Benefits of Advanced Hearing Aid Technologies to Children (and Adults) with Hearing Loss

CAA 2012
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Children with Hearing Loss

- 30 million adults
- 1 million children

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<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Significant Impact?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kids</td>
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<tr>
<td>Age</td>
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Hearing Level
(Pittman & Stelmachowicz, 2002)

Adults (n=248)

Children (n=227)
Hearing Level
(Pittman & Stelmachowicz, 2002)

- 39% Mild (15-40 dB HL)
- 21% Severe (61-80 dB HL)
- 30% Moderate (41-60 dB HL)
- 10% Profound (>80 dB HL)

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<tr>
<td>Hearing Aid Bandwidth</td>
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Amplitude Compression
(Jenstad et al, 1999)

Children
12 HI Children (& adults)

Diagram showing the performance of children with hearing loss across different hearing aid conditions (UNAIDED, LINEAR, WDRC) and age groups (AGE: 0, 20, 40, 60, 80, 100, 120 degrees of hearing loss). The y-axis represents performance (Rau), and the x-axis represents the hearing aid condition.

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Directional Microphones
(Ricketts, Galster & Tharpe, 2007)

Children
26 HI Children

Figure 4. The average speech recognition performance as measured by the Hearing in Noise Test for Children within the five simulated classroom conditions in each of the two microphone modes. The error bars represent 1 SD. Dir = directional; SNR = signal-to-noise ratio.
Digital Noise Reduction
(Stelmachowicz et al, 2011)

Children
16 HI Children

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Digital Noise Reduction
(Stelmachowicz et al, 2010)

Children
16 HI Children

HEARING LOSS (degree)

AGE (years)

NR off
NR on

SIGNAL-TO-NOISE RATIO

0 dB 5 dB 10 dB
5-7 YR OLD 8-10 YR OLD

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Frequency Lowering
(Glista et al, 2009)

Children
11 HI Children

![Graph showing speech recognition scores for consonants, plurals, and vowels across different hearing levels and ages.](image)
Hearing Aid Bandwidth
(Stelmachowicz et al, 2007)

Children
24 HI Children
32 NH Children

Fig. 7. Mean PBK scores (in %) as a function of age group for children with normal hearing (upper panel) and hearing loss (lower panel) children. Error bars represent ±1 SD.
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<td>Digital Noise Reduction</td>
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<tr>
<td>Frequency Lowering</td>
<td>Sometimes</td>
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<tr>
<td>Hearing Aid Bandwidth</td>
<td>Maybe</td>
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Receptive Vocabulary
(Pittman, 1998-2008)

Children
76 HI Children
137 NH Children

Delayed lexical development as a function of age
Receptive Vocabulary
(Blamey et al., 2001)

Children
40 HA Children
47 CI Children

Impaired lexical development as a function of age

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What do children do all day?

1. Manage complex environments
2. Learn new words
Listening Effort and Fatigue
(Hicks & Tharpe, 2002)

Children
14 HI Children
14 NH Children
Listening Effort and Fatigue
(Hicks & Tharpe, 2002)

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

Visual
- Button pushing
- Reaction time

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Listening Effort and Fatigue
(Hicks & Tharpe, 2002)

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

Visual
Button pushing
Reaction time

Word Repetition vs. Signal-to-Noise Ratio

Reaction Time vs. Signal-to-Noise Ratio
Listening Effort and Fatigue
(Hicks & Tharpe, 2002)

Auditory
Word repetition
Percent words correct

Visual
Button pushing
Reaction time

Figure 5. Speech recognition (PBK) scores by condition for children with hearing loss (HL) and children with normal hearing (NH). Bars represent 1 standard deviation.

Figure 4. Average reaction time difference scores by condition for children with hearing loss (HL) and children with normal hearing (NH). Bars represent 1 standard deviation.
Managing Complex Tasks
(Pittman, 2011)

Children
30 HI Children
50 NH Children

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Managing Complex Tasks
(Pittman, 2011)

Auditory
Word categorization
Percent words correct
0 dB SNR

Visual
Dot-to-dot games
Dots/minute

Person
Food
Animal
Managing Complex Tasks
(Pittman, 2011)

Auditory
Word categorization
Percent words correct
0 dB SNR

Noise Reduction Off

Noise Reduction On

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Managing Complex Tasks
(Pittman, 2011)

Figure 7. Average (+1 SD) word categorization (percentage correct) as a function of listening condition (in order of difficulty) for the children with NH (filled bars) and the children with HL (open bars).
Auditory/Visual Task Preference
(Pittman et al, fresh from the booth)

Children
23 HI Children
32 NH Children

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Auditory/Visual Task Preference
(Pittman et al, fresh from the booth)

CHILDMREN WITH NORMAL HEARING

# COMPLETED CORRECTLY

<table>
<thead>
<tr>
<th></th>
<th>Alone w/ Competitors</th>
<th>Alone</th>
<th>w/ Competitors</th>
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<tbody>
<tr>
<td>AUDITORY</td>
<td>25</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>VISUAL</td>
<td>15</td>
<td>15</td>
<td>10</td>
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CHILDMREN WITH HEARING LOSS

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Conclusions

• Children with hearing loss excel at visual tasks.
• In children with hearing loss, visual competitors detract from auditory task performance.
• Complex environments appear to be most detrimental to a child’s weakest modality.
The Word Learning Process

- Word Learning Model (Storkel & Lee 2011)
  - Triggering
    - Detection of a new word
  - Configuration
    - Form a stable acoustic representation
    - Form a semantic representation
  - Engagement
    - Using the new word with other words
Non-word Detection
(Pittman & Schuett, in press)

Children
19 HI Children
29 NH Children

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Non-word Detection
(Pittman & Schuett, in press)

Close all three doors.

Cooks make hot foom.

They want pum gorn.
Non-word Detection
(Pittman & Schuett, in press)

- Overall performance (percent correct)
- Error analyses
  - Under-triggering
  - Over-triggering
Non-word Detection
(Pittman & Schuett, in press)

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Non-Word Detection and Bandwidth
(Pittman et al, in process)

Children

19 HI Children
33 NH Children
31 HI Adults
18 NH Adults

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Non-Word Detection and Bandwidth
(Pittman et al, in process)

Close all three doors.

Cooks make hot foo\textit{m}.

They want \textit{pum gorn}.

4 kHz 9 kHz

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Non-Word Detection and Bandwidth
(Pittman et al, in process)
Non-Word Detection and Bandwidth
(Pittman et al, in process)
Conclusions

• Hearing loss disrupts the detection of new words and may prolong the word learning process.

• A subtle hearing aid feature, like extended bandwidth, may significantly improve the detection of new words.
Children

26 HI Children
41 NH Children

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Word Learning and Bandwidth
(Pittman, 2008)

\[ P_c = 1 - 0.8e^{-n/c} \]

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Word Learning and Bandwidth
(Pittman, 2008)
Word Learning and Bandwidth
(Pittman, 2008)
Word Learning and Noise Reduction (Pittman, 2011)

Children
26 HI Children
40 NH Children

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Word Learning and Noise Reduction
(Pittman, 2011)

8-9 YEAR OLDS

11-12 YEAR OLDS

PERFORMANCE (%)

TRIAL

TRIAL

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Word Learning and Noise Reduction
(Pittman, 2011)

Hearing Loss

8-9 YEAR OLDS

11-12 YEAR OLDS

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SO WHAT CAN WE CONCLUDE?
Conclusions

• Speech perception tests are sensitive to the overall effects of amplification.
• Cognitively demanding tasks are sensitive to the subtle effects of advanced hearing aid features.
Advanced Hearing Aid Features

Digital noise reduction
  1. Maintains auditory task performance in a complex environment
  2. Promotes word learning in older grade-school children with hearing loss

Extended high-frequency bandwidth
  1. Aides in the detection of new words
  2. Promotes word learning in younger and older grade-school children.
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  – Phonak AG

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  – Mollie Hiipakka
  – Madalyn Rash
  – Ashley Pederson
  – Amanda Willman
  – Allison Latto
  – Brittany Schuett
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Thanks!

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