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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 NORTH CAROLINA
at CHAPEL HILL



continued

Acknowledgement



Sophie
Ambrose, PhD



Ryan McCreery,
PhD



Bruce
Tomblin, PhD



Jacob Oleson,
PhD



Amanda Owen
Van Horne, PhD



Merry
Spratford, AuD



Beth Walker,
PhD



Ruth Bentler,
PhD



Melody Harrison,
Ph.D.



Patricia
Roush, AuD

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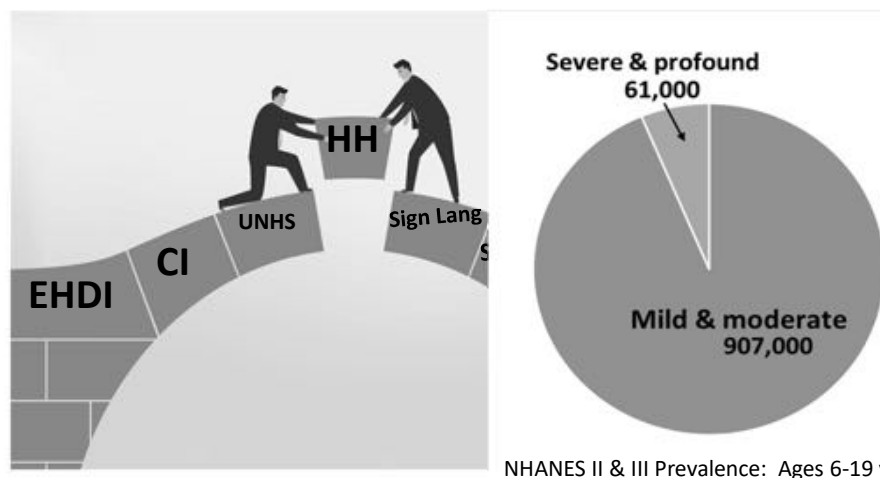
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Course Objectives

- 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



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

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continued

▪ Ambiguity in the 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

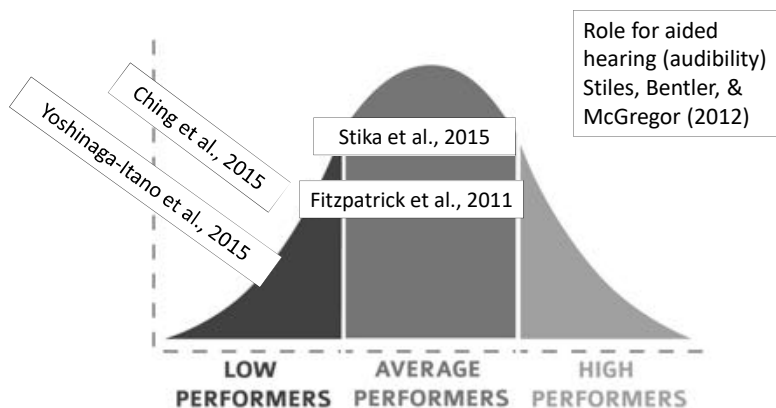
Even mild HL has consequences
Persistent risks in speech, grammar

Many = hearing peers and > Language Disorders
Selected children impaired

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continued

Post NHS: Risk or Resilience?



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continued

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



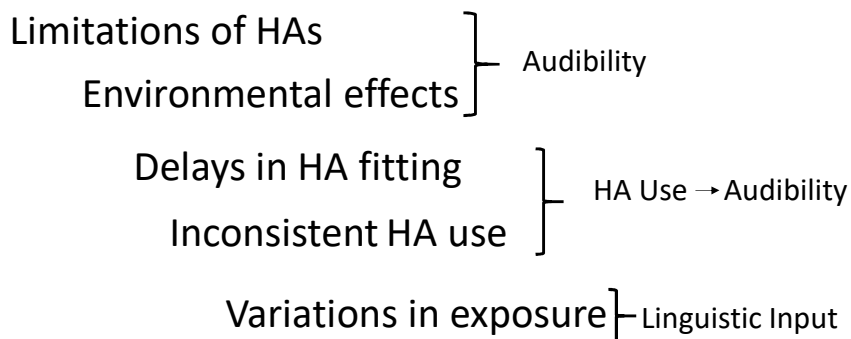
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Inconsistent Access Hypothesis

- 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

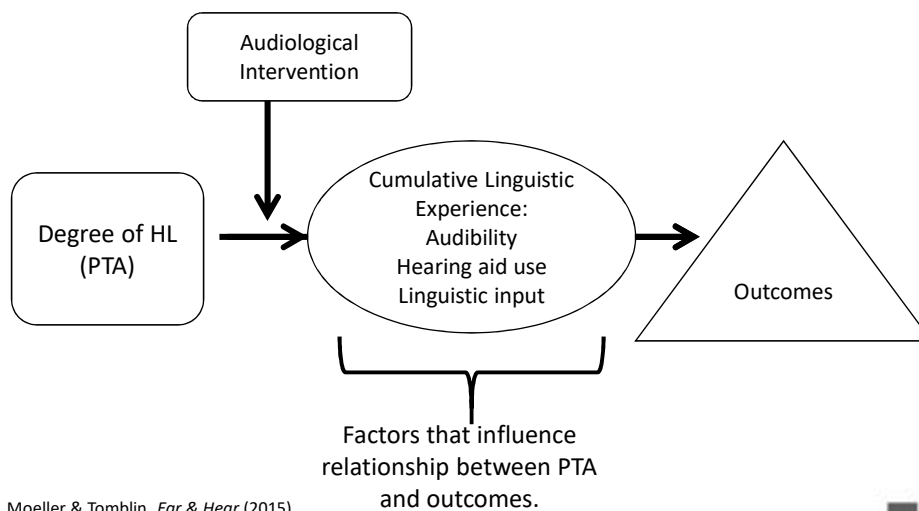
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Barriers to Access



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Modeling Factors Influencing Access

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

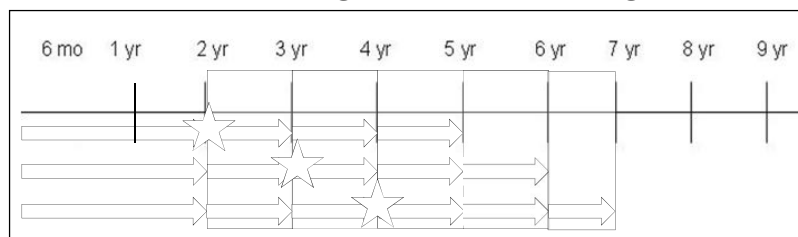
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METHOD



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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

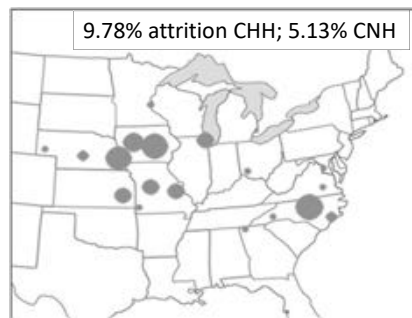
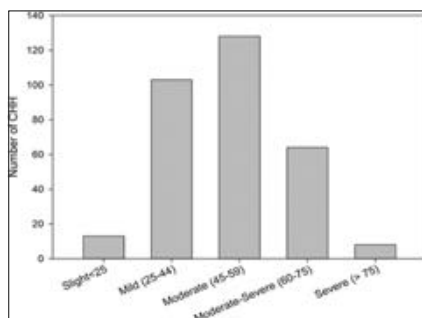
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	CHH	CNH
Number	317	117
Gender	173 male; 144 female	54 male; 63 female
Hearing	M= 48.88 dB HL 7 without amplification 76% identified from NHS Confirmation: 7.32 mos Late group: 29 mos	< 20 dB HL

Groups

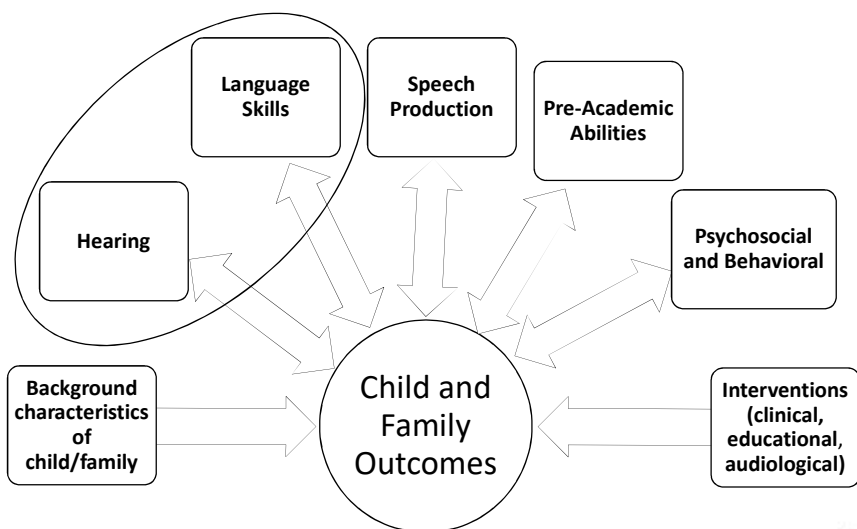
- Matched on income & maternal education
- Higher than typical US sample



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Comprehensive Outcomes

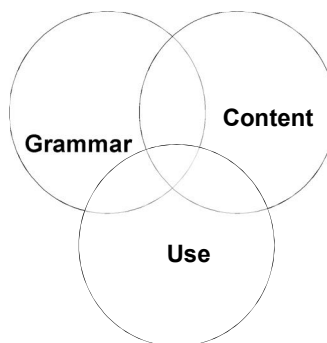


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Language Measures

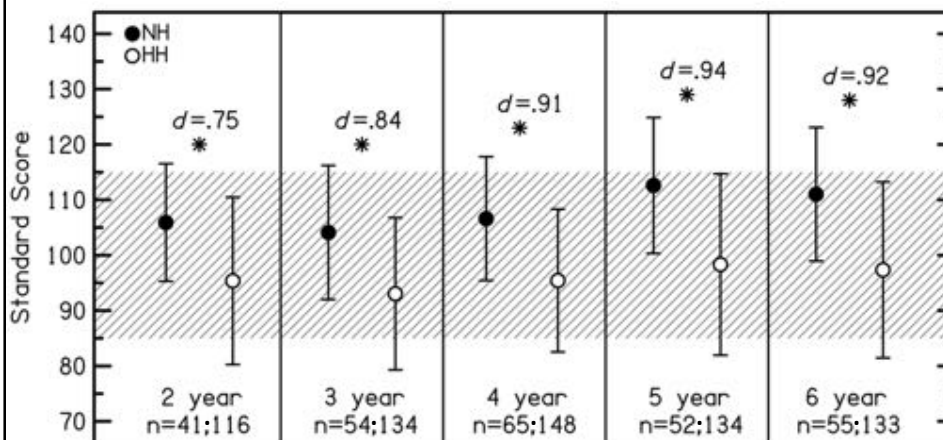
- Age-appropriate measures
- Norm-referenced
 - parent report
 - clinician administered
- Interactive language samples
- Focused probes



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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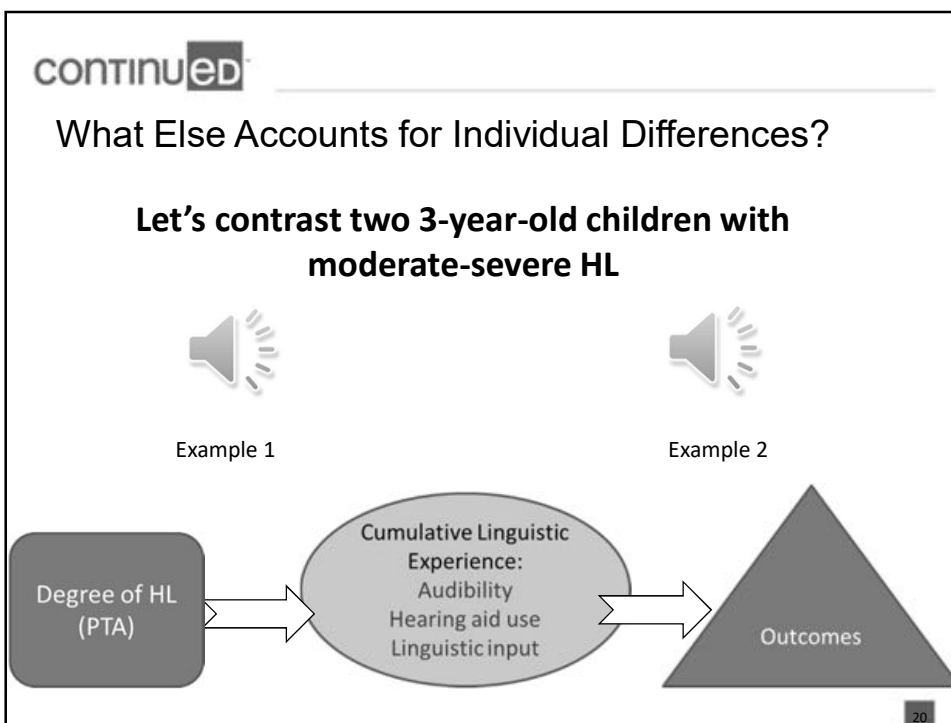
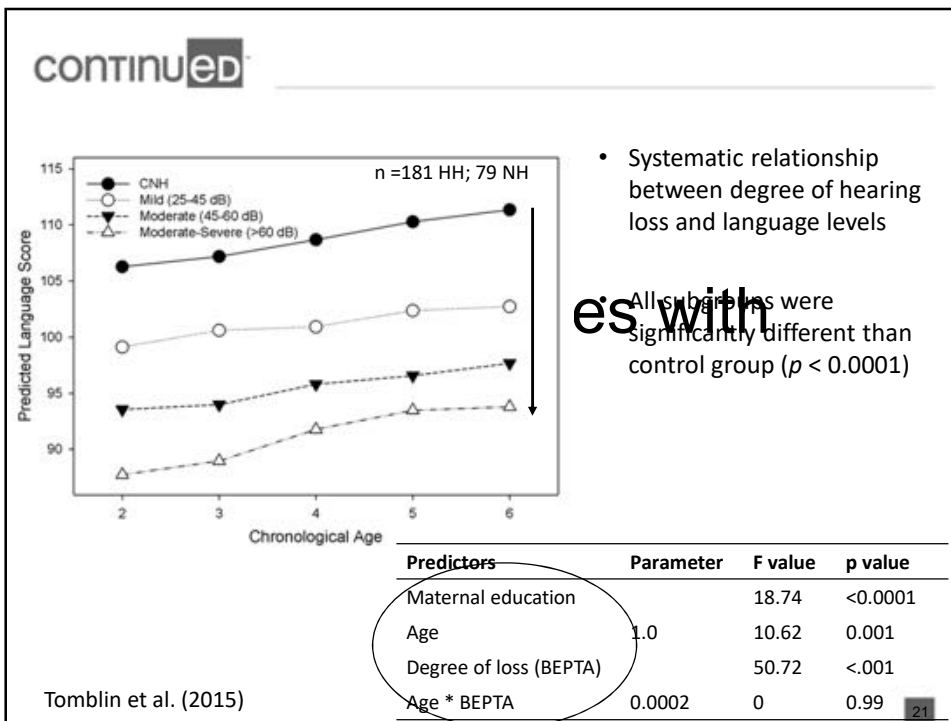


* $p < .0001$ CHH differed significantly from SES-matched age mates.

Conclusion: CHH are at risk for depressed language development

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

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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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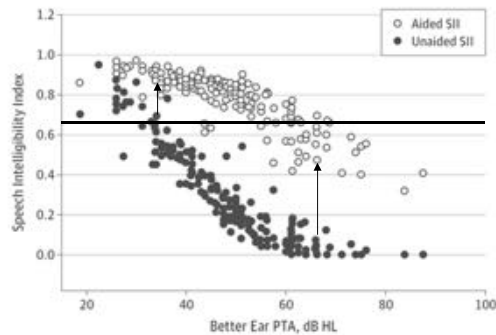
What is audibility?

- 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



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Measuring “boost” from HA



Solution:

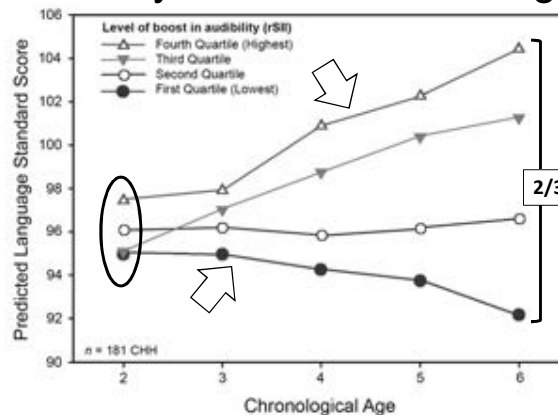
- Residualized SII (rSII)
- Measures “boost” from HA independent of degree of hearing loss

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

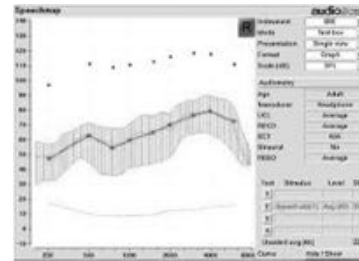
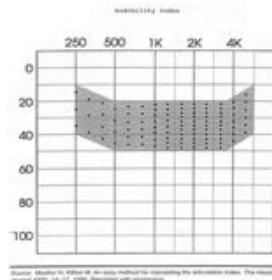
Conclusion: Children who receive the most benefit from HAs show steeper growth in language skills

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)



RMS = root-mean-square

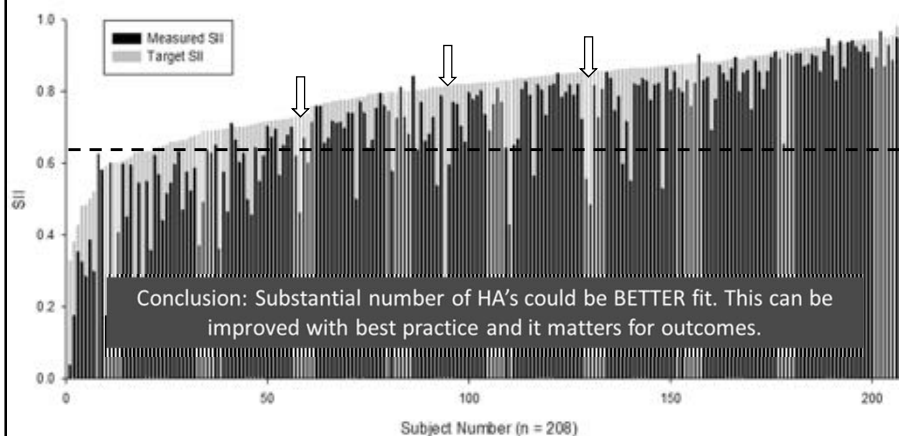
Compare DSL target SII to **measured SII**

- 0-1, with 1 = completely audible

RMS error to DSL target at 4 frequencies

- RMS error < 5 dB = optimal HA fitting

Target vs. Measured SII



Conclusion: Substantial number of HA's could be BETTER fit. This can be improved with best practice and it matters for outcomes.

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



Cumulative Linguistic
Experience:
Audibility
Hearing aid use
Linguistic input

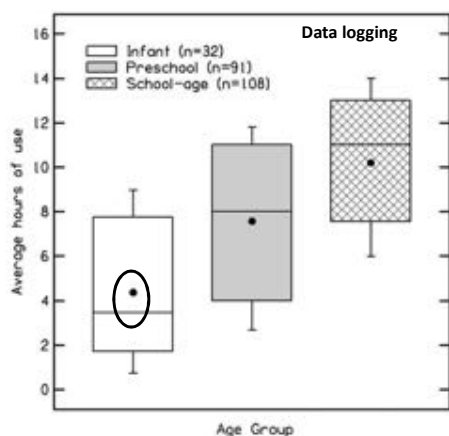
Factors in the Access Model

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?



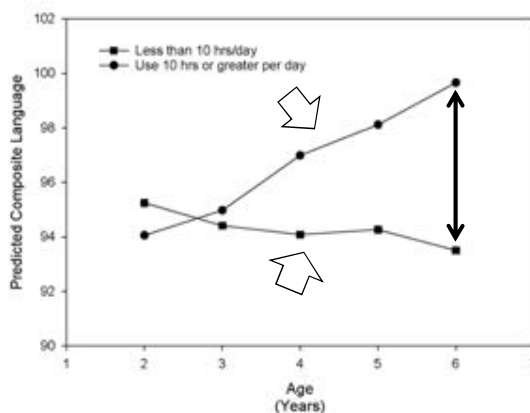
Infants of mothers with H.S. education

- 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

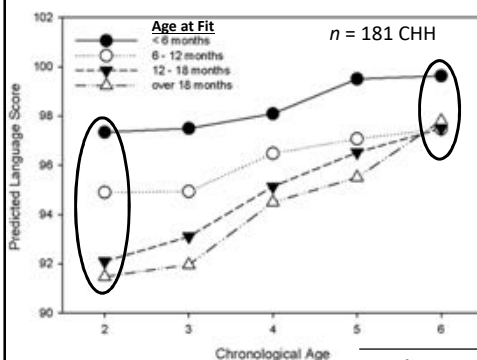


Conclusion: Children who wear HAs more than 10 hours/day show steeper growth in language skills than children wearing HAs less than 10 hours/day

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

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Duration of Fit Benefits Growth



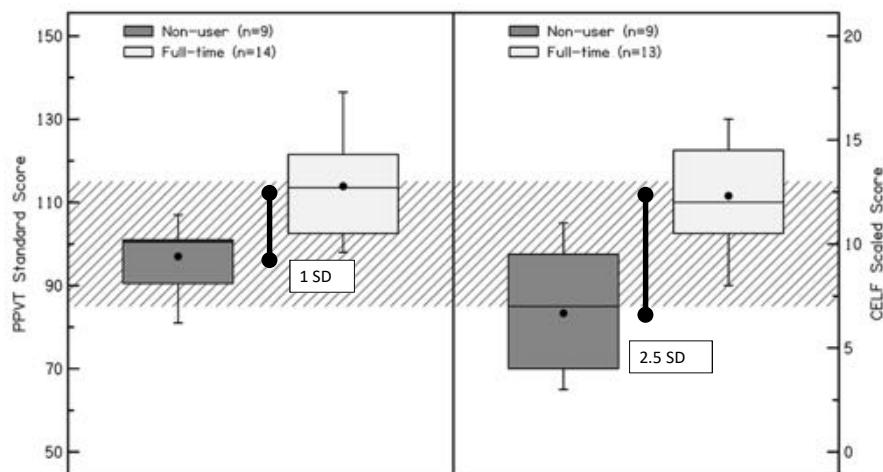
- Early fitting associated with strongest outcomes
- Later-fit children showed promising growth once aided

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 interaction
 - $n = 41$ CNH; $n = 41$ CHH
- CHH exposed to more concrete 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

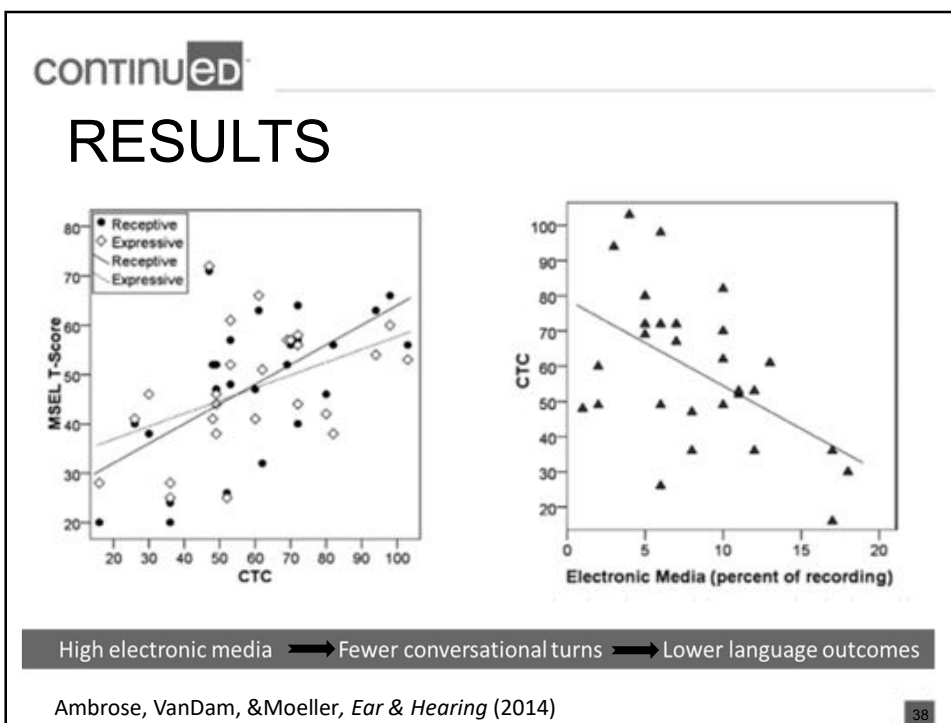
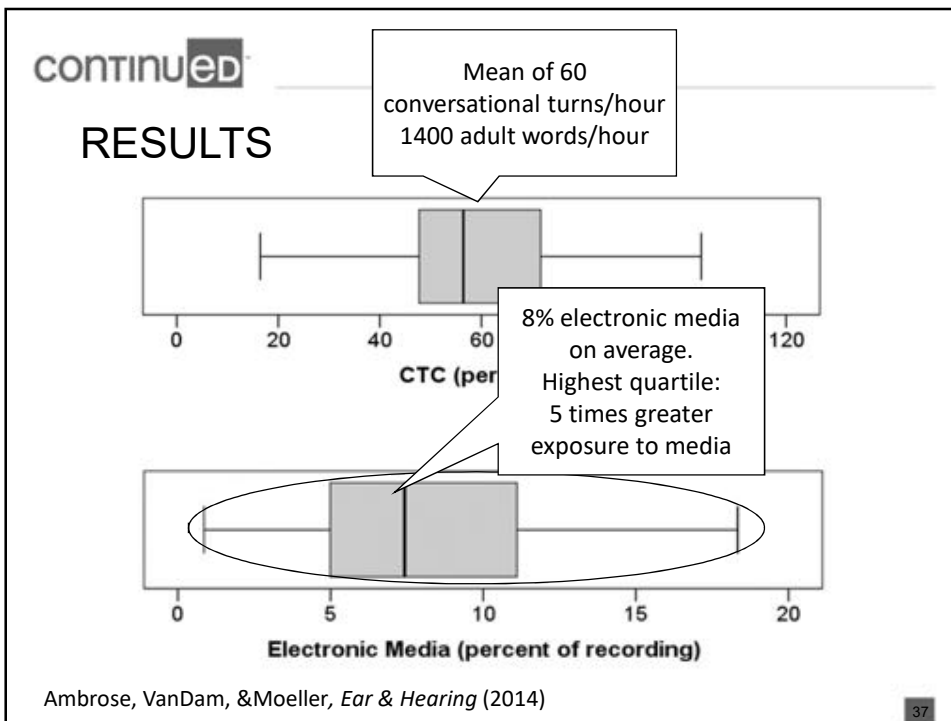



Language ENvironment Analysis System (LENA)



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

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Summary


Factors Influencing
Access/Experience:

Audibility
Hearing aid use
Linguistic input

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Audibility <ul style="list-style-type: none"> Does aided audibility contribute to variance in language growth? Are HAs fit to optimize audibility? 	<input type="text" value="Yes"/> <input type="text" value="Not always"/>
Hearing Aid Use <ul style="list-style-type: none"> Are HAs worn consistently? Does this matter? Does age at fit influence outcomes? 	<input type="text" value="Not by all; Yes it matters"/> <input type="text" value="Yes, but..."/>
Linguistic Input <ul style="list-style-type: none"> Is caregiver input directed to CHH comparable to that directed to CNH at 36 months of age? 	<input type="text" value="No Electronic media reduces conversation"/>

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Are there differential areas of vulnerability?

Grammar:
Word
Endings

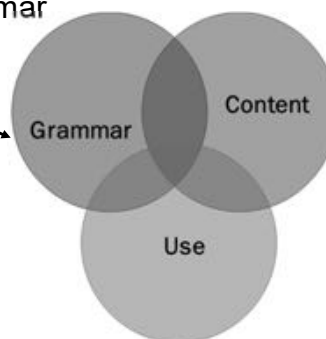
Speech
Production

Other? Social?

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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.



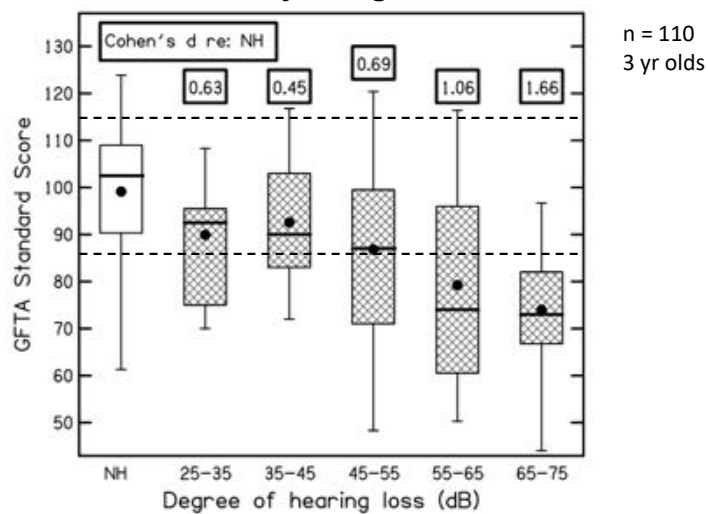
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Child with bilateral mild-moderate hearing levels

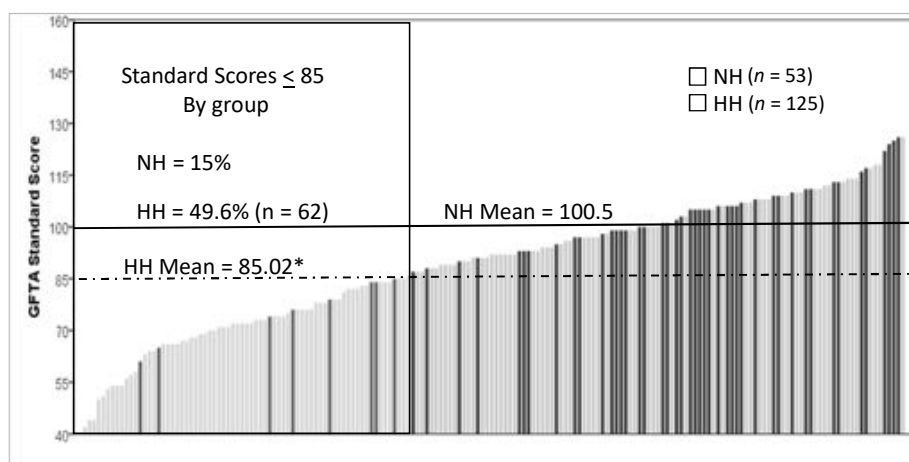
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Speech Outcomes by Degree of HL



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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

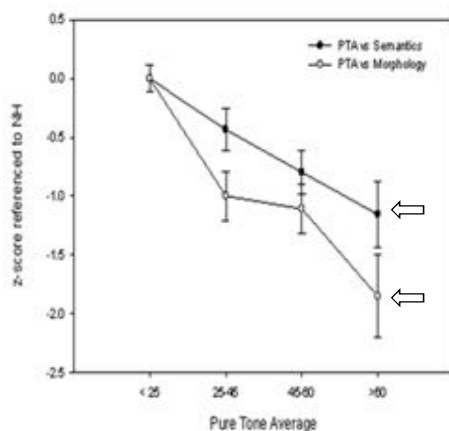


This is dad's coat. Whose dress is this? It's _____ (baby's).

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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



continued

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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continued

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Sarcasm (Grade 2)

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

Positive Predictors: (36% of variance)

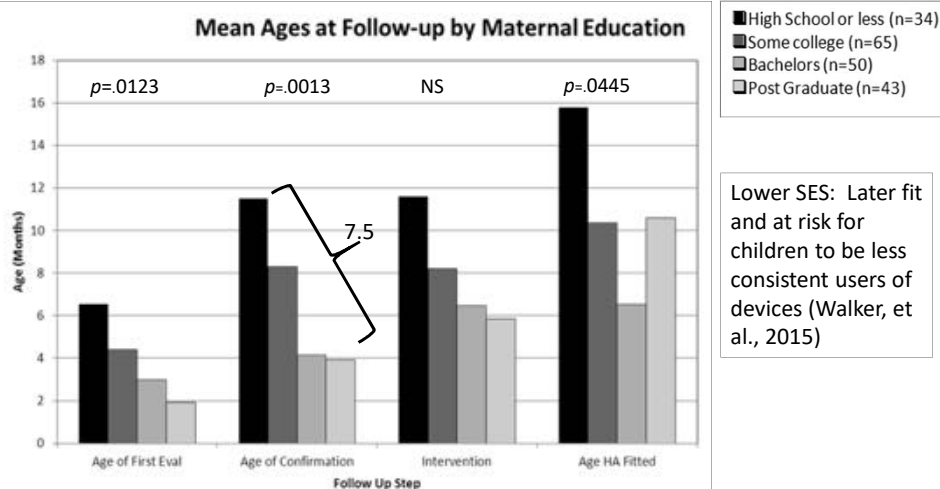
- Language
- Social Cognition

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



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

Preschoolers with Mild to Severe Hearing Loss: Findings and Implications

Main Conclusions	Implications for Parents
Many children in the study developed language abilities like those hearing peers. However, the study showed that some preschoolers who are hard of hearing are at risk for delays in speech and language development, even when hearing loss is identified early in life. Children with poorer hearing levels are at greatest risk for delays.	Speech and language delays can be prevented or kept at a minimum. ✓ Early hearing and (HA) fitting, consistent HA use and consistently talking with your child help prevent delays. Your efforts in these areas will pay off!
HAu provide benefits for children with all degrees of hearing loss (in no small, especially when they are fit carefully and well. When HAu were fit so that speech could be heard well (audibility), language growth was strong.	✓ Well fit HAu (with good audibility) benefit language for all children who are hard of hearing! Ask your audiologist to use methods that result in the best aided hearing. ✓ Listen to your child's HAu daily.
The goal in fitting HAu is for children to hear as much speech as possible with their HAu (audibility). Approximately 10% of children in the study had HAu that were not fit in a way that allowed speech to be heard well.	✓ Ask your child's audiologist about aided audibility. ✓ Aided audibility should be checked regularly (after hearing evaluations and earmold fittings).
The best early language development was seen in children who got HAu before 6 months of age. Children fit later showed poorer language growth once aided, drawing closer to peers by 4 years of age.	✓ Provide HAu as soon as possible once hearing loss is confirmed. ✓ Recognize that early fitting is best, but later identified children still benefit from HAu.

your child • OUR RESEARCH • Improved outcomes for children with hearing loss

Study Sites: **Brady Children's Medical Center** (Cleveland, OH), **University of Iowa** (Iowa City, IA), **University of North Carolina** (Chapel Hill, NC)

Total children who are hard of hearing: 107
Total children who have typical hearing: 117

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continued

Pediatric Audiology

Biostatistics, Linguistics, & Psychology

Child Language

Project Management

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continued

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Volume 36
Supplement 1

For and Hearing
Loss
continued
continued
continued

EAR and HEARING

The Official Journal of the American Auditory Society
Outcomes in Children with Hearing Loss

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J. Bruce Tomblin and Mary Pat Mueller

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Mary Pat Mueller and J. Bruce Tomblin

Outcomes of Children with Hearing Loss: Data Collection and Methods
J. Bruce Tomblin, Elizabeth A. Walker, Ryan W. McCreary, Richard W. Davis, Wendy Harrison, and Mary Pat Mueller


Longitudinal Predictors of Adult Speech Availability in Infants and Children
Ryan W. McCreary, Elizabeth A. Walker, Meredith Spennord, Ruth Bentler, Lauren Hilly, Patricia Hout, David Olson, John Van Buren, and Mary Pat Mueller

Heeds and Predictors of Longitudinal Hearing Aid Use for Children Who Are Hard of Hearing
Elizabeth A. Walker, Ryan W. McCreary, Meredith Spennord, David J. Olson, John Van Buren, Ruth Bentler, Patricia Hout, and Mary Pat Mueller

Stability and Quality of Longitudinal Speech for 18-Month and 3-Year-Old Children Who Are Hard of Hearing
Stephen E. Anderson, Elizabeth A. Walker, Lauren W. Underberg, David J. Olson, and Mary Pat Mueller

Speech Recognition and Parent Ratings From Auditory Development Questionnaires in Children Who Are Hard of Hearing
Ryan W. McCreary, Elizabeth A. Walker, Meredith Spennord, David Olson, Ruth Bentler, Lauren Hilly, and Patricia Hout

Language Outcomes in Young Children with Mild to Severe Hearing Loss
J. Bruce Tomblin, Wendy Harrison, Eugene E. Anderson, Elizabeth A. Walker, David J. Olson, and



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

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