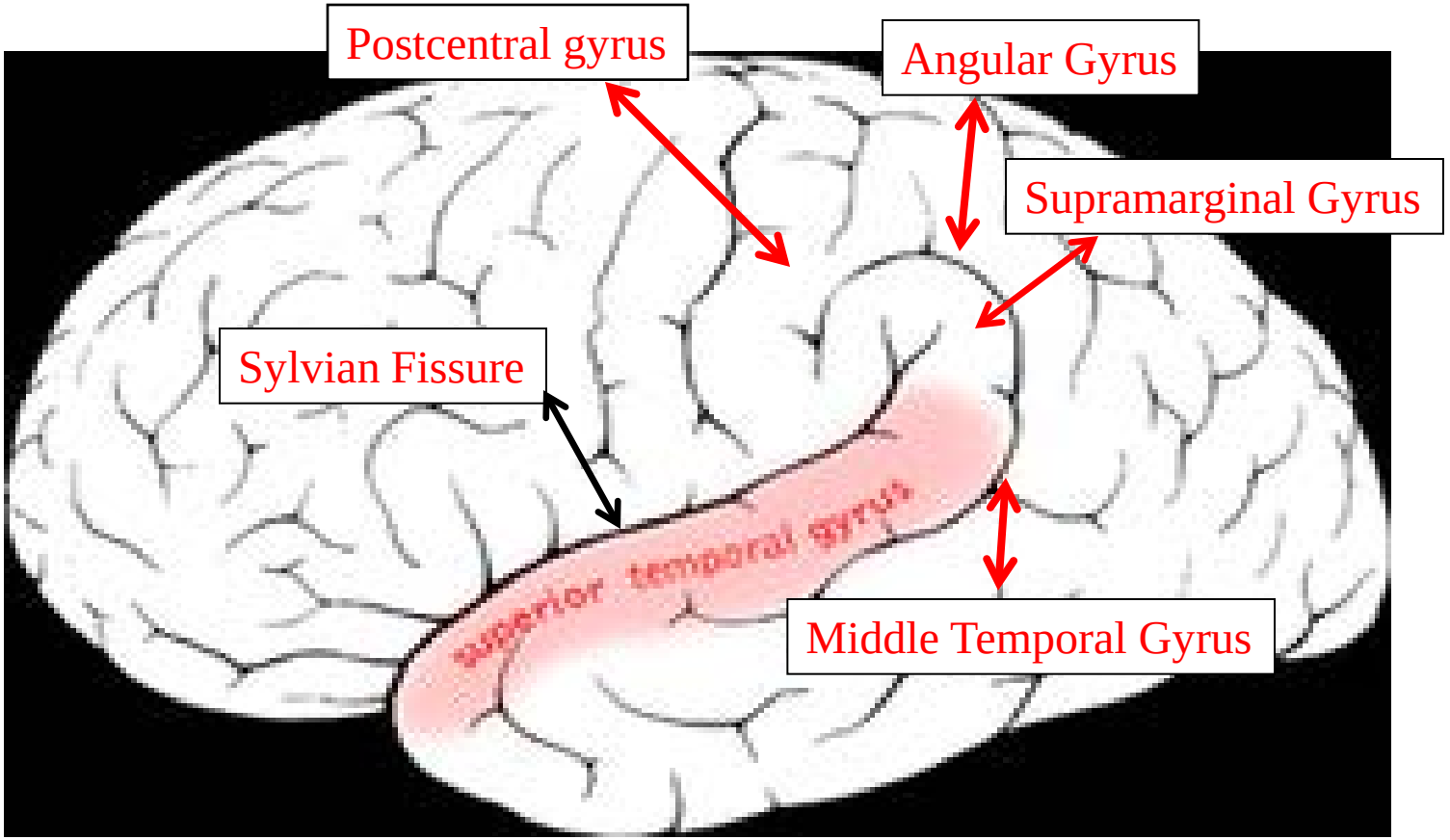
Hear Well or Hearsay? Do Modern Wireless Technologies Improve Hearing Performance for CI Users?

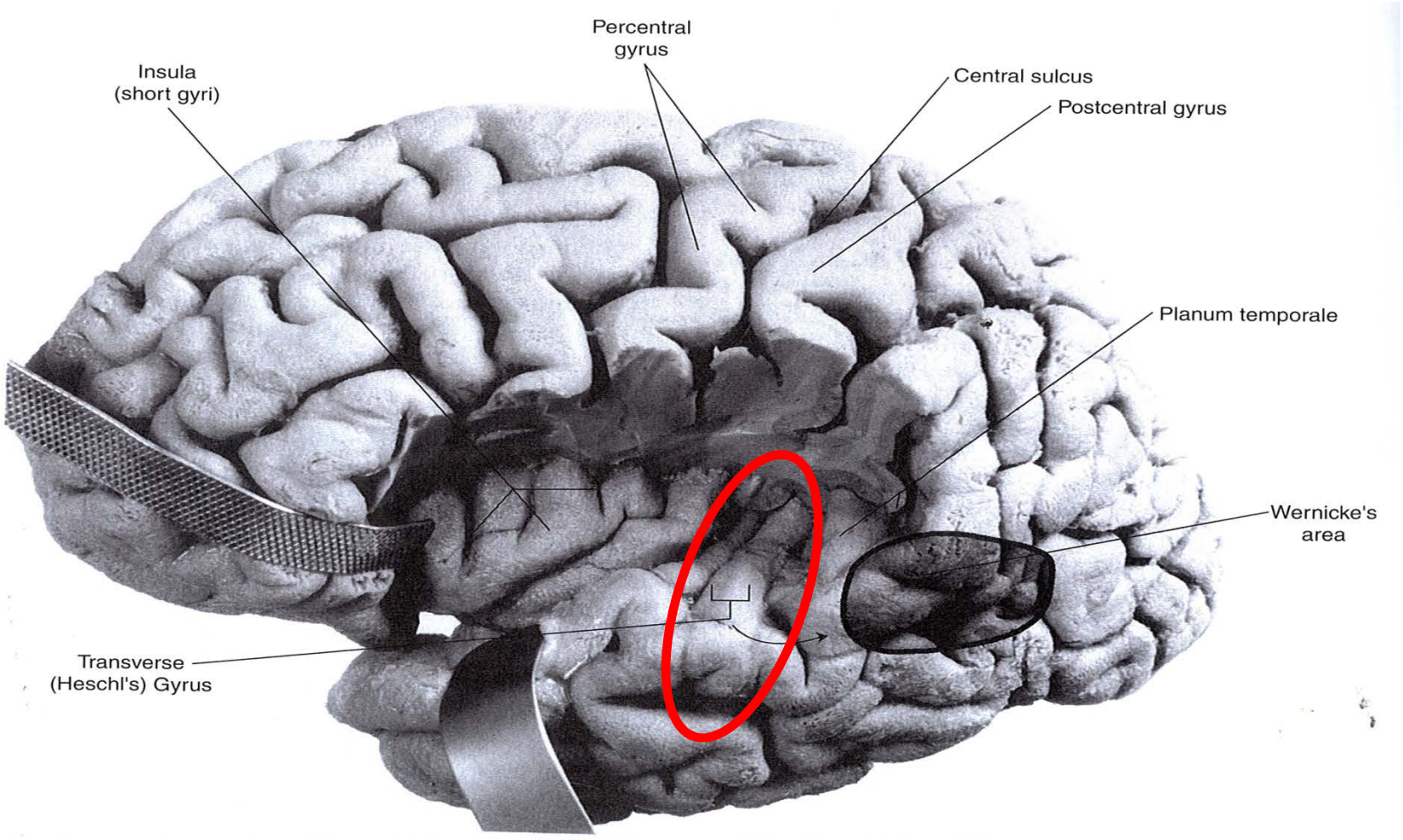
Jace Wolfe, Ph.D.

Road Map

- Review of Auditory Brain Development
- Promoting Auditory Brain Development of Children with Cochlear Implants with the Use of Remote Mic Technology

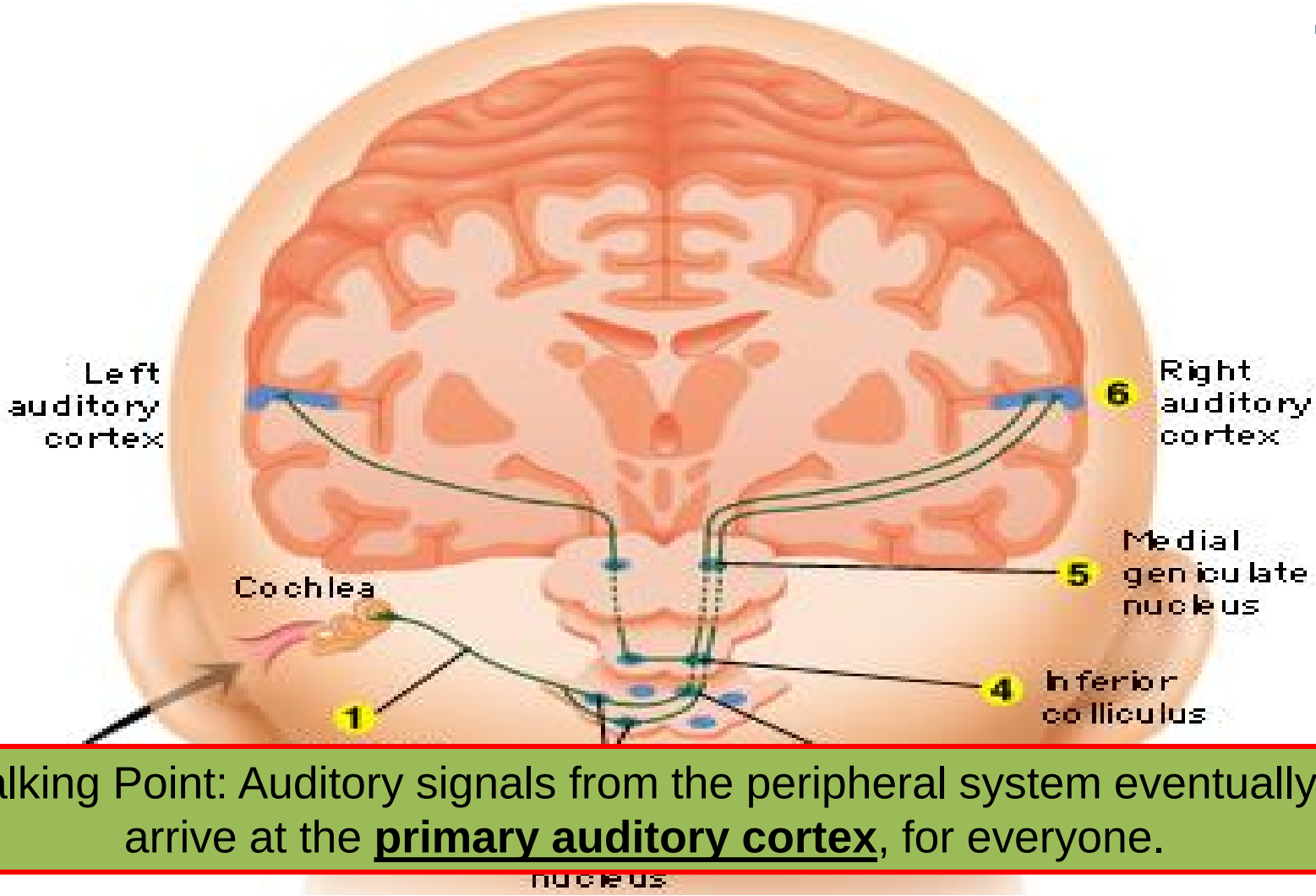

Postcentral gyrus
Angular Gyrus
Supramarginal Gyrus
Sylvian Fissure
superior temporal gyrus
Middle Temporal Gyrus

Auditory Cortex



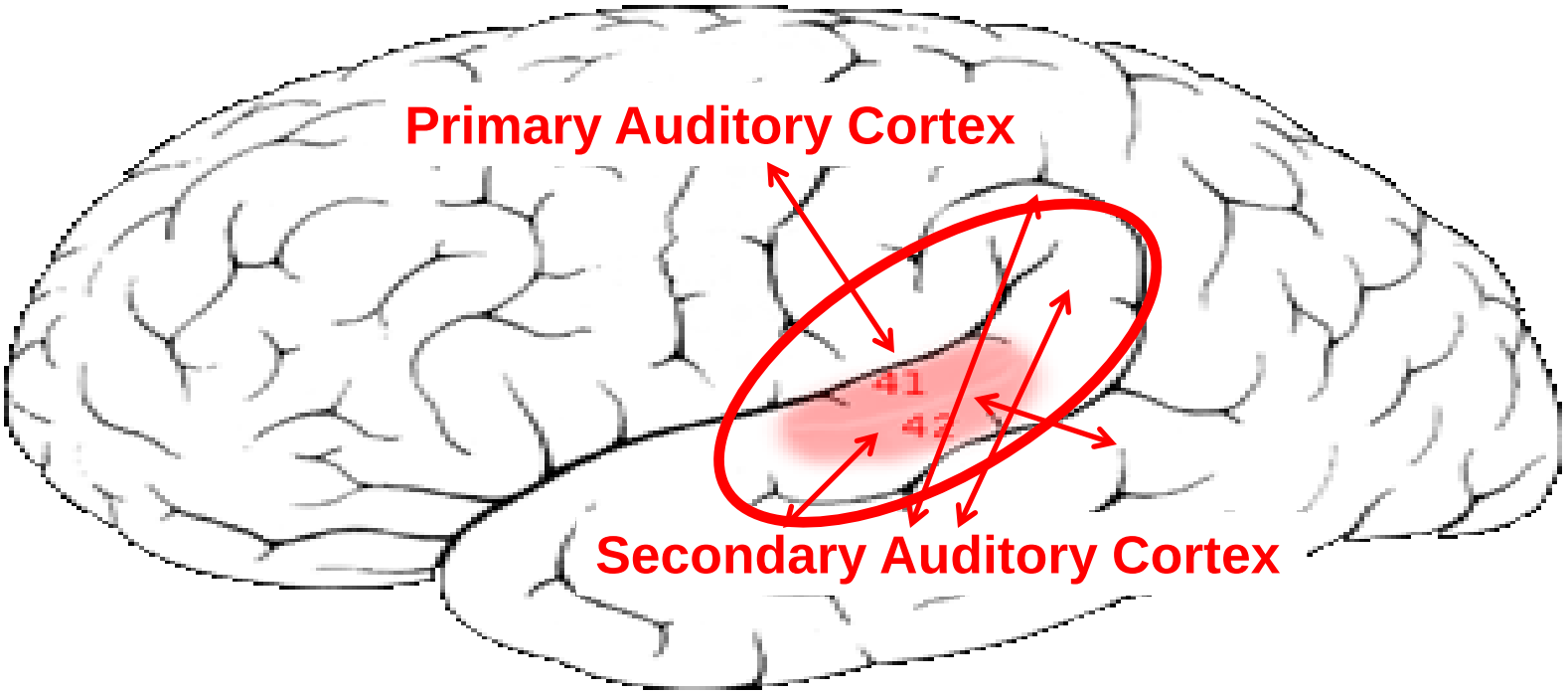
Subhash Bhatnagar

Auditory Nervous System



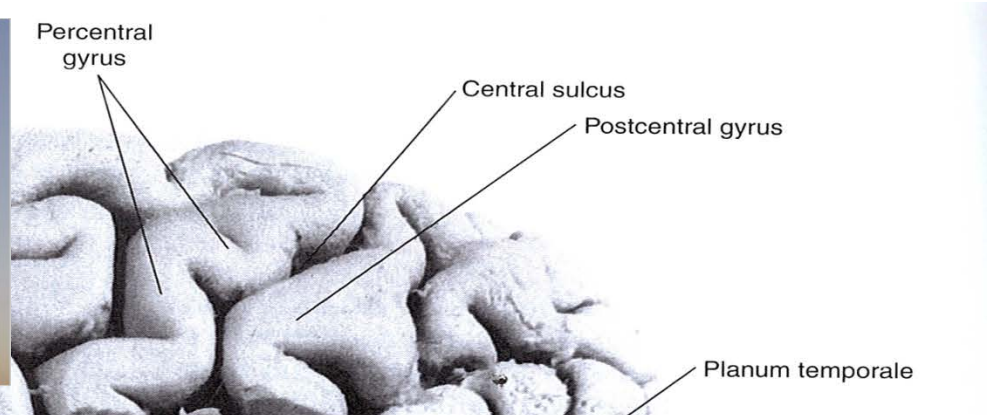
Talking Point: Auditory signals from the peripheral system eventually arrive at the **primary auditory cortex**, for everyone.

Primary auditory cortex



Auditory Cortex

Secondary Auditory Area = Launching Pad

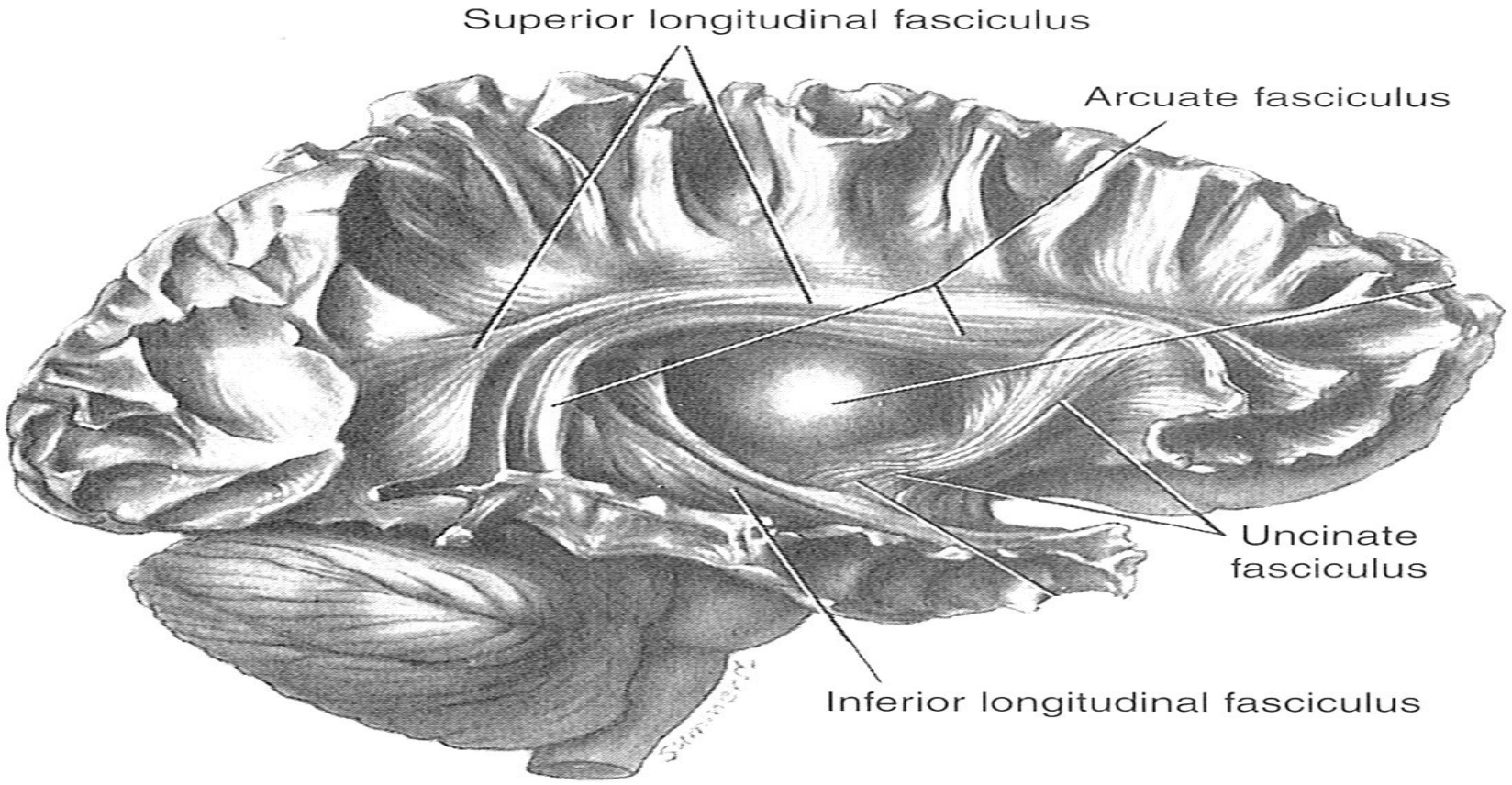


Secondary auditory cortex possesses pluripotent neurons, which are capable of processing multi-modal stimuli

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

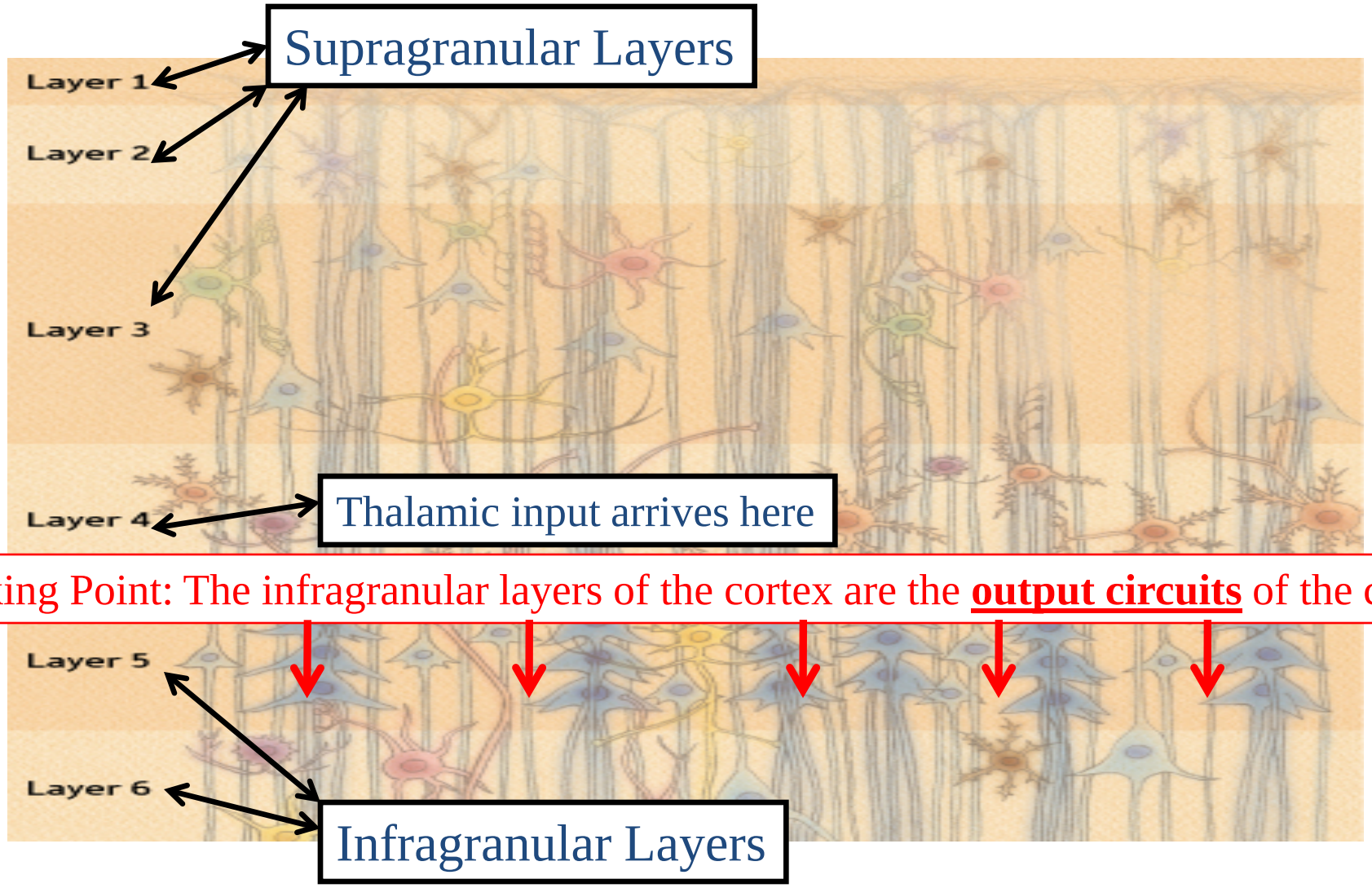
Arcuate Fasciculus

Intrahemispheric Fiber Tracts



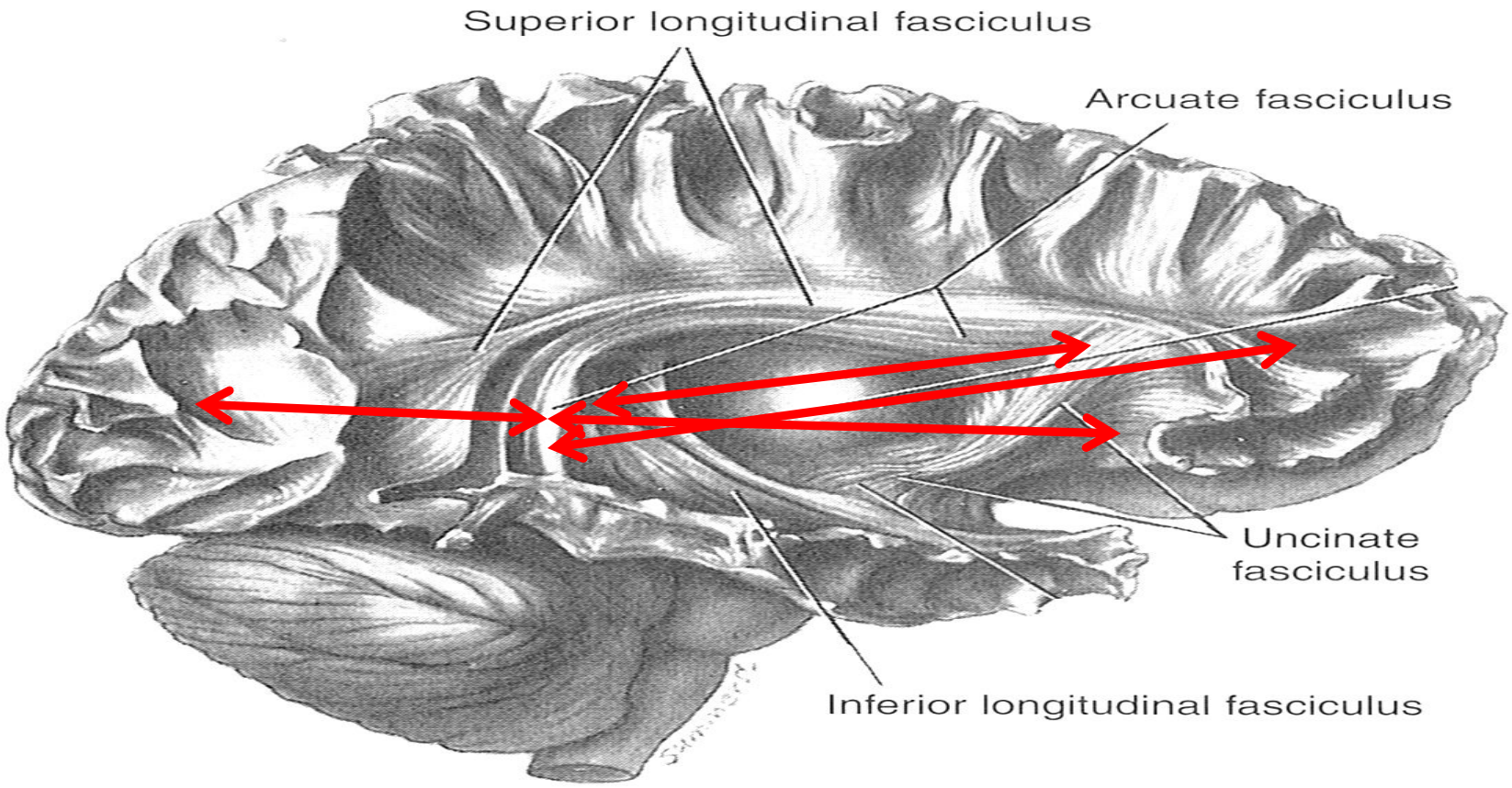
Subhash Bhatnagar

Cortical Layers



Primary Auditory Cortex

Arcuate Fasciculus



Connectome

Higher-order cognitive functions are mediated by neural networks comprised of neurons communicating across several locations of the brain

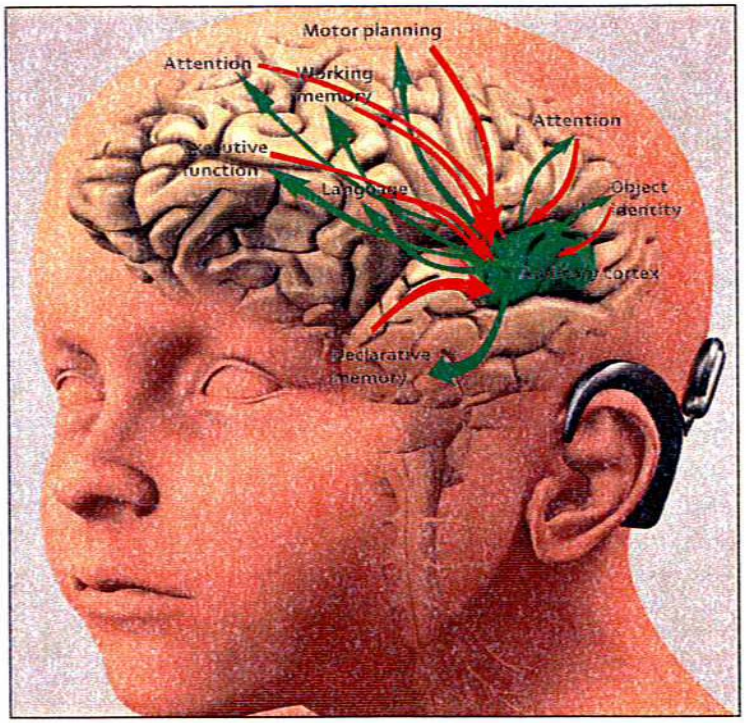
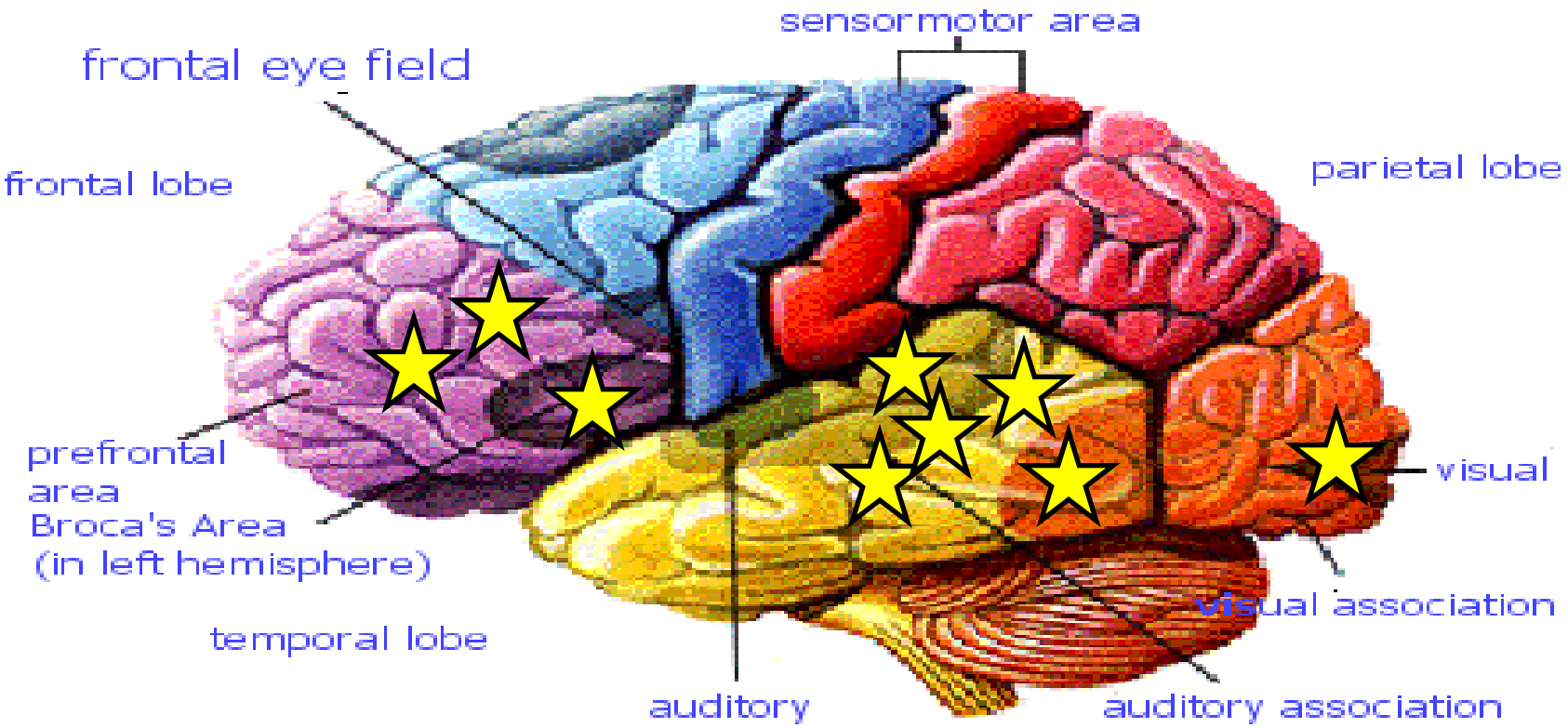


Figure 4: **Auditory component of the human brain's connectome**
Illustration of interactions of the human auditory cortex with higher order areas involved in cognitive functions. Locations of the functions on the brain are schematic. Bottom-up connections are shown in green, top-down in red. The thickness of the lines does not reflect connection strength. The speech processor and the active cortex are shown on the same side of the brain for illustration purposes.

Kral et al., 2016
Lancet Neurology

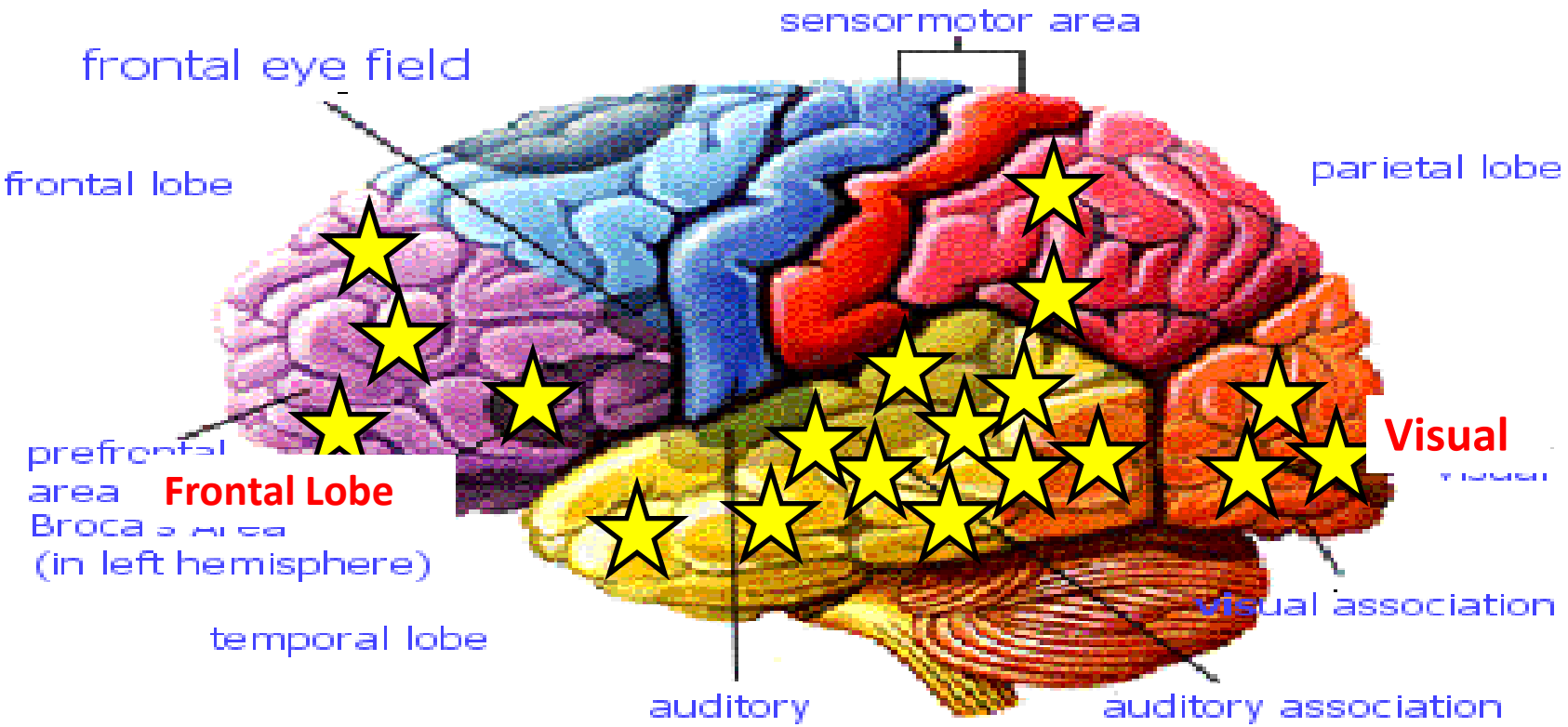
The Listening Brain
Intra-hemispheric Transfer



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

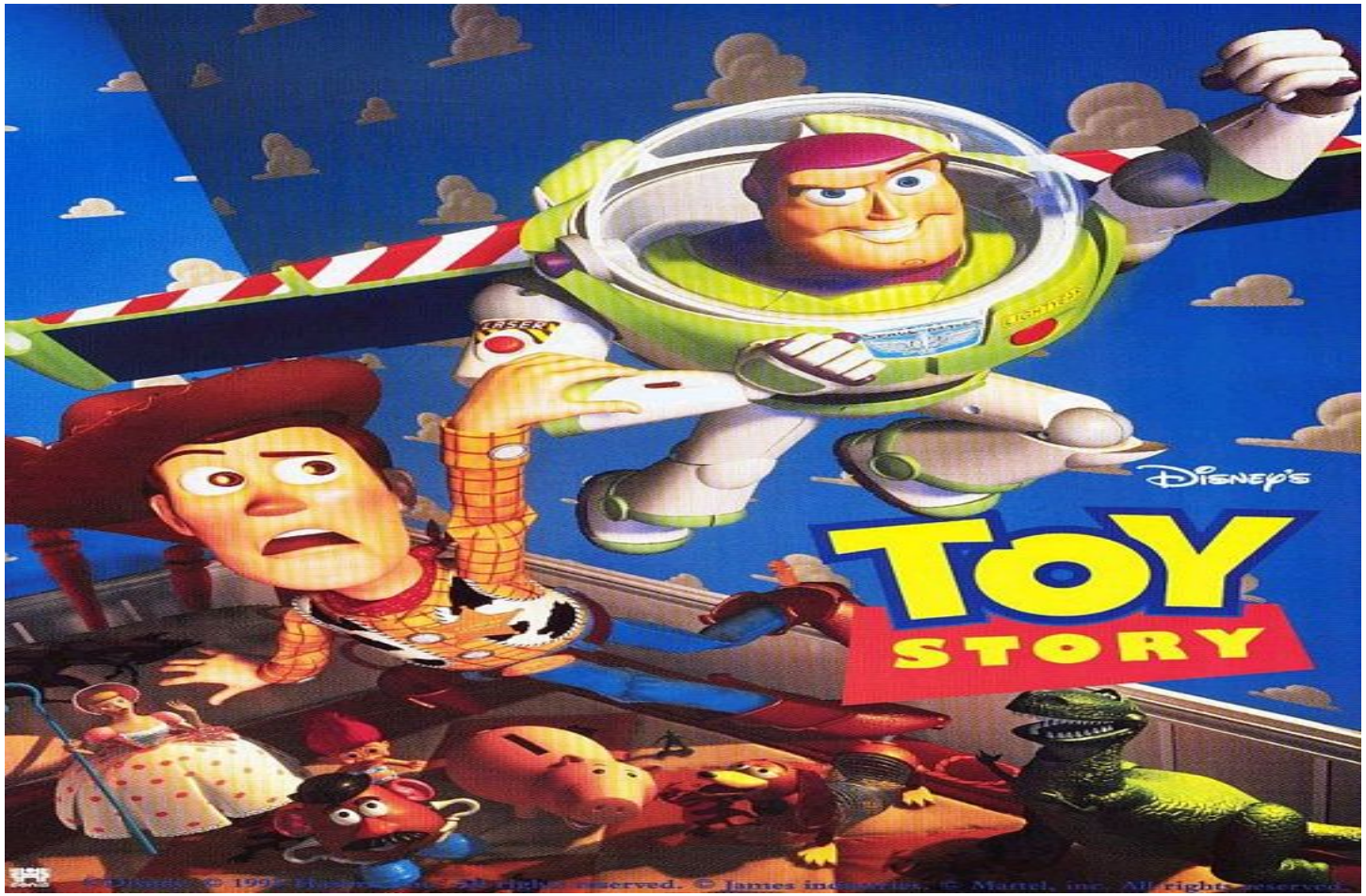
-- Kai-How Farh

The Learning Brain



Fundamentally, everything that comes into our minds reduces to <u>patterns</u> of <u>neural activity</u>.

Exploring the World Through Listening

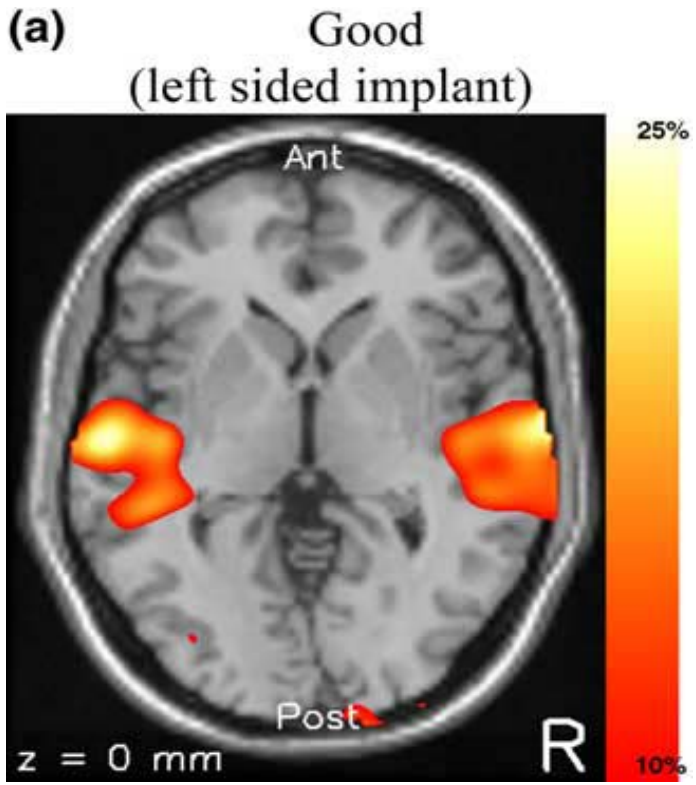


Exploring the World Through Listening

- **Landmark Studies of Auditory Brain Development**

Green et al., 2005

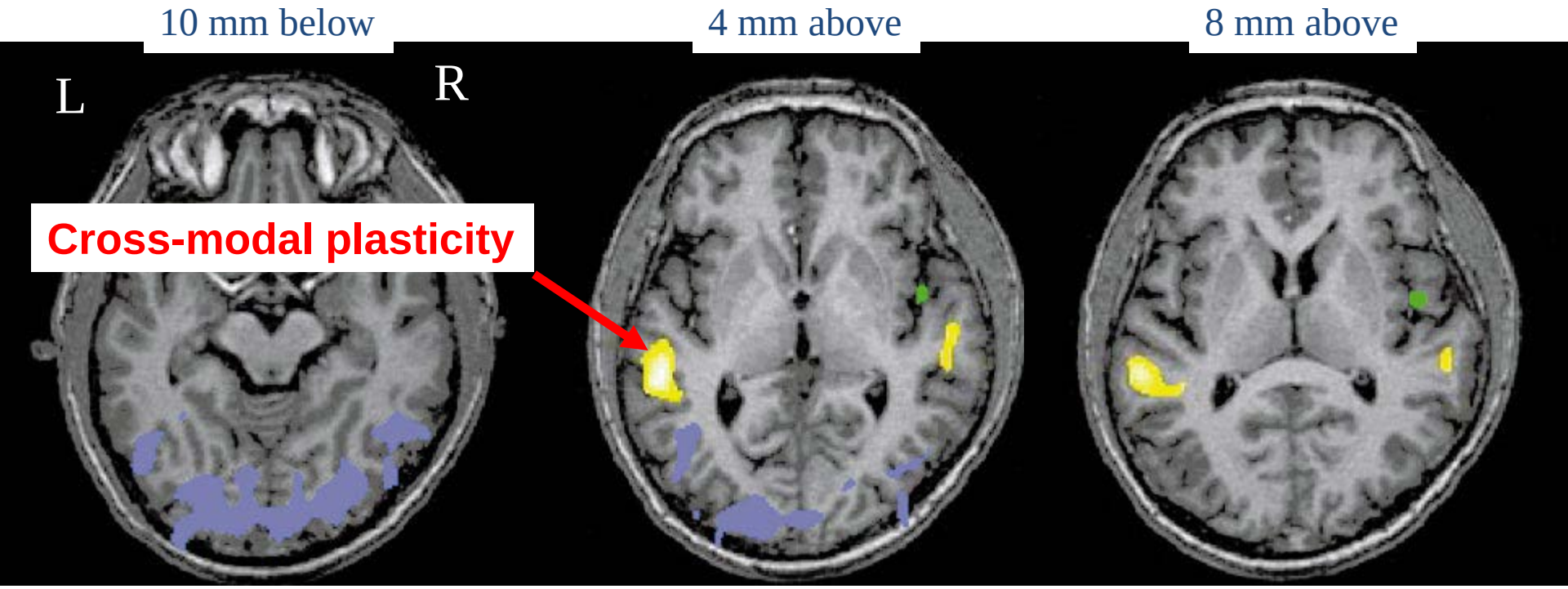
- Measured PET scan while post-lingually deafened adult implant users listened to a story.
- Showed activation of right and left primary and secondary auditory areas.



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:



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

Yellow: Areas activated by sign language

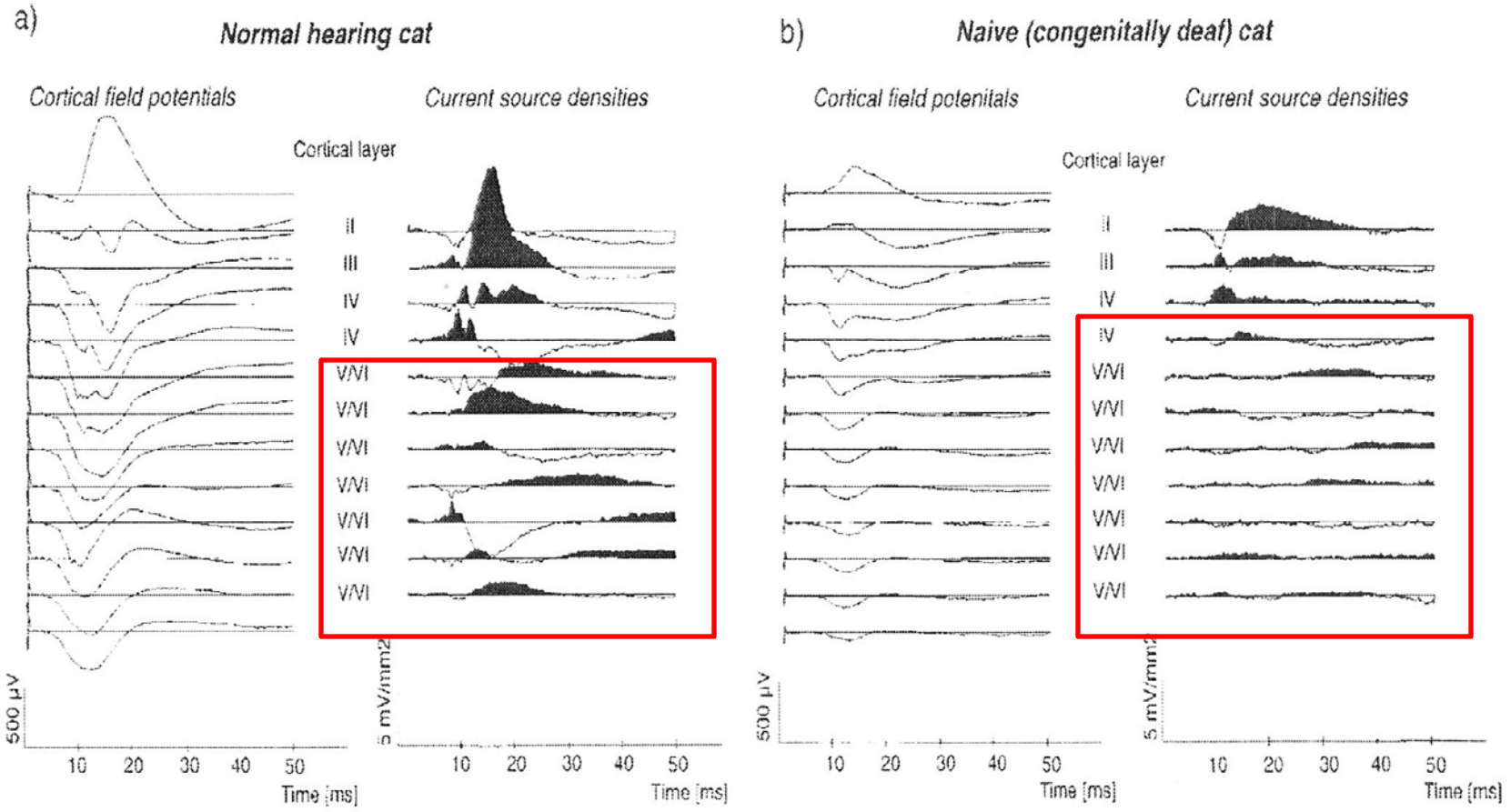
Green: Areas activated by spoken language (CI: Left Ear)

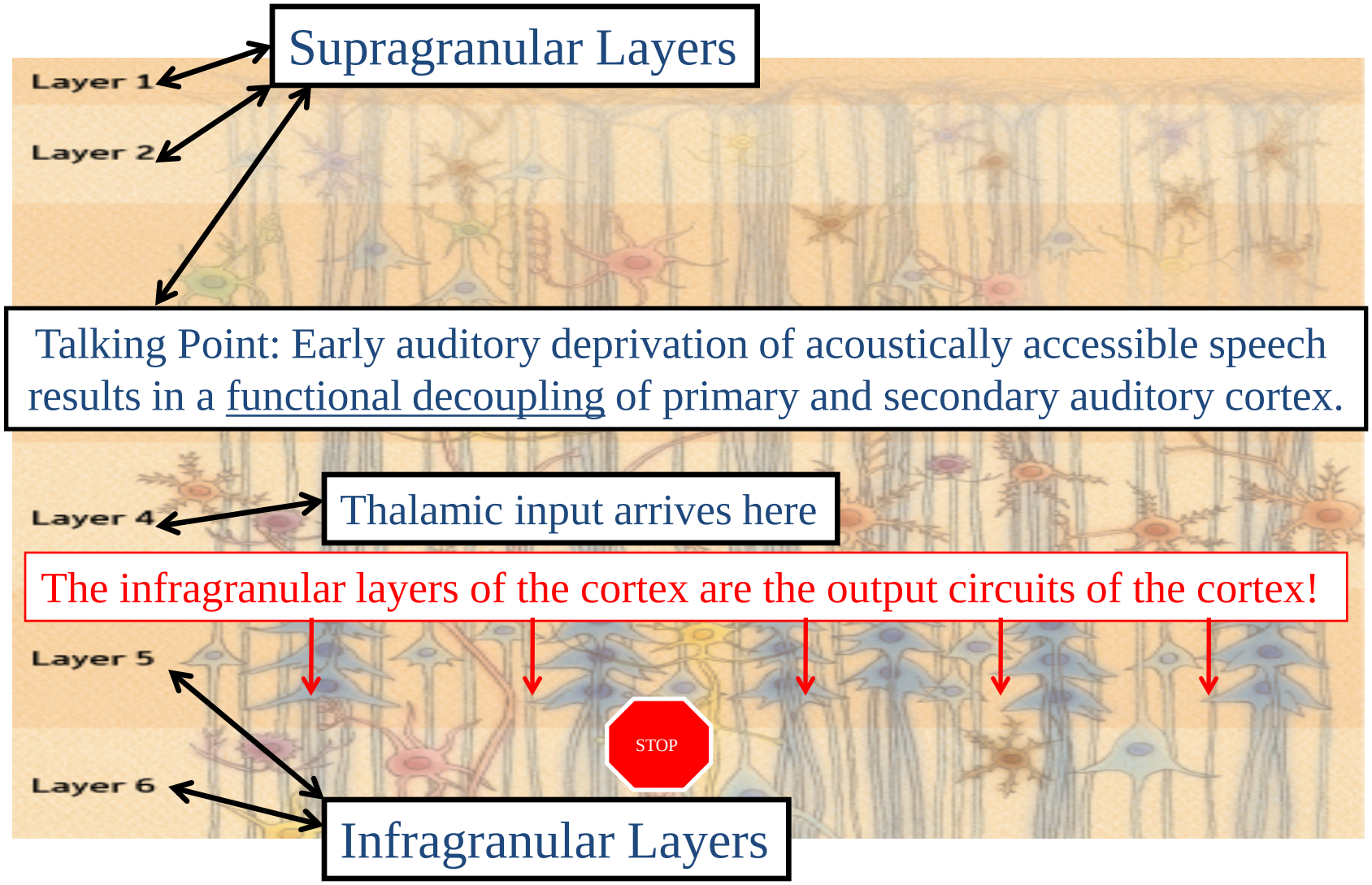
- Why does cross-modal plasticity occur in secondary auditory cortical areas in the absence of sound stimulation?

Kral et al., 2000

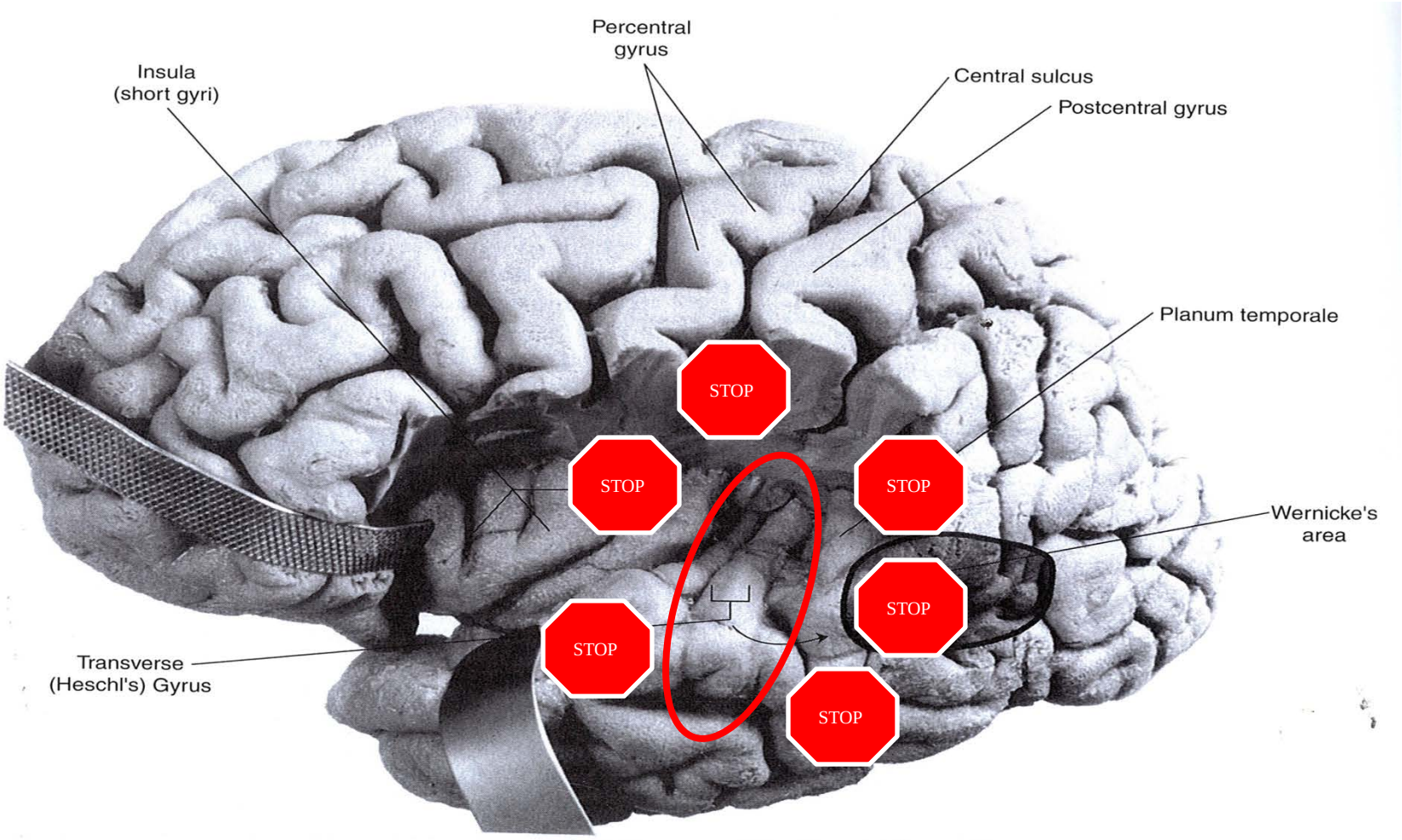
- Used microelectrodes to record local cortical auditory potentials in NH and congenitally deaf cats with and without cochlear implants

Kral et al., 2000

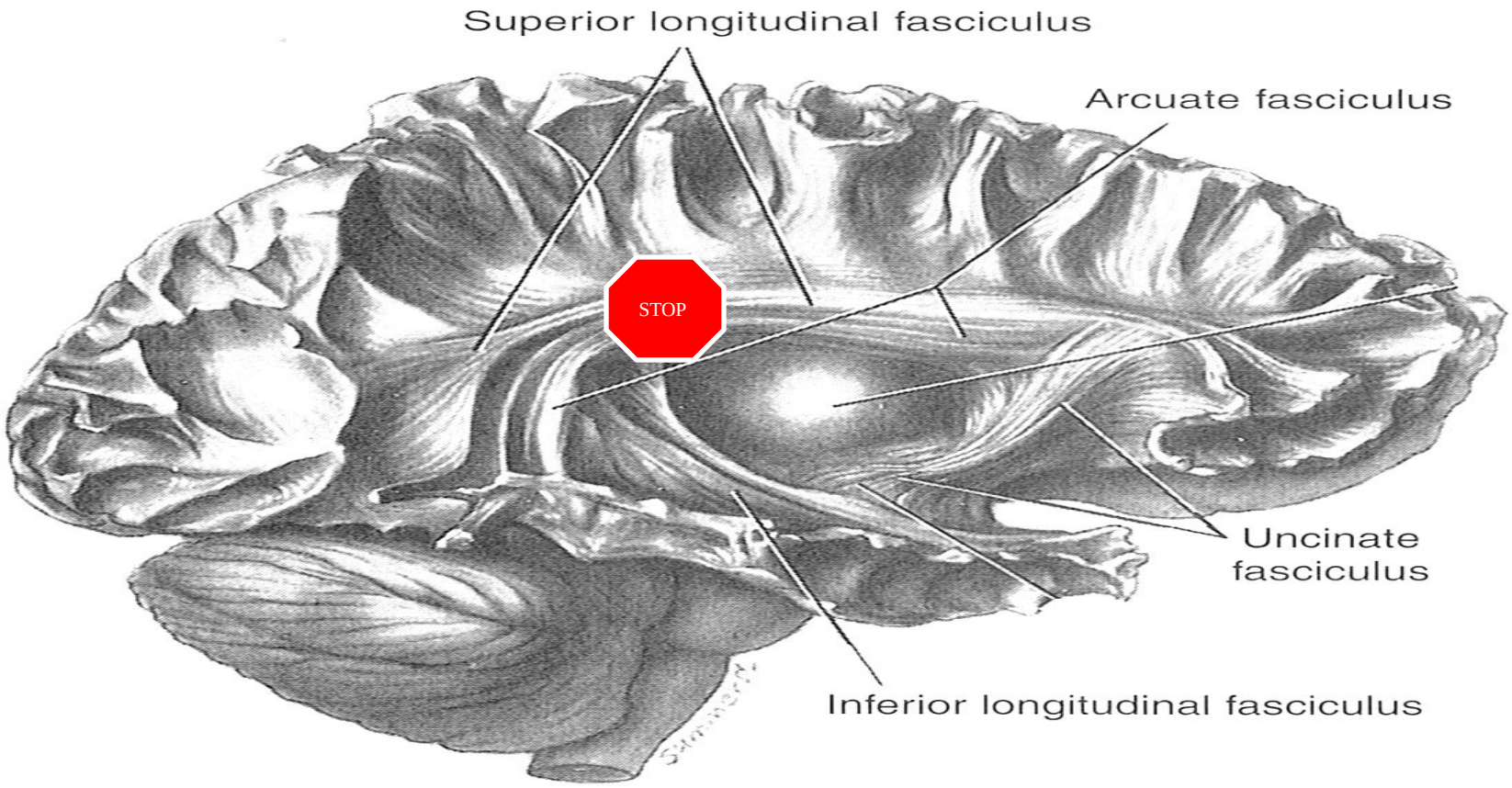



Supragranular Layers
Layer 1
Layer 2
Talking Point: Early auditory deprivation of acoustically accessible speech results in a functional decoupling of primary and secondary auditory cortex.
Layer 4
Thalamic input arrives here
The infragranular layers of the cortex are the output circuits of the cortex!
Layer 5
STOP
Layer 6
Infragranular Layers

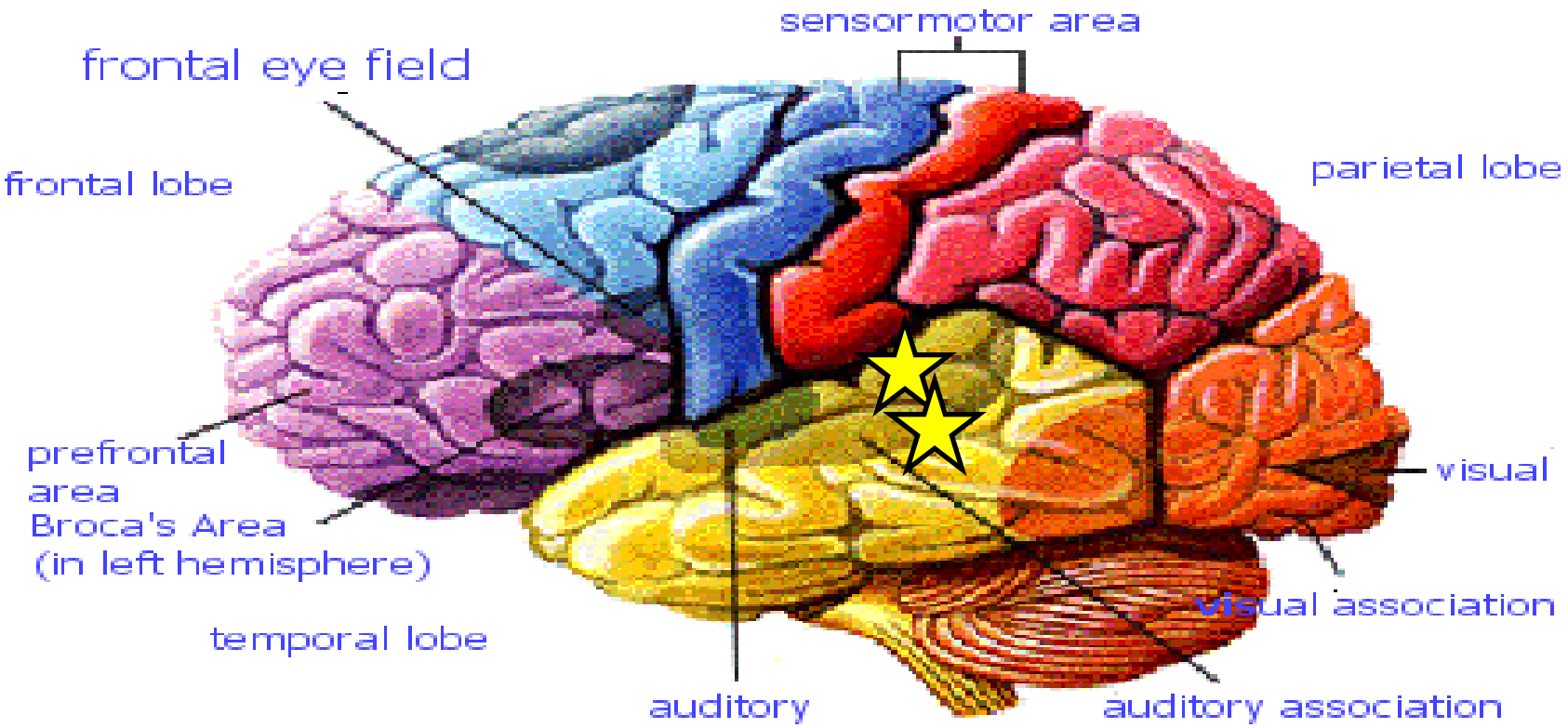
Primary Auditory Cortex



Arcuate Fasciculus



The Listening Brain
Intra-hemispheric Transfer



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

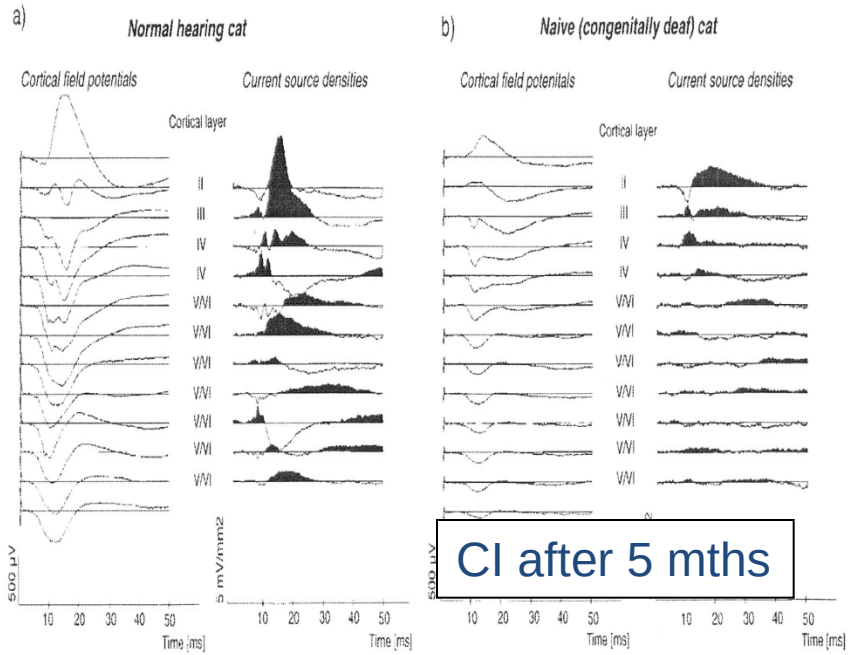
-- Kai-How Farh

Kral et al., 2000

- 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

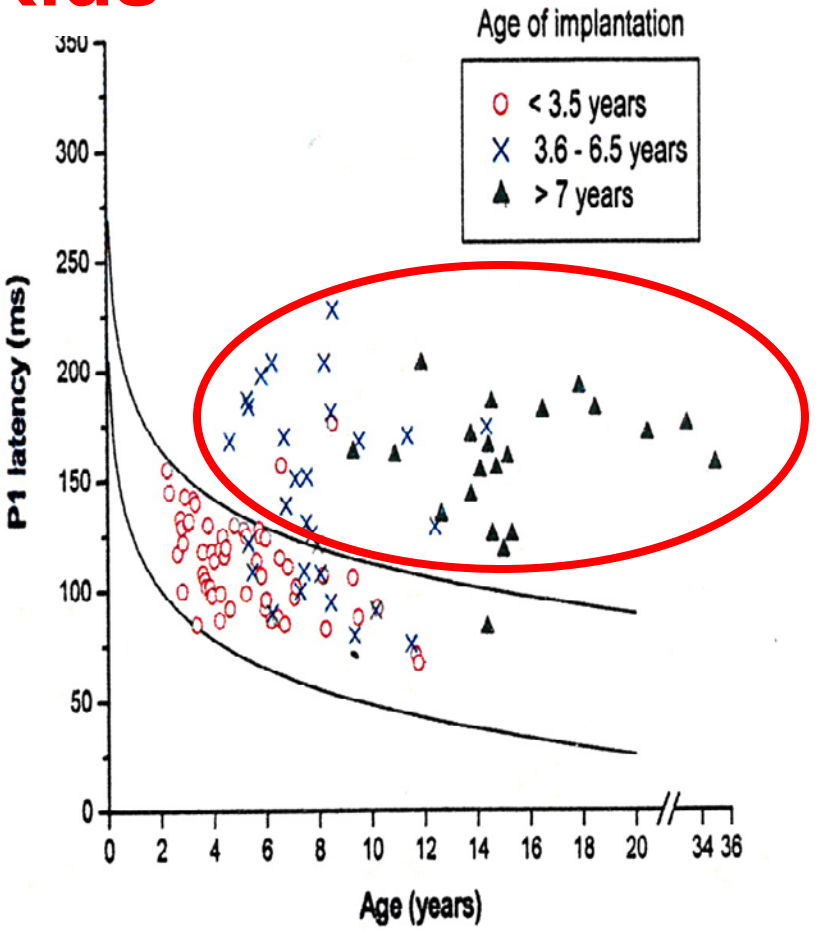
Kittens



CI after 5 mths

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.

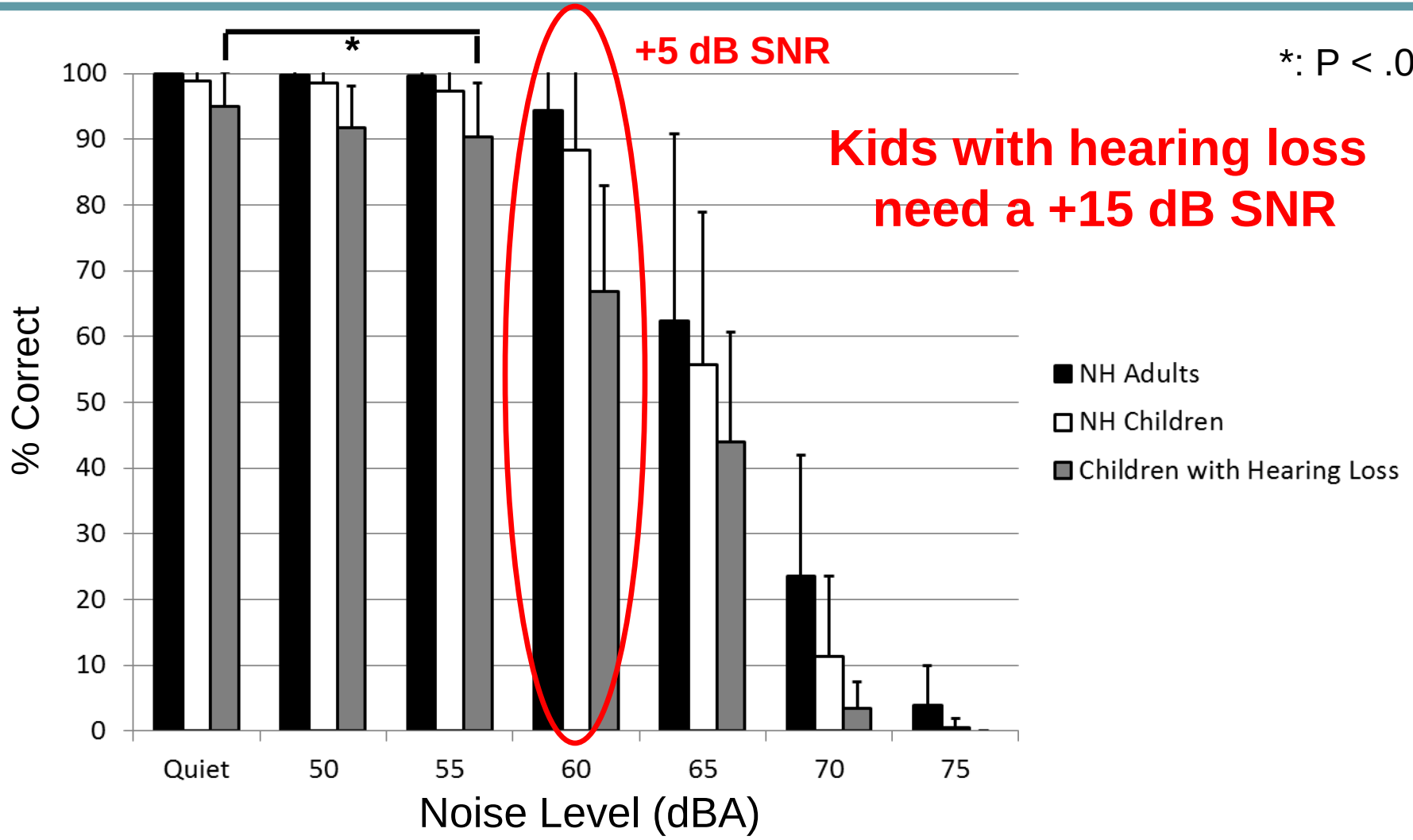
- How much exposure is necessary?
  - **Risley and Hart: 46 million words by 4 years of age**

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

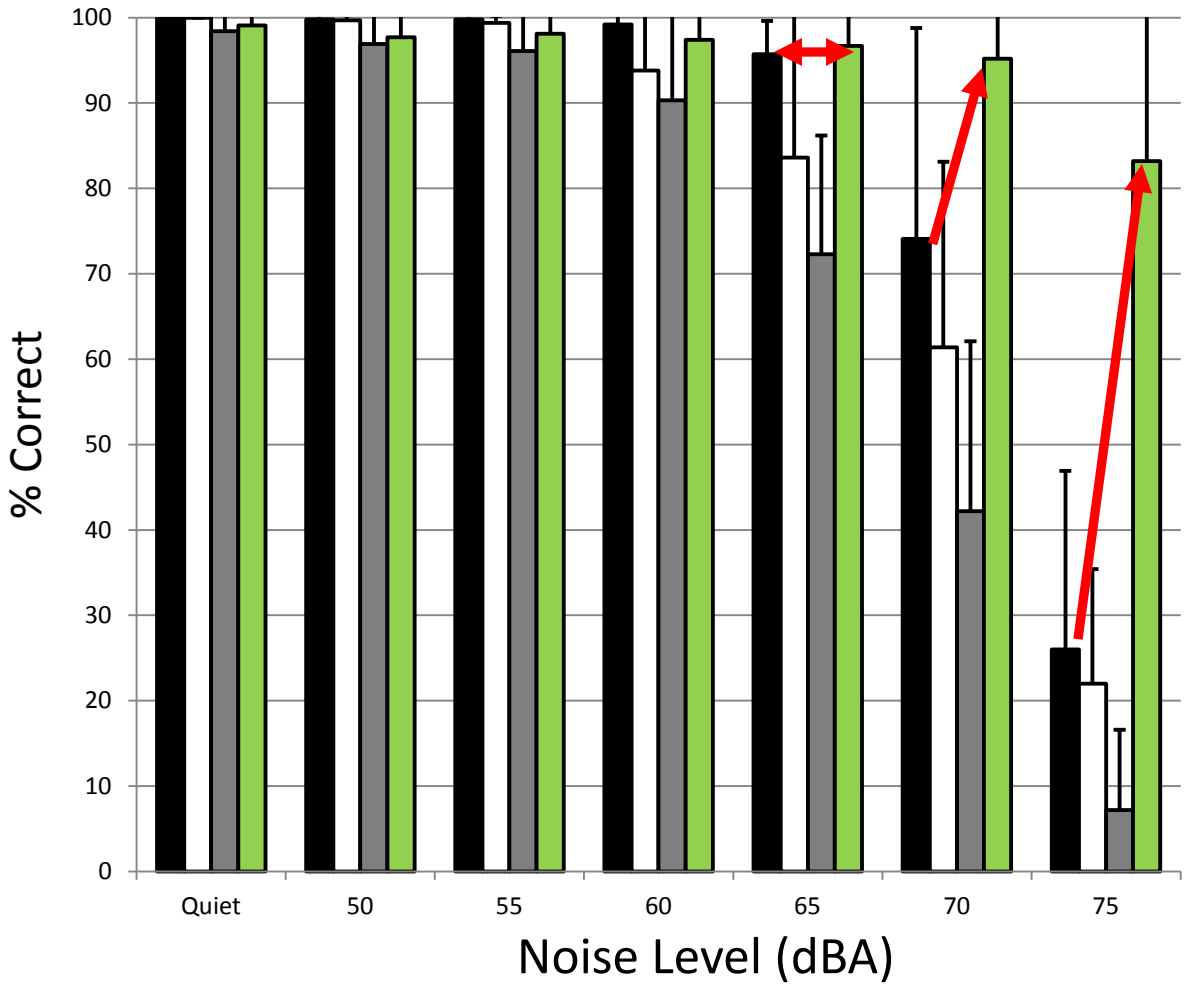
Speech Recognition without Remote Mic HAT



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.**

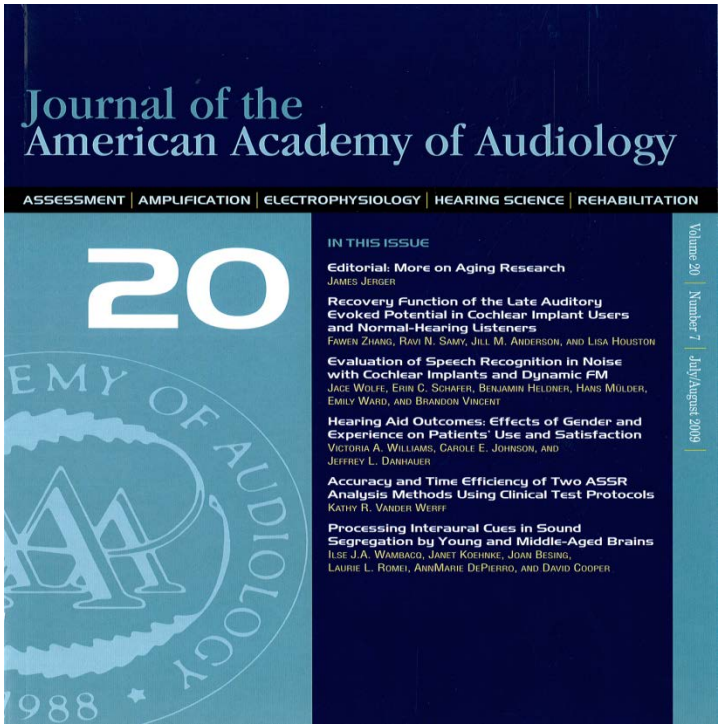
Good News!
Children with Hearing Loss vs. "Gold Standard"



- Adults with Dynamic SF
- NH Children with Dynamic SF
- Children with HL and Dynamic SF
- Children with HL and Dynamic SF+Personal FM

Wolfe et al., 2013

Evaluation of Dynamic FM with Cochlear Implants



J Am Acad Audiol 20:409–421 (2009)

Evaluation of Speech Recognition in Noise with Cochlear Implants and Dynamic FM

DOI: 10.3766/jaaa.20.7.3

Jace Wolfe*
Erin C. Schafer†
Benjamin Heldner‡
Hans Mülder‡
Emily Ward§
Brandon Vincent§

Abstract

Background: Use of personal frequency-modulated (FM) systems significantly improves speech recognition in noise for users of cochlear implants (CIs). Previous studies have shown that the most appropriate gain setting on the FM receiver may vary based on the listening situation and the manufacturer of the CI system. Unlike traditional FM systems with fixed-gain settings, Dynamic FM automatically varies the gain of the FM receiver with changes in the ambient noise level. There are no published reports describing the benefits of Dynamic FM use for CI recipients or how Dynamic FM performance varies as a function of CI manufacturer.

Purpose: To evaluate speech recognition of Advanced Bionics Corporation or Cochlear Corporation CI recipients using Dynamic FM vs. a traditional FM system and to examine the effects of Autosensitivity on the FM performance of Cochlear Corporation recipients.

Research Design: A two-group repeated-measures design. Participants were assigned to a group according to their type of CI.

Study Sample: Twenty-five subjects, ranging in age from 8 to 82 years, met the inclusion criteria for one or more of the experiments. Thirteen subjects used Advanced Bionics Corporation, and 12 used Cochlear Corporation implants.

Intervention: Speech recognition was assessed while subjects used traditional, fixed-gain FM systems and Dynamic FM systems.

Data Collection and Analysis: In Experiments 1 and 2, speech recognition was evaluated with a traditional, fixed-gain FM system and a Dynamic FM system using the Hearing in Noise Test sentences in quiet and in classroom noise. A repeated-measures analysis of variance (ANOVA) was used to evaluate effects of CI manufacturer (Advanced Bionics and Cochlear Corporation), type of FM system (traditional and dynamic), noise level, and use of Autosensitivity for users of Cochlear Corporation implants. Experiment 3 determined the effects of Autosensitivity on speech recognition of Cochlear Corporation implant recipients when listening through the speech processor microphone with the FM system muted. A repeated-measures ANOVA was used to examine the effects of signal-to-noise ratio and Autosensitivity.

Results: In Experiment 1, use of Dynamic FM resulted in better speech recognition in noise for Advanced Bionics recipients relative to traditional FM at noise levels of 65, 70, and 75 dB SPL. Advanced Bionics recipients obtained better speech recognition in noise with FM use when compared to Cochlear Corporation recipients. When Autosensitivity was enabled in Experiment 2, the performance of Cochlear Corporation recipients was equivalent to that of Advanced Bionics recipients, and Dynamic FM was significantly better than traditional FM. Results of Experiment 3 indicate that use of

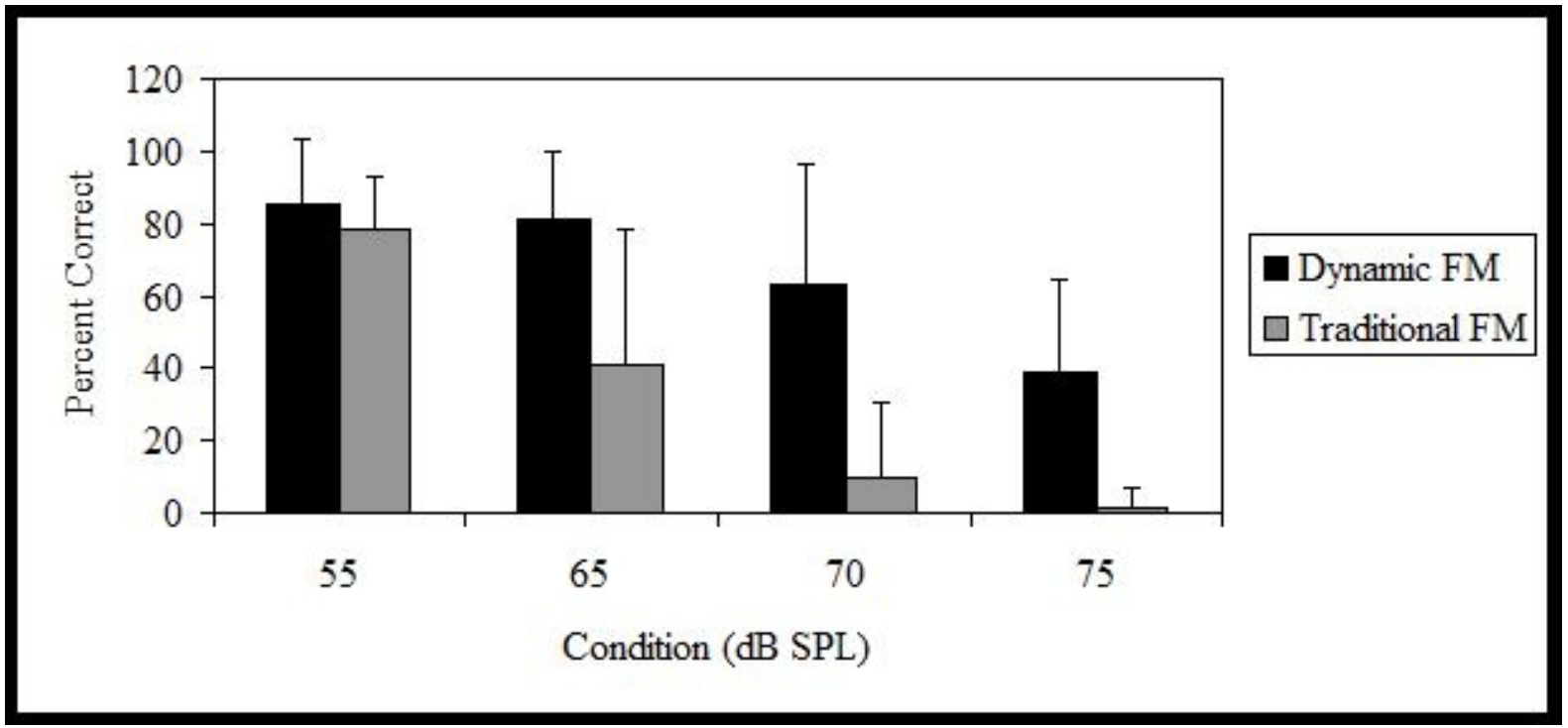
*Hearts for Hearing Foundation; †Department of Speech and Hearing Sciences, University of North Texas; ‡Phonak Hearing Aid Company; §University of Oklahoma Health Sciences Center

Jace Wolfe, 3525 NW 56th Street, Suite A-150, Oklahoma City, OK 73120; Phone: 405-822-8584; Fax: 405-548-4350; E-mail: jace.wolfe@heartsforhearing.org

The Phonak Hearing Aid Company provided financial support for this study.

Wolfe et al. (2009)

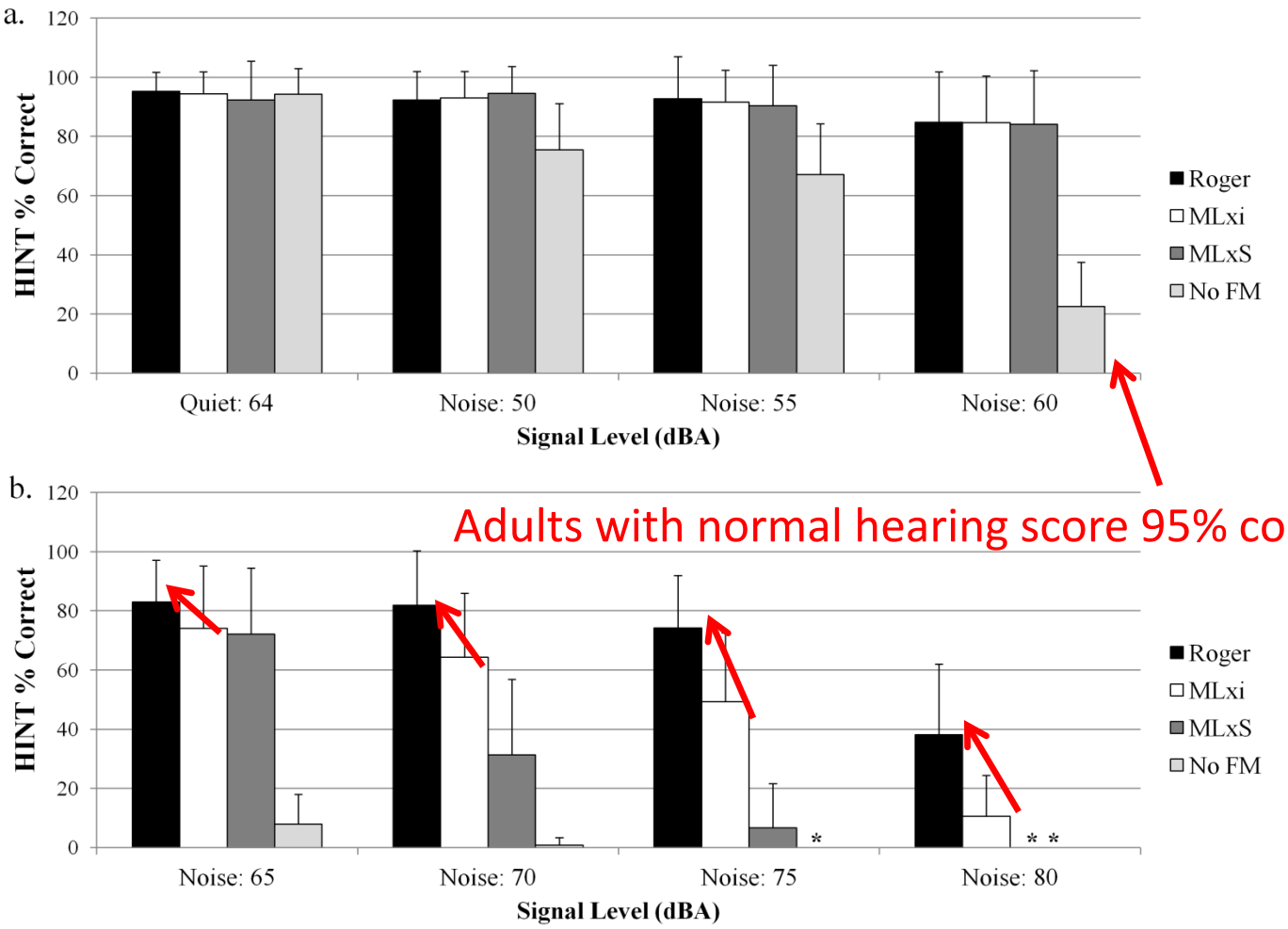
Speech Recognition in Noise Results – Advanced Bionics



Wolfe et al. (2009)

- What about digital adaptive RF?

Results
Advanced Bionics Recipients (n = 16)



Adults with normal hearing score 95% correct here!

Wolfe et al., 2013, JAAA

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?

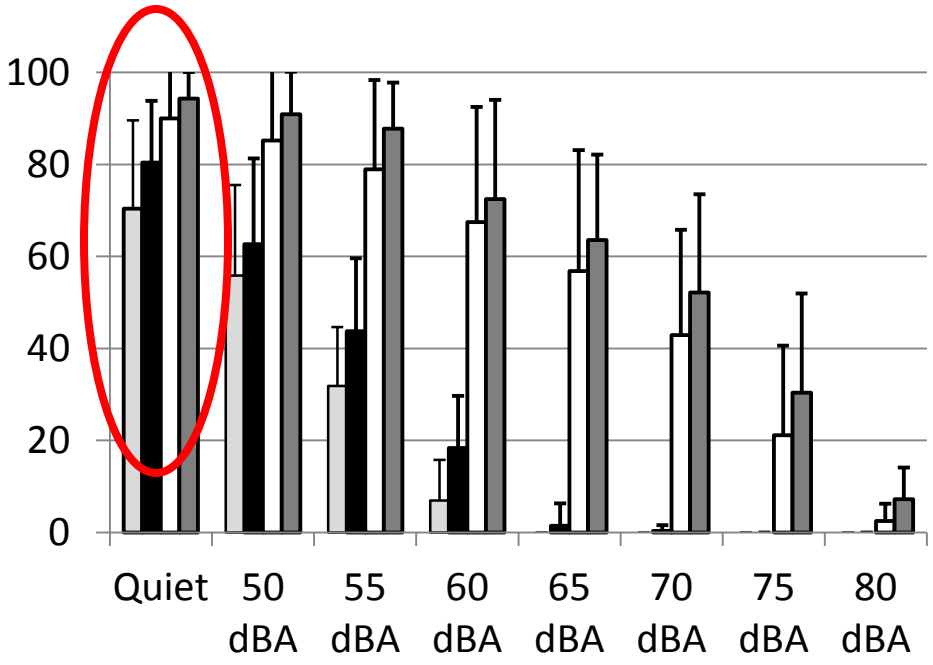
Imran Mulla, 2013

- 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

<u>Conservative Take</u>: 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

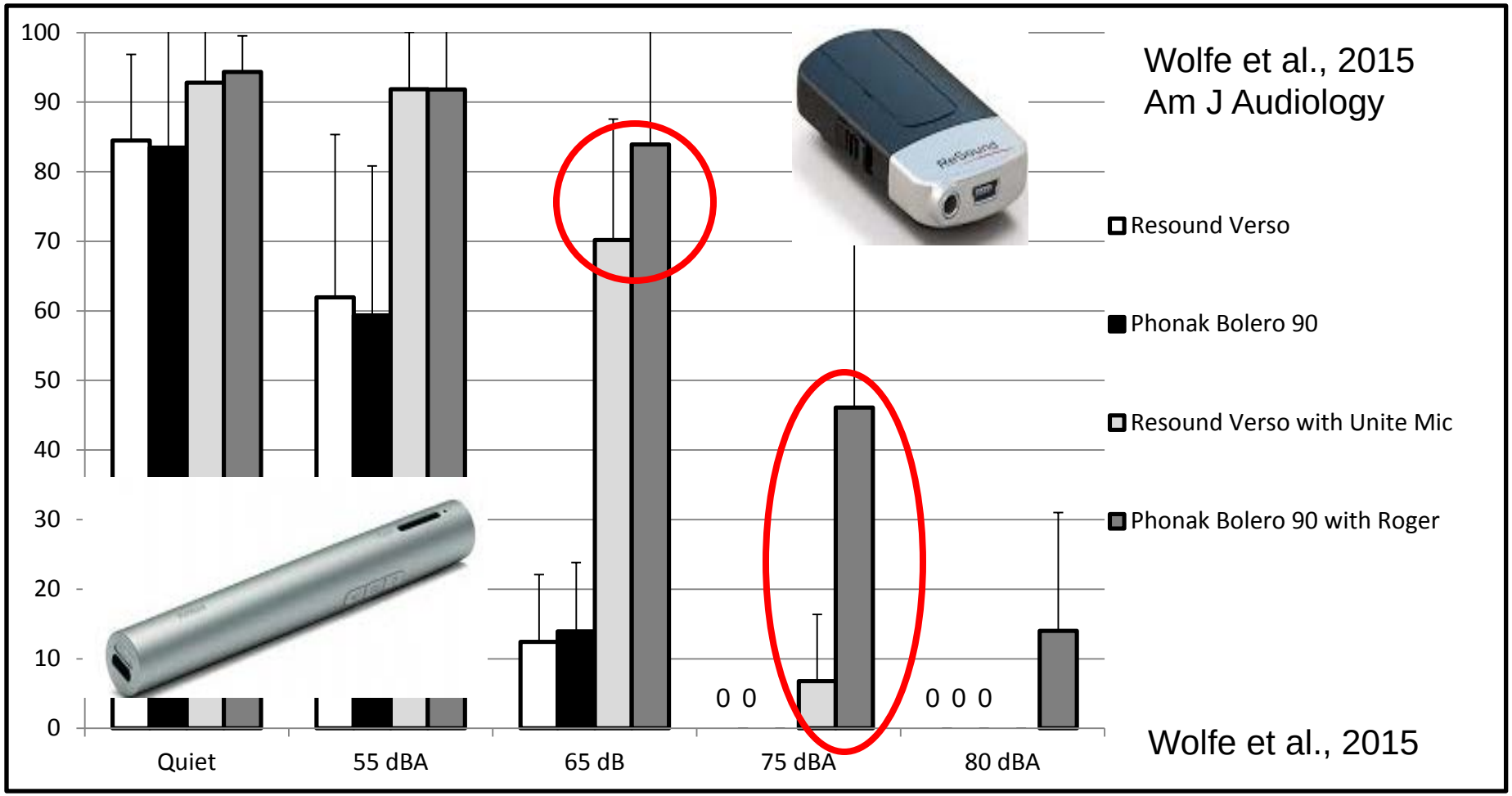
- Better with CV ON than OFF
- Better with Roger ON than OFF
- Best with CV + Roger

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



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

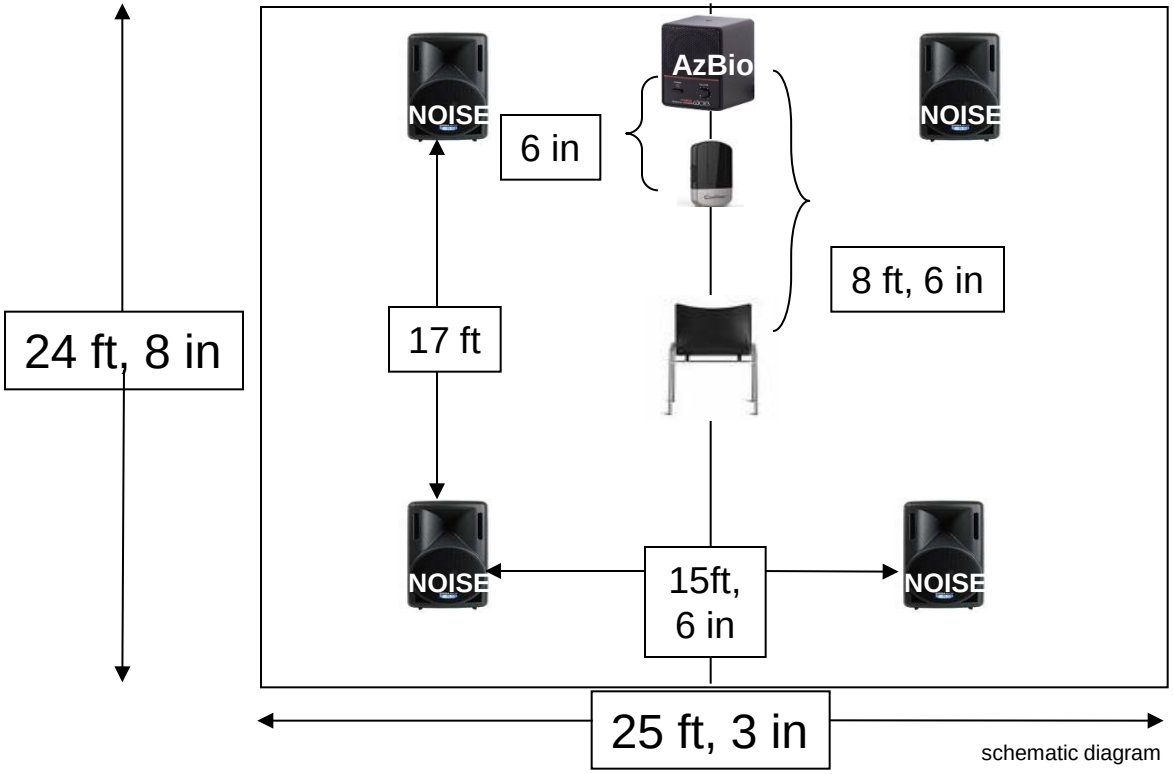
Mini Mic 2+

Roger Touchscreen

Roger Pen

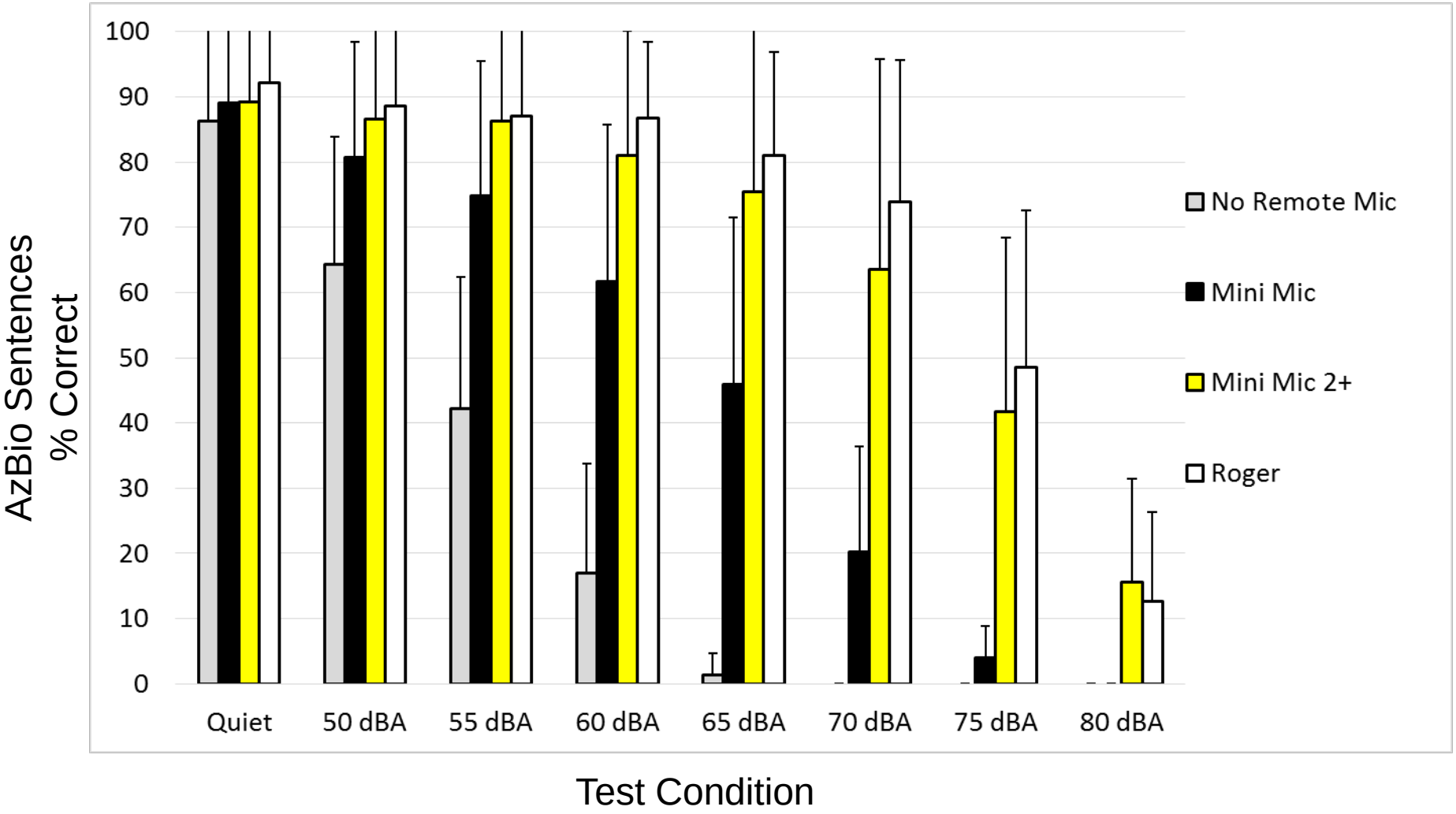
Phonak Roger

Equipment Setup



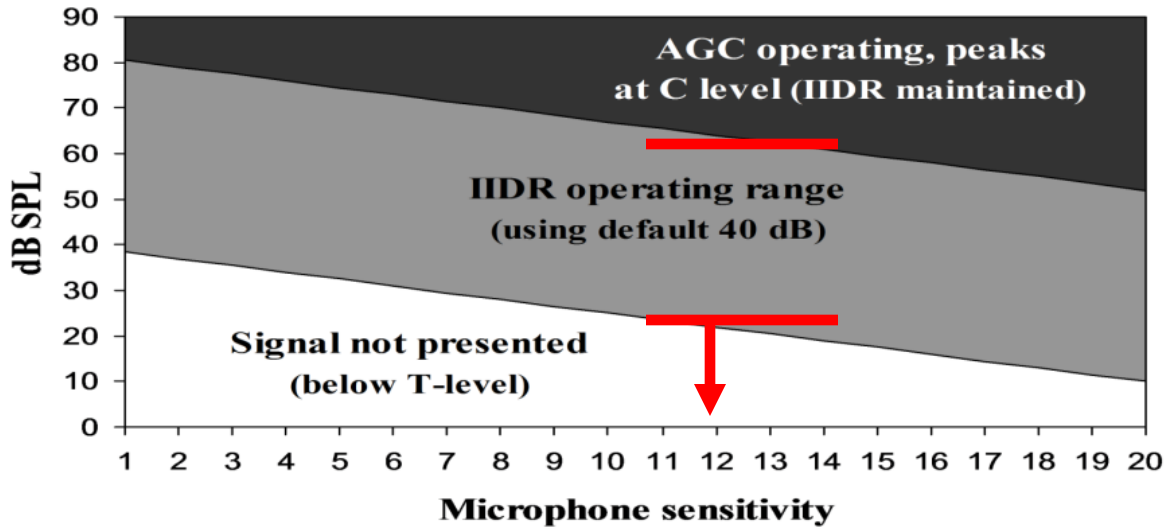
schematic diagram

Cochlear Implant Only Users



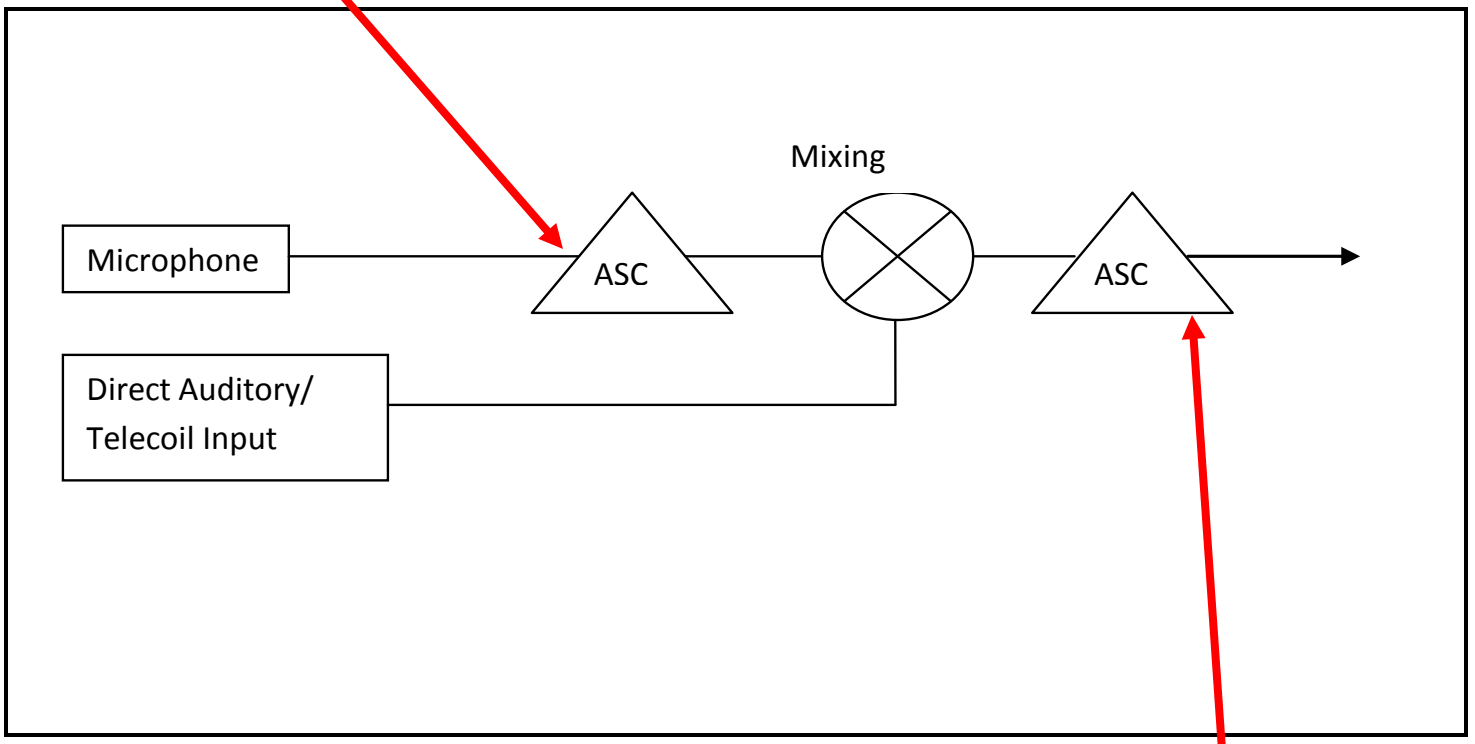
n = 15

Autosensitivity Control (ASC)



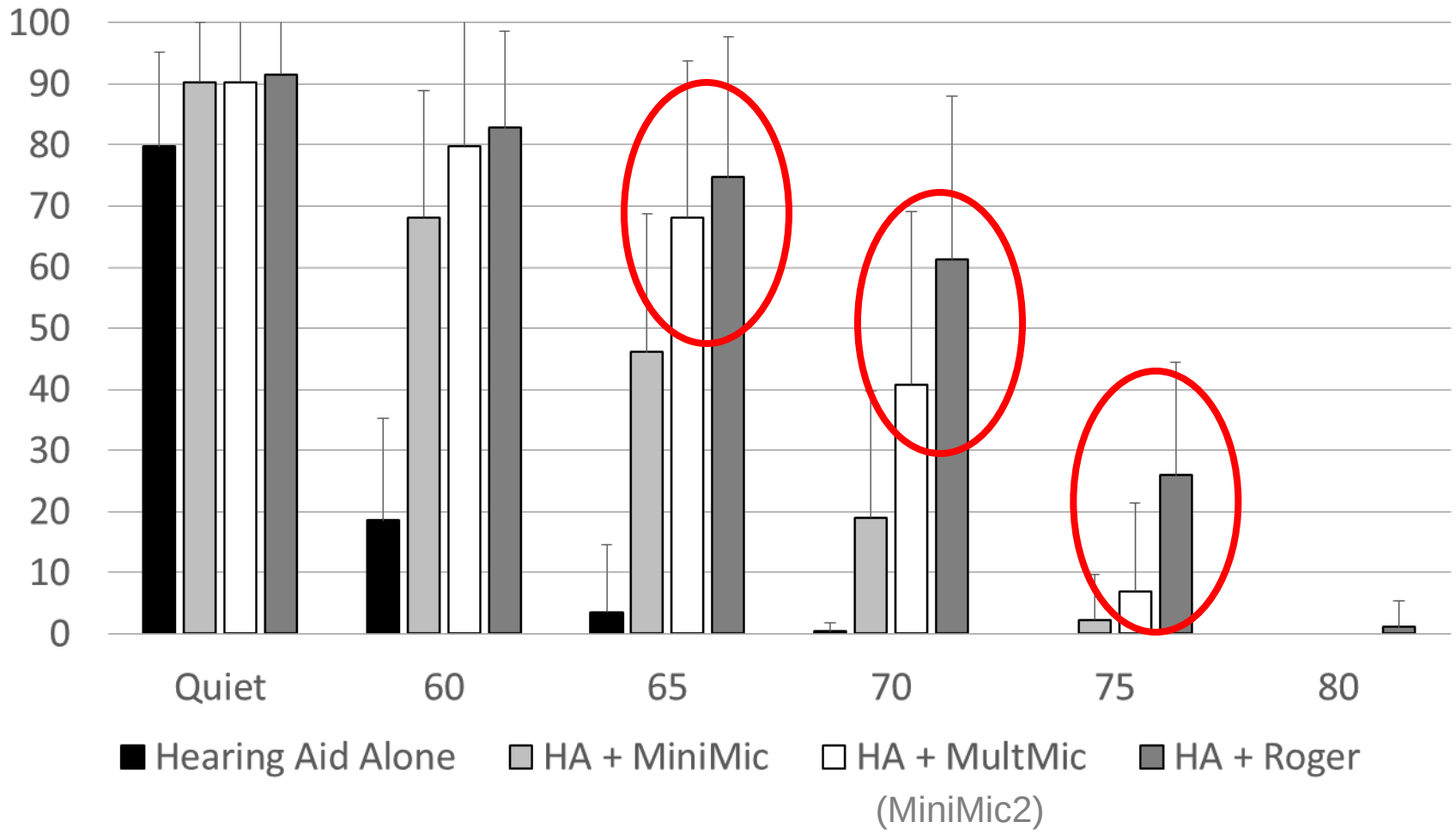
Nucleus 6 Signal Pathway

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



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

Model	Recommended CI module setting	Recommended EasyGain	AutoConnect
MED-EL OPUS 2 and ML CI S (automatic setting)	Default	0dB	ON
MED-EL OPUS 2 (manual setting)	Setting 2	0dB	OFF
AB Naída CI Q70 with ComPilot and Roger X	Setting 3	0dB	OFF
AB Harmony / Auria	Setting 4 or Setting 1	+8dB or 0dB	OFF
MicroLink CI S (manual setting)	Setting 5	0dB	OFF
Cochlear Nucleus 6 / 5	Setting 9	0dB	OFF

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