The Importance of Bilateral Cochlear Implantation in Children who are Profoundly Deaf in Both Ears

SickKids®
THE HOSPITAL FOR SICK CHILDREN
COCHLEAR IMPLANT PROGRAM

Karen A. Gordon

Phonak Latin American Pediatric Conference III, Buenos Aires, Argentina, October 11-13, 2012

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Children need binaural hearing

Can we promote binaural hearing with bilateral cochlear implants?

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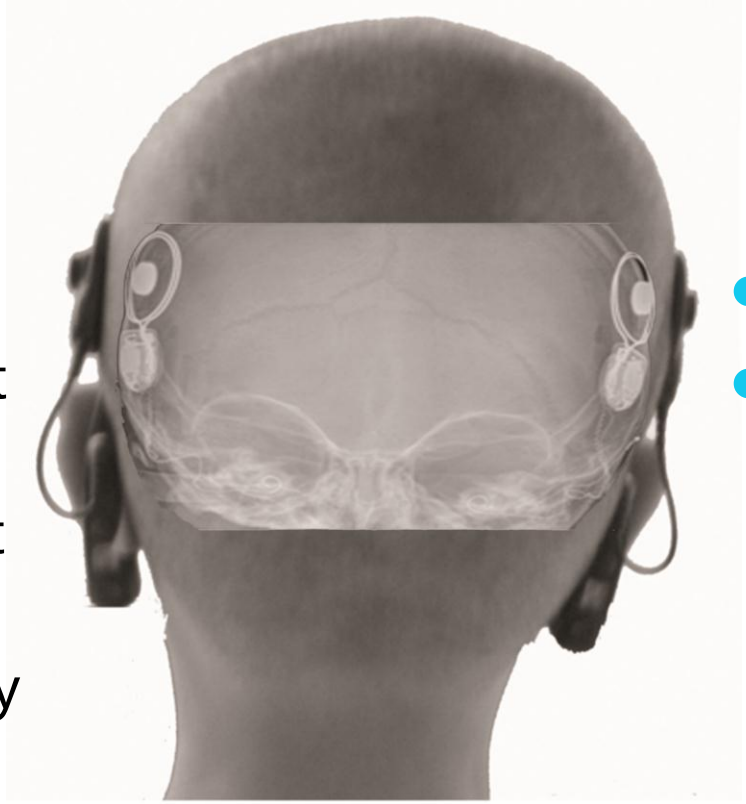
Sequential implants

- n=156
- Age at 1st implant = 3.3 ± 3.1 yrs
- Age at 2nd implant = 9.3 ± 4.7 yrs
- Inter-implant delay = 5.9 ± 3.8 yrs



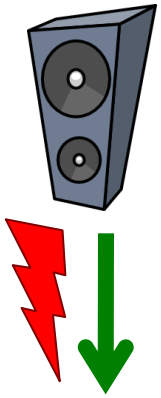
Simultaneous implants

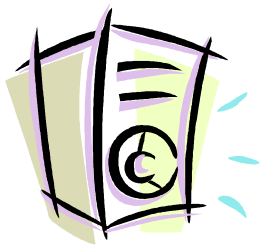
- n=166
- Age at implant = 2.8 ± 3.2

Recruitment as of May 2012

Spatial unmasking: better hearing in noise

(noise at 0°) vs. (noise at 90°)





Spatial unmasking: better hearing in noise

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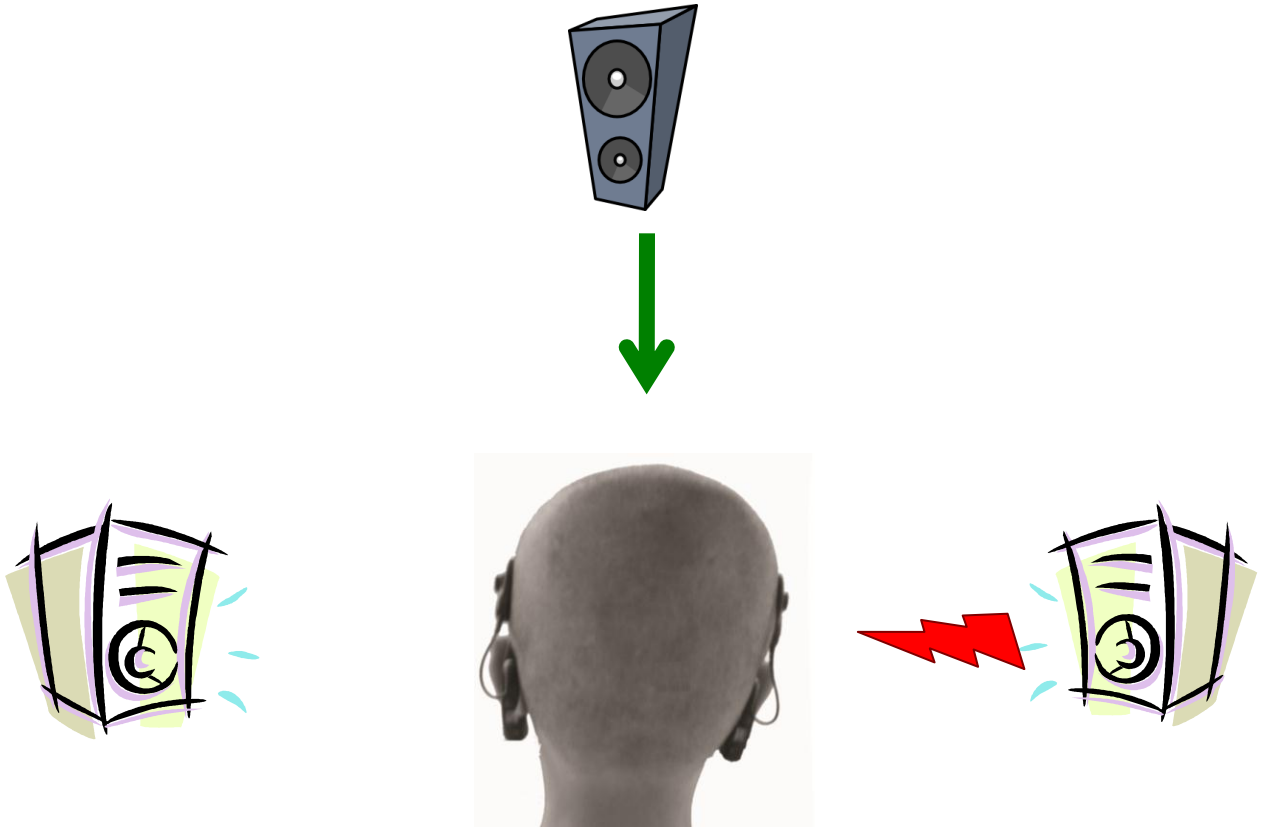

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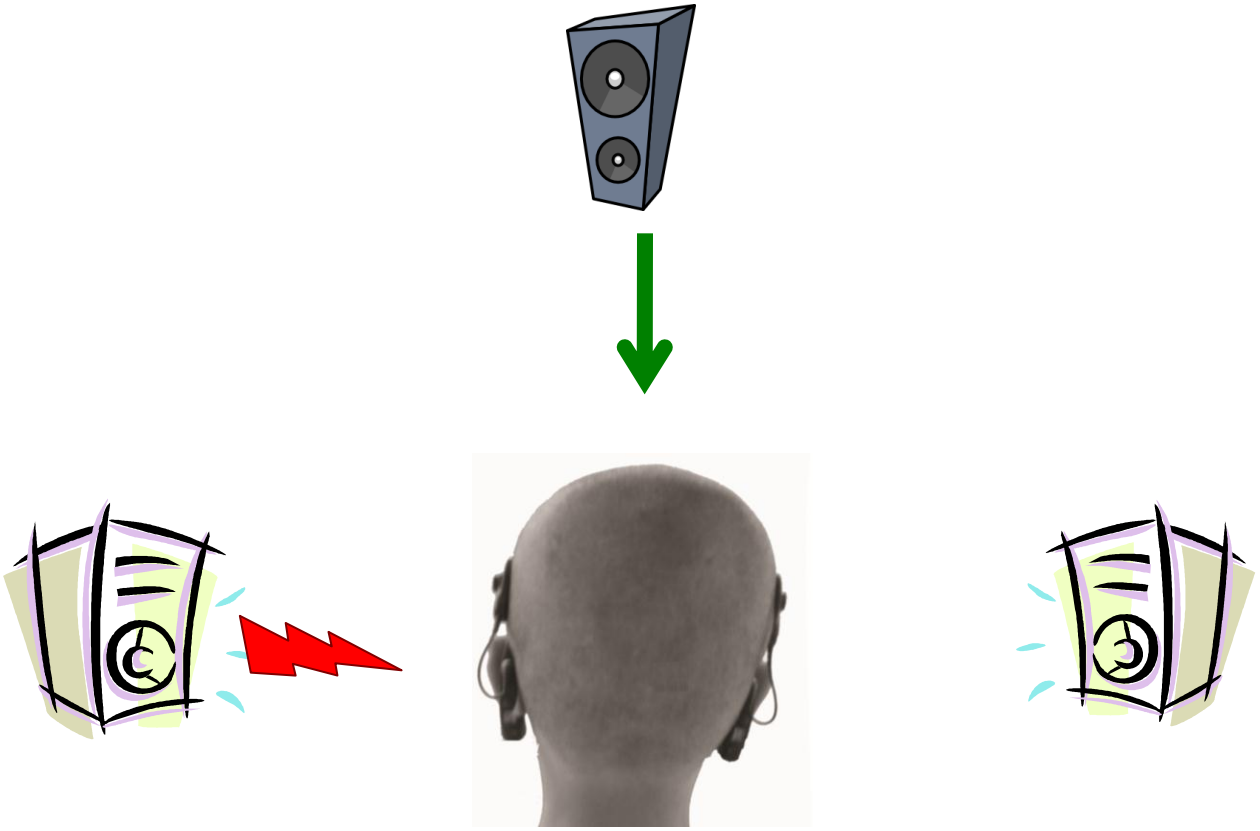
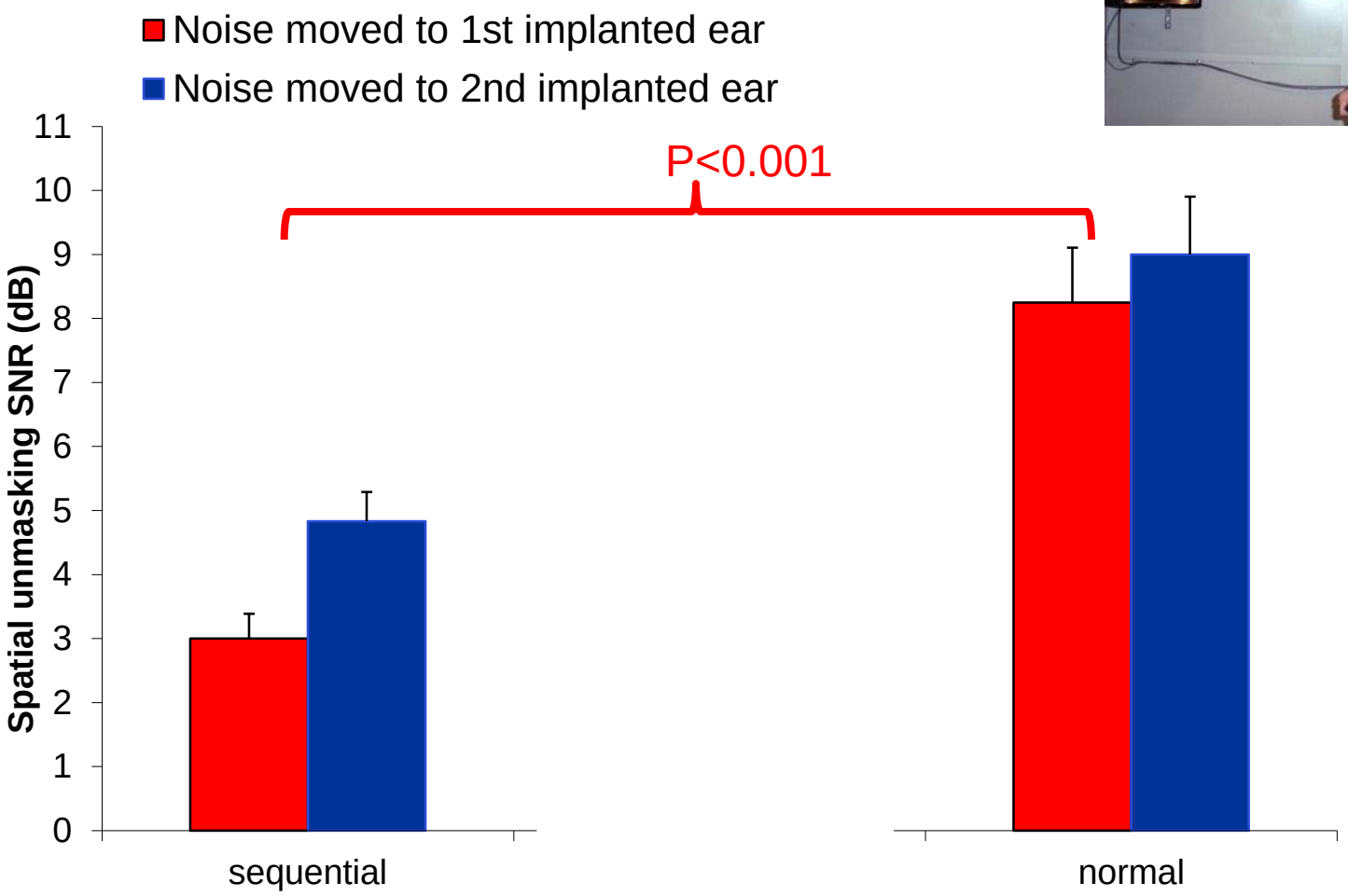
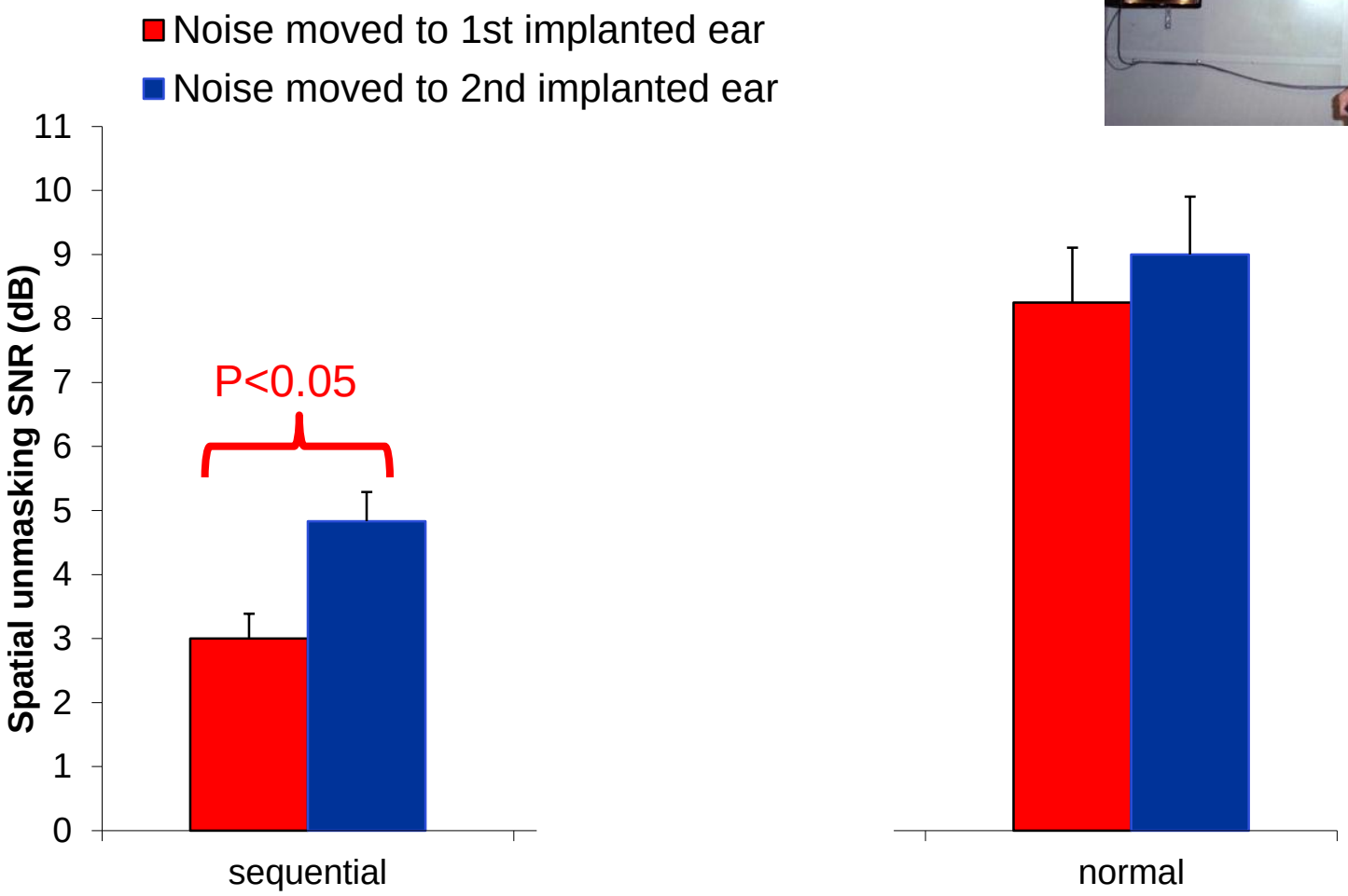


Spatial release from masking



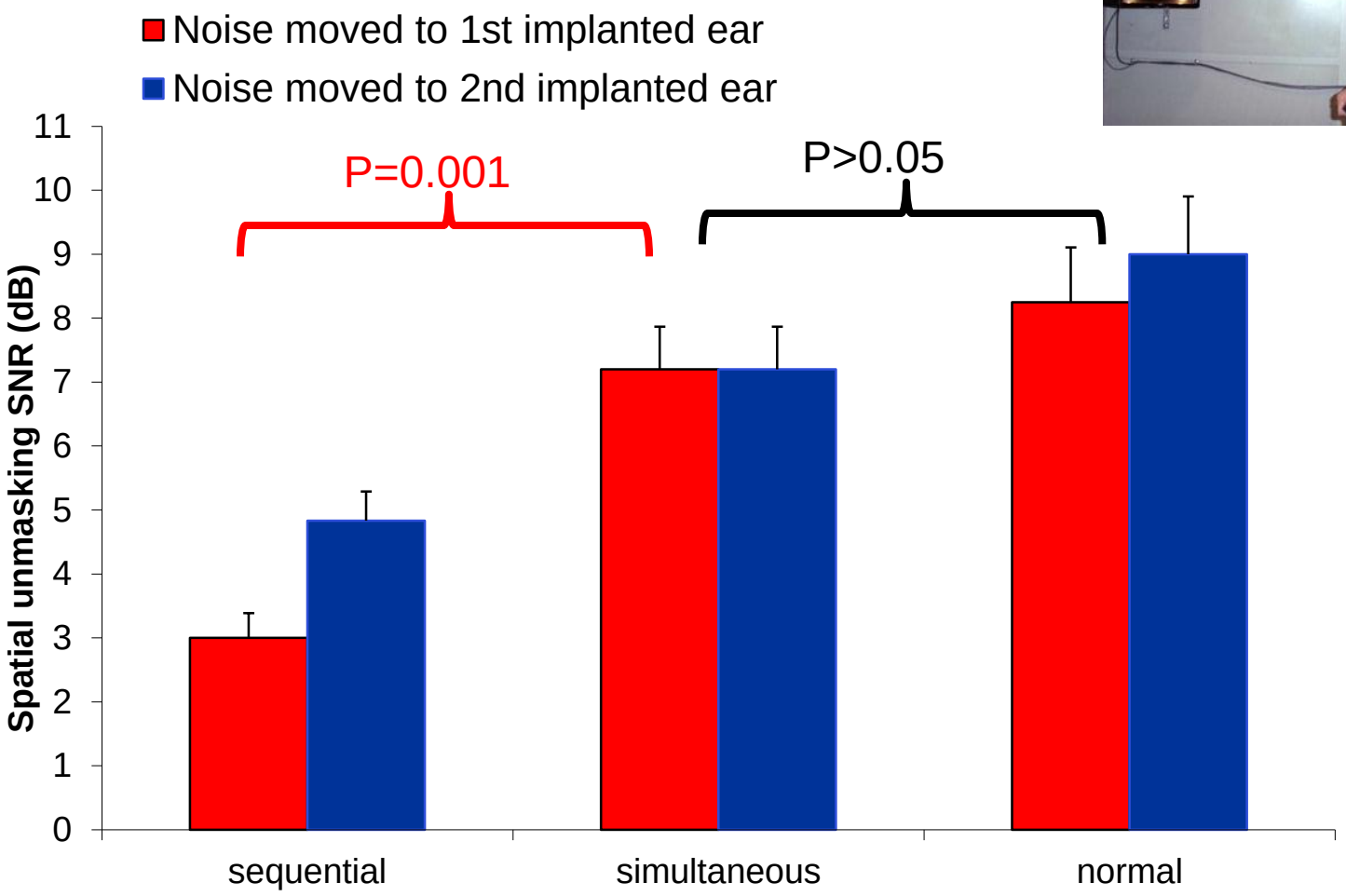
Chadha et al., *Otol NeuroOtol*, 2011

Spatial release from masking



Chadha et al., *Otol NeuroOtol*, 2011

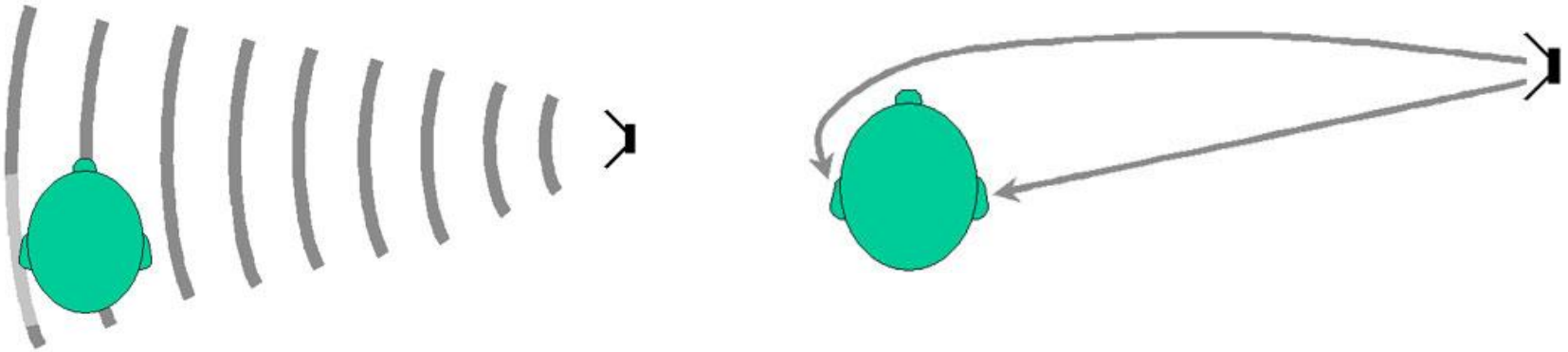
Spatial release from masking



Chadha et al., *Otol NeuroOtol*, 2011

How does binaural hearing work?

- Sound reach one ear before the other and at different levels



- These cues must be detected by the central auditory system

Can we promote binaural hearing with bilateral cochlear implants?

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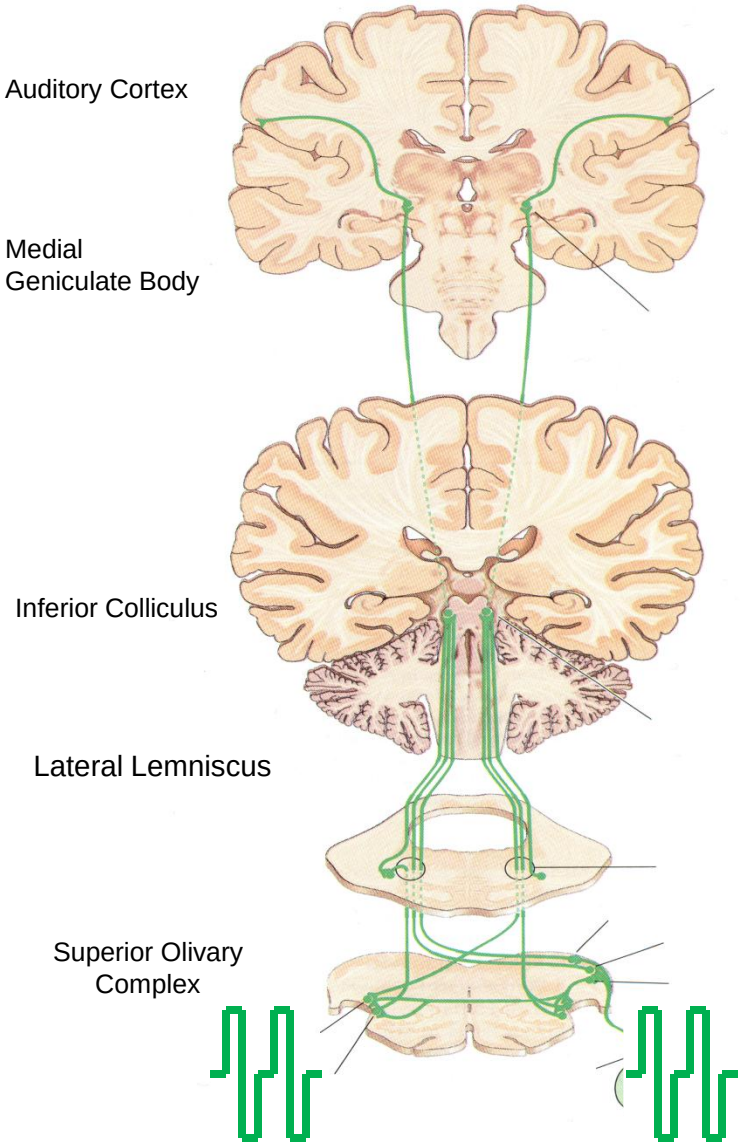
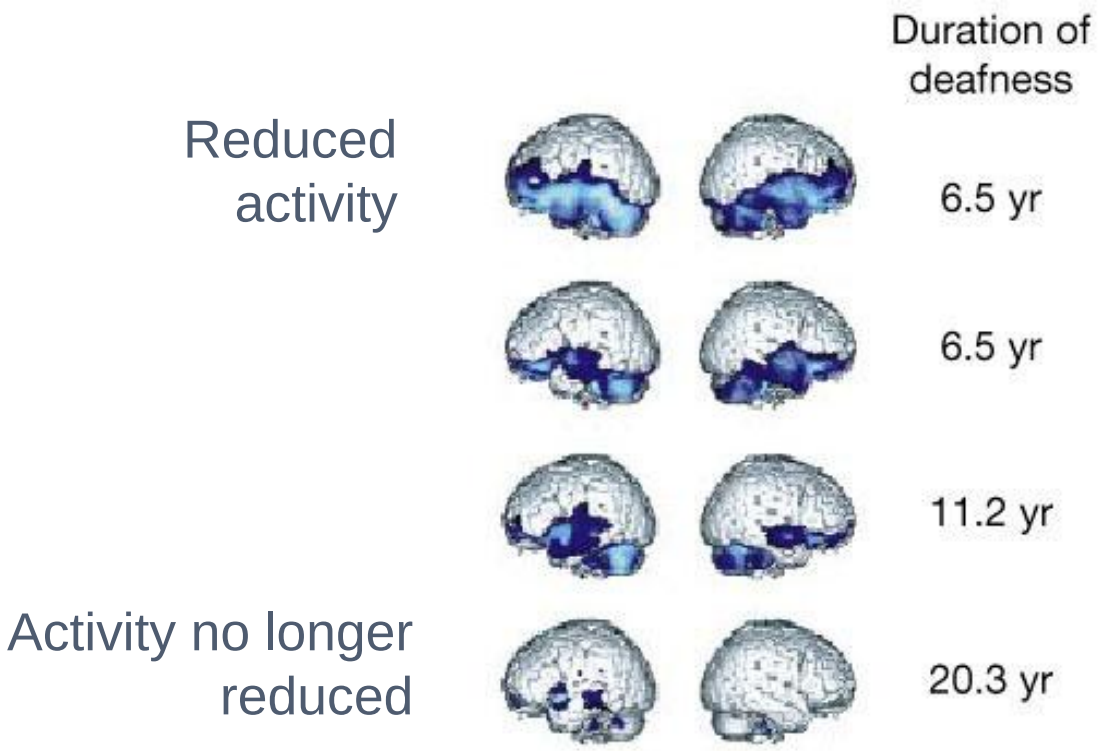


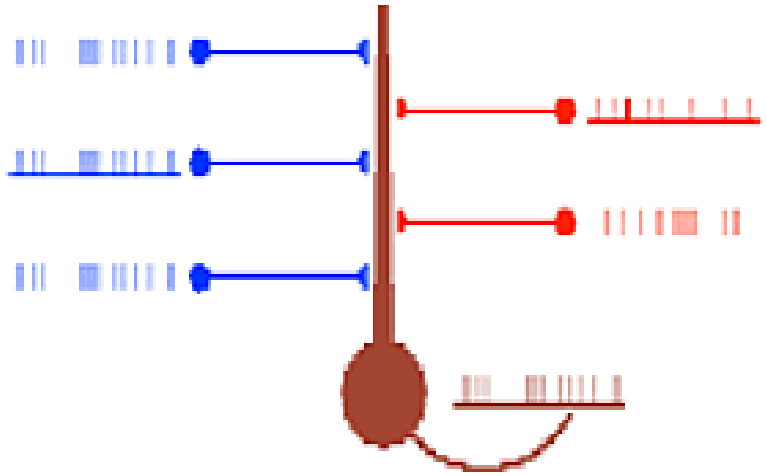
Will binaural processing be limited by deafness in early development?



Lee, et al., Nature, 2001

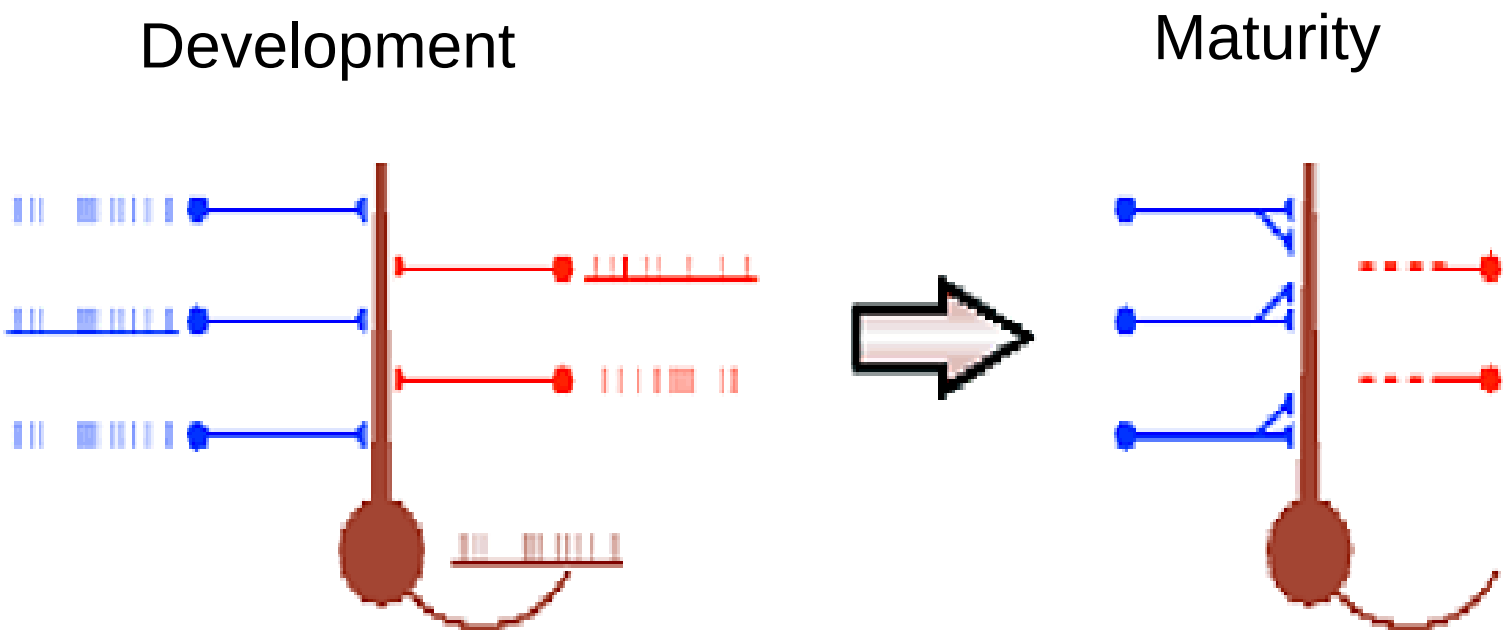
Neural competition in development

Development



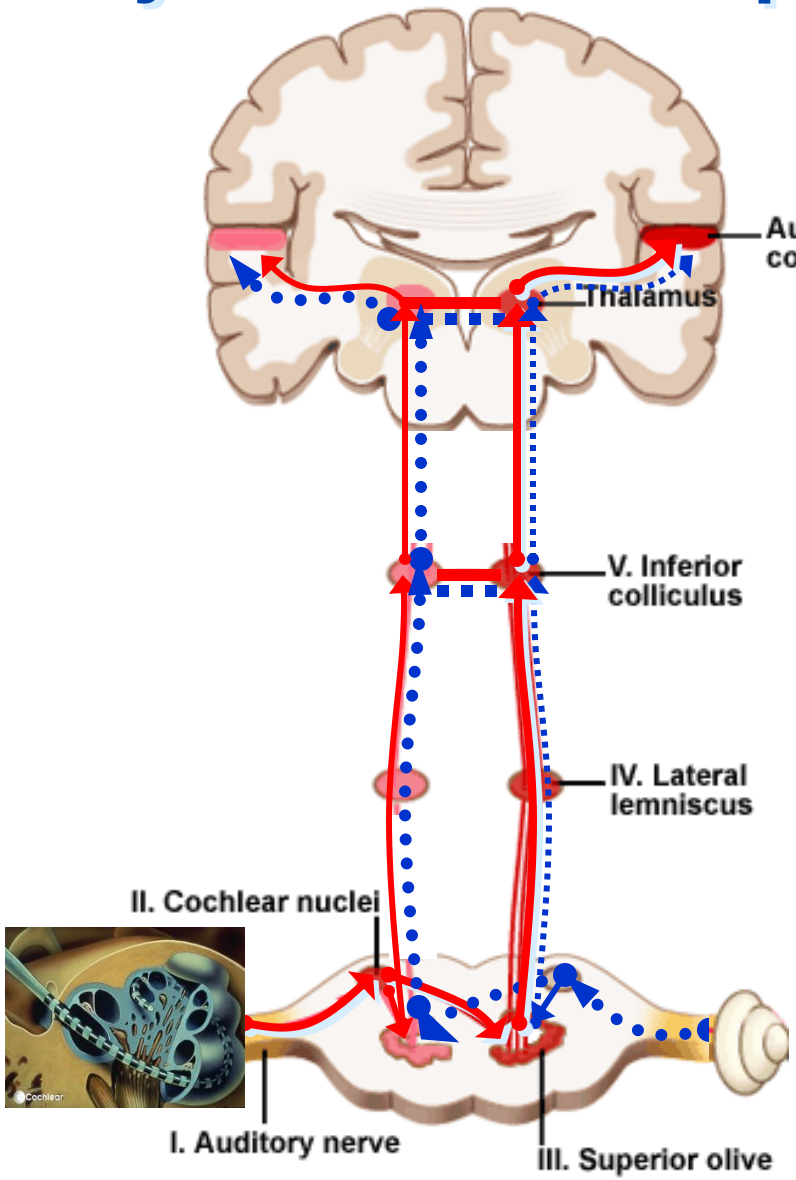
Sherman, *Nature Neuroscience* **3**, 525 - 527 (2000)

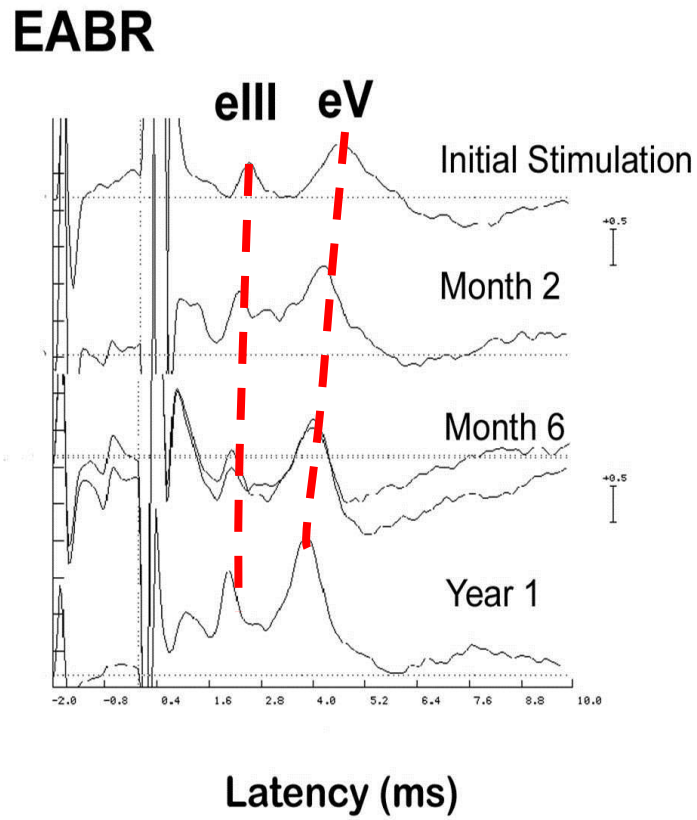
Neural competition in development



Sherman, *Nature Neuroscience* **3**, 525 - 527 (2000)

Unilaterally driven development

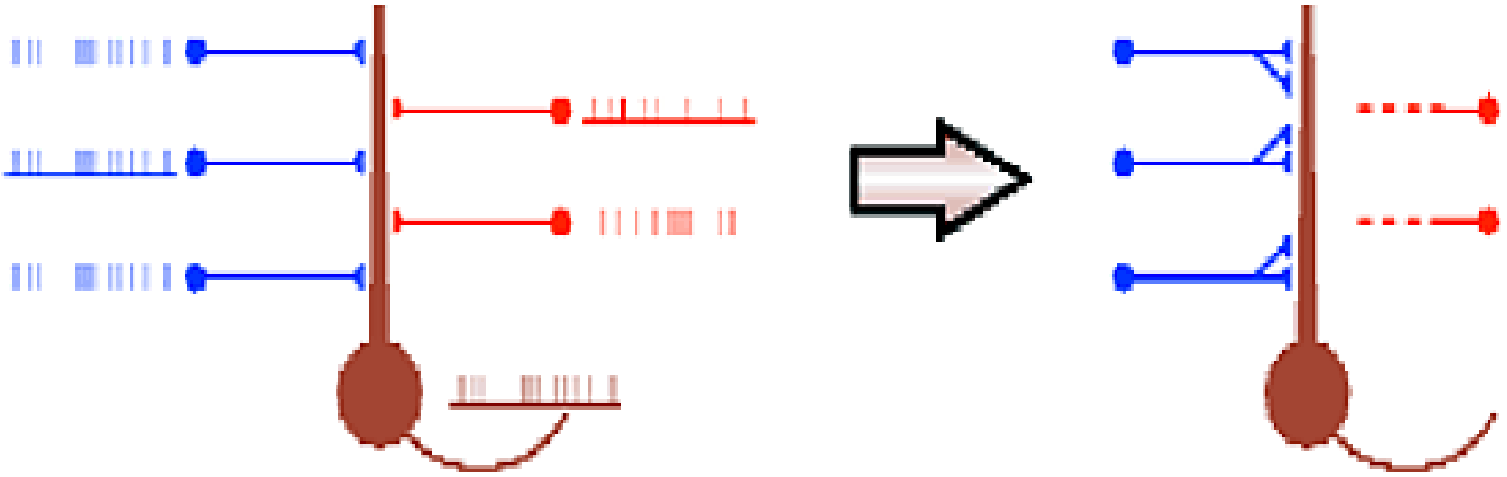




Neural competition in development

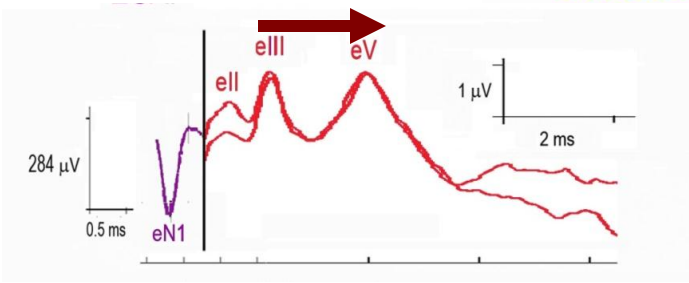
Development

Maturity in auditory brainstem with 2 years CI use



Sherman, *Nature Neuroscience* **3**, 525 - 527 (2000)

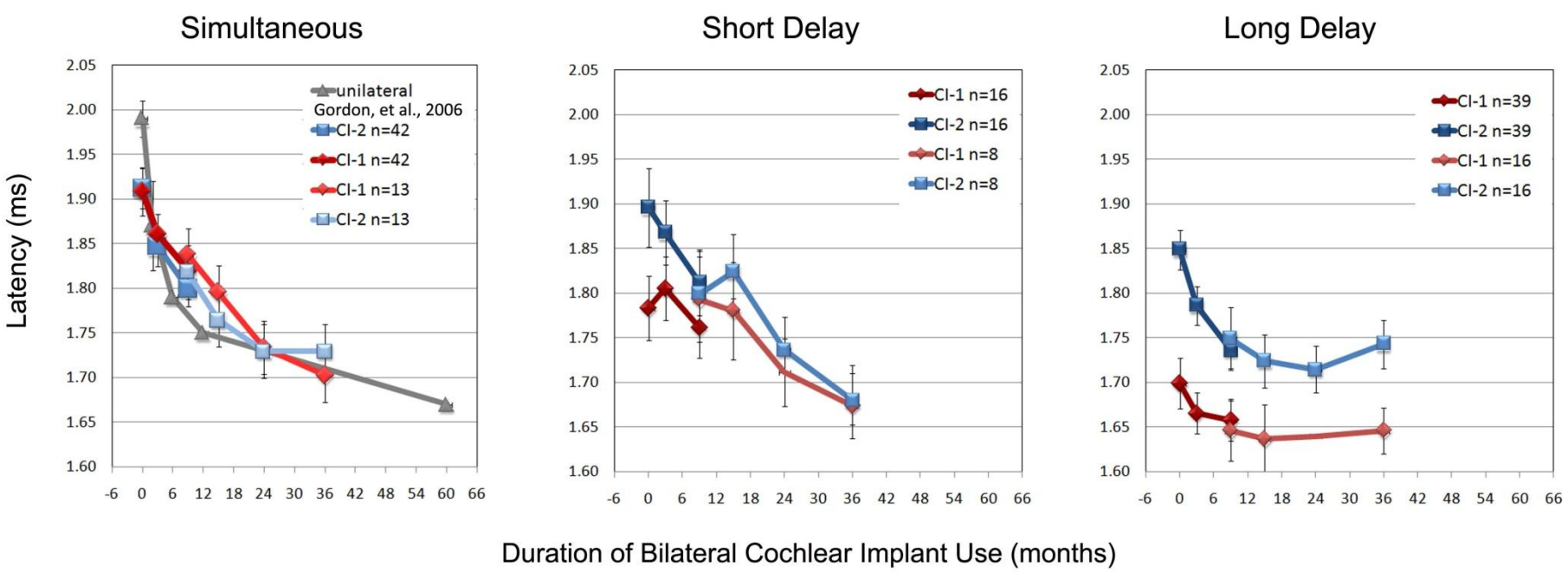
Restricted auditory brainstem plasticity after 2 years of unilateral implant use



Unilateral CI use: nil

Unilateral CI use: 6-12 months

Unilateral CI use: > 2 years



Gordon, et al., 2010

Auditory evoked cortical responses are abnormal in the naïve ear

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Experienced ear

Naïve ear

Imaging brain activity in cochlear implant users

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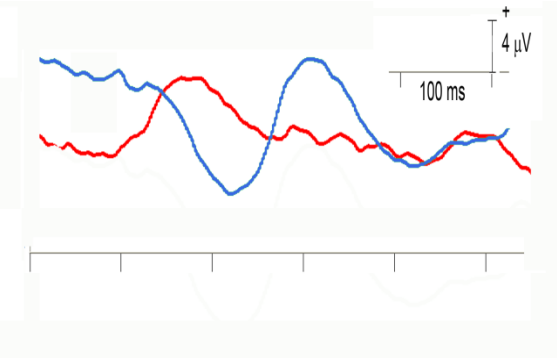
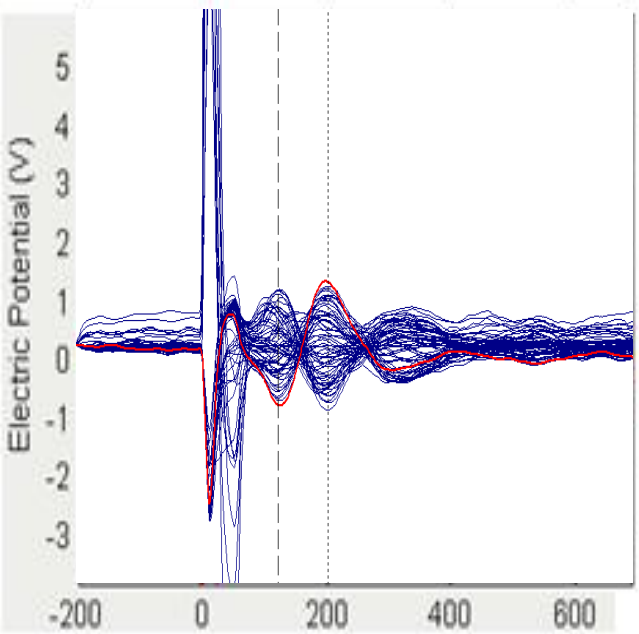
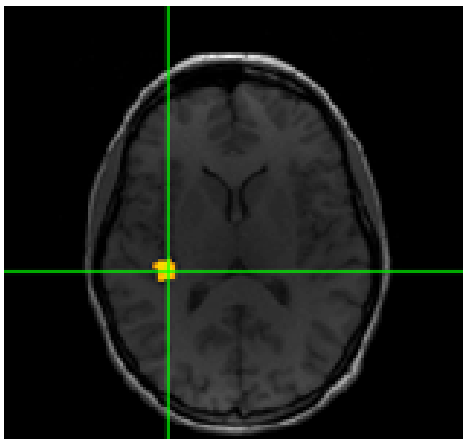
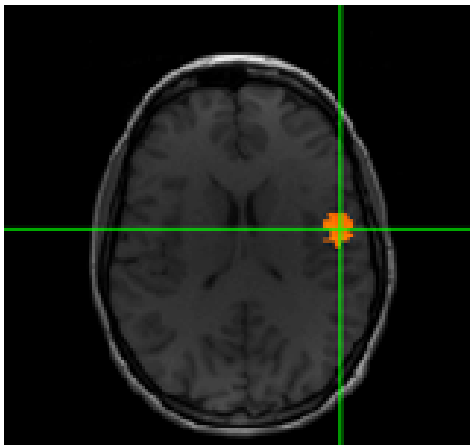
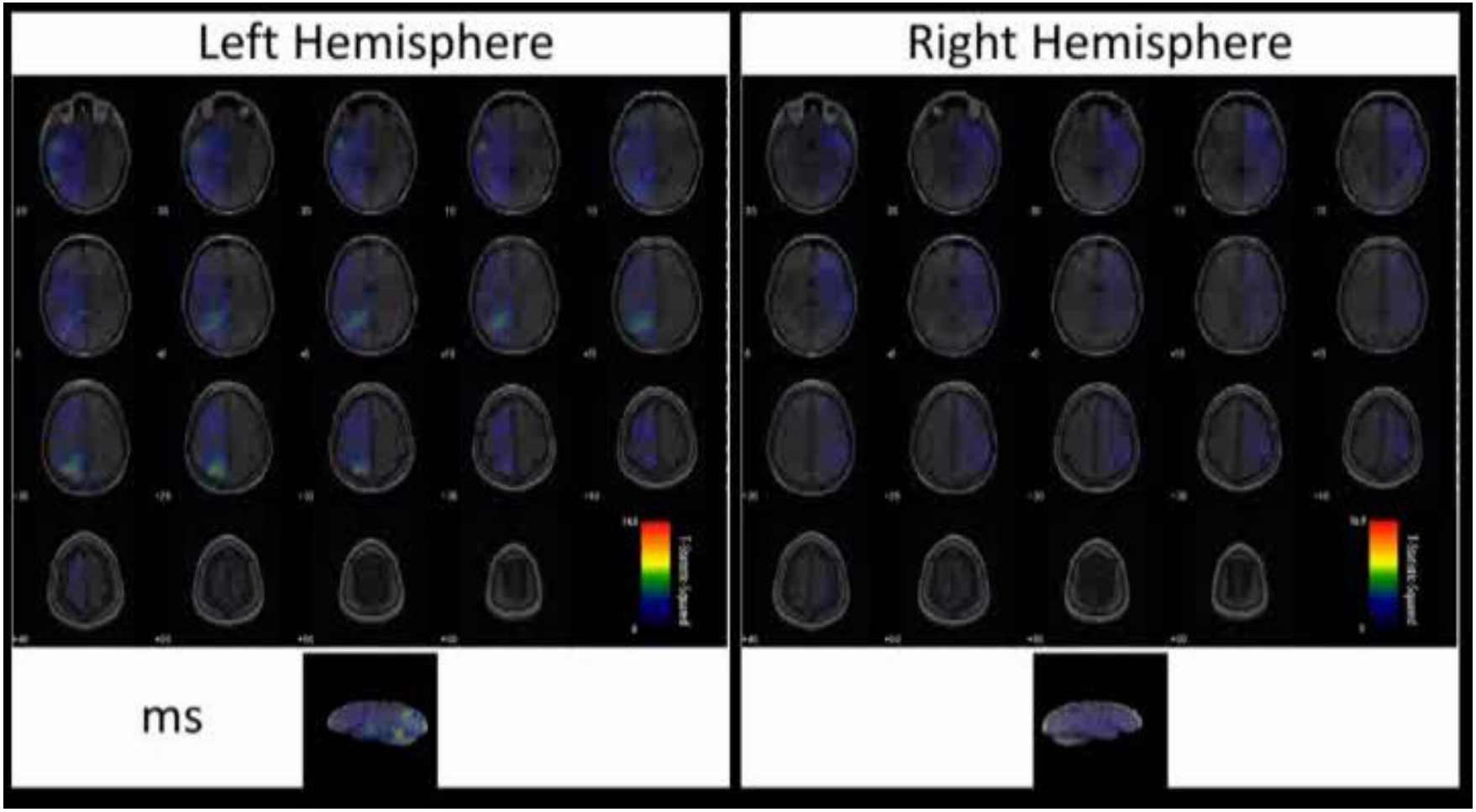




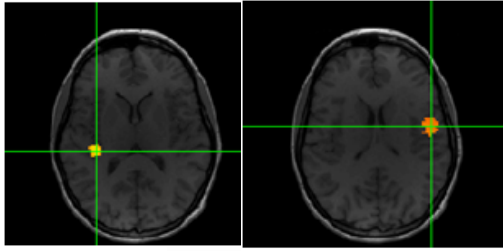




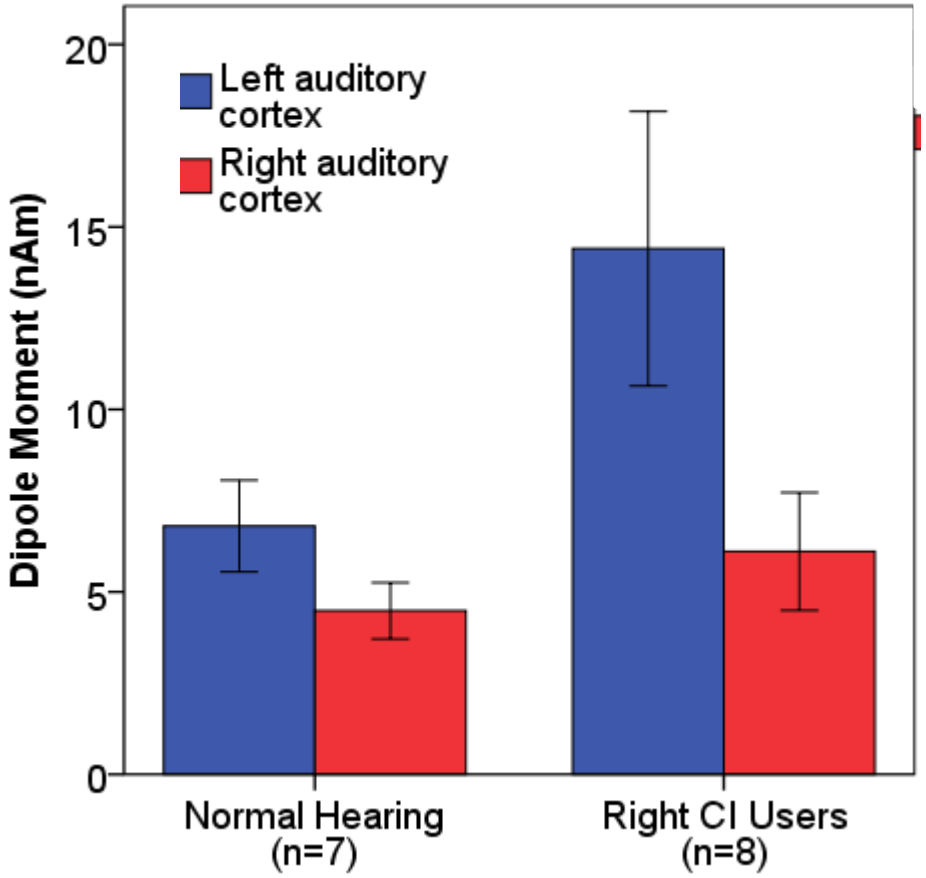
Imaging brain activity in cochlear implant users

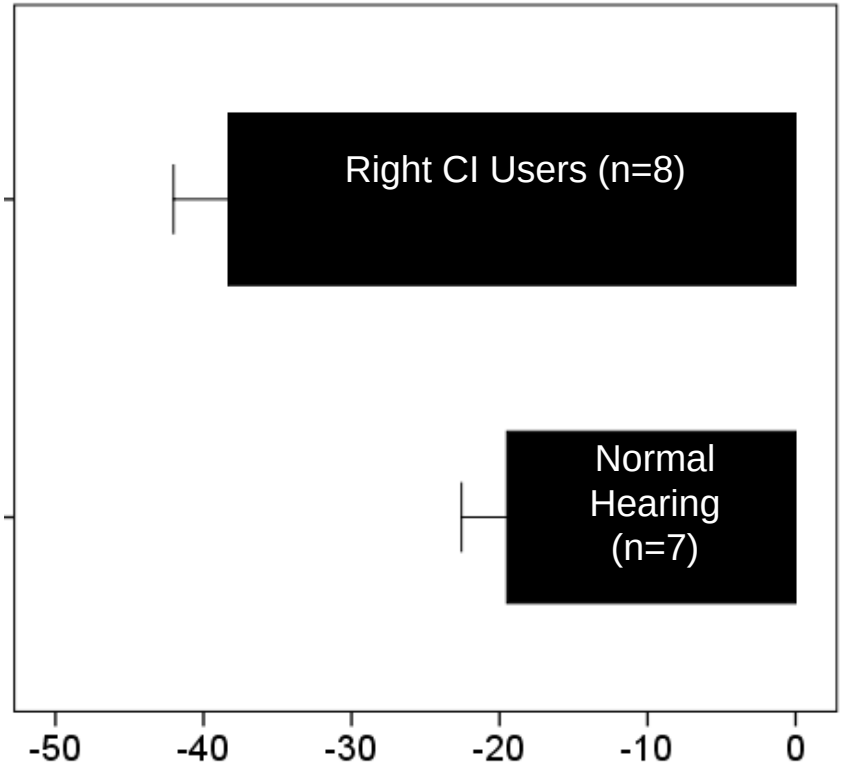


Abnormal cortical activity after right cochlear implant use



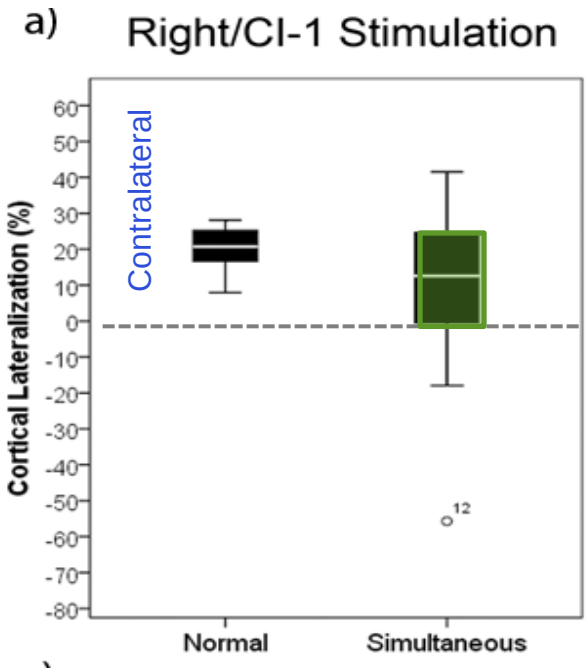
Clicks/pulses presented to right ear

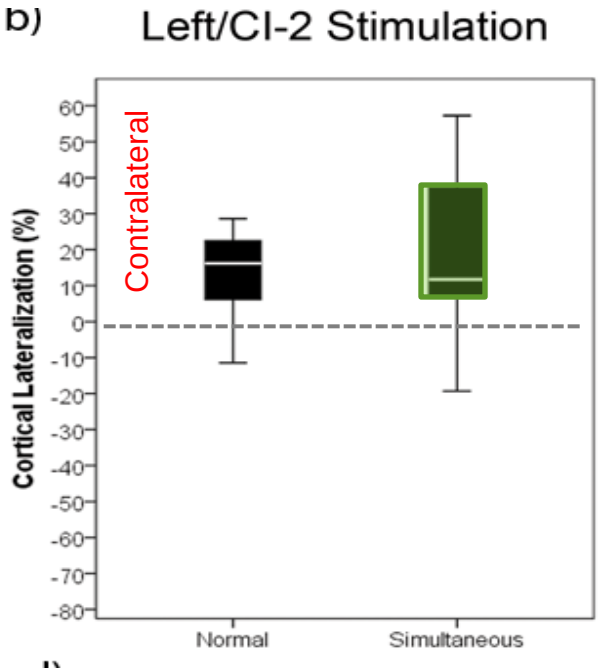




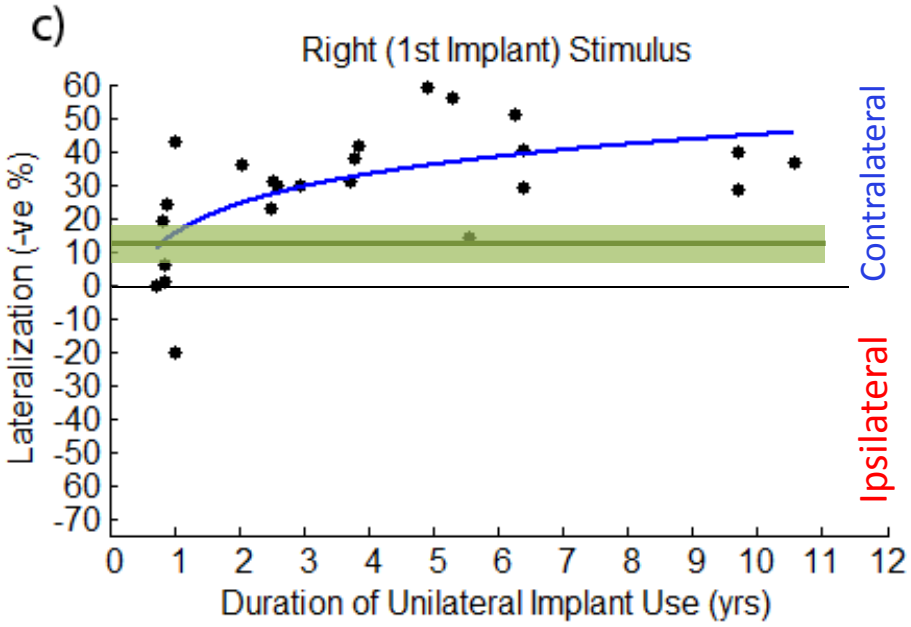
% Activity in Left Auditory Cortex
[(R-L)/(R+L)x100]

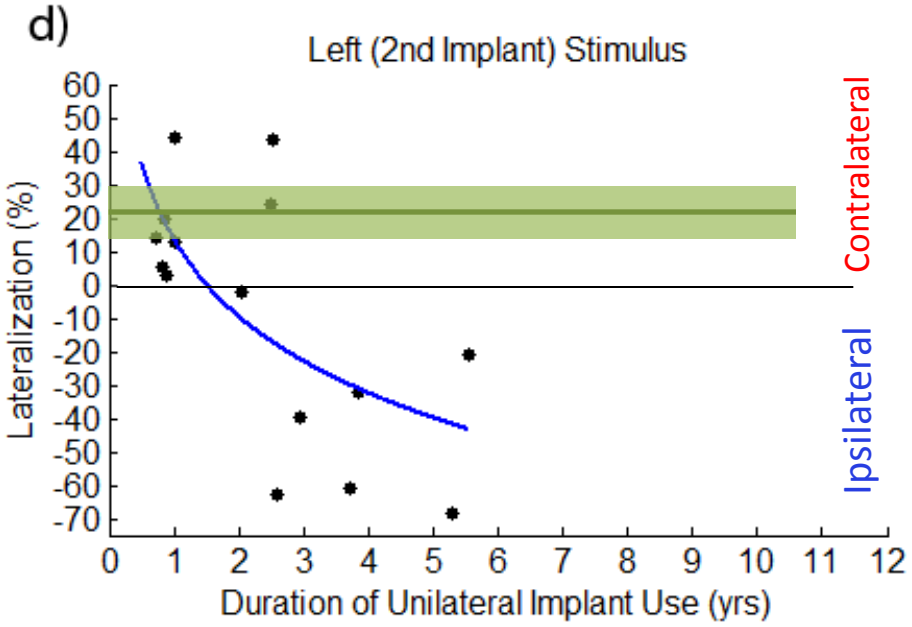
Normal cortical lateralization after simultaneous bilateral cochlear implantation



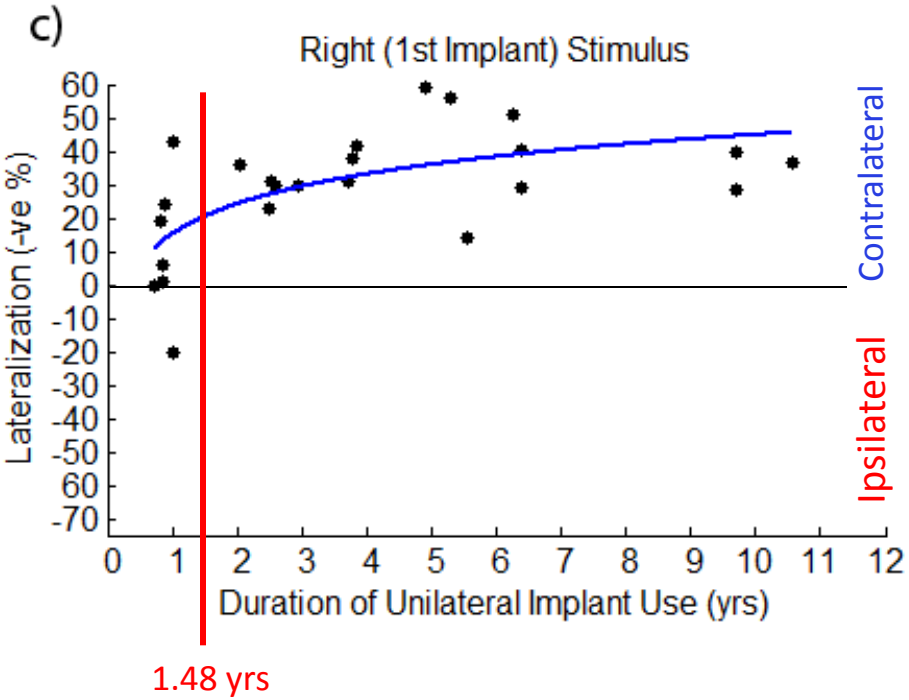


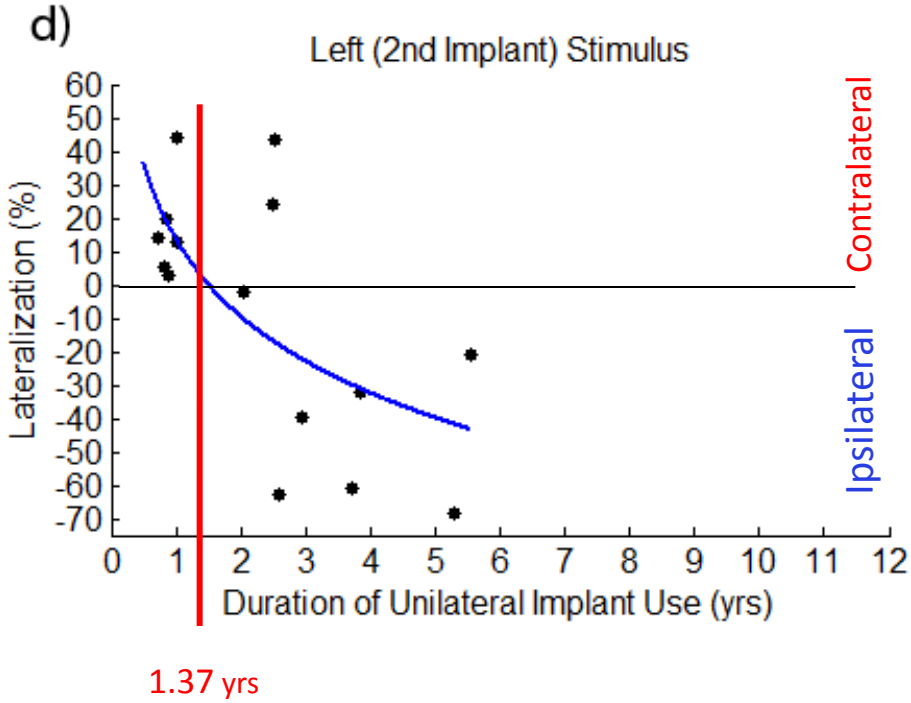
Increasing abnormality in cortical activity with unilateral cochlear implant use



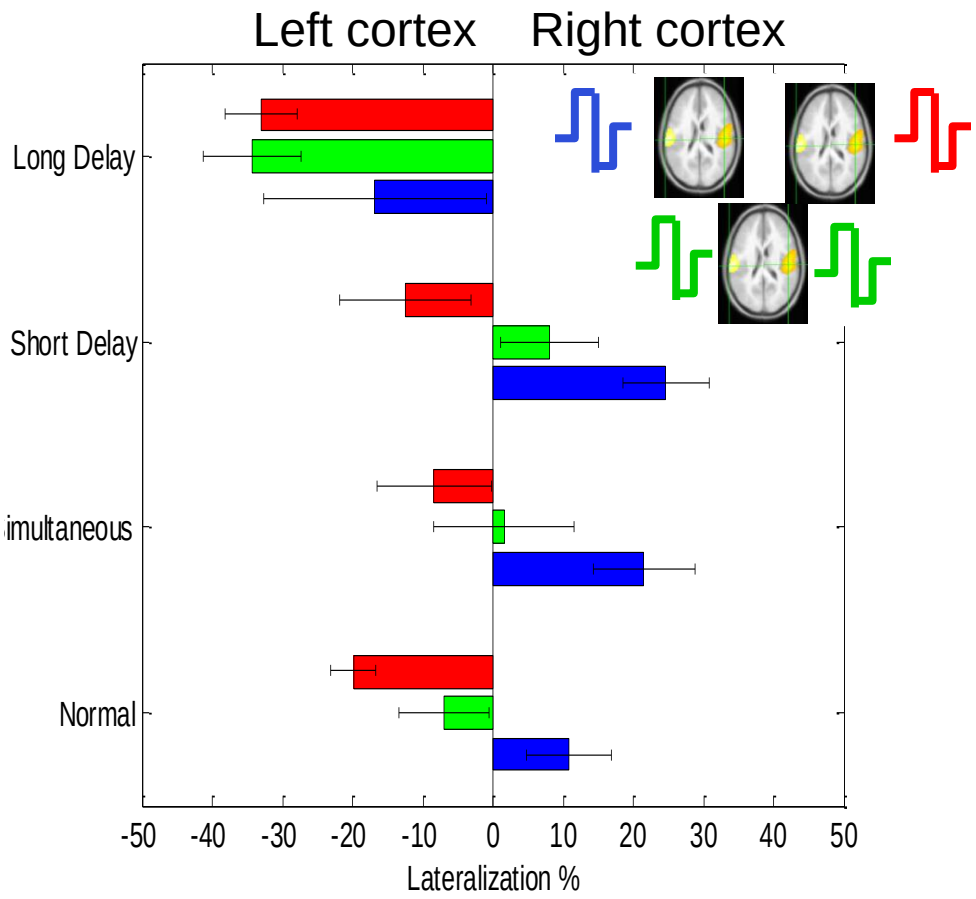


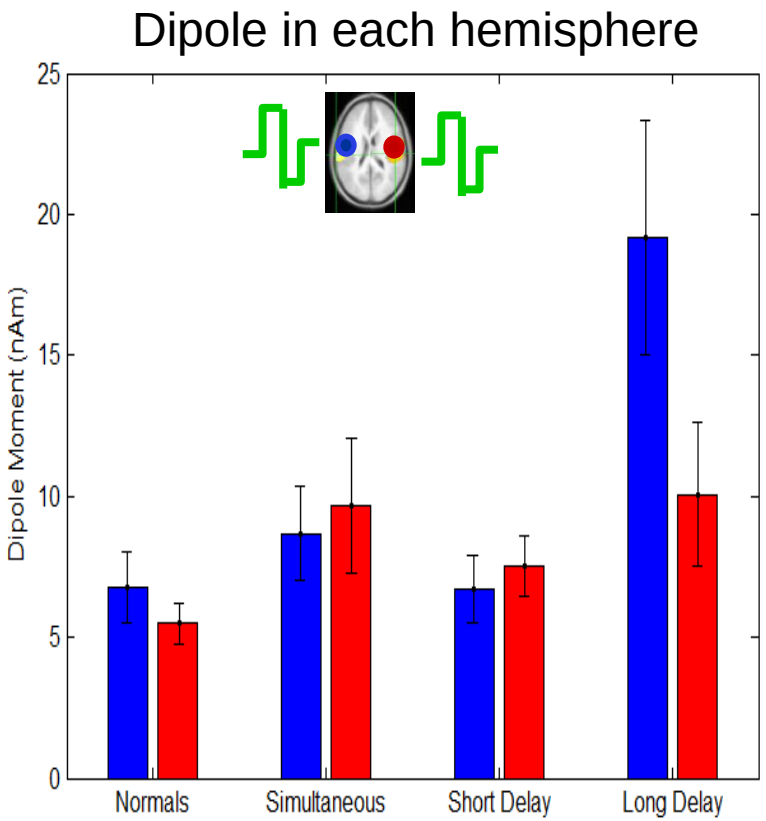
Significant change in cortical activity with ≥1.5 years unilateral cochlear implant use





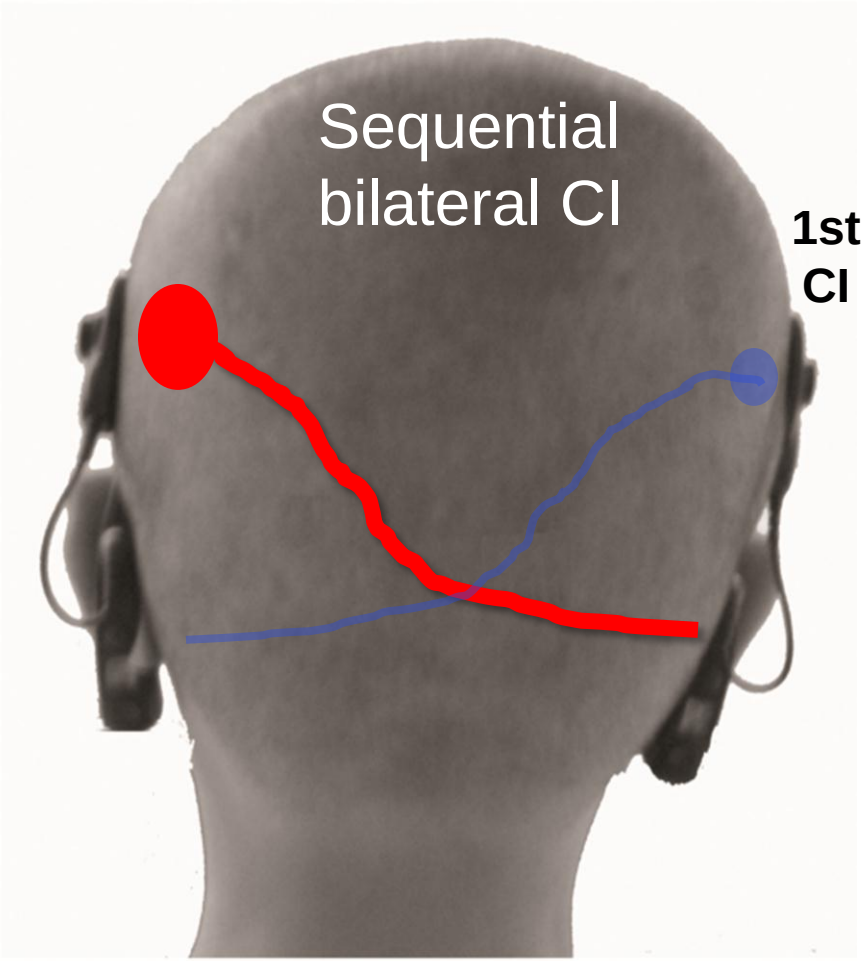
Bilateral input goes to dominant hemisphere after 2+ years unilateral stimulation





Abnormal auditory development with unilateral implant use

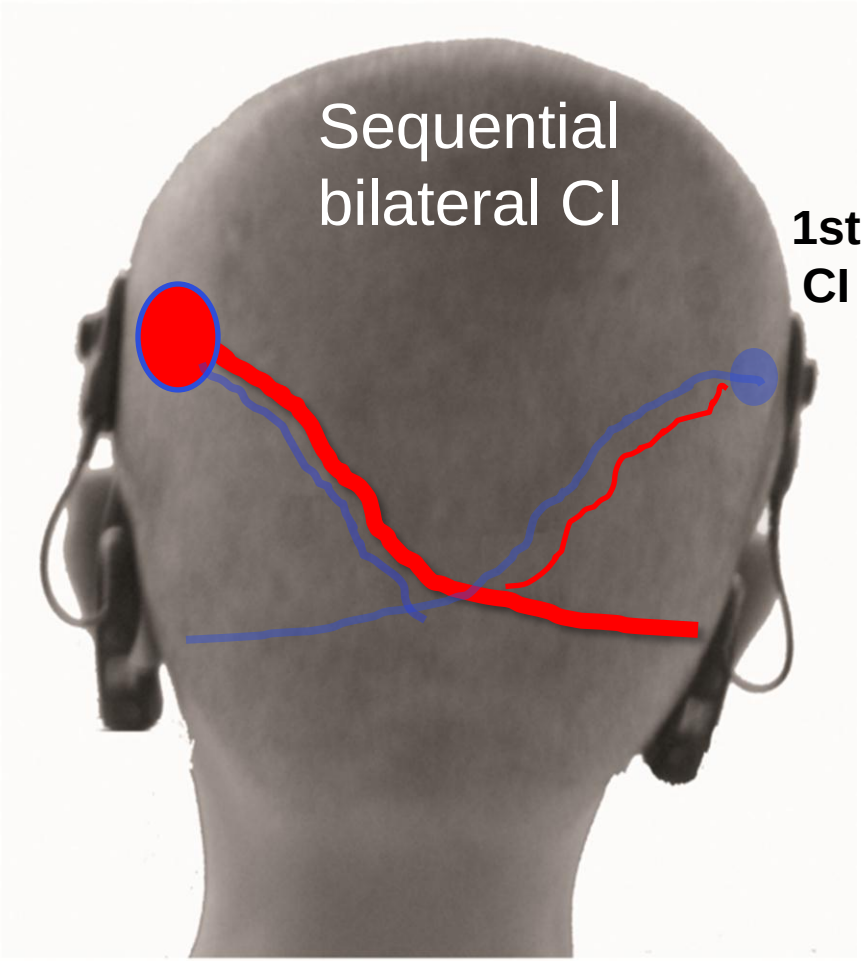
- Dominance of contralateral auditory cortex
  - Lack of inhibitory binaural processing during development

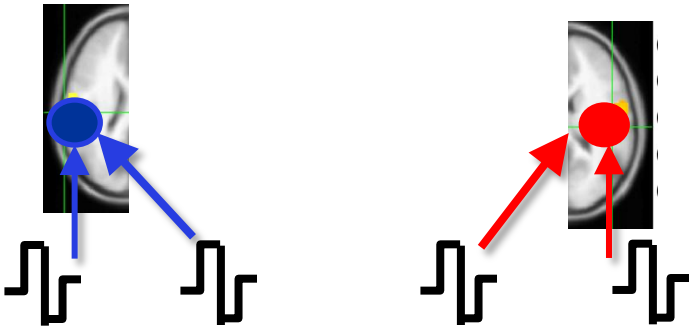


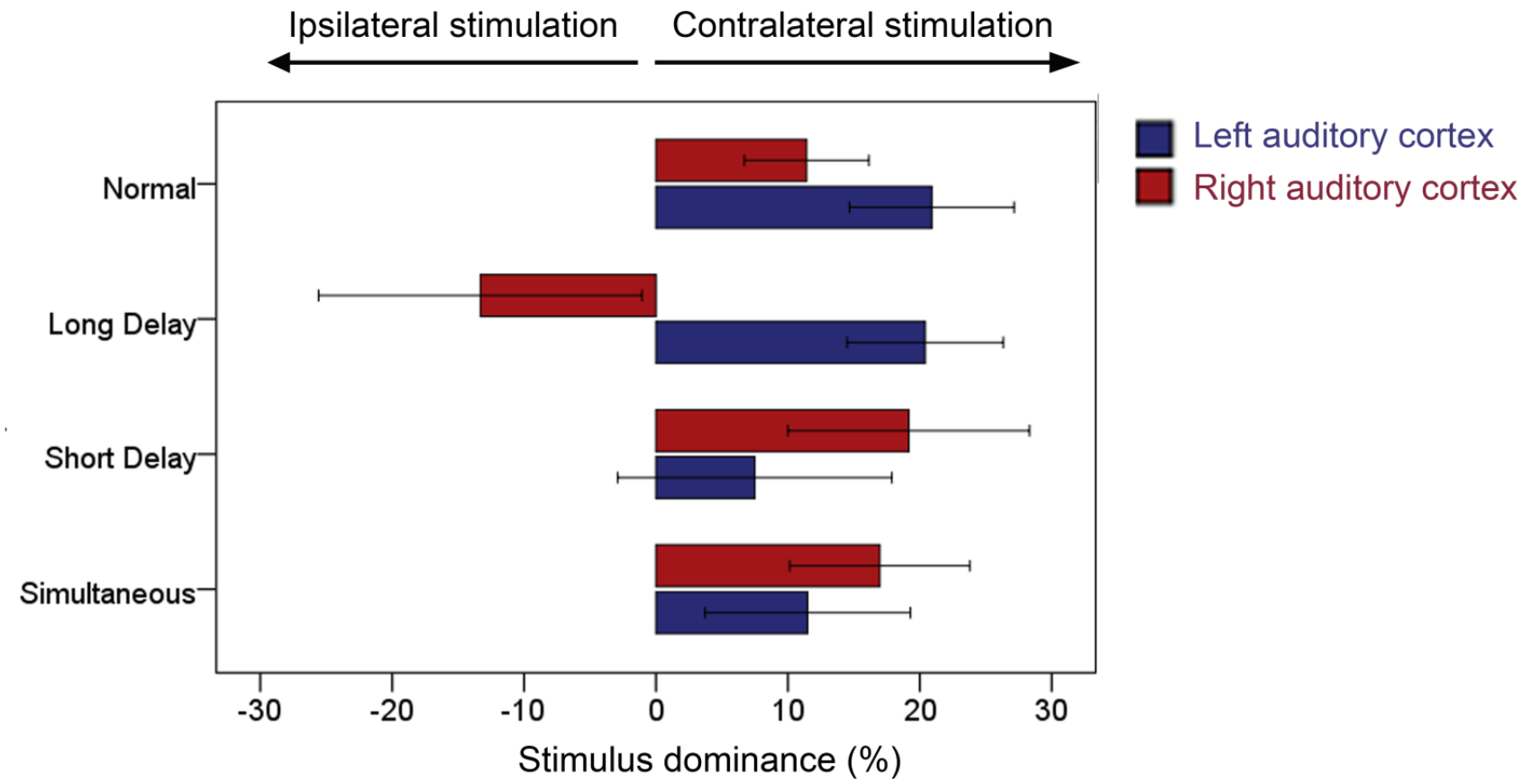
Abnormal auditory development with unilateral implant use

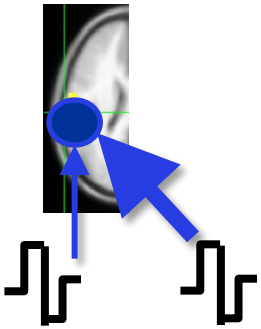
- Dominance of contralateral auditory cortex

- Ipsilateral cortex?

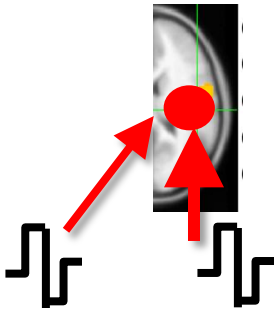




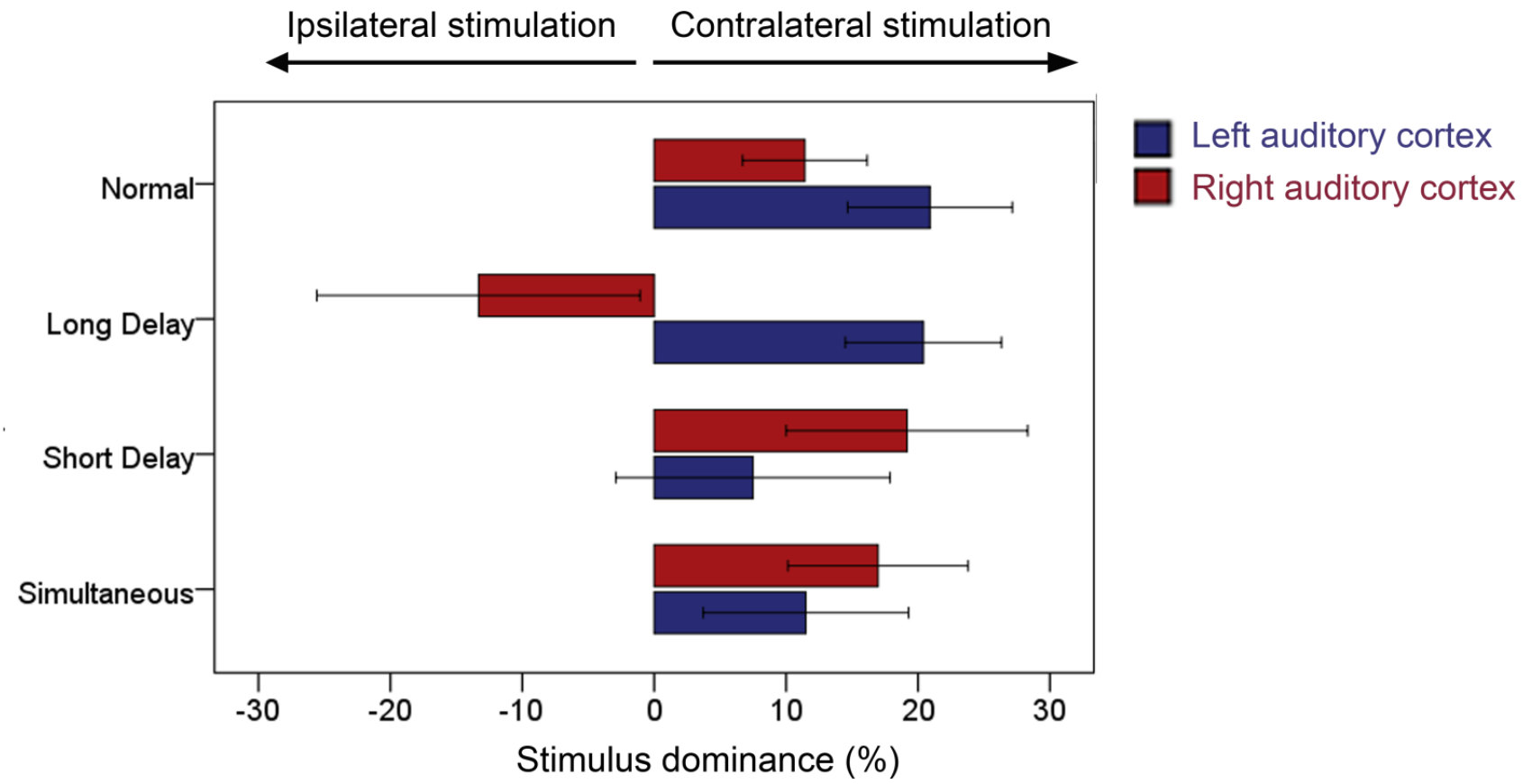

Ipsilateral stimulation
Contralateral stimulation
Normal
Long Delay
Short Delay
Simultaneous
-30
-20
-10
0
10
20
30
Stimulus dominance (%)
Left auditory cortex
Right auditory cortex



CI1



CI1


Ipsilateral stimulation
Contralateral stimulation
Normal
Long Delay
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-30
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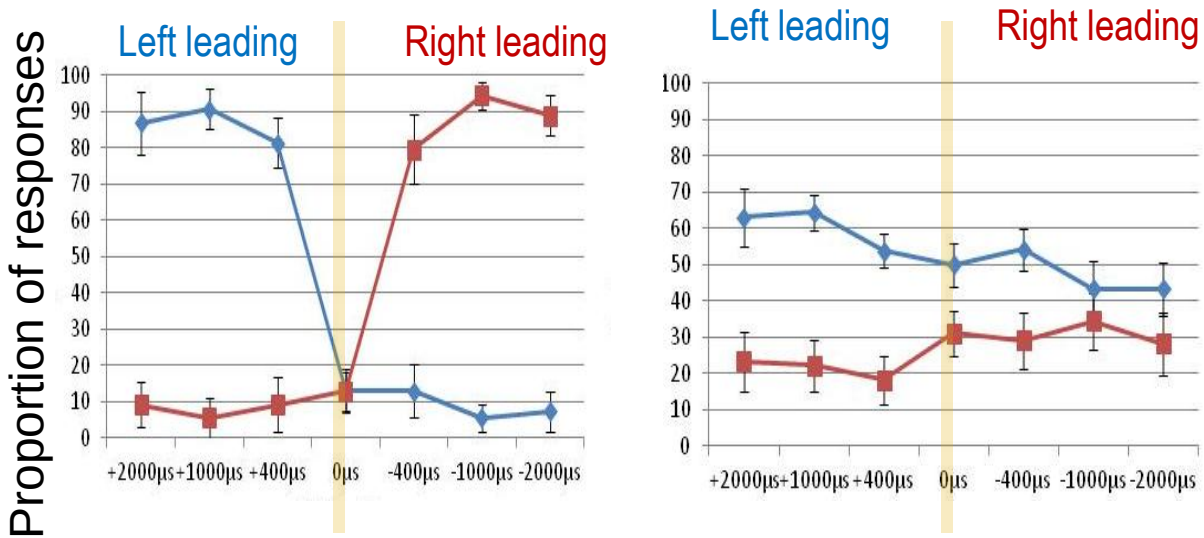
0
10
20
30
Stimulus dominance (%)
Left auditory cortex
Right auditory cortex

Perception of binaural cues restored by simultaneous bilateral implantation

● Left Responses ● Right Responses

Normal Hearing (n=9)

Sequential bilateral cochlear implant (n=19)



Inter-aural Timing Differences (us)

Salloum et al., *Ear and Hearing* , 2010

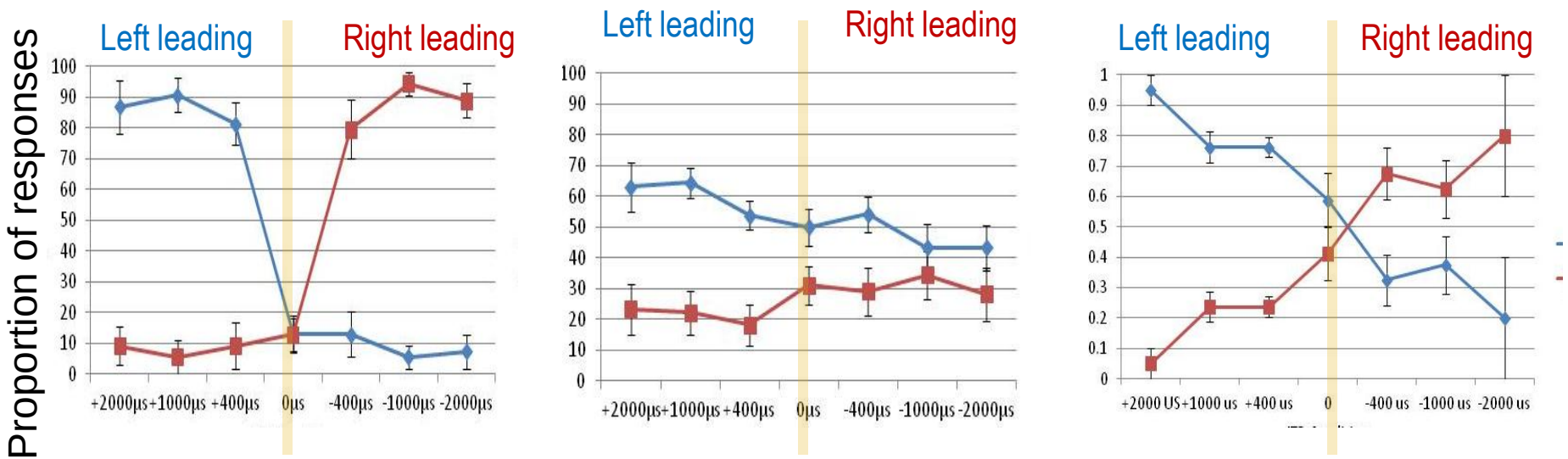
Perception of binaural cues restored by simultaneous bilateral implantation

● Left Responses ● Right Responses

Normal Hearing (n=9)

Sequential bilateral cochlear implant (n=19)

Simultaneous bilateral cochlear implant (n=8)

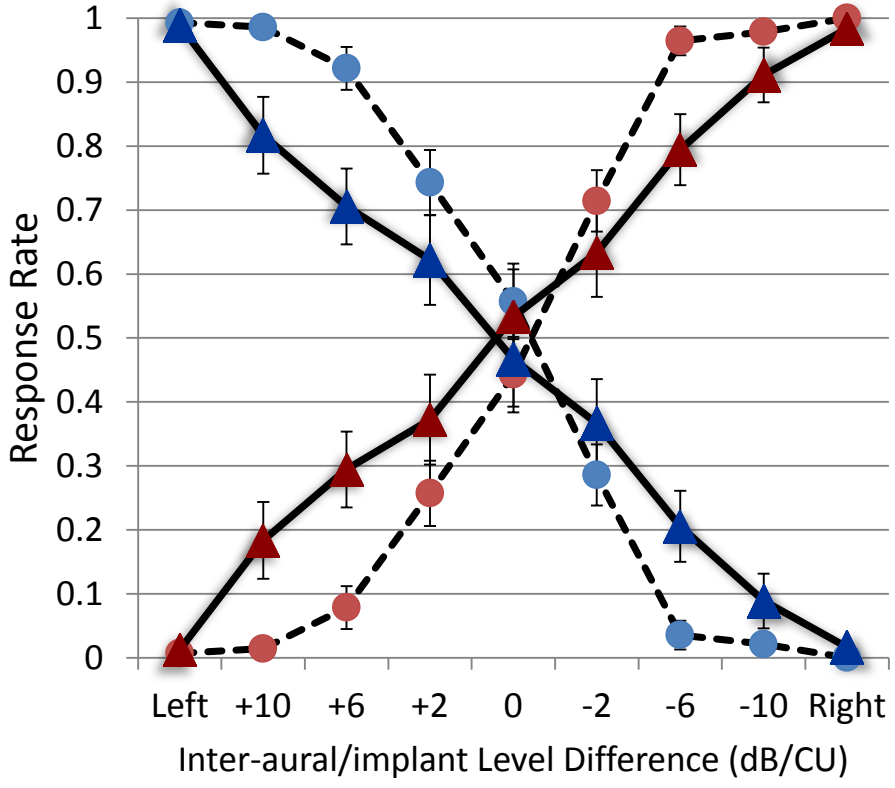


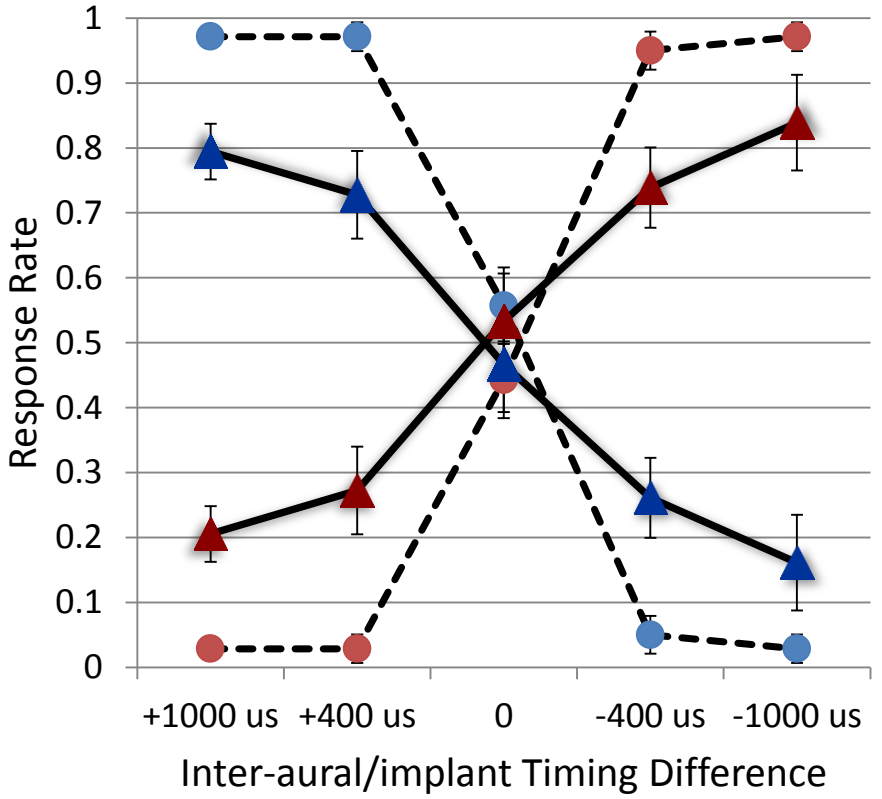
Inter-aural Timing Differences (us)

Salloum et al., *Ear and Hearing* , 2010

Perception of binaural cues restored by simultaneous bilateral implantation

Left Responses Right Responses Normal Hearing
Left Responses Right Responses Simultaneous Bilateral CI





Non-auditory benefits of simultaneous implantation

- Hospital cost-savings
  - 35% over sequential procedures
- Similar length of stay as unilateral procedures (~ 1 day)
- No increased complications (Ramsden, et al., 2009)
- Increased parental satisfaction compared with 2 surgeries in short period.
- One course of programming and therapy

Summary and Conclusions

- There is a sensitive developmental period for bilateral auditory input
- Simultaneous bilateral cochlear implantation
  - Allows symmetric development of auditory brainstem and cortex
  - Protects the brain from abnormal reorganization
  - Promotes binaural hearing
  - Provides significant cost savings over sequential procedures
- Sequential bilateral cochlear implantation
  - Does not reverse effects of unilateral stimulation
    - Abnormal asymmetry of brainstem and cortical activity
    - Abnormal binaural processing

Conclusion

- Simultaneous bilateral cochlear implantation offers a cost-effective way to promote symmetric development and function along the bilateral auditory pathways and to establish binaural hearing for children who are deaf.

Thank you to all of our participants