Hearing Aid Fitting in Children: Audibility Matters

4th Latin American Pediatric Conference
Sao Paulo, Brazil
August 21-22, 2015

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Objectives

- Objectives of Early Amplification
- Importance of Verification
- Introduction to the Outcomes of Children with Hearing Loss (OCHL)
  - Large, multi-center study of hard of hearing children in US
  - Brief discussion of characteristics of hearing aid fitting on enrolled children

Acknowledgements

Ryan McCreery, Ph.D.
BTNRH

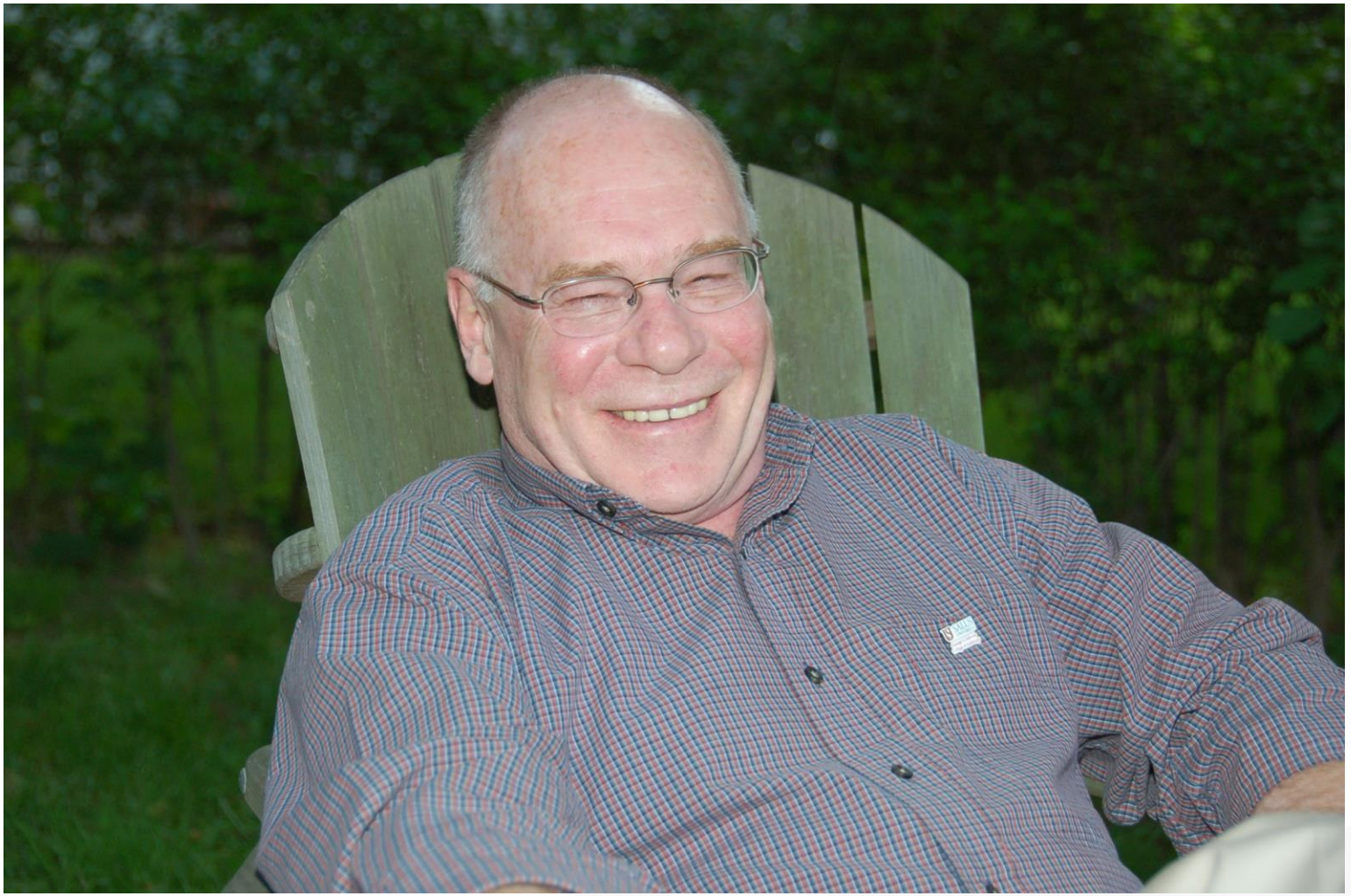
Meredith Spratford, Au.D.
BTNRH

Elizabeth Walker, Ph.D.
University of Iowa

Acknowledgements

- The Outcomes of Children with Hearing Loss team (Mary Pat Moeller & Bruce Tomblin, PIs)
- US National Institutes of Health
  - R01 DC009560
  - R01 DC013591

Acknowledgements: “Mr. DSL”



Sao Paulo 2007

Soracaba 2007

University Of North Carolina Chapel Hill

Universal NB screening legislation 1999

Pediatric Audiology and CI Teams

CASTLE pre-school

Total 1400 infants and children

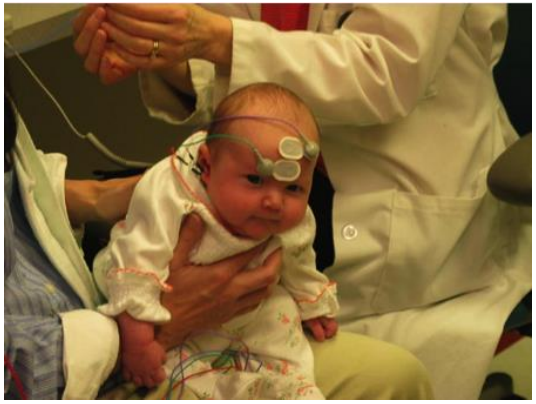
- 900 using amplification
- 800 with cochlear implants
- 200+ with ANSD diagnosis

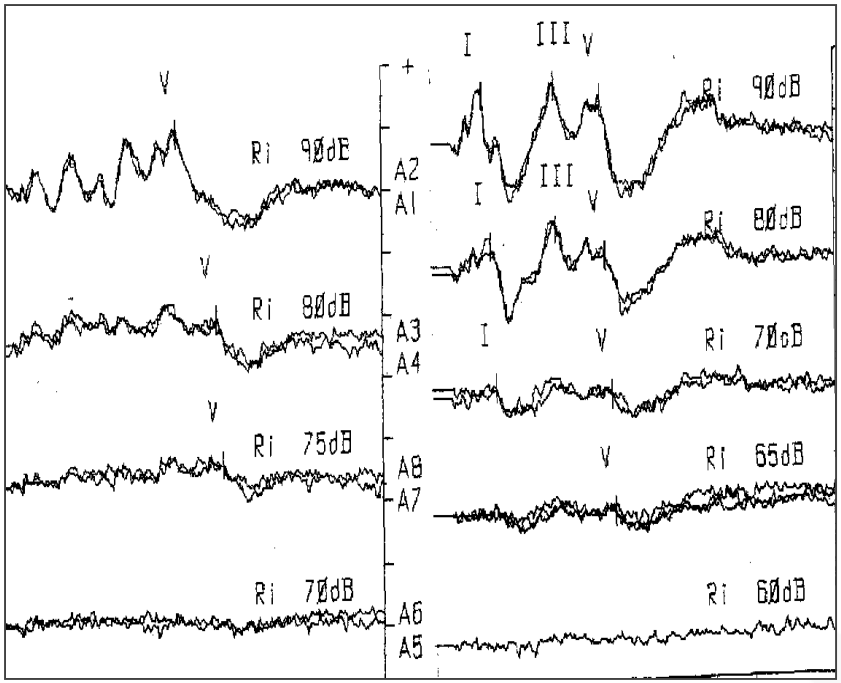
Where is North Carolina?

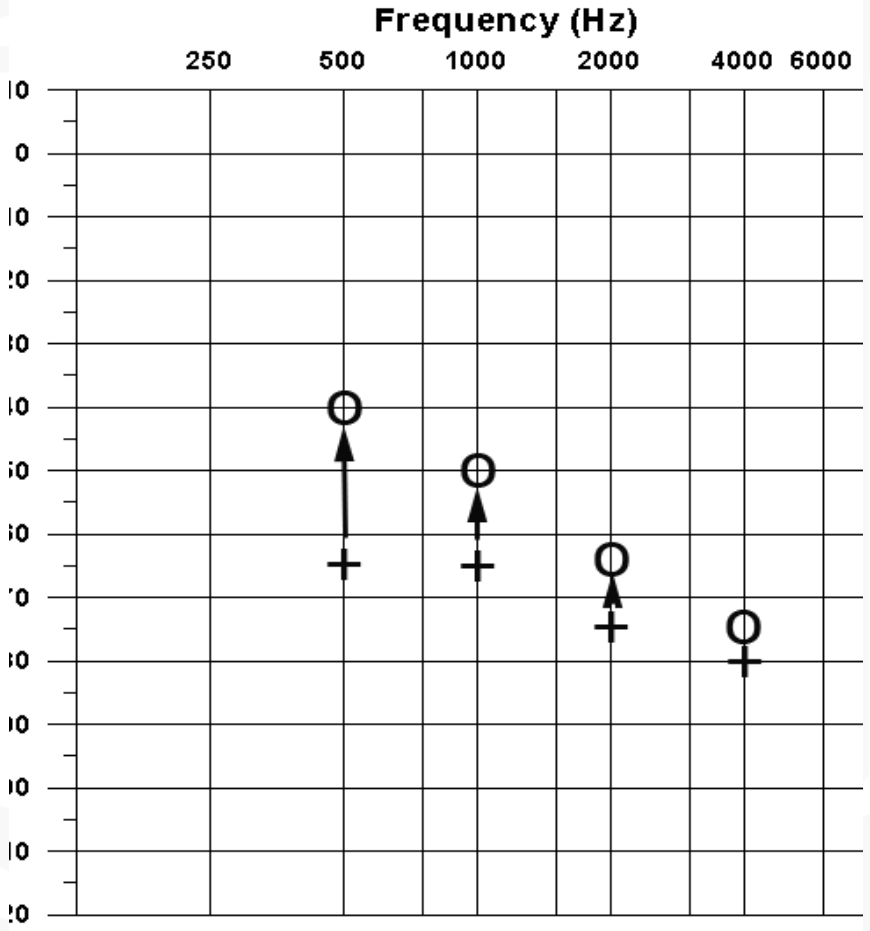
Audiologic Management of Infants and Young Children: Essential Components

- Diagnostic Evaluation
  - Auditory Brainstem Response (ABR)
  - Acoustic Immittance
  - Otoacoustic Emissions
- Hearing Aid Selection and Fitting
  - Appropriate selection of device (size, features)
  - Hearing aid programming
  - Hearing aid verification
  - Hearing aid validation
- Behavioral Audiometry
  - Visual reinforcement audiometry (VRA)
  - Conditioned play audiometry (CPA)

Estimate Audiogram Using ABR

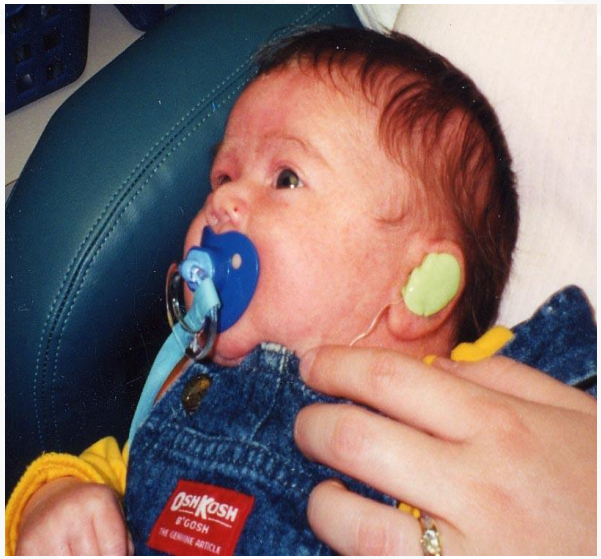


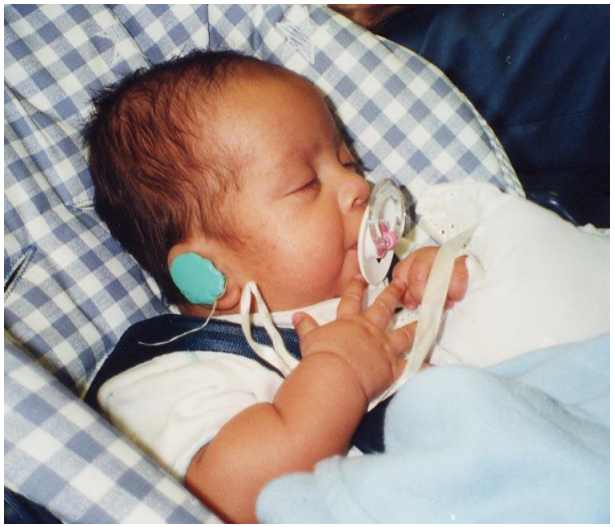




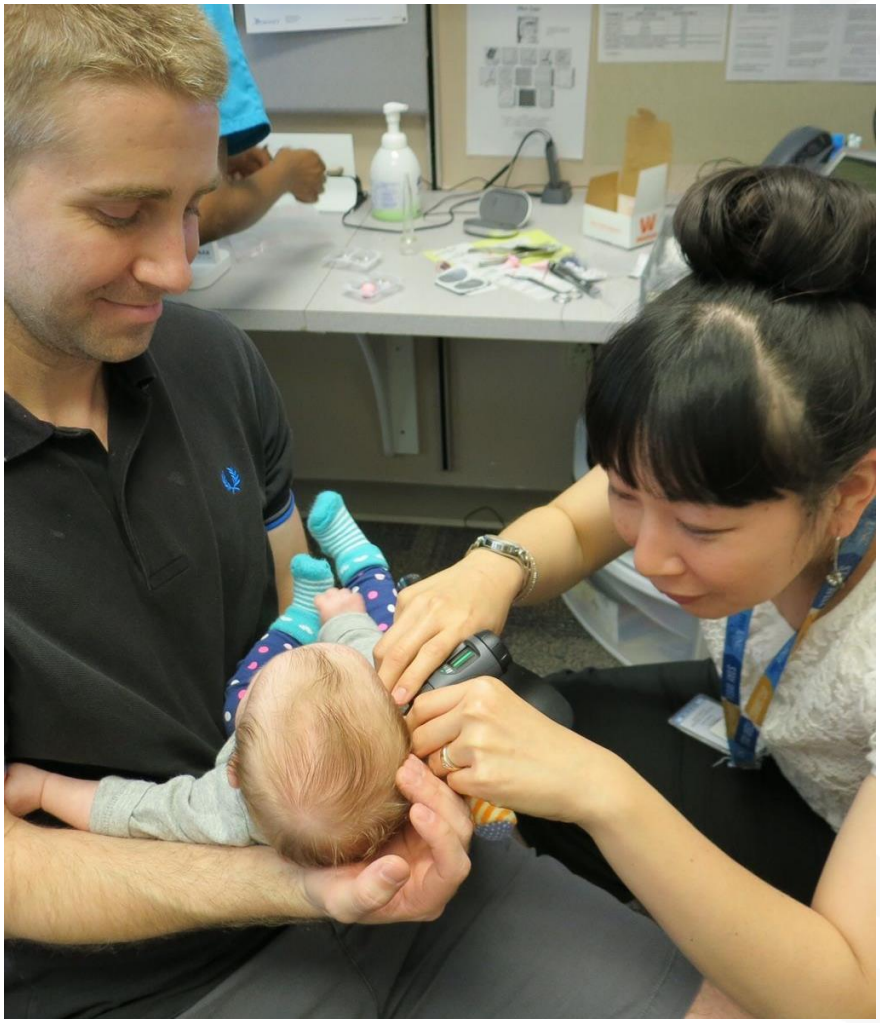
Hearing Instrument Selection and Ear Impressions

- If family ready to proceed, ear impressions taken
- Hearing instruments selected
- Return appt for hearing instrument fitting two weeks later
- Ideally between 2-3 months of age





Hearing Aid Fitting Using Evidence Based Protocols



- AAA Pediatric Amplification Protocol 2013
- Ontario Protocol for the Provision of Amplification 2014

Referral for Early Intervention

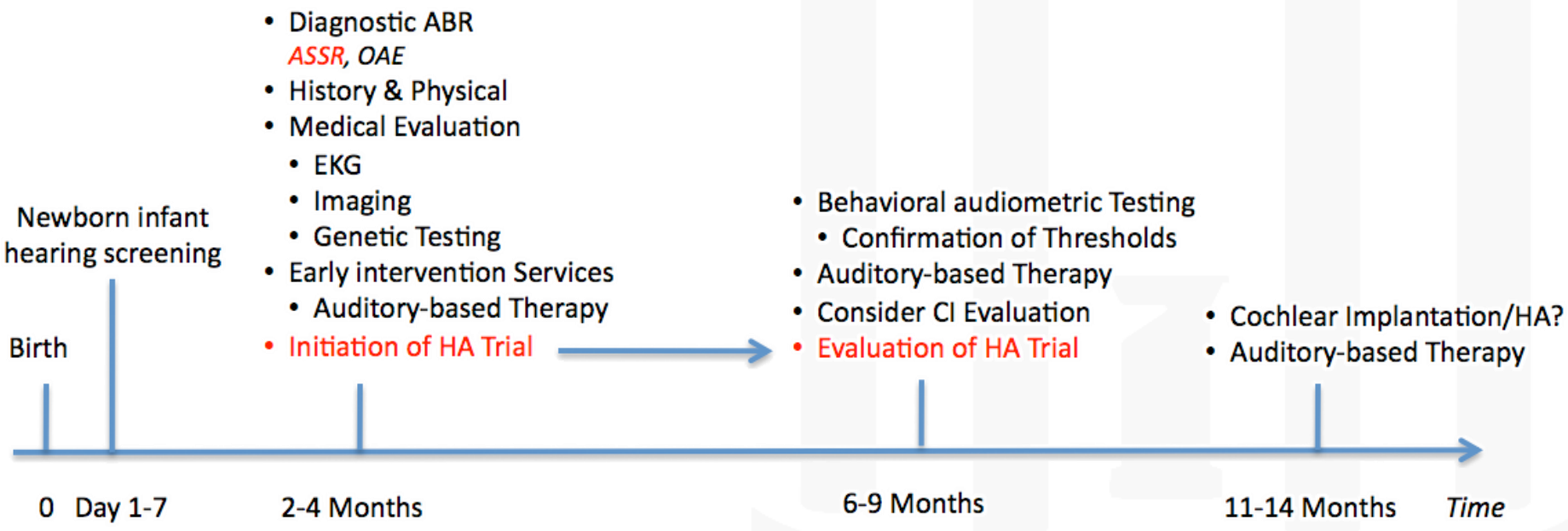
- Referral to “Beginnings” on day hearing loss diagnosed (www.ncbegin.org)
- Family contacted within one week of diagnosis and home visit from early childhood specialist scheduled
  - » Written materials and video provided to family
- Weekly home visits with teacher of the deaf/speech and language pathologist scheduled

Behavioral Audiologic Assessment

- Begin VRA at 6-7 months
- Goal: Complete audiogram for each ear (air and bone) by 8-9 months of age.
- Hearing aids readjusted as new threshold information is obtained ***

Timeline

Early Diagnostic Evaluation & Management of Hearing Loss



Protocol for the provision of amplification
Ontario Infant Hearing Program

Objectives of Early Amplification

- *Provide amplified speech signal that is consistently audible across varying input levels*
- *Avoid distortion of varying inputs at prescribed settings*
- *Ensure amplification of sounds in as broad a frequency range as possible*
- *Include sufficient electro-acoustic flexibility to allow for changes in required frequency/output characteristics related to ear growth or changes in the auditory characteristics of the infant*

Bagatto, Scollie, Hyde and Seewald
- International Journal of Audiology 2010

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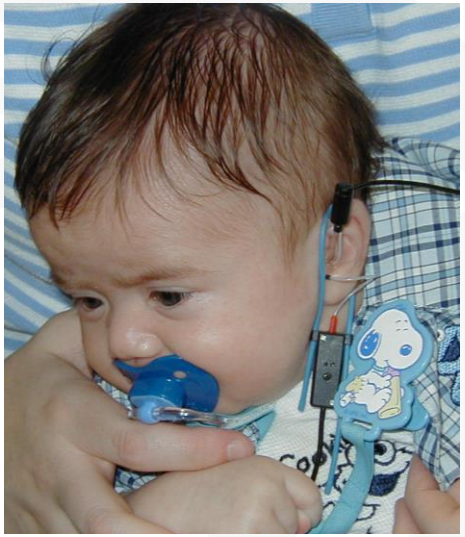
How Do We Ensure that Speech is Audible for Infants and Young Children?

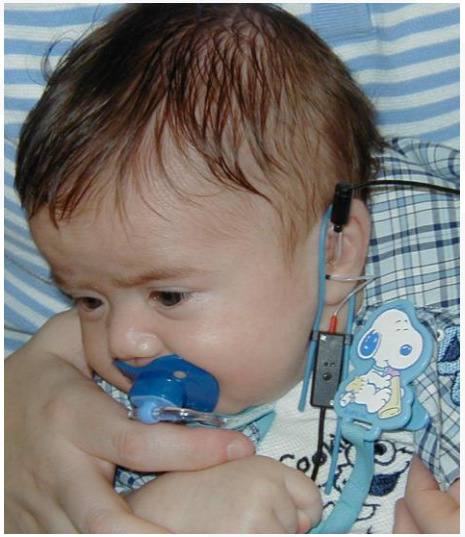
- ***Accurate determination of thresholds*** at time of diagnostic hearing evaluation using frequency specific ABR
- ***Program hearing aids*** using manufacturer's software as a starting point
- ***Verify*** that hearing aid settings are appropriately matching prescriptive targets for gain and output across frequency range after measuring the RECD
- ***Follow*** established pediatric amplification protocols
  - AAA Pediatric Amplification Protocol 2013
  - Ontario Protocol for the Provision of Amplification 2014

Verification Methods



- Functional gain/aided soundfield (not recommended)
- Real ear measures with probe mic
- Simulated real ear measures in test box—measured RECD
- Simulated real ear measures in test box—average RECD

Verification Methods



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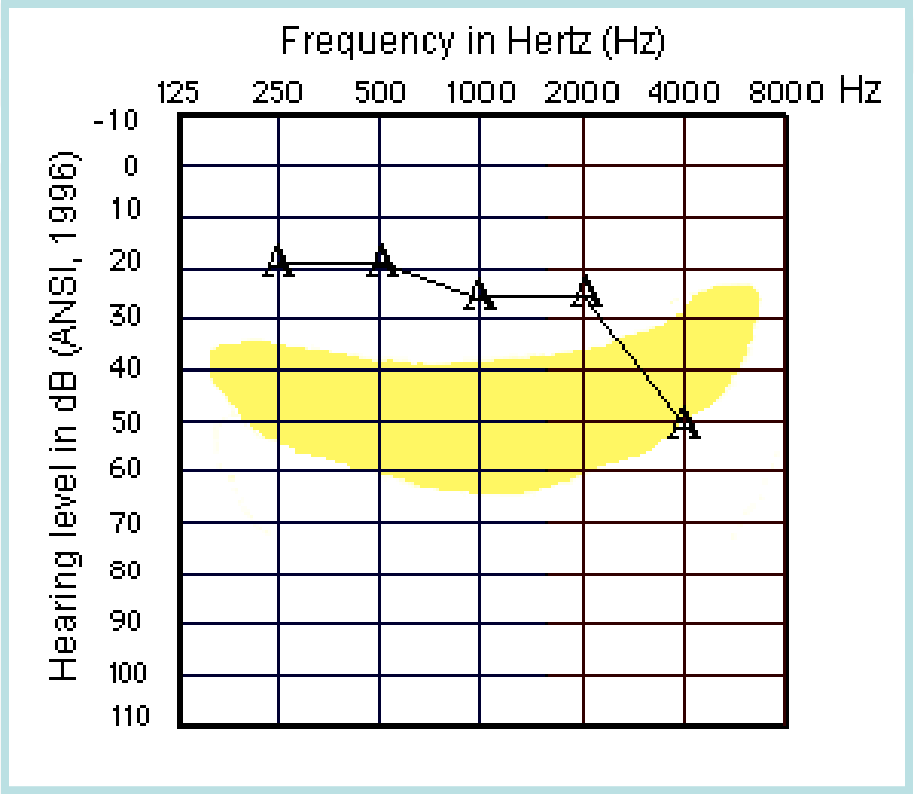
We wouldn't consider fitting hearing aids like this…

Why Would We Consider Verifying Hearing Aids Like this…

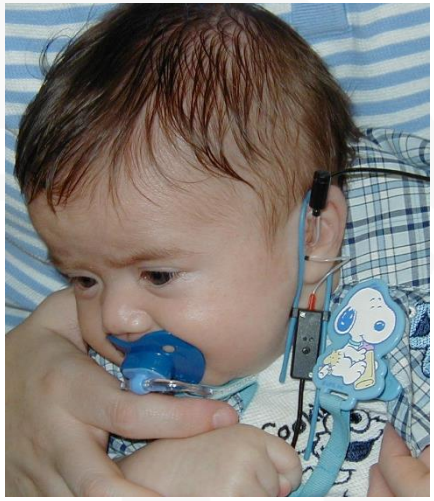


Audiogram with hearing aids is NOT verification

- No information about speech audibility.
- Cannot assess maximum output.
- Represents a stimulus and level that are not encountered by children e.g. warbled tones.
- No estimation of advanced features

ONLY appropriate for validation of CIs and bone conduction devices or as a demonstration to families!

Verification Methods



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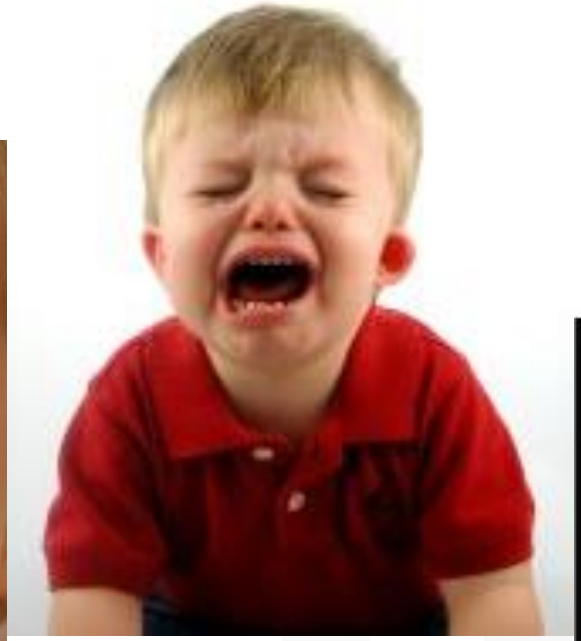
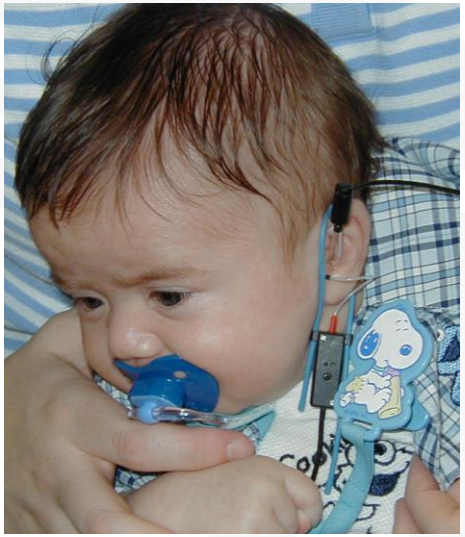
Real Ear Measures Optimal But…

- Accurate method for determining if prescriptive targets met but…
- Requires child or adult to sit quietly while programming and verifying match to targets

Most Toddlers Aren't So Patient…



Verification Methods



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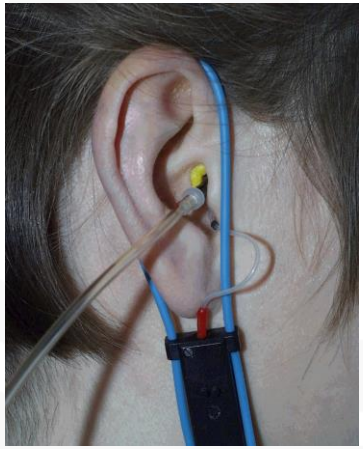
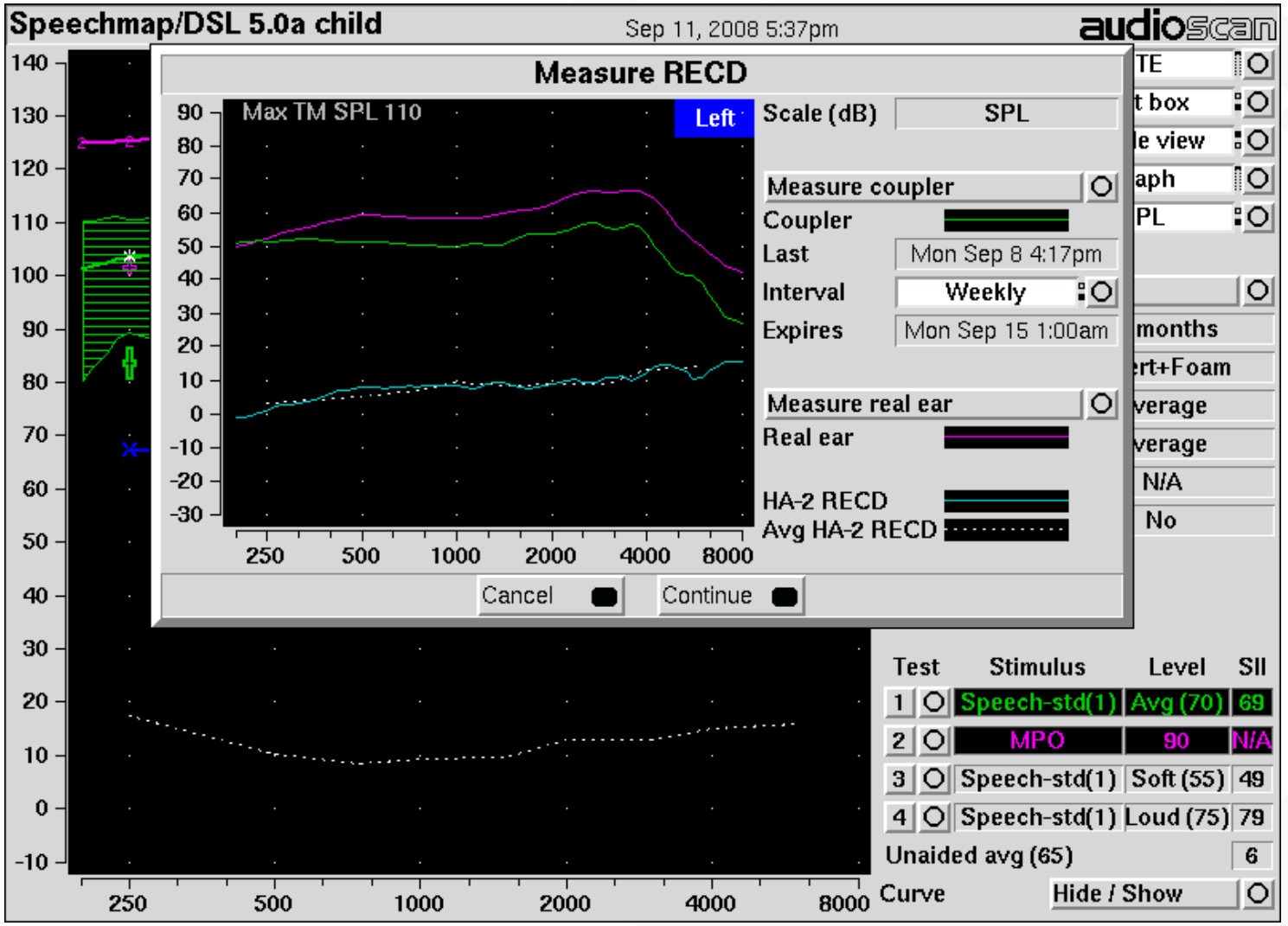
Measuring the RECD

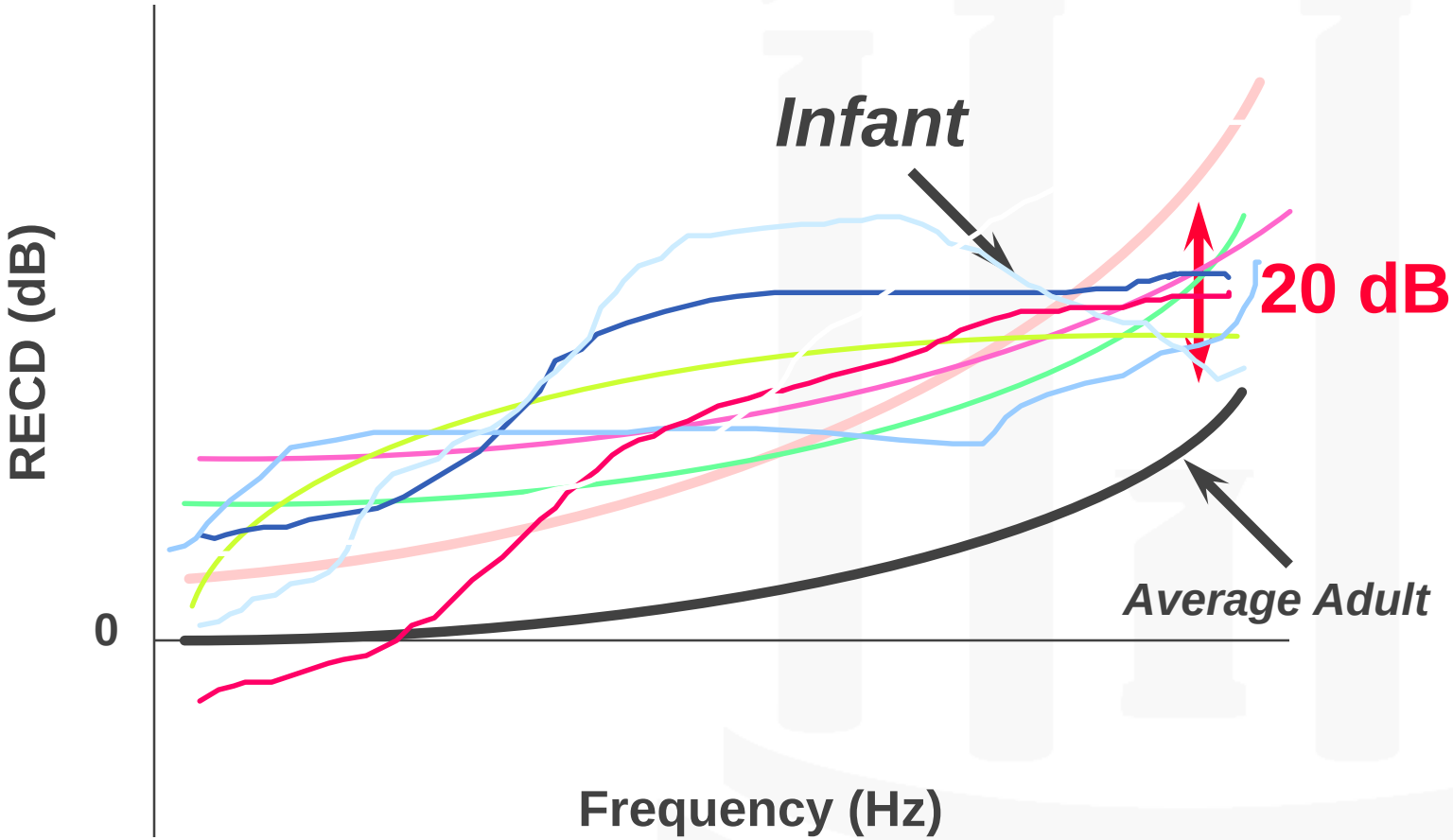
- Measure signal of known intensity in a 2 cc coupler
- Measure the *real ear SPL* for the same signal with insert earphone or child's earmold
- *RECD=real ear SPL-coupler SPL*



RECD Measurement



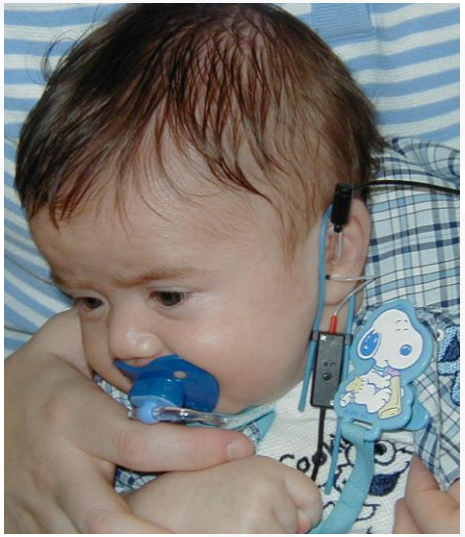
RECDs for Infants and Toddlers



Slide Courtesy of Richard Seewald

Measured RECDs are best but there are times when measurement just not possible…

Verification Methods



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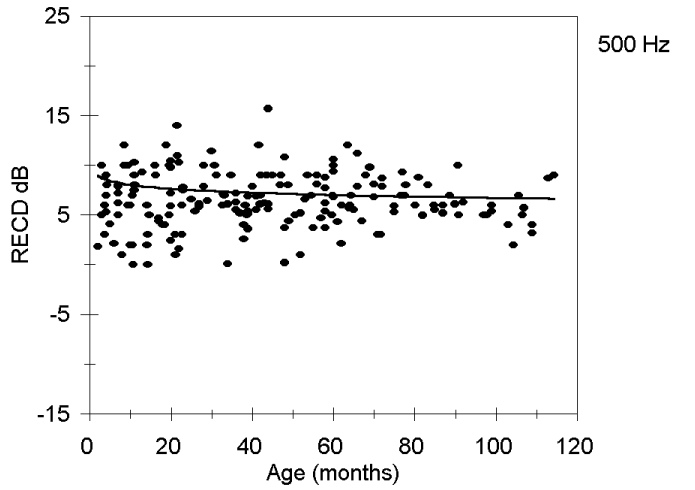
Predicted (Average)RECD values

Real-Ear-to-Coupler Difference (RECD) Predictions as a Function of Age for Two Coupling Procedures

Marlene Bagatto, Susan Scollie, Richard Seewald, K. Shane Moodie, & Brenda Hoover

2002, JAAA, vol 13(8)

Predicted RECD Values: Earmolds



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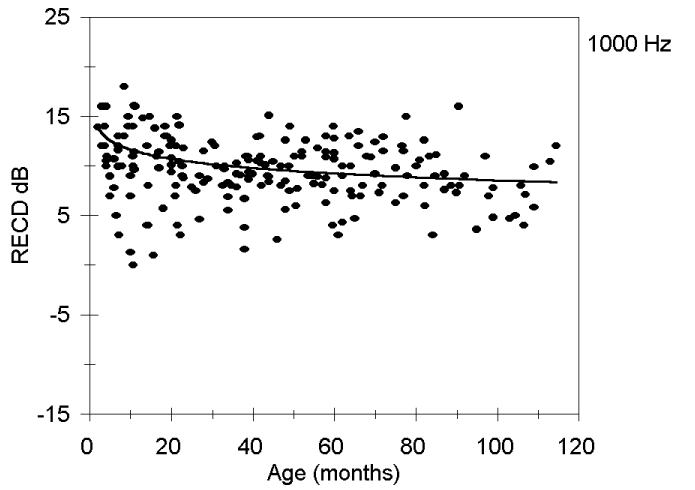
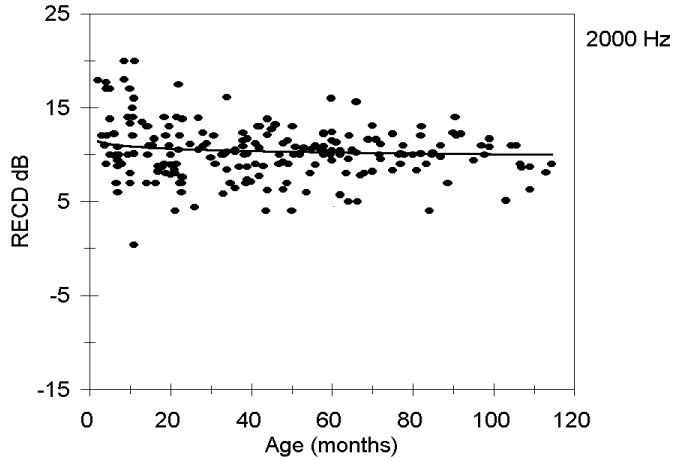
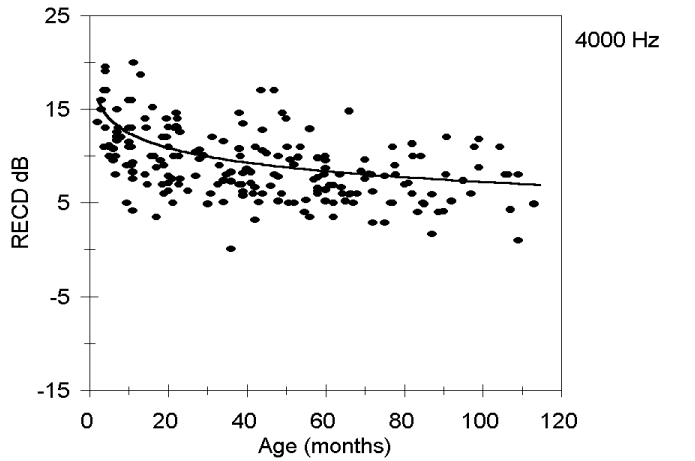


b)



c)



d)

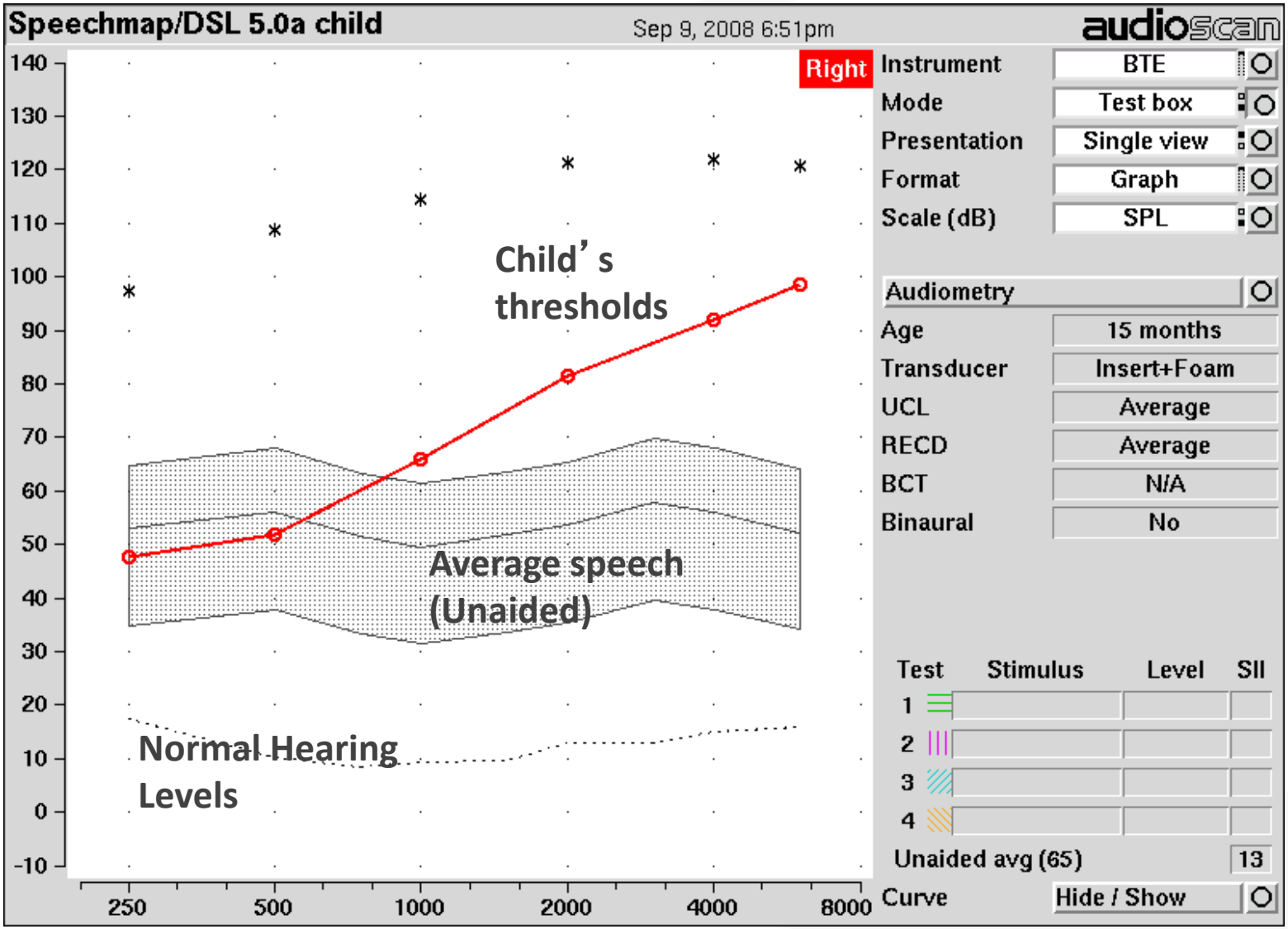
Predicted RECD Values

Limitations:

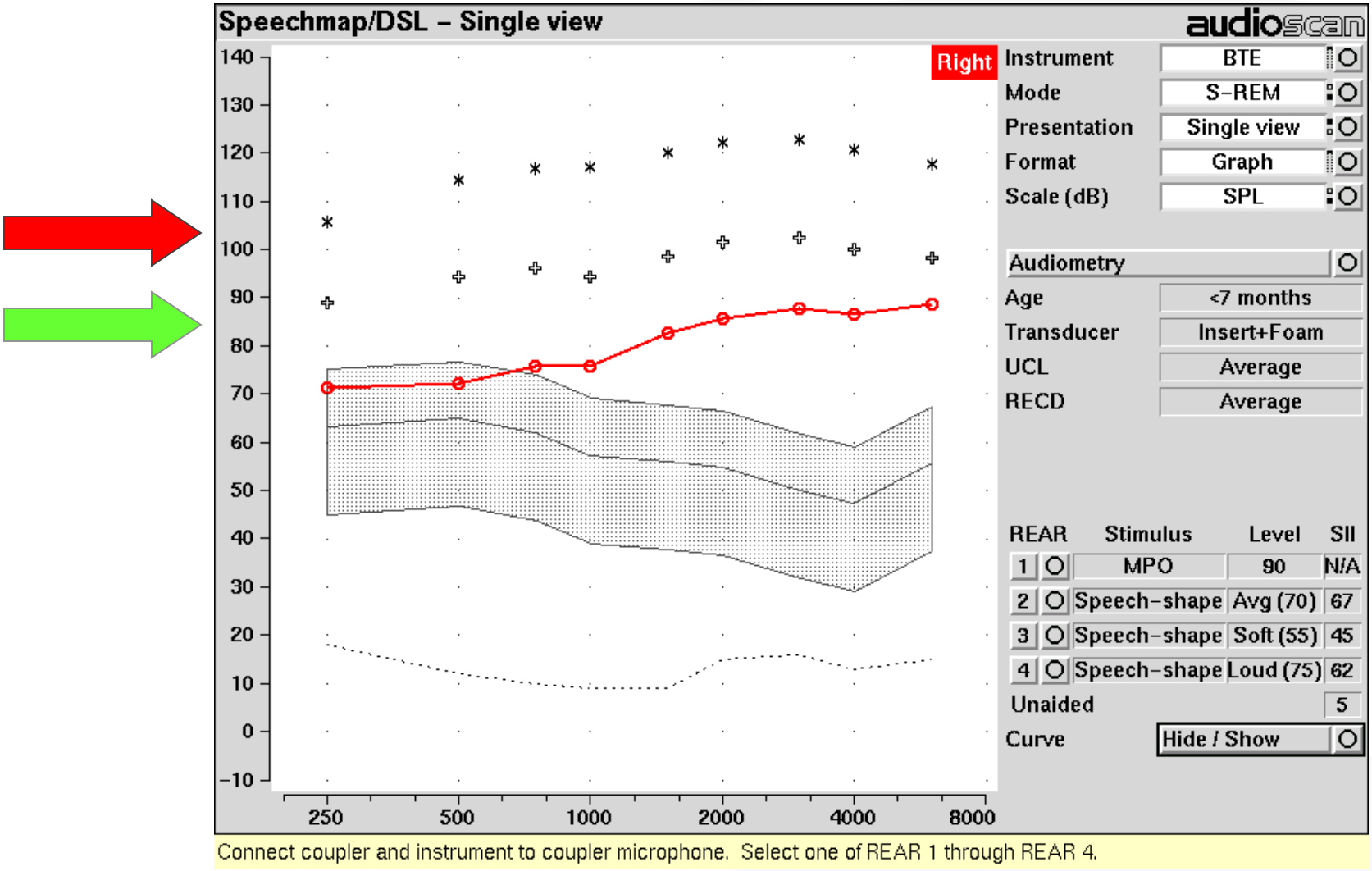
- High variability in RECD measures associated with children of the same age

Therefore, whenever possible, predicted values should NOT replace a more precise RECD measurement.

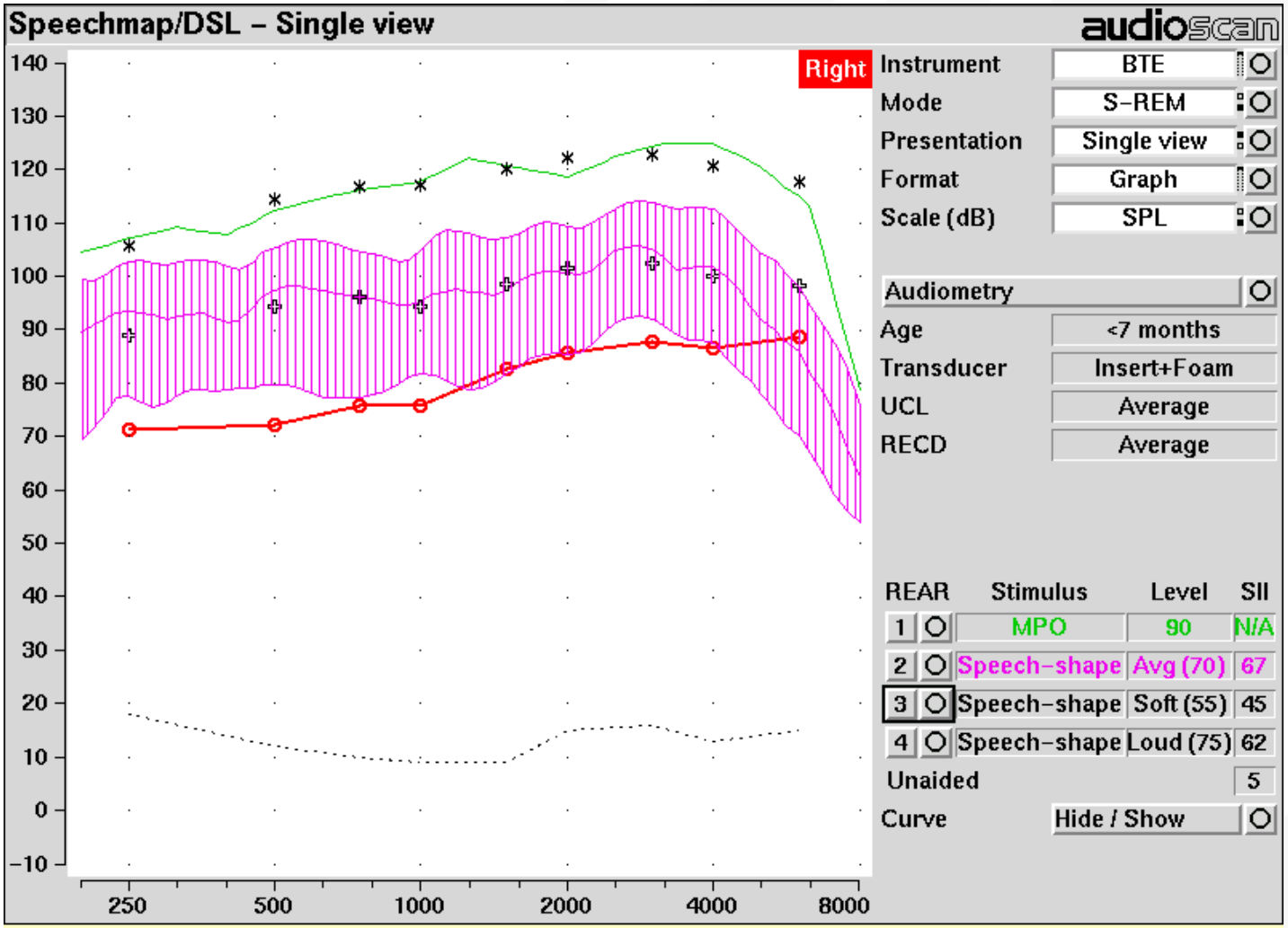
Speech Mapping



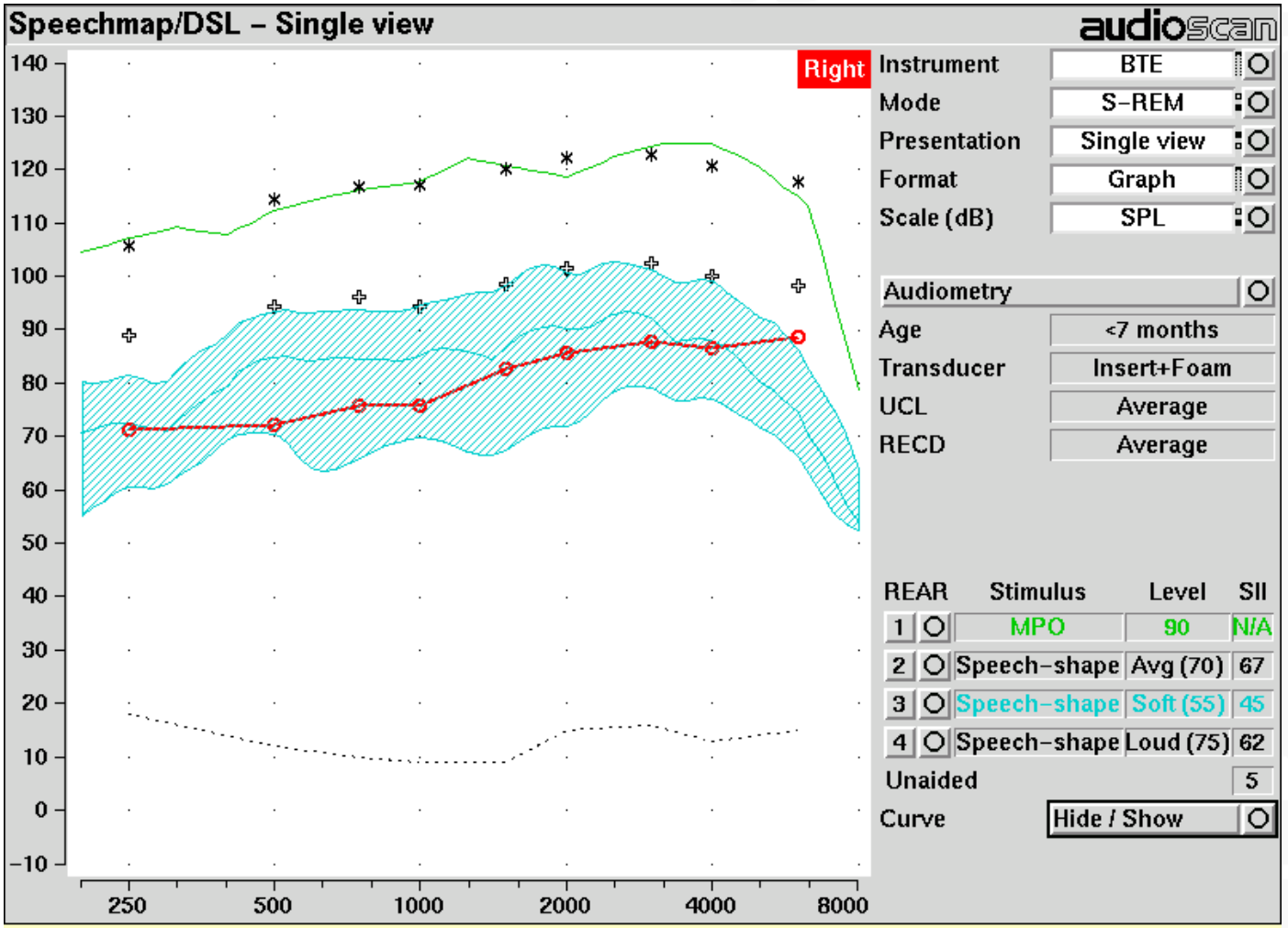
Match targets for Gain and Output



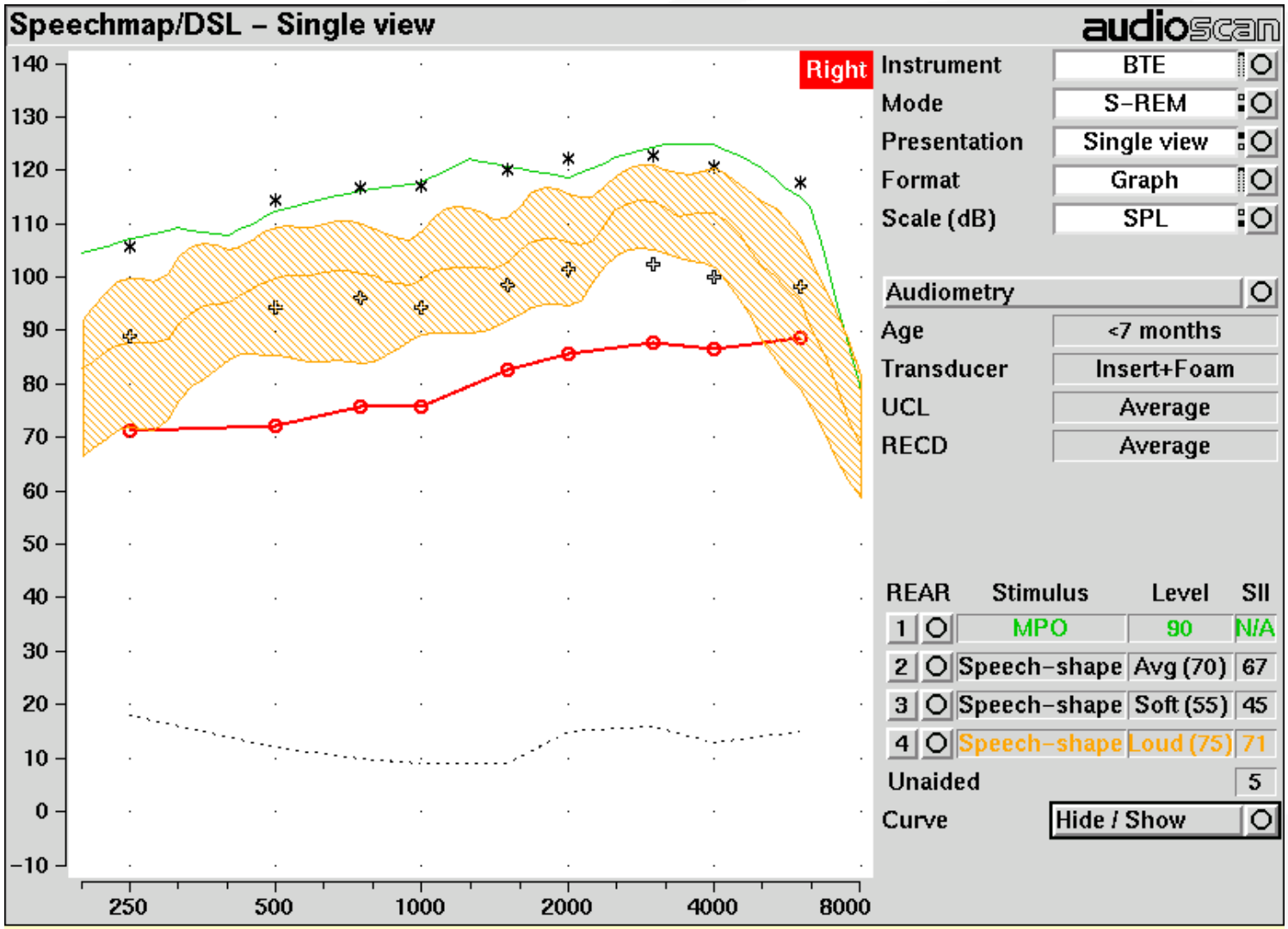
Goal: Audible Speech Signal for Average Speech Inputs…



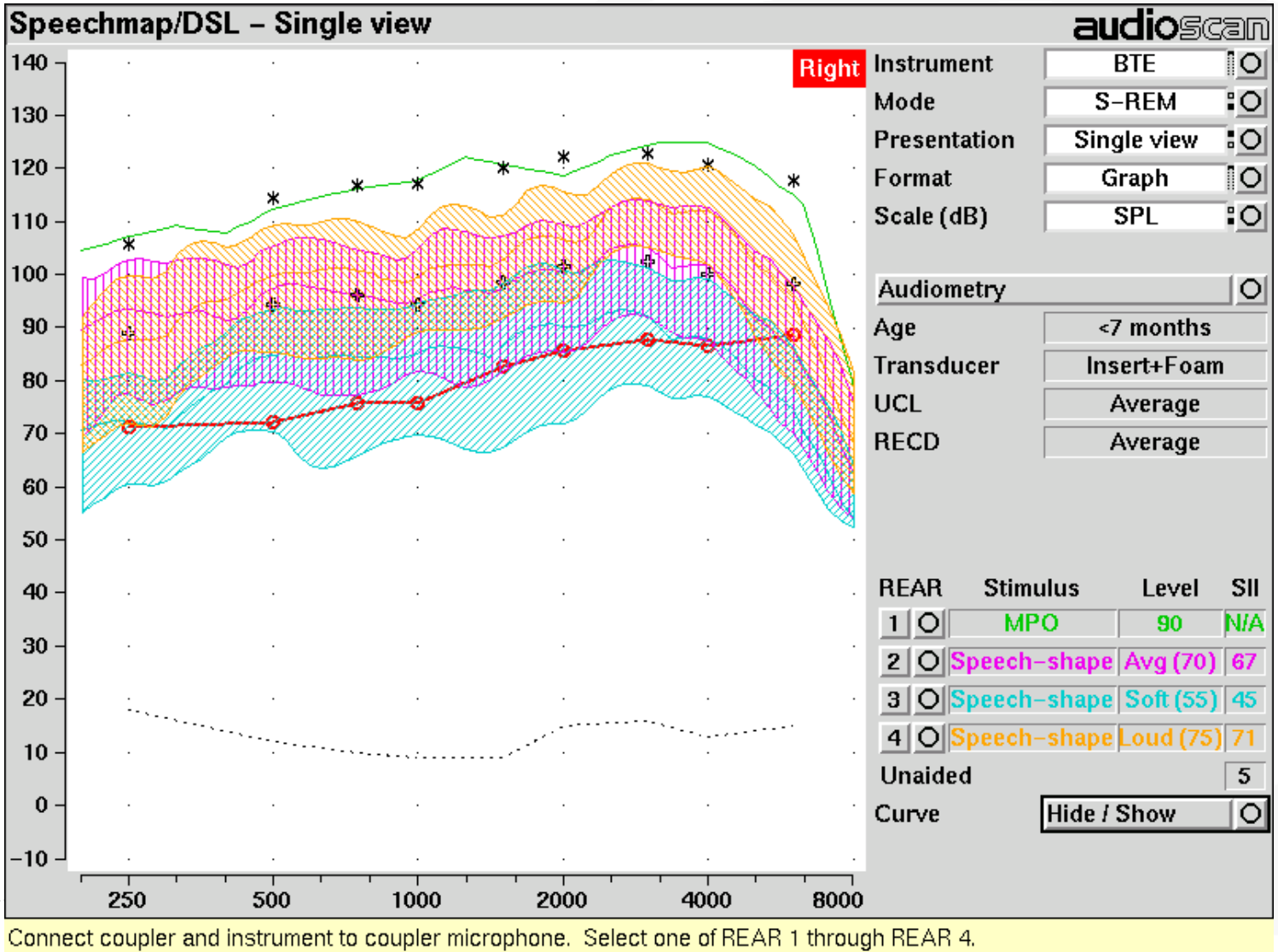
…Soft Speech (55dB input level)



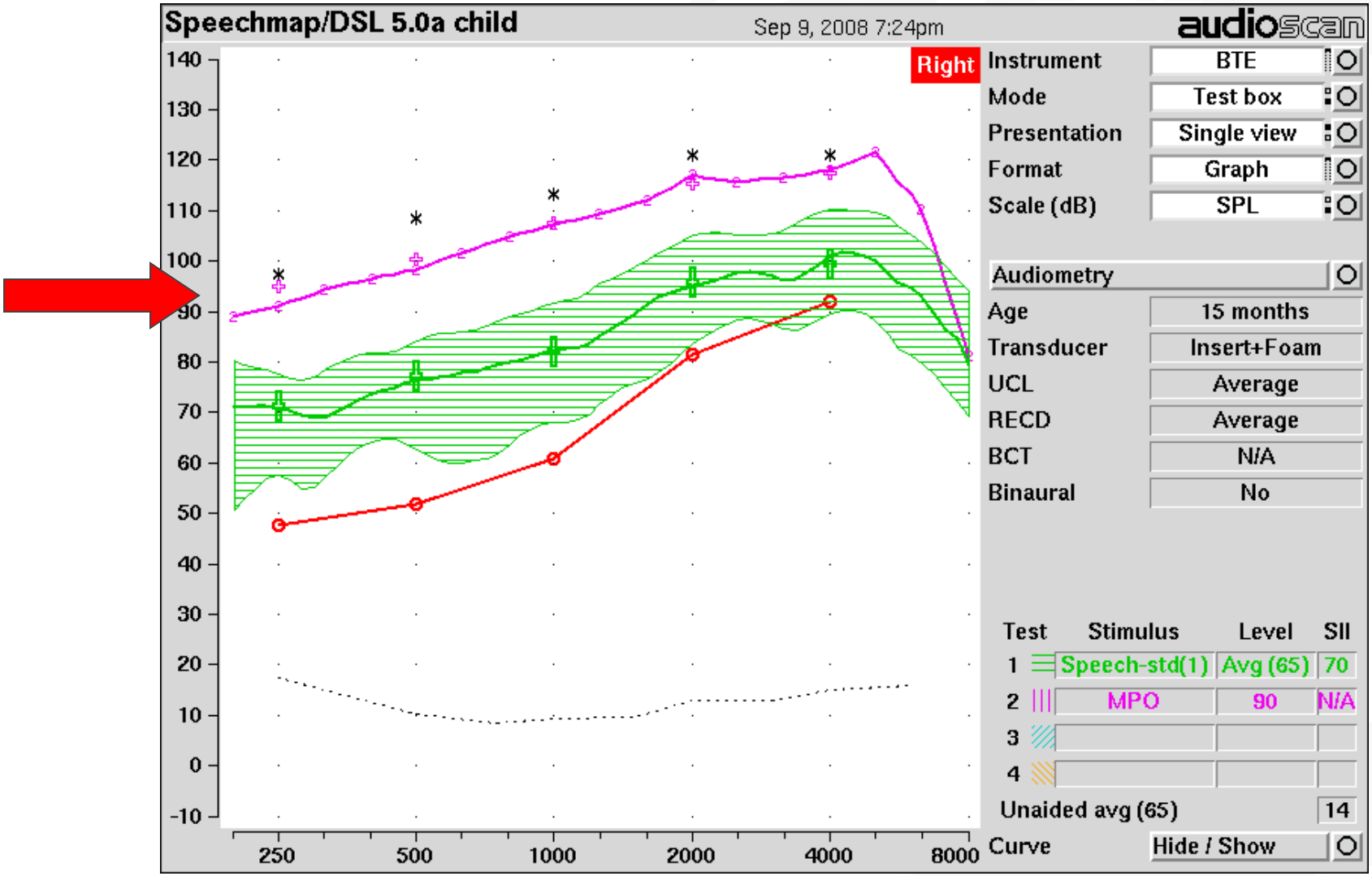
And…Loud Speech (75dB input level)



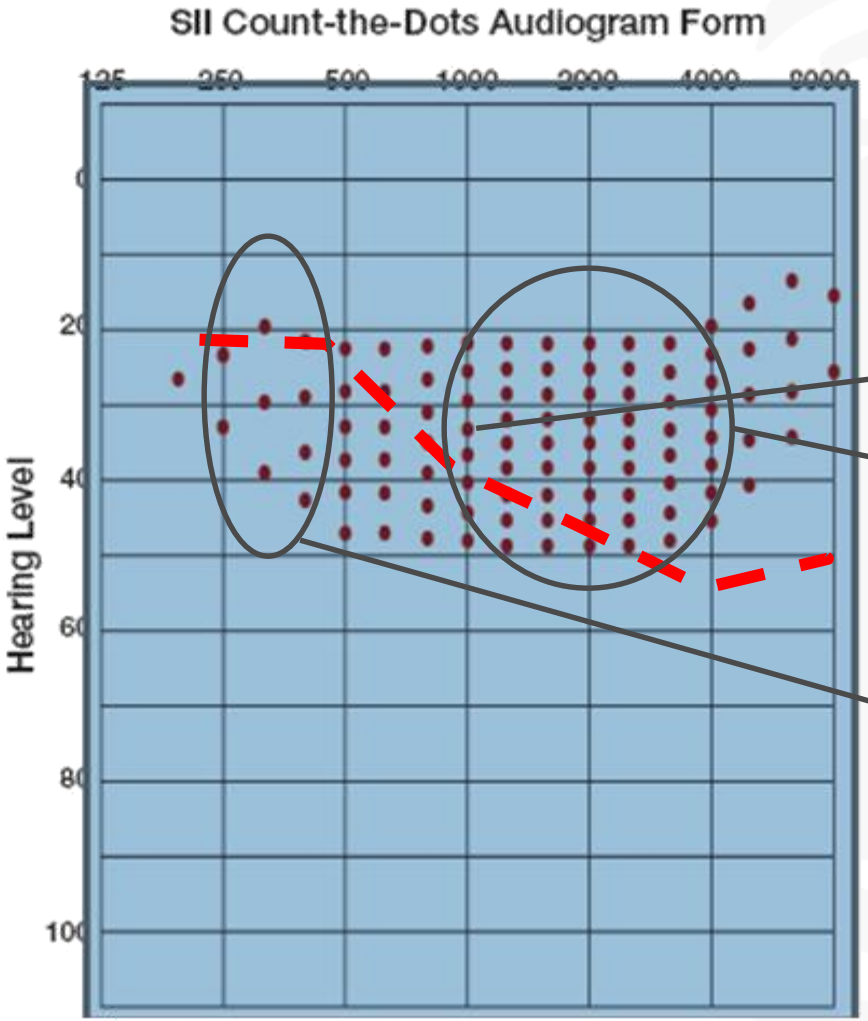
Audibility and Comfort With Varying Speech Input Levels



Goal: Maximum Output that Does Not Exceed Comfort Levels



Another way to quantify audibility.... Speech Intelligibility Index (SII)



Some frequencies contribute more than others to the intelligibility of speech.

Above line = dots inaudible; below line = dots audible

More dots=more important

Less dots=less important

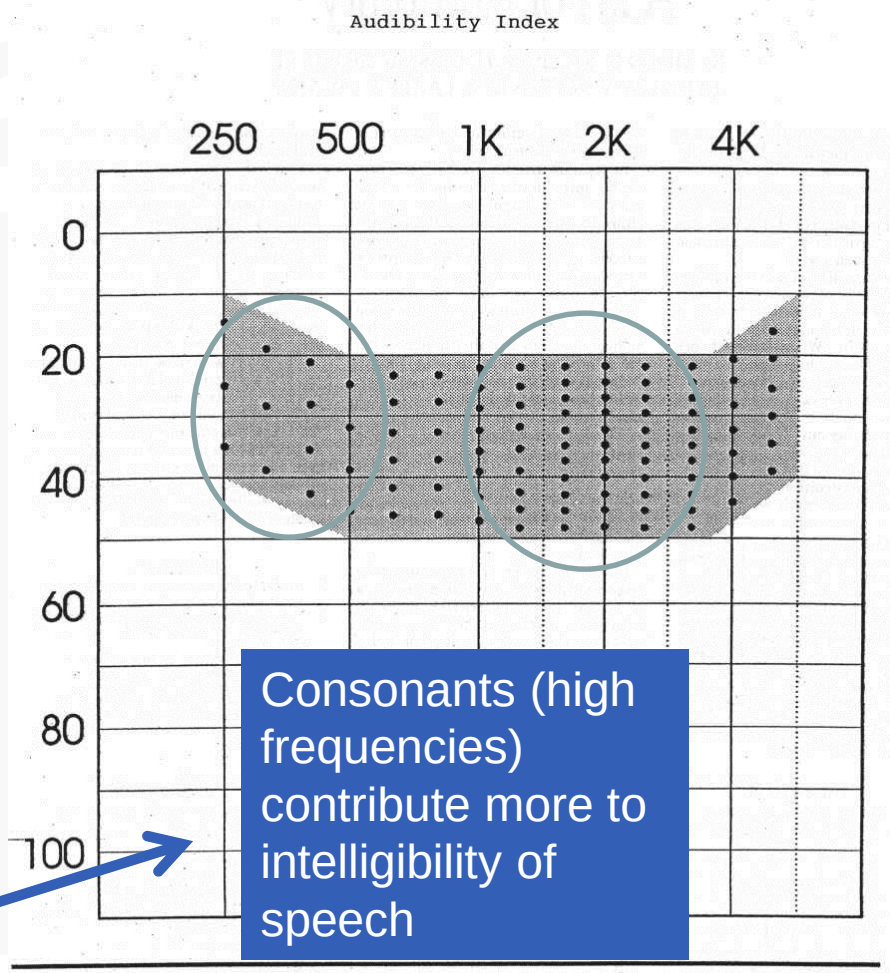
Quantifying audibility: Speech Intelligibility Index

Each dot = ~1% of the information contributing to speech clarity.

Number of dots that are audible predict how well one understands quiet speech from a six foot distance.

Dots unevenly distributed - more between 1000 and 3000 Hz than 250 to 500 Hz.

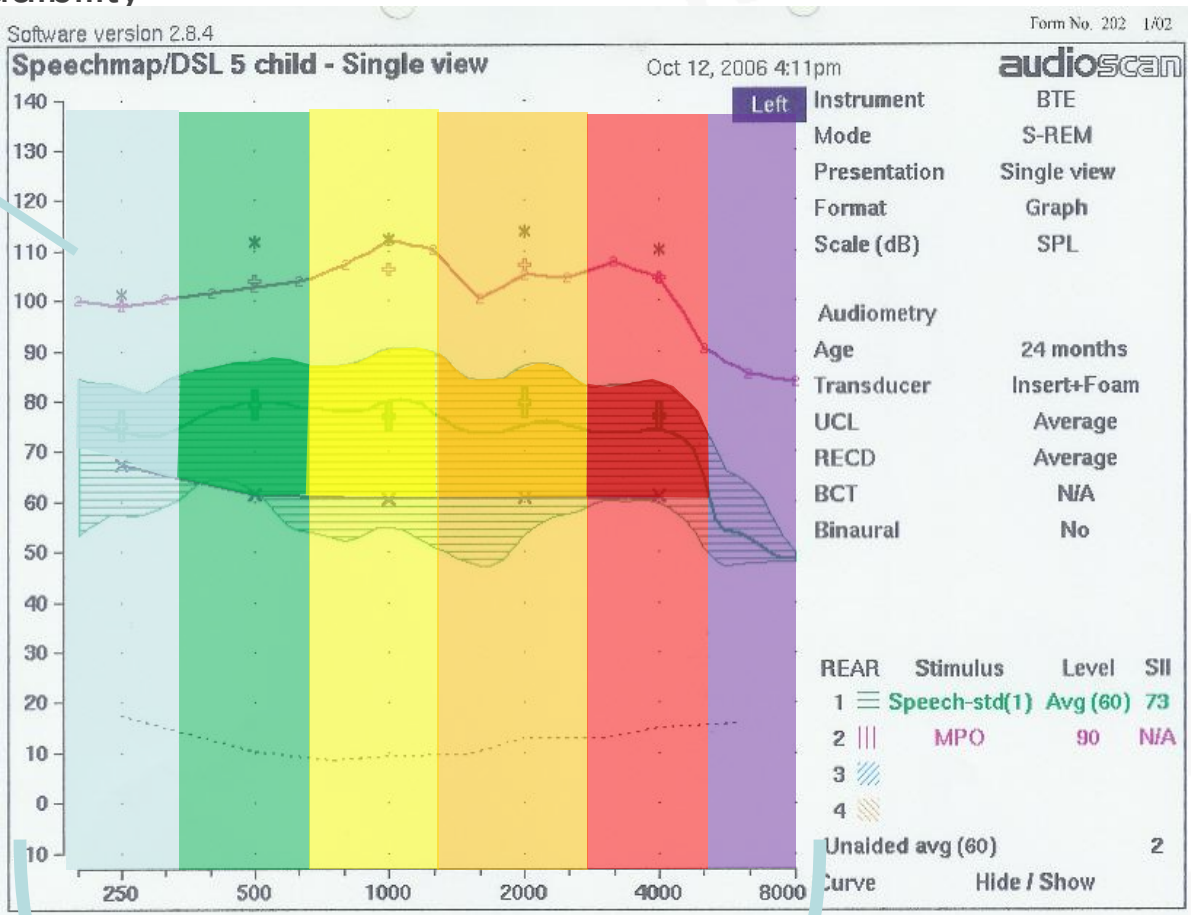
Why?



Source: Mueller H, Killion M. An easy method for calculating the articulation index. *The Hearing Journal 43*(9): 14–17, 1990. Reprinted with permission.

Speech intelligibility index (SII)

For each band:
Audibility x FIW =
weighted audibility

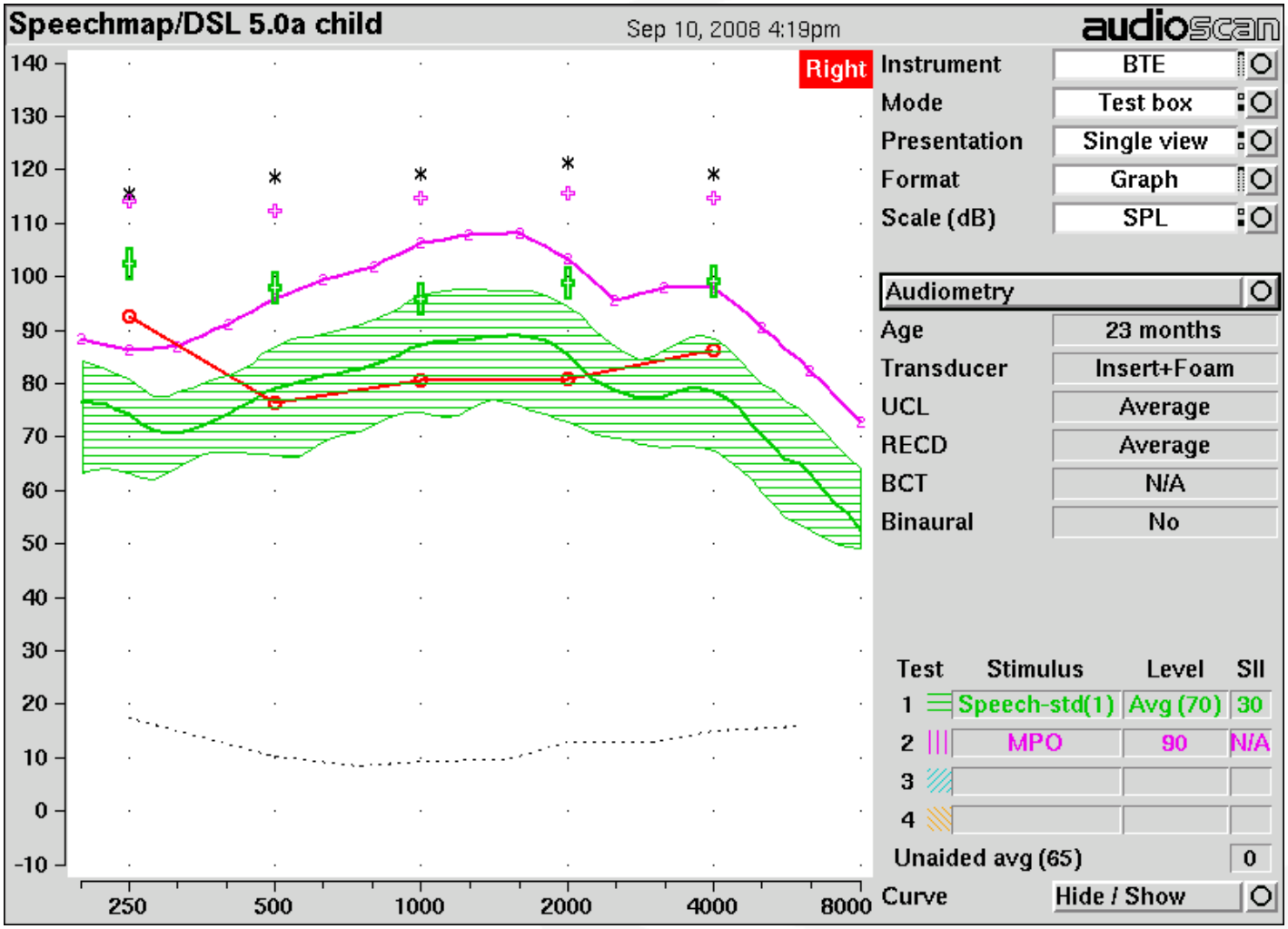


SII = Sum of weighted audibility of all frequency bands

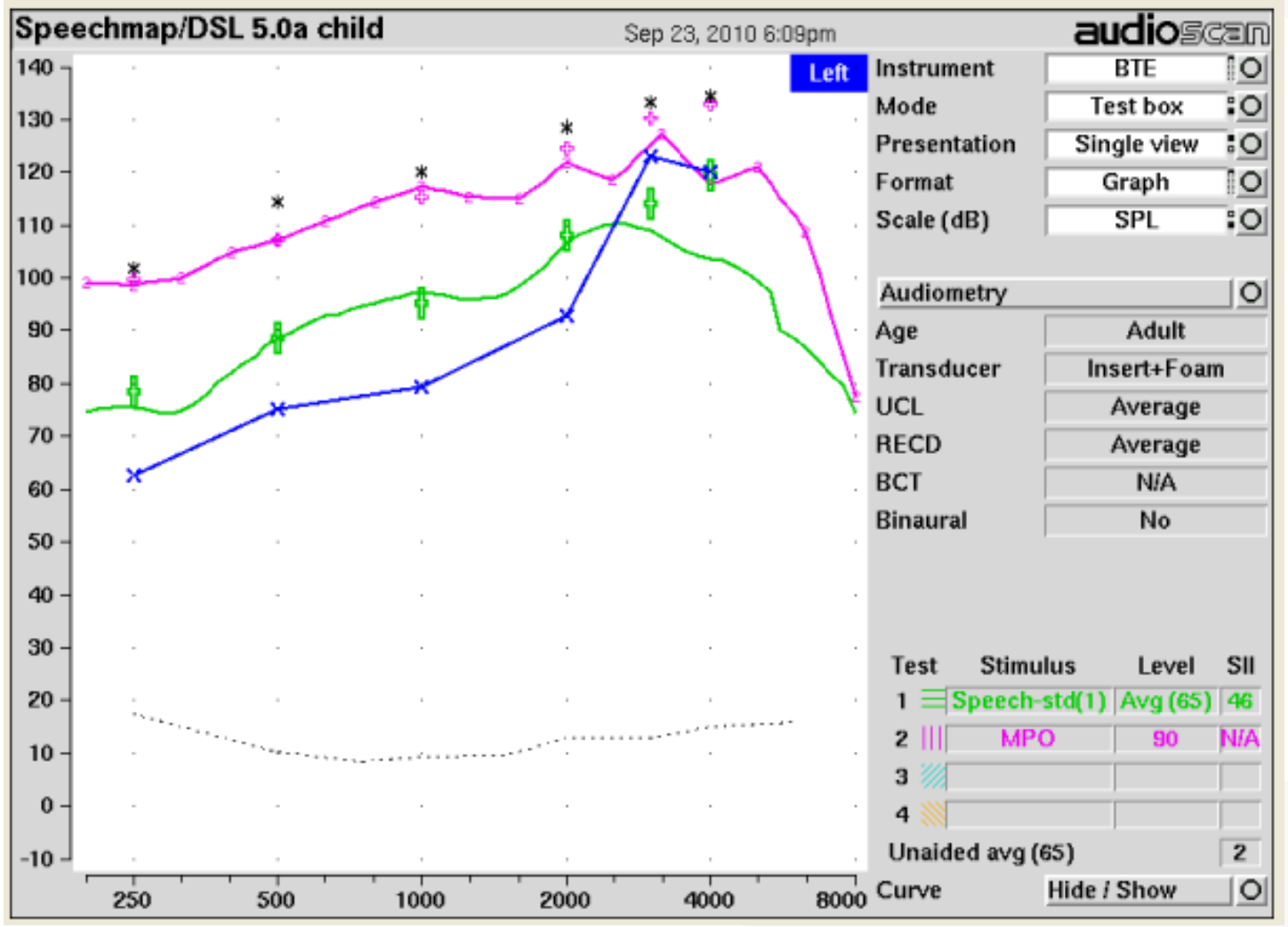
Aided SII

Unaided SII

What Happens When We Don't Verify?



Best Match to Targets…but SII only 46 Consider Other Strategies?



DOES ALL OF THIS WORK??

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Outcomes of Children with Hearing Loss

A study of children ages birth to six

(2008-2013)

Principle Investigators:
Mary Pat Moeller, PhD
Bruce Tomblin, PhD

A study funded by the National Institutes of Health – National Institute on Deafness and Other Communication Disorders

(NIH-NIDCD)

Grant # DC009560

Introduction to OCHL

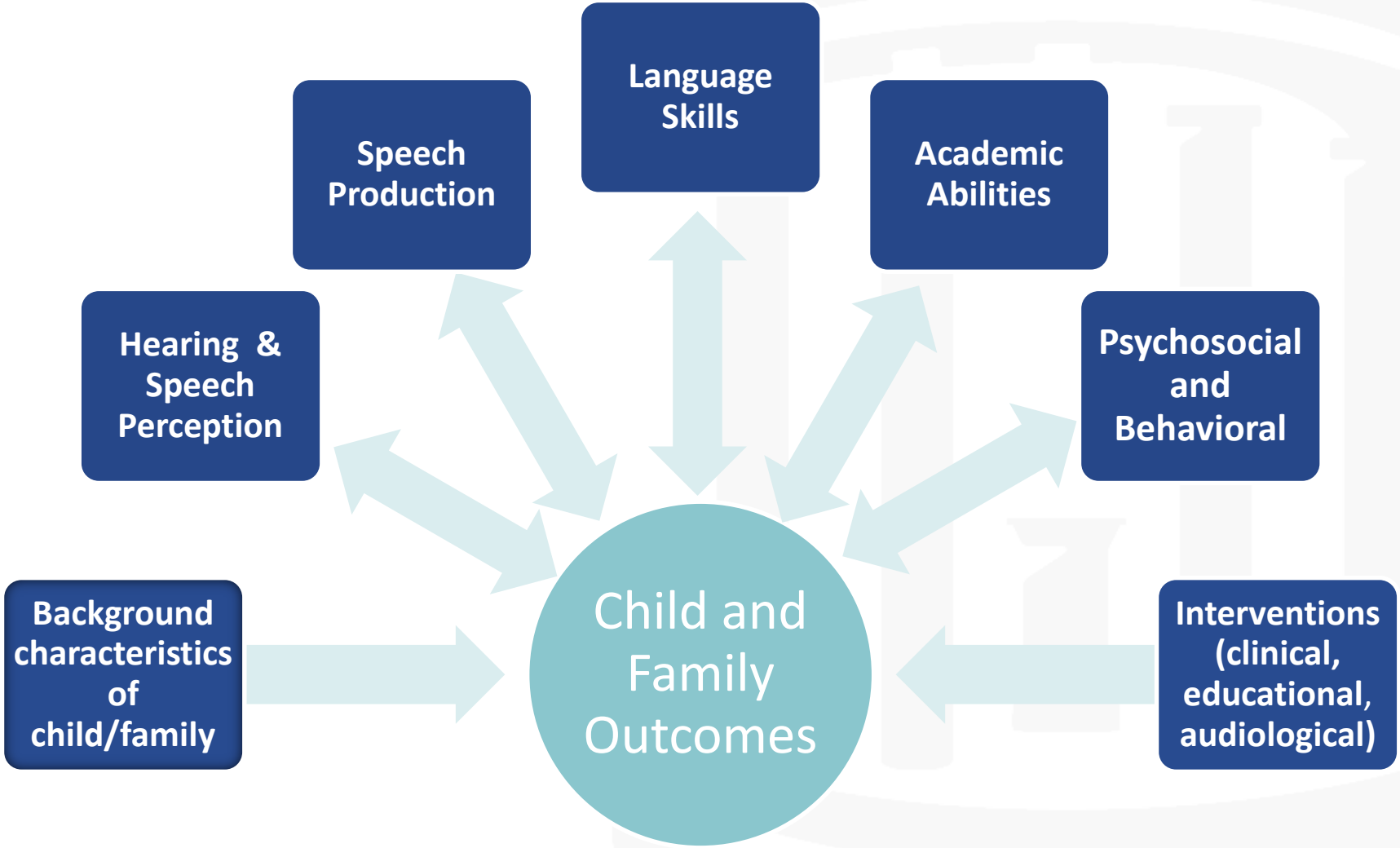
- Participating sites:
  - University of Iowa
  - Boys Town National Research Hospital
  - University of North Carolina—Chapel Hill
- Target population:
  - Epidemiologic sample of children with HL
    - Ages 6 months to 6 years 11 months
    - English spoken in the home
    - No major secondary disabilities
    - Permanent Mild to Severe Hearing Loss
      - PTA of 25-75 dB HL (.5, 1, 2, 4 kHz)
  - Cohort of age-matched, normal hearing children

THE UNIVERSITY OF IOWA

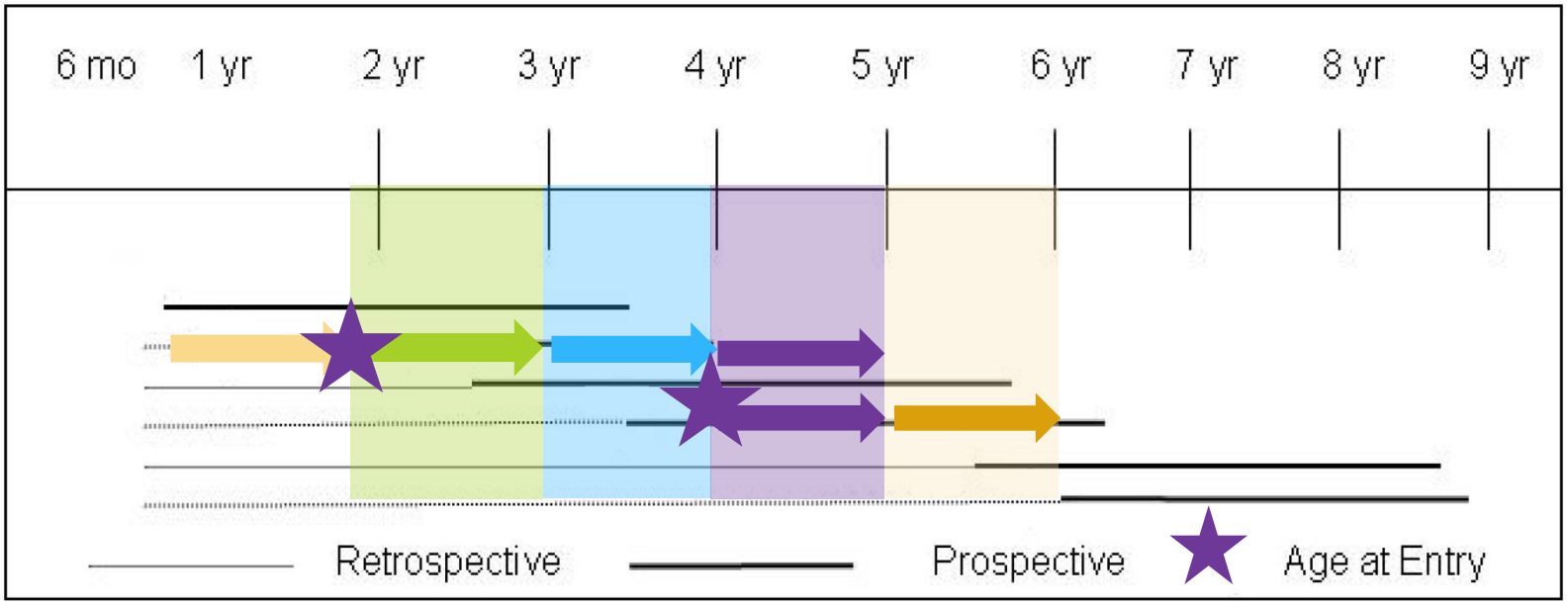
BOYS TOWN National Research Hospital SM

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

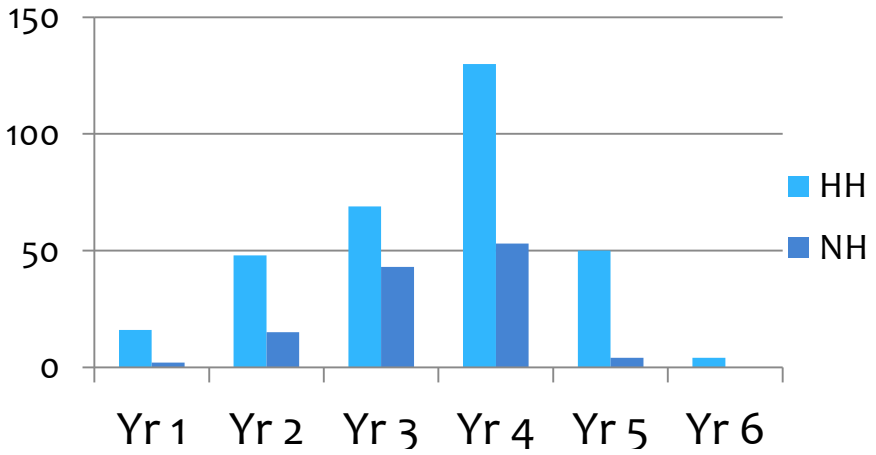
Domains of study



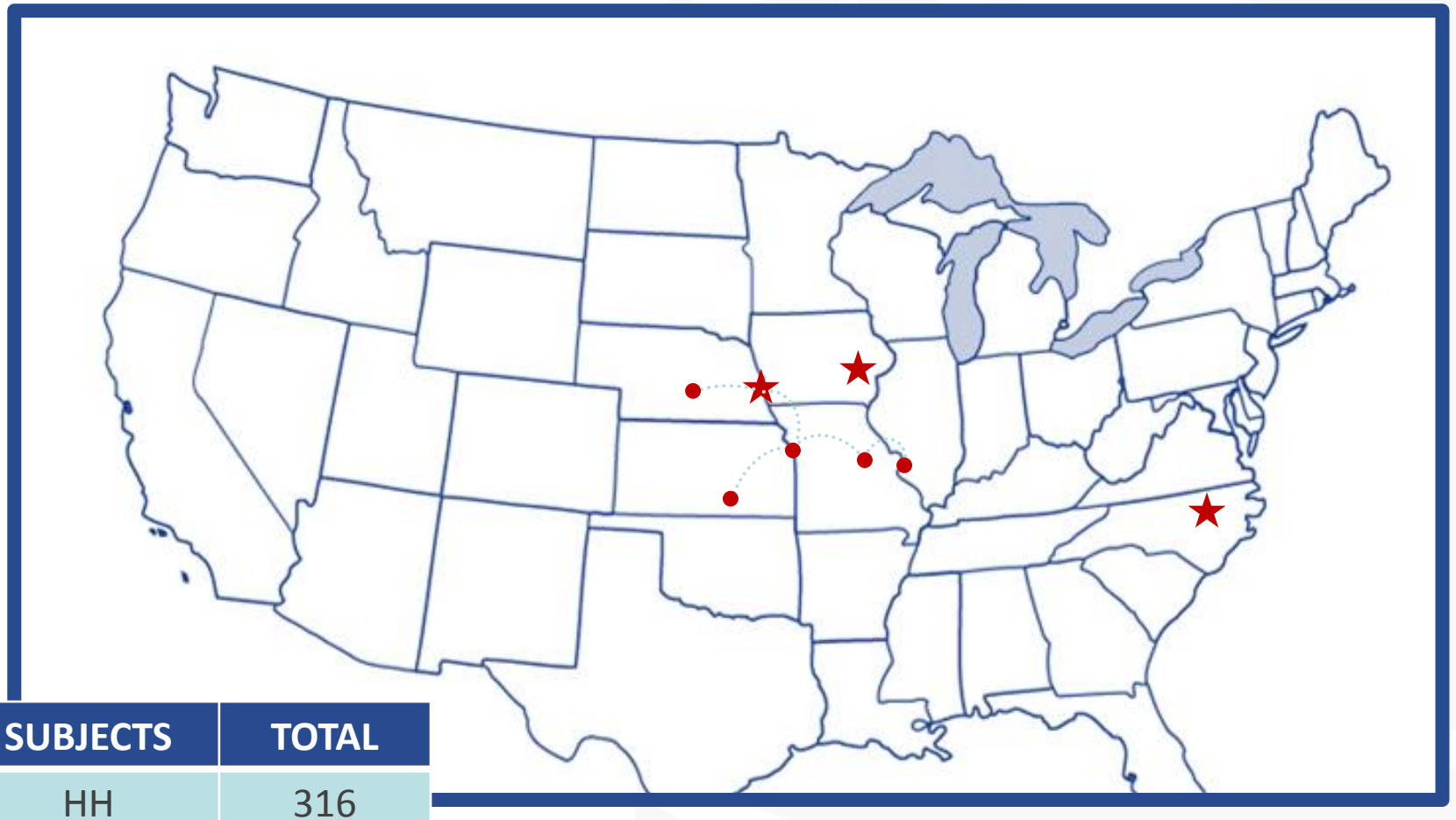
Accelerated Longitudinal Design



* Retrospective data prior to enrollment obtained through medical records
* Cross-sectional and longitudinal



Who are the OCHL participants?

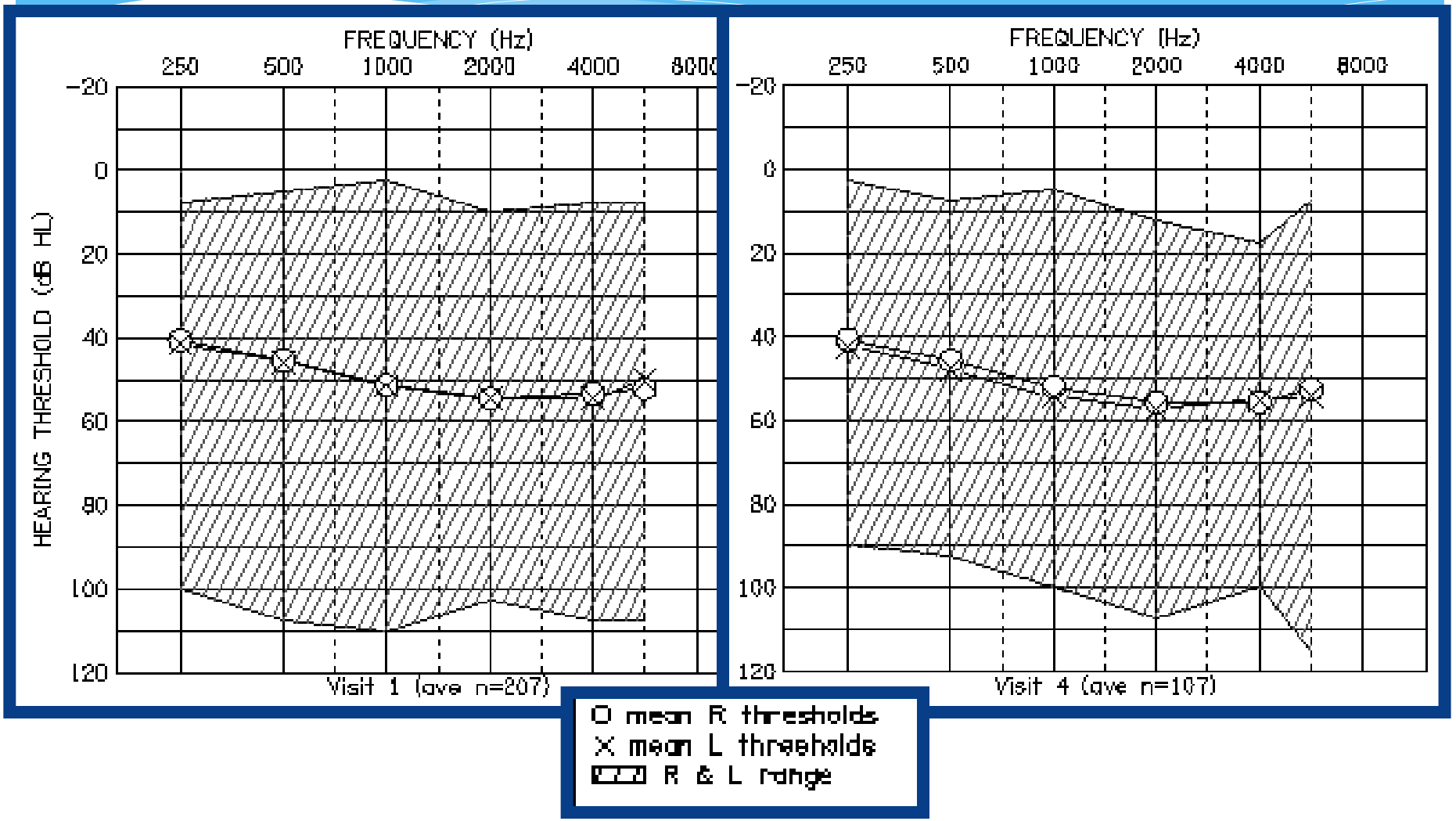


SUBJECTS	TOTAL
HH	316
NH	115

Audiograms from visit 1-4

First visit

Fourth visit



HH-NH Matched sample

	HH	NH
Number of subjects	316	115
Hearing (PTA)	25-75 dB HL	< 20 dB HL
Age ranges	0;6 to 6;11 at entry	
Nonverbal IQ	Within the average range	
Maternal education	Matched but > US sample	
Language use	Spoken English in the home	
Additional disabilities	No autism; no major vision, cognitive, or motor disabilities	

How does OCHL differ from other studies?

- No additional disabilities
  - » Other studies of children with disability showed much variability
- Only children who wear hearing aids
  - » Auditory experience for children with Cis less variable
  - » Children with hearing aid understudied
- Amplification data collected at each study visit
- Mix of standardized measures and experimental measures

Amplification data

- Hearing aid verification and hearing aid use data collected at each study visit
- Other studies have assumed
  - Good audibility
  - Consistent hearing aid use
- Allowed analysis of the specific effects of amplification on development

Characteristics of Hearing Aid Fittings in Infants and Young Children

Ryan McCreery, Ruth Bentler, Patricia Roush

Ear and Hearing 2013 Nov-Dec;34(6):701-10

Characteristics of Hearing Aid Fittings in Infants and Young Children

Data from 195 children participating in OCHL study analyzed

- Proximity of the hearing aid fitting to the intended prescriptive targets quantifies by:
  - Calculating the average root-mean-square (RMS) error of the fitting compared to the DSL prescriptive target for 500, 1000, 2000 and 4000Hz
- Aided audibility was quantified by using the Speech Intelligibility Index (SII)

Characteristics of Hearing Aid Fittings in Infants and Young Children

- Survey data from the pediatric audiologists who fit the amplification for children in the study were collected to:
  - » Evaluate fitting practices and relate those patterns to proximity of the fitting to prescriptive targets and aided audibility

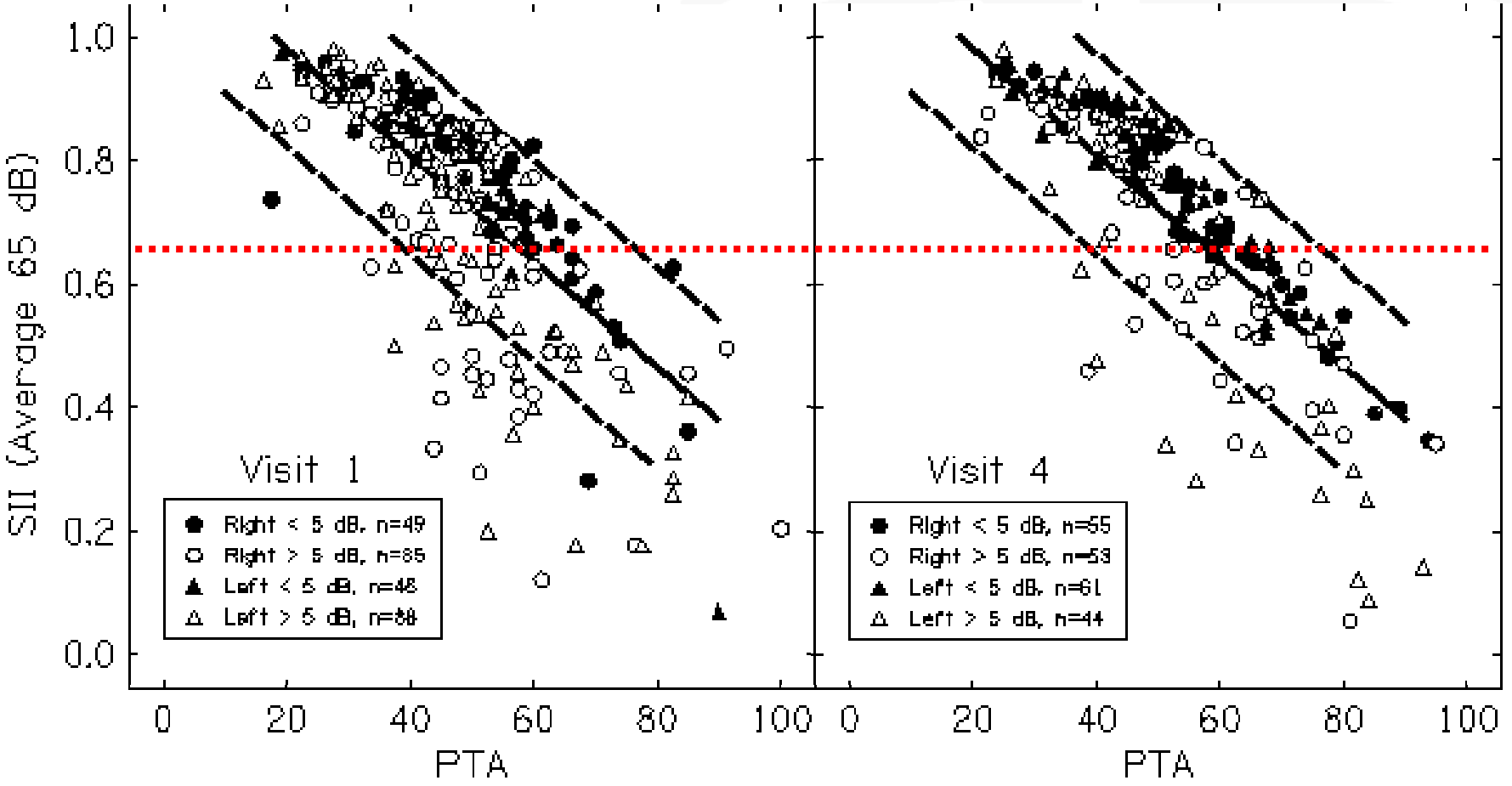
Results

- More than ½ (55%) of children had at least one ear that deviated from prescriptive targets by more than 5 dB RMS on average
  - Deviation from prescriptive target was not predicted by PTA, assessment method or reliability of assessment.
- Study location was a significant predictor of proximity to prescriptive target with locations that recruited participants who were fit at multiple locations having larger deviations from target than the location where participants were recruited from a single, large pediatric audiology clinic

Results

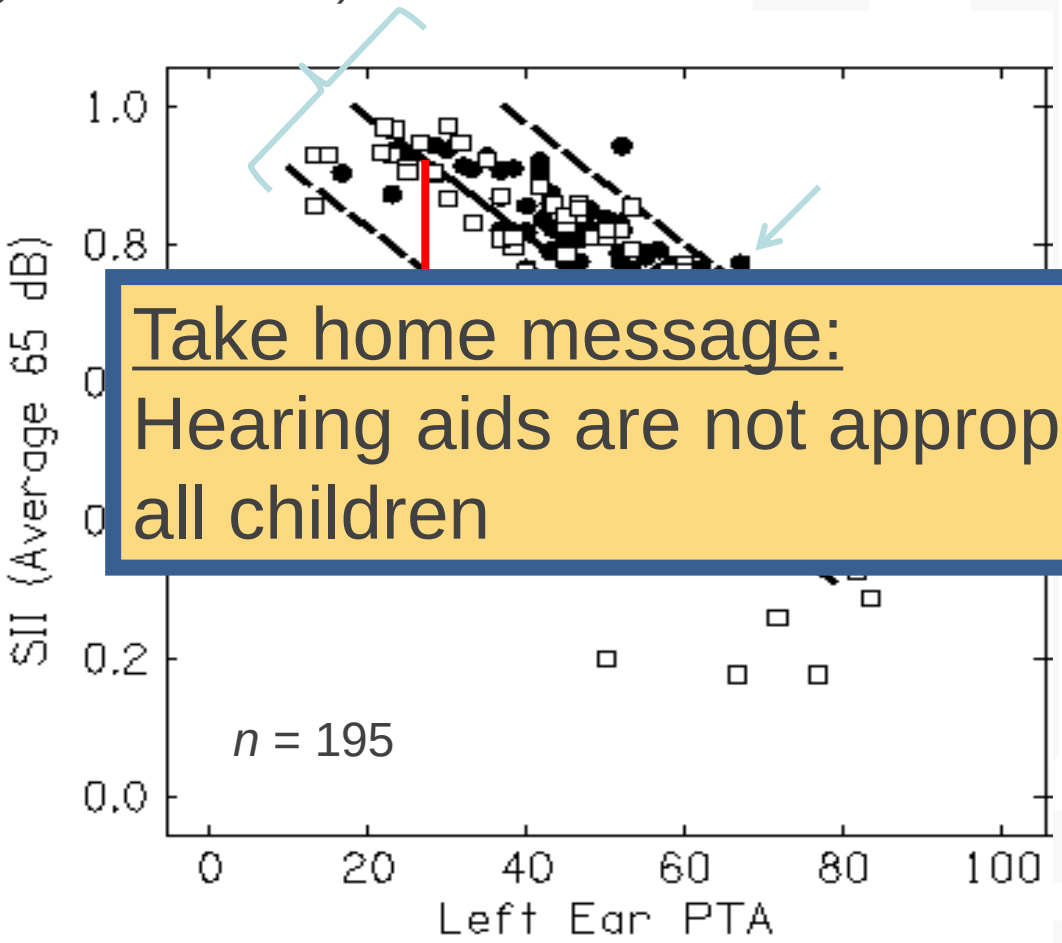
- Approximately 26% of children had aided audibility less than 0.65 on the Speech Intelligibility Index (SII)
- Fittings based on average RECDs resulted in larger deviations from prescriptive targets than fittings based on individually measured RECDs.
- Aided audibility was significantly predicted by proximity to prescriptive targets and pure tone average.

Actual Hearing aid fit quality



McCreery, Bentler, Roush, 2013

Range of expected values for SII relative to PTA (Bagatto et al., 2011)



Optimal fitting of hearing aid (< 5dB RMS error)

Filled symbols = rms error < 5 dB

Take home message:
Hearing aids are not appropriately fit for all children

McCreery, Bentler, Roush, 2013

Accuracy of Verification methods

Probe microphone real ear measures
RMS error= 5.67 dB (SD = 3.95 dB)

Functional gain (aided soundfield)
RMS error=7.92 dB (SD = 4.67 dB)

McCreery, Bentler, Roush, 2013

Conclusions

- Quality of hearing aid fitting is dependent on accurate threshold information
  - » Accurate estimated thresholds from ABR or ASSR or
  - » Accurate thresholds from behavioral audiometry
- Ear canal acoustics must be accounted for in HAF
- Verification of hearing instrument fitting with real ear or simulated measures provide best audibility
  - » Best method is either actual real ear measures or
  - » Measured RECDs and simulated real ear measures

Conclusions

- Unaided and Aided Speech Intelligibility Index (SII) can also be useful in determining adequacy of hearing aid fitting
- Results from large multi-center study in US indicates that while many children have hearing aids that are fit appropriately and show good audibility; some are still not receiving adequate audibility in order to achieve optimal outcomes

Pediatric Audiology

Biostatistics, Linguistics, & Psychology

Child Language

Project Management

References and Resources

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Obrigado!

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