) Better ear alone (HA, if worn)
  - 2) Poor ear alone (HA)
    - Better ear plugged/muffed or masked
  - 3) Everyday Listening Condition
- Post-CI:
  - 1) Better ear alone (HA, if worn)
  - 2) CI alone
    - Better ear plugged/muffed or masked
  - 3) Bimodal (Everyday Listening)

Everyday Listening Condition Pre-CI vs Post-CI Speech in Noise



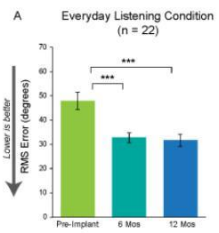
Firszt et al 2018, Ear Hear

6 Month Post-CI SF Threshold Levels



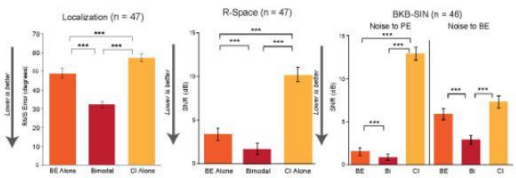
Firszt et al 2018, Ear Hear

Everyday Listening Condition Pre-CI vs Post-CI Localization



Firszt et al 2018, Ear Hear

6 Month Results for 3 Listening Conditions

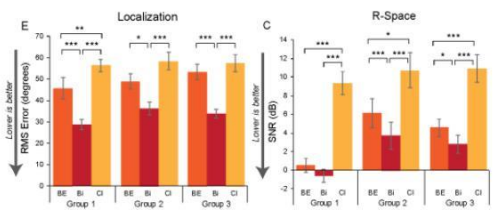


Firszt et al 2018, Ear Hear

Summary: Adult AHL Study (Overall)

- Poor ear alone performance improved with CI
- Performance in the Everyday Listening condition improved with CI
- Post-implant, the Bimodal condition was significantly better than either ear alone
- Patients reported improvements in speech understanding, spatial abilities and quality of sound with CI

Impact of Better Ear Hearing – 6 months



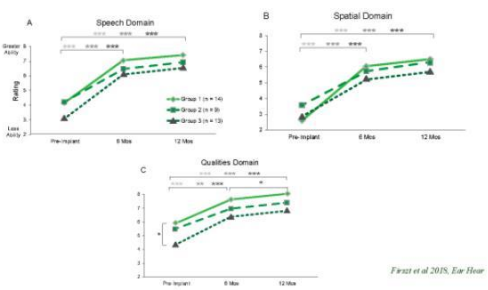
Three Groups: Grp 1 PTA < 40 dB HL, Grp 2 PTA of 41-55 dB HL, Grp 3 PTA of 56-70 dB HL

Firszt et al 2018, Ear Hear

Summary: Adult AHL Study (Three Groups)

- For speech recognition:
  - The groups with the least contralateral hearing (Groups 2 and 3) had the greatest bimodal benefit compared to the better ear alone
  - The group with the best contralateral hearing (Group 1) had the least room for improvement and the best better ear and bimodal scores
- For localization, all three hearing groups scored best bimodally compared to either ear alone

Impact of Better Ear Hearing



Firszt et al 2018, Ear Hear

Asymmetric Adults: Treatment with CIs

Ongoing Multi-Center Clinical Trial Study

U01 Clinical Trial on Asymmetric Hearing Loss

- Cochlear implantation of the poor ear is beneficial.
- Yet, asymmetric hearing loss is not an FDA approved indication.
- This means that many centers in the US will not consider implanting patients with asymmetric hearing loss.
- Our goal: Provide evidence that might influence FDA guidelines to include implantation of AHL patients
  - First step: Create a multi-center study protocol and seek FDA approval
  - Second step: Seek funding through NIH
  - Third step: Conduct the study

Study Design

- Multicenter, prospective, single-arm clinical trial
  - Repeated-measures analysis; patients act as own controls
  - Up to 40 participants will be implanted at four sites
    - WUSM, Midwest Ear (KC), NYU, and House Clinic (CA)
- Pre-implant Evaluation
  - Candidacy Evaluation & Pre-implant Study Testing
- Post-implant Evaluations
  - 3, 6, 9, & 12 months
- Participants will be in the study for approximately 18 months
- All 3 CI manufacturers are included

History: Asymmetric Hearing Loss Clinical Trial

- Submitted to FDA 12/5/14
  - Revised 1/4/15
  - Approved 1/7/15
- Submitted NIH/NIDCD (U01 Clinical Trial grant, Firszt, PI)
  - Awarded 12/22/16
  - Funding period 1/1/17 through 12/31/20 (4 years)
  - Registered on clinicaltrials.gov
  - WU IRB approval Feb 2017
- Submitted to Medicare 3/23/17
  - Approved 5/26/17 (must meet NCD 50.3, B2)
- Subcontracts, IRB approvals, and on-site training at all sites completed by Oct 2017

Inclusion Criteria

- 18 years of age or older
- English as the native language
- Desire for functional binaural hearing
- Previously tried HA treatment for asymmetric hearing loss (either a HA in the poor ear or a BiCROS) or willing to complete a trial
- Willingness to comply with all study requirements
- Ability to provide informed consent

Study Objectives

Primary Objective
- Obtain preliminary efficacy data in adults with AHL who receive a CI in the poor ear and maintain a hearing aid (HA) in the better hearing ear
  - Efficacy: Post-implant improvement in the poor ear with a CI compared to pre-implant with a HA

Secondary Objectives
- Obtain efficacy data related to bimodal hearing
  - Efficacy: Post-implant improvement (CI + HA) compared to the pre-implant best-aided condition
- Evaluate safety of CI in individuals with AHL
  - Number, type and degree of all adverse events
- Collect preliminary information related to test measures and methodology

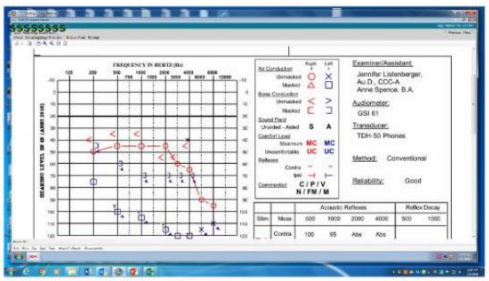
Audiometric Inclusion Criteria

- **Poor ear (ear to be implanted):**
  - PTA at .5, 1 & 2 kHz > 70 dB HL
  - Aided word recognition score (CNC words) at 60 dB SPL ≤ 30%
  - Duration of SPHL ≥ 6 months
  - Onset of hearing loss ≥ 6 years of age
- **Better ear:**
  - PTA at .5, 1, 2 & 4 kHz of <u>40 to 70 dB HL</u>
  - Currently using a HA
  - Aided word recognition score (CNC words) at 60 dB SPL <u>> 40%</u>
  - Stable hearing for the previous 1-year period
    - ✓ "Stable" is defined as thresholds that have not changed by more than 10 dB at 2 or more octave interval audiometric frequencies

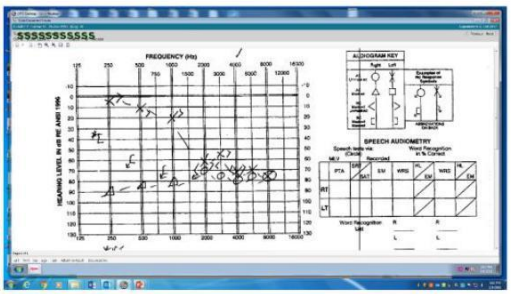
Exclusion Criteria

- Medical condition that contraindicates surgery
- Actively using an implantable device in poor ear
- Known cochlear malformation or obstruction that would preclude full insertion
- Hearing loss of neural or central origin
- Unrealistic expectations related to the benefits and limitations of CI
- Unwillingness or inability to comply with all investigational requirements

Sample Audiogram



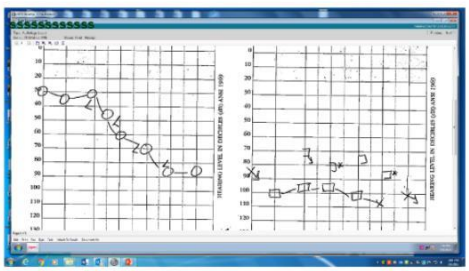
Sample Audiogram



Test Measures/Conditions

- Air and bone conduction
- FM tone sound field threshold levels
- CNC words
- AzBio Sentences
  - Quiet (50 and 60 dB SPL)
  - Noise (60 dB SPL +8 SNR)
- BKB-SIN – Speech Front
  - 1) Noise to Better Ear (S_0N_{BE})
  - 2) Noise to Poor Ear (S_0N_{PE})
- Localization (quiet & noise): Better ear and Bilateral
- Test Conditions: Better ear alone, Bilateral, Poor ear alone (limited)

Sample Audiogram



Localization

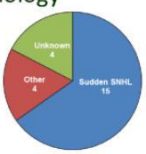
Questionnaires

- **CI Participant**
  - Patient Interview Form
  - Hearing Handicap Inventory (HHIE)
  - Health Utilities Index (HUI3)
  - Speech, Spatial and Qualities (SSQ) Questionnaire
  - Glasgow Benefit Inventory (GBI)
  - Satisfaction with Amplification in Daily Life (SADL)
- **Spouse/Significant Other will be asked to participate**
  - Communication Profile for the Hearing Impaired (CPHI)
  - The Hearing Impaired Impact – Significant Other Profile (HII-SOP)

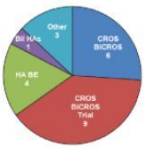
Participant Demographics (n = 23)

	Age at CI (yrs)	Length of HL PE (yrs)	Length of SPHL PE (yrs)	BE 3f PTA (dB HL)	PE 3f PTA (dB HL)
Mean (SD)	56.7 (10.9)	13.8 (13.2)	8.8 (10.8)	19.5 (12.3)	102.4 (18.0)
Range	32 – 76	<1 – 42	<1 – 35	0 – 38	67 – >120

Etiology



HA Use

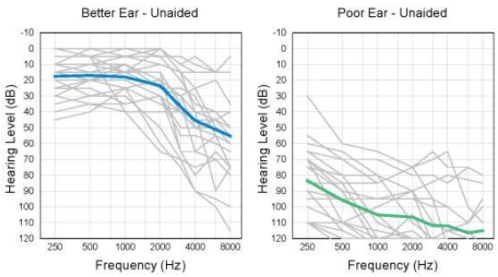


Update--Summary of Participants

- 25 participants enrolled
- 18 implanted

  WU – 9, MEI – 3, House -3, NYU – 3
- Post-implant intervals completed
  - 3 months = 13
  - 6 months = 11
  - 9 months = 7
  - 12 months = 2

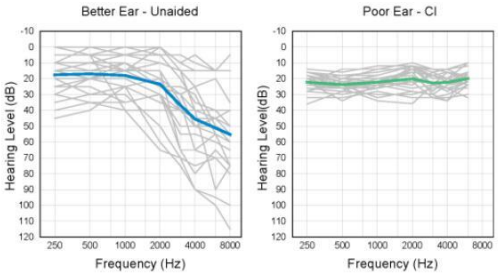
Hearing Thresholds Pre-Implant



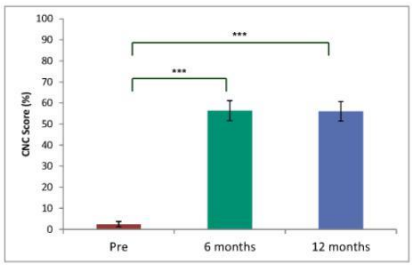
Asymmetric Adults: Treatment with CIs

Substantial Contralateral Hearing

CI SF Thresholds Post-Implant (6 mos)



Poor Ear - CNC Words: Group



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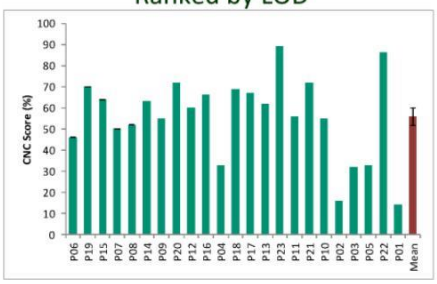
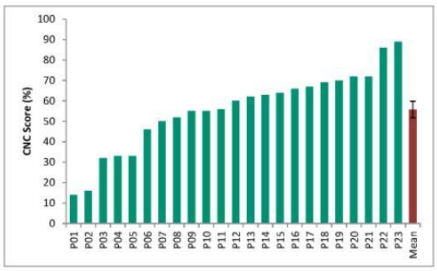
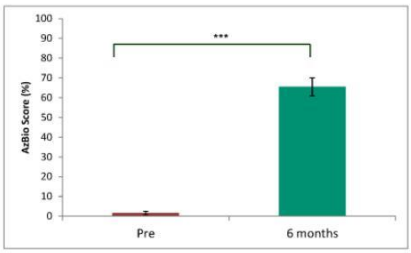
Poor Ear – CNC Words: Ranked by LOD



Poor Ear – CNC Words: Individual



Poor Ear – AzBio Sentences: Group



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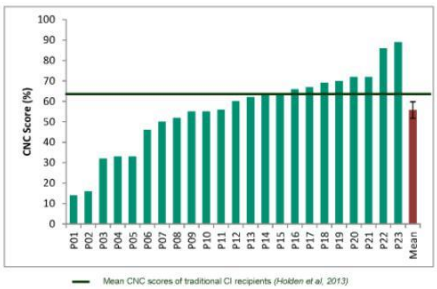
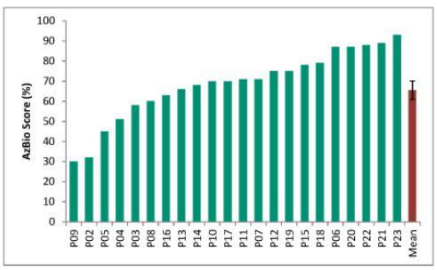
Poor Ear – CNC Words: Individual



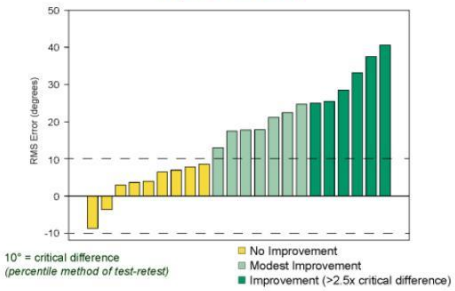
Poor Ear – AzBio Sentences: Individual



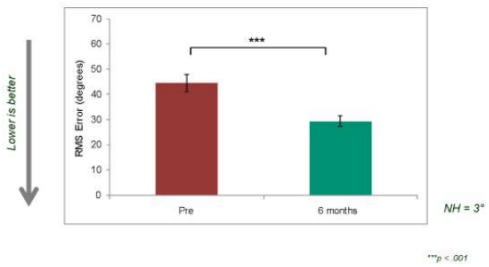
Localization Methods

- CNC words (100) presented randomly via loudspeaker array
- 15 speakers; 10 active, 5 inactive
- 140 degree arc, speakers 10 degrees apart
- Roved at 60 dB SPL (+/- 6 dB)
- Asked to identify speaker location

Pre to 6 mo Everyday Localization Improvement



Everyday Listening Condition Localization



HINT Sentences in Restaurant Noise R-Space™

- 8 loudspeakers surround the listener
- Sentences front
- Restaurant noise from all loudspeakers
- Adaptive measure: Noise at 60 dB SPL, speech level is varied
- Participants repeat the sentence
- SNR-50 score (SNR at which the patient scores 50% correct)

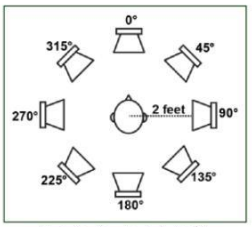
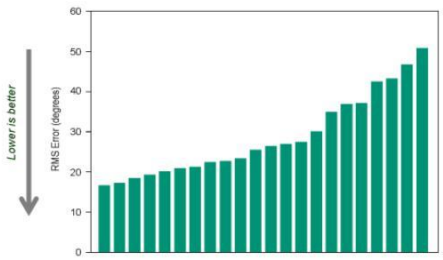
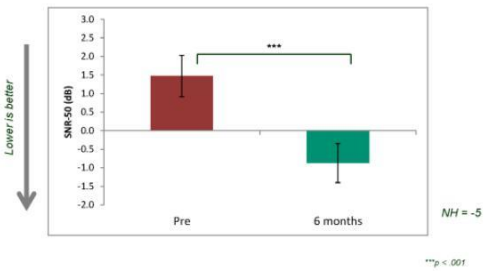


Illustration from Revit et al, 2002

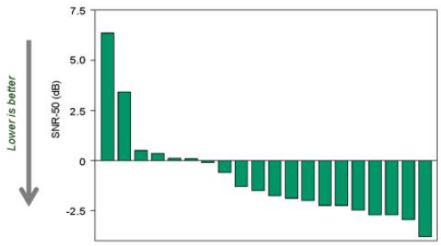
Everyday Listening Condition Individual Localization Scores (6mo)



Everyday Listening Condition - R-Space



Everyday Listening Condition Individual R-Space Scores (6mo)

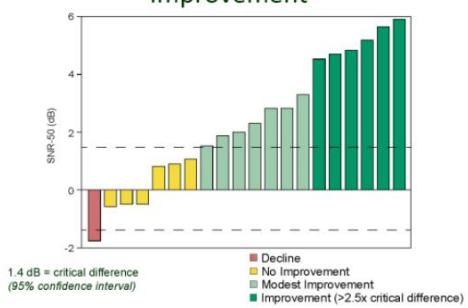


Relations between Variables and Performance

Preliminary analysis:

- Length of deafness, Age at implant, Better ear hearing thresholds, Poor ear hearing thresholds
- Outcomes for CI ear – CNC words at 6 months
- Outcomes in Bimodal Everyday condition - R space and Localization at 6 months
- No relations

Pre to 6 mo Everyday R-Space Improvement

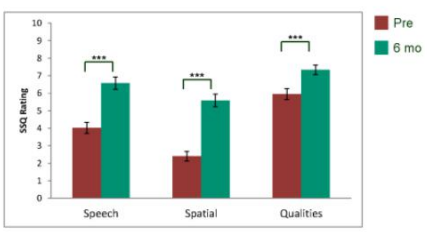


Counseling Recommendations

Based on results and discussions with participants, pre-implant counseling very important:

- Improvements may be realized in some but not all listening environments
- Sound quality from CI will differ from acoustic hearing; may need additional time to adjust
- Practice with CI alone is essential to maximize CI benefit (direct connect to CI, wireless accessories, or better ear plugged)

Speech, Spatial, Qualities of Hearing Scale (SSQ)



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Patient Selection Recommendations

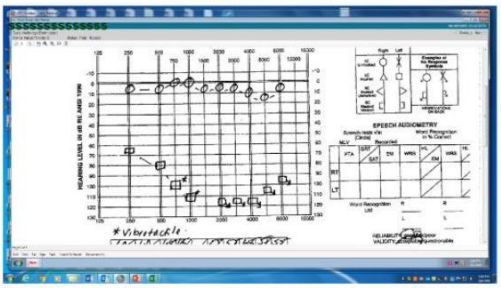
- Hearing history
  - Age at onset (later onset vs congenital)
  - Cochlear anatomy
  - Previous trials with other hearing devices
- Communication needs
  - Work environment
  - Family and social environment
- Motivation and realistic expectations
- Commitment to rehab process

Careful selection is needed to avoid non-use in the future

Programming Comments

- Protocol—similar to traditional CI users
  - —Plug the better ear, especially for balancing and Ts
- Loudness—difficulty determining volume
  - —Set CI volume with BE plugged, may be too loud with BE + CI. When evaluating CI alone and BE ear plugged, CI volume may be too soft
- Subjective feedback—some have more difficulty giving feedback re programming changes, small differences not as apparent (better ear dominant)
- Acclimatization—can take longer to adjust, longer to reach maximum performance

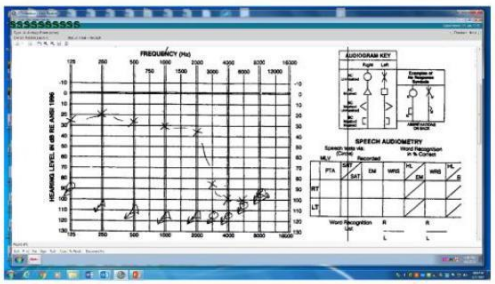
Single Sided Deafness



Overall Conclusions

- Group data identify significant benefit for speech recognition and localization with CI to the poor ear
- Substantial individual variability - unexplained
  - Even when we reduce Length of Deafness to < 10 years, results vary, some perform lower than expected
- Possibilities for the variability
  - In CI ear alone: peripheral?
  - In Bimodal condition: discrepancy in frequency and loudness between CI and NH ear? Interaural pitch and loudness mismatches
  - Cognitive? Interference using two very different signals together?

SSD VA Study



Overall Conclusions

- Quality differences between ears limit reliance on CI (Traditional CI users rely on their CI side)
- Better Ear remains dominant and may require time to assimilate the CI ear with the acoustic ear
- Practice with the CI ear alone is important
- Most patients have adjusted well and perceive some level of benefit
- More work needed: understand the variability, predict individual outcomes, eventually refine clinical protocols

Future Considerations

- The auditory system is designed to be binaural. We should treat the system by treating each ear
- We should consider treatment for each ear be it acoustic or electric
- CI Candidacy requirements should be modified to allow treatment to each ear rather than requiring bilateral hearing loss for cochlear implantation

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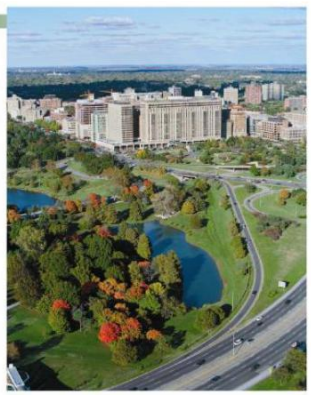

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