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CONTINUED

Longitudinal Outcomes of Children with Mild to Severe Hearing Loss: Auditory Experience Matters

Mary Pat Moeller, PhD
AudiologyOnline
November 15, 2017

The University of Iowa
The University of North Carolina at Chapel Hill
Boys Town National Research Hospital

CONTINUED

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Supported by NIDCD R01DC009560

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CONTINUED

Course Objectives

- Identify aspects of language that are especially vulnerable in early-identified children who are hard of hearing and factors that contribute to risk or protection.
- Describe the influence of age at hearing aid fitting and degree of hearing loss on longitudinal outcomes.
- Explain which children are at greatest risk for low device use, and how consistency of hearing aid use relates to the inconsistent access hypothesis.

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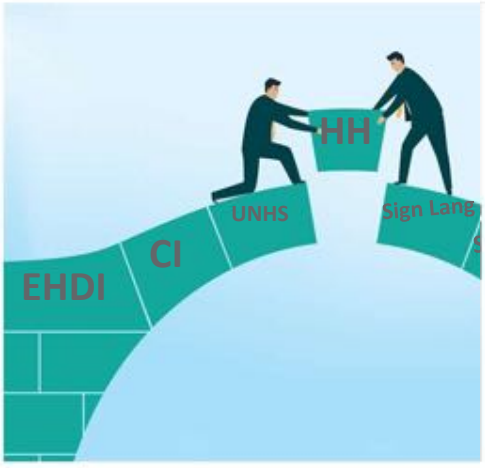
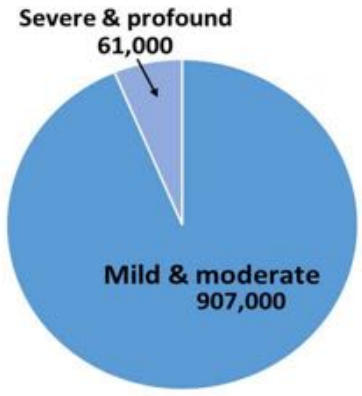
NIDCD Working Group: Research Gaps





NHANES II & III Prevalence: Ages 6-19 yrs

Donahue (2007); Eisenberg et al. (2007); Tomblin & Hebbeler (2007)

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CONTINUED

- Ambiguity in th
  posed by mild to

Note:
- Small sample sizes
- School age children
- Little consideration of receipt of clinical intervention – hearing aid use in particular

Delayed relative to peers	n	Age (yr)	Like typical peers	n	Age (yr)
Davis et al., 1986	40	5-18	Briscoe et al., 2001	19	5-10
Elfenbein et al., 1994	40	5-18	Gilberston & Kamhi, 1995	20	7-10
Blair et al., 1985	24	7-10	Norbury et al., 2001	19	5-10
Delage & Tuller, 2007	19	11-15	Wolgemuth et al., 1998	13	10-15

Even mild HL has consequences
Persistent risks in speech, grammar

Many = hearing peers and > Language Disorders
Selected children impaired

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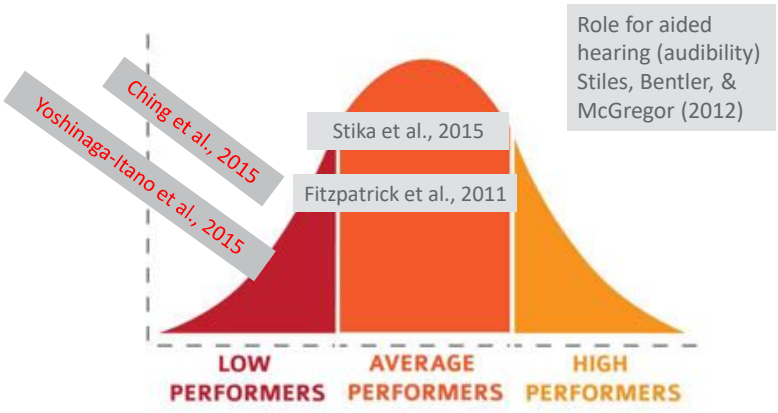
CONTINUED

Post NHS: Risk or Resilience?



Role for aided hearing (audibility)
Stiles, Bentler, & McGregor (2012)

8

Translational Research Questions

- To what extent are children who are hard of hearing at-risk for delayed speech and language outcomes?
- To what extent do clinical interventions such as early service provision and hearing aids offer protection?
- What additional factors contribute to risk or resilience?

Outcomes of Children with Hearing Loss
a study of children ages birth to six

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Theoretical Considerations

- To what degree is the language acquisition system dependent on input?
  - Robust learner accounts
    - Beyond a minimum level, additional amounts of exposure are not important
  - Input dependent learning systems
    - Language acquisition is based on general-purpose learning systems
    - From initial learning to mastery, experience matters
- Findings from CHH could inform these positions

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Background: Access to Input

- Exposure to linguistic input essential for language development
- Characteristics of input associated with differences in language growth
- Language learning may draw heavily on statistical learning processes
  - Requires access to acoustic-phonetic properties in the input
- Access to input and quality interaction support spoken language development

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Inconsistent Access Hypothesis

- Children with hearing loss experience variations in the consistency of their access to linguistic input
  - Any factor that constrains the child's access to language input may reduce learning efficiency
  - Constraints could create challenges for recovery of statistical properties in the input
  - Inconsistent access over time reduces cumulative language experience
- Enhanced audibility with hearing aids should offer protection against this risk

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Barriers to Access

Limitations of HAs
Environmental effects
} Audibility

Delays in HA fitting
Inconsistent HA use
} HA Use → Audibility

Variations in exposure
} Linguistic Input

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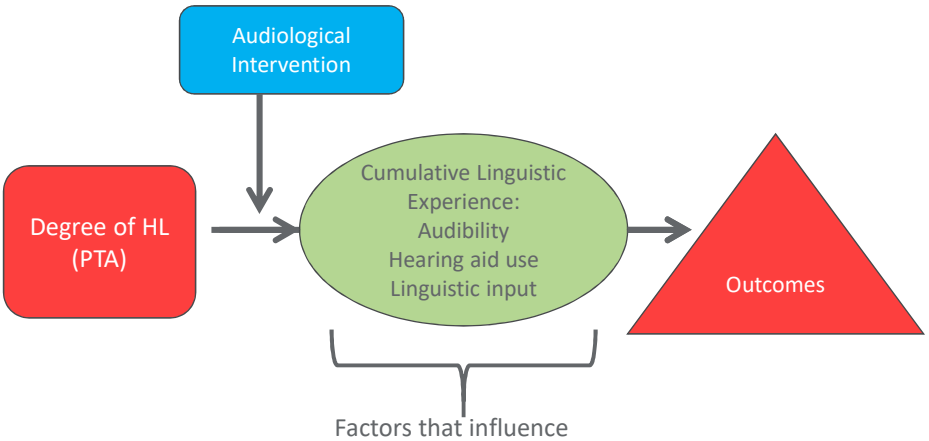
Modeling Factors Influencing Access



Moeller & Tomblin, *Ear & Hear* (2015)

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METHOD

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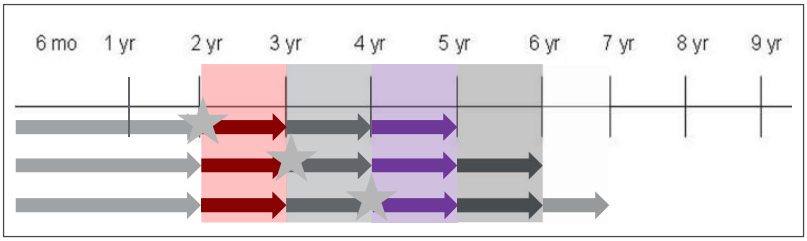
Accelerated Longitudinal Design



- Inclusion criteria:
  - English spoken in home
  - No major secondary disabilities (cognitive, motor delays, autism, vision)
  - Permanent bilateral mild to severe HL (25 – 75 dB HL)
  - No cochlear implants

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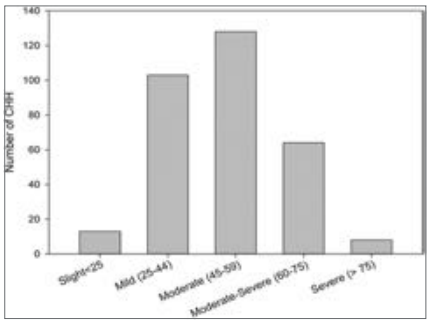
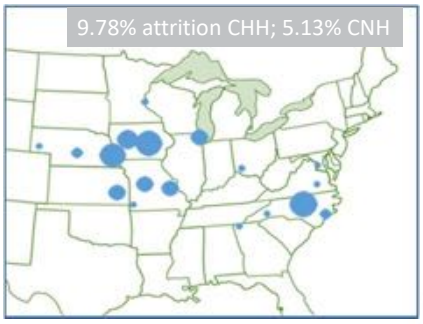
	CHH	CNH
Number	317	117
Gender	173 male; 144 female	54 male; 63 female
Hearing	*M*= 48.88 dB HL 7 without amplification 76% identified from NHS Confirmation: 7.32 mos Late group: 29 mos	< 20 dB HL

Groups
- Matched on income & maternal education
- Higher than typical US sample





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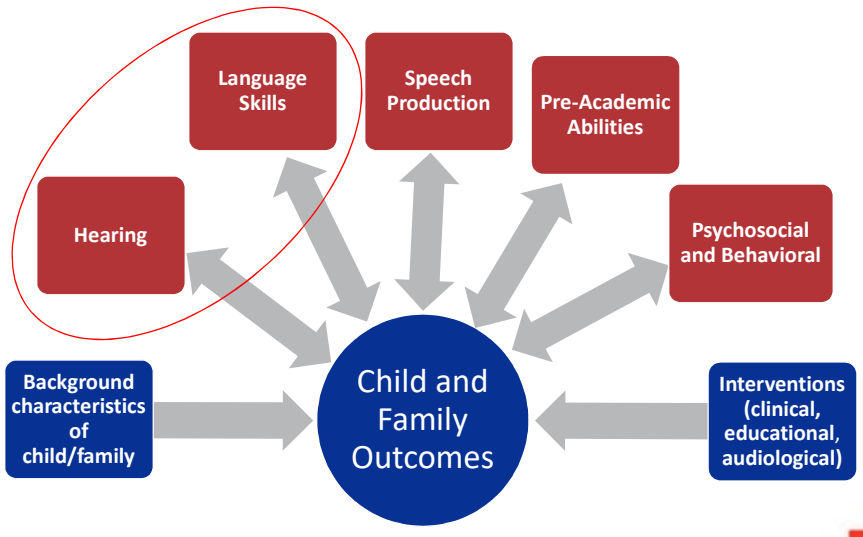
Comprehensive Outcomes



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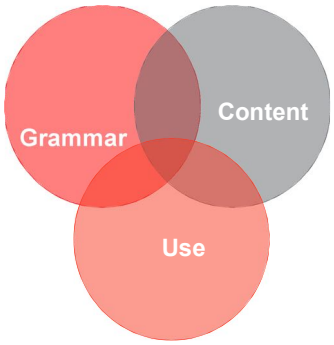
Language Measures

- Age-appropriate measures
- Norm-referenced
  - parent report
  - clinician administered
- Interactive language samples
- Focused probes



Derived a **composite language score** for each child at each age using Principal Components Analysis (2 to 6 years of age).

Tomblin, Harrison, Ambrose, Walker, Oleson, & Moeller, *Ear & Hearing*, 2015

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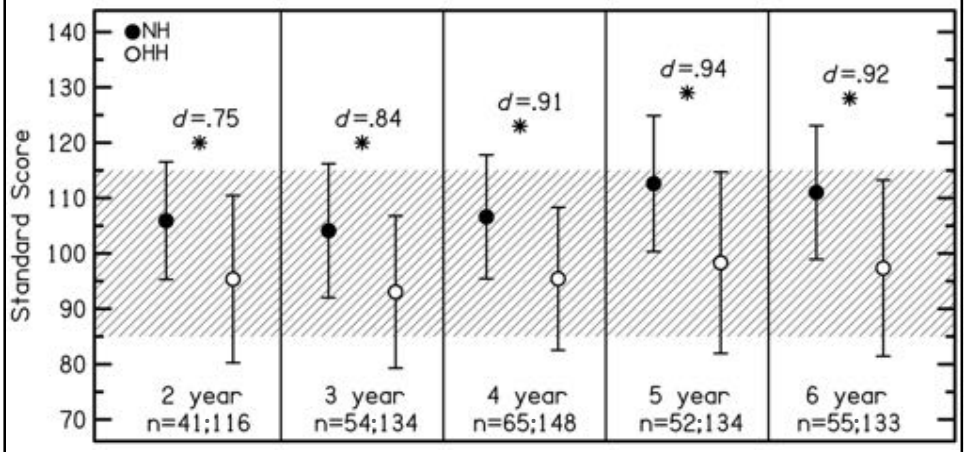

* $p < .0001$ CHH differed significantly from SES-matched age mates.

Conclusion: CHH are at risk for depressed language development

Tomblin et al. , *Ear & Hearing*, 2015

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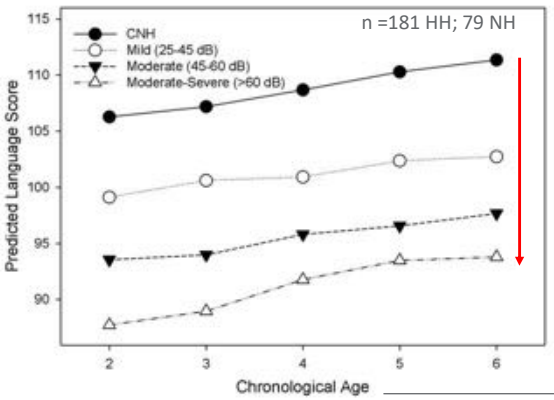

- Systematic relationship between degree of hearing loss and language levels
- All subgroups were significantly different than control group ($p < 0.0001$)

Predictors	Parameter	F value	p value
Maternal education		18.74	<0.0001
Age	1.0	10.62	0.001
Degree of loss (BEPTA)		50.72	<.001
Age * BEPTA	0.0002	0	0.99

Tomblin et al. (2015)

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What Else Accounts for Individual Differences?

Let's contrast two 3-year-old children with moderate-severe HL

Example 1

Example 2

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CONTINUED

Audibility
Hearing aid use
Linguistic input

Factors in the Access model

Audibility

- Does aided audibility contribute to variance in language growth?
- Are HAs fit to optimize audibility?

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CONTINUED

What is audibility?

- Proportion of the speech spectrum that can be heard
  - Measured across a number of frequency bands (weighted for importance)
- Quantified with the Speech Intelligibility Index (SII)

  -Fit to computer based prescriptive targets

SII=0.0 not audible

SII = 1.0 fully audible

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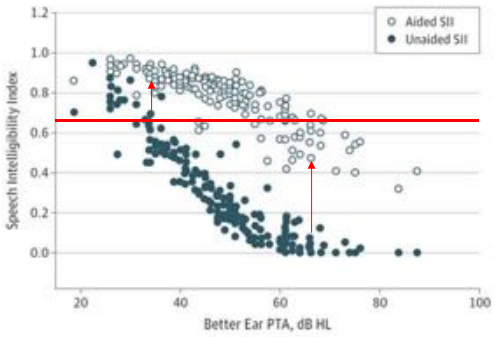
CONTINUED

Measuring "boost" from HA



Degree to which hearing aids can boost SII is constrained by severity of hearing loss

Solution:
- Residualized SII (rSII)
- Measures "boost" from HA independent of degree of hearing loss

Tomblin et al. JAMA OTO, 2014; Tomblin et al., *E&H*, 2015

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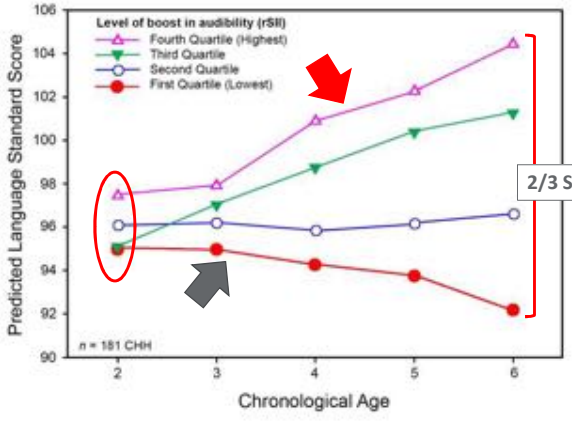
Audibility Contributes to Language GROWTH



- **Quartiles of Aided Benefit**, after controlling for degree of loss
- Audibility did not have an overall effect (p = 0.88), but was **significantly associated with differential growth** (p = 0.009)
- **Benefit holds for mild to severe degrees of HL**

Conclusion: Children who receive the most benefit from HAs show steeper growth in language skills

Tomblin, Harrison, Ambrose, Walker, Oleson, & Moeller, *E&H* (2015); McCreery et al., *E &H* (2015)

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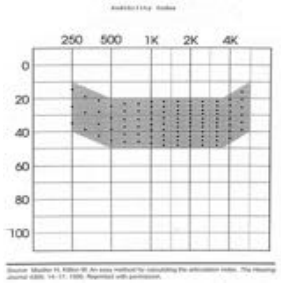
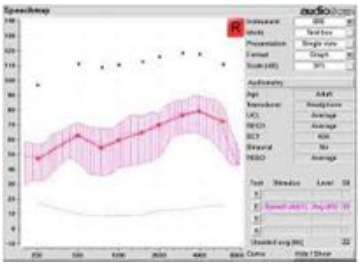
Determining how close HA fittings are to target?

"The characteristics of hearing aid fittings in infants and young children" (McCreery, Bentler, & Roush, 2013)





Compare DSL target SII to **measured SII**	**RMS error** to DSL target at 4 frequencies
• 0-1, with 1 = completely audible	• RMS error < 5 dB = optimal HA fitting

RMS = root-mean-square

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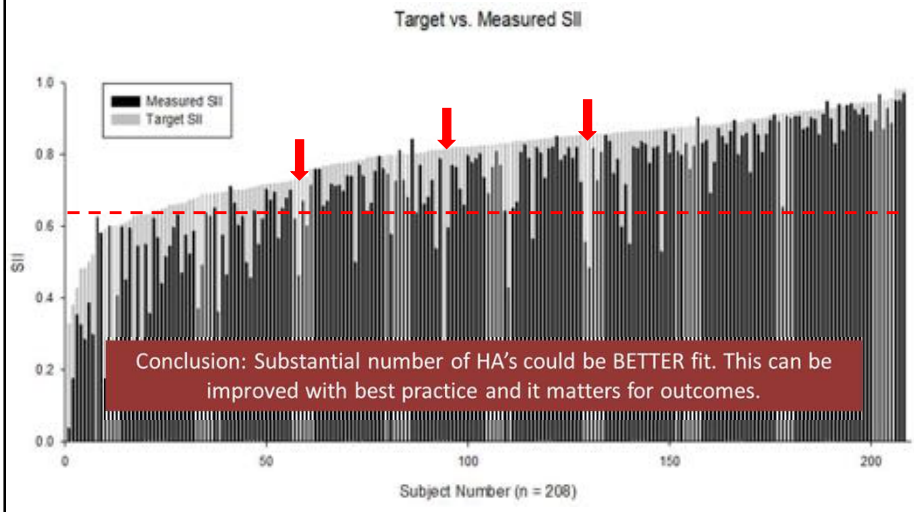

McCreery, Bentler, & Roush (2013);
McCreery et al., *Ear & Hearing* (2015)

55% missed targets, which affects audibility
26% of group with audibility (SII values) below .65

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Cumulative Linguistic Experience:
Audibility
Hearing aid use
Linguistic input

Factors in the Access Model

Hearing Aid Use

- How consistently are HAs worn? Does it matter?
- Does age at fit influence outcomes?

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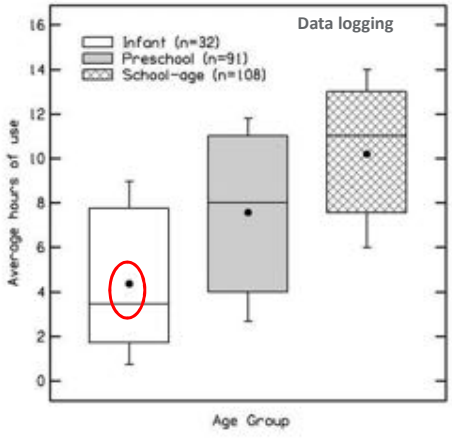
How consistently are HAs worn?



Infants of mothers with H.S. education

- 9 times more likely to be low users
- Compared to college educated moms

Walker, et al., *LSHSS,* 2013; Walker, et al., *E & H*, 2015

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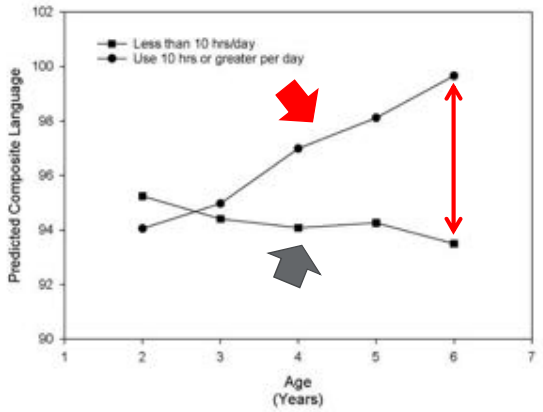
Consistent HA Use Benefits Language Growth



Conclusion: Children who wear HAs more than 10 hours/day show steeper growth in language skills than children wearing HAs less than 10 hours/day

Tomblin, Harrison, Ambrose, Walker, Oleson, & Moeller, *E&H* (2015)

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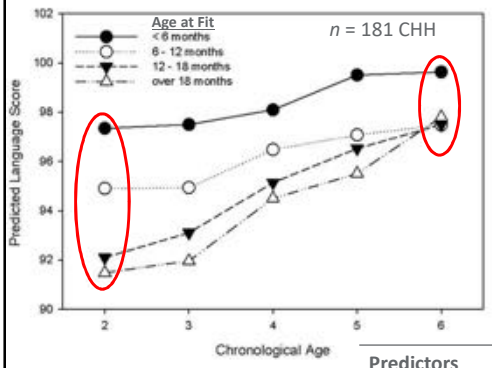
Duration of Fit Benefits Growth



- Early fitting associated with strongest outcomes
- Later-fit children showed promising growth once aided

Predictors	Parameter	F value	p value
Maternal education		28.84	<0.0001
Average BEPTA	-0.35	29.65	<0.0001
CA	0.15	0.08	0.78
Age at HA fit	-0.34	12.79	0.0005
CA*Age at HA fit	0.07	5.12	0.02

Tomblin et al. (2015)

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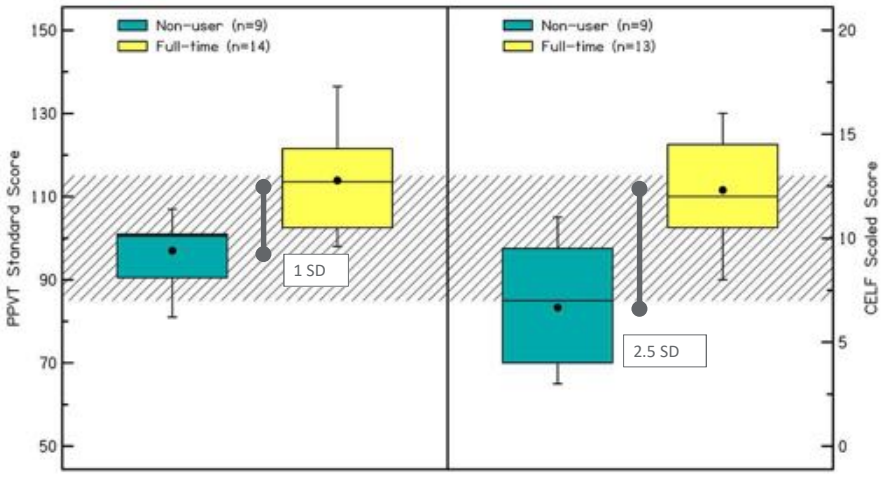
Benefit Extends to Children with Mild Losses



Walker, et al., *JSLHR* (2015)

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Cumulative Linguistic Experience:
Audibility
Hearing aid use
Linguistic input

Factors in the Access model

Linguistic Input

- How does caregiver input directed to CHH compare to that directed to CNH at 36 months of age?

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- Compared parental input at 36 months
  - Coding of intera
  - *n* = 41 CNH; *n* =
- CHH exposed to sentences
  - fewer abstract ideas
  - more directive statements
- Use of abstract (higher level) language positively related to language outcomes
- Directive utterances negatively related to outcomes

I think he is hungry…I wonder what this is.

Say "ball"
Sit down.

Ambrose et al., *E&H* (2015)

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Conducive Environment: LENA Samples

- 28 children with mild to severe HL
  - Better ear pure tone average
    - *M* = 49.9, *SD* = 14.0, Range: 23-83
  - Age at hearing aid fitting
    - *M* = 4.8 months, *SD*=3.0, Range = 2-12

Language **EN**vironment **A**nalysis System (LENA)

Ambrose, VanDam, & Moeller, *Ear & Hearing* (2014)

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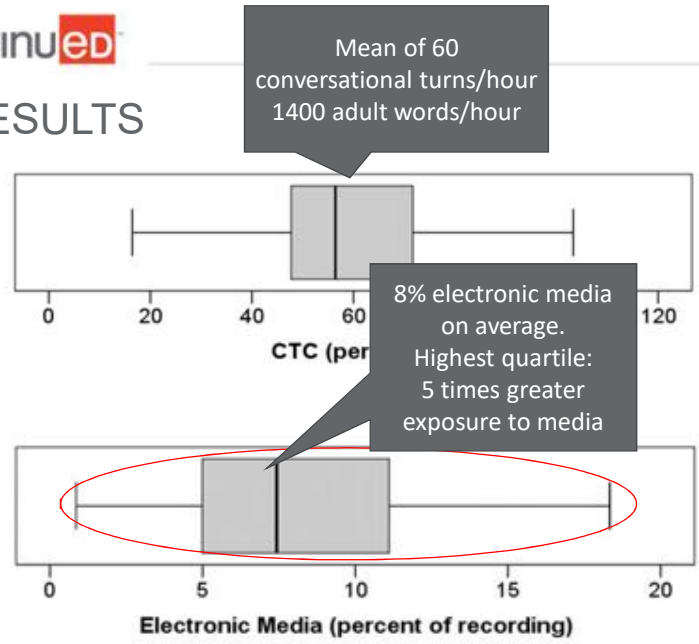
RESULTS



Ambrose, VanDam, &Moeller, *Ear & Hearing* (2014)

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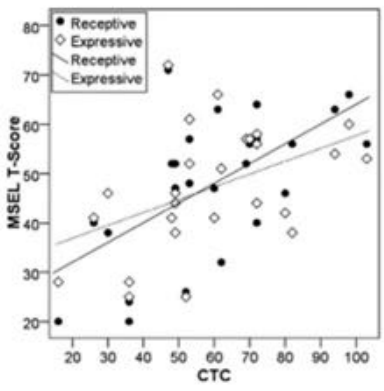
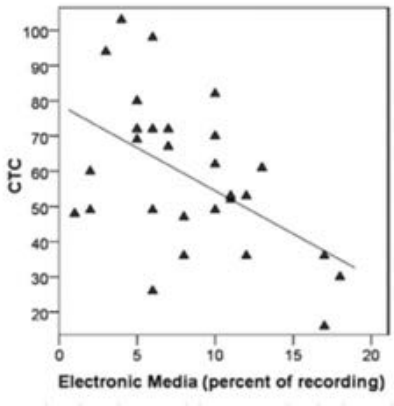
RESULTS





High electronic media → Fewer conversational turns → Lower language outcomes

Ambrose, VanDam, &Moeller, *Ear & Hearing* (2014)

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CONTINUED

Factors Influencing Access/Experience:
Audibility
Hearing aid use
Linguistic input

Audibility

- Does aided audibility contribute to variance in language growth?
- Are HAs fit to optimize audibility?

Yes

Not always

Hearing Aid Use

- Are HAs worn consistently? Does this matter?
- Does age at fit influence outcomes?

Not by all; Yes it matters

Yes, but...

Linguistic Input

- Is caregiver input directed to CHH comparable to that directed to CNH at 36 months of age?

No Electronic media reduces conversation

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CONTINUED

Are there differential areas of vulnerability?

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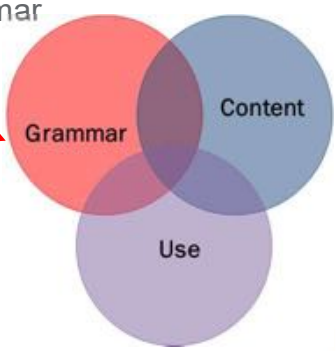
Differential Vulnerability?

- Greater risk for domains that depend on access to phonetic structure?
  - HL reduces opportunities for perceiving elements that are perceptually subtle
  - Speech production & grammar
  - She wants more cookies.



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Child with bilateral mild-moderate hearing levels

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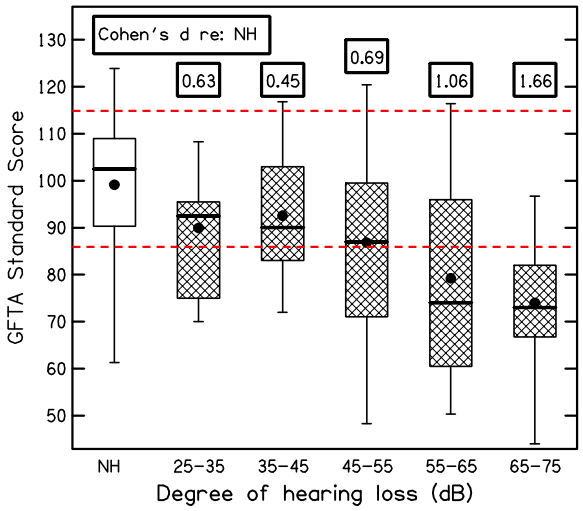
Speech Outcomes by Degree of HL



n = 110
3 yr olds

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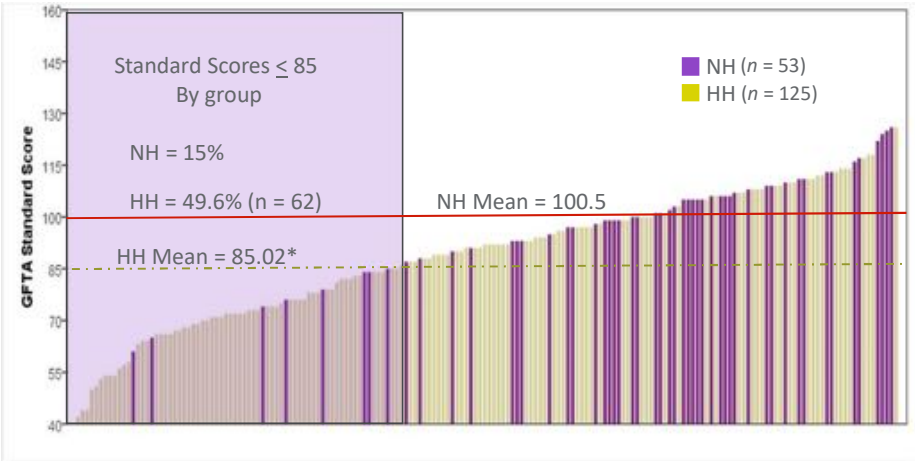
Speech at 3 Years of Age (GFTA)



*(*p* = .004)

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Grammar: Morphology Elicitation Task

Form	Example
Auxiliary	He**'s** mixing it.
Copula	She**'s** a dancer
Progressive	He is knock**ing** on the door
Third singular	Everyday she dance**s**. He want**s** more milk.
Irregular past	He **fell** off the chair
Regular past	Sara walk**ed** fast
Possessive	Dad**'s** shirt
Plural	Three ball**s**

This is dad's coat. Whose dress is this? It's _____ (baby's).

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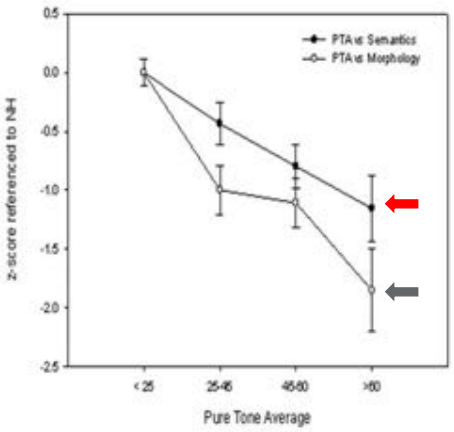
Morphology is at Greater Risk than Vocabulary

n = 154 CHH; 69 CNH Age = 4 years



Basic concepts & vocabulary versus Production of word endings

Morphology has a specific relationship with hearing beyond that found for semantic scores.

Conclusion: CHH show differential areas of vulnerability in language development

Tomblin, Harrison, Ambrose, Walker, Oleson, & Moeller, *E&H* (2015)

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Social Vulnerability? IRONY/SARCASM

Method

- 9 Picture-Supported Stories
  - de Villiers & de Villiers
- Presented in standard A-V format
- Child answered questions requiring interpretation or reasoning

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1. What did the big brother mean when he said that?

2. Did the brother think that the little boy was a bad hitter or a good hitter?
   Bad _____
   Good _____

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Sarcasm (Grade 2)

Main effect of hearing category
F (3, 198) = 5.478, p = .001

Positive Predictors: (36% of variance)
- Language
- Social Cognition

Not maternal education or audibility

- CNH = 68
- CHH = 134 (59 Mild, 47 Mod, 28 Mod-Severe)
- Main effect of hearing category
  - Mod-Severe group < Moderate and CNH
  - Distribution for children with moderate HL = CNH
  - Distribution for children with Mild HL = Moderate-Sev
  - Sweet spot?

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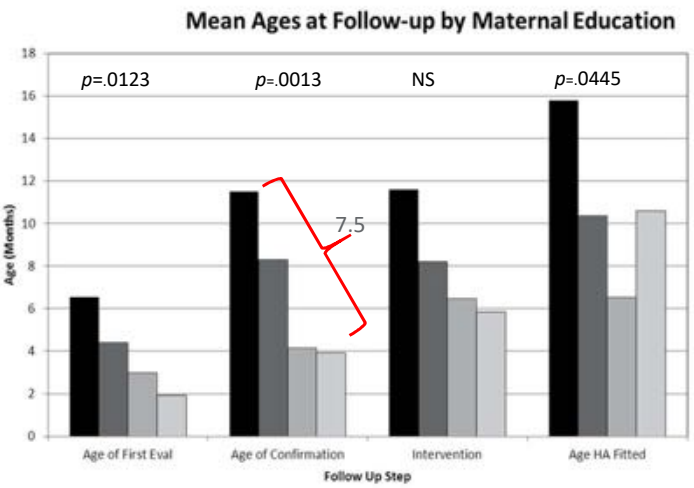
Additional Considerations: Maternal Education



Lower SES: Later fit and at risk for children to be less consistent users of devices (Walker, et al., 2015)

Holte, et al. *AJA*, 2012

Conclusions and Implications

- HL does have an effect on speech and language development during the preschool years
  - Even the mild group was significantly poorer
  - Children with moderate to severe HL were in the low average to poor range
- Audibility provided by HAs resulted in improved language growth
- Early identification and clinical management including well-fit HAs that are worn consistently improved outcomes

Theoretical Implications

- The data support the importance of language input
  - Findings are consistent with input-dependent learning
    - Modest variations in auditory access are associated with individual differences
    - Constraints on acoustic phonetic details differentially affect phonology and grammar
- Results have implications for theories about sensitive periods and role of experience in language development
    - The language development system appears to remain open to experience
    - Possibly at a lower level of learning efficiency

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Future Research Directions

1. Cascading effects of early delays (literacy, psychosocial)?
2. Impact of complex listening environments on learning and listening effort?
3. Protection offered by working memory & linguistic knowledge?
4. Can strategic interventions protect against risk and better support families at risk?

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CONTINUED

www.ochlstudy.org

Free access to OCHL supplement in Ear & Hearing

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CONTINUED

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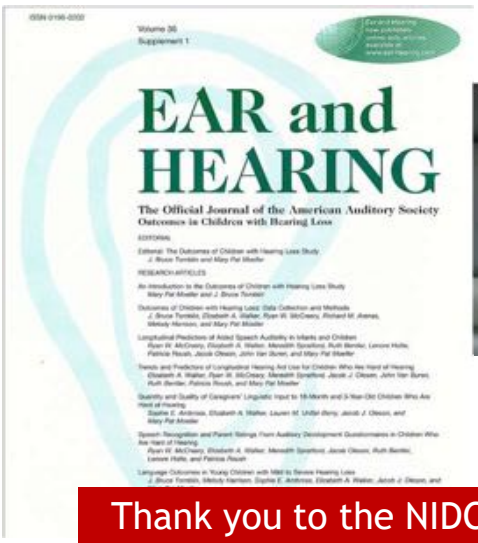

Thank you to the NIDCD and the families and children for their dedicated participation.

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