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- Email [customerservice@AudiologyOnline.com](mailto:customerservice@AudiologyOnline.com)
Assessing the Benefits of Advanced Hearing Aid Features for Recognizing and Learning Unknown Words

Andrea Pittman, PhD
Associate Professor
Arizona State University

Disclosures

Funding: 

Hearing Industry Research Consortium

Collaborators:

Elizabeth Stewart, PhD
Ian Odgear, AuD
Amanda Willman, AuD
Learning Outcomes

After this course, participants will be able to:

- Describe the nature of learning new information at ages across the lifespan.
- Describe the behavior of the signal processing for select hearing devices.
- Identify the challenges of children and adults with hearing loss for detecting and learning new words.

- Two-year study funded by the Hearing Industry Research Consortium 2013-15


- Overall project goal: Determine the benefits of selected amplification features for auditory tasks that require the detection and learning of new words.
In addition, the results point to a dependence on frequency of hearing loss, in that the hearing-impaired listeners were not using the high-frequency information (particularly in the 4000- and 8000-Hz bands) to improve their score, in some cases when the hearing loss was less than 55 dB HL (Fig. 9).

Hearing Loss and Vocabulary

- Children
- 5-14 years of age
- 116 Normal Hearing
- 99 Mild to Moderate Hearing Loss

Lexical Neighborhood Activation

Stimulus Input

Acoustic Phonetic Pattern Activation

Lexical Processing (Neighborhood Activation)

Known Words Recognition

Higher Level Lexical Information


Word Learning Model

Stimulus Input

Acoustic Phonetic Pattern Activation

Lexical Processing (Neighborhood Activation)

Known Words Recognition

Higher Level Lexical Information

Learning Configuration

Detection (Triggering)

Unknown Engagement


Storkel, & Lee (2011) The independent effects of phonotactic probability... Language and Cognitive Processes, 26(2), 191-211

Participants

Children: 20 NH (8-12 years)
21 HL (8-12 years)

Adults: 15 NH (50-67 years)
17 HL (52-78 years)

Amplification Conditions

1. No amplification
2. Narrow-band amplification (4 kHz)
3. High-frequency amplification (10 kHz)
   Extended bandwidth or
   Non-linear frequency compression

The best performance with either type of amplification was included in the analyses.
Amplification Conditions

**Bandwidth**

- FF Thresholds
- 10 kHz
- 4 kHz

**Frequency Lowering**

- FF Thresholds
- 10 kHz
- 4 kHz

Test parameters

**Stimuli**
- 53 dB SPL in quiet
- 0° azimuth

**Data collection**
- Computer interface
- Digital audio recordings

**Sessions**
- 1 Unaided
- 1-2 Aided

Word Recognition Stimuli

<table>
<thead>
<tr>
<th>Narrow-Band</th>
<th>High-Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boat</td>
<td></td>
</tr>
<tr>
<td>Shout</td>
<td></td>
</tr>
<tr>
<td>Puff</td>
<td></td>
</tr>
</tbody>
</table>
Word Recognition

Non-linear frequency compression
Wide-band amplification

High-Frequency Amplification (% correct)
Narrow-Band Amplification (% correct)

HIC
HIA

Word Recognition

Children
Adults

Unaided
Aided

Listening Condition

Performance (% Correct)

p=.29
p=.051
Word Recognition

- Word recognition is equally poor in children and adults with hearing loss when not using amplification.
- Children and adults with hearing loss benefit equally from amplification.

![Bar chart showing performance comparison between Children and Adults with and without amplification.](chart.png)

Auditory Lexical Decision

- baby
- soovie
- doppers
- only
- grandma torses
- before
- taybe
- outside
- stoobi
Auditory Lexical Decision

Auditory Lexical Decision

- **Non-linear frequency compression**
- **Wide-band amplification**

Graph showing performance (% correct) for different amplification levels.

Children vs. Adults comparison:
- **Unaided**: p=.76
- **Aided**: p<.01

Performance levels:
- **Children**: 33
- **Adults**: 65
Auditory Lexical Decision

- With amplification, children are better than adults at identifying words they don’t know when they occur in isolation.
- Hearing loss makes adults vulnerable to misperceiving new words they don’t know.
Non-Word Detection

Close all three doors.

Cooks make hot foom.
Non-Word Detection 1.0

![Graph showing performance of High-Frequency Amplification (% correct) vs. Narrow-Band Amplification (% correct).](image)

- **HiC**: Non-linear frequency compression
- **HIA**: Wide-band amplification

Non-Word Detection 1.0

![Bar graph showing performance (% correct) for Unaided and Aided Listening Conditions for Children and Adults.](image)

- **Children**:
  - Unaided: 35%
  - Aided: 63%
  - p = 0.36
- **Adults**:
  - Unaided: 36%
  - Aided: 63%
  - p = 0.27
Hearing loss decreases detection of unfamiliar words in both adults and children.

- Children with hearing loss improve to age-appropriate levels with amplification but adults do not.

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**Non-Word Detection 2.0**

<table>
<thead>
<tr>
<th># of nonsense words</th>
<th>Example phrase</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Clocks tick on time.</td>
</tr>
<tr>
<td>1</td>
<td>Birds rike long worms.</td>
</tr>
<tr>
<td>2</td>
<td>Dats catch slow bice.</td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

Pittman (in process) Audibility of unfamiliar words in adults and children with hearing loss.
Non-Word Detection 2.0

Pittman (in process) Audibility of unfamiliar words in adults and children with hearing loss.
Non-Word Detection 2.0

- Detection of unknown words is directly related to audibility.
- At low levels of audibility
  - Children repair unknown words to be real
  - Adults misperceive real words as unknown

Rapid Word Learning

Michel et al., 2011 Quantitative Analysis of Culture Using Millions of Digitized Books, Science, 331, 176-182
Rapid Word Learning

Children

26 HI Children
41 NH Children

Rapid Word Learning


Rapid Word Learning

Rapid Word Learning

![Graph showing performance over trials with learning speed categories: 3 = 1 trial (perfect learning), 2 = 10 trials, 1 = 100 trials, 0 = 1000 trials (no learning).]

Learning Speed:
- 3 = 1 trial (perfect learning)
- 2 = 10 trials
- 1 = 100 trials
- 0 = 1000 trials (no learning)

![Graph showing the relationship between non-linear frequency compression, wide-band amplification, high-frequency amplification (HIC), and high-intensity amplification (HIA) with learning speed.]

△ Non-linear frequency compression
○ Wide-band amplification

\[ P_n = 1 - 0.80e^{-n/c} \]
Rapid Word Learning

Learning Speed (log 1000/n)

Children
Adults

NH
HL

Rapid Word Learning

Learning Speed (log 1000/n)

Children
Adults

Unaided
NB Amp
Rapid Word Learning

- Normal Hearing
  - Children and adults are equally good at associating novel words with novel images

- Hearing Loss
  - Children can learn as well as their peers if given a comprehensive signal
  - Adults experience greater deficits from hearing loss relative to their peers
Summary

- There’s more to hearing than perceiving familiar words.
- Adults with normal hearing are as capable as children of detecting and learning new words.
- The effects of hearing loss are greater in adults than in children.
- Audibility facilitates detection of new words while bandwidth facilitates learning.
- The best perception and learning was achieved by optimizing amplification in both groups.

Thanks for listening!