

Plasticity in the developing auditory system

Karen A. Gordon



Cochlear Implant Team

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STUDENTS

- Daniel Wong
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TEAM CLINICIANS

- Sharon Cushing
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- Naureen Sohail
- Laurie MacDonald
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- Nancy Greenwald-Hood
- Susan Druker

COLLABORATORS

Local - SickKids

- Bob Harrison
- Tracy Stockley
- Mark Crawford
- Maureen Dennis

Local - external

- Sandra Trehub
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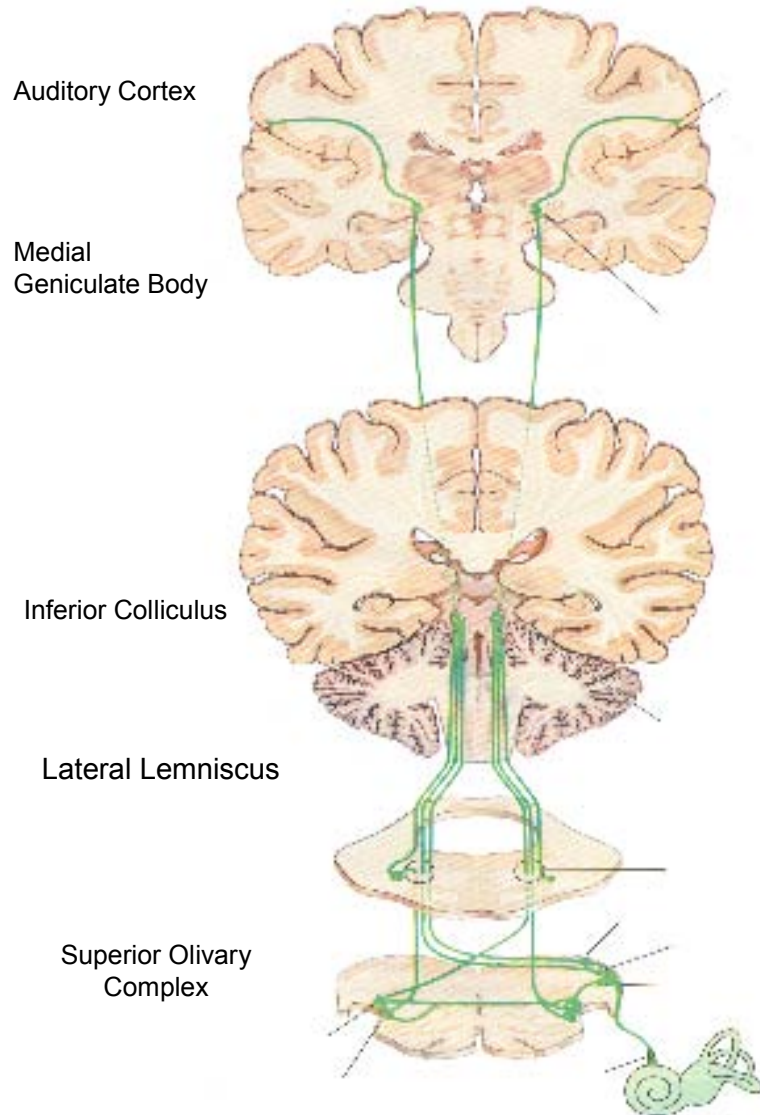
International

- Robert Cowan
- Richard van Hoesel

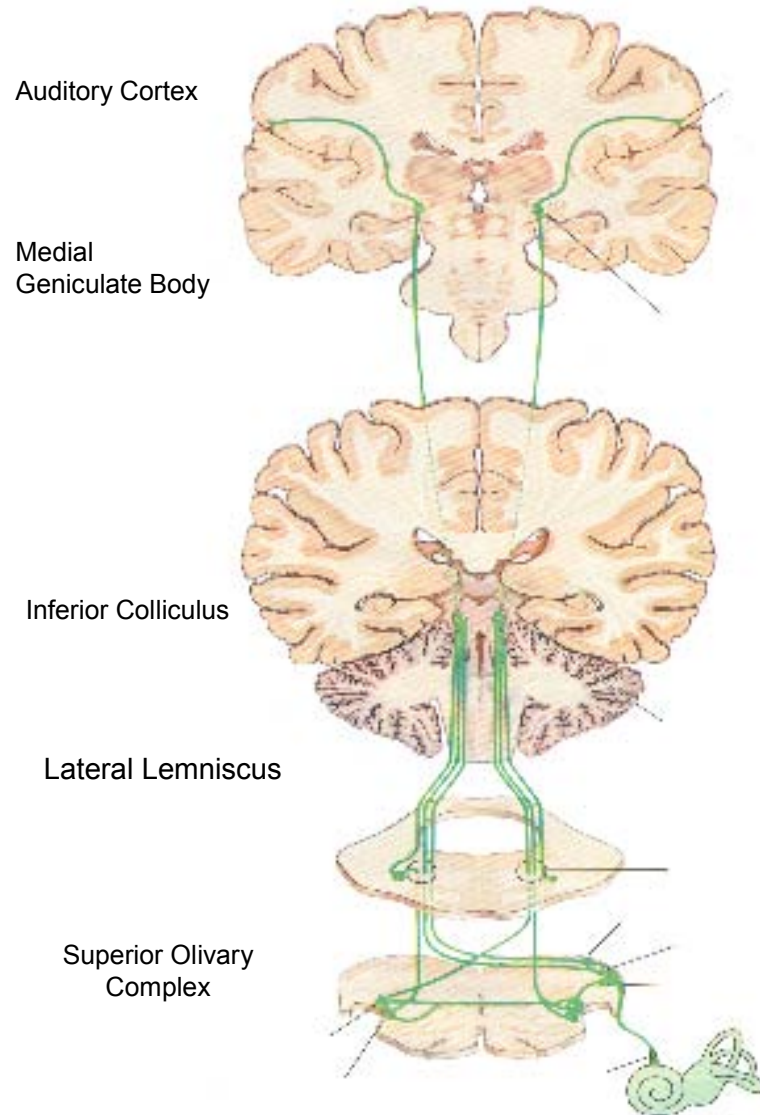
Hearing loss



Cochlear implants and hearing aids “awaken” the auditory pathways

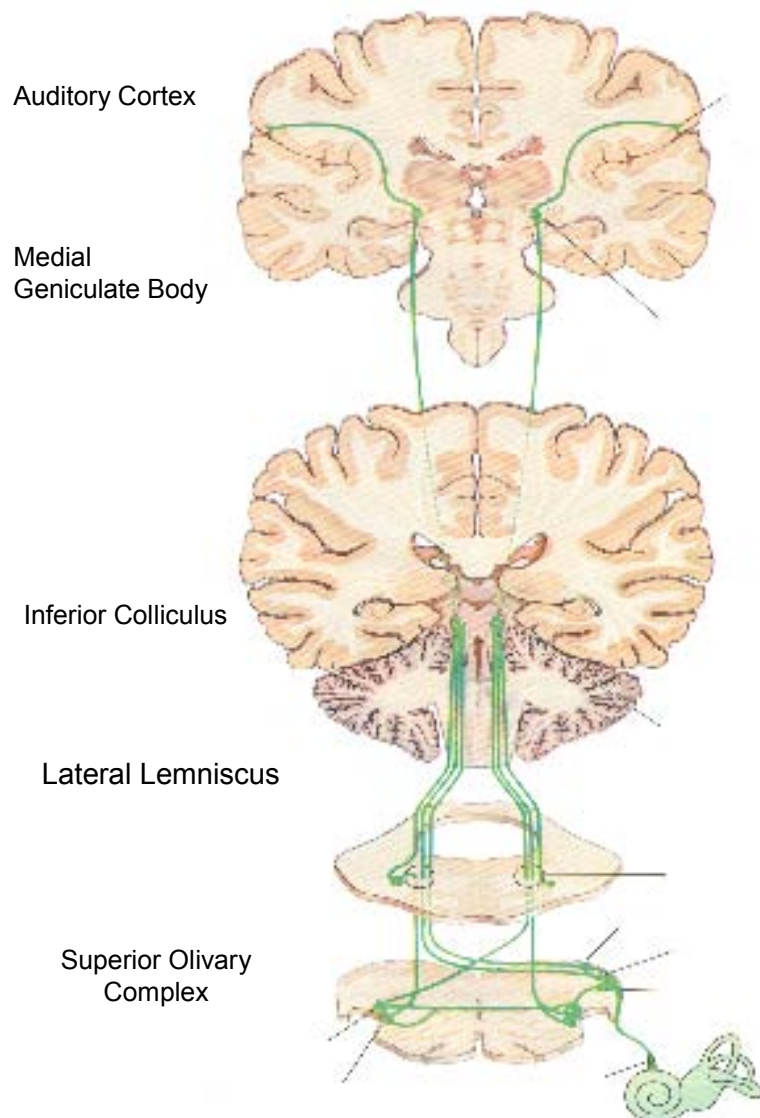


What pathways are awakened and can they develop normally?



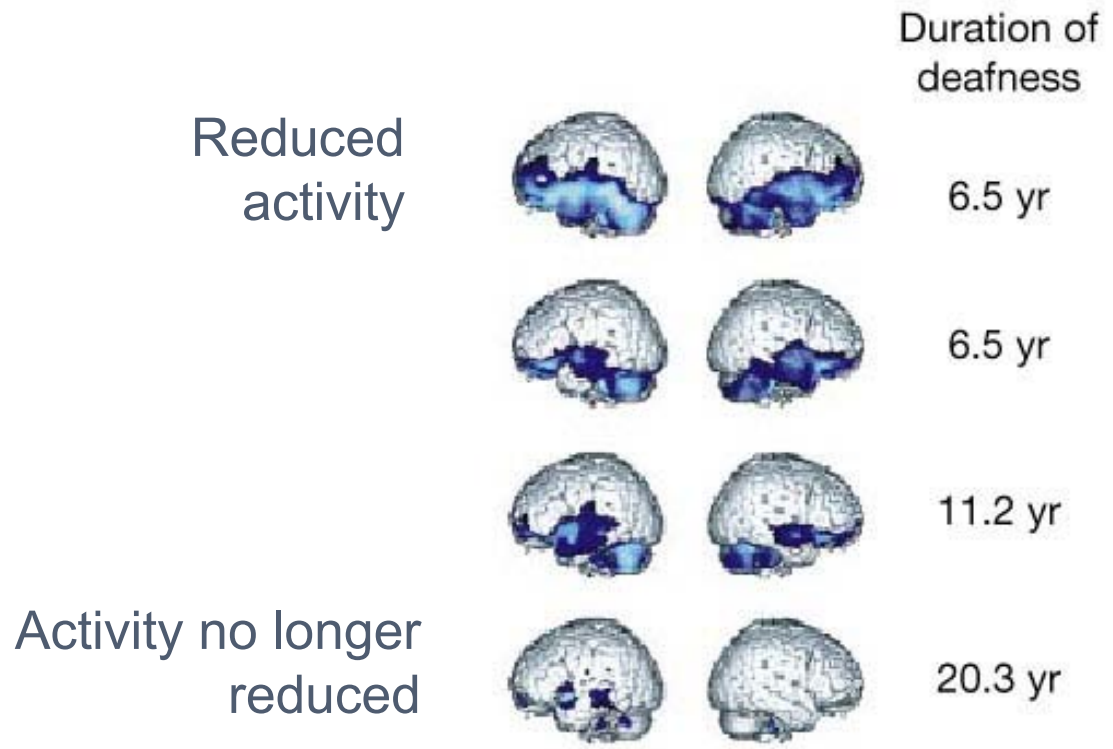
- Effects of bilateral deafness?
- Developmental plasticity?

What pathways are awakened and can they develop normally?



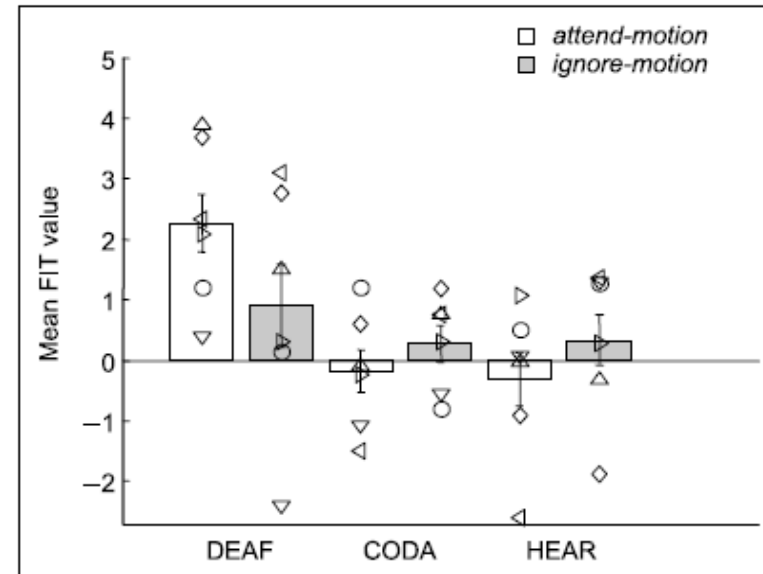
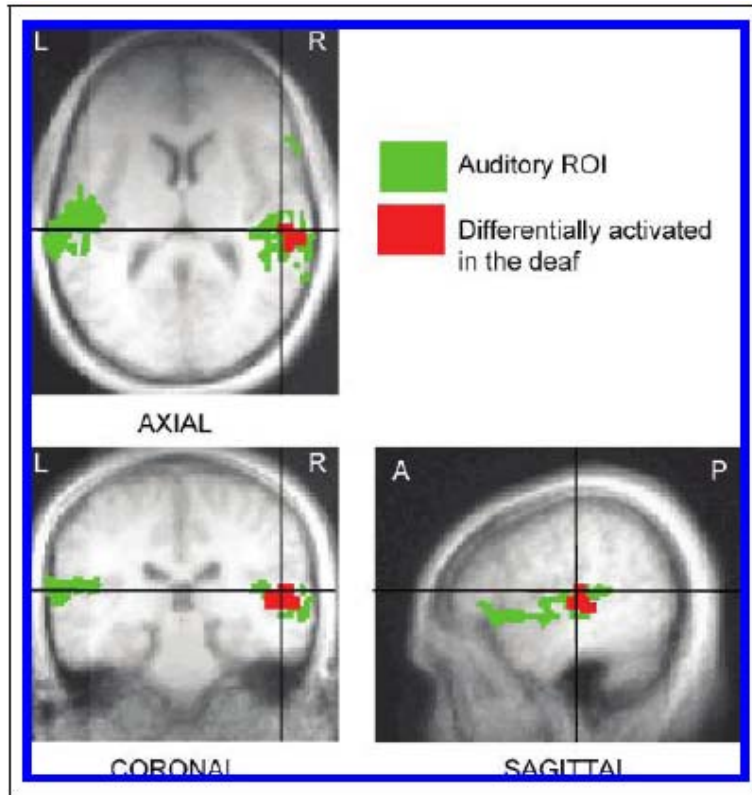
- Effects of bilateral deafness?
 - Abnormal cortical function
 - Effects of etiology
- Developmental plasticity?
 - Normal and abnormal auditory development
 - Effects of unilateral stimulation

Cortical effects of bilateral deafness in early development



Lee, et al., Nature, 2001

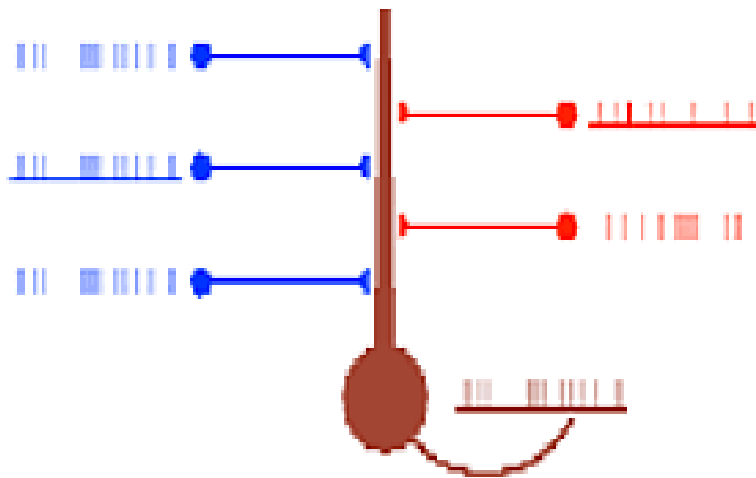
Deafness allows reorganization of association areas of auditory cortex



Fine, et al., 2005

Neural competition in development

Development



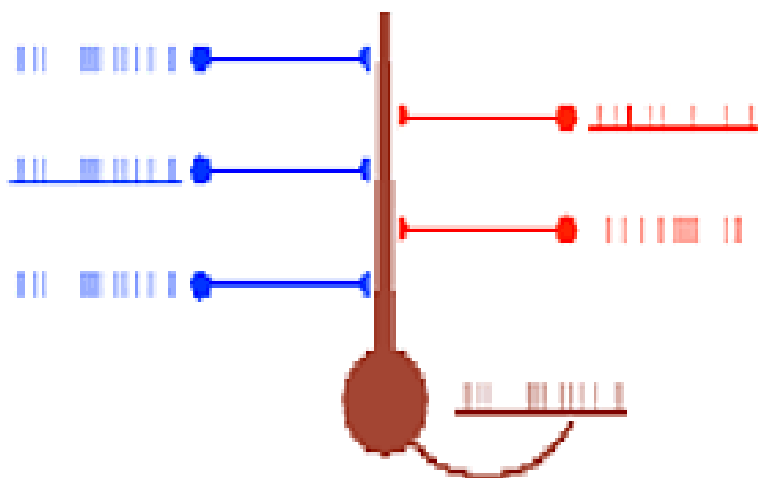
Sherman, *Nature Neuroscience* **3**, 525 - 527 (2000)

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

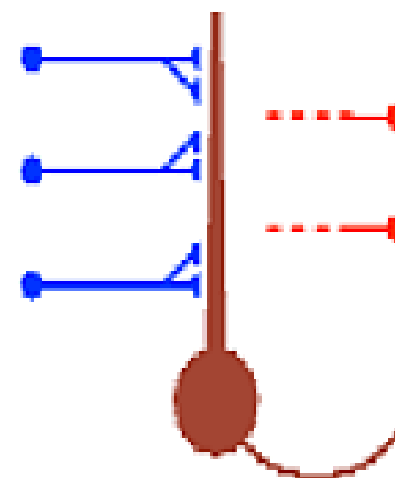
Neural competition in development



Development



Maturity



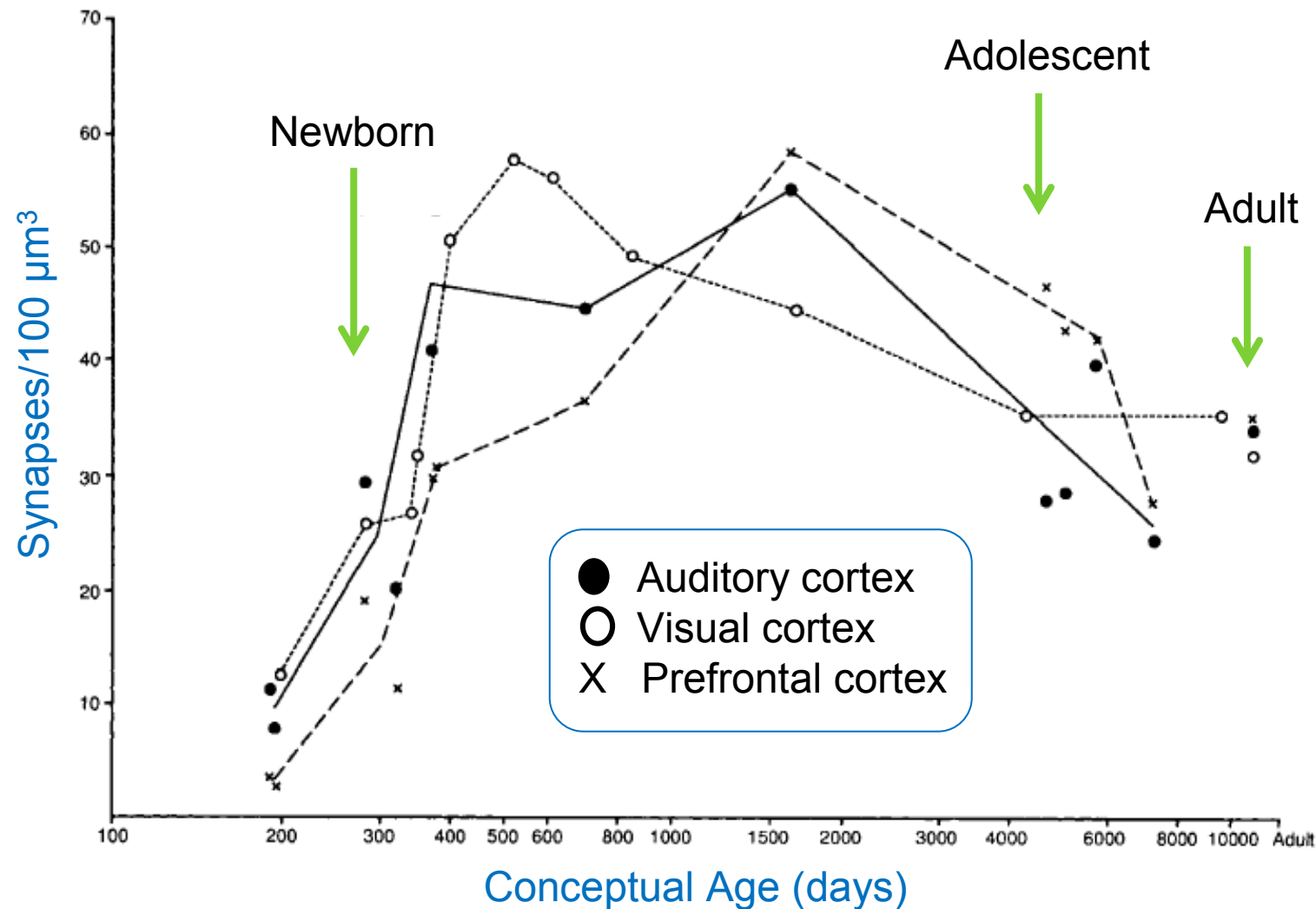
Sherman, *Nature Neuroscience* 3, 525 - 527 (2000)

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

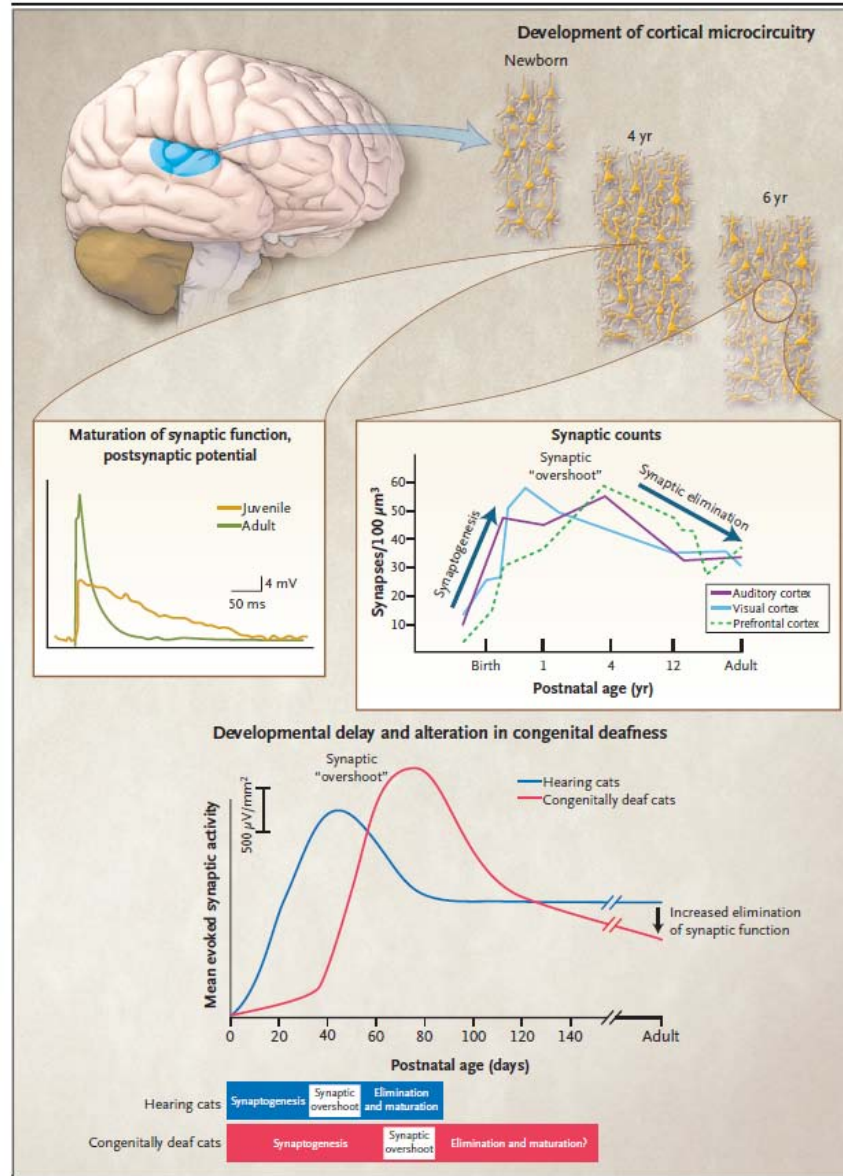
Synaptic pruning in developing human cortex

170

P.R. HUTTENLOCHER AND A.S. DABHOLKAR



Abnormal synaptic changes in congenitally deaf cats

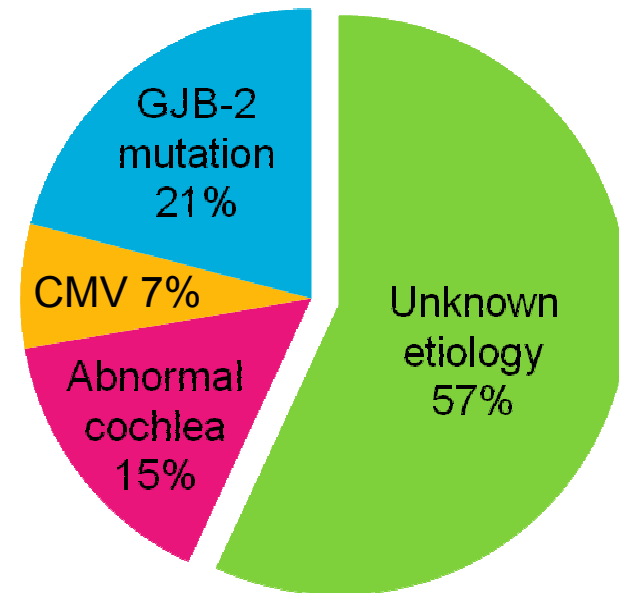


Kral and O'Donoghue, NEJM, 2010

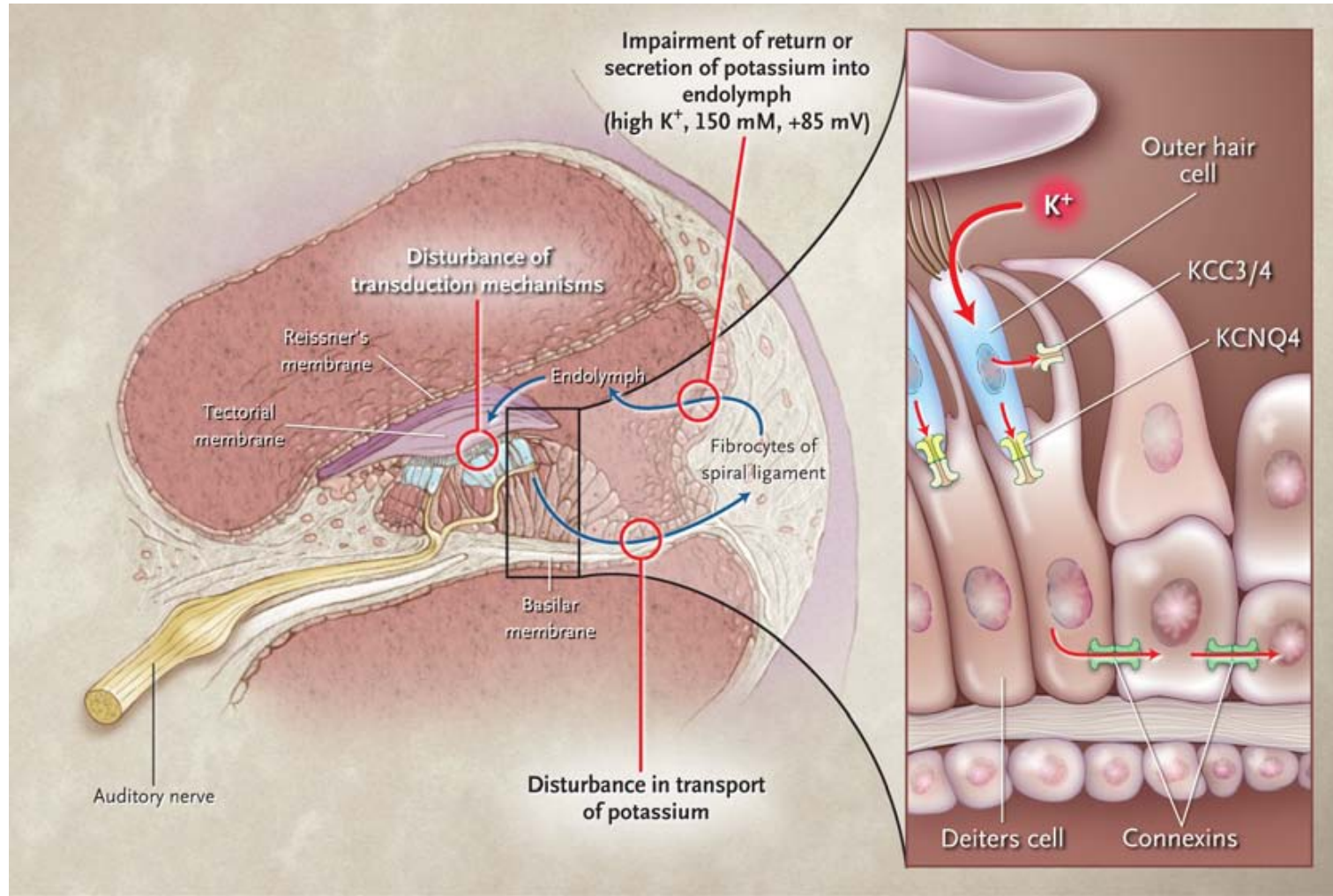
Deafness in children is not uniform



**Aetiology of Deafness
(n=72)**



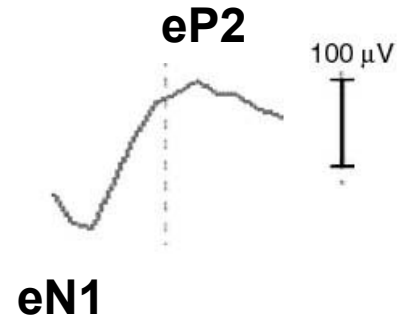
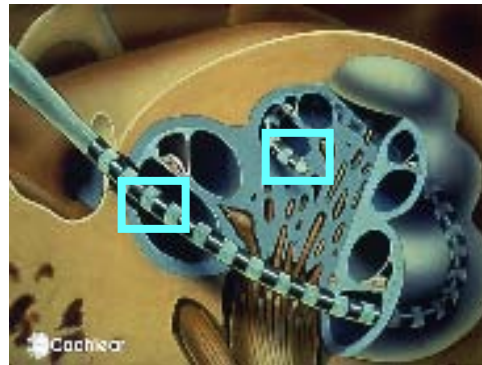
Multiple possible cochlear lesions



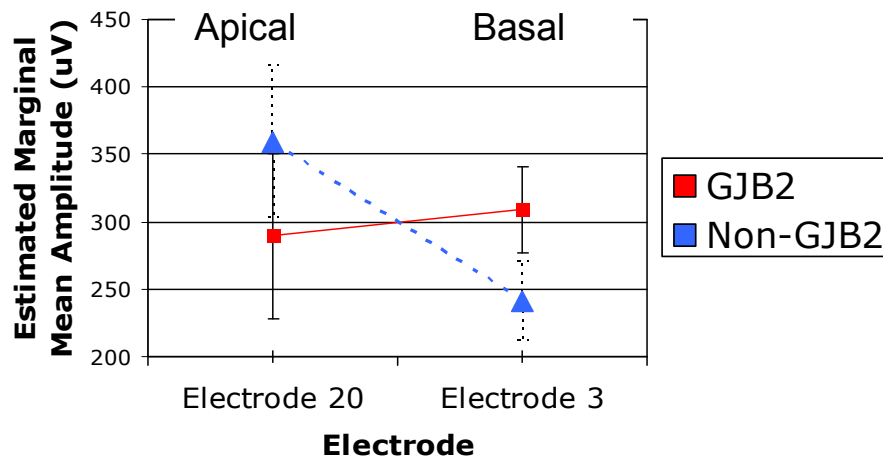
Kral and O'Donoghue, NEJM, 2010

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

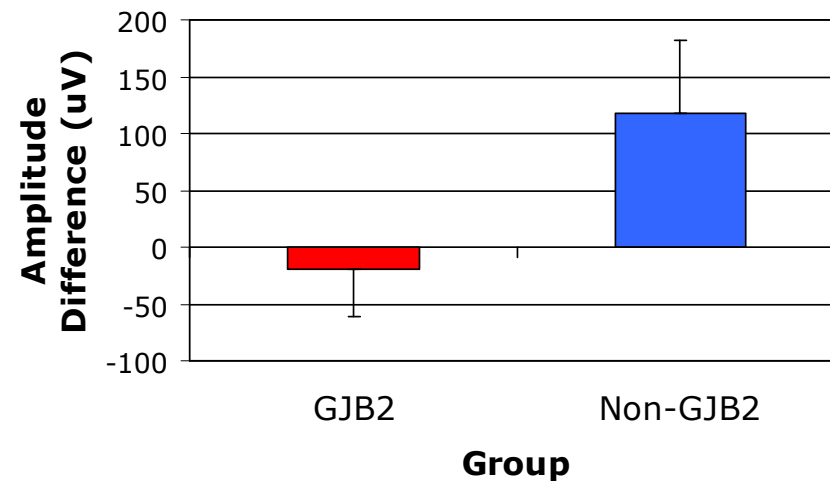
Effects of GJB-2 mutations on auditory nerves



Amplitude

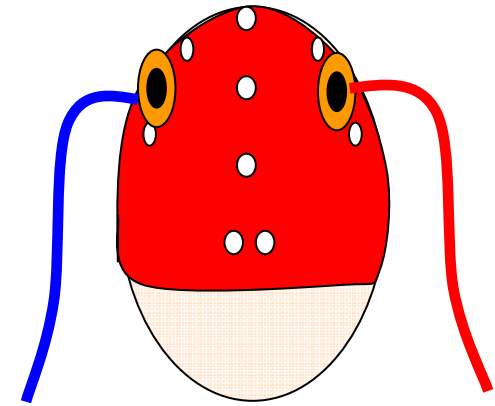
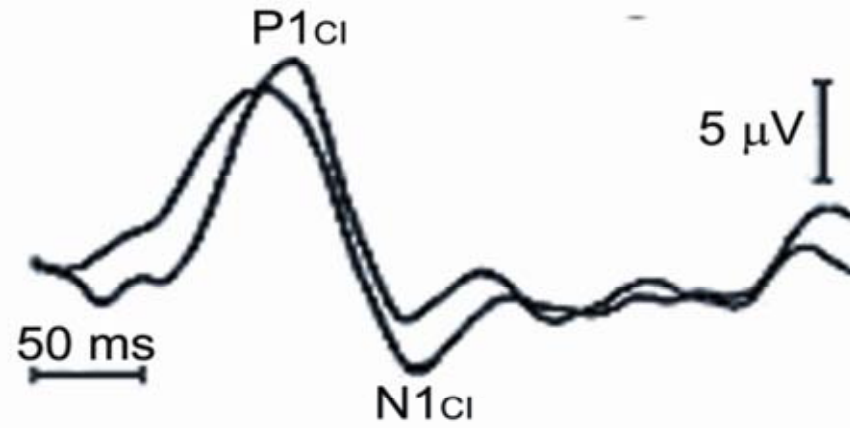
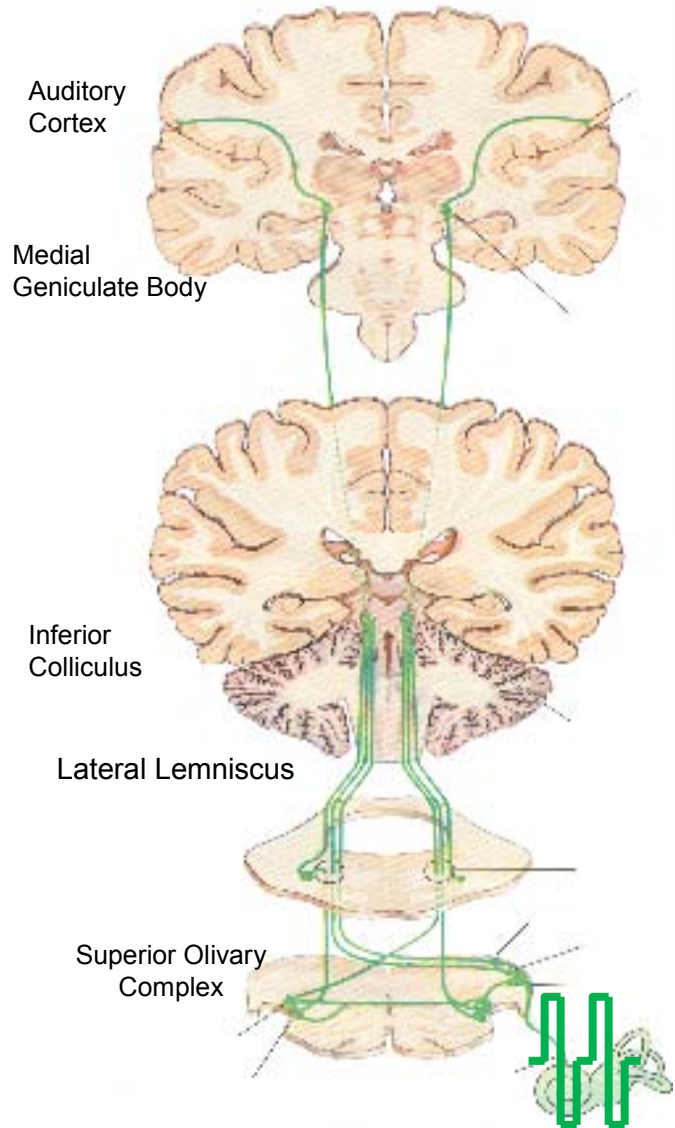


Difference in Amplitude (Apical to Basal)



Propst, et al., 2006

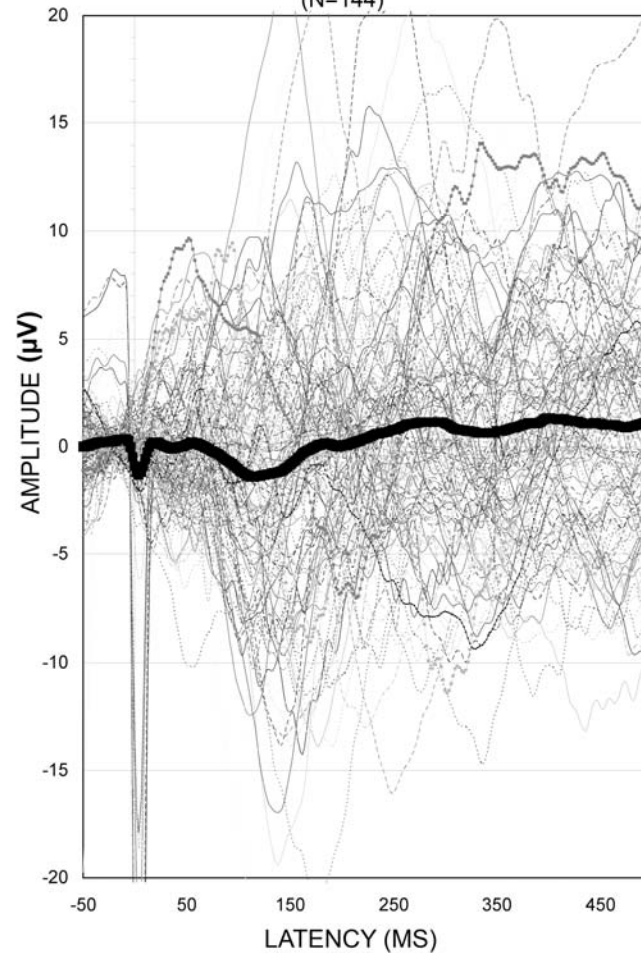
Effects of deafness on cortical responses



Responses from the deaf and immature auditory cortex



CORTICAL RESPONSES EVOKED IN 72 CHILDREN RECEIVING BILATERAL COCHLEAR IMPLANTS SIMULTANEOUSLY (N=144)

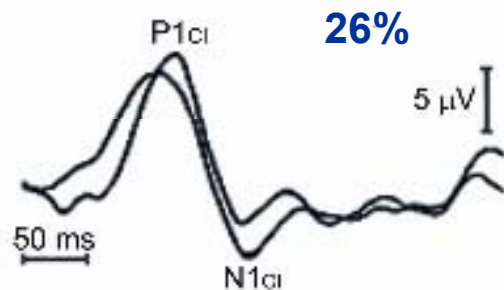


Gordon et al., *Clin Neurophys*, 2010

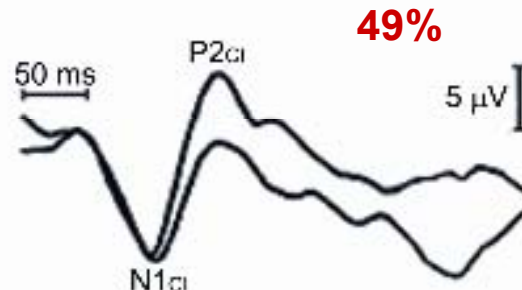
Cortical responses reflect multiple effects of deafness in childhood

(144 cortical responses from 72 young children receiving bilateral CIs simultaneously)

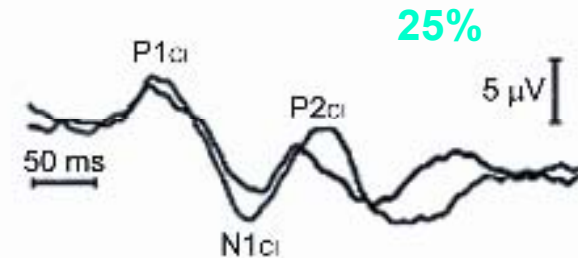
POSITIVE PEAK RESPONSE



NEGATIVE PEAK RESPONSE



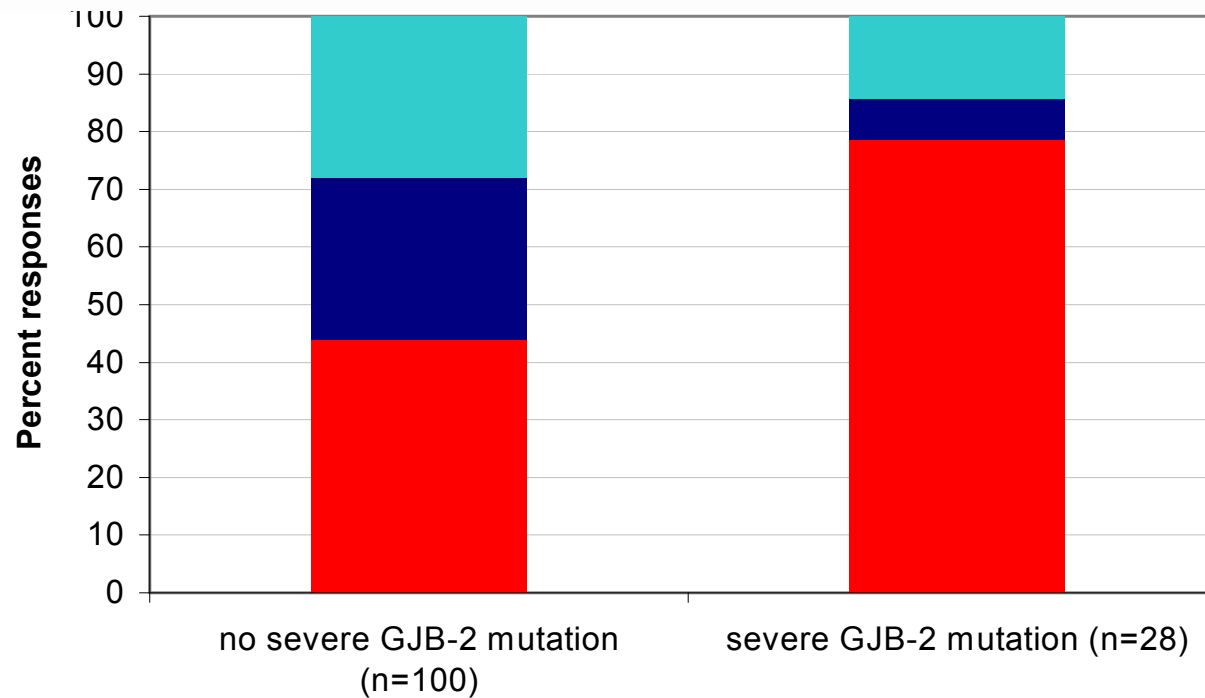
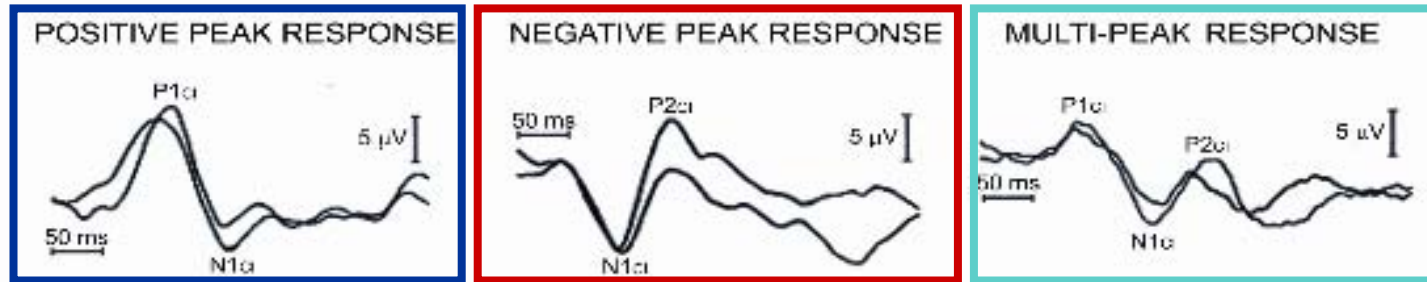
MULTI-PEAK RESPONSE



- Non-significant demographic influences ($p > 0.05$)
 - Age at implantation, duration of deafness, age at onset of bilateral deafness, duration of residual hearing, cochlear abnormalities, neonatal complications

Gordon et al., *Clin Neurophys*, 2010

Cortical immaturity predicted by GJB-2 deafness

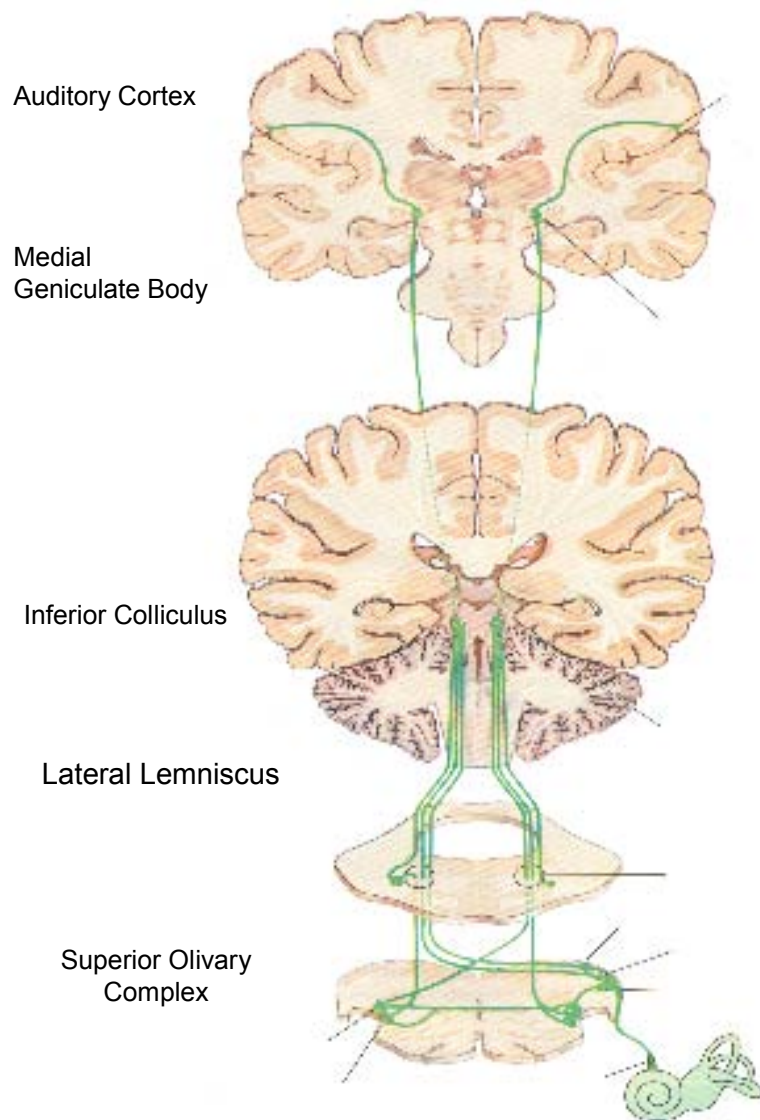


Gordon et al., *Clin Neurophys*, 2010

Summary of effects of bilateral deafness

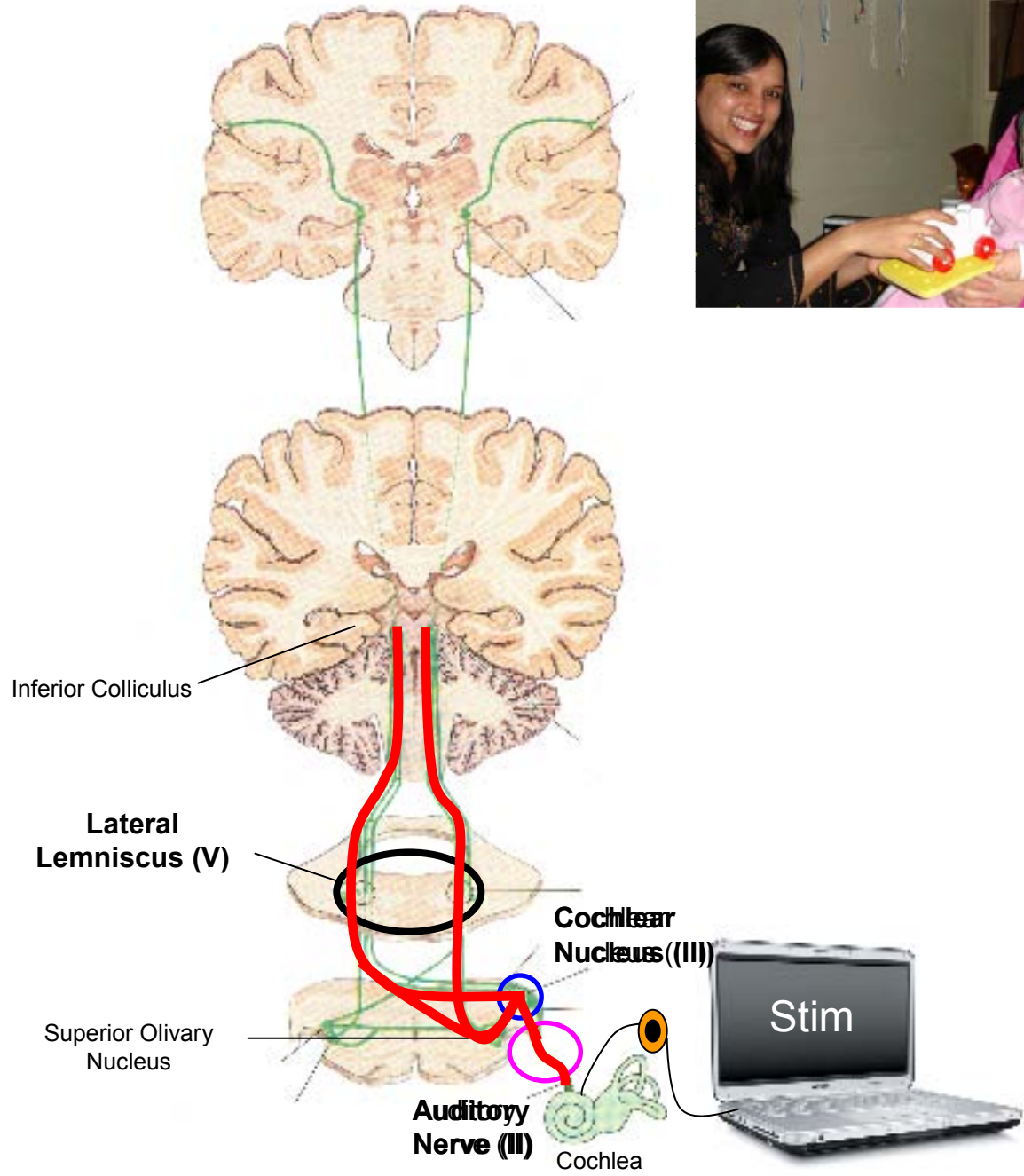
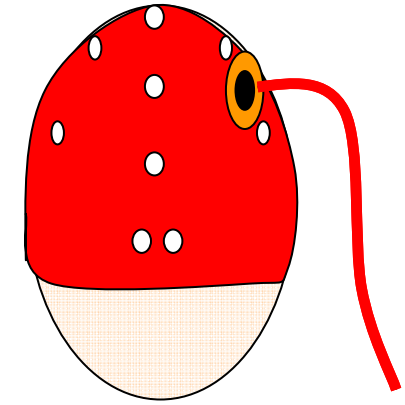
- Reorganization in thalamo-cortical areas
 - Due to competition from non-auditory inputs (visual, somatosensory)
- GJB-2 deafness is an important predictor of activity in auditory nerve and cortex
 - GJB-2 mutations predict uniform activity in auditory nerve and very early stage of cortical development

What pathways are awakened and can they develop normally?



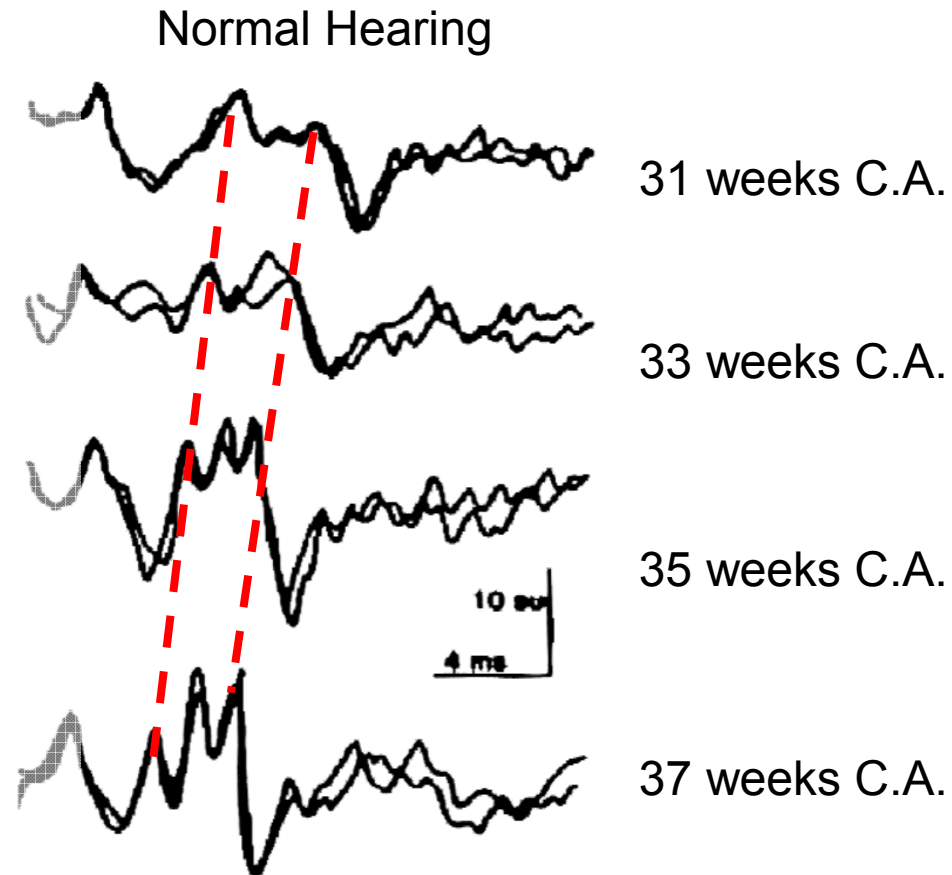
- Effects of bilateral deafness
 - Abnormal cortical function
 - Effects of etiology

- Developmental plasticity?
 - Normal and abnormal auditory development
 - Effects of unilateral stimulation



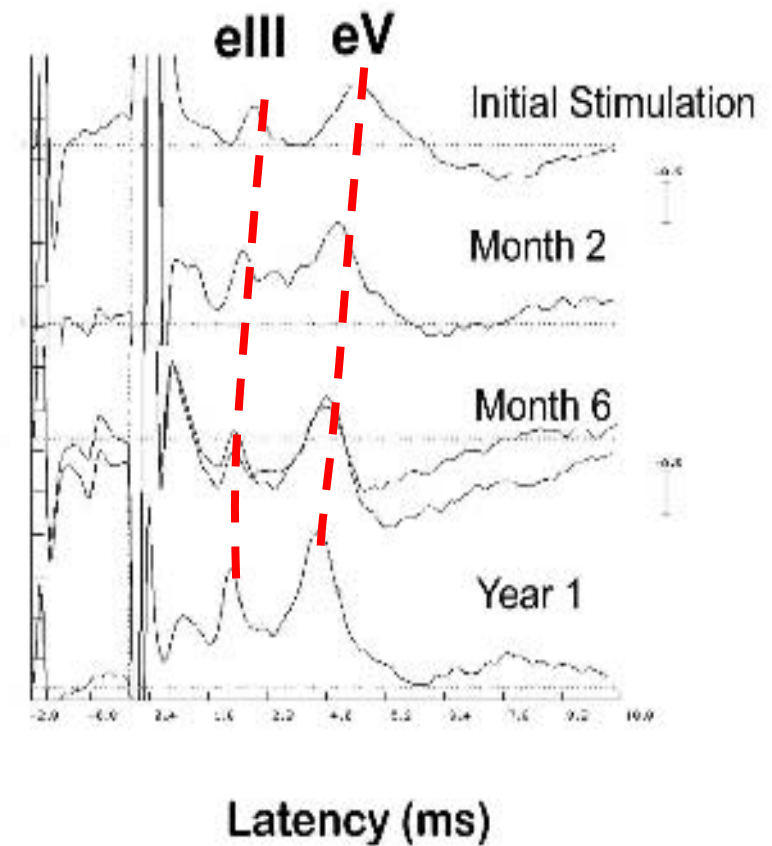
Unilateral cochlear implants promote development in auditory brainstem

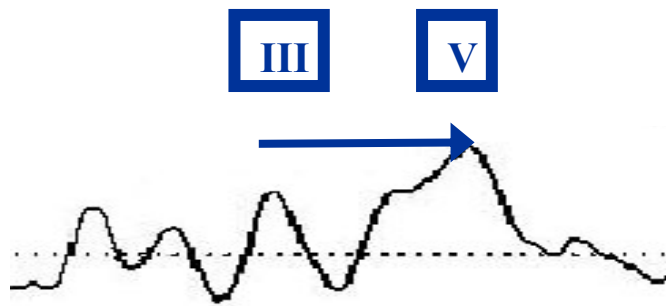
Salamy, 1980



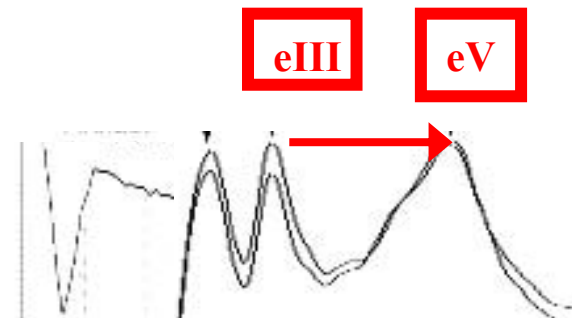
Gordon et al., *Ear Hear*, 2003

Unilateral Cochlear Implant

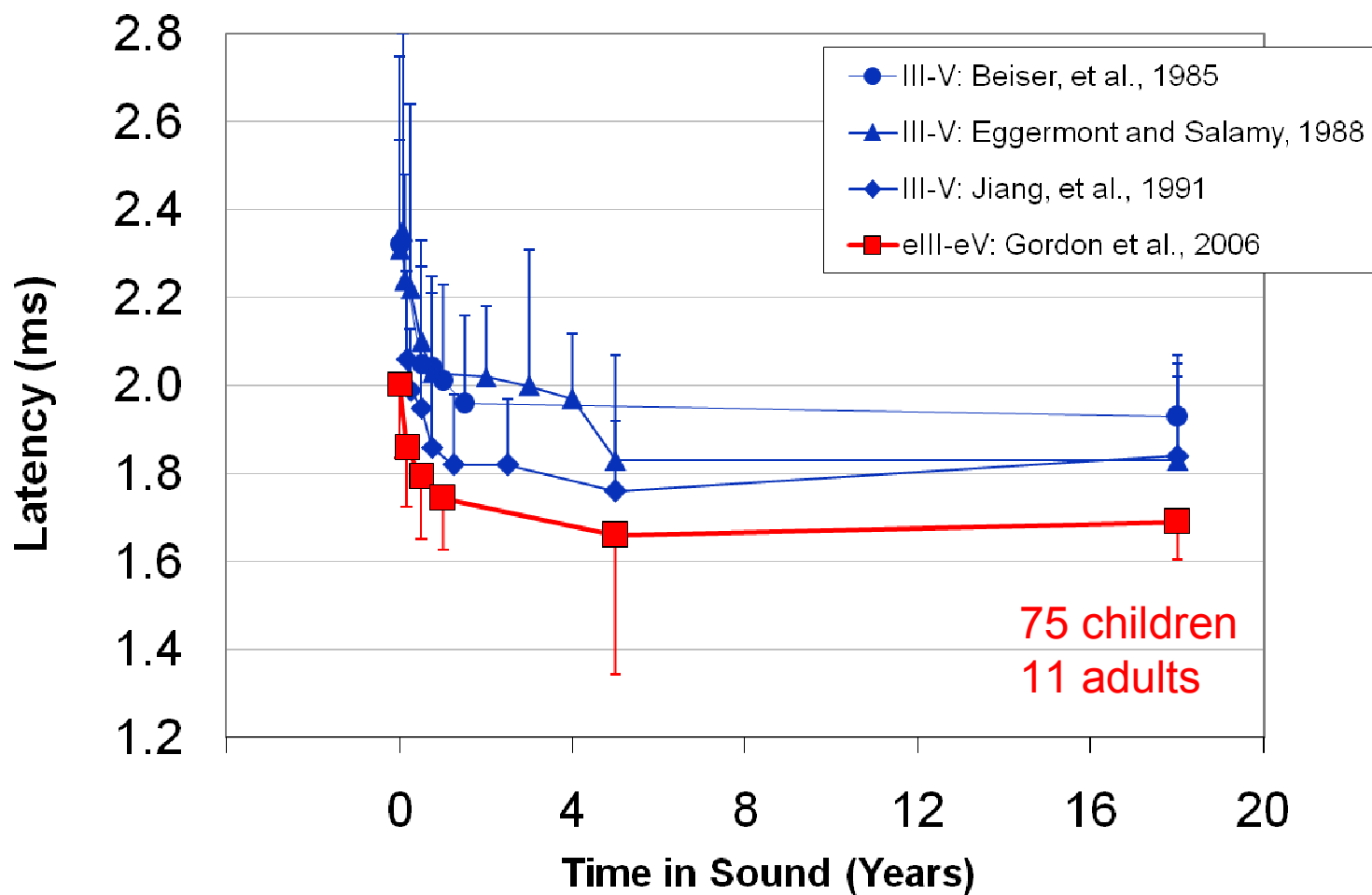




Normal Hearing

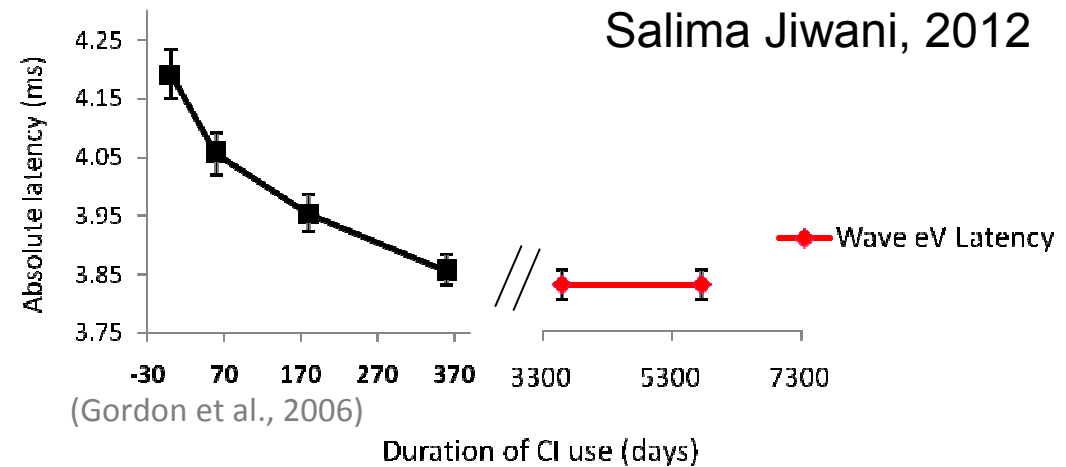
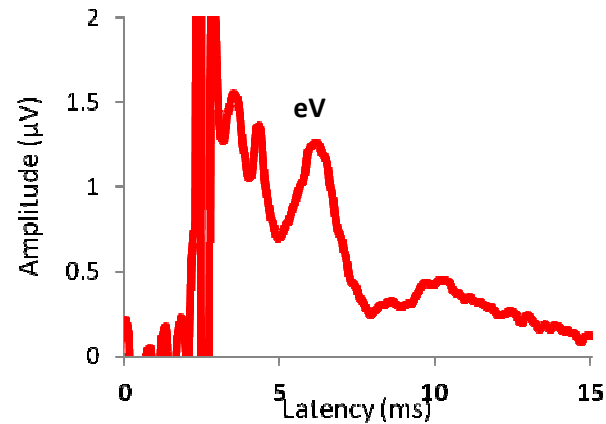


Cochlear Implant



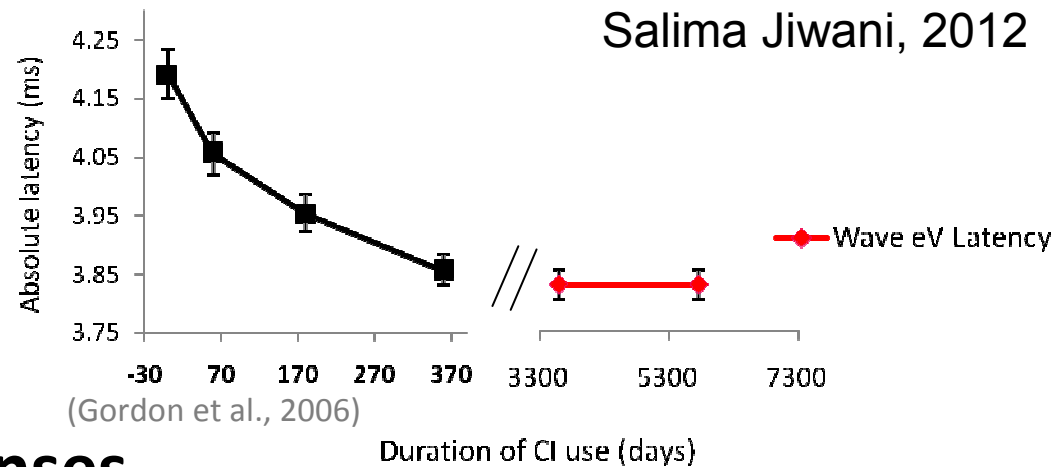
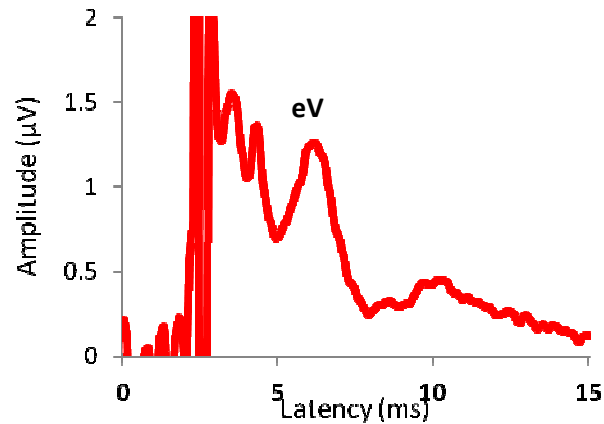
Brainstem and thalamo-cortical responses mature with CI use

Brainstem responses



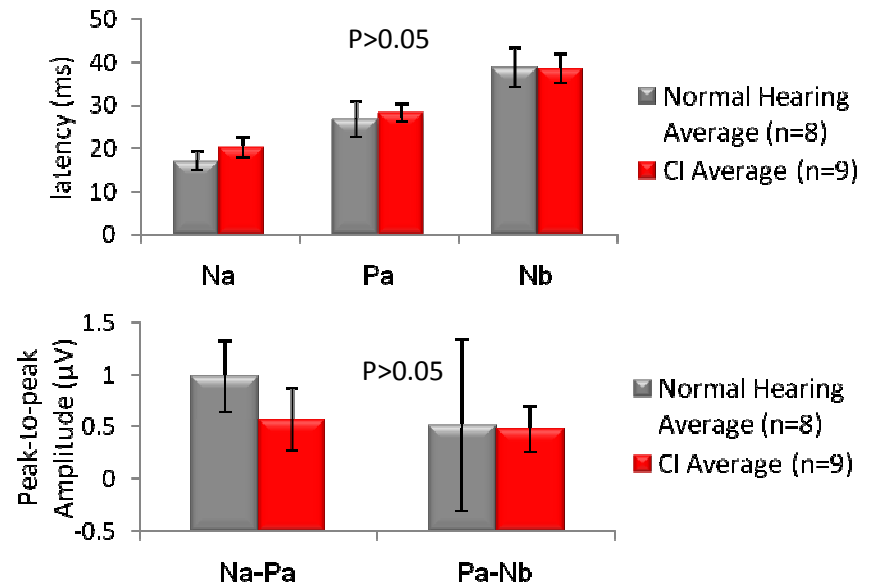
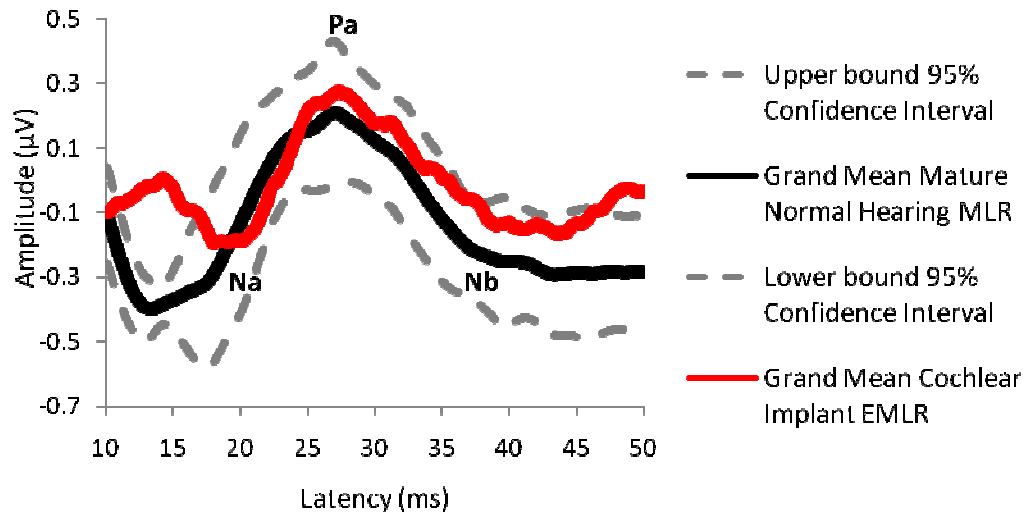
Brainstem and thalamo-cortical responses mature with CI use

Brainstem responses

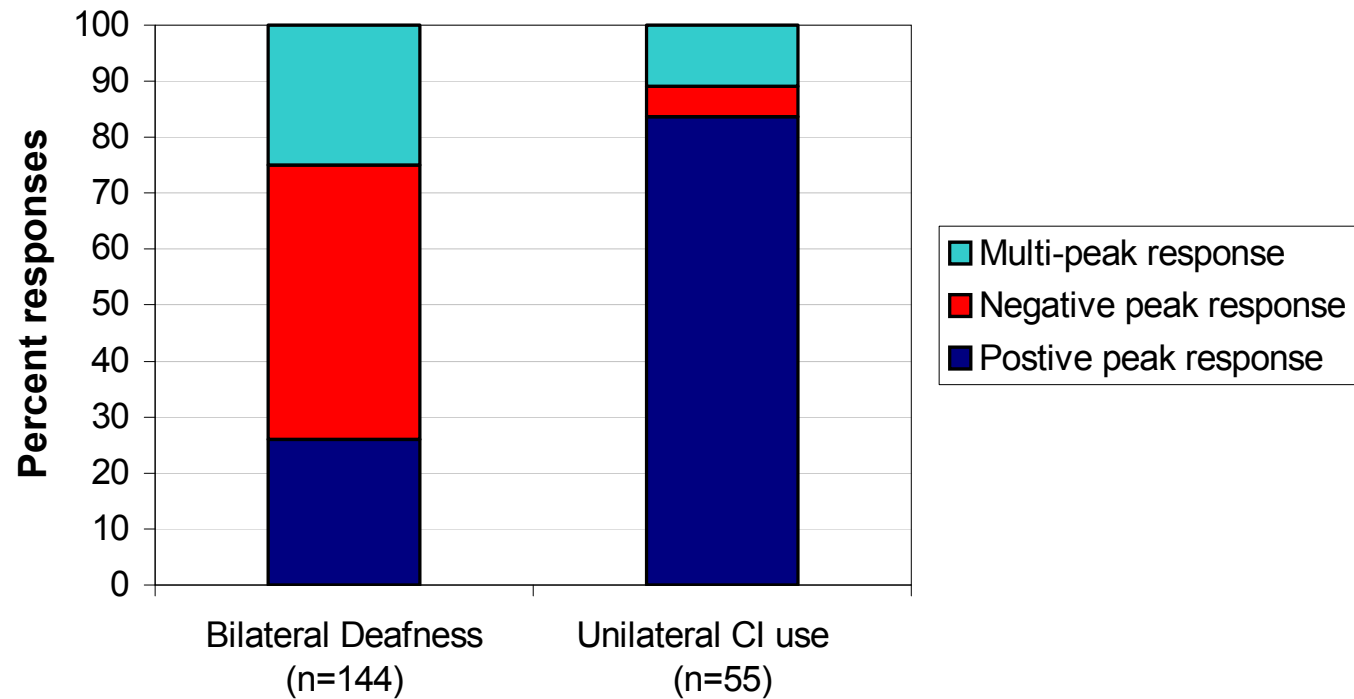
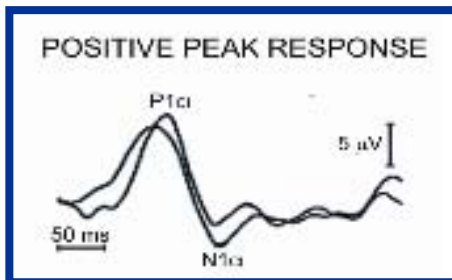
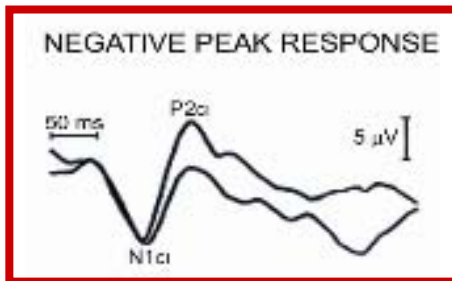
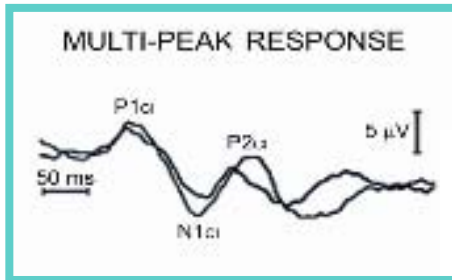


(Gordon et al., 2006)

Middle latency responses

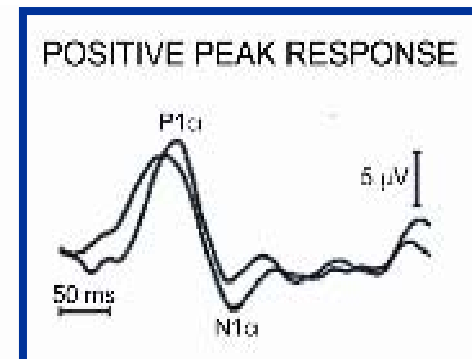
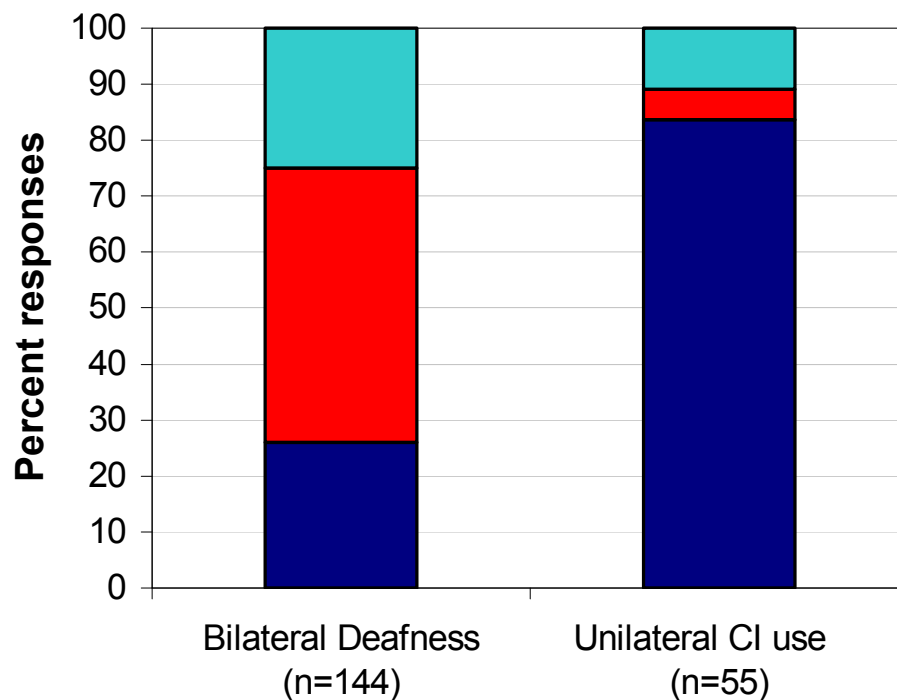
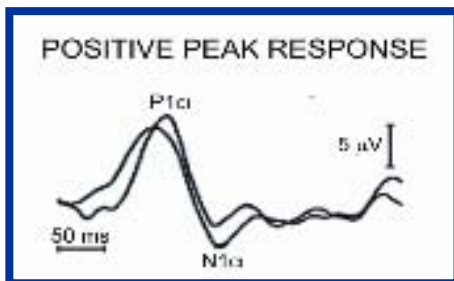
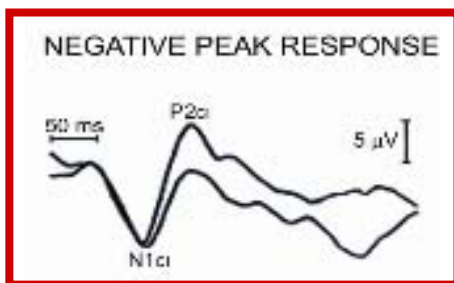
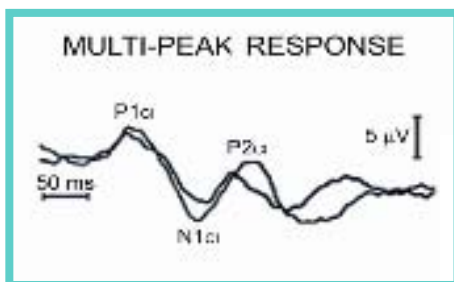


Unilateral cochlear implants provided in early life promote cortical development



Gordon et al., *Clin Neurophys*, 2010

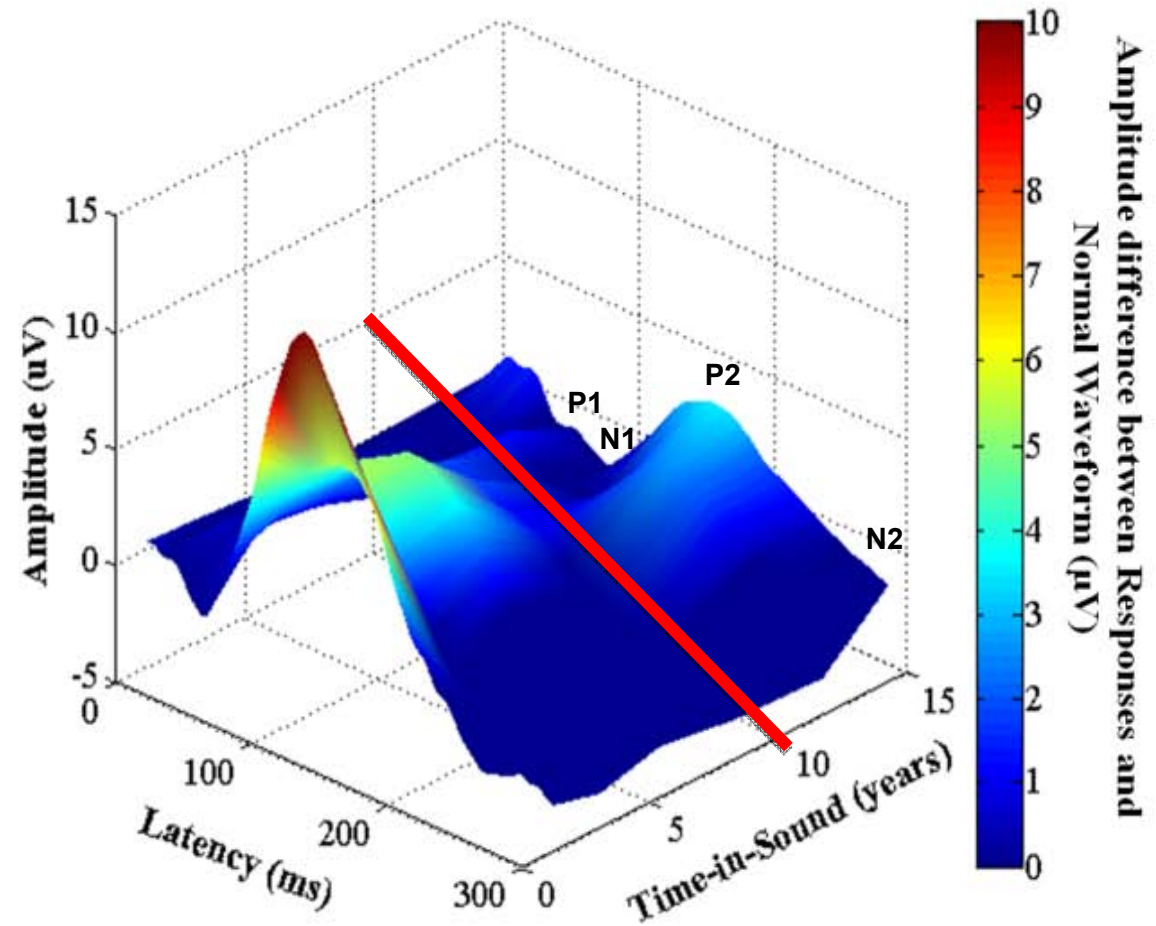
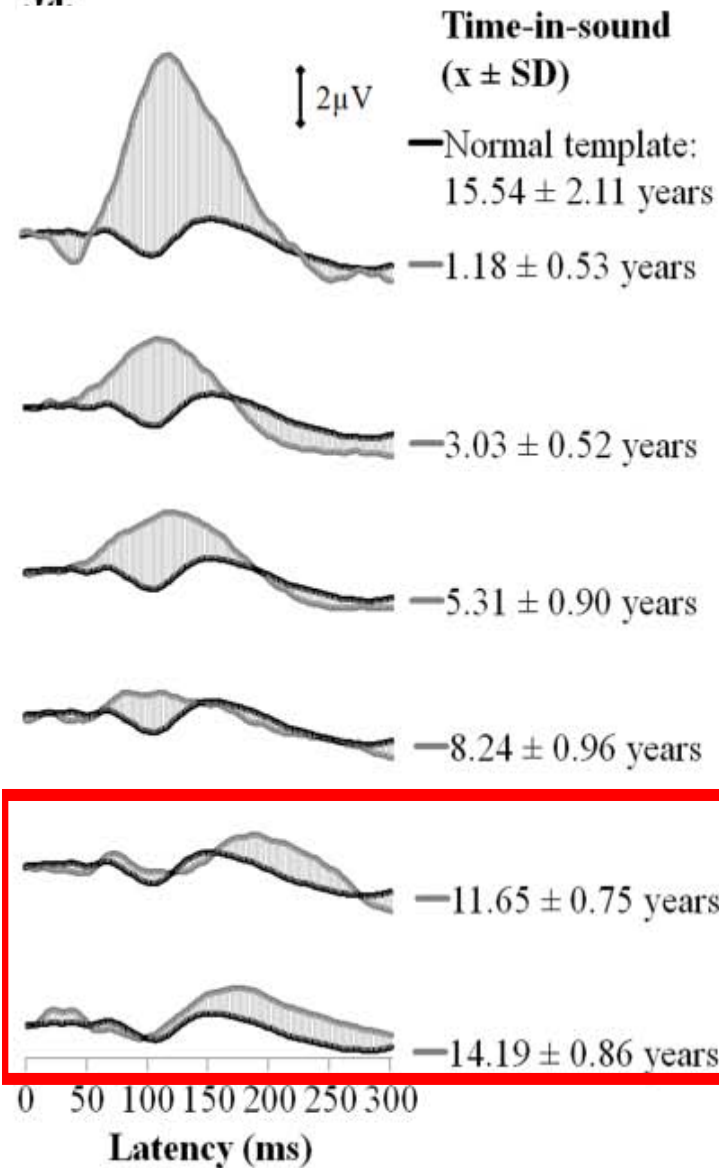
Unilateral cochlear implants provided in early life promote cortical development



Gordon et al., *Clin Neurophys*, 2010

Cochlear implant stimulation promotes normal-like trajectory of cortical auditory development

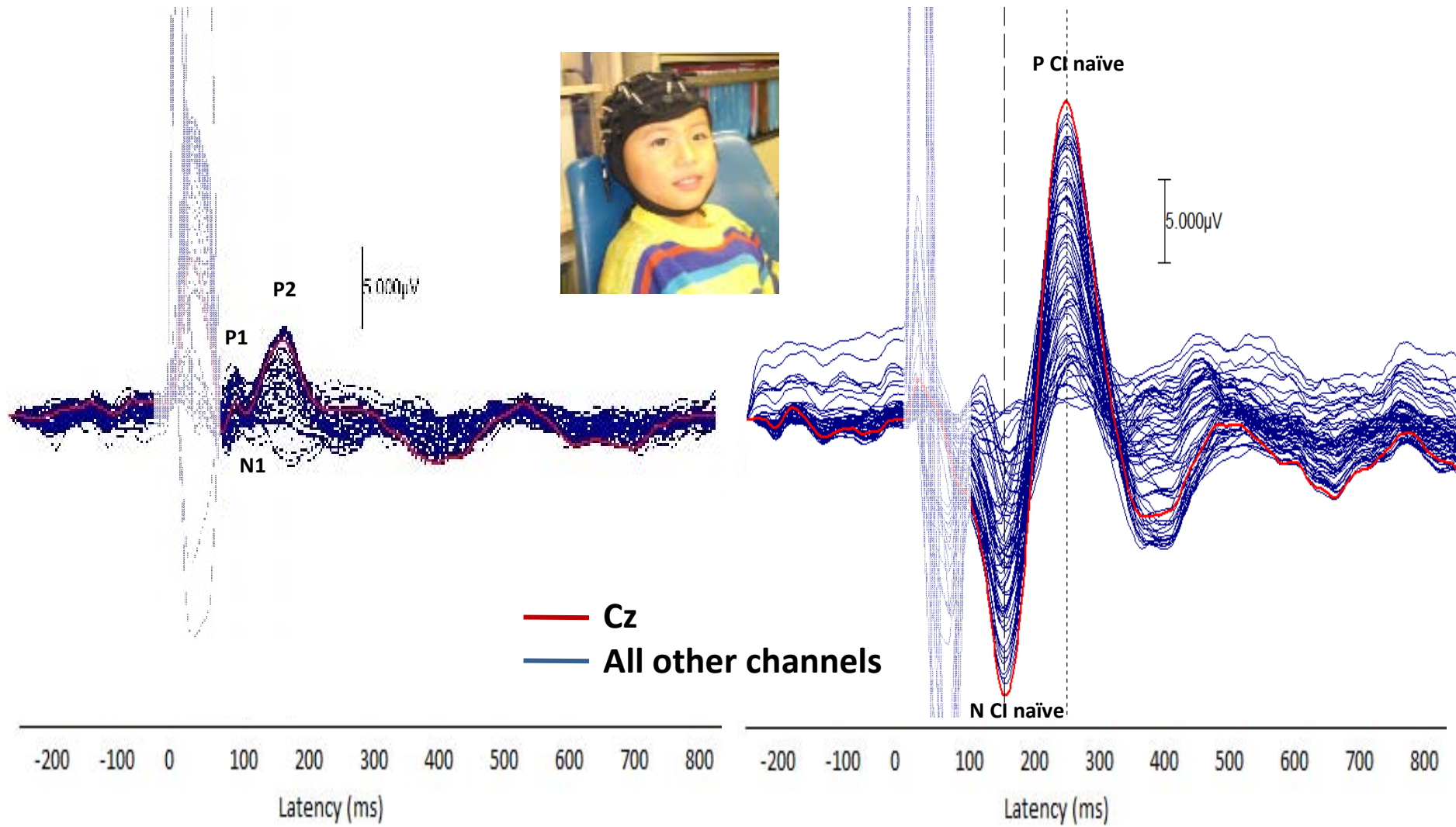
Salima Jiwani, 2012



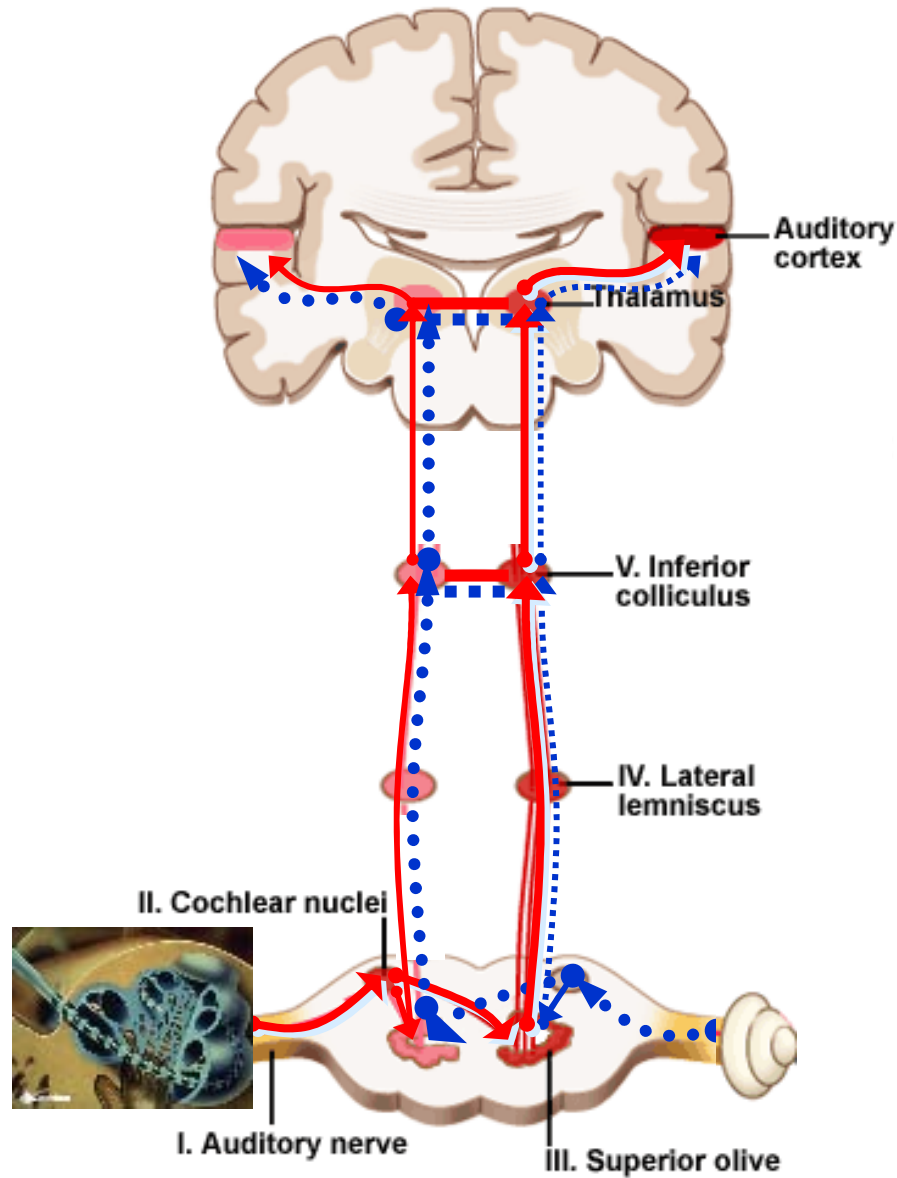
Auditory evoked cortical responses are abnormal in the second implanted ear

Experienced ear

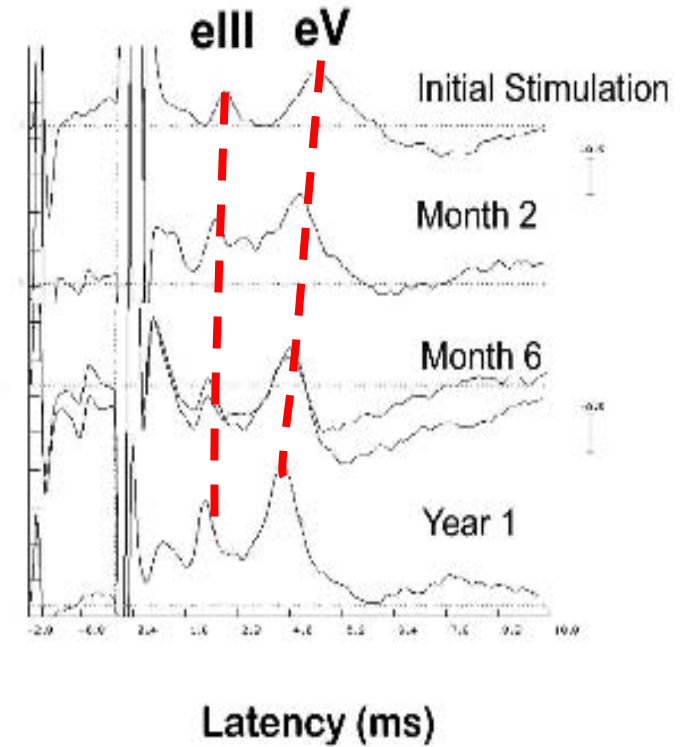
Naïve ear



Unilateral cochlear implant use

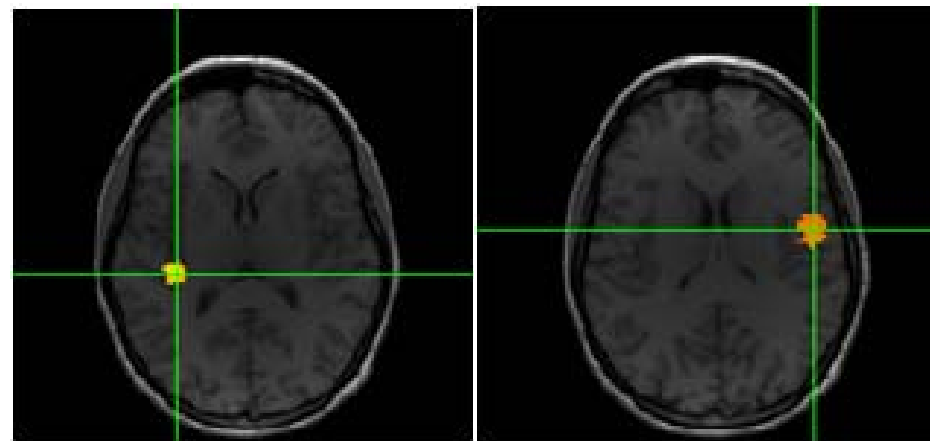
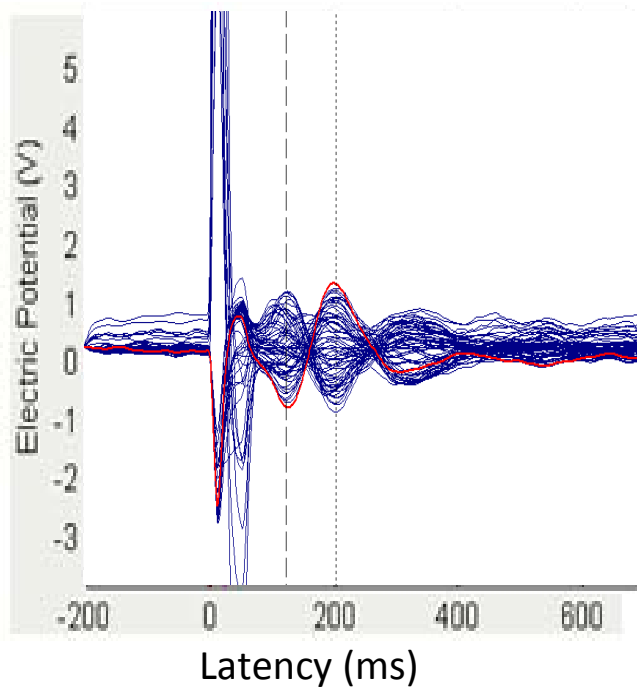
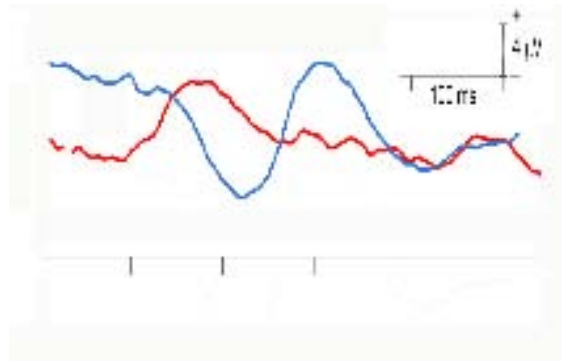


EABR

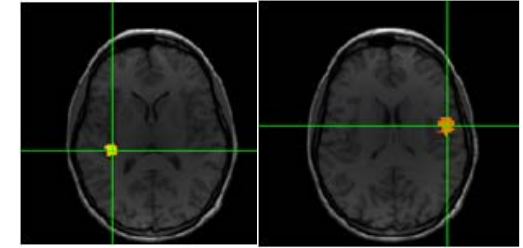


Gordon et al., *Ear and Hear*, 2003

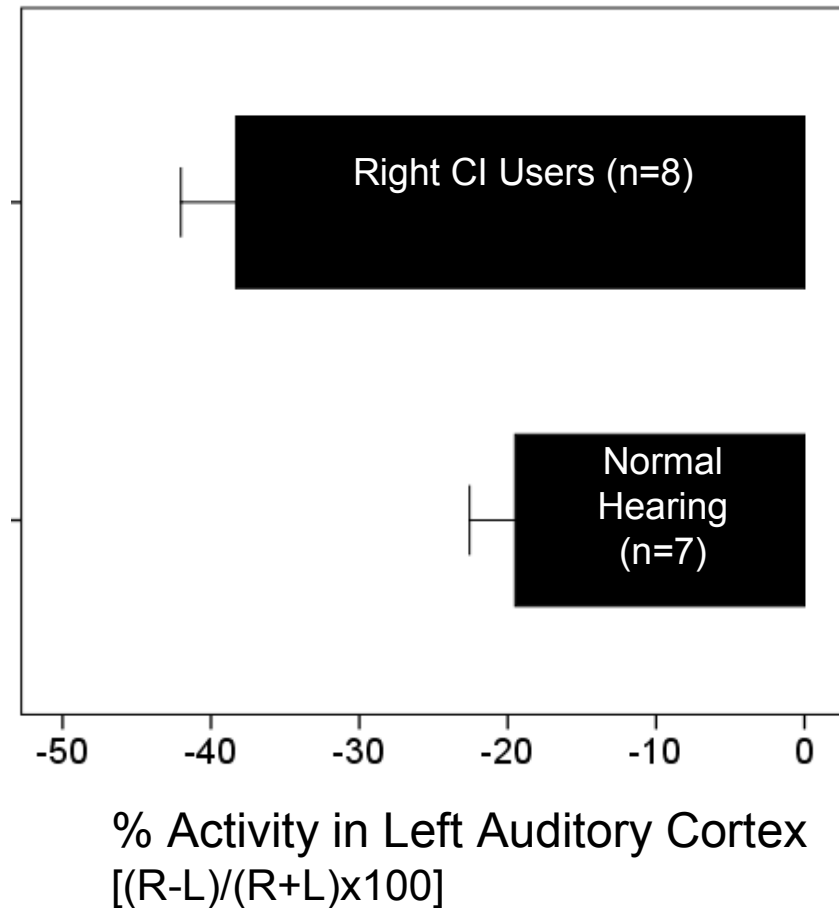
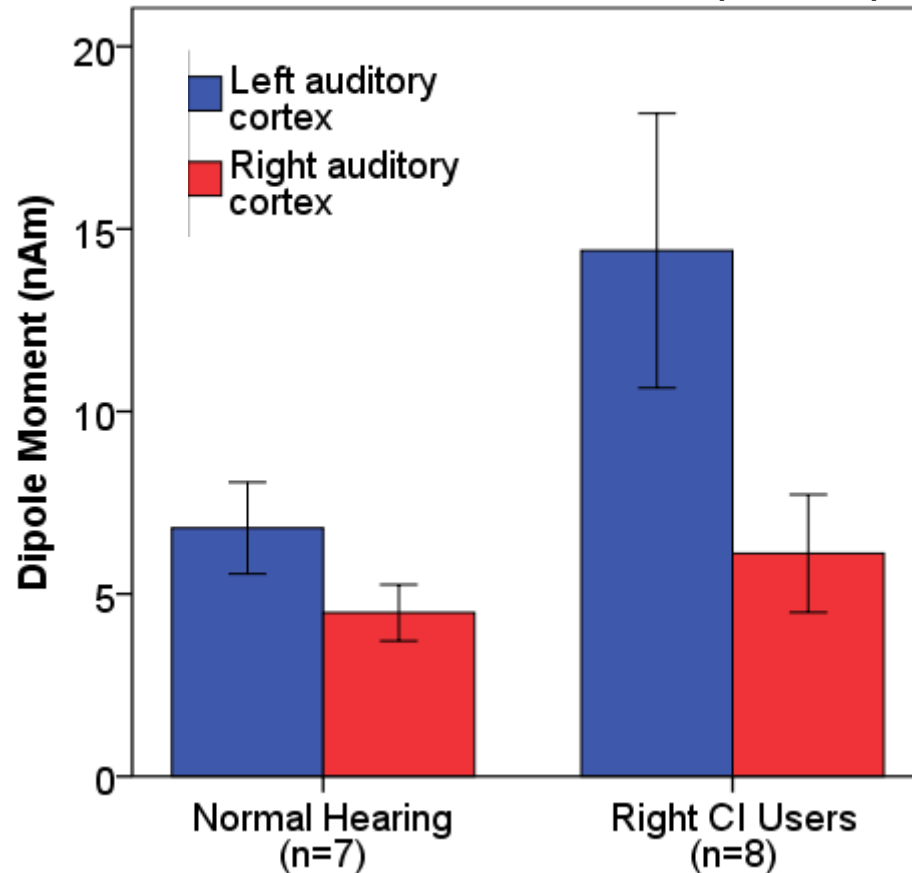
Imaging brain activity in cochlear implant users



Abnormal cortical activity after right unilateral cochlear implant

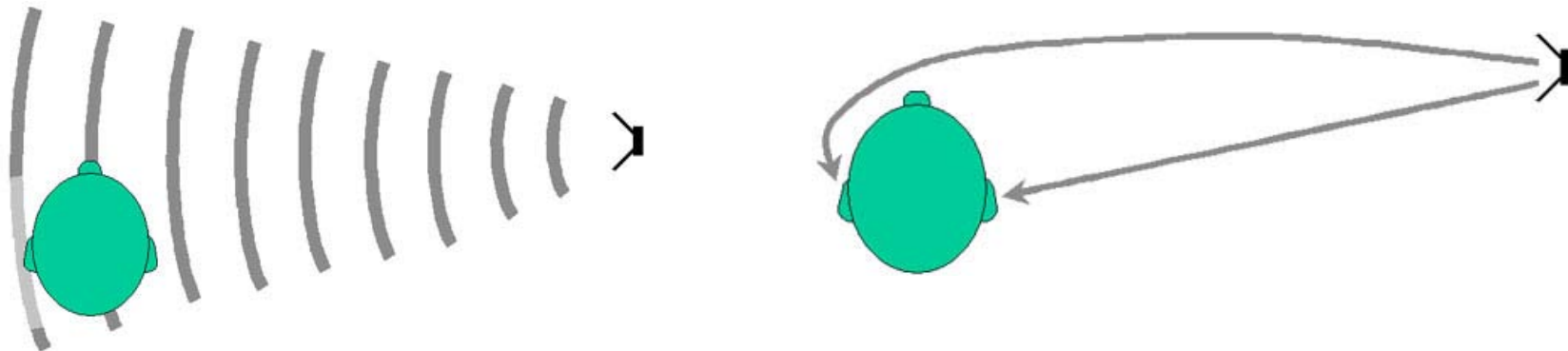


Clicks/pulses presented to right ear



Binaural hearing

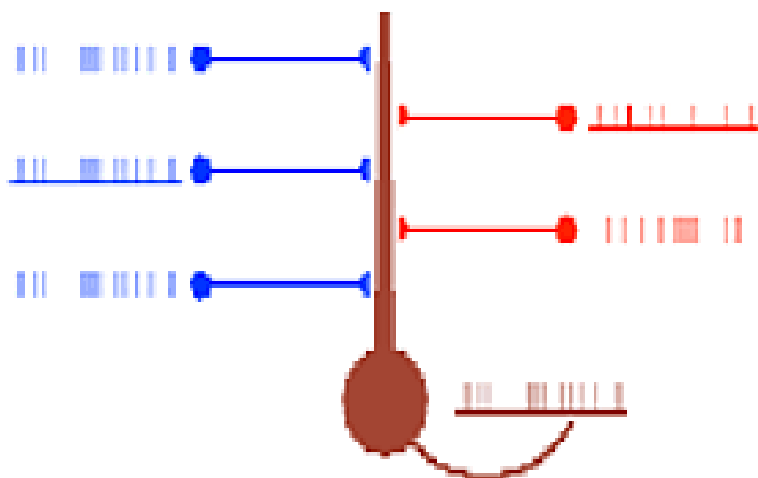
- Sound reach one ear before the other and at different levels



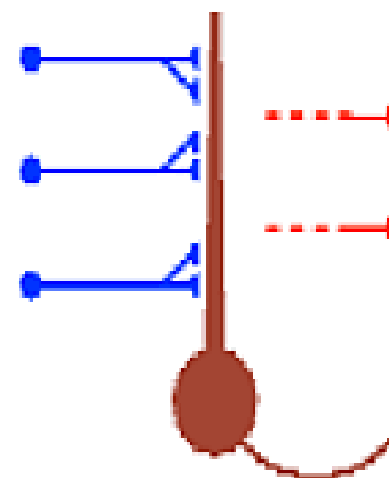
- These cues must be detected by the central auditory system

Neural competition in development

Development



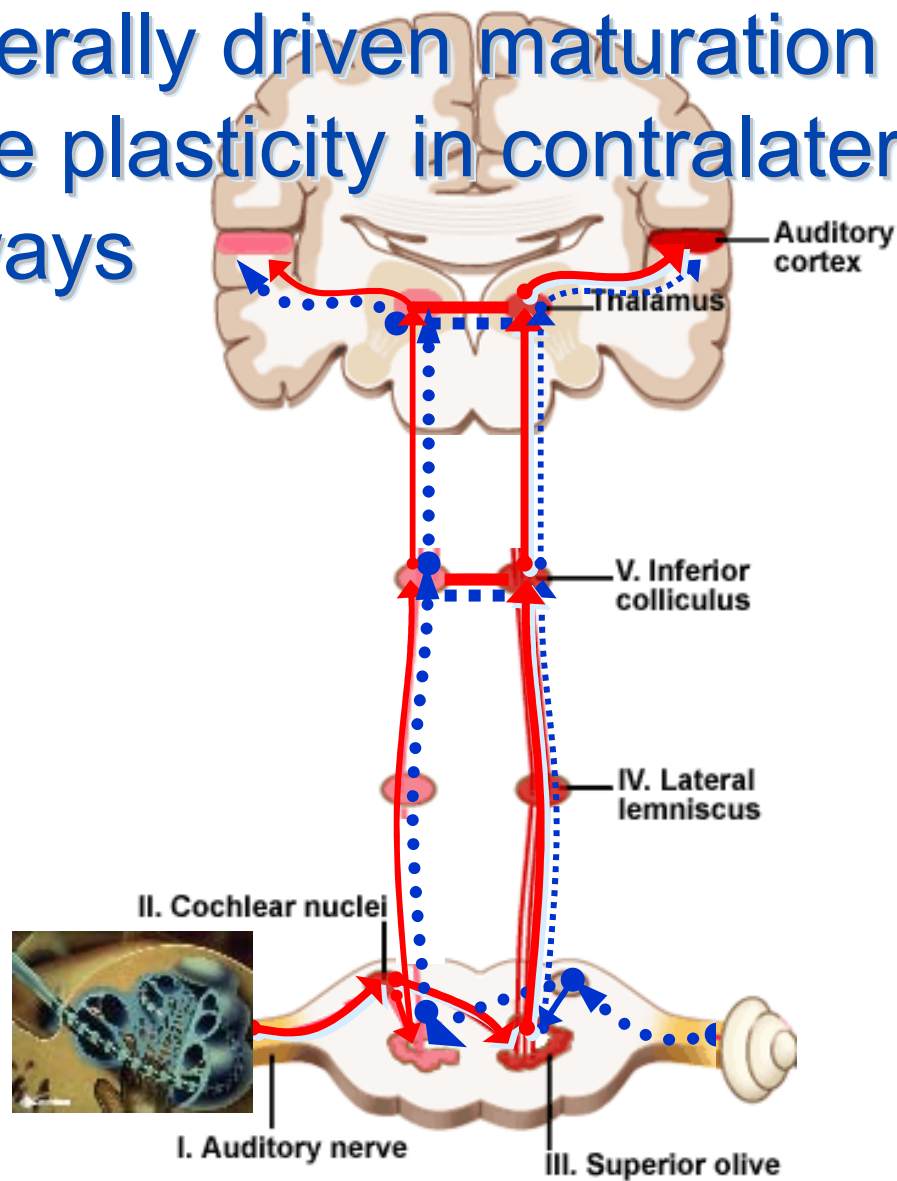
Maturity in auditory brainstem
with 2 years CI use



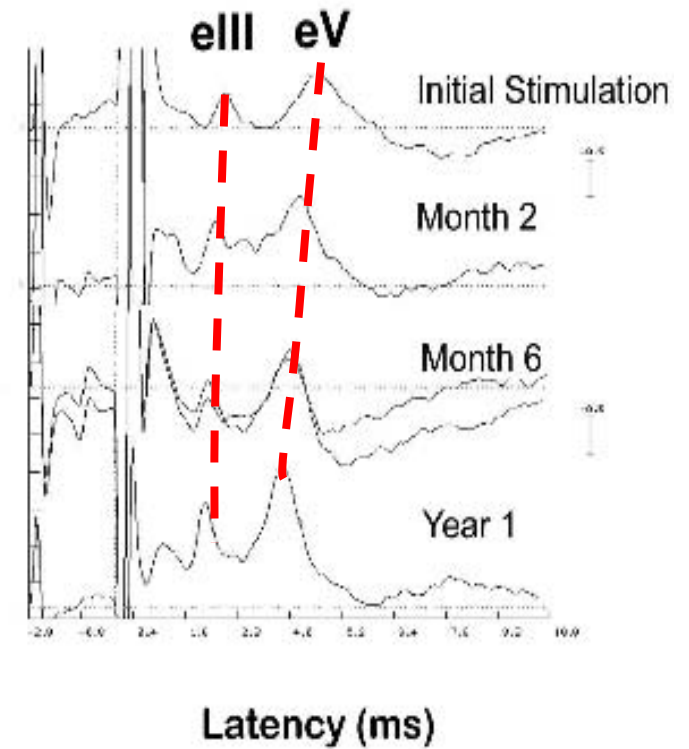
Sherman, *Nature Neuroscience* 3, 525 - 527 (2000)

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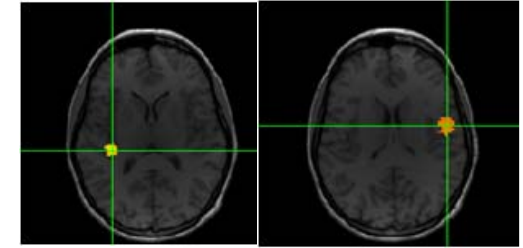
Hypothesis:
 Unilaterally driven maturation will
 reduce plasticity in contralateral
 pathways



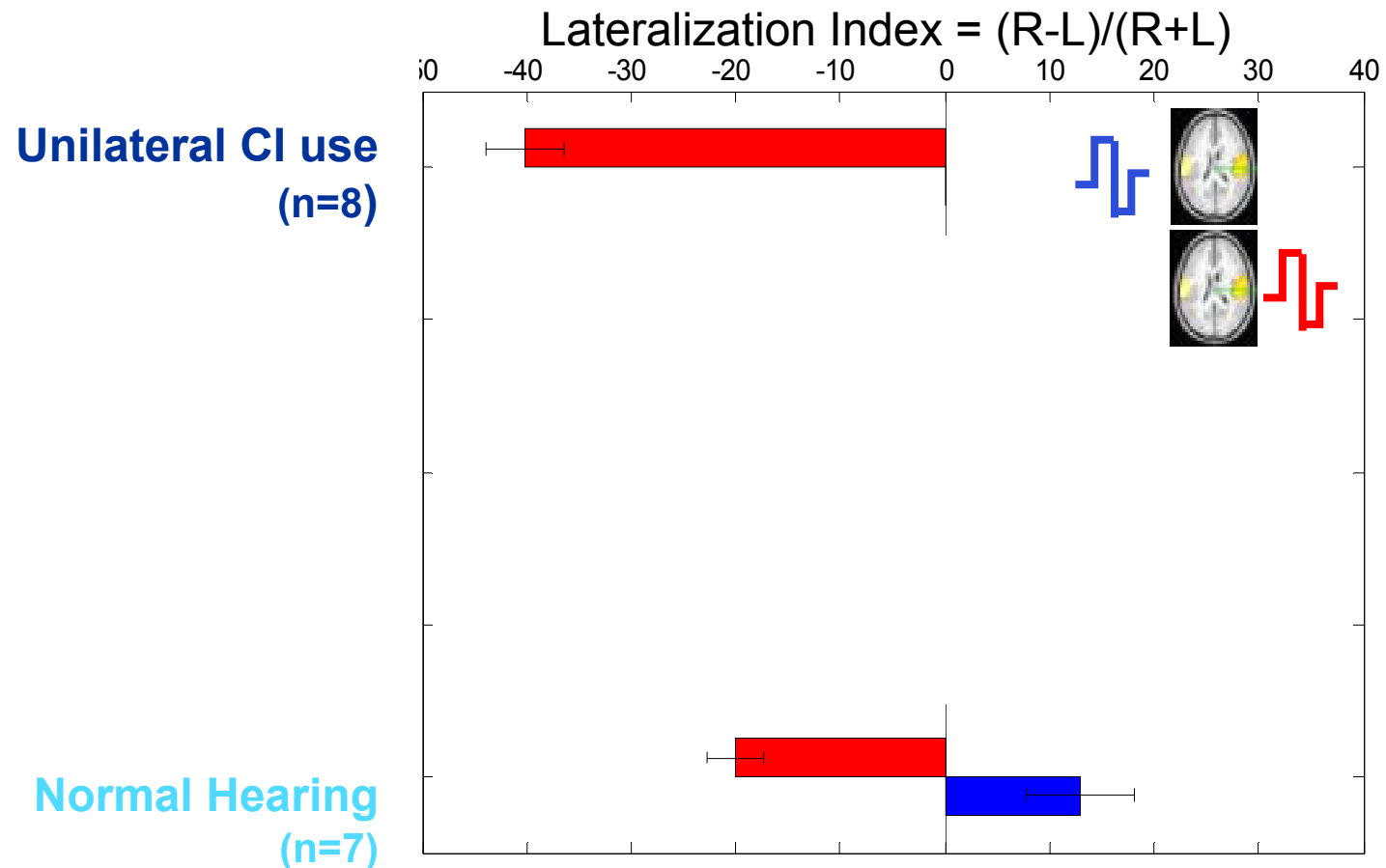
EABR



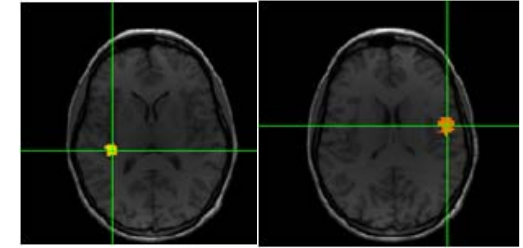
Reorganization in auditory pathways after unilateral implant use



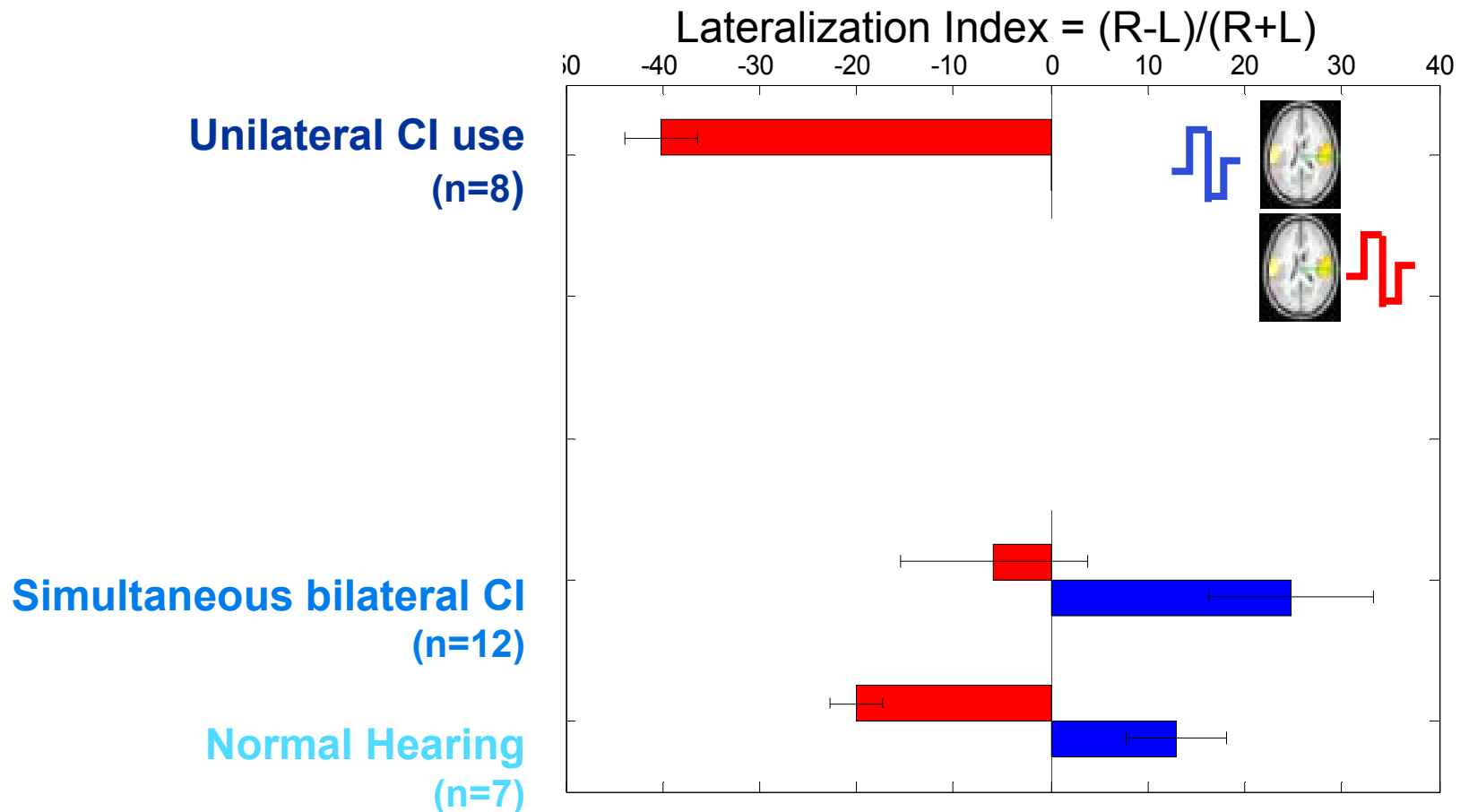
Left Auditory Cortex Right Auditory Cortex



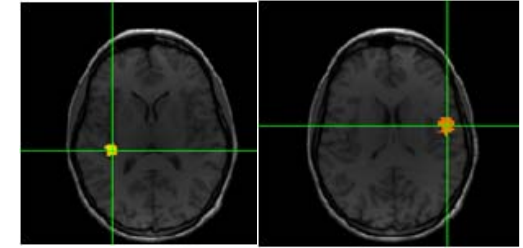
Simultaneous bilateral implantation protects the cortex against reorganization



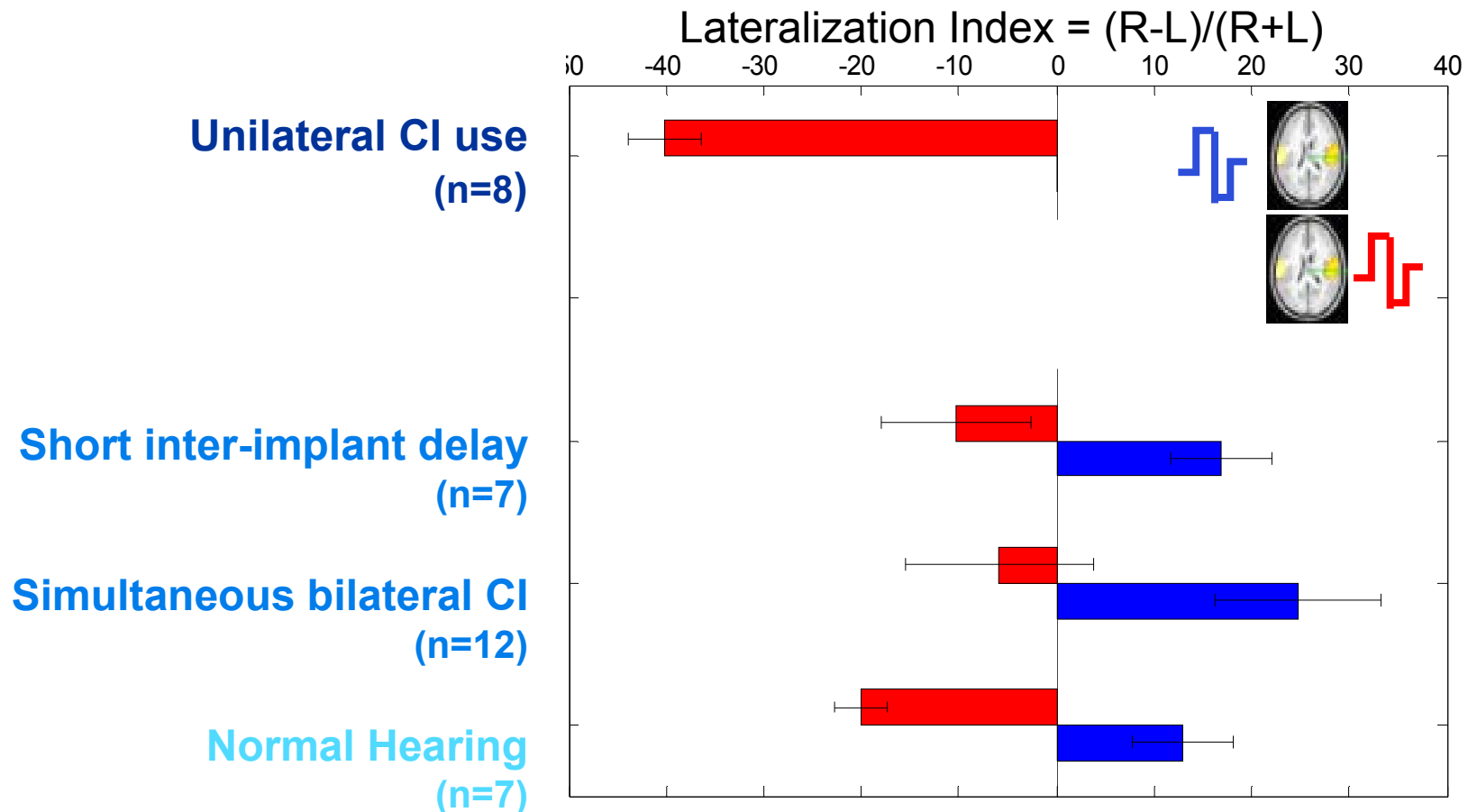
Left Auditory Cortex Right Auditory Cortex



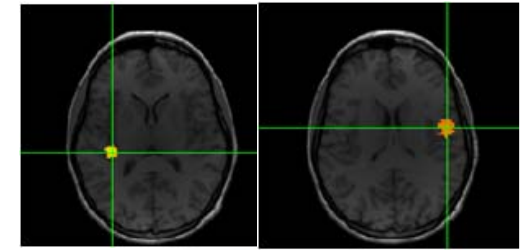
Bilateral implantation protects the cortex against reorganization if the delay is short



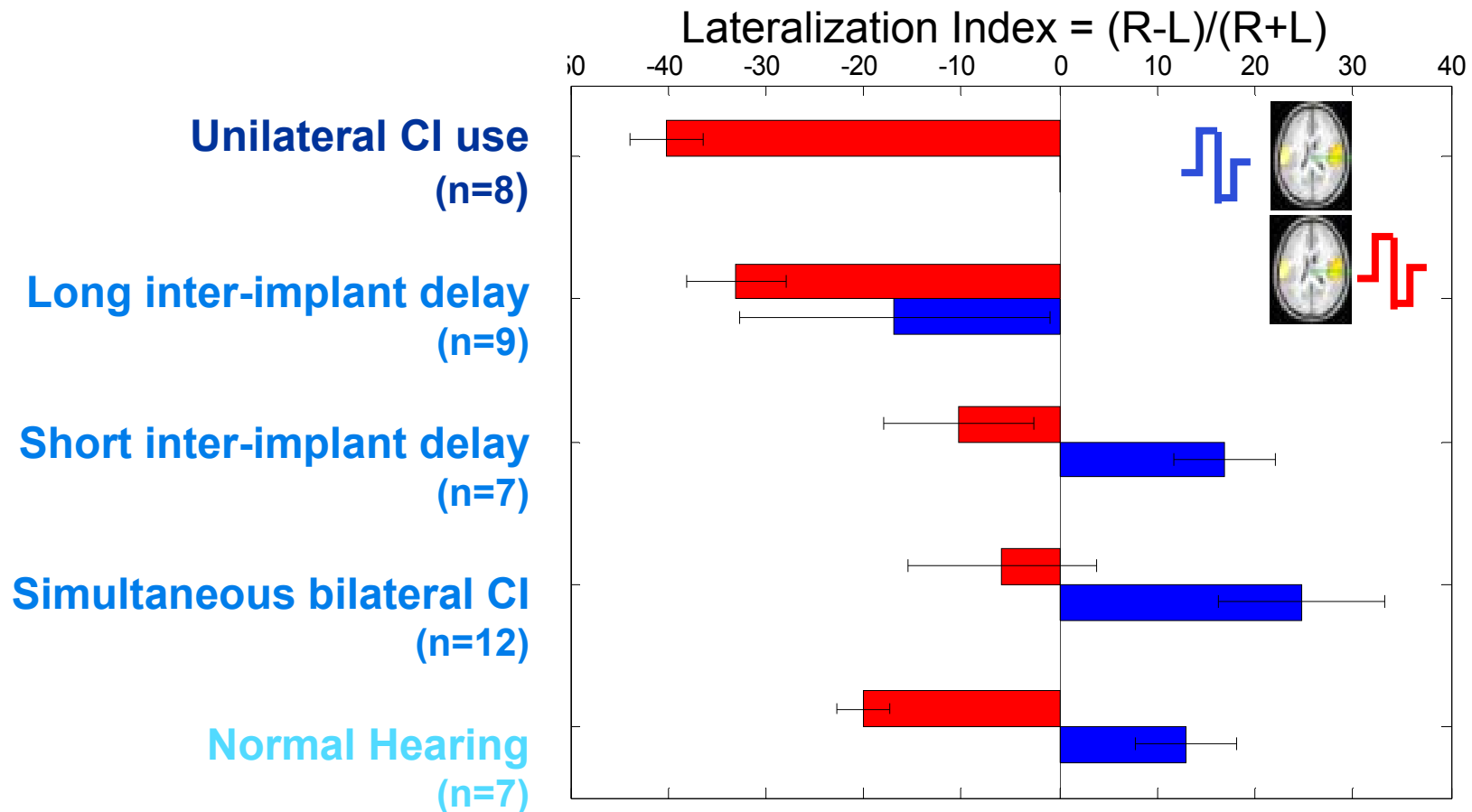
Left Auditory Cortex **Right Auditory Cortex**

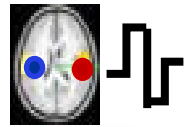


Effects of unilateral CI use are not reversed by bilateral implantation

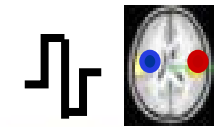


Left Auditory Cortex Right Auditory Cortex



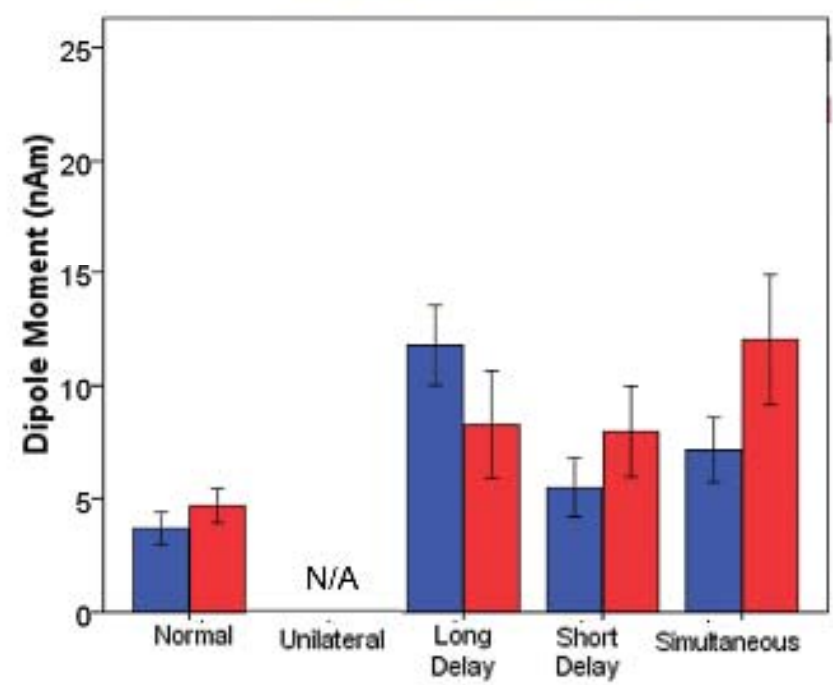
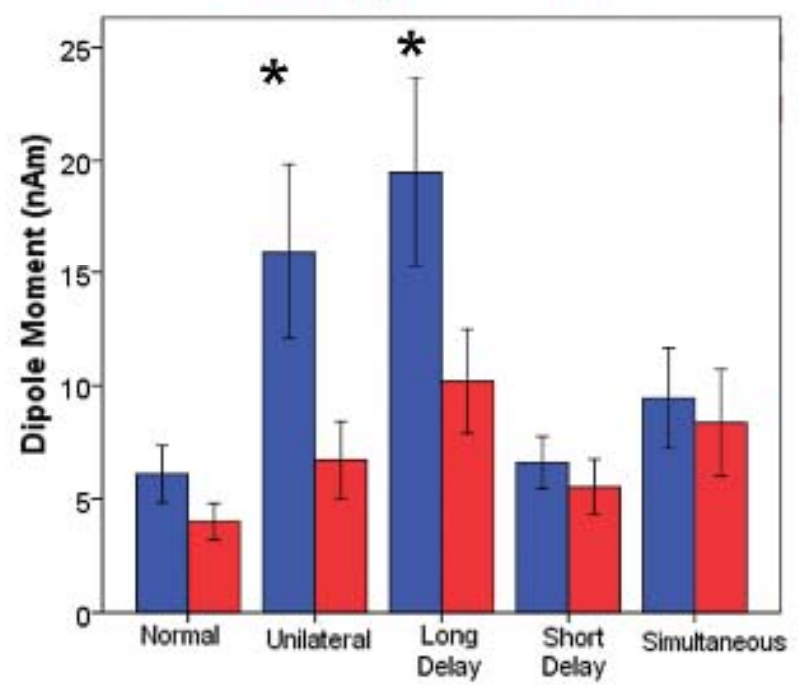


■ Left auditory cortex
 ■ Right auditory cortex

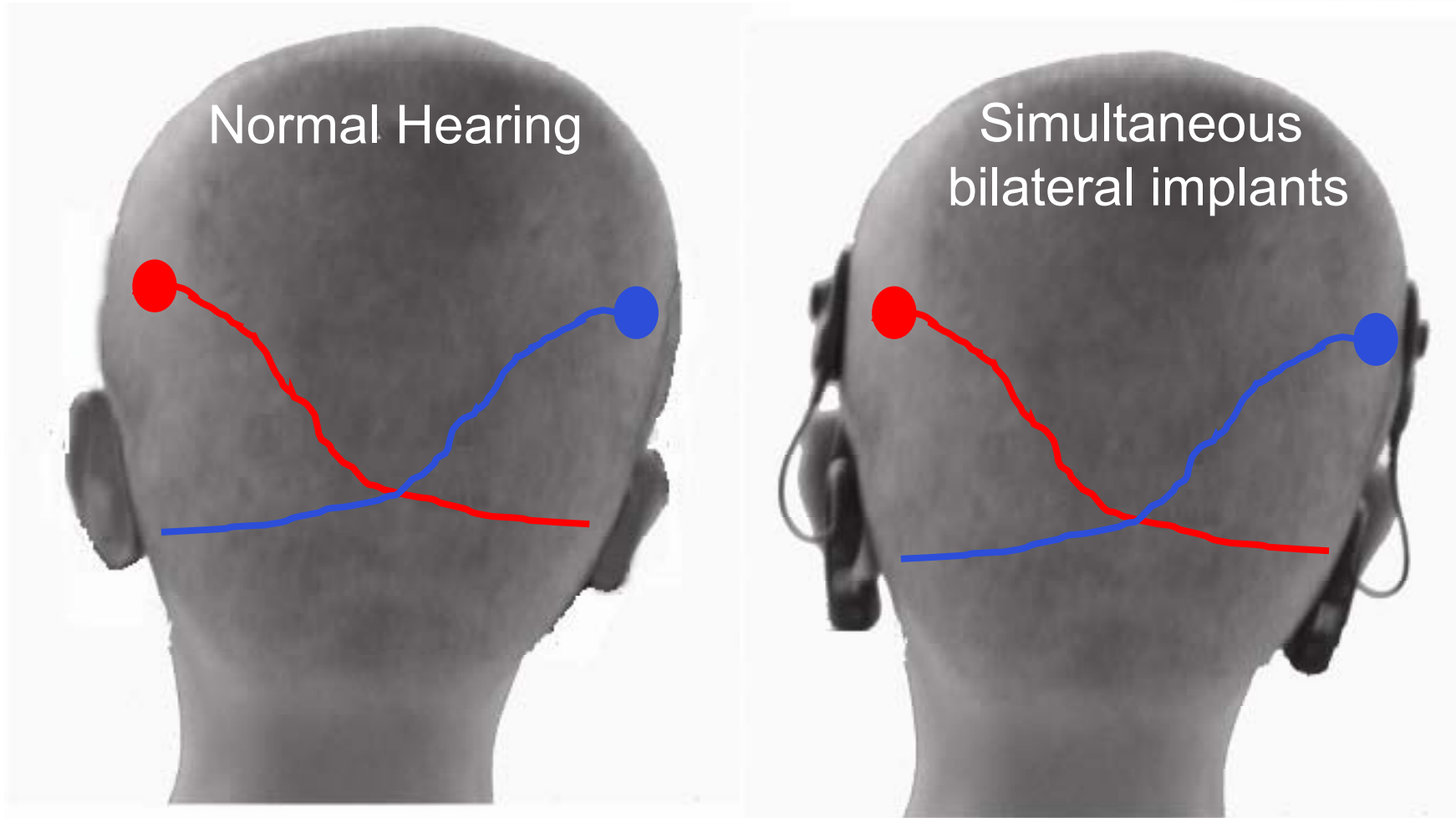


CI-1/Right Stimulation

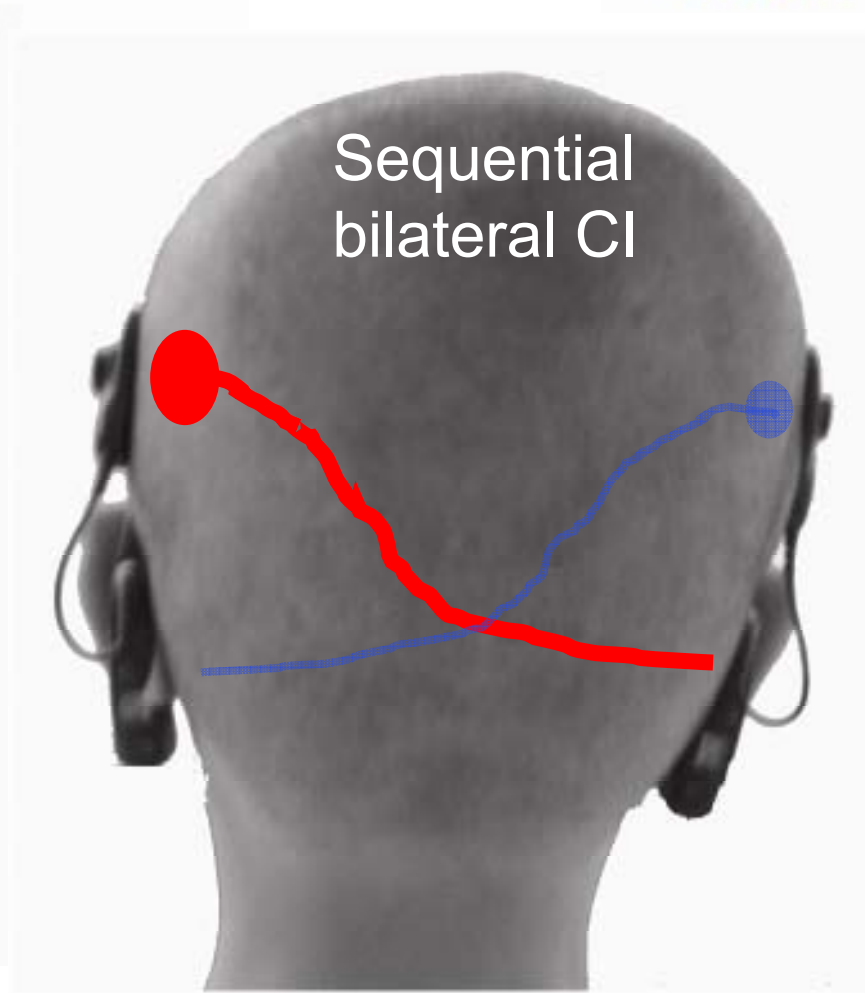
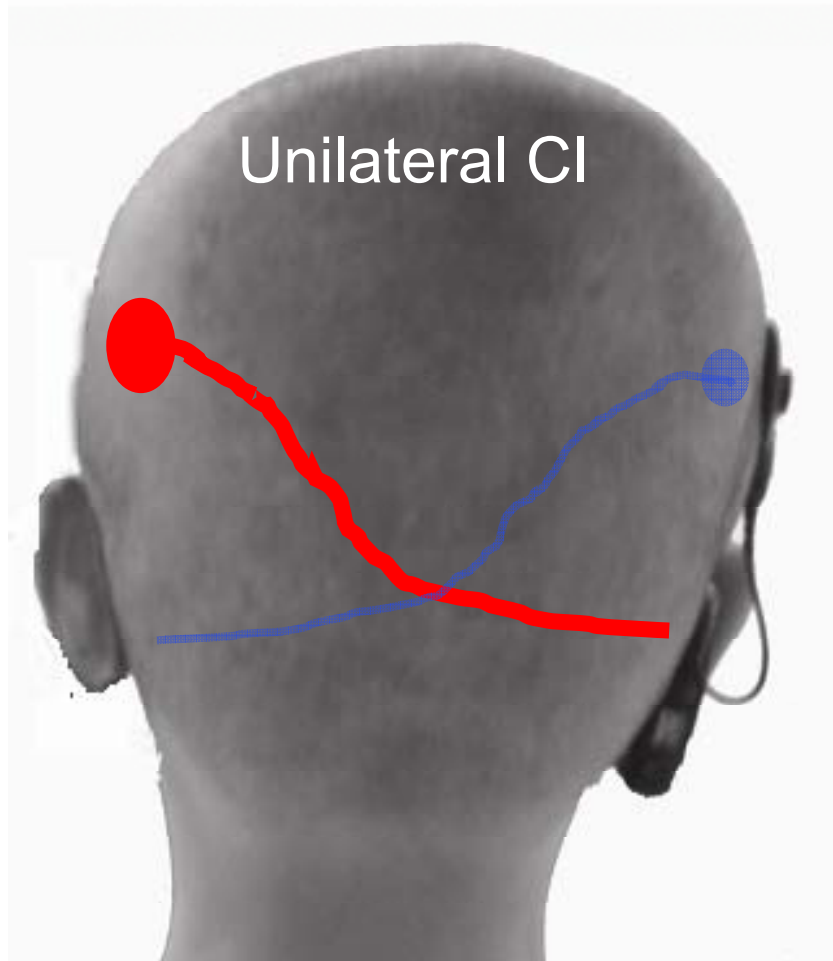
CI-2/Left Stimulation



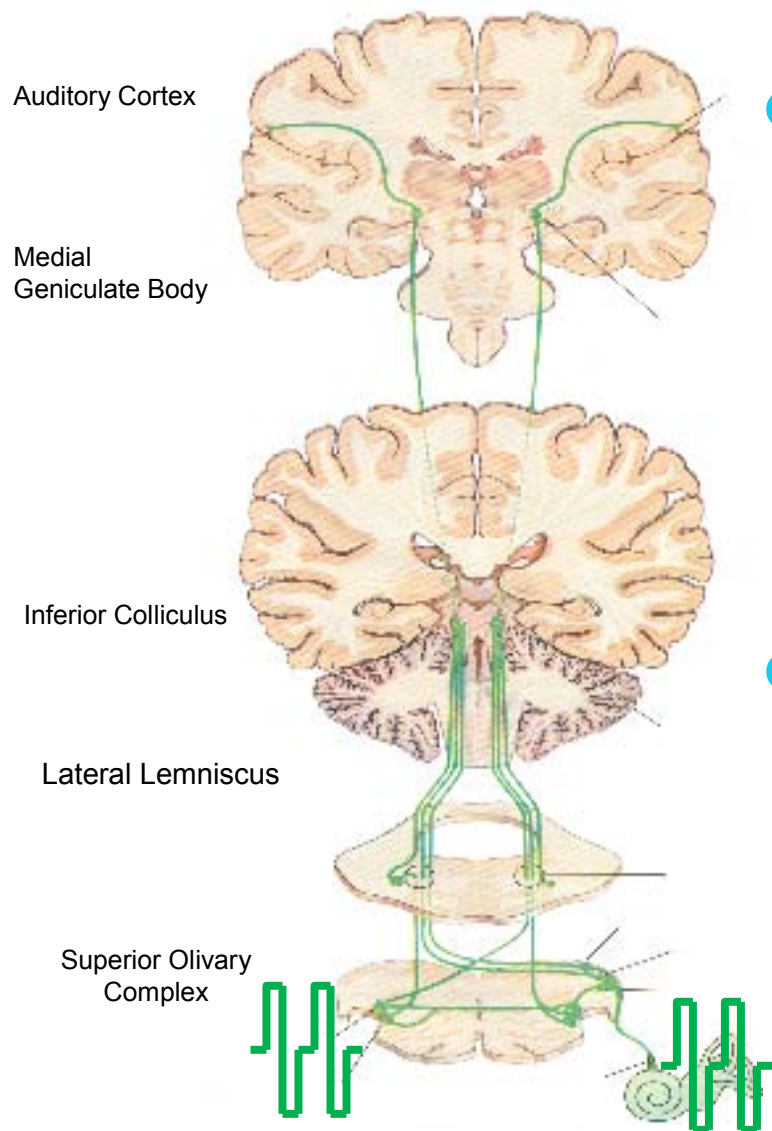
Symmetric auditory activity supports binaural processing



Abnormal binaural processing with unilateral implant use



What pathways are awakened and can they develop normally?



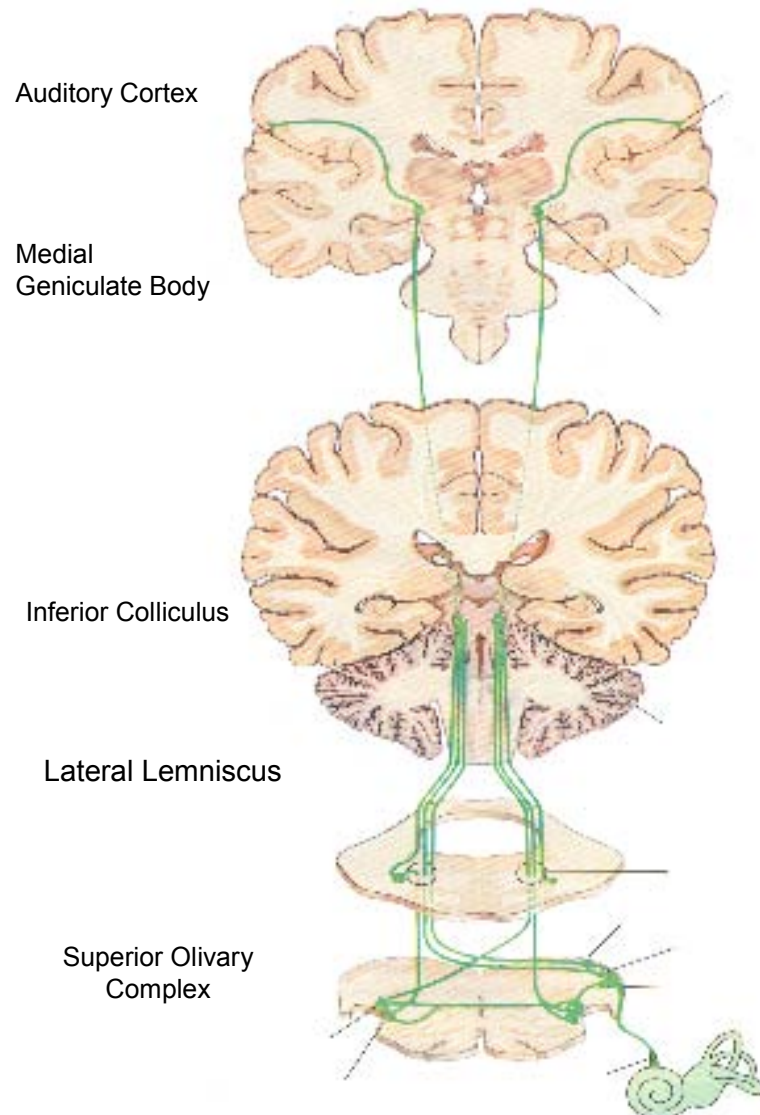
- Effects of bilateral deafness

- Abnormal cortical reorganization if left untreated
- Unique effects of BJK-2 associated hearing loss

- Developmental plasticity

- Unilateral stimulation drives auditory development but also creates abnormalities in bilateral pathways.

Clinical implications for children with hearing loss



- Limit duration of bilateral auditory deprivation
- Understand the onset and cause of hearing loss in childhood
- Limit duration of unilateral auditory deprivation

Thank you to all of our participants



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