Blake Papsin

Programa de Implantes Cocleares. The Hospital for Sick Children

Departamento de ORL, University of Toronto

Toronto, Canadá

Percepción auditiva significativa (lenguaje, emociones y música), en niños con IC: papel de la plasticidad en el desarrollo del sistema auditivo

Meaningful auditory perception (language, emotion and music) after CI in children: the role of plasticity in the development of the auditory system

Reassembling the Auditory Environment in Children with Cochlear Implants

SickKids®
THE HOSPITAL FOR SICK CHILDREN
COCHLEAR IMPLANT PROGRAM

FUNDACION RAMON ARECES

Deteccion, Diagnostico Y Tratamiento Precoz de la Sodera en la Infancia, Madrid – May 28, 2011

Cochlear Implant Research Team

DIRECTORS
- Karen Gordon
- Blake Papsin

RESEARCH ASSISTANTS
- Jerome Valero
- Stephanie Jewell

STUDENTS
- Daniel Wong
- Claire Salloum
- Sho Tanaka
- Patrick Yu
- Brad Hubbard
- Lauren Schofield
- Brittany Harrison
- Brooke Allemang

FELLOWS
- Talar Hopyan
- Neil Chadha
- James Ramsden

COLLABORATORS
Local - SickKids
- Bob Harrison
- Tracy Stockley
- Susan Blaser
- Adrian James
- Paolo Campisi
- Vicky Papaioannou
- Mark Crawford
- Maureen Dennis
- Gina Sohn
- Naureen Sohail
- Laurie MacDonald
- Mary Lynn Feness
- Pat Di Santos
- Nancy Greenwald-Hood
- Susan Druker

Local - external
- Sandra Trehub
- Frank Russo

International
- Robert Cowan
- Richard van Hoesel

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The Three Questions

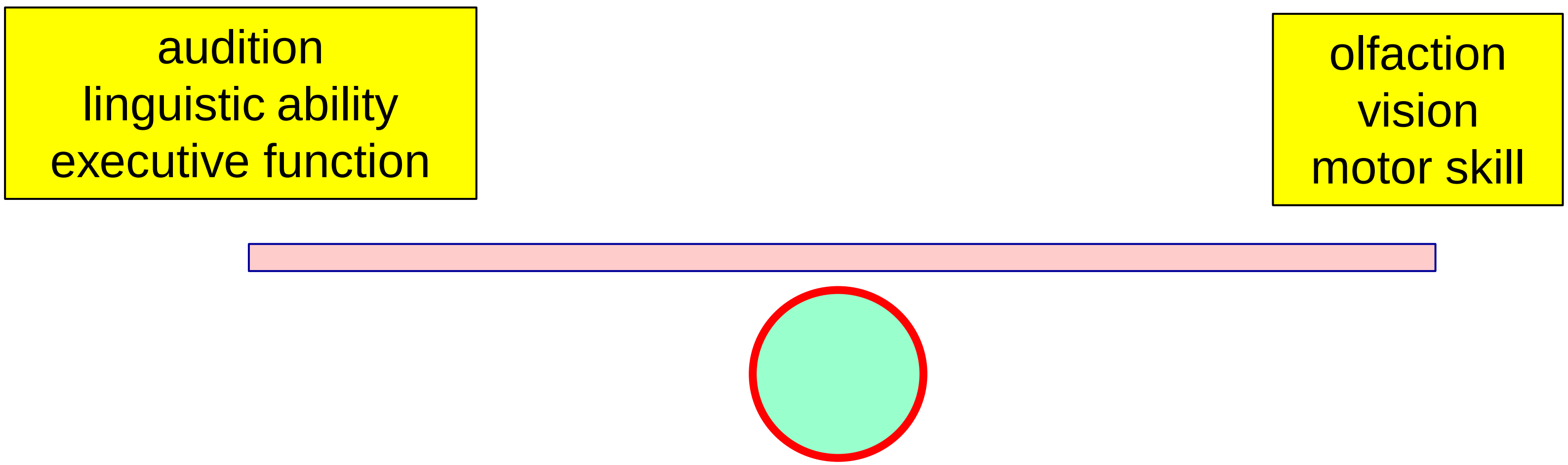
- do I run from it?
- do I eat it?
- do I mate with it?

Evolution in Our Time?

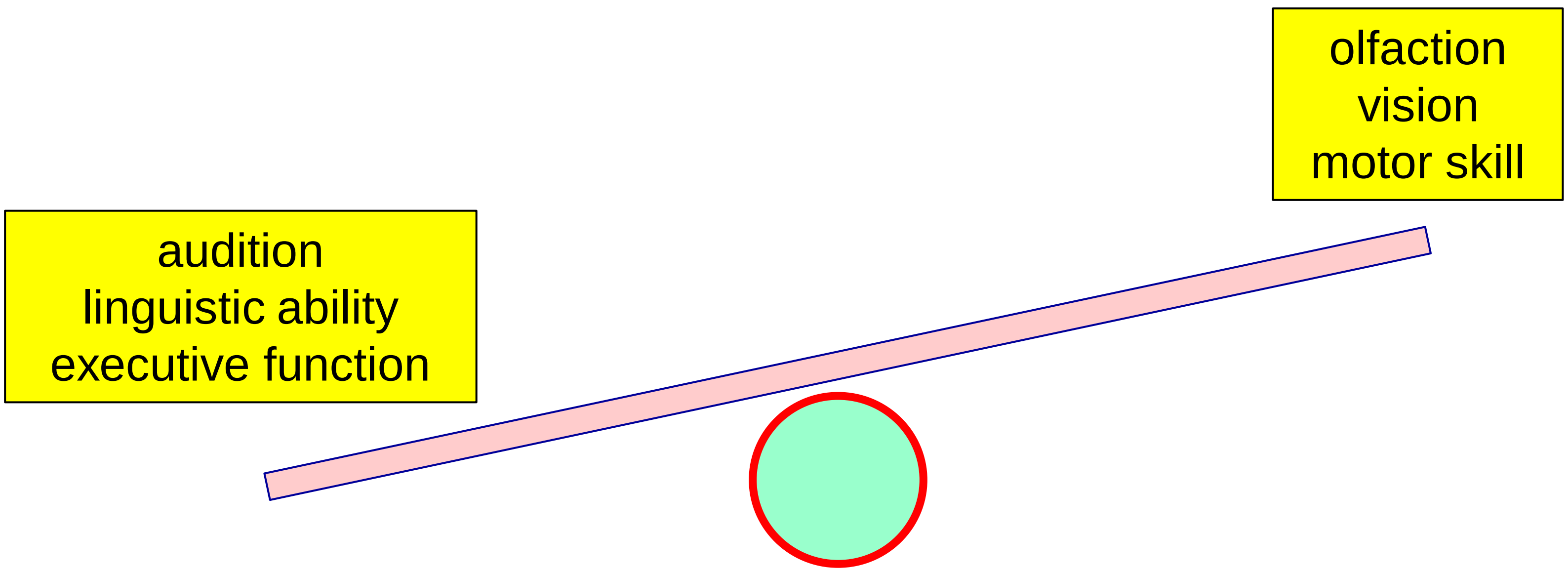
Biston betularia f. typica

Biston betularia f. carbonaria

Human = Information Processor



Human = Information Processor



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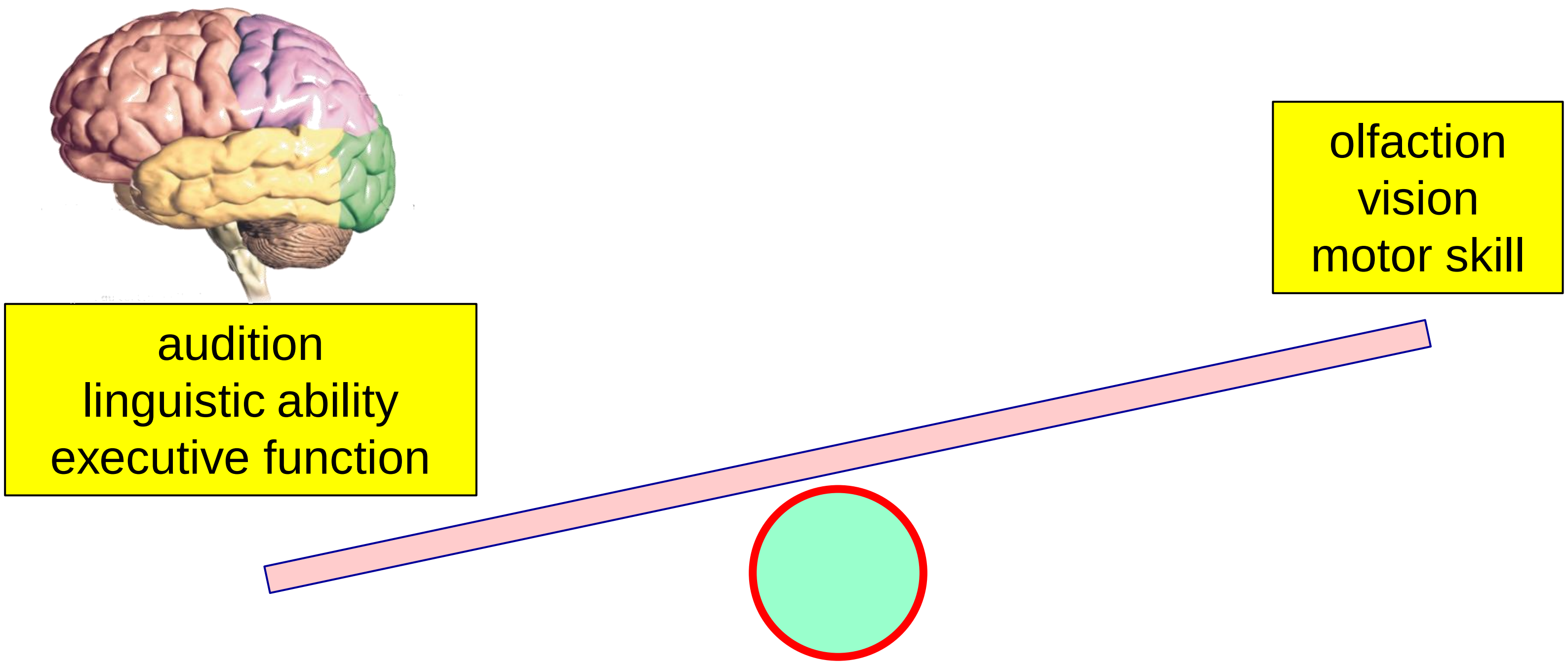
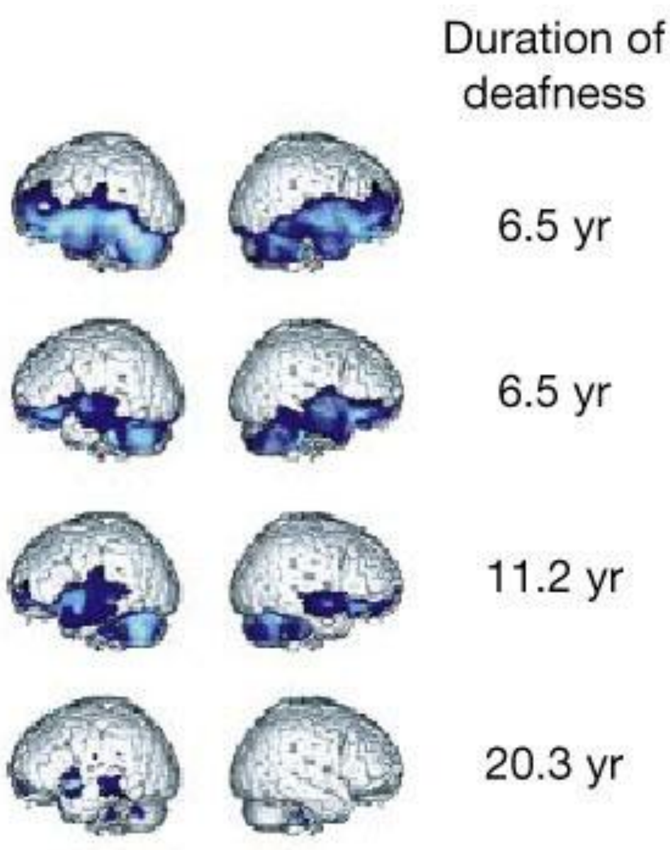


Auditory Cortex in Silence

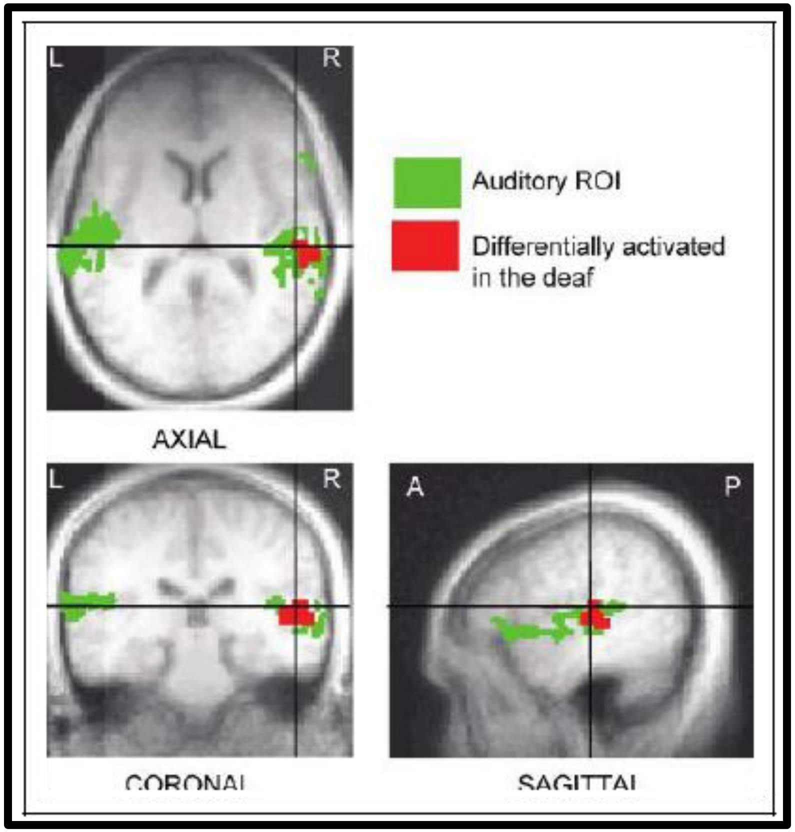
Reduced activity

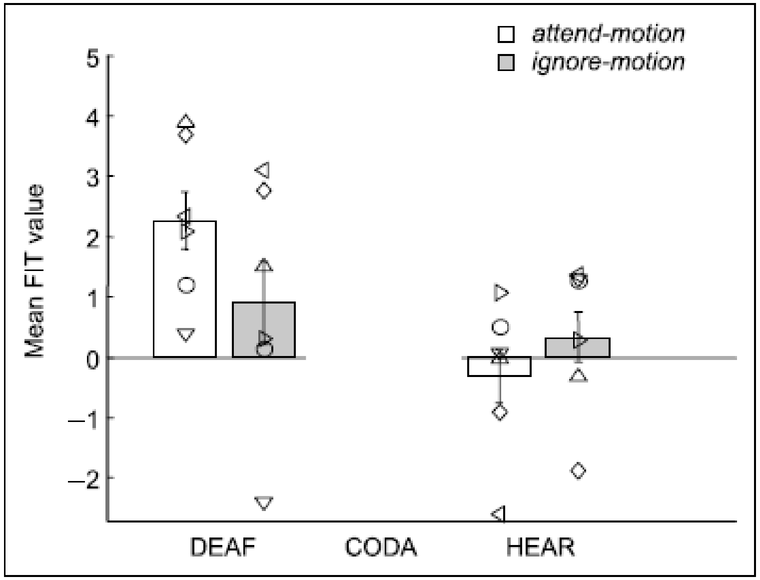


Activity no longer reduced

Lee, et al., Nature, 2001

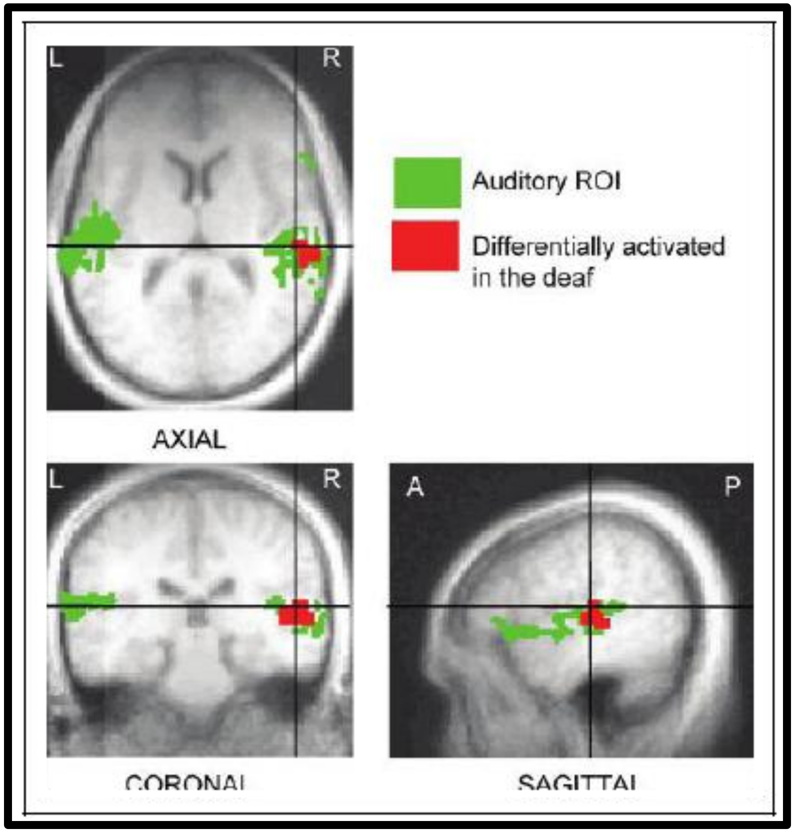
Reorganization of Auditory Cortex

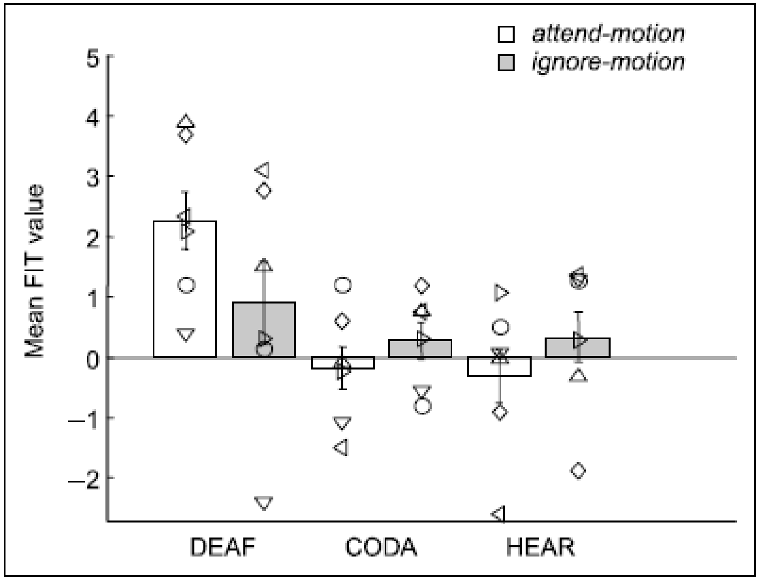




Fine, et al., 2005

Reorganization of Auditory Cortex





Fine, et al., 2005

Human = Information Processor

IQ = 107

IQ = 7

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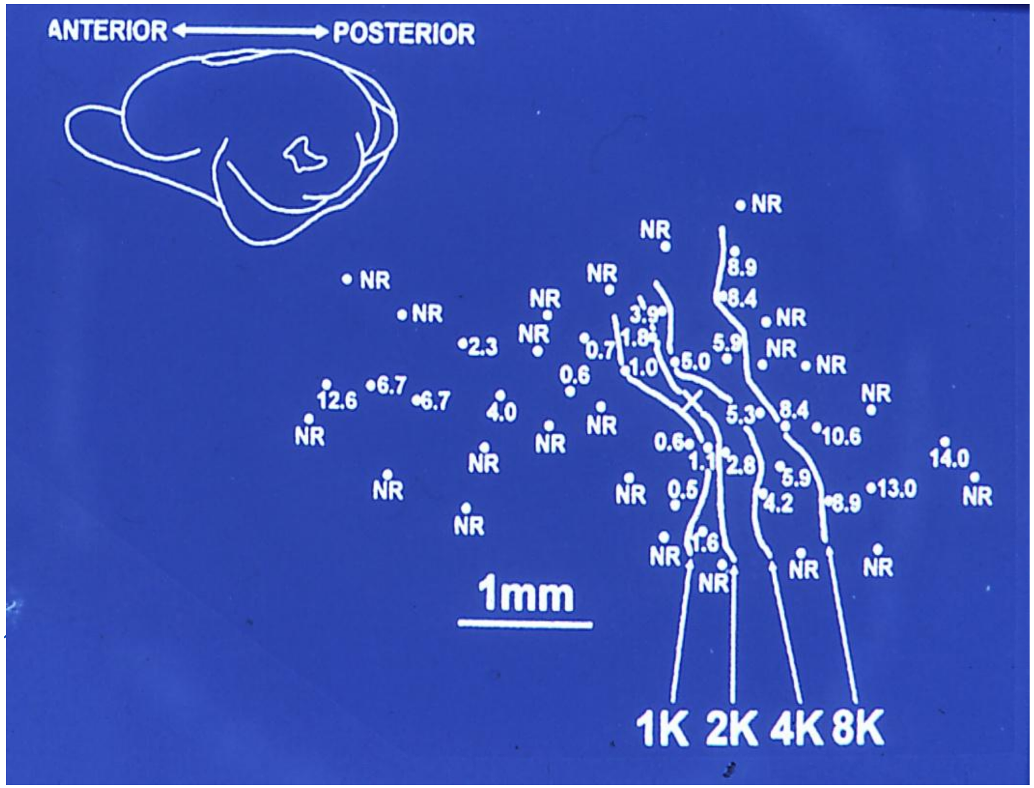
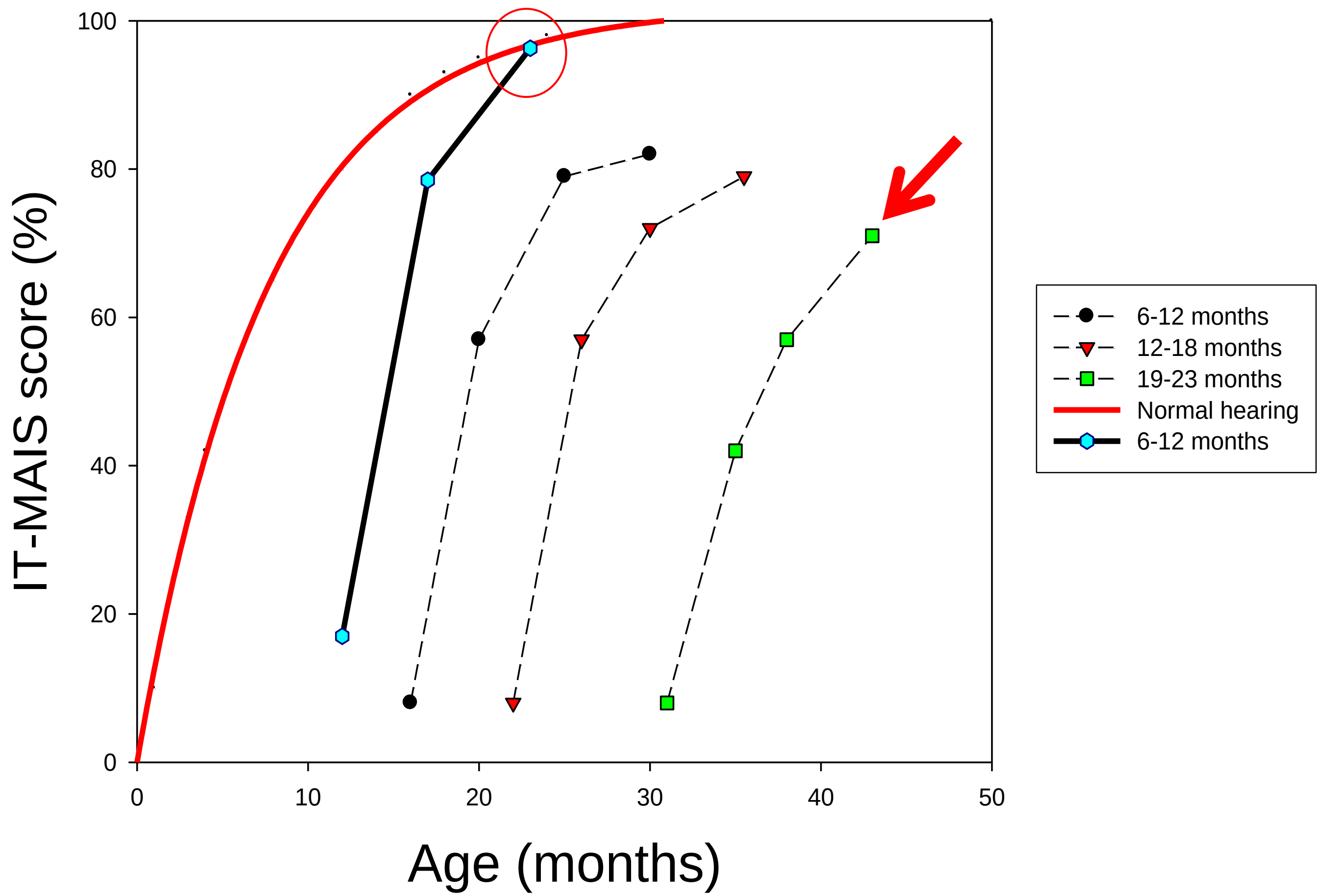
COCHLEAR IMPLANT PROGRAM

Auditory Plasticity (Learning)



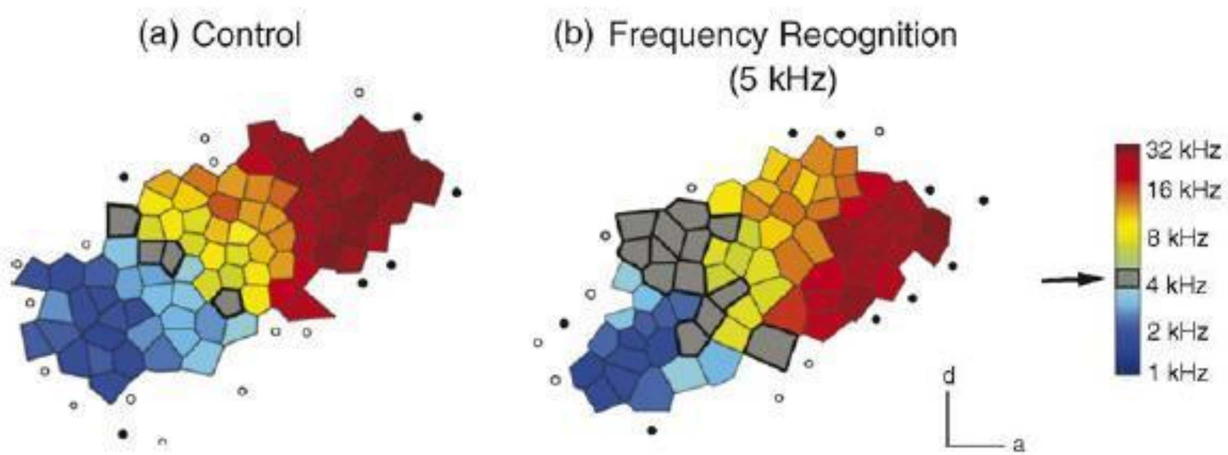
FUNDACION RAMON ARECES

Capitalizing on Plasticity



Developmental Plasticity

- adult map reorganization reported:
  - If animal is trained to attend to the stimulus



(Polley, Steinberg & Merzenich, 2006)

Senses

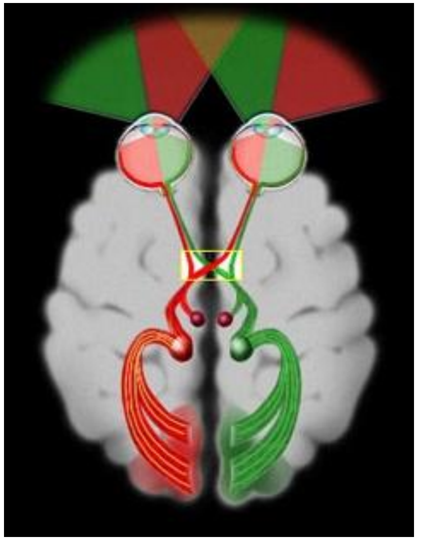
- collect data
- extract data
- orient

Senses

- illusory
- reassemble the world – most probable state

Vision and Audition

- fundamentally different
  - bilateral pathways
  - temporal relationships



Vision and Audition

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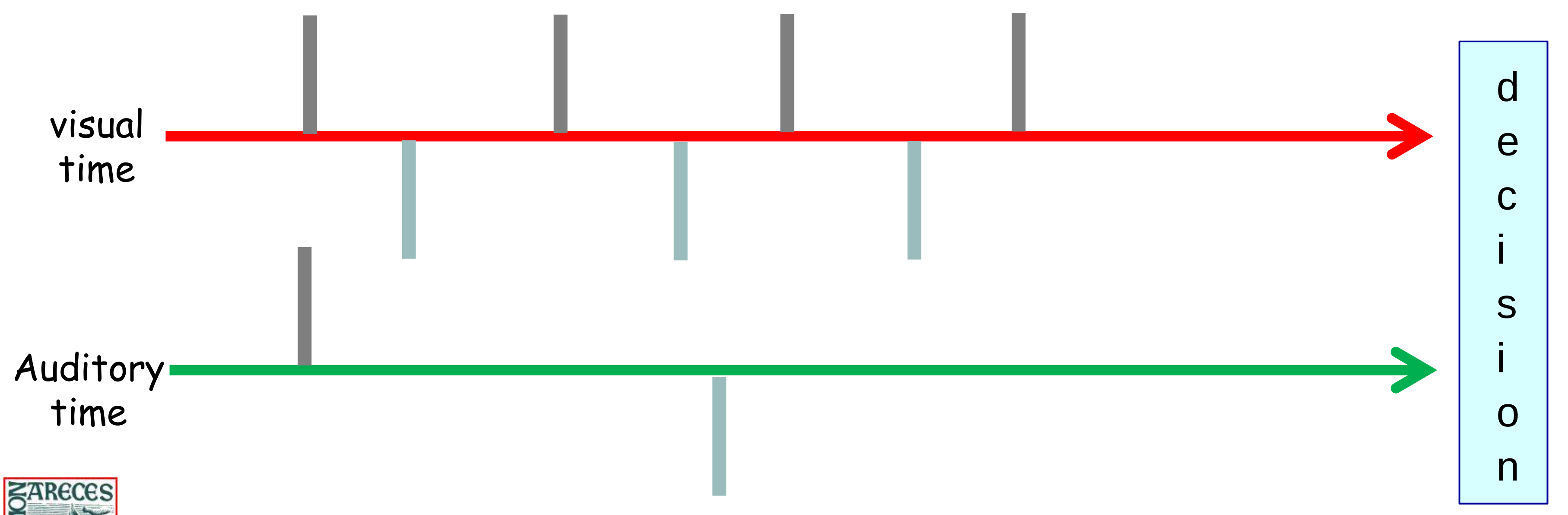
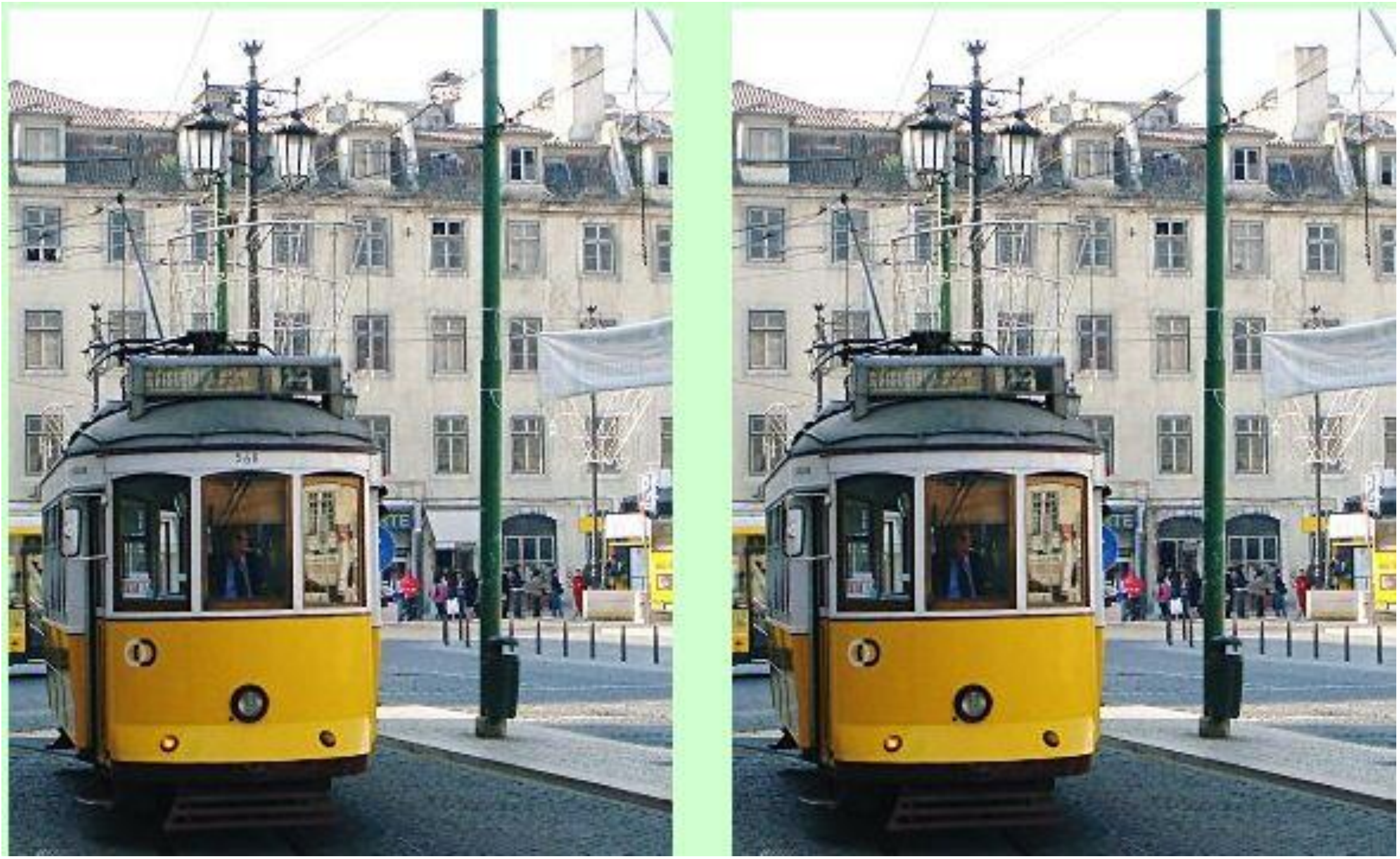


Spot the Difference



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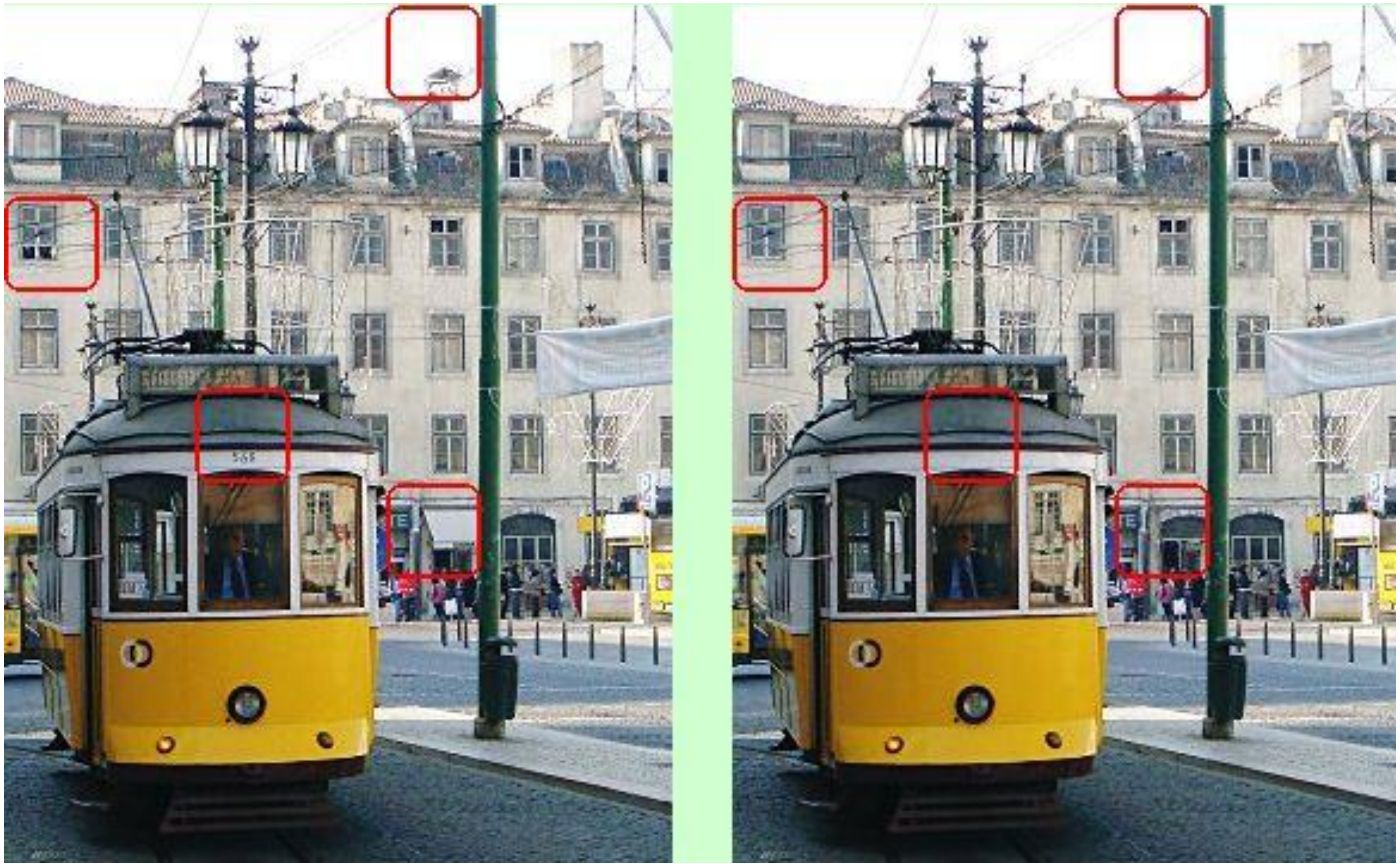
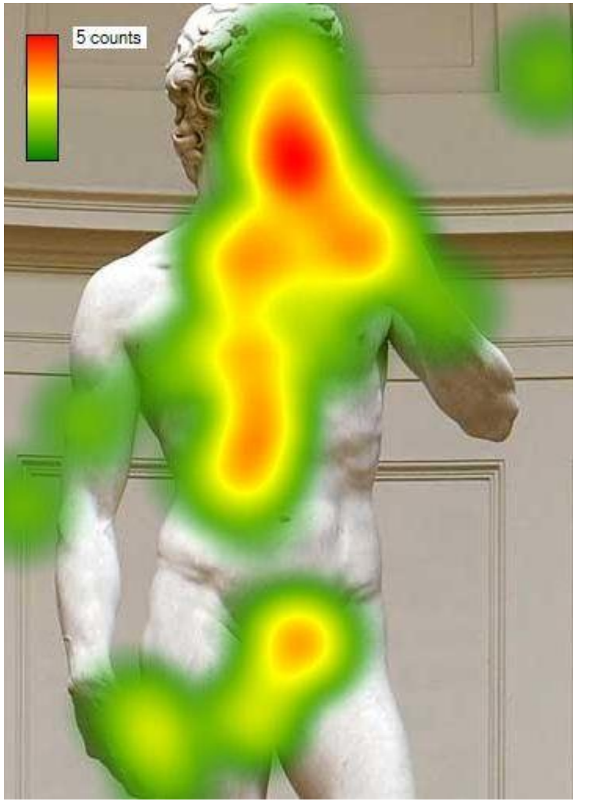


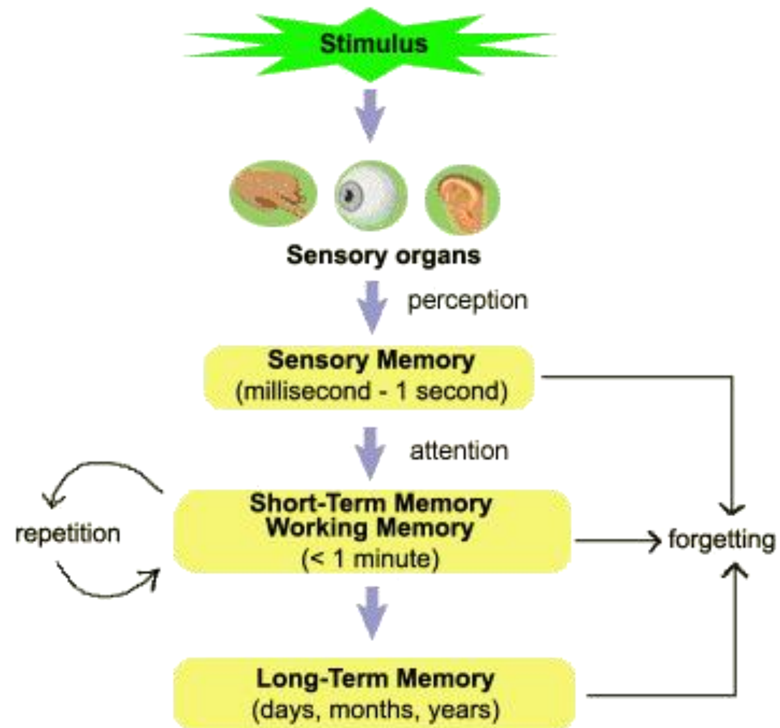
Visual Attention

- saccades scan visual environment

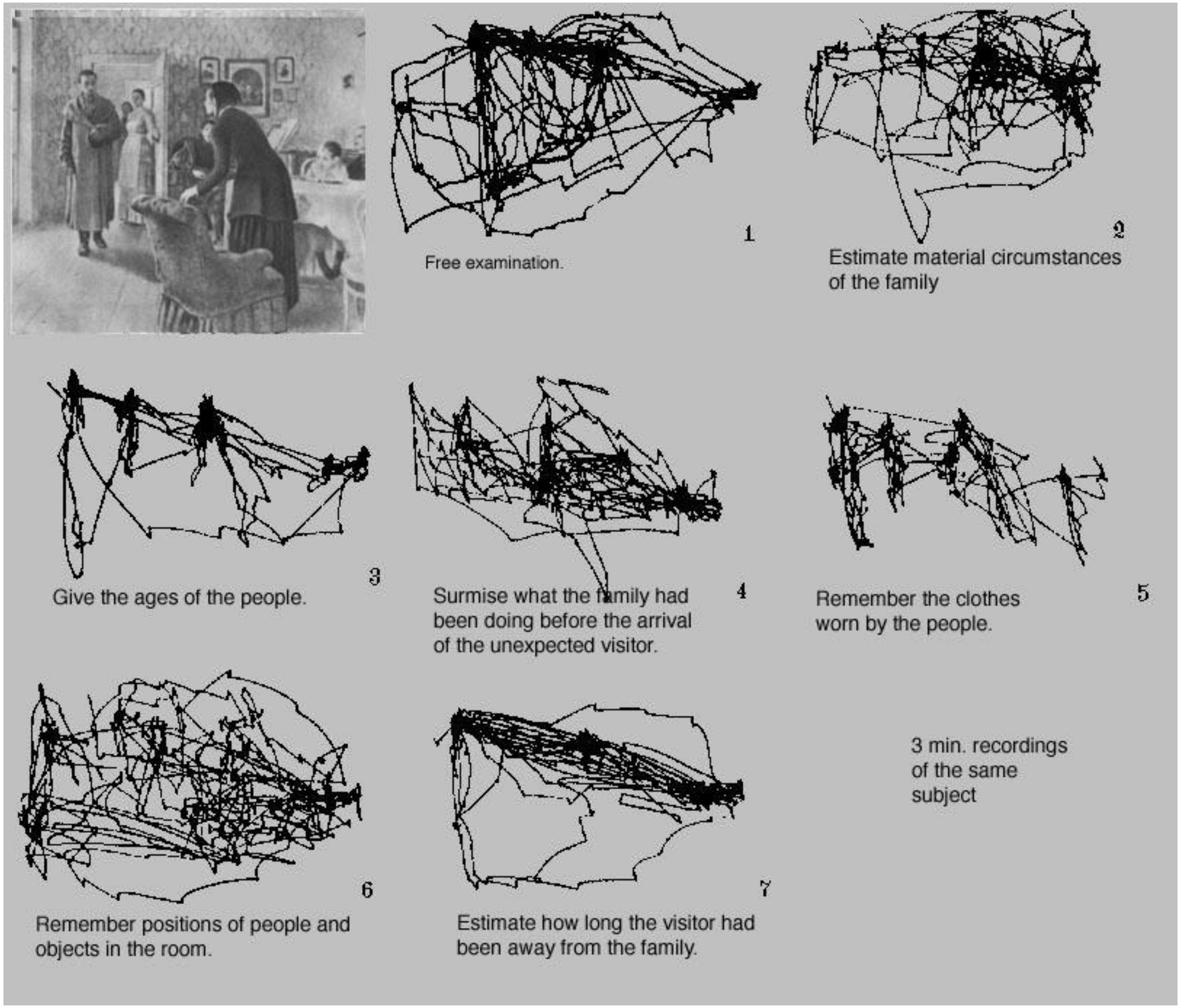


Auditory Processing

- must process environment in one pass
  - extract
  - identify
  - categorize



Feature Extraction



Feature Extraction

- key to extraction missed by
  - Euclid, Archimedes, Da Vinci, Newton

Feature Extraction

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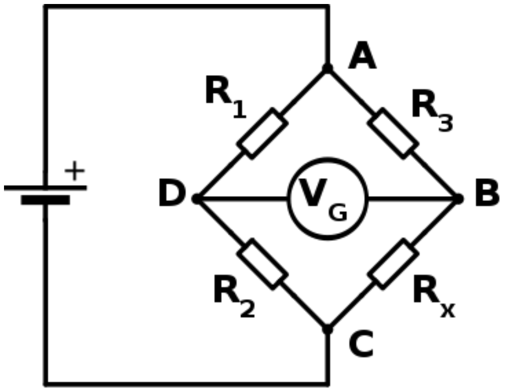

Feature Extraction

- key to extraction missed by
  - Euclid, Archimedes, Da Vinci, Newton
- Wheatstone 1838
  - "there is an essential difference between the impressions on the organs of sensation"

SickKids
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COCHLEAR IMPLANT PROGRAM

Importance of Stereoscopy

- the slight differences between the two eyes define orientation in space

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Development of Stereoscopy

- altricial

- Hubel and Wiesel
  - patched one side
    = all input neurons to one eye

  - patched both sides
    = all inputs neurons active

Can You Patch an Ear?

- paths cross early
- hearing occurs in utero
  - conductive loss models

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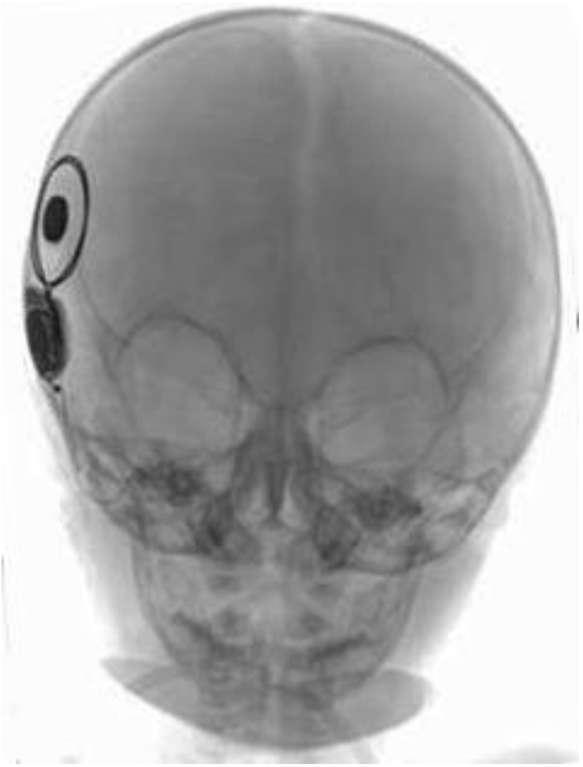

Can You Patch an Ear?

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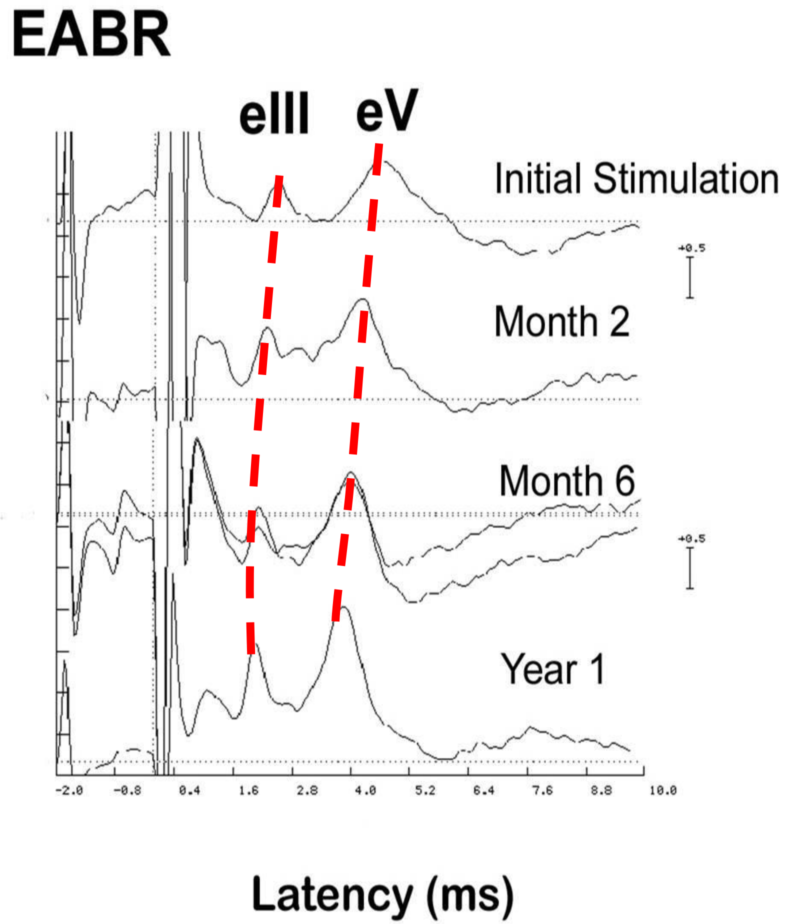
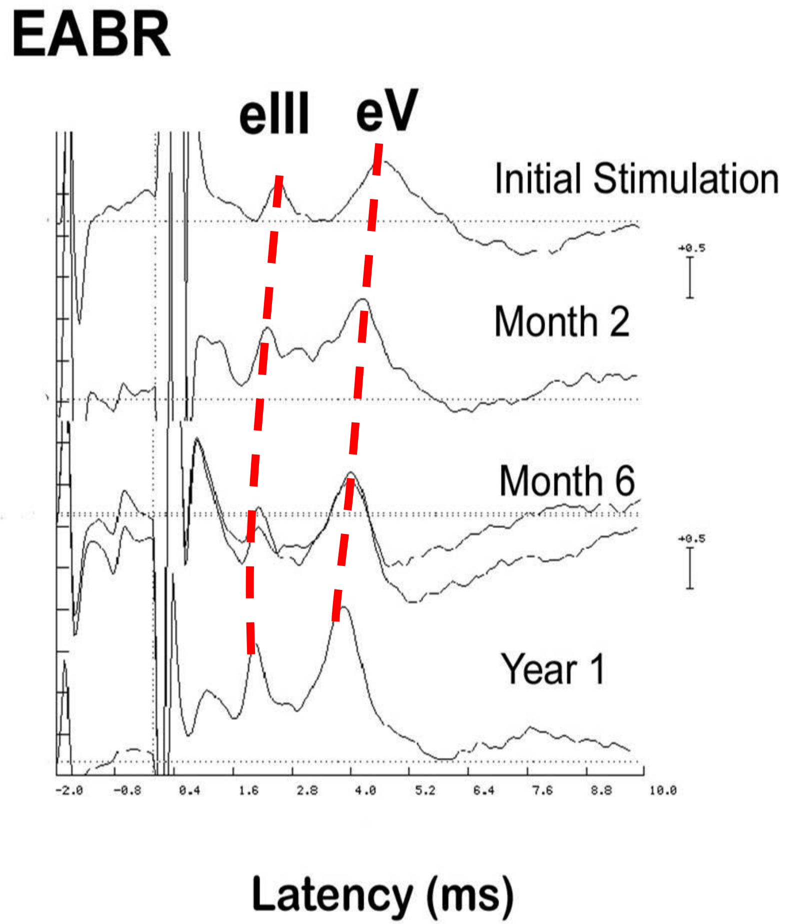
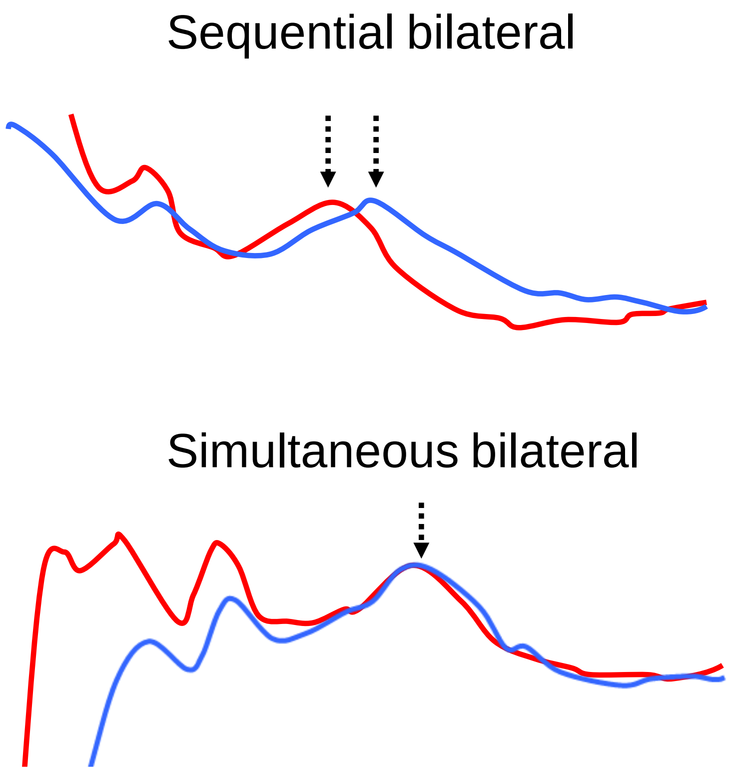
Auditory Brainstem Development



Ear and Hearing, 2003

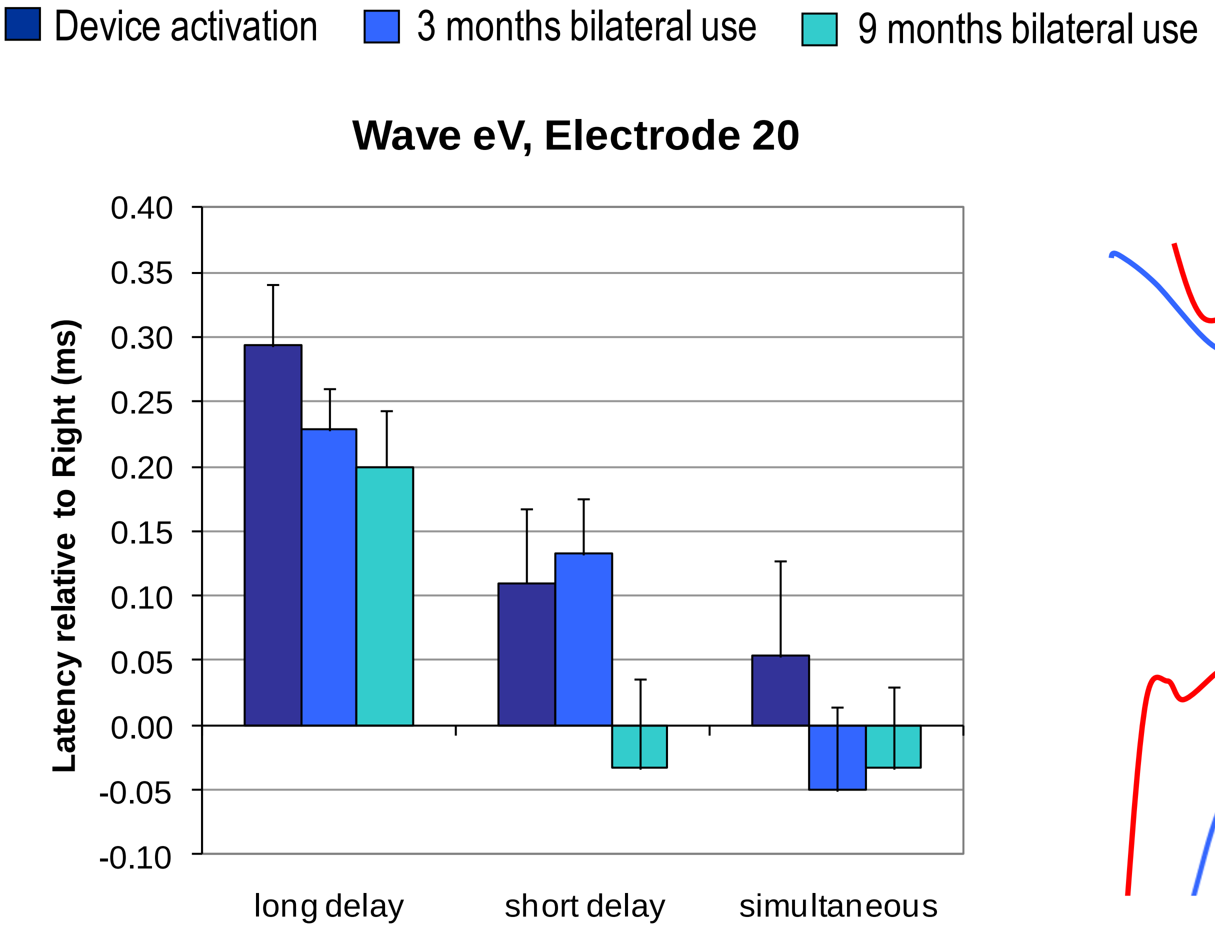
Auditory Brainstem Development

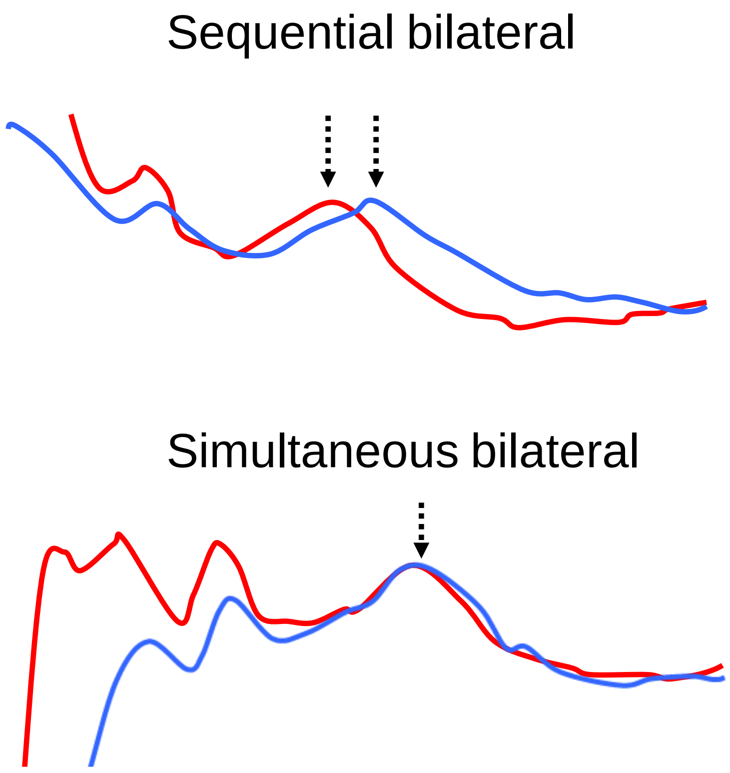




Ear and Hearing, 2003

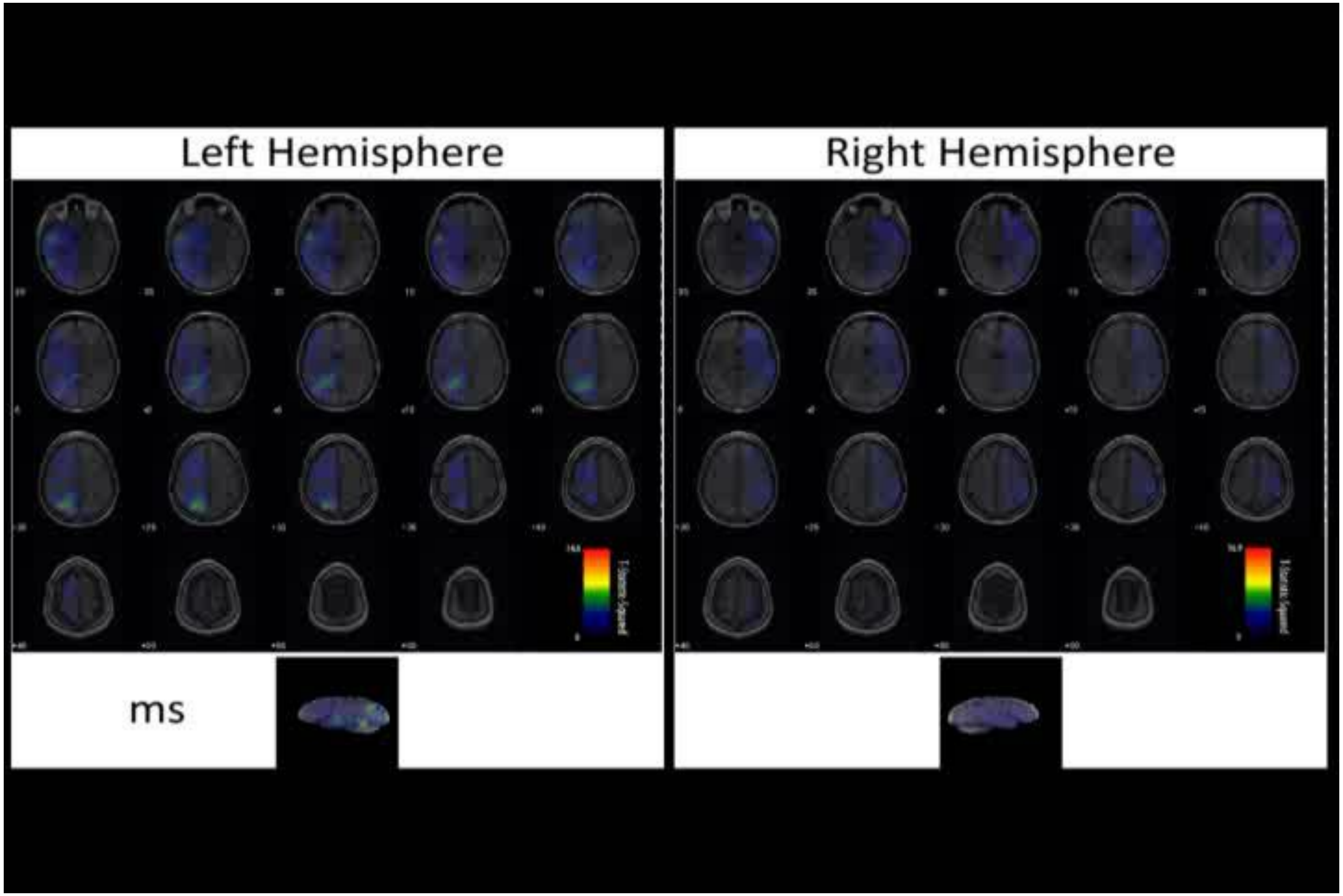
Asymmetry at the Lateral Lemniscus



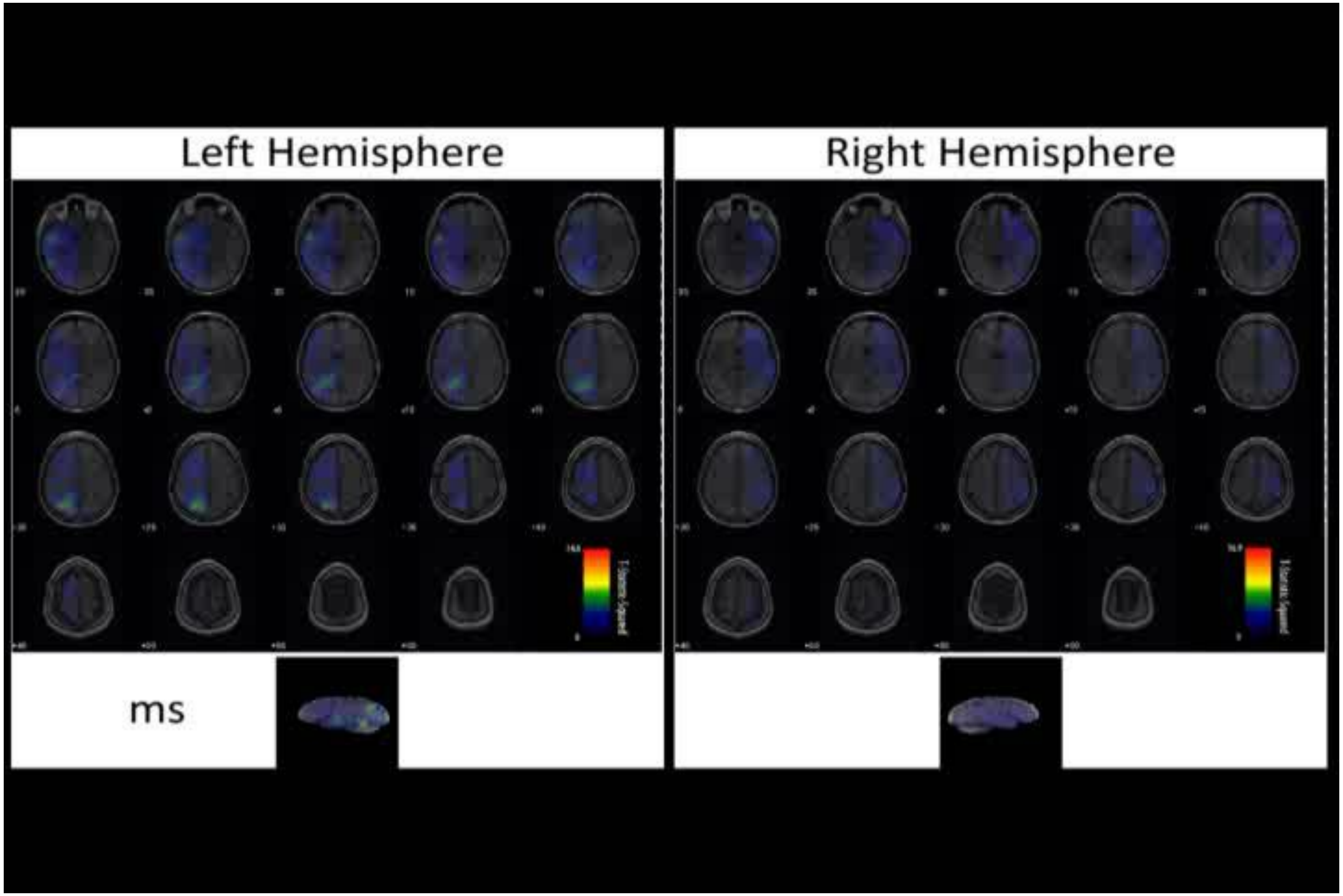


Otology & NeuroOtology, 2007

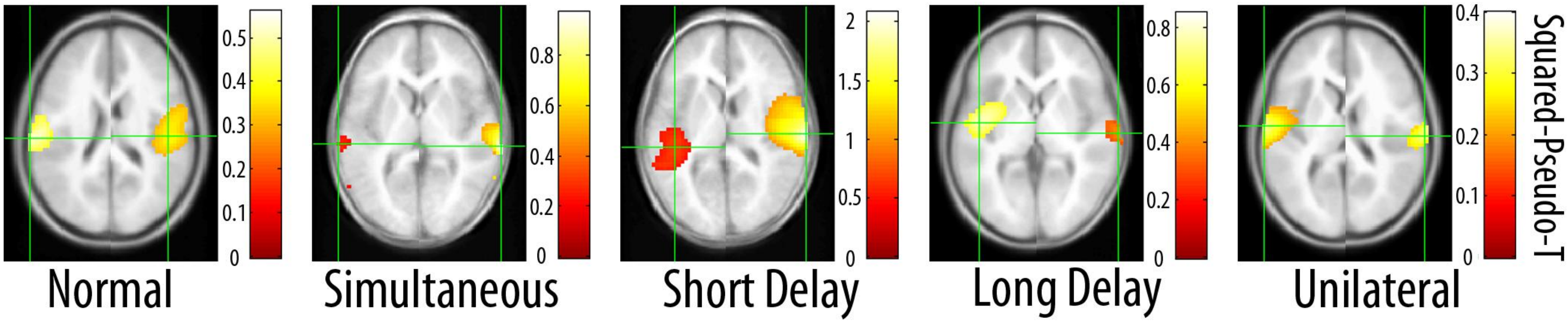
Studying Binaural Perception



Studying Binaural Perception

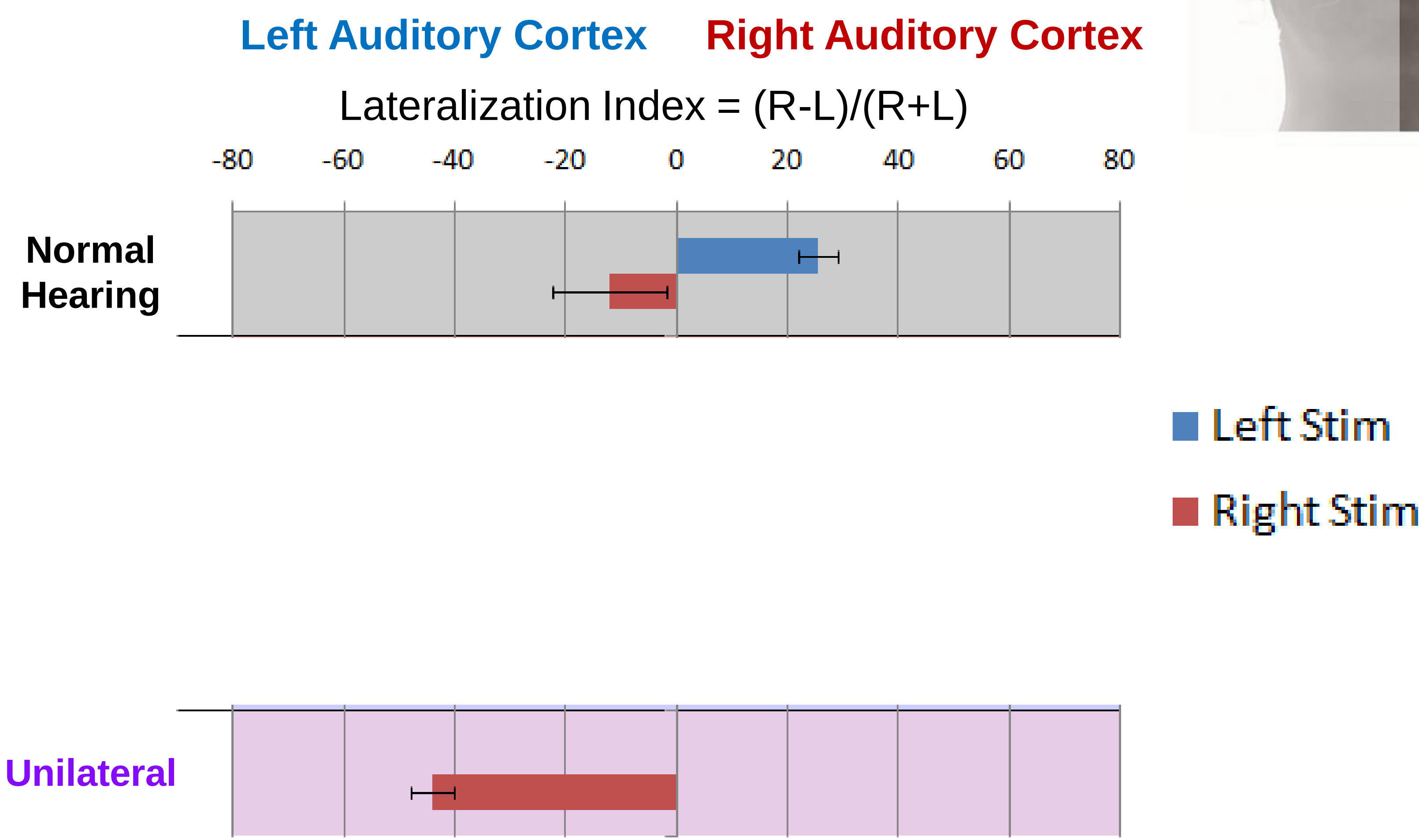


Studying Binaural Perception



Lateralization Index = (R-L)/(R+L)

“Patching” the Ear



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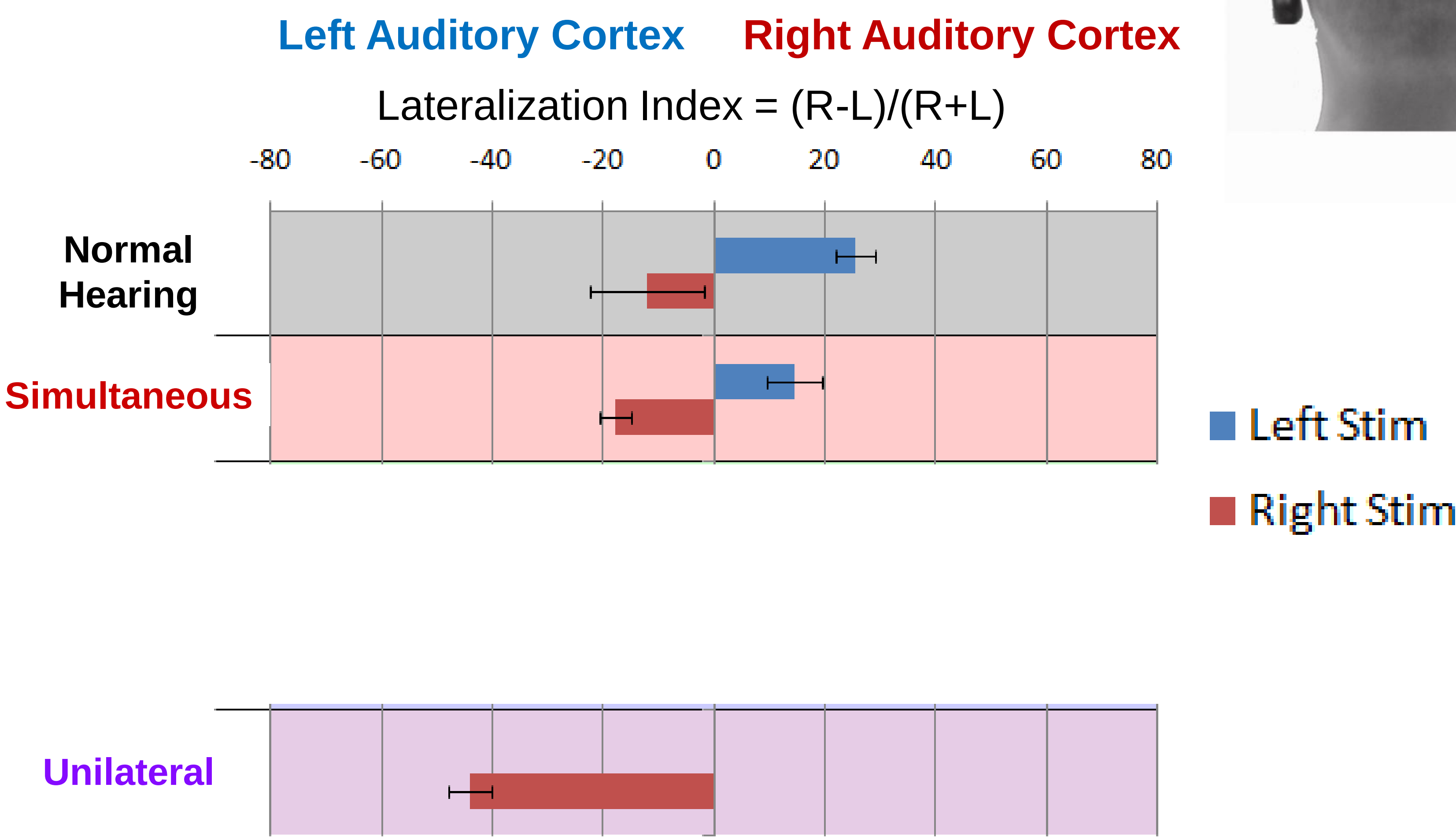

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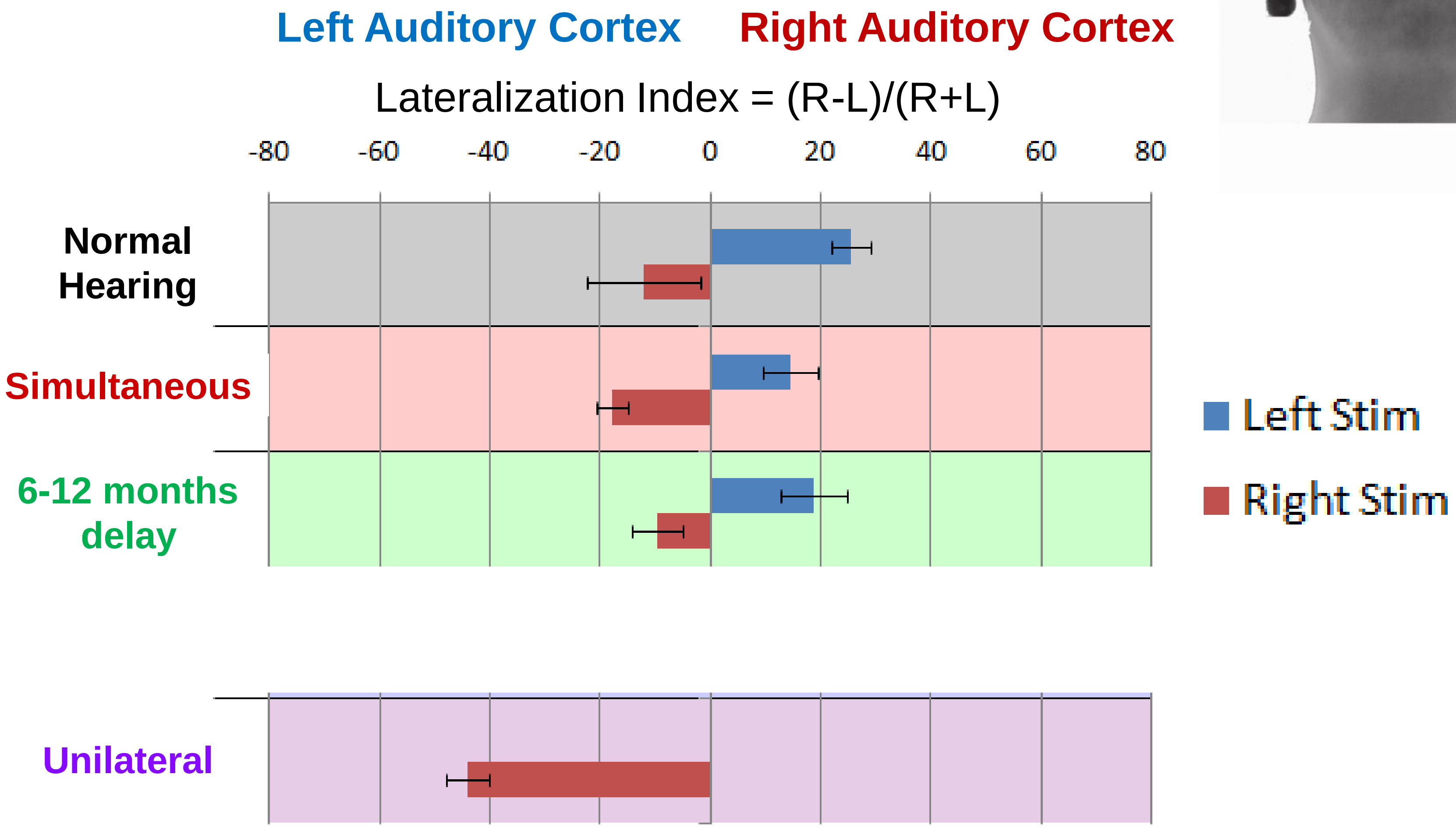

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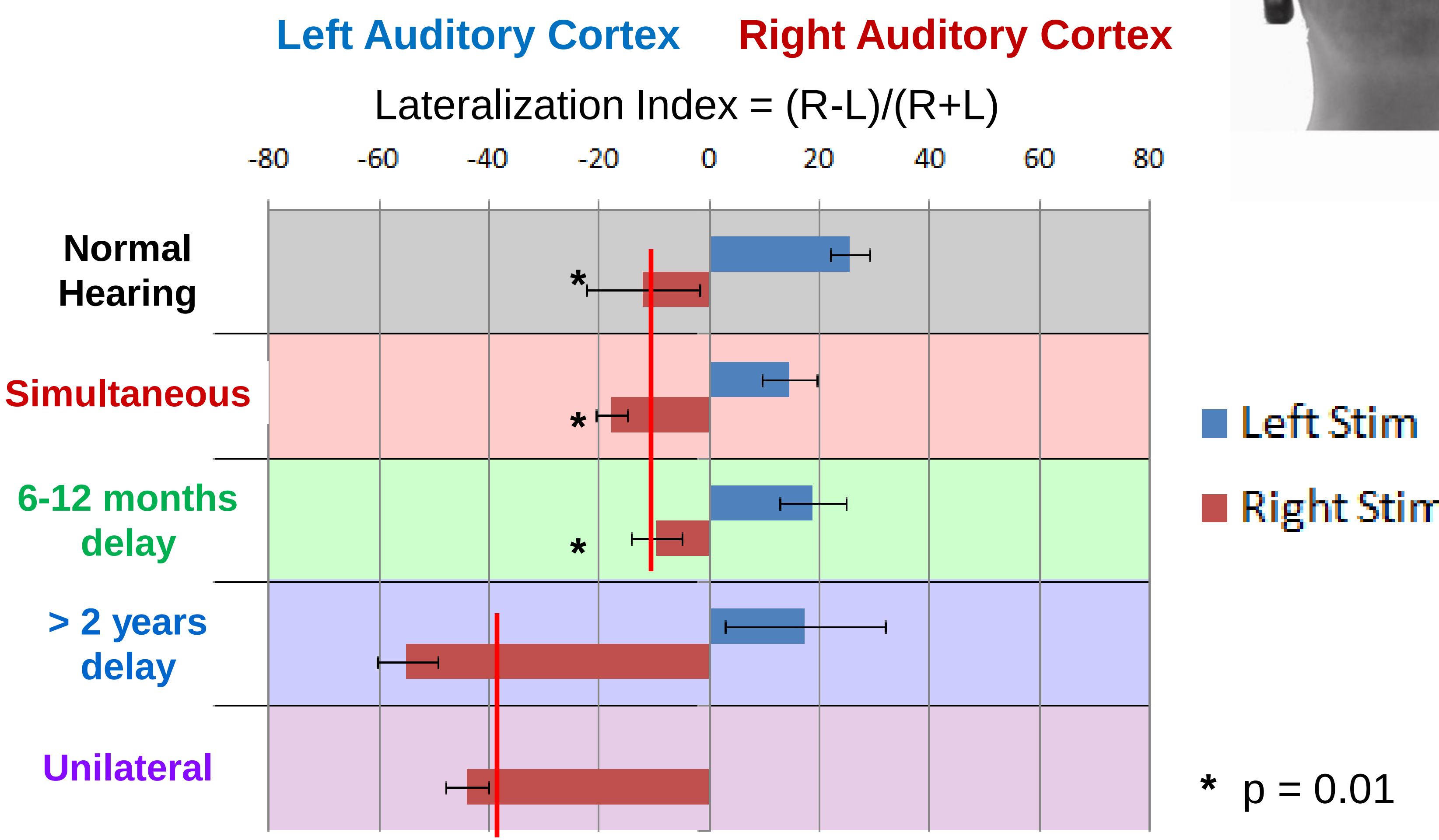
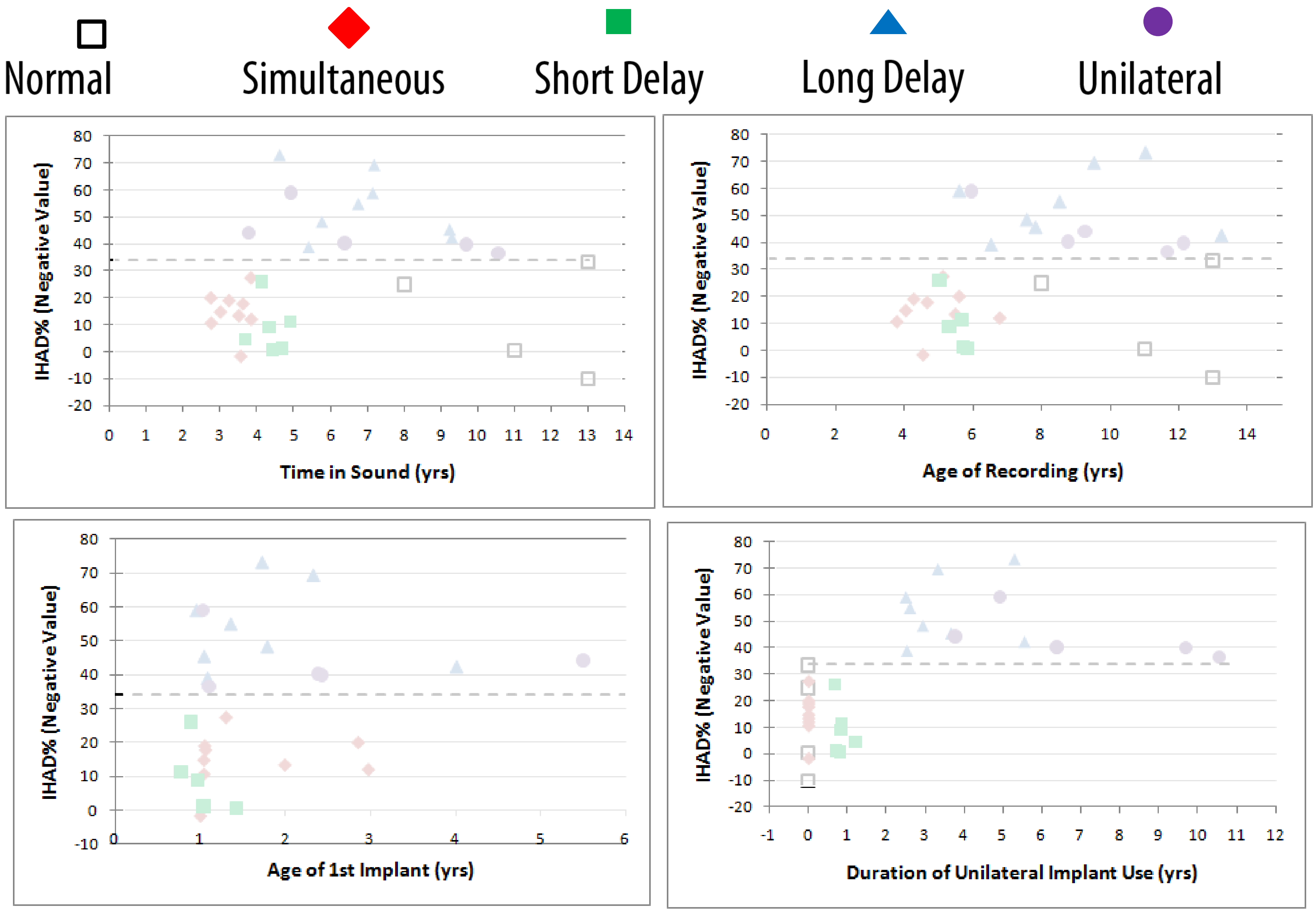


Effect of Unilateral Stimulation



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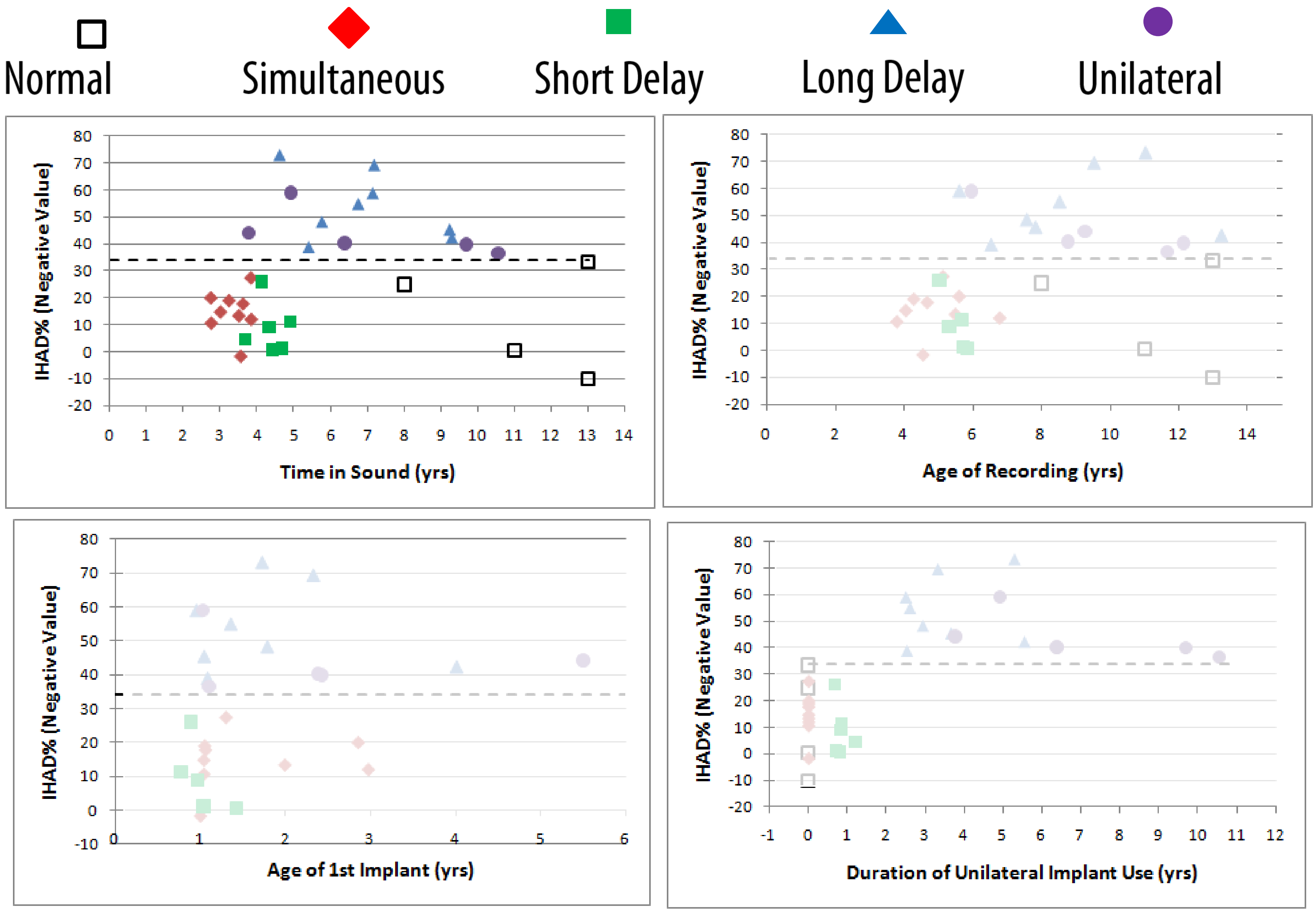

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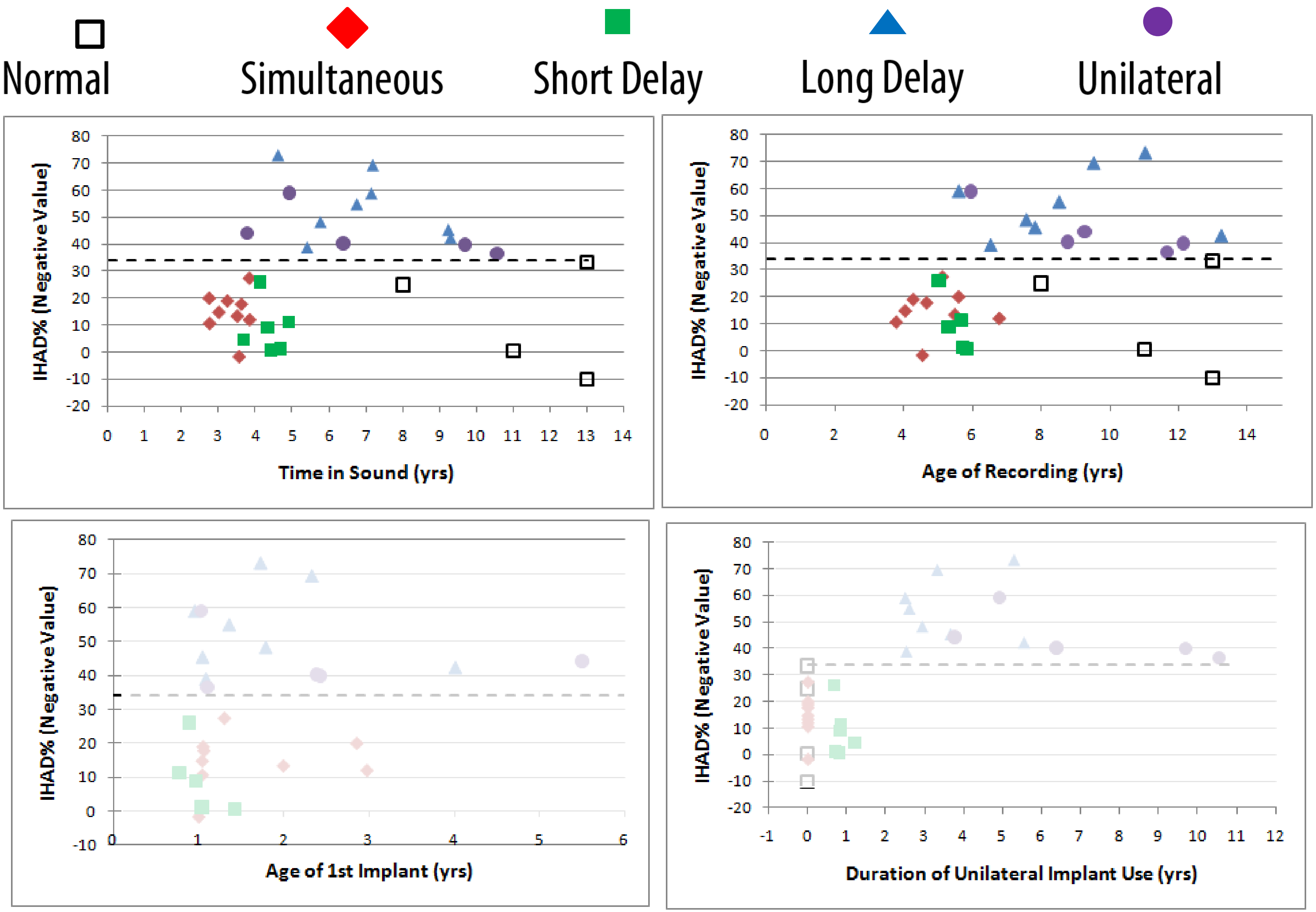

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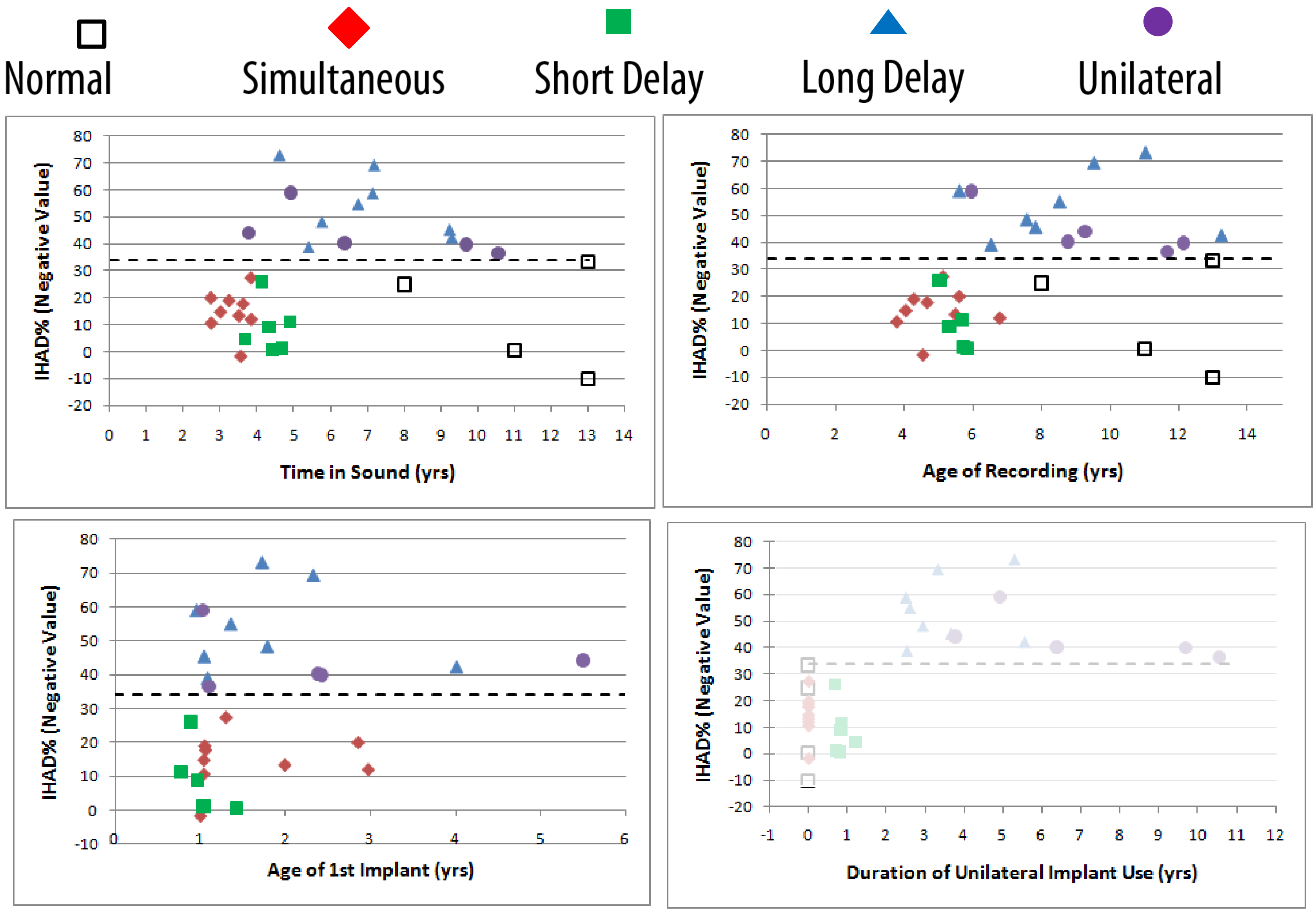

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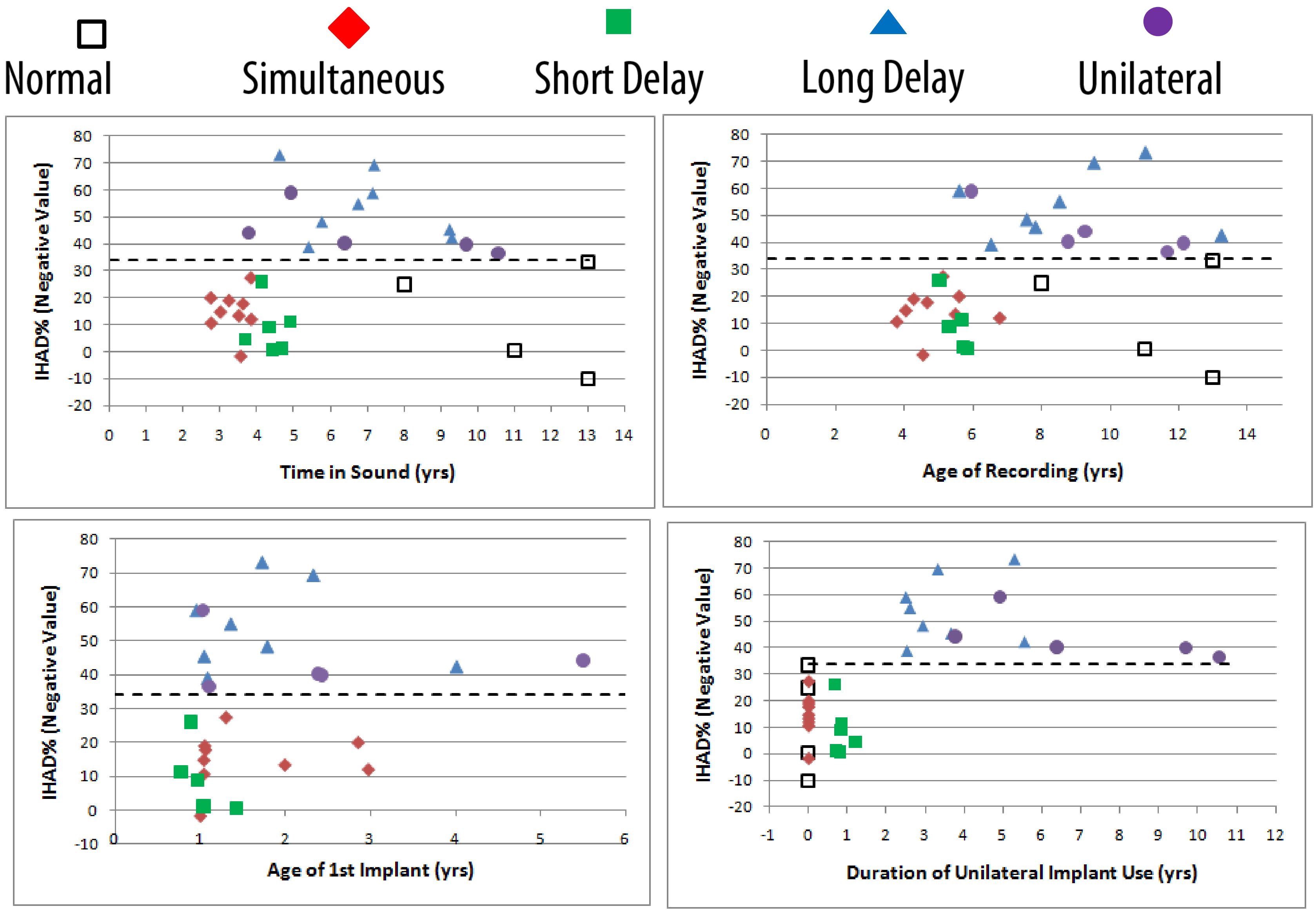

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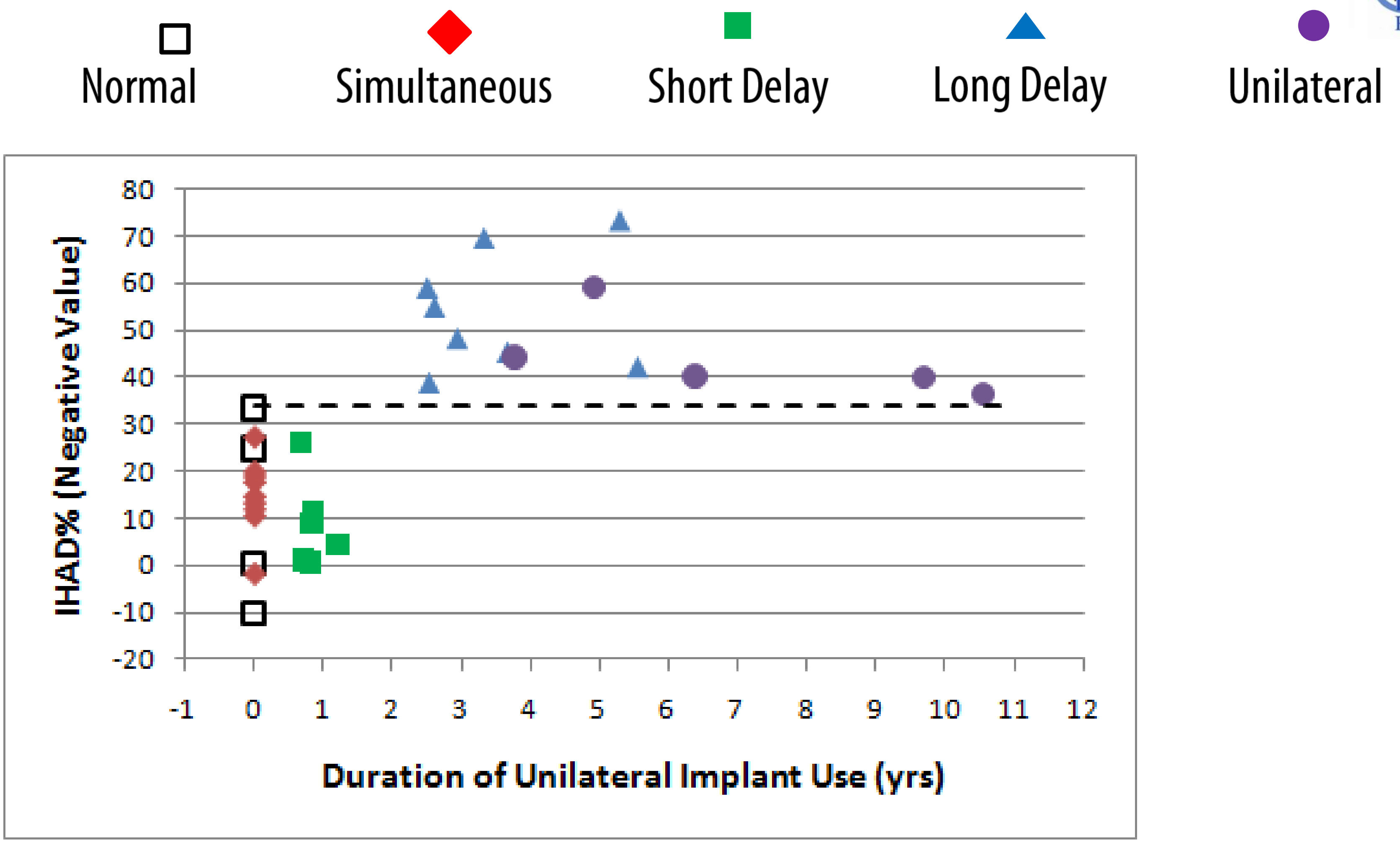
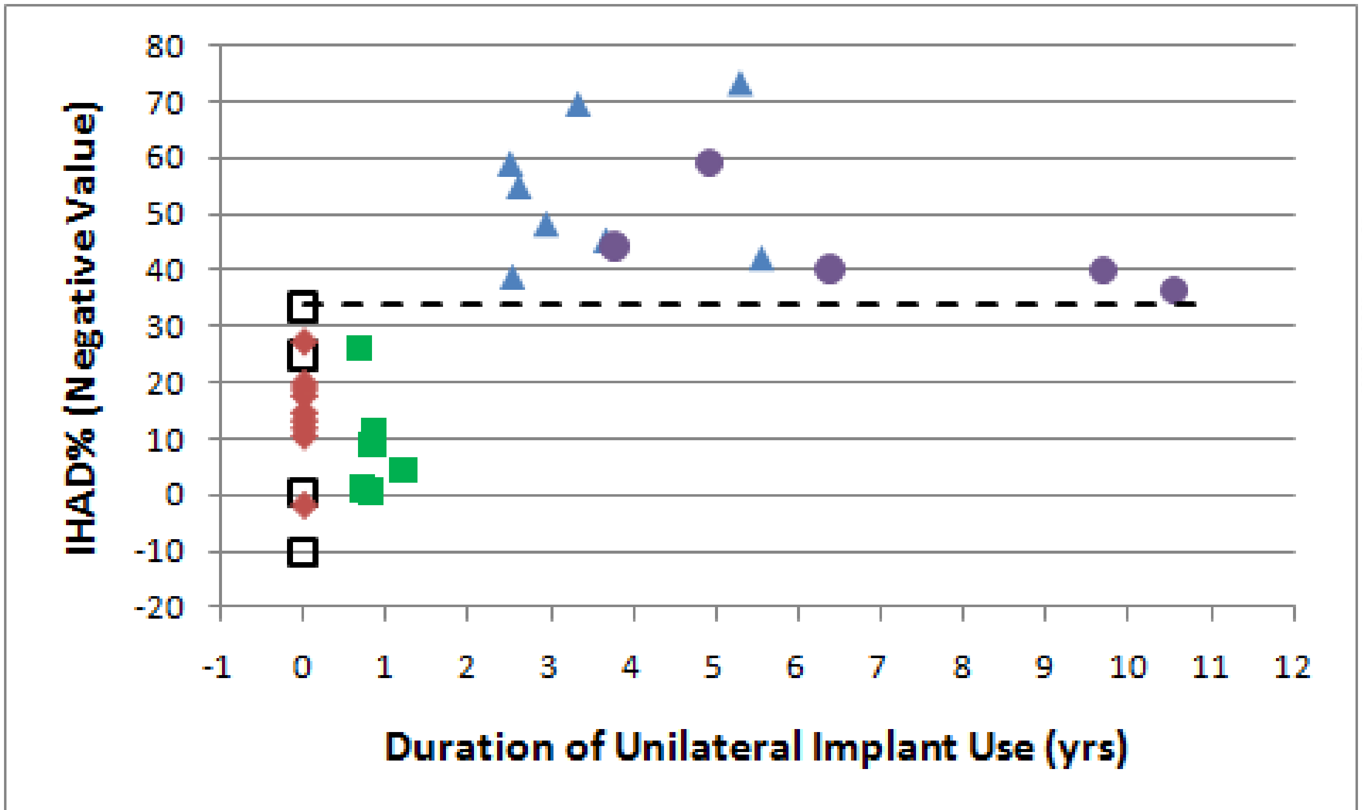
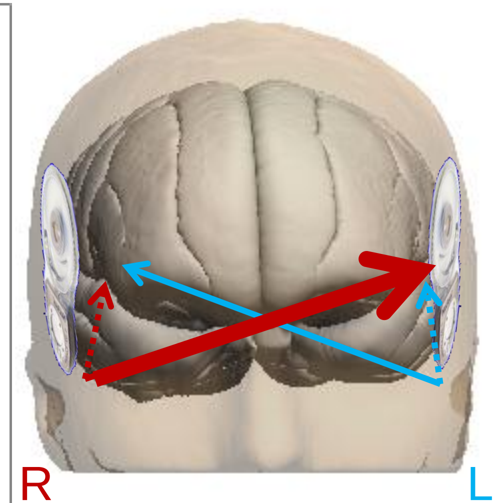


Effect of Unilateral Stimulation

Normal Simultaneous Short Delay Long Delay Unilateral





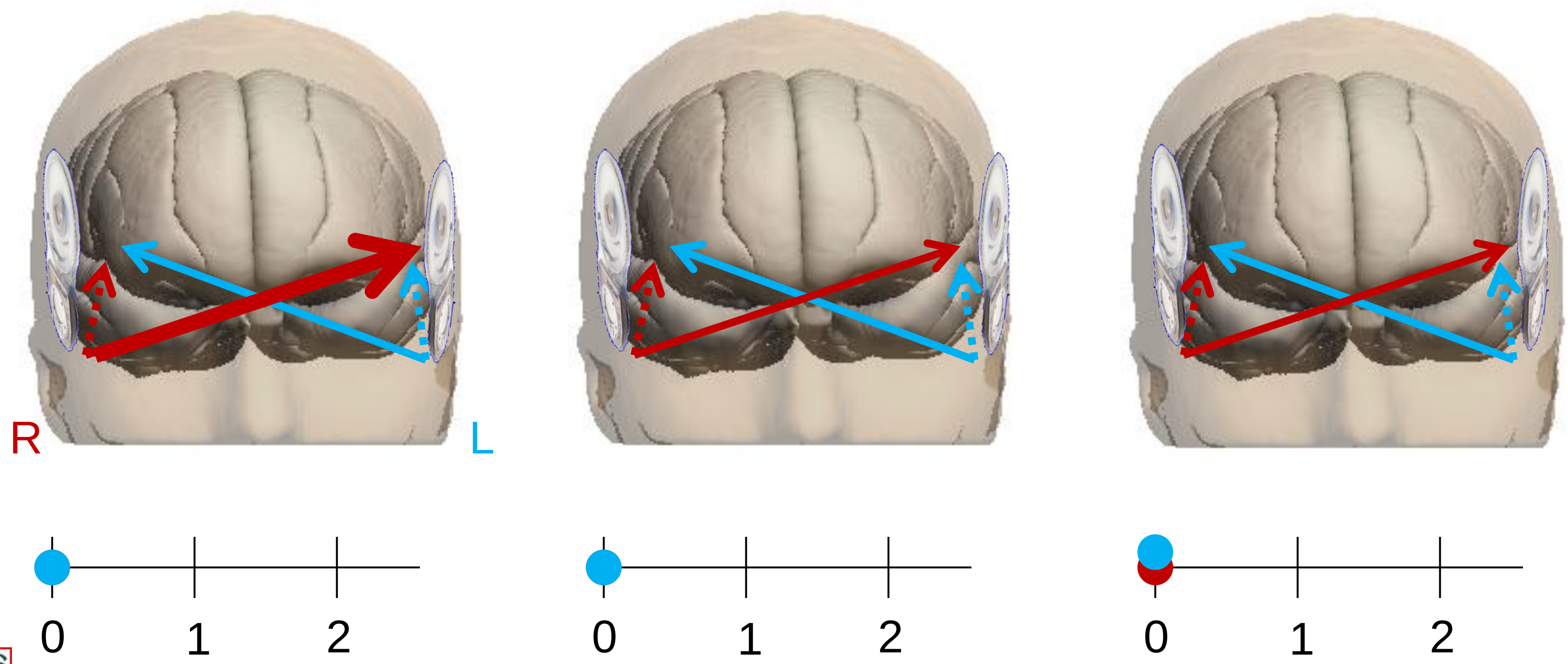
Long Delay (> 2 yrs)

Hubel and Wiesel

- explained their “patching” experimental outcomes
  - “…early in life the functional integrity of the pathway may depend not only on the amount of afferent impulse activity, but also on the interrelationships between the various sets of afferents.”

Abnormal cortical organization is promoted by unilateral cochlear implant use

Long Delay (> 2 yrs) | Short Delay (< 1 yr) | Simultaneous (0 yrs)

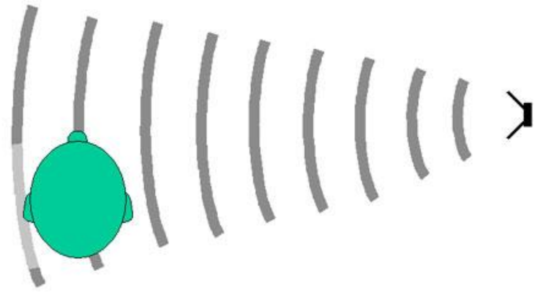


Time (Yrs)

Binaural Hearing

- sounds reach:
  - one ear before the other

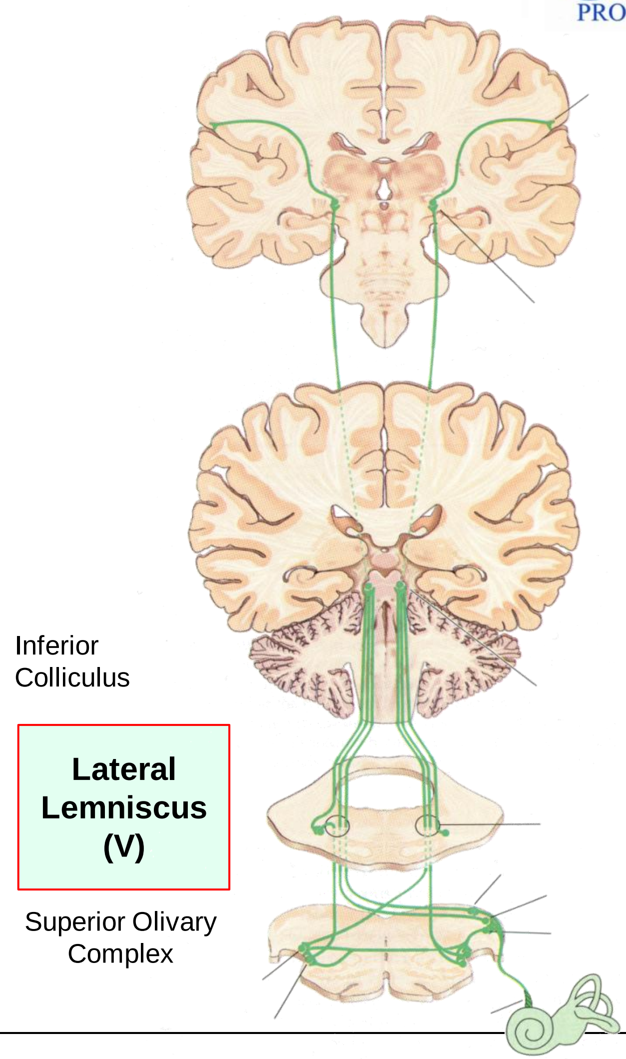
  - at different levels



Binaural Hearing

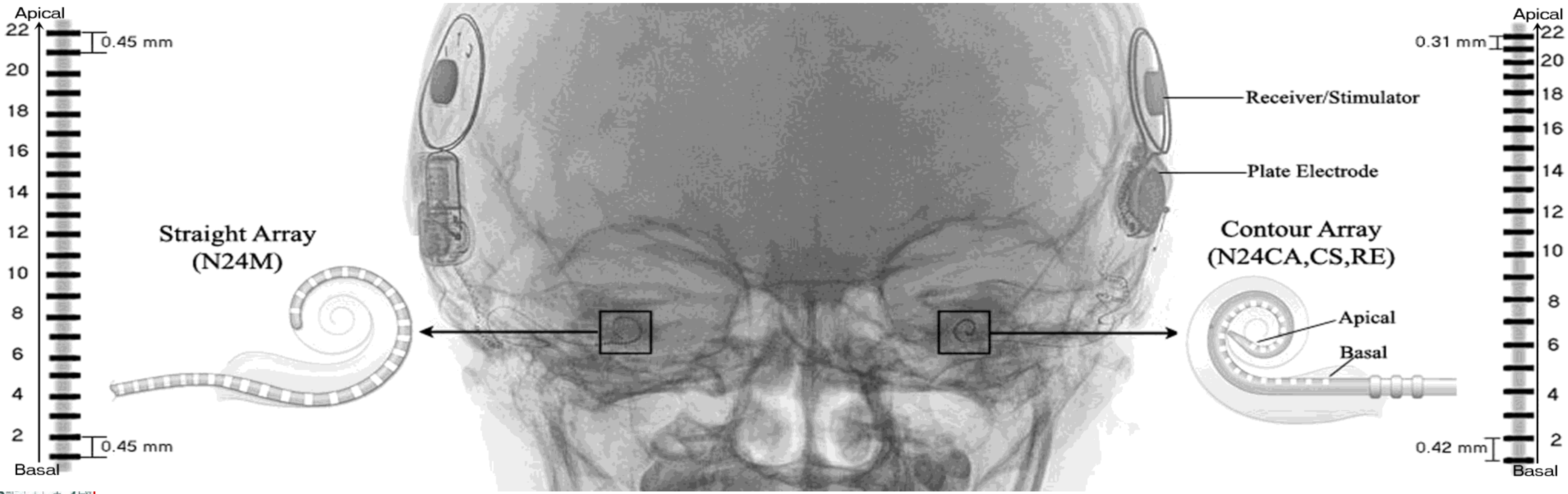
- binaural processing occurs first at the level of the brainstem

- timing and level differences are compared (sound localization)

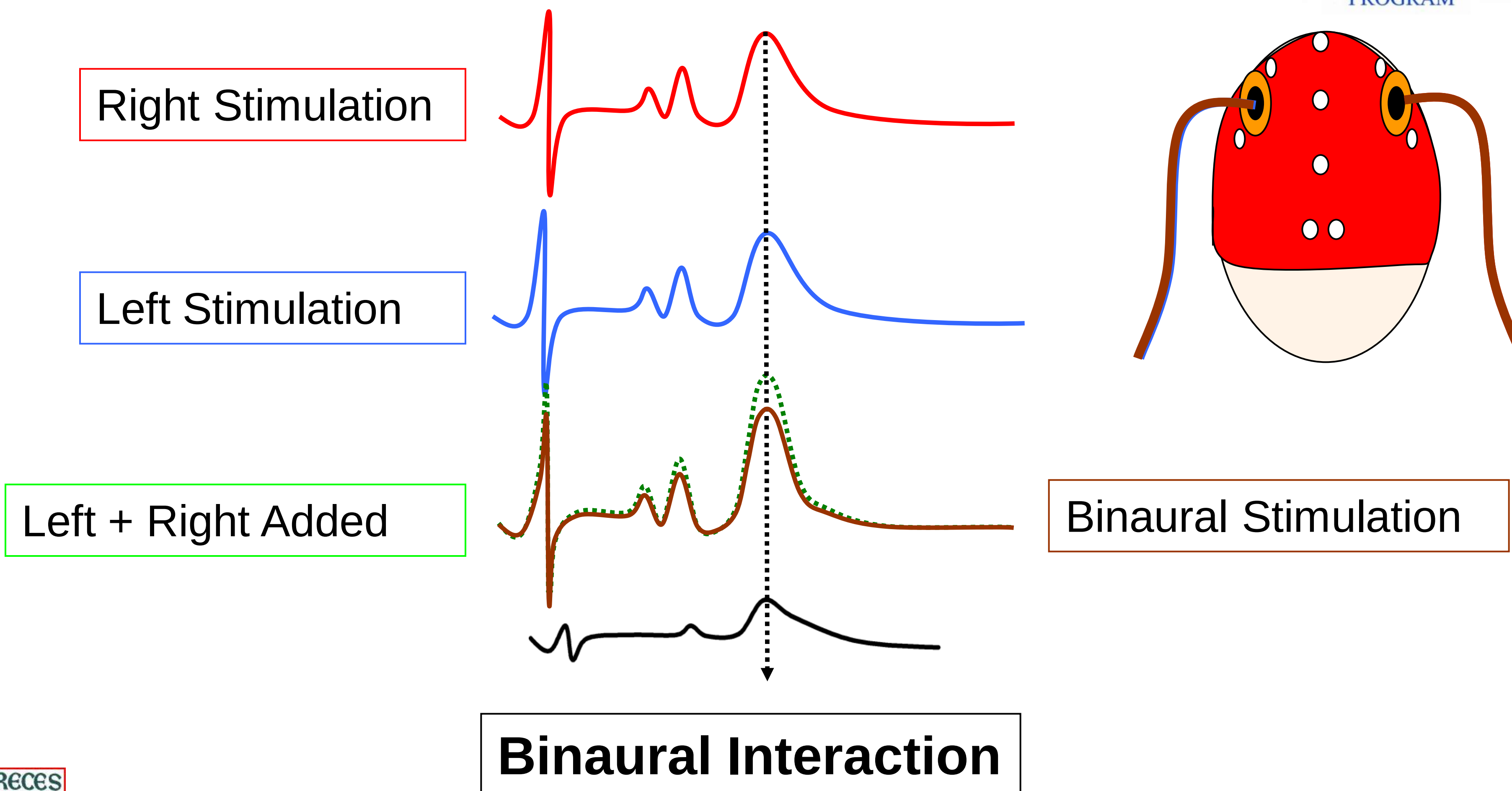


Cochlear Implants and Binaural Hearing

- effects of inter-implant place
- effects of inter-implant level cues
- effects of inter-implant timing cues



Binaural Interaction



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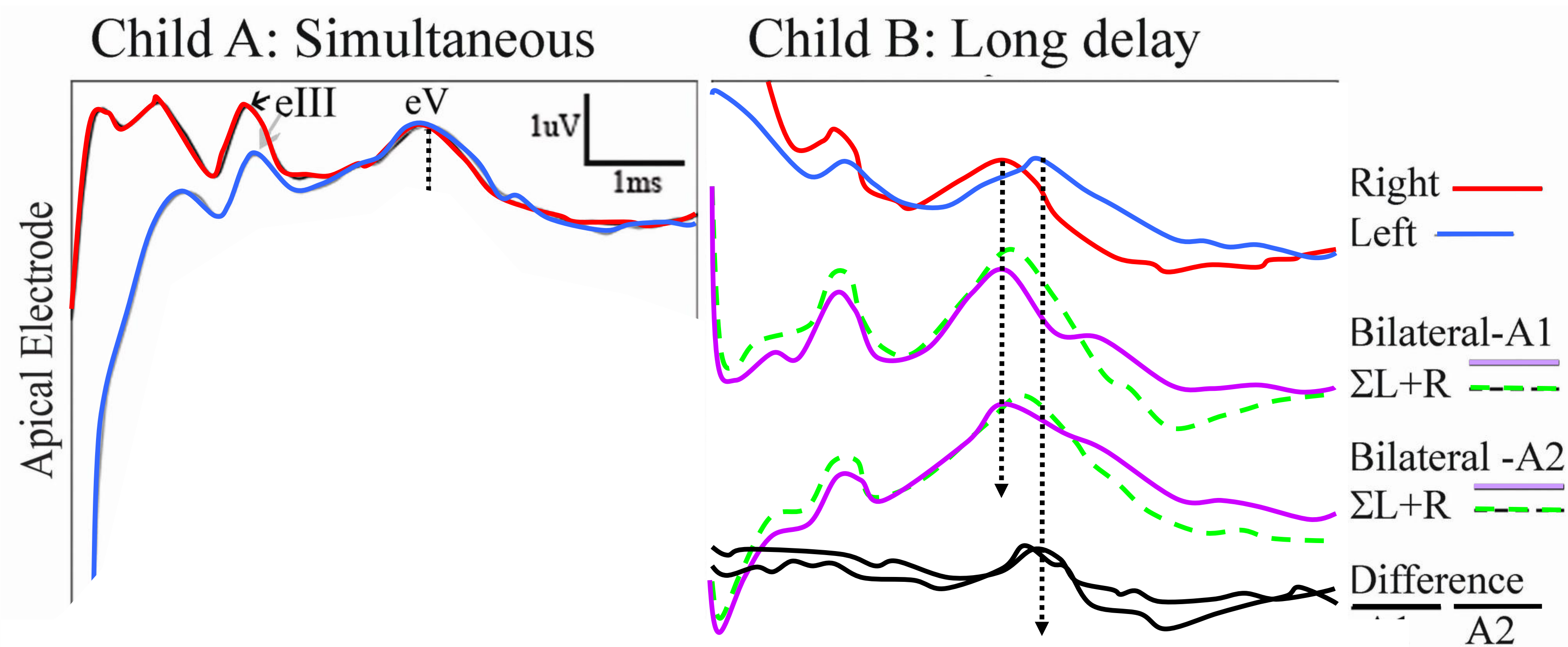
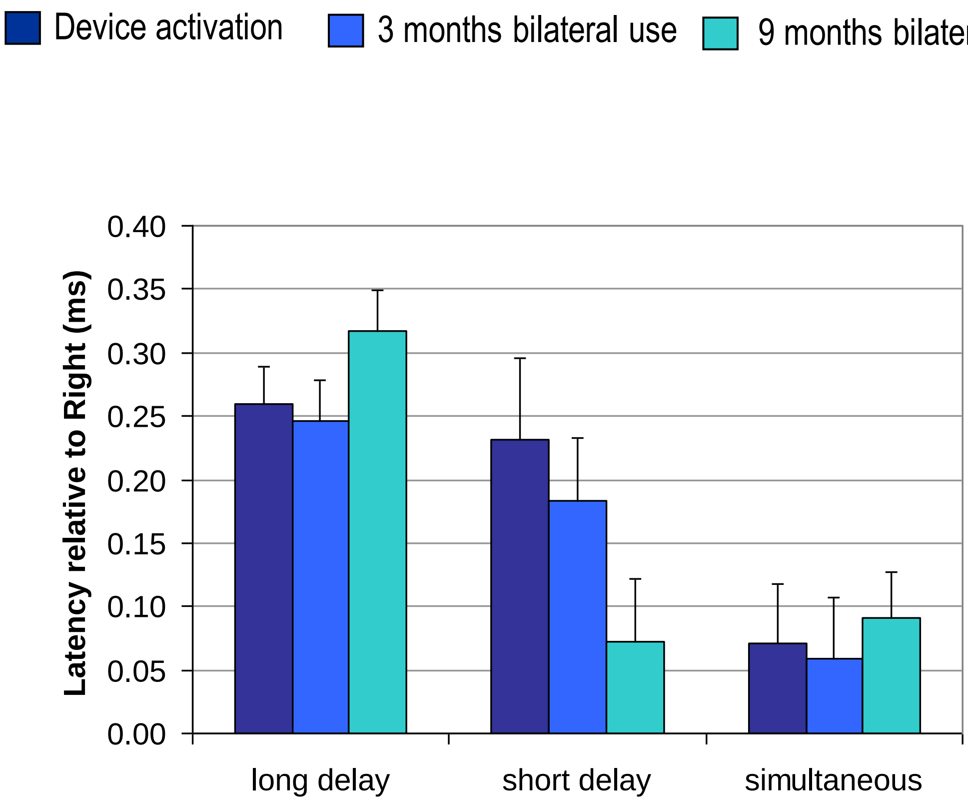
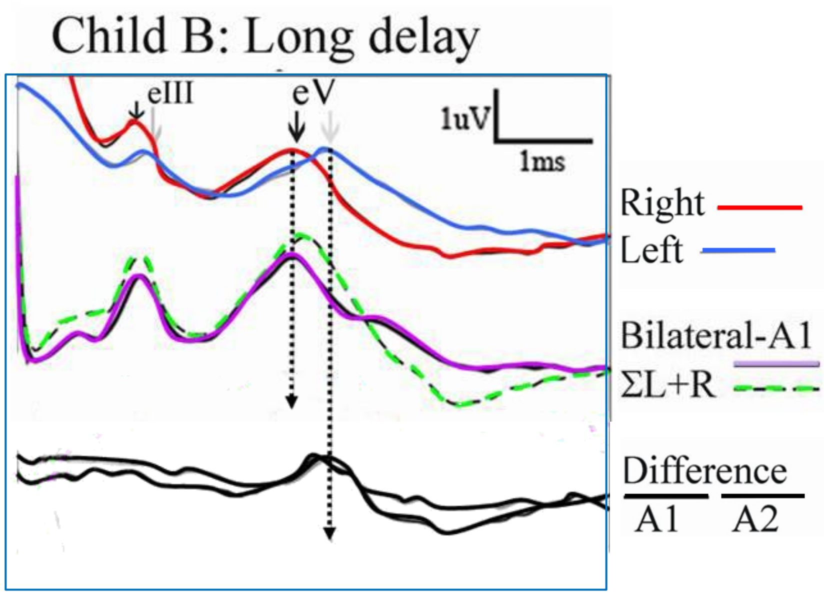


Binaural Interaction





Development of Stereoscopy

- Hubel and Wiesel
  - patched one side = all input neurons to one eye
  - patched both sides = all inputs neurons active

  - eso- or exotropia resulted in amblyopia
  - the eye still could "see" but the cortex couldn't

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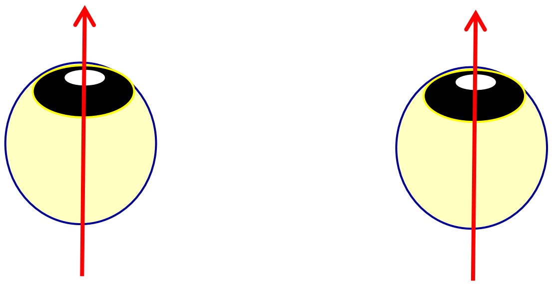

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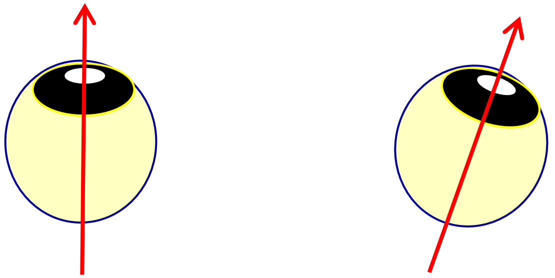
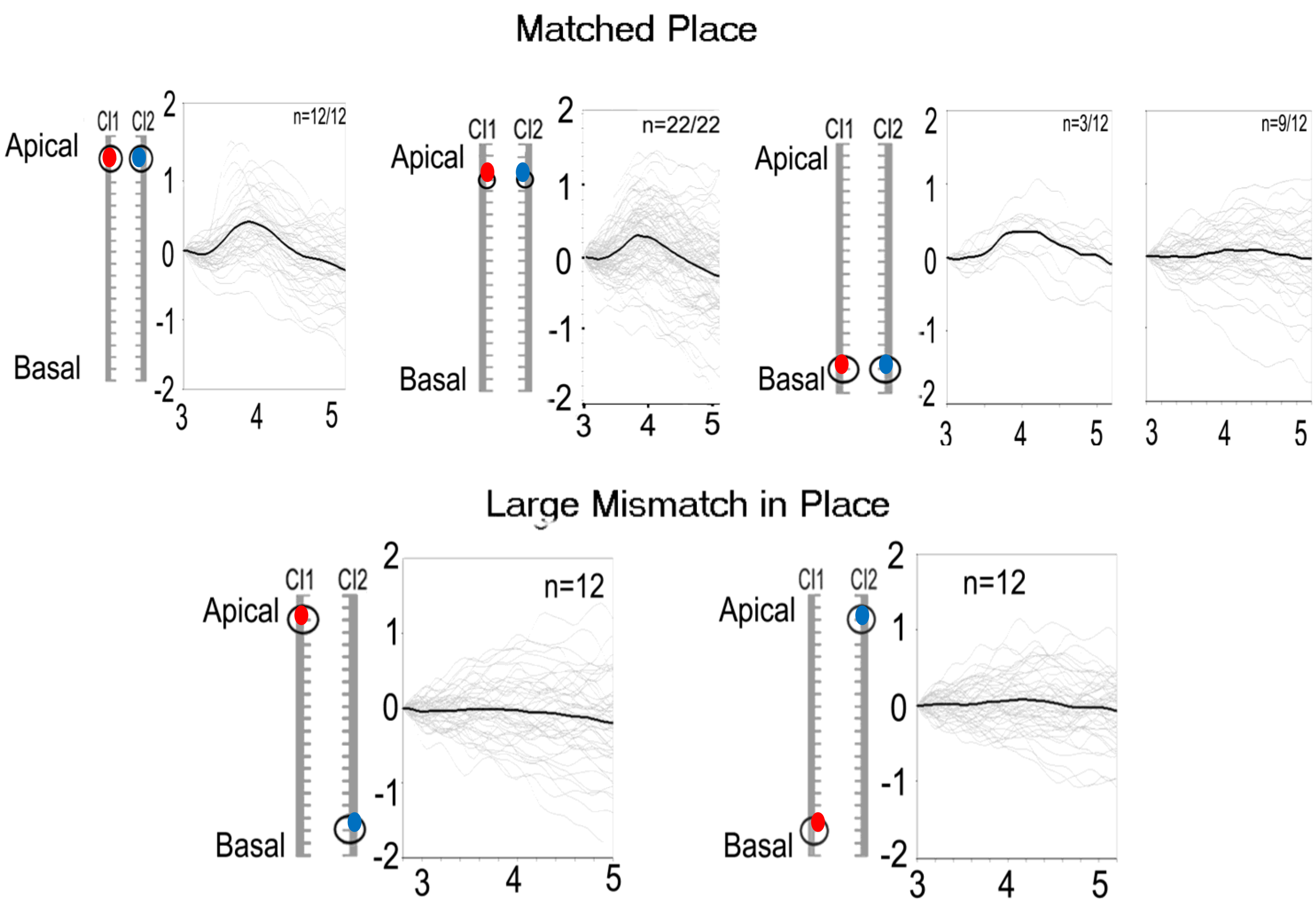
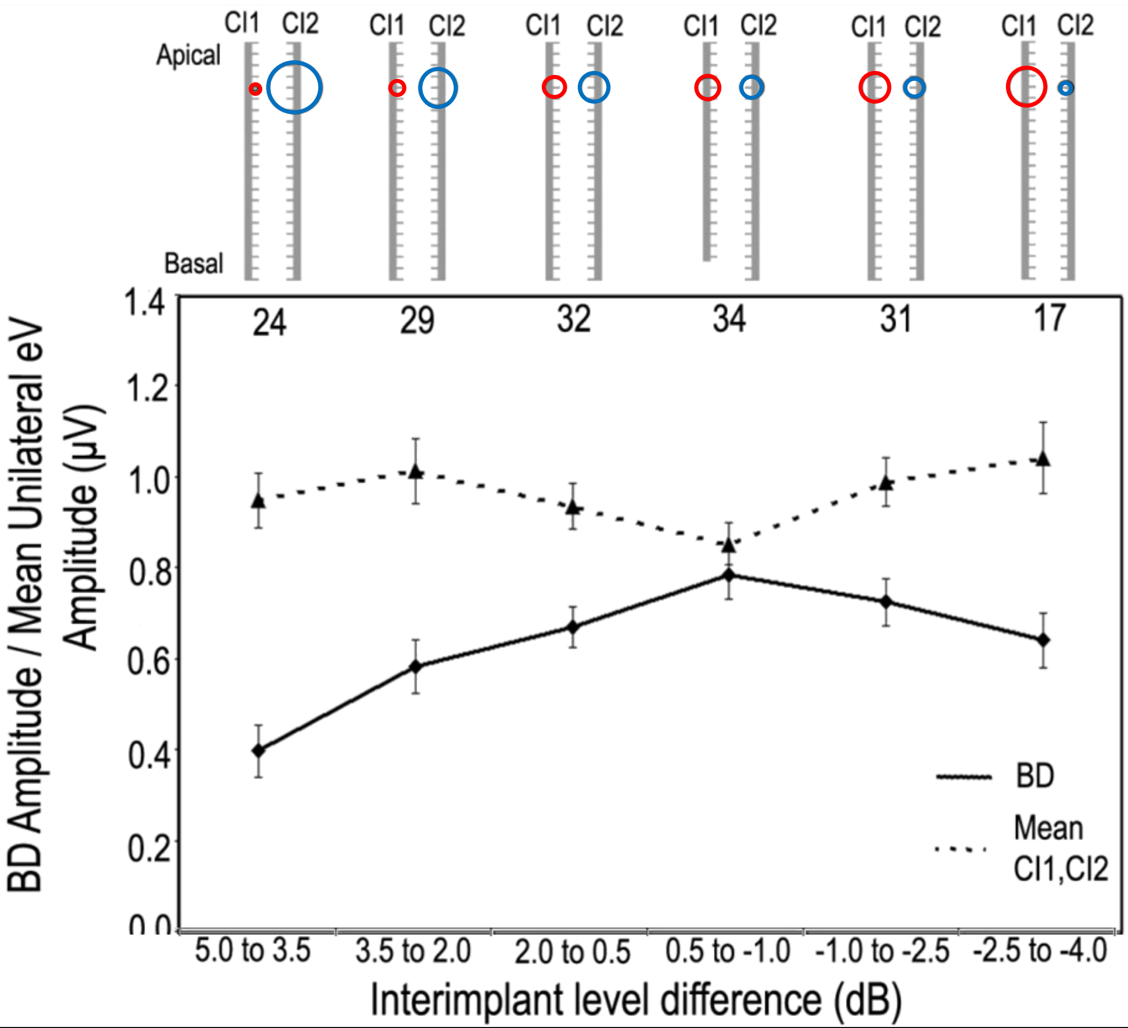


Coding of Inter-Implant Place



Coding of Inter-Implant Level



Development of Stereoscopy

- Hubel and Wiesel
  - patched one side = all input neurons to one eye
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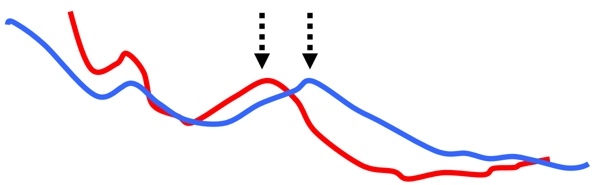
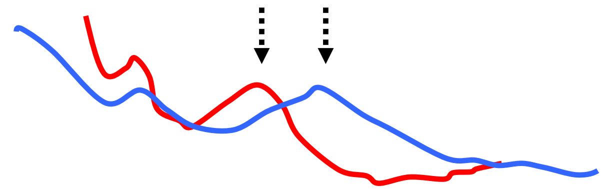
Coding of Inter-Implant Timing

ITD=0 ms 0.2 ms



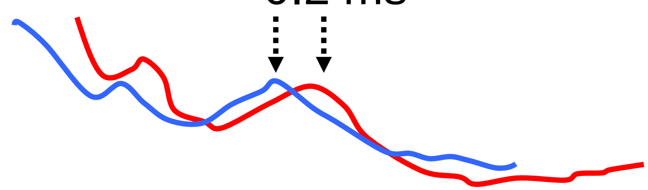
ITD=-0.4 ms (R leads L)

0.6 ms



ITD=+0.4 ms (L leads R)

0.2 ms



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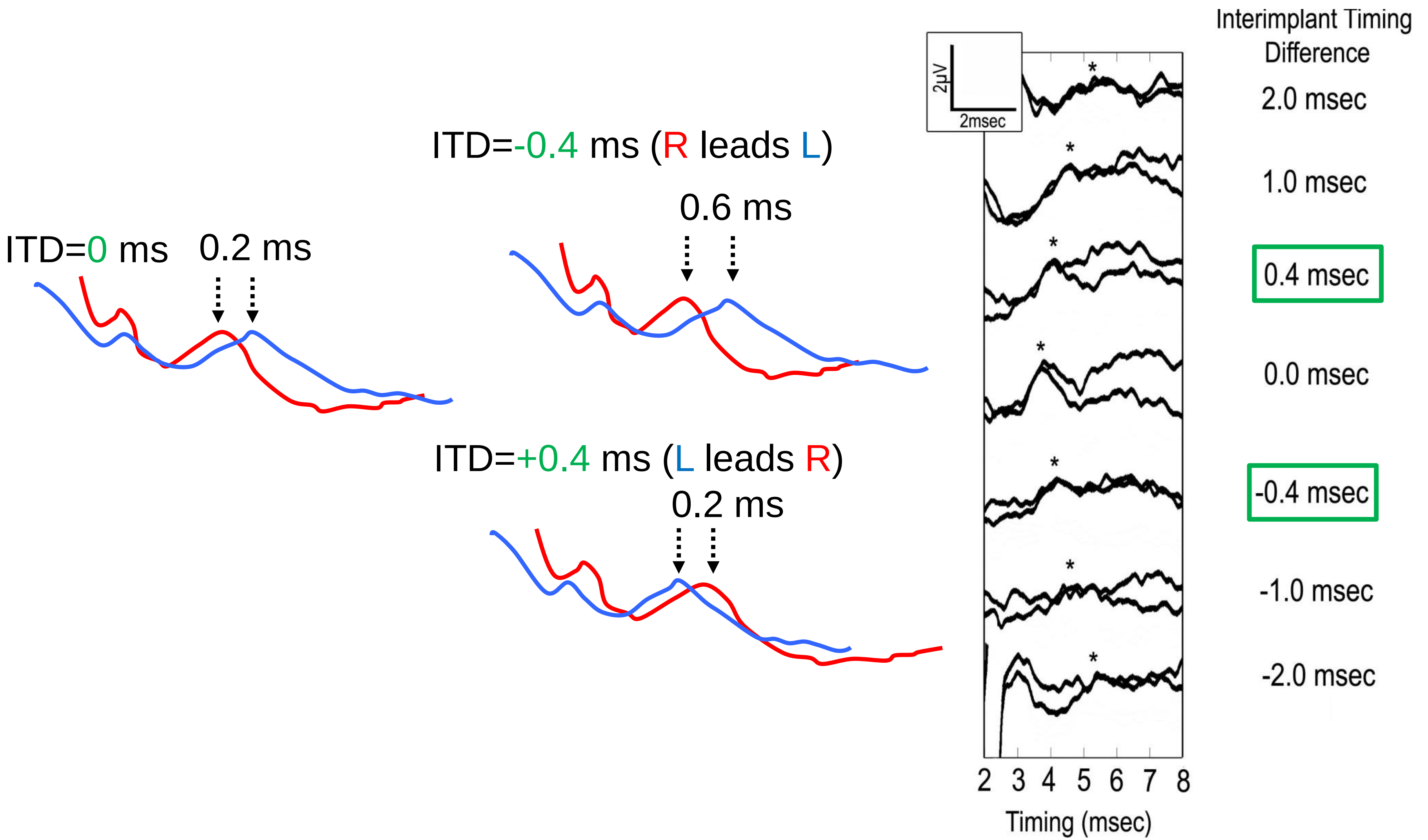
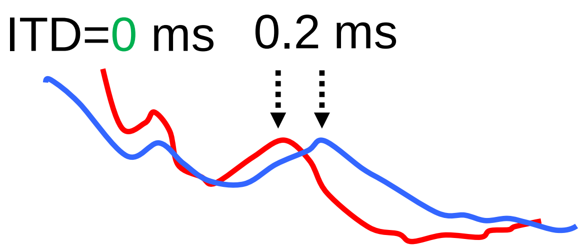
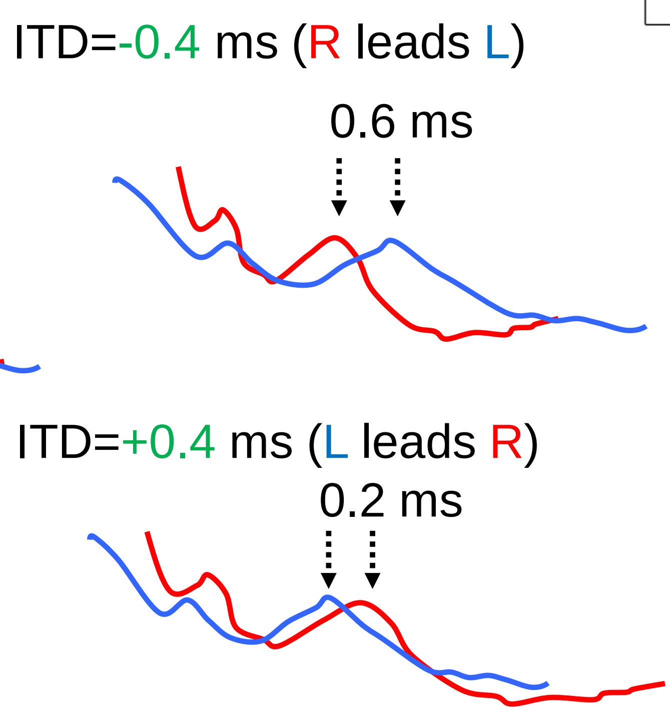
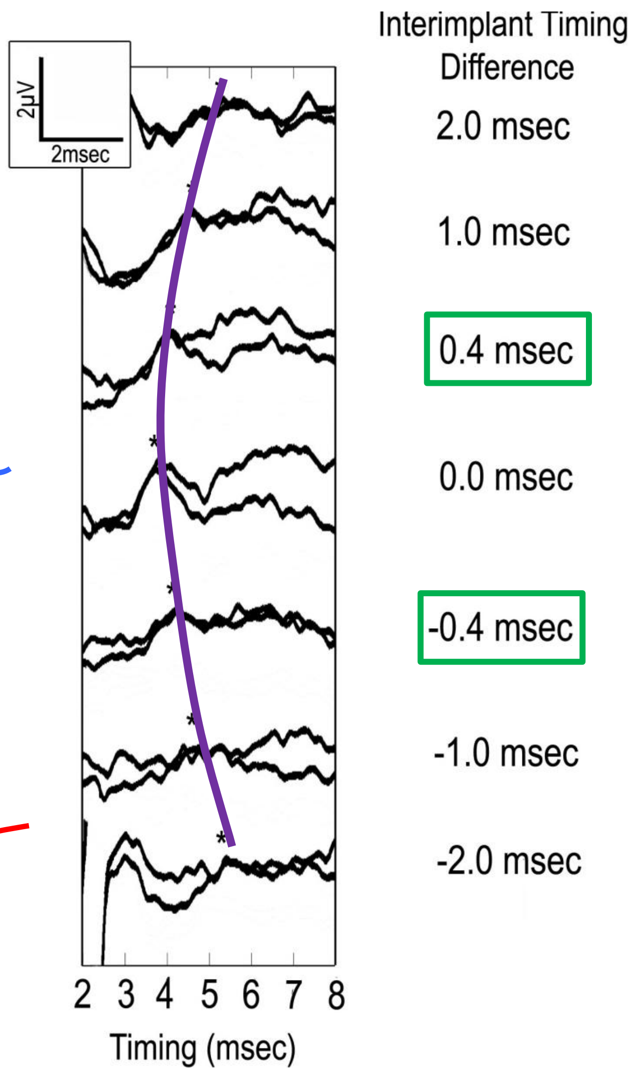


Coding of Inter-Implant Timing







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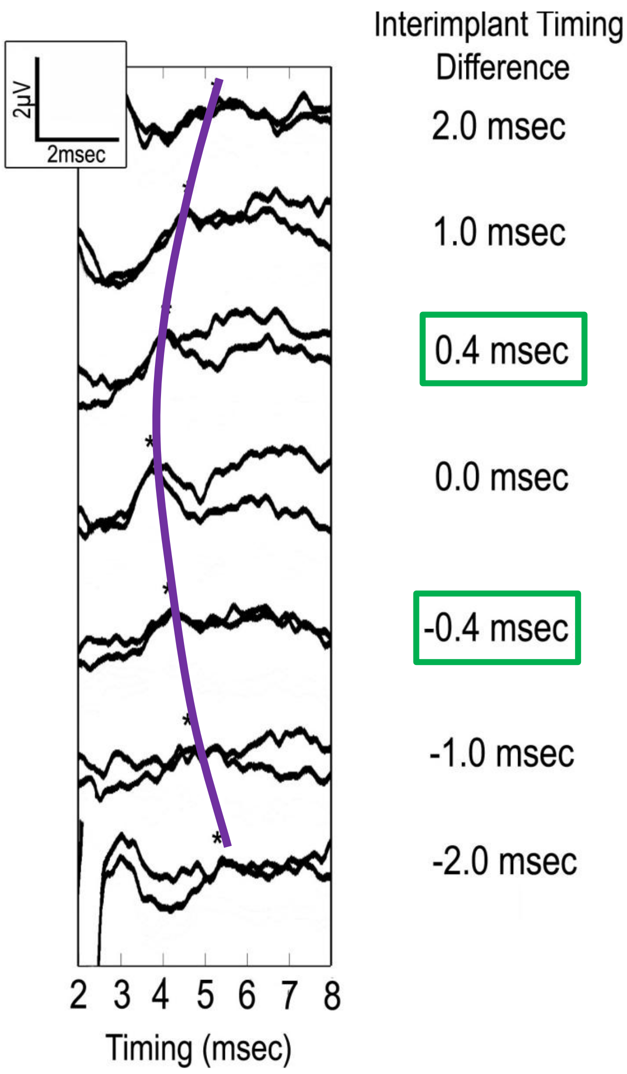

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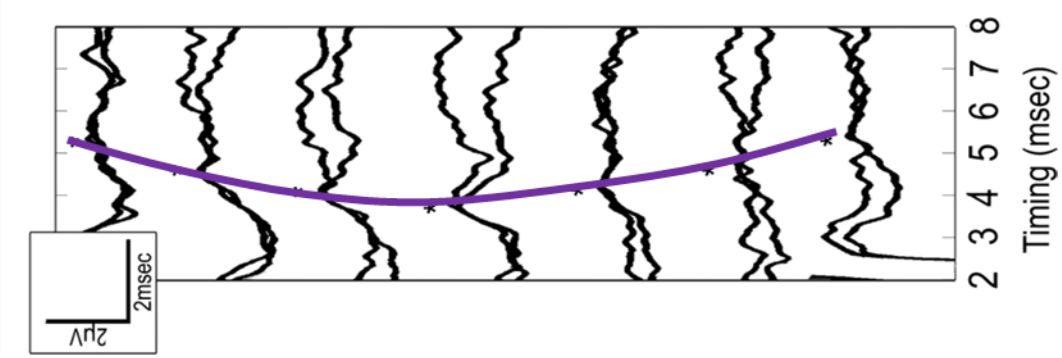

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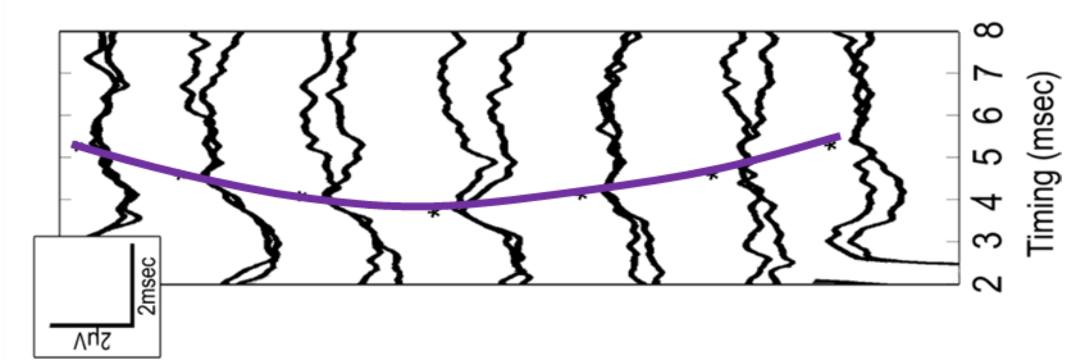
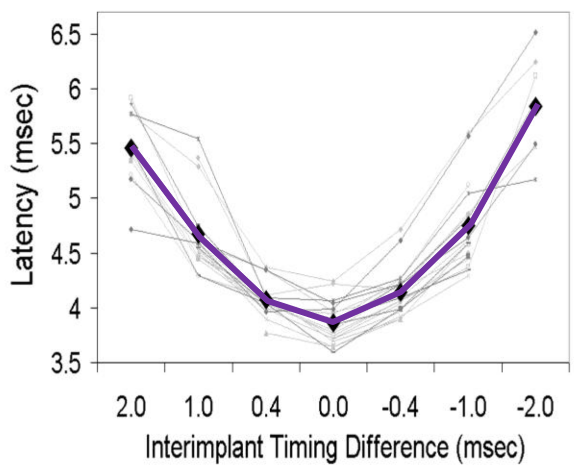
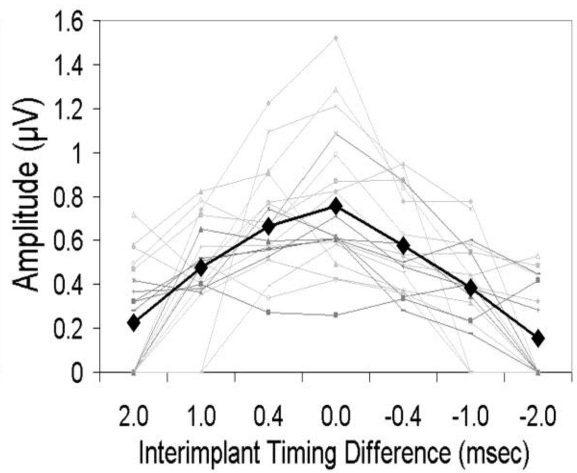
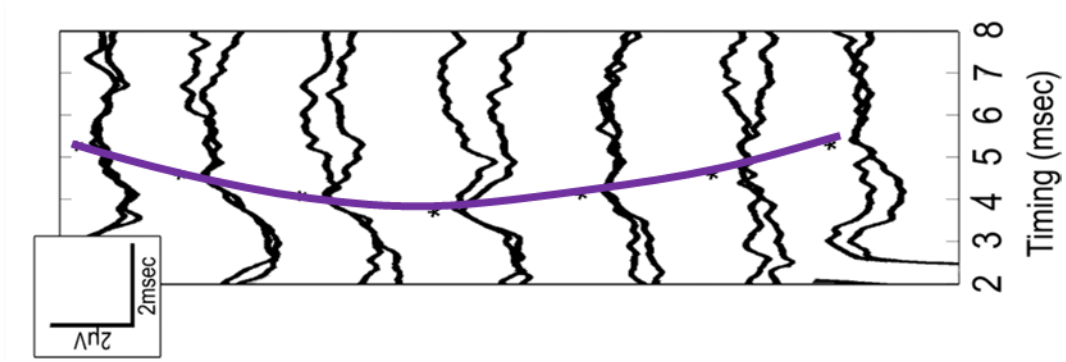
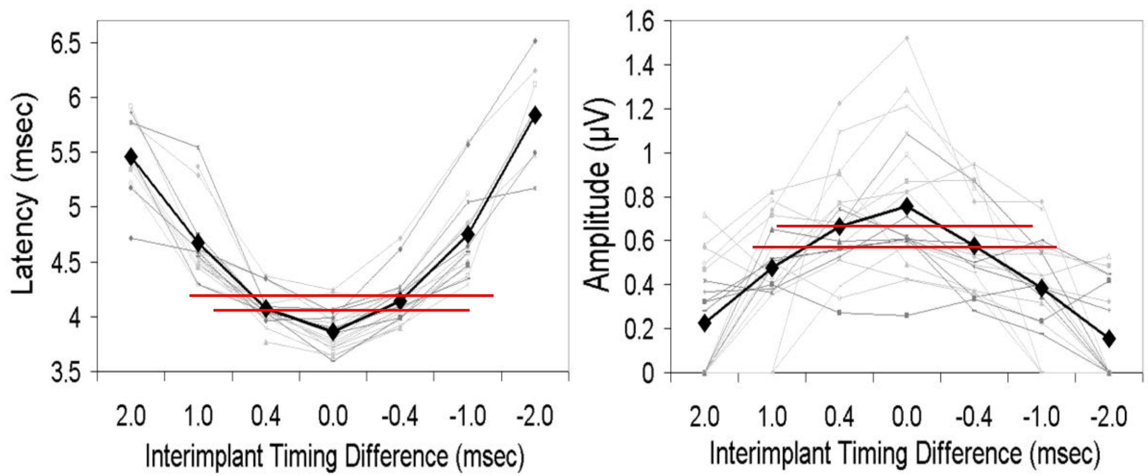






Coding of Inter-Implant Timing



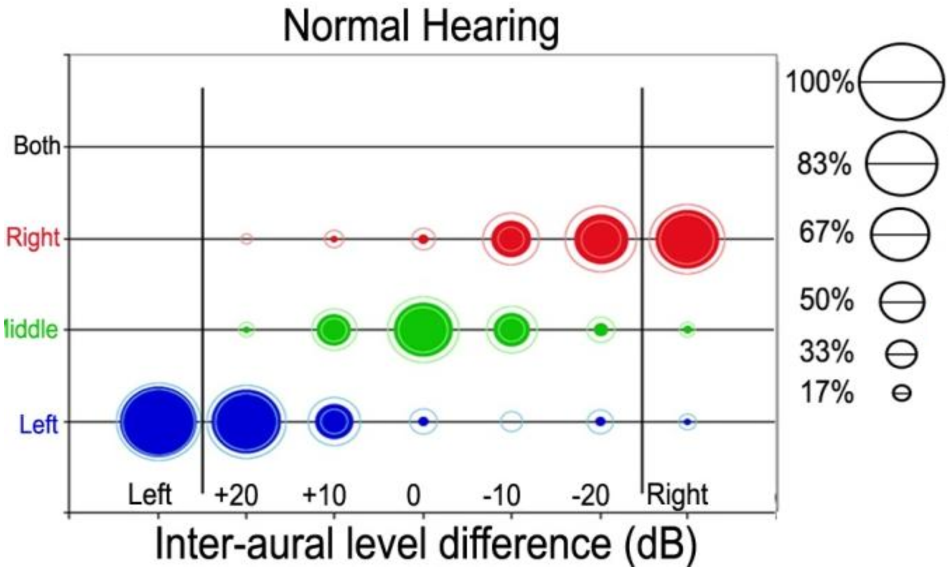


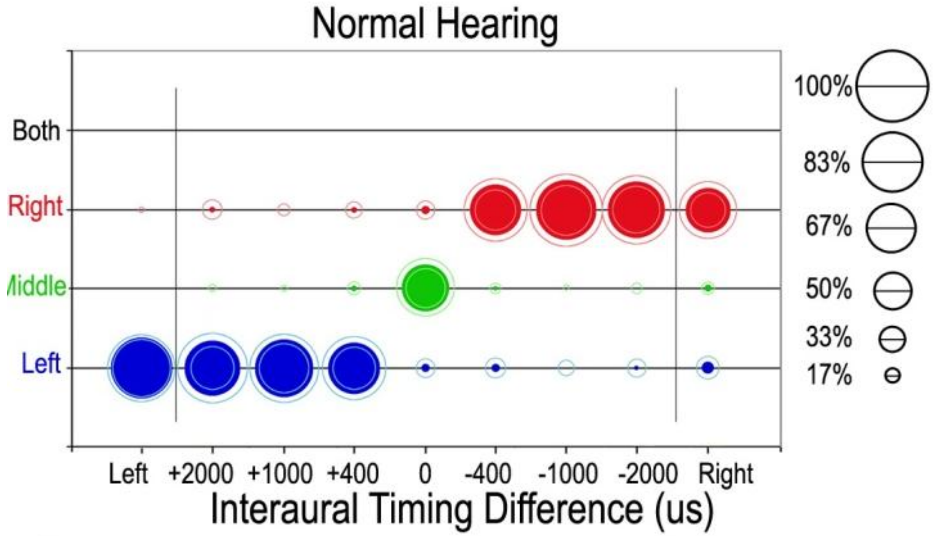
Binaural Perception

- Hubel and Wiesel
  - in the blind eye edge perception still possible!
  - primary processor still perceives edge

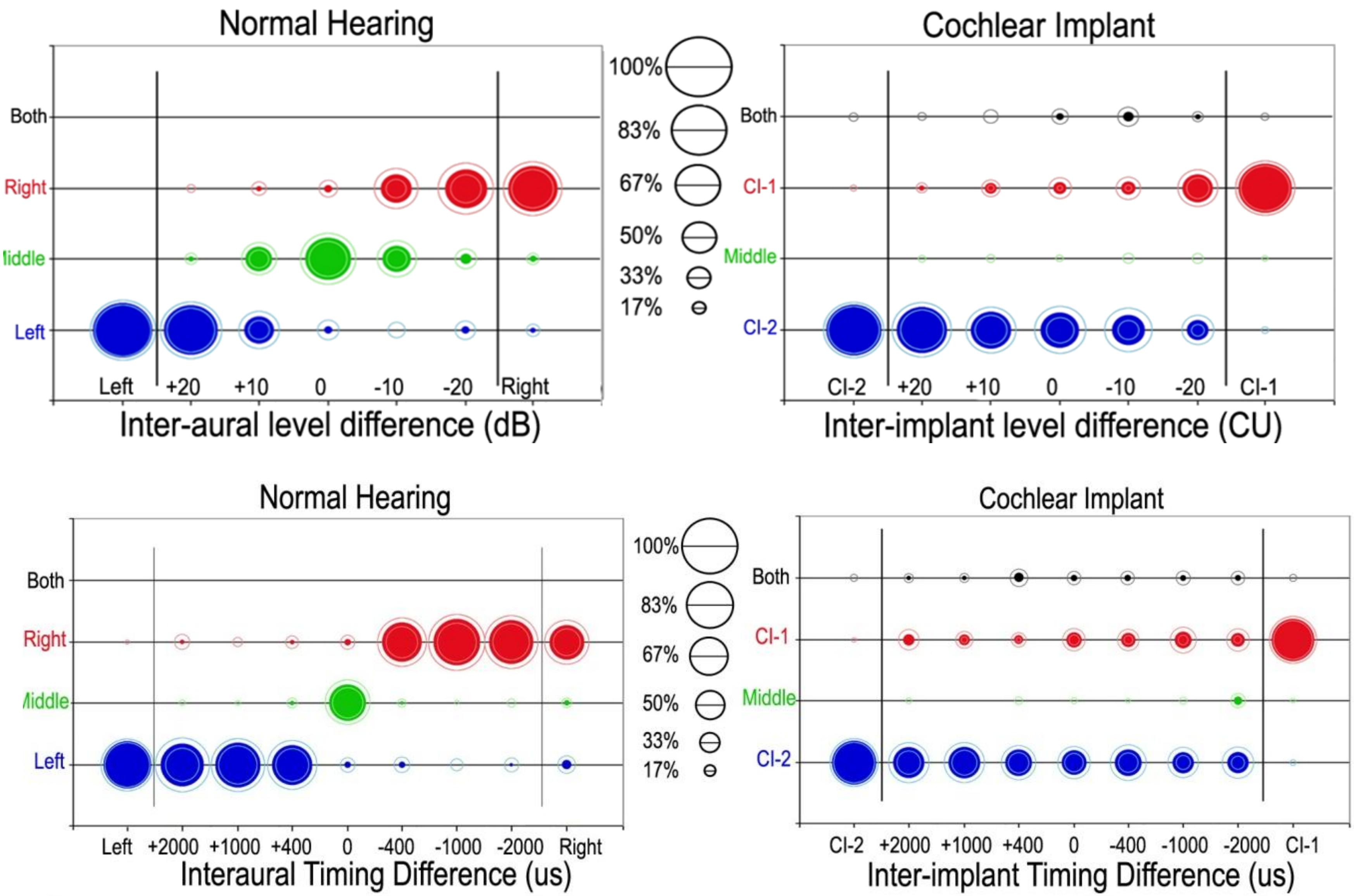
  - cortex stereo blind
  - edges in audition are coded by timing

Behavioural Implications

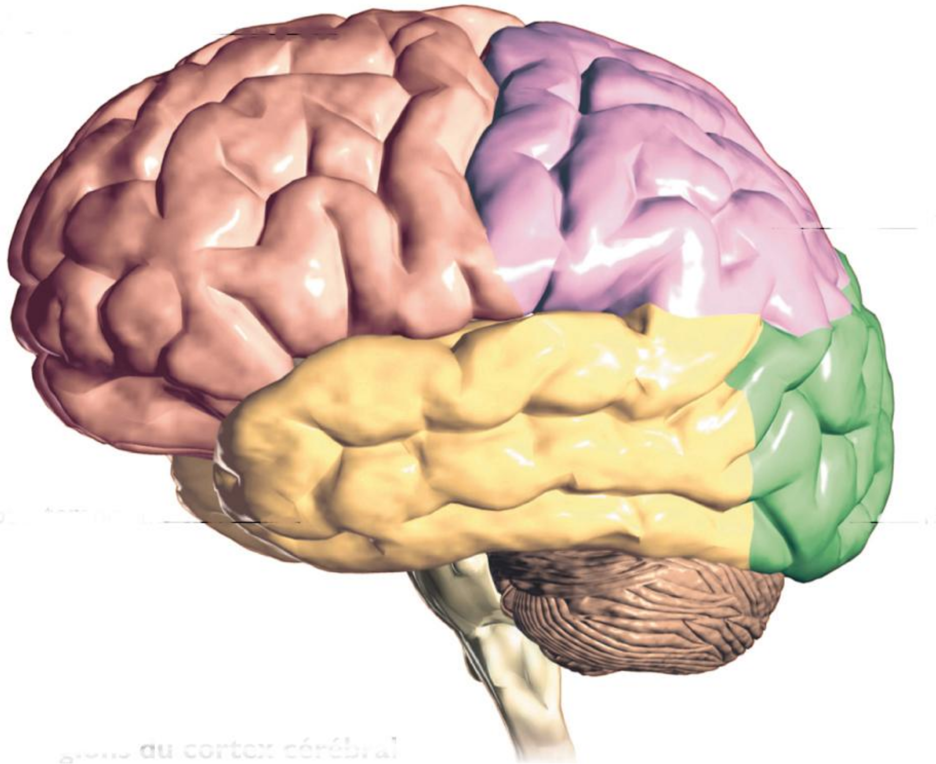




Behavioural Implications

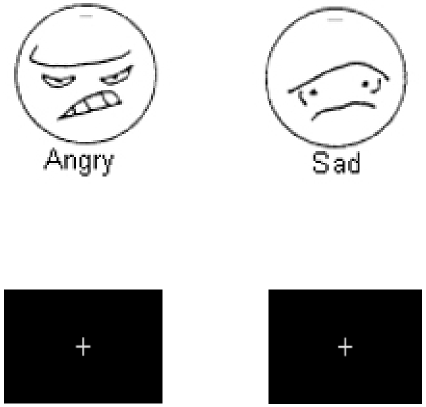


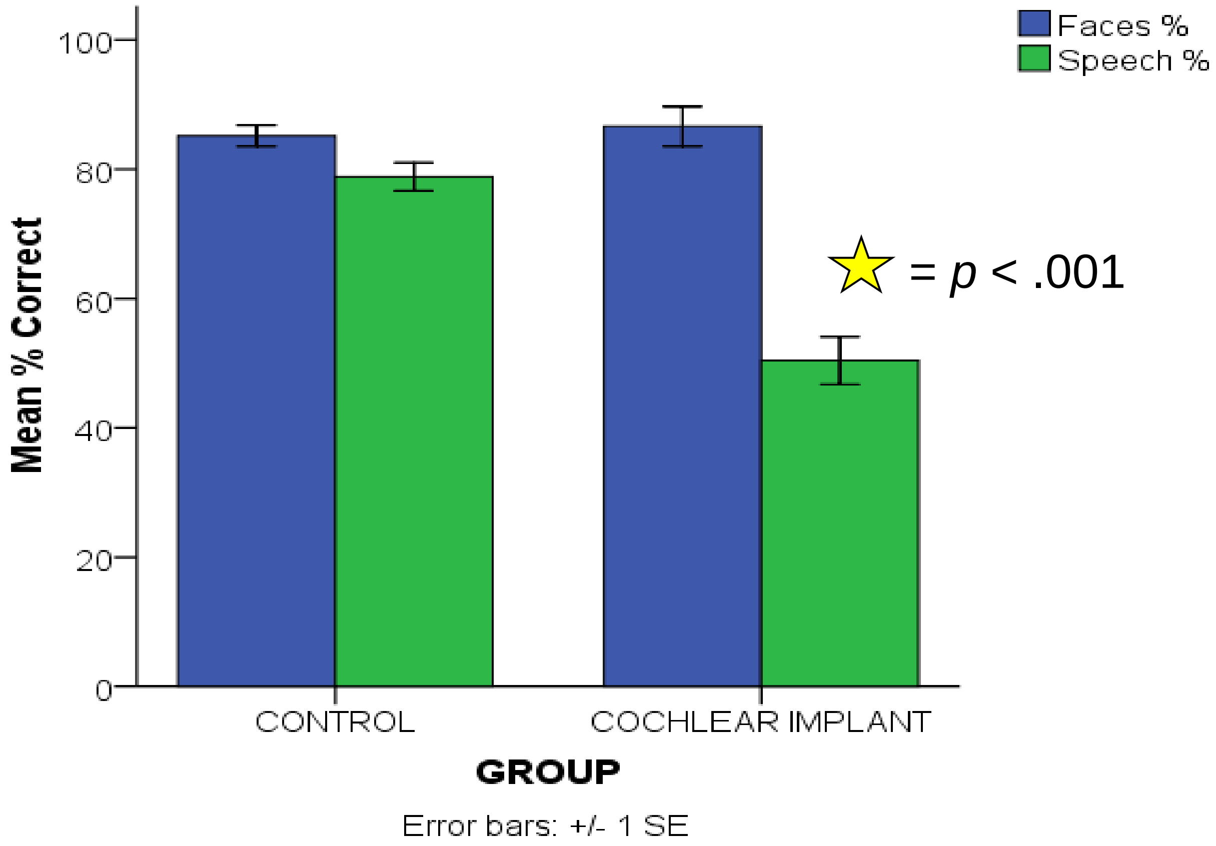
Reassembling the Auditory Environment



Emotion in Faces But Not in Speech

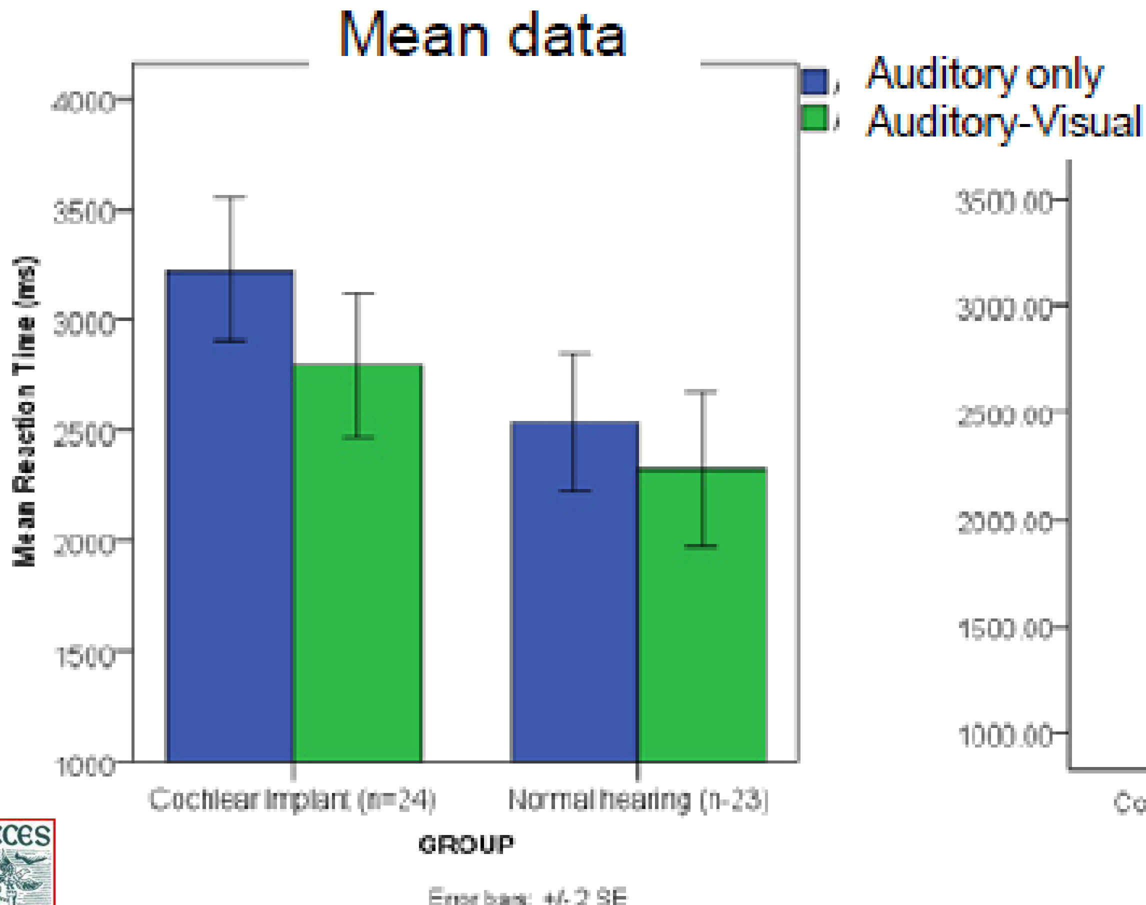
ANGRY SAD

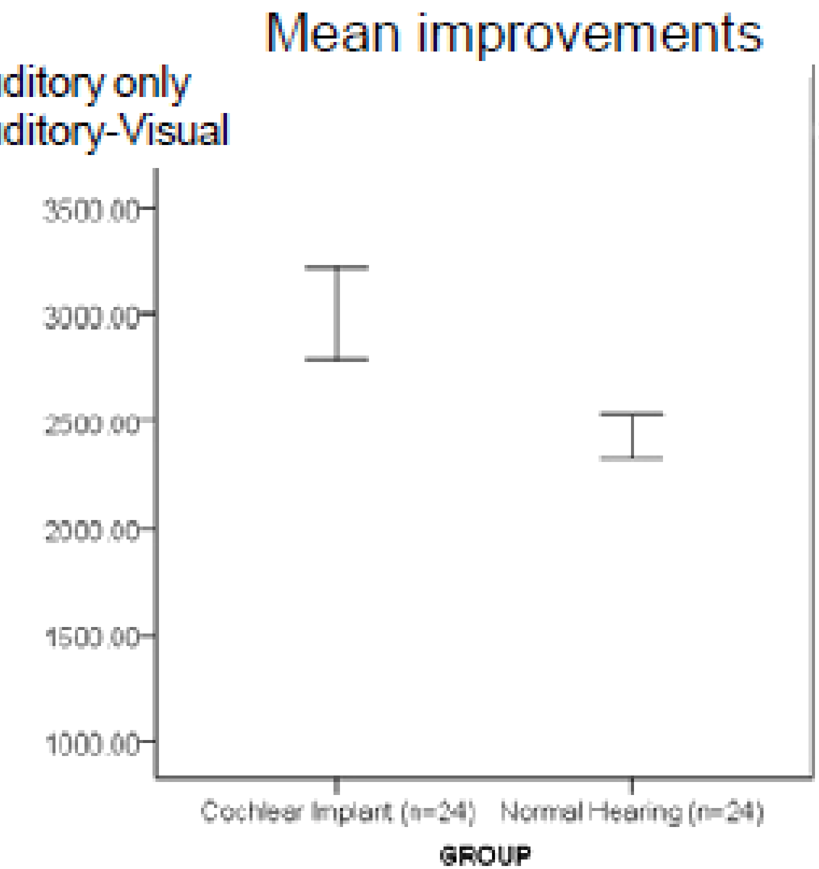




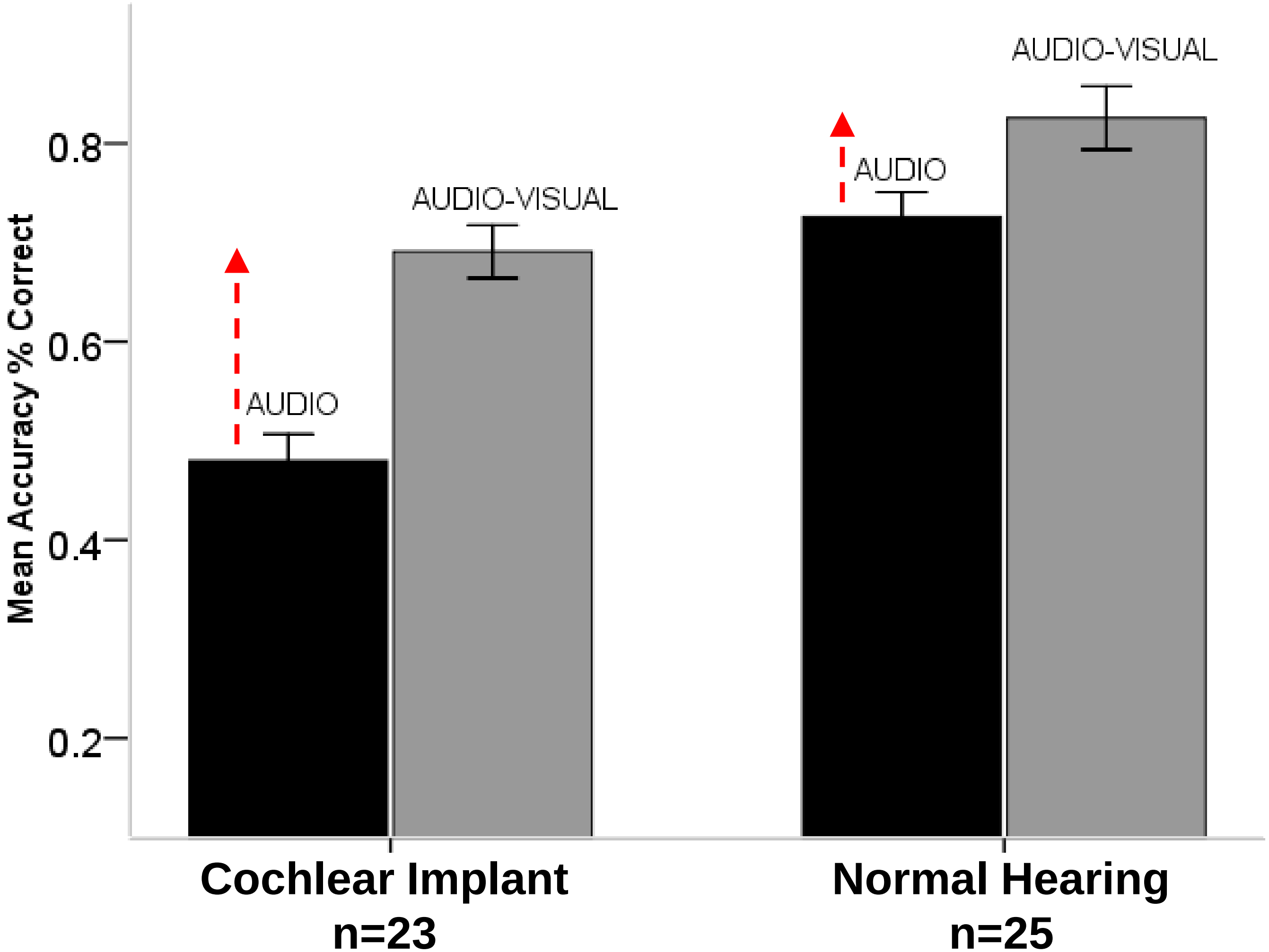
Hopyan et al. (2009), Child Neuropsychology

Reaction Time



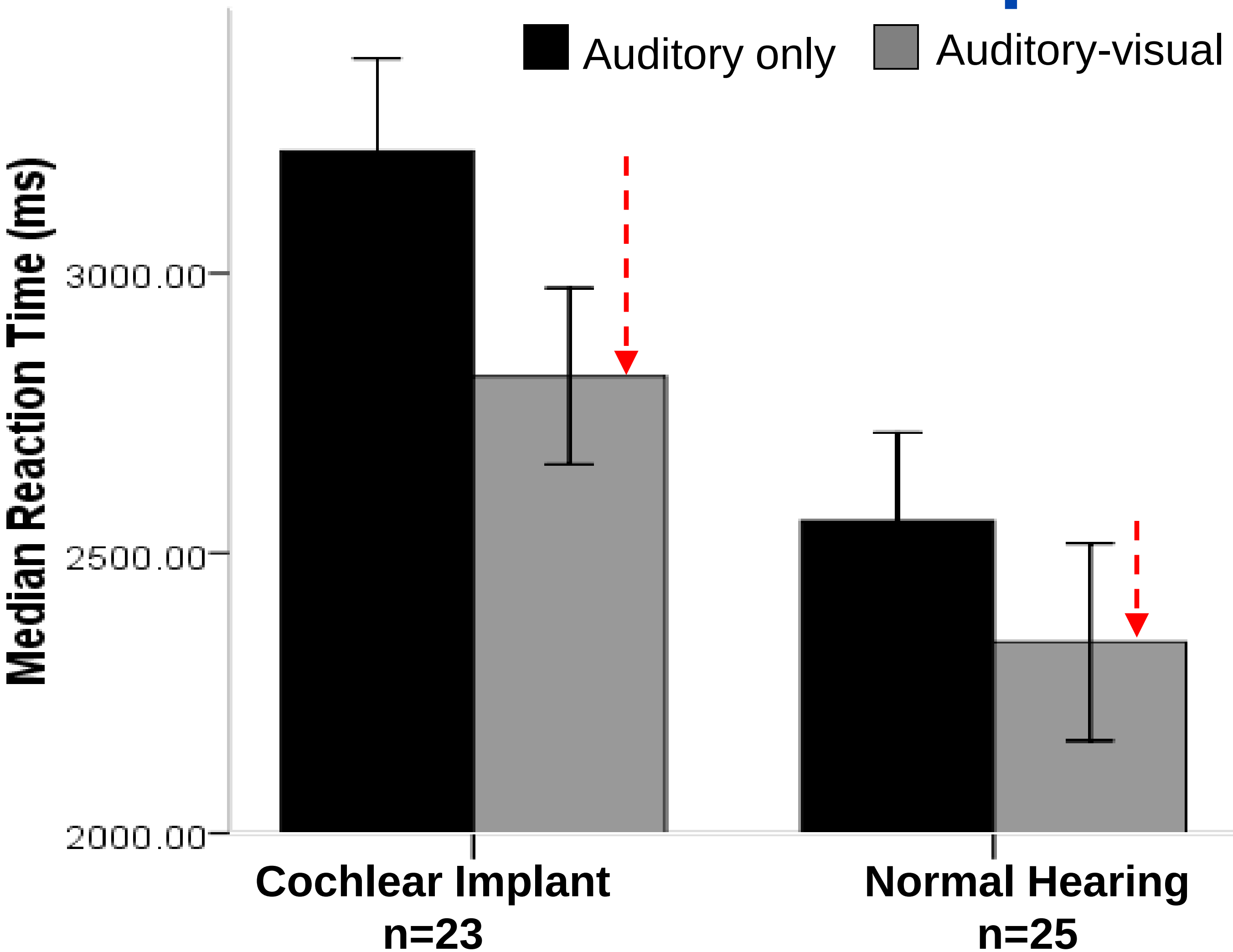


Enhanced Use of Visual Input



Mean age = 11. 7 years

Reaction Time & Visual Input

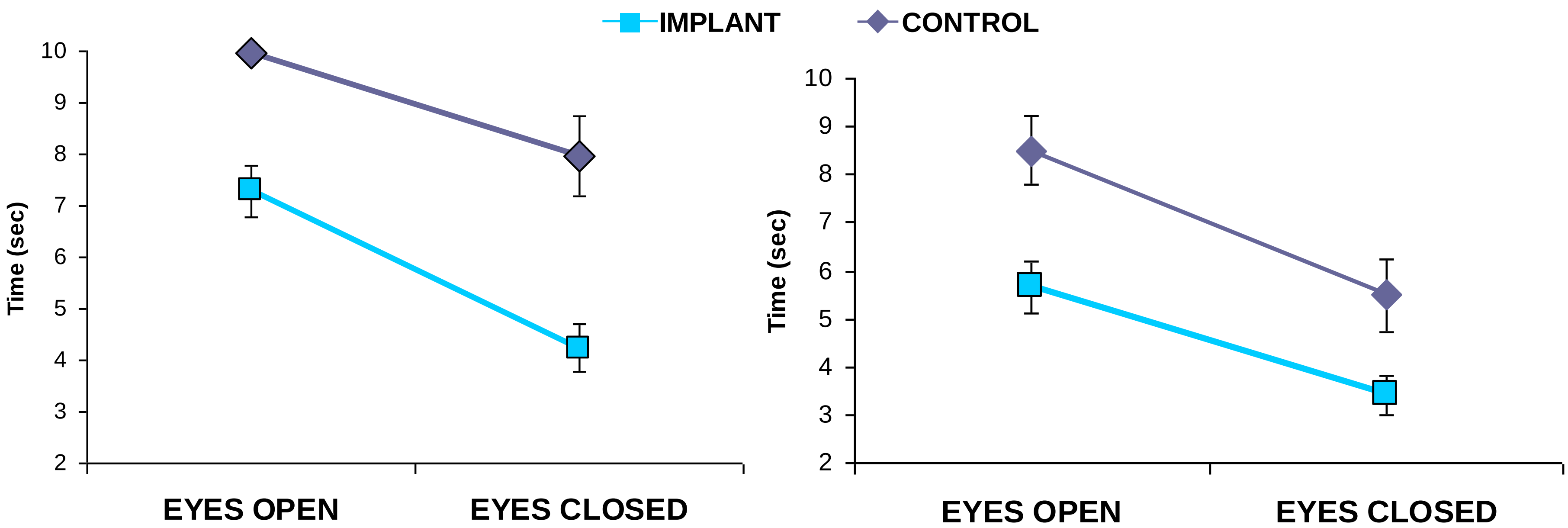


Mean age =
11. 7 years

Impact of vision

Standing on one foot

Standing on one foot on a balance beam

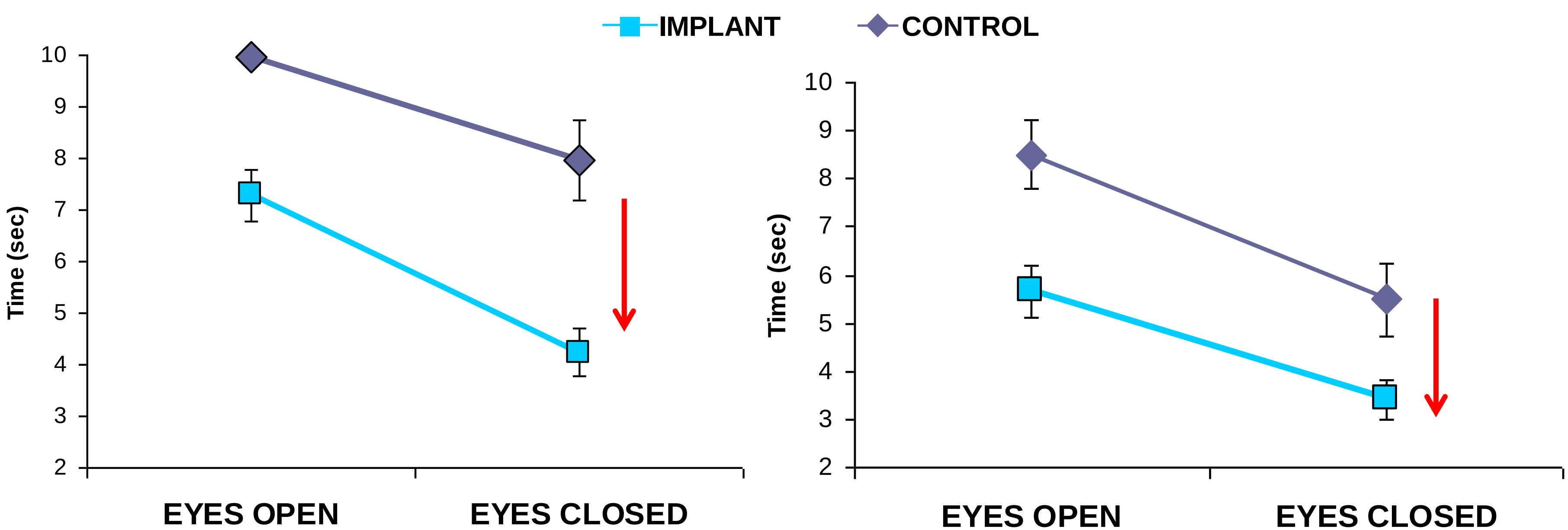


VISION*GROUP INTERACTION
p=0.88

Impact of vision

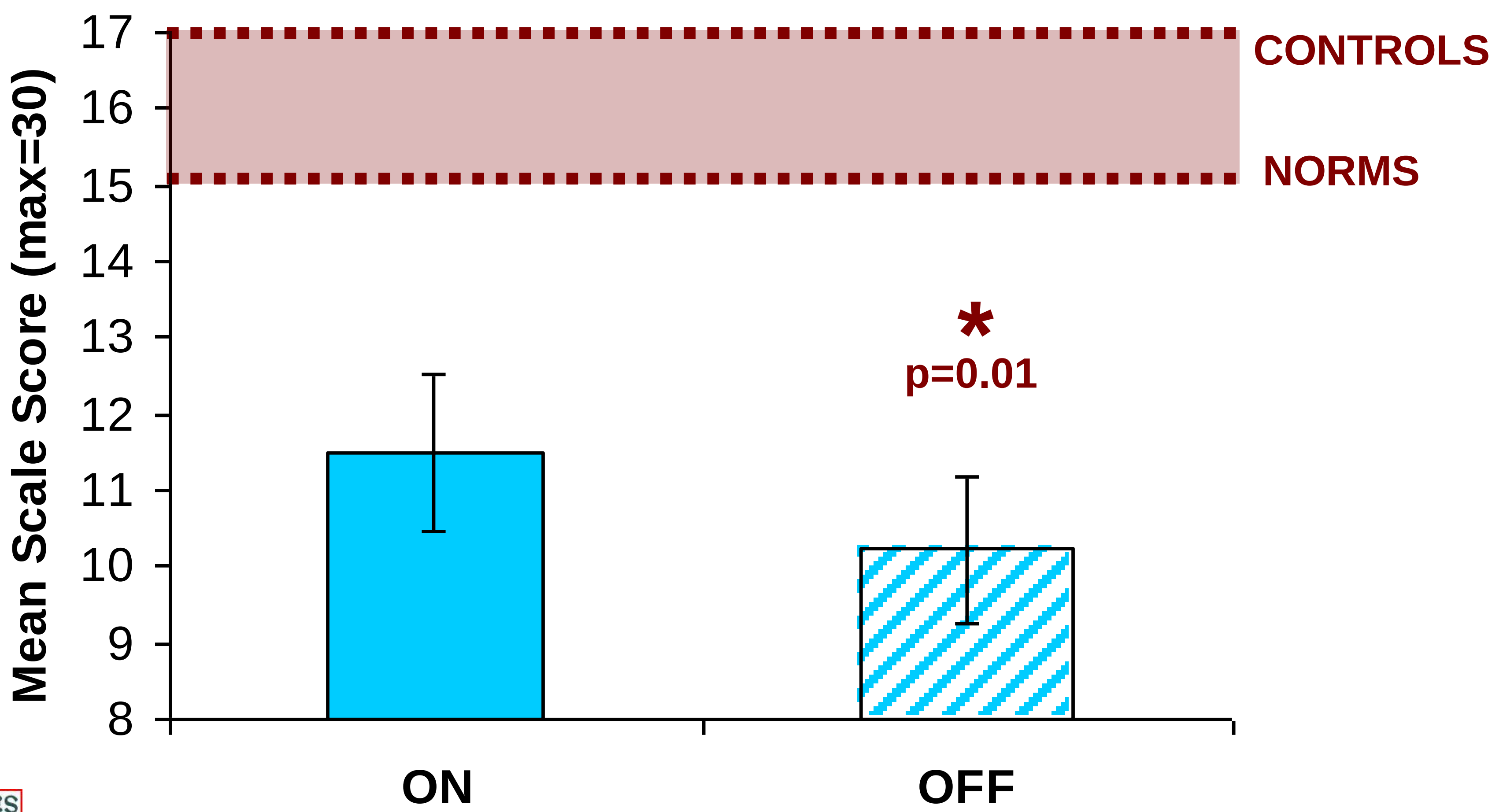
Standing on one foot

Standing on one foot on a balance beam

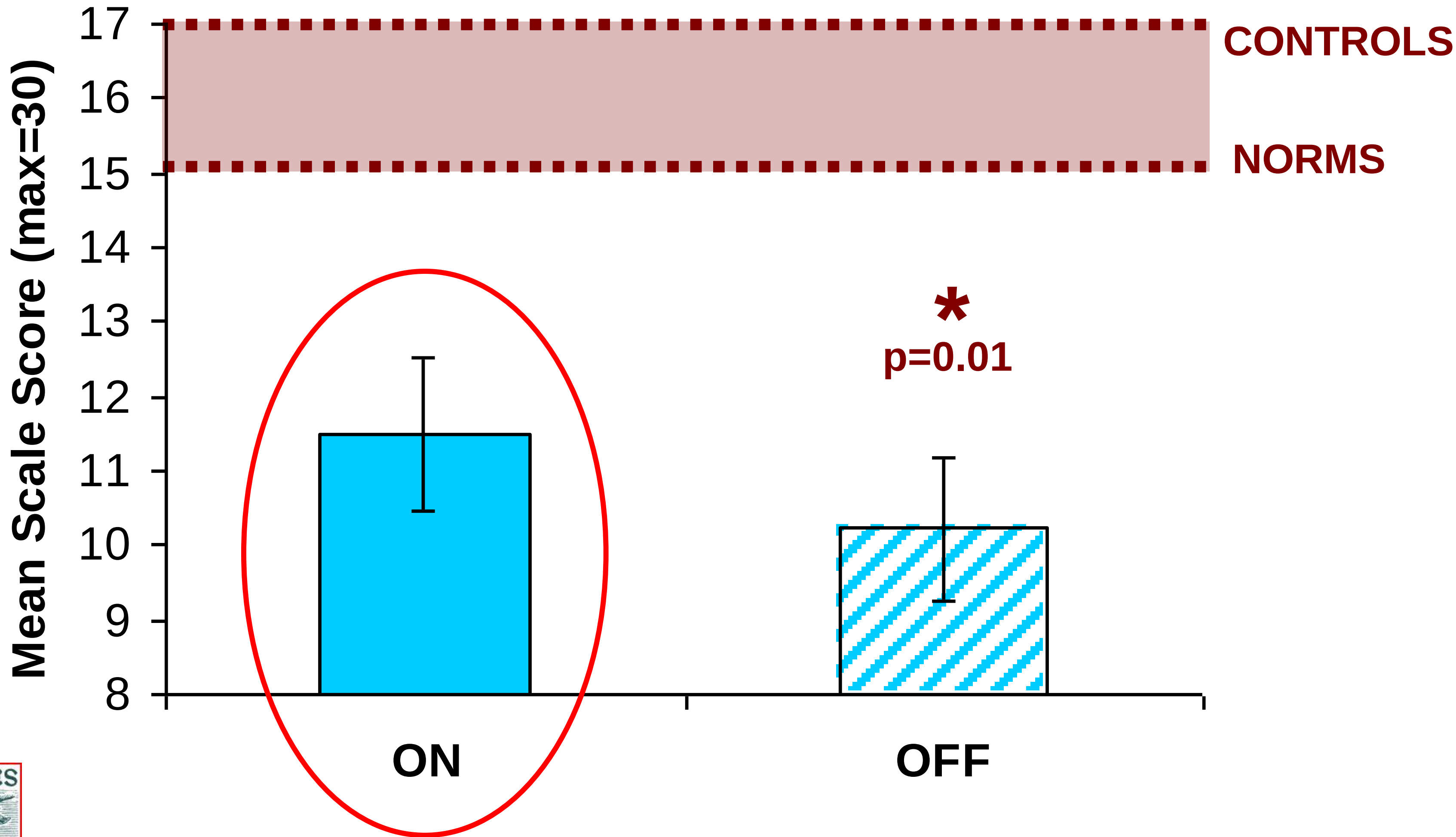


VISION*GROUP INTERACTION
p=0.88

Implant ON vs. OFF



Implant ON vs. OFF



Summary

- sequential bilateral cochlear implantation
  - allows asymmetric auditory development
    - alters but does not eliminate binaural processing in the brainstem
  - compromises binaural processing in the auditory cortex
    - facilitates perception of inter-implant level, but not timing, cues

Summary

- simultaneous bilateral cochlear implantation
  - allows symmetric auditory brainstem development
  - protects the auditory cortex from reorganized lateralization

Conclusions

- there are multiple sensitive periods in auditory development
- duration of both bilateral and unilateral auditory deprivation should be limited in children