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

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AudiologyOnline
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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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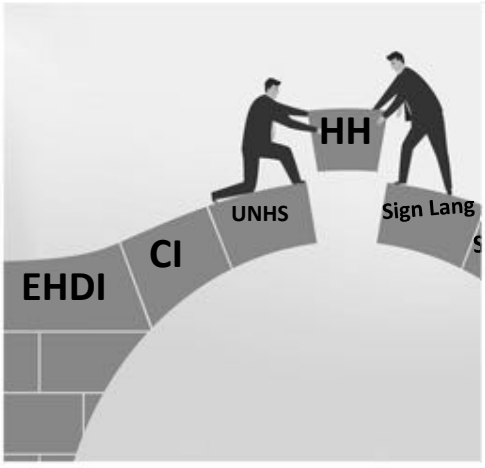
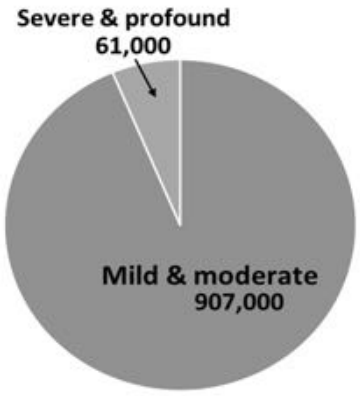
NIDCD Working Group: Research Gaps





NHANES II & III Prevalence: Ages 6-19 yrs

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

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- 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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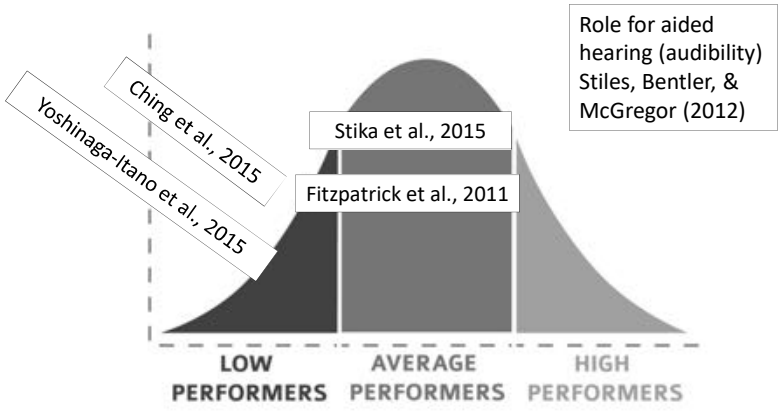
Post NHS: Risk or Resilience?



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

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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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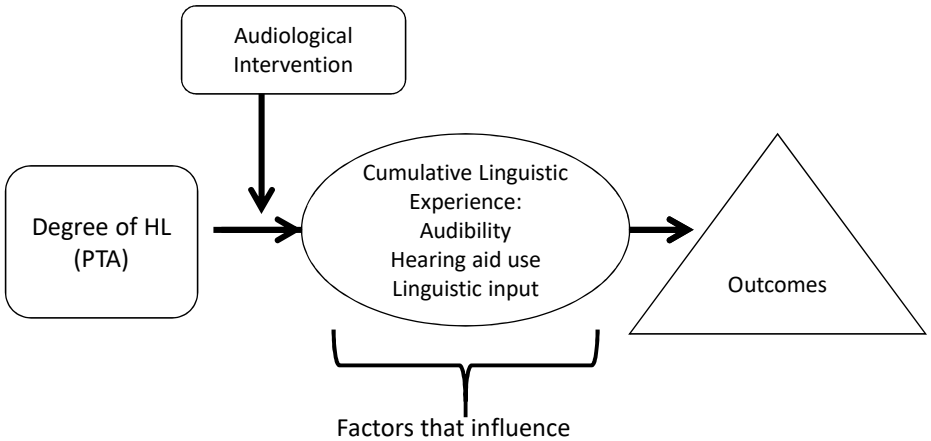
Modeling Factors Influencing Access



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

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METHOD

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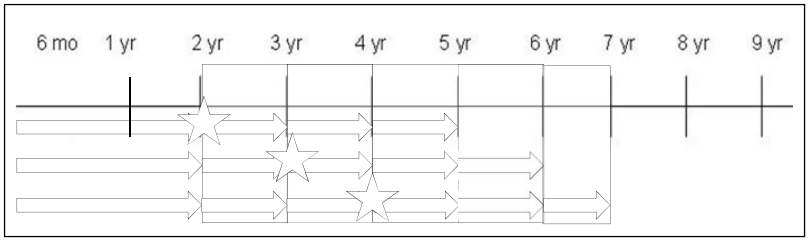
Accelerated Longitudinal Design



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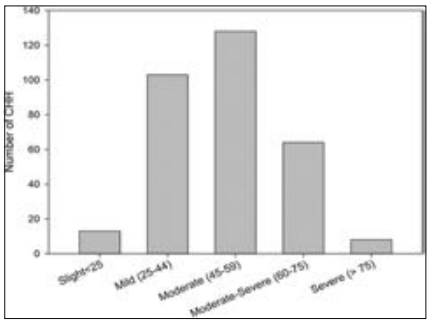
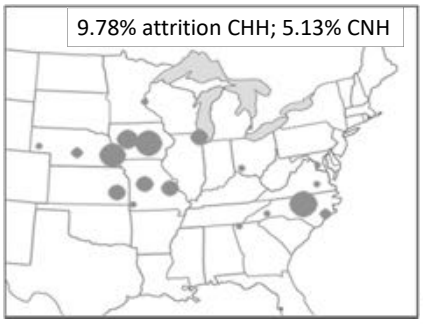
	CHH	CNH
Number	317	117
Gender	173 male; 144 female	54 male; 63 female
Hearing	*M*= 48.88 dB HL 7 without amplification 76% identified from NHS Confirmation: 7.32 mos Late group: 29 mos	< 20 dB HL

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





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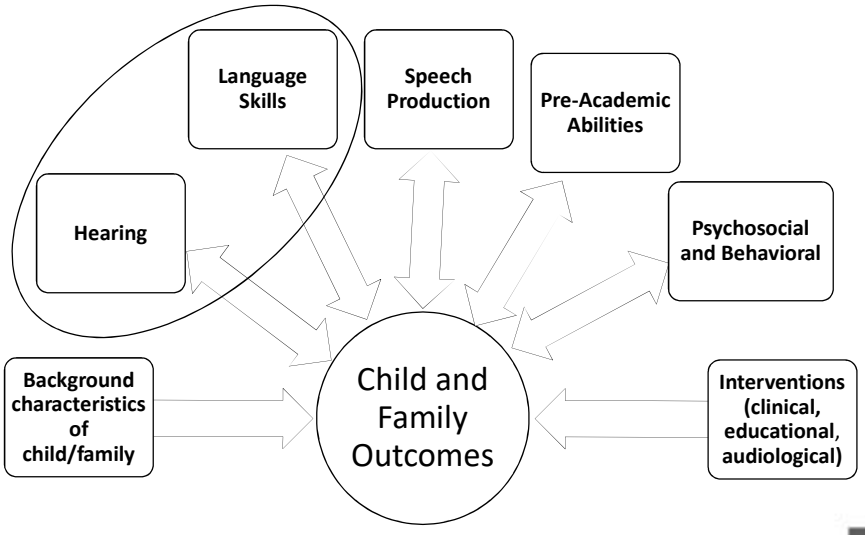
Comprehensive Outcomes



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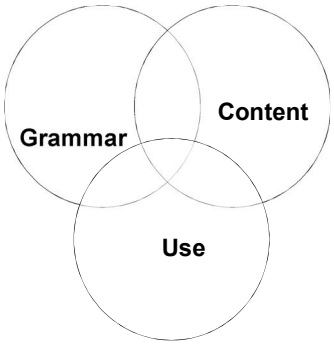
Language Measures

- 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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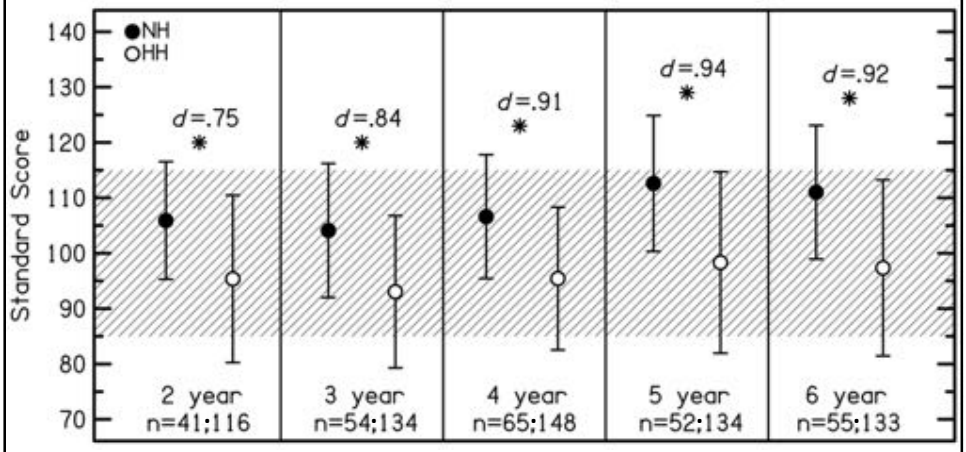

* $p < .0001$ CHH differed significantly from SES-matched age mates.

Conclusion: CHH are at risk for depressed language development

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

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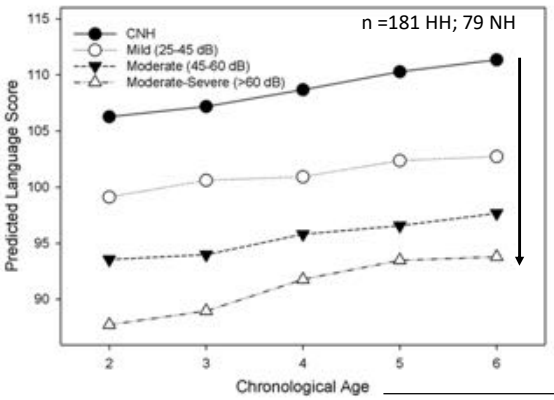

- Systematic relationship between degree of hearing loss and language levels
- All subgroups were significantly different than control group ($p < 0.0001$)

es with

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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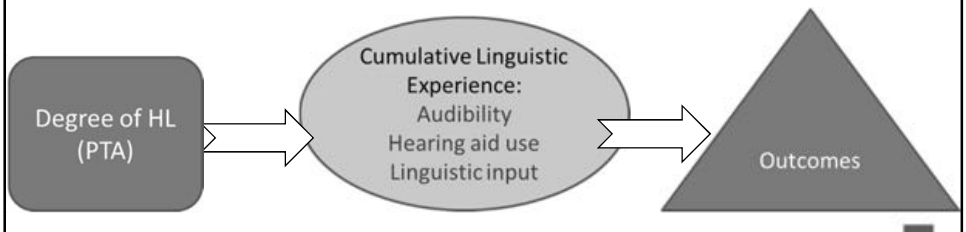
What Else Accounts for Individual Differences?

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

Example 1

Example 2



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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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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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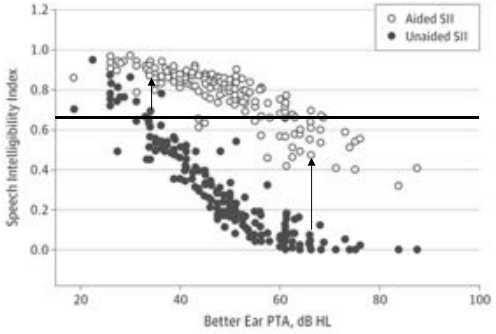
Measuring "boost" from HA



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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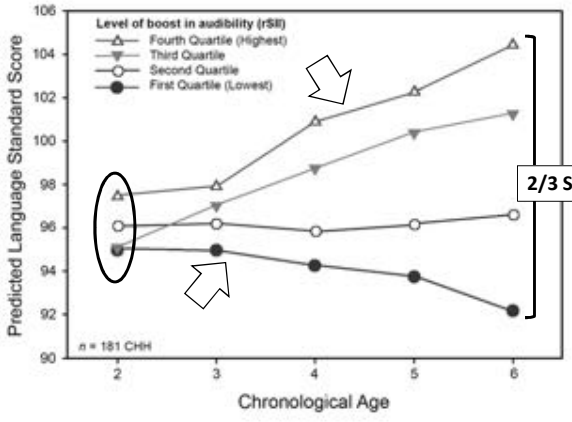
Audibility Contributes to Language GROWTH



- **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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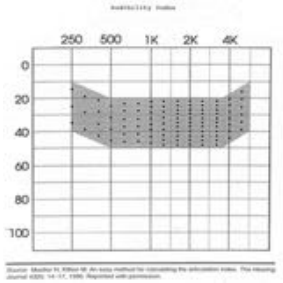
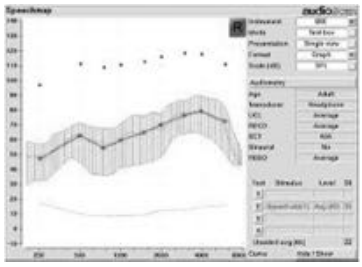
Determining how close HA fittings are to target?

"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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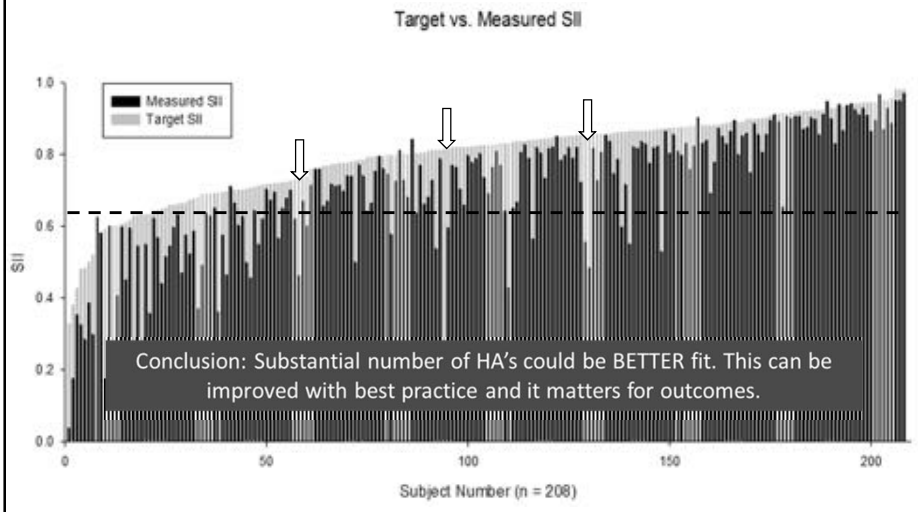

McCreery, Bentler, & Roush (2013); McCreery et al., *Ear & Hearing* (2015)

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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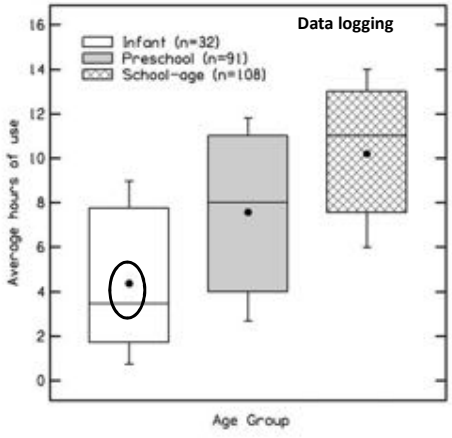
How consistently are HAs worn?



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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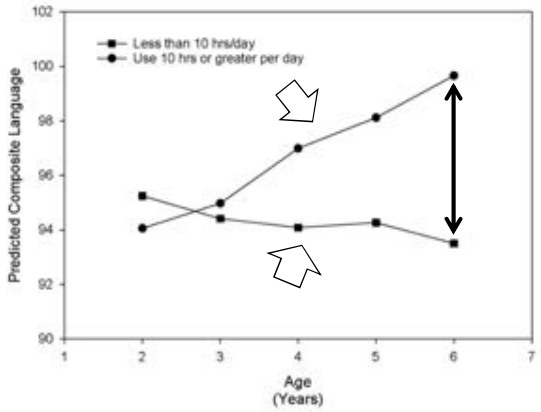
Consistent HA Use Benefits Language Growth



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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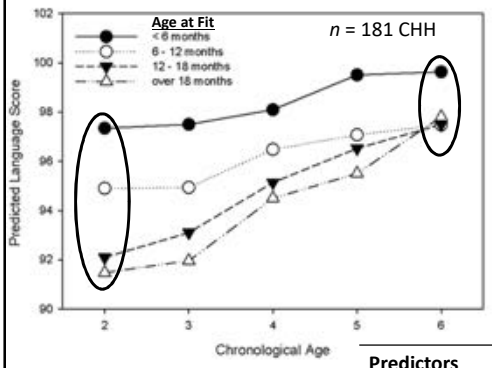
Duration of Fit Benefits Growth



- 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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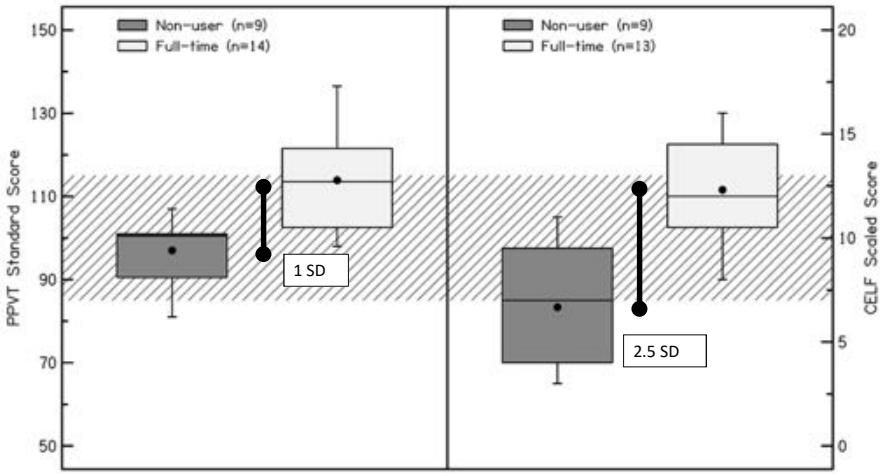
Benefit Extends to Children with Mild Losses



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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Caregiver Input

- 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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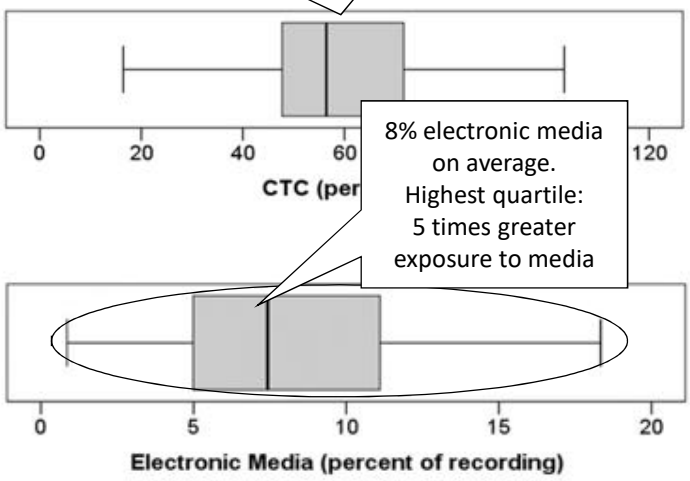
CONTINUED

RESULTS

Mean of 60 conversational turns/hour
1400 adult words/hour



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

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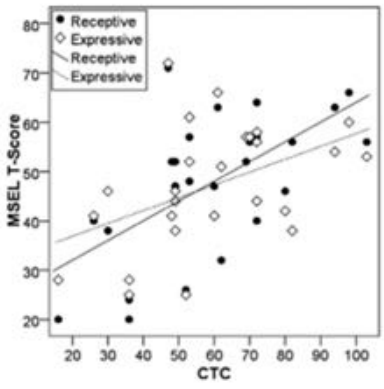
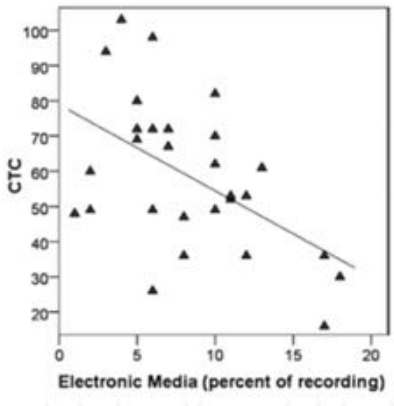
CONTINUED

RESULTS





High electronic media → Fewer conversational turns → Lower language outcomes

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

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CONTINUED

Summary

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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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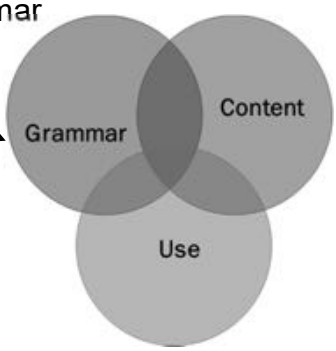
Differential Vulnerability?

- 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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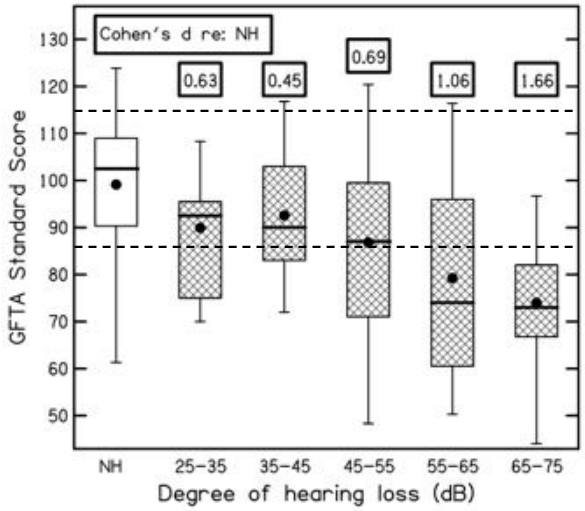
Speech Outcomes by Degree of HL



n = 110
3 yr olds

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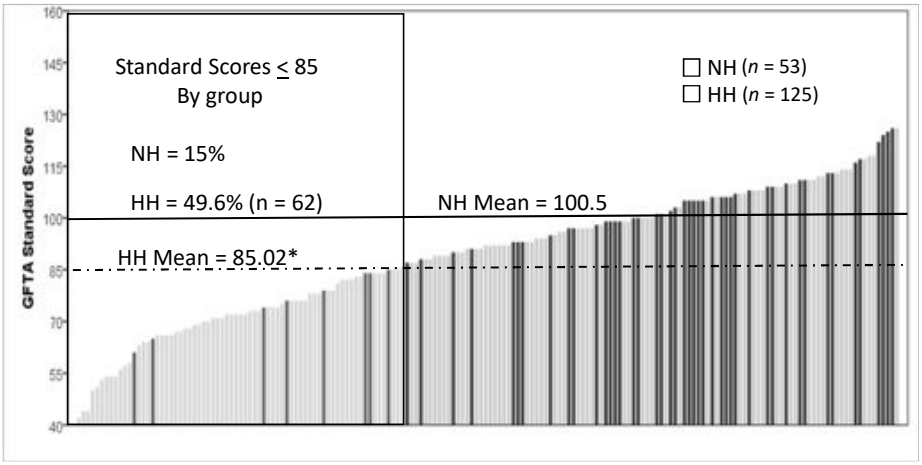
Speech at 3 Years of Age (GFTA)



*(*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 knocking on the door
Third singular	Everyday she dances. He wants more milk.
Irregular past	He fell off the chair
Regular past	Sara walked fast
Possessive	Dad's shirt
Plural	Three balls

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

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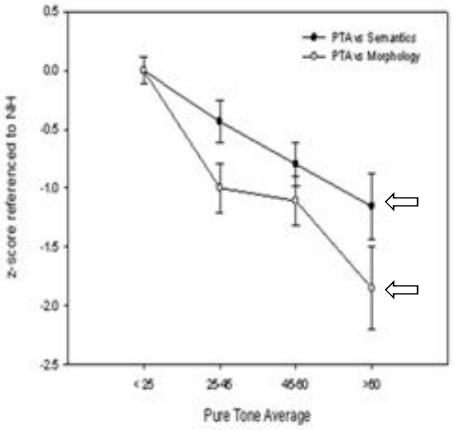
Morphology is at Greater Risk than Vocabulary

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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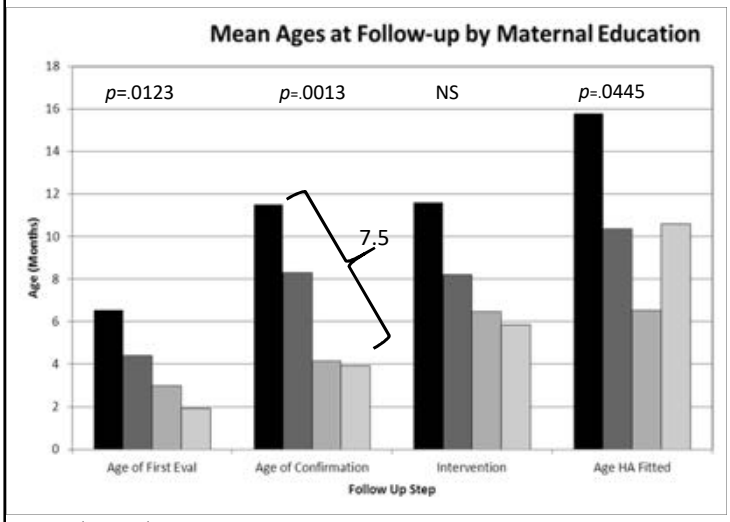
Additional Considerations: Maternal Education



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

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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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CONTINUED

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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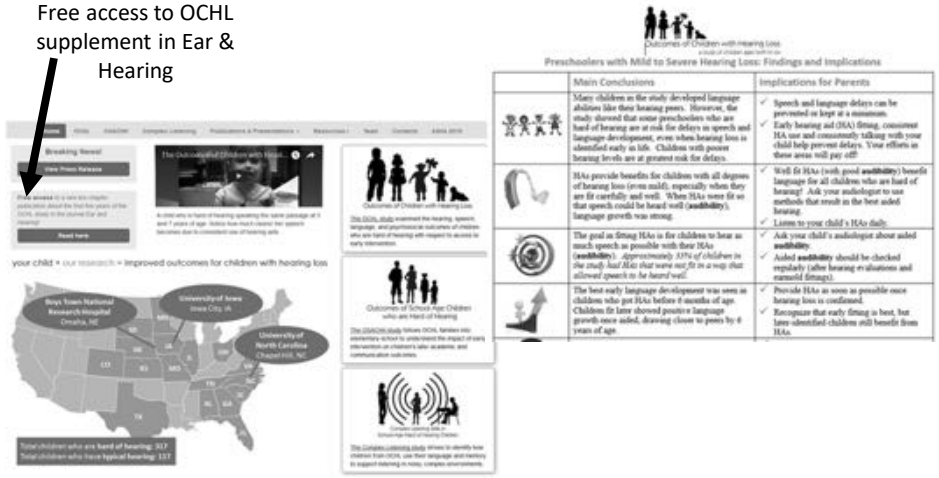
www.ochlstudy.org

Free access to OCHL supplement in Ear & Hearing



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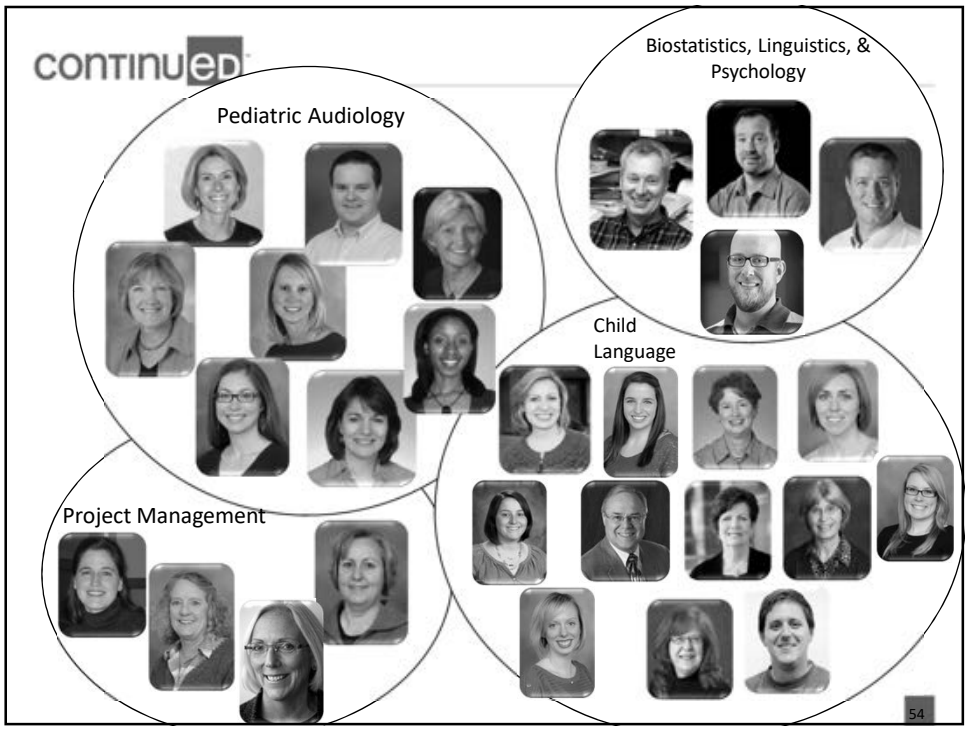

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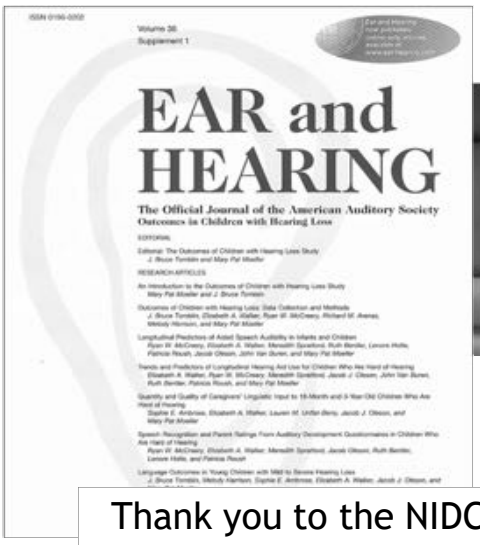

Thank you to the NIDCD and the families and children for their dedicated participation.

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