Outcomes of Children who are Hard of Hearing: What’s Working?

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Children who are “Hard of Hearing”

- Characteristics of children who are HH:
  - Hearing levels in the mild through moderately severe range
  - Use hearing aids rather than CIs
  - Reliant on spoken language for functional communication (Jamieson, 2010)
- Described by Julia Davis as “Our Forgotten Children”
Why Called “Forgotten Children?”

- Underestimation of needs
- Limited training of classroom teachers, school personnel
- Little is known about:
  - outcomes and academic achievements
  - problems faced in classrooms
  - extent of support services & impact
- Poorly monitored amplification

Davis, J. (1977)

Background

- 30,000 children < age 6 have mild-to-severe, persistent bilateral hearing loss
- Paucity of research on outcomes of HH children
  - Reflect a belief that HL does not place these children at risk?
- NIDCD Working Group in 2006 identified research gaps & needs
  - Ear & Hearing, 2007
OCHL Study: Aims

- To describe the characteristics of:
  - children and families
  - intervention services
  - factors associated with service variations
- To measure a range of:
  - child and familial outcomes
  - compared to NH age-mates with similar backgrounds
- To explore:
  - how variations in child & family factors & intervention characteristics relate to functional outcomes

Supported by NIDCD R01 DC009560

Accelerated Longitudinal Design

- Each child followed for 3+ years (around birthday)
- Comprehensive battery of child, family, & intervention measures
Sample Description

<table>
<thead>
<tr>
<th></th>
<th>HH</th>
<th>NH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of subjects</td>
<td>316</td>
<td>115</td>
</tr>
<tr>
<td>Hearing (PTA)</td>
<td>25-75 dB HL</td>
<td>&lt; 20 dB HL</td>
</tr>
<tr>
<td>Age ranges</td>
<td>0;6 to 6;11 at entry</td>
<td></td>
</tr>
</tbody>
</table>

From 17 states
76.1% HH children identified through NHS

Language use
Spoken English in the home

Additional disabilities
No autism; no major vision, cognitive, or motor disabilities

Big Picture Findings to Date

Many HH children demonstrate resilience
✓ Some children (25-30%) & some aspects of development are particularly susceptible to effects of HL.
✓ Strong and systematic effects of degree of loss on speech and language development.
Don’t we already know this?...

- Contradictory claims in the literature
  - Power & sampling issues contribute
  - Gilbertson & Kamhi (1995) did not find a relationship between degree of loss and language outcomes (n = 20)
  - They concluded that language delays should not be an expected consequence of hearing loss
- Half their subjects were delayed
  - Described as children with language impairment who happened to have hearing loss

Why does input matter?

- Exposure to linguistic input is essential for speech and language development¹-³
- Simply being exposed to more words is a potent factor in children’s development⁴-⁶
- Young language learners rely on an array of subtle acoustic cues⁷-⁹
  - Infants track statistical properties to identify word boundaries
  - Distributional & phonological cues support learning
Inconsistent Access Hypothesis

- Hearing loss impedes language learning by interfering with consistency, and/or quality of access to input.
- We predict that selected aspects of language learning that are most dependent on the fidelity of the speech signal will be most vulnerable to the effects.
- Effects of inconsistent access on cumulative auditory experience.

Inconsistent Access?

Children with HL experience inconsistent access to linguistic input, due to:

- Periods without amplification
  - Delays in hearing aid fitting \(^{10, 11, 12}\)
  - Inconsistent hearing aid use \(^{13, 14}\)

- Limitations of hearing aids
  - Bandwidth
  - Audibility

- Effects of negative environmental acoustics
  - Distance, noise, and reverberation
What Led Us in This Direction?

PROFILE OF OUTCOMES FOR HH 3-Year OLDS

Profile of Relative Strengths and Vulnerabilities at 3 yrs

★ ★  Mild hearing loss (25-45 dB HL)
★ ★★  Moderate & Mod-Severe (> 45 dB HL)

<table>
<thead>
<tr>
<th></th>
<th>70</th>
<th>85</th>
<th>100</th>
<th>115</th>
<th>130</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASIC CONCEPTS</td>
<td>★</td>
<td>★</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SYNTAX</td>
<td>★</td>
<td>★</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRAGMATICS</td>
<td>★</td>
<td>★</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPEECH PRODUCTION</td>
<td>★</td>
<td>★</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

15) Tomblin, Oleson, Ambrose, Walker, & Moeller, in review
Most Vulnerable Domains

- Speech production
- Grammar use
- Early literacy skills
- Social reasoning

Speech Production Skills: Age 2

- O & C test - a measure of perception-production
- Developed by Ertmer, et al. (2004)
- 10 items, realistic pictures
- Prompted production followed by picture identification

Mom: And "keys"....
Child: /tis/...
Mom: uhhuh, where are they?
Child: /tis/ + point.
Mom: very good
Speech Production at Age 2

**All p values < .01**

![Graph showing speech production data](image)

- Significant Predictors: sex (p = .03) and vocabulary (p = .001)

Subtest:
- Phonemes Matched
- Word Acceptability
- Word Recognition

16) Ambrose, Unflat Berry, Walker, Harrison, Moeller, (accepted). AJSLP

Vulnerable in early speech production?

* Bilateral mild-moderate hearing loss

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Speech Production: Cross Sectional

Most Vulnerable Domains

- Speech production
- Grammar use
- Early literacy skills
- Social reasoning
Inconsistent Access & Morphology

- Effect of HL on language development interacts with the degree to which language learning requires processing of subtle acoustic cues and the audibility of those cues.
  - Morphemes, especially for verbs, have low phonetic substance\(^{15}\)
    - Some forms less frequent in the input
    - Typically sentence medial (He needs to find…)
    - Often involve fricatives in English (HA bandwidth effects)
    - Complex phonetic contexts (It’s, Greg’s calling…)


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Not all word endings are created equal….

- I found my keys.
- I found some sticks.
- Easier to say
  - Often sentence final
- He wants to play tomorrow.
- He wanted to go with you.
- She’s happy that you came.
- Less frequent in the input
  - Often sentence medial
- Hits [s], reads [z], buses [lz]
Accuracy of Verb Endings

Accuracy of use of 4 types of verb endings in spontaneous language samples

ANOVA
- HH < NH (p = .001; \( \eta^2 = .11 \))
- 3 yr olds < 6 yr olds (p = .001, \( \eta^2 = .22 \))
- No interaction

Most Vulnerable Domains

- Speech production
- Grammar use
- Early literacy skills
- Social reasoning
Early Literacy: TOPEL & CTOPP

<table>
<thead>
<tr>
<th>Domain</th>
<th>Mean SS</th>
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<tr>
<td>Print Knowledge</td>
<td>105.7</td>
</tr>
<tr>
<td>Phonological Awareness</td>
<td>94.1</td>
</tr>
<tr>
<td>Phonological Memory</td>
<td>89.6</td>
</tr>
</tbody>
</table>

Most Vulnerable Domains

- Speech production
- Grammar use
- Early literacy skills
- Social reasoning
Accessing multi-talker conversations may be especially difficult, leading to delays in social cognitive development. Social-cognitive development may also be affected by weaknesses in syntax/language and other factors. More research is needed on the mechanisms that affect development in this domain.
What someone believes affects what a person may feel or do... People can have a belief that is false.

4 tasks are administered
Scores range from 0 to 4

Social Cognition at 5 years

NH pass rate = 84%
HH pass rate = 36%
Between groups $\chi^2$: $p < .001$
Emerging Model: Inconsistent Access

Hearing Loss (degree, type, configuration, & stability)

Cumulative Auditory Experience
- Audibility
- HA Use History (duration, consistency)

Linguistic Input

Outcomes
- Linguistic
- Social
- Auditory
- Family

Audiological Interventions

Emerging Model: Inconsistent Access

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Linguistic Input

Outcomes
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Audiological Interventions
1. Audibility provided by HA is significantly associated with speech & language.
2. Audibility has similar relationship with outcomes for children with mild and moderate-to-severe HL.
Is Audibility Associated with Grammar Use?

- Spontaneous language samples - 51 HH 3 yr olds
- Do hearing-related factors predict use of word endings?
  - BEPTA, SII, 4kHz SL
- Does perceptibility influence accuracy in HH?
  - In NH children, /s/ and /z/ emerge before /lz/
  - Hits, cars > houses, fixes

20) Owen Van Horne, Koehlinger, Oleson, & Moeller, in preparation

Summary of Results

- Audibility matters
  - 4kHz SL predicts word endings
  - Audibility in the high frequencies + articulation skills are essential for development of English morphology

- Perceptibility influences in HH
  - HH different from NH /lz/ > /s/ and /z/

20) Owen Van Horne, Koehlinger, Oleson, & Moeller, in preparation
Challenges to Consistent HA Use

More challenges:
- At young ages (toddlers)
- With mild degrees of hearing loss
- Less educated families
Strategic counseling?


Hearing Aid Use

Parent report = 10.84 hrs
Data logging = 8.3 hours
Difference = 2.6 hours
Range = 2-10 hours
Predicted by age
- Younger age = larger prediction error

Hearing Aid Use: Age & Setting

Parent report and data logging are similar
- Agreement improves as child gets older

- Significant variability in data logging for parents reporting “full-time use”

- Ask parents about: 1) tough day, 2) typical day, 3) optimal day & offer strategic supports

How Much Input?

\[ M \text{ age} = 30 \text{ months} \]

\[ \text{HH } n = 38 \]

\[ \text{NH } n = 17 \]

No significant differences between groups

For HH group, more input = better language
  * Mullen Receptive correlated with AWC (\( r = 0.44^{**} \)) and CTC (\( r = 0.46^{**} \))

22) Ambrose, Van Dam & Moeller, JDSDE, 2012

How Rich is the Input?

Parent-child interaction samples analyzed in 3-year olds

HH group exposed to significantly:
  * fewer high-level utterances
  * more directive utterances

HH CASL scores significantly correlated with:
  * proportion of high-level utterances (\( r = 0.57 \))
  * proportion of directives (\( r = 0.38 \))

HH group also exposed to:
  * less complex utterances
  * fewer different words

Ambrose, et al., in preparation
Emerging Model: Inconsistent Access

Hearing Loss (degree, type, configuration, & stability)

Cumulative Auditory Experience
- Audibility
- HA Use History (duration, consistency)
- Linguistic Input

Home/Environmental Factors:
- SES
- Parenting skills
- Auditory environment

Child Factors
- Cognition
- Temperament
- Age
- Executive Function

Educational Interventions

Outcomes
- Linguistic
- Social
- Auditory
- Family

Protective Factors

What protective factors result in resilience?
### Protective Factors: Big Picture

- Milder degree of hearing loss
- Better audibility
- Well-fit amplification
- Longer duration of hearing aid fitting (early fit)
- Amplification worn consistently
- High quantity and quality of linguistic input
- Provision of timely & consistent early interventions
- More resourced homes
- Stronger cognitive abilities

### Well Fit Amplification

Below dashed line =
- poor fit

Filled symbols =
- rms error < 5 dB

Open symbols =
- rms error > 5 dB

26% SII < .65

Early HA Fitting

HH children fit earlier were more likely to perform like NH peers at age two.

Duration of HA fit mattered for both degree of HL groups.

<table>
<thead>
<tr>
<th>Duration Category</th>
<th>Outcome</th>
<th>Linear Slope (Beta)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longest</td>
<td>Language</td>
<td>3.89</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td></td>
<td>Speech</td>
<td>58.49</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Shortest</td>
<td>Language</td>
<td>-0.70</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td></td>
<td>Speech</td>
<td>30.42</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>

n = 161 (Speech); n = 148 (Language)

HH children at 3 and 5 years of age

Audibility significantly associated with speech & language

Greatest Benefit of Aided Hearing Seen With Longer Use

Greatest benefit of aided hearing for s/l seen with longer HA use

15) Tomblin, et al., in review

16) Ambrose, Unflat Berry, Walker, Harrison, Moeller, (accepted). AJSLP
Early Intervention Services

Contribution of number of early intervention visits per month to CASL Scores at 3 years (regression results)

- Covariates (sex, race, maternal ed**, PTA)
- Number visits per month**
- Unexplained

145/155 infants received early intervention

Maybe we need to ask some different questions...

Children live and learn in complex listening environments....How well do they perceive speech in these complex environments? How can predictions be improved?
Socialization Matters for Learning

- Quality of social relationships tied to academic progress
- Learning with friend vs. classmate impacts:
  - Conflict management
  - Deductive reasoning
  - Problem solving
  - Exploration

Summary

- Hearing loss places children at risk for delays in communication development – risk is most often realized in areas that require access to structural aspects of language or multi-talker conversations.
- Protective factors include early and consistent use of well-fit hearing aids, appropriate early intervention services, and a variety of other parent and child factors.
Clinical Implications

- Optimize audibility
  - Audibility matters
  - Benefits observed with longer durations of use
- Promote use consistency
  - Toddlers; mild HL
  - Novel approaches?
- Support families to provide language-rich environments
  - Promotes cumulative auditory-linguistic experience

Cumulative Auditory Experience

- Audibility
- HA Use History (duration, consistency)
- Linguistic Input

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References


References


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