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**Bilateral Cochlear Implants: Recent Advances and Future Directions**

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**Binaural Hearing and Speech Lab**



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**Successes and Challenges**

Cochlear Implants have yielded remarkable success in recent years.  
 But there are remaining challenges, including:

- Listening in noise
- Locating sound sources
- Range in performance and outcomes: Some listeners function similar to NH listeners, and others have a large gap in performance

**Bilateral CIs have been provided to a growing number of patients**

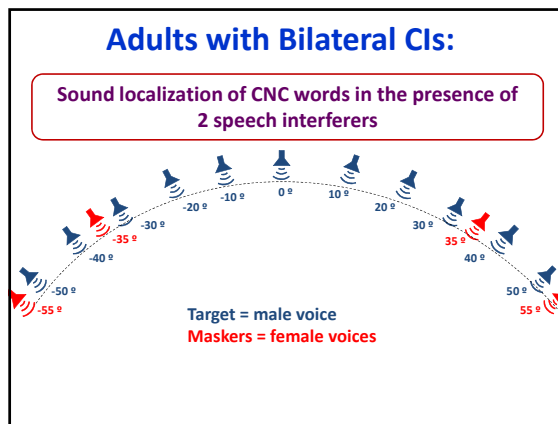



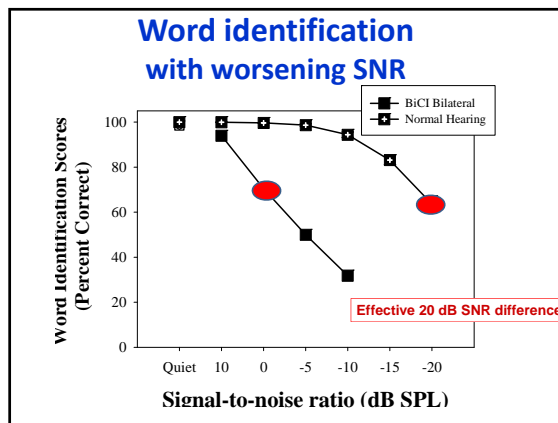
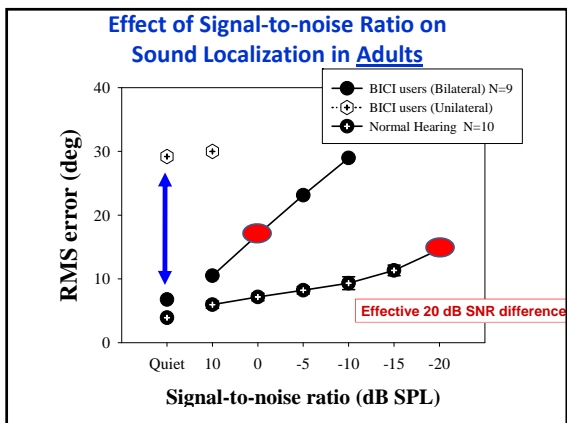
**Motivation:**

- Improve ability to hear speech in noise
- Improve sound localization ability
- Ease of listening (Quality Of Life)
- Language acquisition: Improved by “doubling” the signal?
- Ideally..... Close the gap in performance between CI users and NH listeners

**Behavioral Measures of Bilateral Benefits**

- Sound Localization** → Ability of the auditory system to use spatial cues that need for us to integrate inputs from the two ears
- Speech Intelligibility** →
  - In Quiet: Redundant information from R and L ears
  - In Noise: Redundant information & use of spatial cues
- Quality of Life** → Bilateral CI users report that when using 2 CIs they can function better. Questionnaires are used to conduct studies.
- Language Acquisition** → Little is known about the effects of 2 CIs. If there is benefit, it might come from having redundant information





### Benefits of Bilateral Cochlear Implants?

- Sound localization significantly better (fewer errors) with 2 CIs than 1 CI.
  - Performance similar to NH in **Quite**
  - However, performance is worse than normal-hearing soon as background **noise** introduced
- Speech in noise significantly better (higher %correct) with 2 CIs than 1 CI
  - However, performance is worse than normal-hearing soon as background noise introduced

### Why the gap in performance relative to Normal-hearing?

- Degraded neural circuits due to deprivation
- Inputs to right and left ears are independent

### Studies with Children

Different from adults – lack of exposure to acoustic hearing prior to becoming deaf and using electric hearing

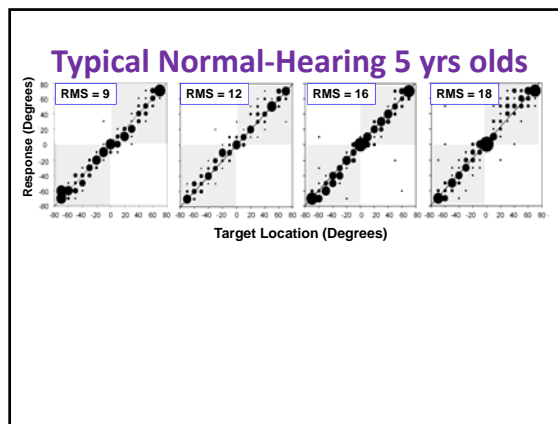
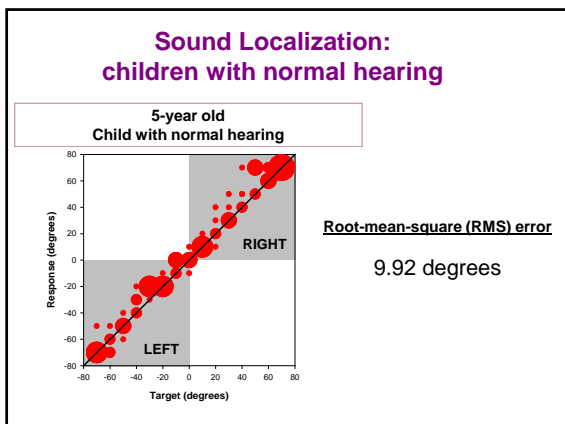
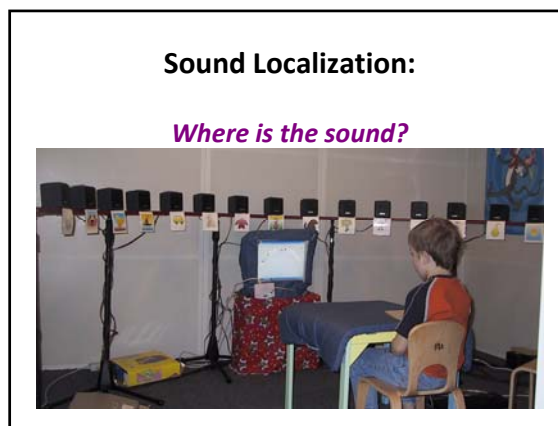
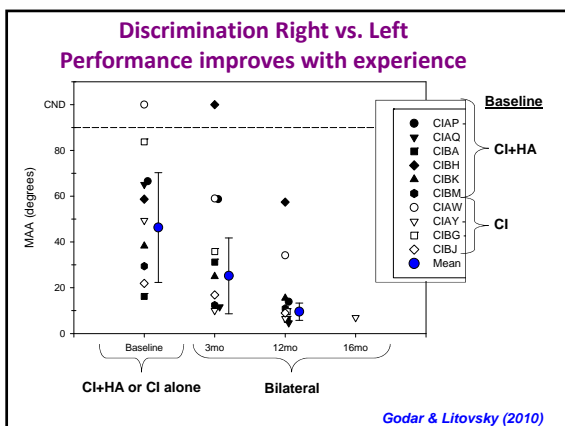
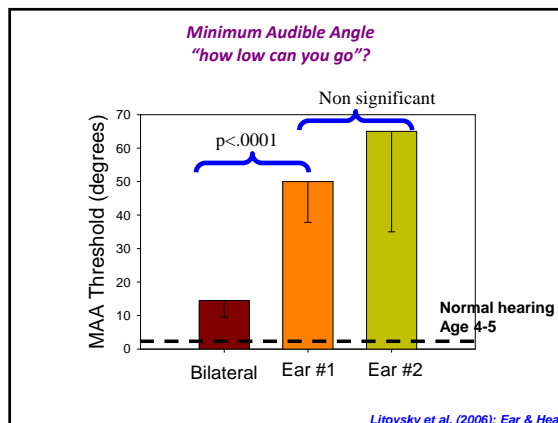
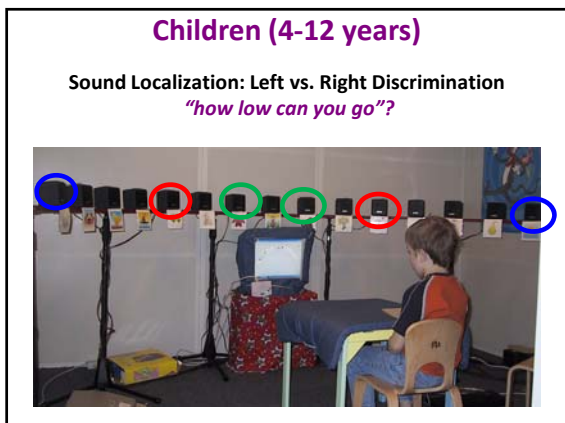
Early-implanted (fewer years with auditory deprivation than many adults)

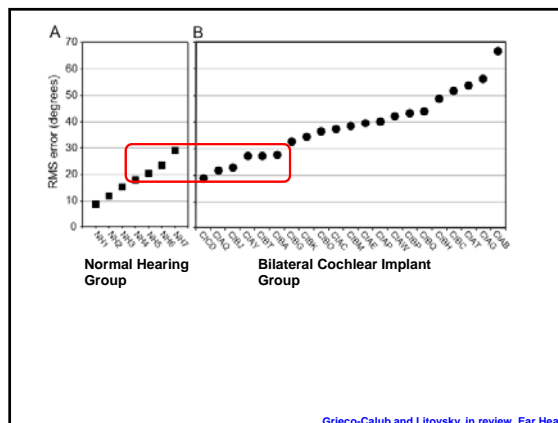
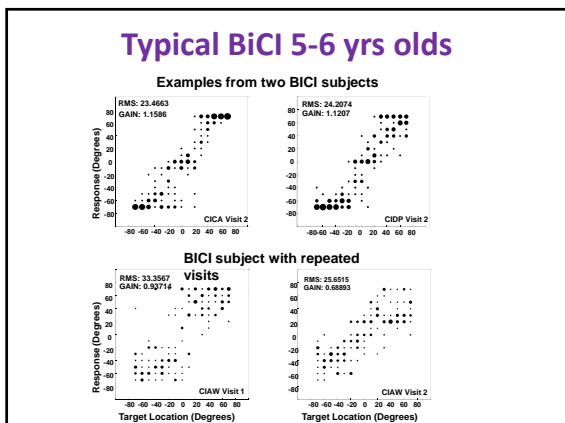
### Will they “catch up”?

Sound localization begins at birth

Normal hearing newborns orient to sounds hours after birth

Unconditioned Behavior; Reflexive





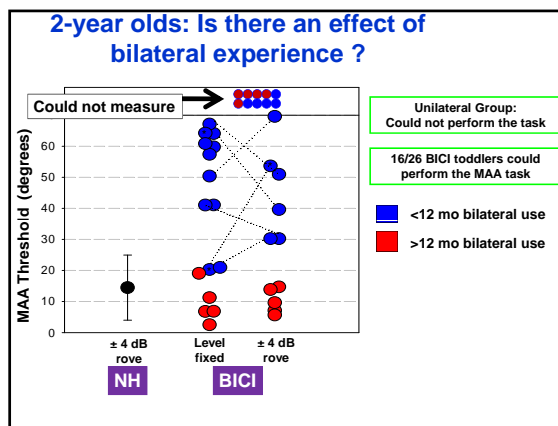
### Toddlers: Observer-Based Method Left/Right Discrimination

N = 26 BiCI; 12 Uni

**Inclusion Criteria:**  
 1<sup>st</sup> cochlear implant by 12 months  
 2<sup>nd</sup> cochlear implants 18-24 months  
 Age at testing = 30 months

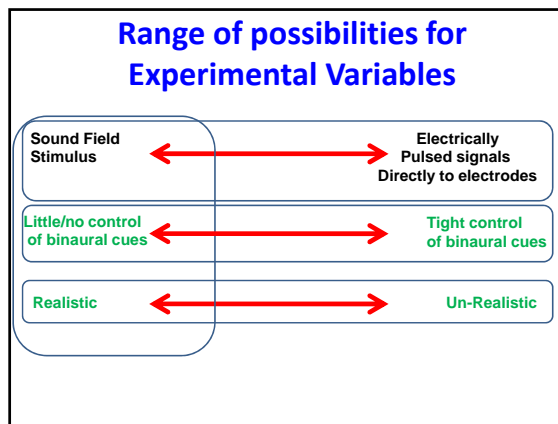
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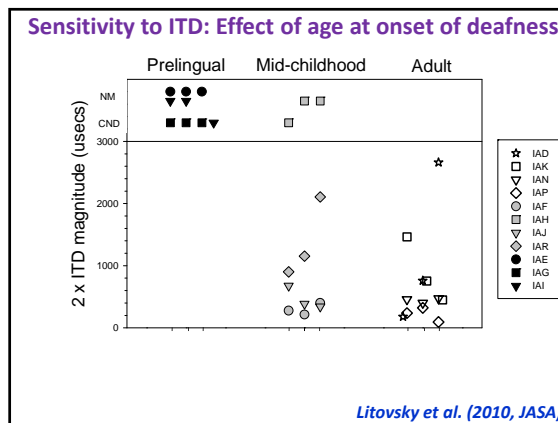
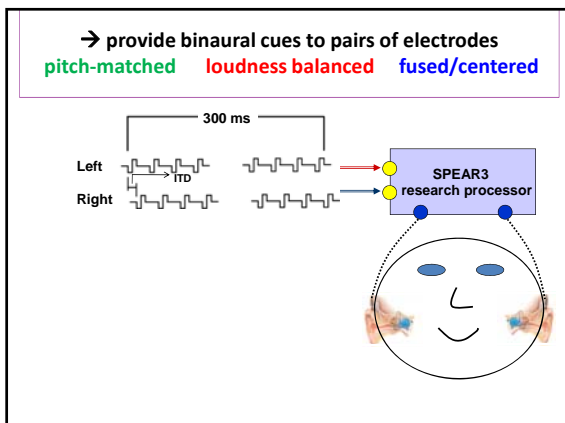
Grieco-Calub, Litovsky, Werner (2008)  
 Grieco-Calub & Litovsky (in prep)



### Why can't all early-implanted children localize sounds well?

- **Degraded neural circuits?** If the auditory system is wired for acoustic hearing, then the auditory circuits in children who are born deaf and are not exposed to acoustic binaural cues early in life may struggle to develop sensitivity to those cues.
- **Inputs to right and left ears are independent:** If the auditory cues are not coordinated (synchronized) between the ears, then binaural hearing may be compromised on an ongoing basis, perhaps more in some than others.





- ### Interim Conclusions
- There are clearly measurable benefits from wearing 2 CIs in 2 independent ears
    - Sound localization is better with 2 than 1
    - But it's much harder for BICl users than NH listeners
    - Spatial hearing in children depends on a combination of complex factors that need to be teased apart
    - Children who are born deaf are not exposed to binaural cues and may never attain the ability to utilize those cues on functional tasks
  - Under controlled experimental conditions adults with childhood- or adult-onset of deafness are sensitive to ITDs
  - Goal: preserve binaural cues in a “binaural processor”

### Next Question: Language Acquisition

**Question:**  
 Can they Recognize spoken words?  
 Baby hears an auditory label → Baby learns to look at the visual object

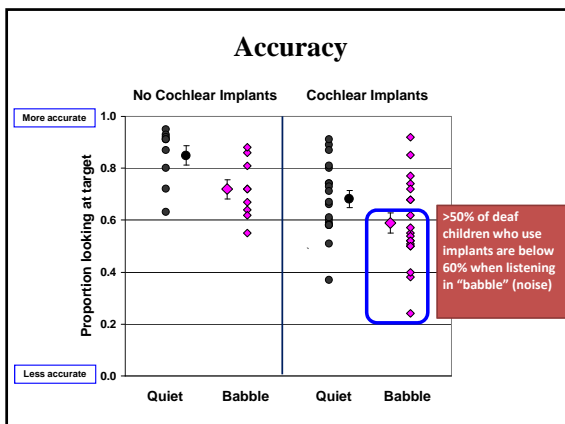
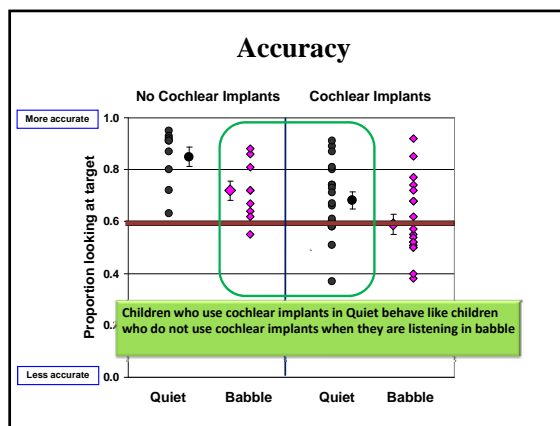
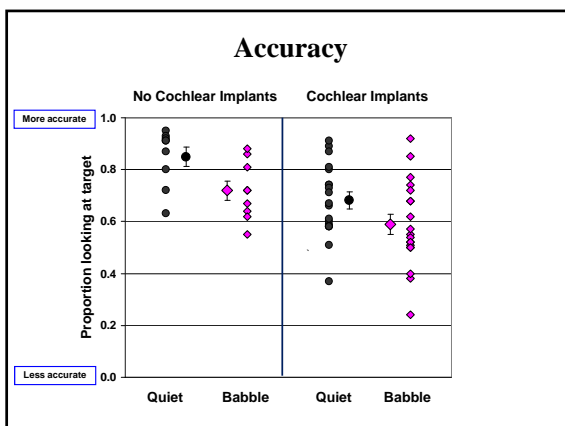
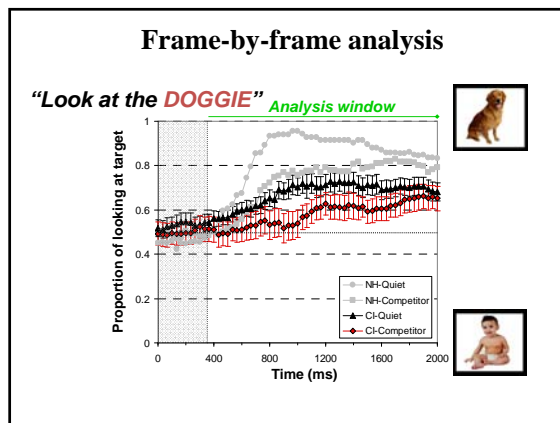
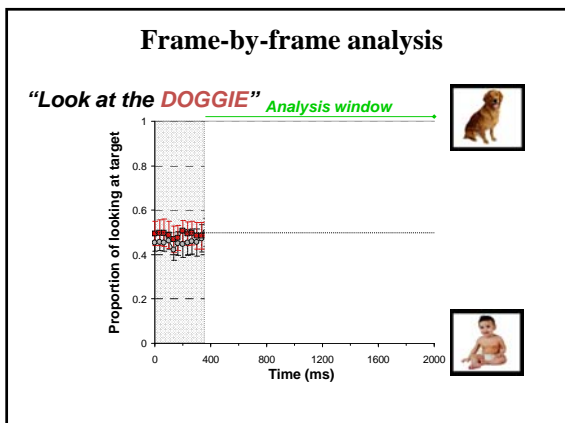
Baby hears an auditory label → Baby learns to look at the visual object

Competing speech condition: +10 dB signal-to-noise ratio

Grieco-Calub, Saffran, Litovsky (JSLHR, 2009)

### Visual fixation method

**Quiet condition:** target at 65 dB SPL  
**Competitor condition:** target at +10 dB signal-to-noise ratio



### Back to where we started

**Motivation for Bilateral CIs:**

- Improve ability to hear speech in noise
- Improve sound localization ability
- Ease of listening (Quality Of Life)
  - Data showing this is positive (not shown)
- Language acquisition: No evidence to date, but future studies continue to explore other conditions.
- Future directions: Improve technology so that gap in performance between CI users and NH listeners can be closed