The effects of hearing loss on children’s ability to attend in the classroom

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Issue #1

• Children with hearing loss have unique needs
  – Children vs. adults
    • Think differently
    • Lack world knowledge
    • Bombarded with new information every day
    • Physically small and grow rapidly
    • Unique listening situations
    • Less/no control over their listening environment
Issue #1

• Children with hearing loss have unique needs
  – Hearing impaired vs. normal hearing
    • Higher signal-to-noise ratio
    • Wider bandwidth
    • More repetitions to learn/communicate
Issue #1

• Children with hearing loss have unique needs
  – Children with hearing loss vs. everyone else
    • Have no reference to normal hearing
    • Cannot participate in hearing aid fitting process
    • Effects of hearing loss are pervasive
      – Academic
      – Social
      – Emotional
      – Vocational
Issue #2

- Hearing aids now include many advanced signal processing features but the way they work is a mystery.
- Designed to improve signal audibility and listening comfort:
  - Wide dynamic range compression
  - Directional microphones
  - Frequency lowering
  - Digital noise reduction
  - Feedback suppression
Issue #2

• Hearing aids now include many advanced signal processing features but the way they work is a mystery
  – Digital noise reduction (Hoetink et al 2009)
Issue #2

• Hearing aids now include many advanced signal processing features but the way they work is a mystery

• Development has been recent and rapid
  – No ANSI standards regarding the manner in which performance is reported
  – Lack of evidence regarding effectiveness in children
  – Current pediatric amplification guidelines do not include advice regarding advanced features
Converging Issues

• Pediatric audiologists are fitting very young children with advanced signal processing (Rigsby et al, 2008)
These issues have converged to create a pressing need for research to determine the impact of advanced signal processing on children’s communication development.
Evaluating Advanced Signal Processing in Children with Hearing Loss

- 2-year project funded by a grant from the ASHA Foundation
- Digital Noise Reduction
  - Elementary school classrooms are noisy
  - Classroom learning is largely oral
  - DNR has the potential to make more of the auditory signal available to children to improve their performance for auditory tasks
Digital Noise Reduction

• Studies in adults have been... boring.

• Paradigms
  – Speech perception in noise (% correct)
  – Speech recognition threshold (SRT) in noise (dB SNR)

• Results
  – No improvement in performance with the use of digital noise reduction
  – No decrement in performance either*
Our Approach

• Use materials and methods consistent with the listening demands placed on children in the classroom to reveal practical benefits of advanced signal processing.

• Divided Attention (Multitasking)
  – Speech perception
  – Information processing
  – Noise
  – Attending to concurrent tasks
Divided Attention

apple

apple

?
Divided Attention

• Hicks & Tharpe (2002)

Auditory
Word repetition
Percent words correct
Varied signal-to-noise

Visual
Button pushing
Reaction time
Divided Attention

- Hicks & Tharpe (2002)

Auditory
- Word repetition
- Percent words correct
- Varied signal-to-noise

Visual
- Button pushing
- Reaction time

Diagram:

Word Repetition
- Signal-to-Noise Ratio

Reaction Time
- Signal-to-Noise Ratio
Divided Attention

apple

FOOD
Divided Attention

- McFadden & Pittman (2008)

Auditory
- Word categorization
- Percent words correct
- Signal-to-noise

Visual
- Dot-to-dot games
- Dots/minute

Person
Food
Animal
Divided Attention

- McFadden & Pittman (2008)

Auditory
- Word categorization
- Percent words correct
- Signal-to-noise

Visual
- Dot-to-dot games
- Dots/minute

Signal-to-Noise Ratio

Word Categorization
Divided Attention

• Overall conclusions
  – Children’s performance for visual tasks is not affected by their performance for auditory tasks
  – Don’t know if children’s performance for auditory tasks is affected by visual tasks
Divided Attention
Effects of Digital Noise Reduction on Children’s Performance in Progressively Demanding Listening Conditions

• Purpose
  – To determine the effect of task demand on children’s ability to process auditory information
  – To determine the benefits of digital noise reduction to manage those demands
Conditions

- Used noise and a visual task as competitors to an auditory task
  - Auditory task alone
  - Auditory + visual
  - Auditory + noise
  - Auditory + visual + noise
  - Auditory + visual + noise + digital noise reduction
Method

• Subjects
  – 8- to 12-years old children
    • Equal numbers in each age group (8, 9, 10...)
    • Equal numbers of boys and girls
  – Mainstreamed into public schools or home schooled
  – Performing at grade level
Method

• Hearing
  – 50 children with normal hearing
  – 30 children with hearing loss
    • Mild to moderately-severe
    • Degree of loss appropriate for amplification

• Receptive Vocabulary
  – PPVT IIIIB

• Speech Intelligibility Index (SII)
  – Audibility in quiet and noise
Which hearing aid to use?

- Phonak Naida
- Widex Mind
- ReSound Azure
- Siemens Explorer
Stimuli

- 5 lists of 30 words
  - Words common to children
  - Drawn from three categories
    - Person (exp: policeman, uncle)
    - Food (exp: donut, hamburger)
    - Animal (exp: frog, cat, gopher)
- Children indicated the category to which each word belonged
Stimuli

- Presented in the sound field
  - 0 degrees azimuth
  - 50 dB SPL
  - Broadband noise at 0 dB SNR

- Noise Reduction On
  - Overall level -4 dB
  - SNR +2 dB
Visual Task

• Dot-to-dot games
  – Booklet
  – Dots numbered in increments of 3
  – Starting point of each game was identified

• Scored in dots/min
Let’s try it!

Person

Food

Animal
Results

![Graph 1: PPVT Age vs Chronological Age](image1)
- NHC $r^2=0.36$
- HIC $r^2=0.54$

![Graph 2: Performance vs Speech Intelligibility](image2)
- Single Task $r^2=0.37$
- Dual Task $r^2=0.27$
Results

• Significant Effects:
  – Age
  – Group
  – Condition
  – Group x Condition Interaction
Results

• Significant Effects:
  – Age
  – Group
  – Condition
  – Group x Condition Interaction

• Not Significant:
  – DNR
## Factor Analysis

<table>
<thead>
<tr>
<th>Principal Component</th>
<th>Description</th>
<th>% Variability Accounted for</th>
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</thead>
<tbody>
<tr>
<td>Communication</td>
<td>PPVT age, chrono age</td>
<td>30%</td>
</tr>
<tr>
<td>Audibility</td>
<td>SII in quiet/noise, PTA</td>
<td>28%</td>
</tr>
<tr>
<td>Hearing History</td>
<td>Age at ID, age at amp</td>
<td>21%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>79.6%</td>
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</table>
## Factor Analysis

<table>
<thead>
<tr>
<th>Principal Component</th>
<th>A</th>
<th>+V</th>
<th>A</th>
<th>+V</th>
<th>+N</th>
<th>+N</th>
<th>+DNR</th>
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</thead>
<tbody>
<tr>
<td>Communication</td>
<td>0.29</td>
<td>0.42*</td>
<td>0.48*</td>
<td>0.51*</td>
<td>0.45*</td>
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<tr>
<td>Audibility</td>
<td>0.58*</td>
<td>0.49*</td>
<td>0.54*</td>
<td>0.54*</td>
<td>0.55*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hearing History</td>
<td>0.03</td>
<td>-0.04</td>
<td>0.04</td>
<td>-0.03</td>
<td>0.07</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A=Auditory, V=Visual, N=Noise, DNR=digital noise reduction
Conclusions

• Normal-hearing children
  – Tasks unrelated to hearing did not affect their performance for auditory tasks

• Hearing-impaired children
  – Tasks unrelated to hearing did interfere with their performance for auditory tasks
  – Consistent with comments of parents and teachers
    • “When they’re busy doing something else they don’t pay attention to what I say.”
Conclusions

• Hearing-impaired children
  – Performance for increasingly demanding tasks was related to:
    • Communication/Intelligence
    • Audibility of the signal
  – Performance was not affected by:
    • Previous hearing aid experience
    • Digital noise reduction
To Fit or Not to Fit Digital Noise Reduction on Children?

• As long as digital noise reduction is working reasonably well, it is appropriate for children
  – No evidence that digital noise reduction decreases performance in children
  – No evidence that previous hearing aid use prevents their ability to use digital noise reduction effectively

• Benefits of digital noise reduction
  – Improve listening comfort without affecting performance