Divided Attention in Children with Hearing Loss using Digital Noise Reduction

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Grade-School Class Rules

- Keep hands, feet, and objects to yourself
- Use kind, respectful words
- Be quiet when someone else is talking
- Always do your very best
- Follow all directions the first time given
Children’s Unique Listening Situations

- Listening situations common to children
  - Classroom
  - Gym
  - Cafeteria
  - Playground
  - Back seat of the car
- Children have little/no control over their listening environment
How can we help these children?

- Hearing aids now include many advanced signal processing features
  - Wide dynamic range compression
  - Directional microphones
  - Frequency lowering
  - Digital noise reduction
- Designed to improve signal audibility and listening comfort
How can we help these children?

- The way that advanced processing works is a mystery
- Development has been rapid
- No ANSI standards and few verification procedures
- Lack of research regarding effectiveness in children
Pediatric audiologists are fitting very young children with advanced signal processing (Rigsby et al., 2008)
Advanced Signal Processing in Children with Hearing Loss

- Two-year project funded by a grant from the ASHA Foundation
- Digital Noise Reduction (DNR)
  - Elementary schools are noisy places
  - Learning /communication takes place outside the classroom
Results in adults are “not very exciting”
(Bentler et al, 2008; Nordrum et al, 2006; Peeters et al, 2009; Ricketts & Hornsby, 2005)

- No change in performance with the use of digital noise reduction
  - Speech perception in noise (% correct)
  - Speech recognition threshold (SRT) in noise (dB)
- Adults prefer DNR
A Different Approach

- Task Criteria
  - Demanding perceptual tasks that are sensitive to small changes in the acoustic signal
  - Consistent with the demands of a typical classroom
- Project
  - Divided Attention
  - Word Learning
Divided Attention
Hicks & Tharpe (2002)

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

Visual
- Button pushing
- Reaction time
Hicks & Tharpe (2002)

Auditory
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- Percent words correct
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Visual
- Button pushing
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Diagram:
- Word Repetition vs. Signal-to-Noise Ratio
- Reaction Time vs. Signal-to-Noise Ratio
Divided Attention

- McFadden & Pittman (2008)

  **Auditory**
  - Word categorization
  - Percent words correct
  - Varied signal-to-noise

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

- Person
- Food
- Animal
Divided Attention

- McFadden & Pittman (2008)

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

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

- Signal-to-Noise Ratio
- Signal-to-Noise Ratio

- Word Categorization
- Dot Rate
We know that children’s ability to engage in a visual task is not influenced by the difficulty of a concurrent auditory task.

Is a child’s ability to engage in an auditory task influenced by visual and auditory competitors?
To determine the effect of hearing loss on children’s ability to process auditory information under complex conditions

To determine the benefits of digital noise reduction in the management of those complex conditions
Method

- Progressively demanding conditions
  - Used noise and a visual task as competitors to an auditory task
    - Auditory
    - Auditory + visual
    - Auditory + visual + noise
    - Auditory + visual + noise + digital noise reduction
Which hearing aid to use?

Phonak Naida

Widex Mind

ReSound Azure

Siemens Explorer
Method

- 8-12 year-old children
  - 50 children with normal hearing
  - 30 children with hearing loss
    - Mild to moderately-severe
    - Degree of loss appropriate for amplification
- Receptive Vocabulary
  - PPVT IIIB
- Speech Intelligibility Index (SII)
  - Audibility in quiet and noise
Auditory Task

- 5 lists of 30 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
Auditory Task

- 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
  - Dots numbered in increments of 3
  - Starting point of each game was identified by a box
- Performance was scored in dots/min
Visual Task

- Dot-to-dot games
  - Dots numbered in increments of 3
  - Starting point of each game was identified by a box
- Performance was scored in dots/min
Results - Auditory Task

The graph illustrates the percentage of word categorization for different groups and conditions:

- **NHC** group:
  - Auditory (dark grey): Approximately 100%
  - Auditory + Noise (light grey): Approximately 90%
  - Auditory + Noise + Visual (light grey): Approximately 80%

- **HIC** group:
  - Auditory (dark grey): Approximately 80%
  - Auditory + Noise (light grey): Approximately 70%
  - Auditory + Noise + Visual (light grey): Approximately 60%
Results - Auditory Task

The graph shows the comparison of word categorization (%) for different categories: Auditory, Auditory + Visual, Auditory + Noise, and Auditory + Visual + Noise, across two groups: NHC and HIC.

- **NHC Group**:
  - Auditory: High performance with minimal variation.
  - Auditory + Visual: Lower than Auditory but higher than Auditory + Noise.
  - Auditory + Noise: Lower performance compared to other categories.

- **HIC Group**:
  - Auditory: Moderate performance.
  - Auditory + Visual: Lower than Auditory but higher than Auditory + Noise.
  - Auditory + Noise: Lower performance compared to other categories.

The error bars indicate variability within each category.
Results - Auditory Task

- Significant main effects of group and listening condition.
  - The performance of the children with hearing loss was poorer than that of the children with normal hearing.
  - Performance decreased with task difficulty.
- Significant group x listening condition interaction.
  - The effects of noise and the visual task was greater for the children with hearing loss.
Results - Auditory Task

The bar graph shows the word categorization performance across different conditions:
- **Auditory**
- **Auditory + Visual**
- **Auditory + Noise**
- **Auditory + Visual + Noise**

The x-axis represents the HIC, and the y-axis represents the word categorization percentage. The error bars indicate the variability in the performance.
### Results - Speech Intelligibility Index

<table>
<thead>
<tr>
<th>Noise Reduction</th>
<th>Average</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off</td>
<td></td>
<td></td>
</tr>
<tr>
<td>On</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Noise Reduction Off](image1.png)

![Noise Reduction On](image2.png)
9-year-old girl
- 8-year-old vocabulary
- Identified at 4 years
- Amplified at 4 years

<table>
<thead>
<tr>
<th></th>
<th>SII</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quiet</td>
<td>0.70</td>
<td>100</td>
</tr>
<tr>
<td>Noise</td>
<td>0.32</td>
<td>73</td>
</tr>
<tr>
<td>Noise Reduction</td>
<td>0.33</td>
<td>73</td>
</tr>
</tbody>
</table>
# Results - Factor Analysis (HIC only)

<table>
<thead>
<tr>
<th>Principal Component</th>
<th>Description</th>
<th>% Variability Accounted for</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>PPVT, 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><strong>Total</strong></td>
<td></td>
<td><strong>79.6%</strong></td>
</tr>
</tbody>
</table>
## Results - Factor Analysis (HIC only)

<table>
<thead>
<tr>
<th>Principal Component</th>
<th>A</th>
<th>+V</th>
<th>+N</th>
<th>+N</th>
<th>+DNR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.29</td>
<td>0.42*</td>
<td>0.48*</td>
<td>0.51*</td>
<td>0.45*</td>
</tr>
<tr>
<td>Audibility</td>
<td>0.58*</td>
<td>0.49*</td>
<td>0.54*</td>
<td>0.54*</td>
<td>0.55*</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>
</tr>
</tbody>
</table>

A=Auditory, V=Visual, N=Noise, DNR=digital noise reduction
To determine the effect of hearing loss on children’s ability to process auditory information under complex conditions

- Significant effect of hearing status
- Performance was significantly related to:
  - Age
  - Audibility of the signal
- Performance was not related to:
  - Previous hearing aid experience
Conclusions

- To determine the benefits of digital noise reduction in the management of those complex conditions
  - No improvement or reduction in performance with DNR
Is Digital Noise Reduction Appropriate for Children?

- Yes
  - No evidence that digital noise reduction is detrimental to performance in children.
  - Digital noise reduction maintains the audibility of the signal while decreasing the overall level.
    - May improve listening comfort without sacrificing intelligibility.
  - Provides children with an option in noise.
Thanks to...

- People
  - Samantha Gustafson
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