Hear Well or Hearsay?
Do Modern Wireless Technologies Improve Hearing Performance for CI Users?

Jace Wolfe, Ph.D.
Road Map

• Review of Auditory Brain Development

• Promoting Auditory Brain Development of Children with Cochlear Implants with the Use of Remote Mic Technology
Auditory Cortex
Talking Point: Auditory signals from the peripheral system eventually arrive at the **primary auditory cortex**, for everyone.
Primary auditory cortex

Primary Auditory Cortex

Secondary Auditory Cortex
Talking Point: Secondary auditory cortex serves as the **launching pad** for sound to be integrated with the rest of the brain.

Secondary auditory cortex possesses pluripotent neurons, which are capable of processing multi-modal stimuli.
Arcuate Fasciculus

Intrahemispheric Fiber Tracts

Subhash Bhatnagar
Cortical Layers

Talking Point: The infragranular layers of the cortex are the output circuits of the cortex!
Primary Auditory Cortex
Arcuate Fasciculus
Higher-order cognitive functions are mediated by neural networks comprised of neurons communicating across several locations of the brain.

Kral et al., 2016
Lancet Neurology
Fundamentally, everything that comes into our minds reduces to **patterns of neural activities.**

-- Kai-How Farh
Fundamentally, everything that comes into our minds reduces to patterns of neural activity.
Exploring the World Through Listening
Landmark Studies of Auditory Brain Development
Green et al., 2005

- Measured PET scan while post-lingually deafened adult implant users listened to a story.
- Showed activation of right and left primary and secondary auditory areas.

Talking Point: When the brain has early access to intelligible speech, we see bilateral activation of the primary and secondary auditory cortex.
Nishimura et al., 1999

Horizontal sections relative to the intercommissural plane:

- 10 mm below
- 4 mm above
- 8 mm above

Blue: Areas activated by visual stimuli (meaningless hand movement)

Yellow: Areas activated by sign language

Green: Areas activated by spoken language (CI: Left Ear)

Cross-modal plasticity
• Why does cross-modal plasticity occur in secondary auditory cortical areas in the absence of sound stimulation?
Kral et al., 2000

- Used microelectrodes to record local cortical auditory potentials in NH and congenitally deaf cats with and without cochlear implants
Talking Point: Early auditory deprivation of acoustically accessible speech results in a functional decoupling of primary and secondary auditory cortex.

The infragranular layers of the cortex are the output circuits of the cortex!
Primary Auditory Cortex
Arcuate Fasciculus

Superior longitudinal fasciculus

Arcuate fasciculus

Uncinate fasciculus

Inferior longitudinal fasciculus

STOP
Fundamentally, everything that comes into our minds reduces to **patterns of neural activities.**

-- Kai-How Farh
The CAEP in congenitally deafened cats is permanently altered if a CI is not provided by 5 months of age → Critical period

The absence of activity in infragranular layers can be interpreted as a de-coupling of primary auditory cortex from secondary auditory cortex.

The secondary auditory cortex becomes more available to other modalities.
The Listening Brain

**Kittens**

Kral et al., 2000

**Kids**

Sharma et al (2002), Ear and Hearing
The Listening Brain

• Childhood hearing loss is a neurodevelopmental emergency!
  – Without early access to consistent, intelligible speech, the auditory centers of the brain will not optimally develop and allow for integration of auditory information with other sensory systems.

• How much exposure is necessary?
  – Risley and Hart: 46 million words by 4 years of age
A Noisy World!

The SNR in these environments is typically -5 to +5 dB

- **Living Room:**
  - 37 dB A (with A.C. = 52 dBA)

- **Classroom Lecture:**
  - 61 dBA

- **Small Groups:**
  - 66 dBA

- **School Assembly:**
  - 76 dBA

- **School Cafeteria:**
  - 83 dBA

- **OKC Thunder Basketball:**
  - 100 dBA
Speech Recognition without Remote Mic HAT

Kids with hearing loss need a +15 dB SNR

Wolfe et al., 2013
• We must provide infants and young children with technology that optimizes the audibility and intelligibility of speech across a variety of listening environments.
Good News!
Children with Hearing Loss vs. “Gold Standard”

Wolfe et al., 2013
Evaluation of Dynamic FM with Cochlear Implants

Wolfe et al. (2009)
Speech Recognition in Noise Results – Advanced Bionics

Wolfe et al. (2009)
• What about digital adaptive RF?
Results

Advanced Bionics Recipients (n = 16)

Wolfe et al., 2013, JAAA

Adults with normal hearing score 95% correct here!
Why Remote Technology?

• Because most children with hearing loss can’t hear in many realistic situations without it

• Because performance improves dramatically with it
  – By as much as 60-70% points
  – And persons with hearing loss may hear as well as persons with normal hearing in some situations
For Whom?
LENA Data Logging in Infants/Toddlers

- Car seat (70 mph): -10 dB SNR
- Bus: -10 dB SNR
- Stroller: -8 dB SNR
- Shopping cart: -6 dB SNR
- Car seat (30 mph): -5 dB SNR
- Wind Noise: -3 to -10 dB SNR

Conservative Take: Use in situations in which the child has no chance to hear without remote mic use
Remote Mic in Quiet

Study completed in classroom with 44 dBA ambient noise and .6 sec RT60

Speech Recognition is
- Better with CV ON than OFF
- Better with Roger ON than OFF
- Best with CV + Roger

Benefit also seen in “Quiet” (RMANOVA)
Hearts for Hearing Experience
Digital Radio Systems

• Multiple studies with digital radio remote microphone systems
  – Formally evaluated over 150 adult and pediatric subjects
  – Not one subject has complained of noise/interference from one of these systems
  – Digital “all or nothing”
**Dynamic Digital RF vs. Digital Audio Streaming**

Wolfe et al., 2015
Am J Audiology

Hearing Aids Users (Moderately Severe/Severe Hearing Loss)  
\[ n = 17 \]
• Nucleus 6 and Wireless Technology
MiniMic, MiniMic 2+, & Roger

Jace Wolfe, Ph.D.
Study Objective

- Evaluate the effect of microphone technology within the remote microphone accessory
  - Omni-directional vs. Dual-Mic Directional vs. Dual-Mic Adaptive Gain

Mini Mic  
Mini Mic 2+  
Roger Touchscreen  
Roger Pen  

Phonak Roger
Equipment Setup

- 24 ft, 8 in
- 25 ft, 3 in
- 17 ft
- 15 ft, 6 in
- 6 in
- 8 ft, 6 in
Cochlear Implant Only Users

![Graph showing % Correct AzBio Sentences for different test conditions and microphone types.]

- **Test Condition**: Quiet, 50 dBA, 55 dBA, 60 dBA, 65 dBA, 70 dBA, 75 dBA, 80 dBA
- **Microphone Types**: No Remote Mic, Mini Mic, Mini Mic 2+, Roger

n = 15
Autosensitivity Control (ASC)
Nucleus 6 Signal Pathway

Attenuates noise at N6 microphone
Enhances favorable SNR at remote mic

Gain increases are being compressed by ASC and/or AGC
Hearing Aid Only Users

Hearing Aid Alone  | HA + MiniMic  | HA + MultMic (MiniMic2)  | HA + Roger

Quiet  | 60  | 65  | 70  | 75  | 80

n=14
Other Considerations for Children

• Automatic activation

• Multiple children in need of remote microphone use

• Compatibility with pediatric hearing aids for bimodal users
• One more thing for CI & Wireless...
# CI Settings

<table>
<thead>
<tr>
<th>Model</th>
<th>Recommended CI module setting</th>
<th>Recommended EasyGain</th>
<th>AutoConnect</th>
</tr>
</thead>
<tbody>
<tr>
<td>MED-EL OPUS 2 and ML CI S (automatic setting)</td>
<td>Default</td>
<td>0 dB</td>
<td>ON</td>
</tr>
<tr>
<td>MED-EL OPUS 2 (manual setting)</td>
<td>Setting 2</td>
<td>0 dB</td>
<td>OFF</td>
</tr>
<tr>
<td>AB Naida CI Q70 with ComPilot and Roger X</td>
<td>Setting 3</td>
<td>0 dB</td>
<td>OFF</td>
</tr>
<tr>
<td>AB Harmony / Auria</td>
<td>Setting 4 or Setting 1</td>
<td>+8dB or 0dB</td>
<td>OFF</td>
</tr>
<tr>
<td>MicroLink CI S (manual setting)</td>
<td>Setting 5</td>
<td>0 dB</td>
<td>OFF</td>
</tr>
<tr>
<td>Cochlear Nucleus 6 / 5</td>
<td>Setting 9</td>
<td>0 dB</td>
<td>OFF</td>
</tr>
</tbody>
</table>
It’s all about the brain ... and technology!

• Great outcomes are possible when we do what it takes.
• Digital adaptive remote microphone technology is essential for children of all ages.

• Shoot for the moon!
Thank you for your attention!!!

www.heartsforhearing.org