Auditory-Based Learning in Children and Adults with Hearing Loss

Oticon Headquarters, 9/27/18

Andrea Pittman, PhD CCC-A
Arizona State University

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![Oticon Hearing Foundation](https://example.com/oticon_hearing_foundation.png)

![Hearing Industry Research Consortium](https://example.com/irc.png)

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Research Assistants (The Pitt Crew):

Elizabeth Stewart  Ian Odgear
Lauren Meadows  Amanda Willman
Nicole Marzan  Madalyn Rash
Beatriz Lazaro  Brittany Schuett
Elizabeth Rainy  Ashley Wright
Amy Stahl  Jacelyn Olson
(and many more)

And collaborators:

Rachel Krupa – Mesa Public Schools, AZ, US
Judy Attaway – Casa Colina Hospital, CA, US
Dan Duran – Valley Children’s Hospital, CA, US
Tove Rosenbom – Oticon Medical, DK
Ravi Sockalingam – Oticon Medical, US
Liz Presson – Oticon Medical, US
Children 5-14 years of age
116 Normal Hearing
99 Mild to Moderate Hearing Loss

College Students
97 Normal Hearing
93 Mild to Profound Hearing Loss

College Students
89 Normal Hearing
25 w/Cochlear Implants <3.5 yrs
68 w/Cochlear Implants >3.5 yrs

Covertino et al (2014) Word and World Knowledge Among Deaf Learners With and Without Cochlear Implants, J Deaf Studies and Deaf Ed, 19;4
How many words do we need to know?

The average college student knows between 15,000 and 200,000 words (D’Anna et al. 1991).

Oxford Dictionary of American English
430,000 total entries
1000+ new entries each year
  - new words
  - new definitions to existing words

What does this mean?

Children have a lot of word-learning to do.
50,000 words
learned over 18 years (3 to 22 years)
= 7 new words everyday

Adults need to update their vocabularies too.
1,000 word per year
= 3 new words every day
52% of the words we read in books are lexical “dark matter”; they are undocumented in standard dictionaries.
Do adults update their vocabularies?

On standardized vocabulary tests, older adults outperformed younger adults (Verhaeghen, 2003).

Better vocabulary scores with increasing age may be due to a cohort effect that favors the earlier born (Flynn effect).

Stahl, Marzan, and Pittman (in process)


Henriksen’s (1999) lexical knowledge model:
1. Size - how many words are known
2. Depth - how well the words are known
3. Mastery - comprehension and production of the words
## Vocabulary Then and Now Test (VTNT)

<table>
<thead>
<tr>
<th>Word Type</th>
<th>#</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longstanding words with established definitions</td>
<td>15</td>
<td>Aghast: Filled with horror or shock</td>
</tr>
<tr>
<td>Longstanding words with new definitions</td>
<td>15</td>
<td>Ship: The desire of a fan for two fictional characters to be in a romantic relationship</td>
</tr>
<tr>
<td>New words</td>
<td>15</td>
<td>Senioritis: Affliction of students in their final year of high school or college, characterized by a decline in motivation or performance.</td>
</tr>
<tr>
<td>Nonsense words</td>
<td>5</td>
<td>Desill</td>
</tr>
</tbody>
</table>
Vocabulary Then and Now Test (VTNT)

Stahl (2016) Updates to adults vocabulary. ARES

<table>
<thead>
<tr>
<th>Age (yrs)</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-39</td>
<td>68</td>
</tr>
<tr>
<td>40-59</td>
<td>63</td>
</tr>
<tr>
<td>60-74</td>
<td>13</td>
</tr>
<tr>
<td>Total</td>
<td>144</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hearing Status</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown</td>
<td>144</td>
</tr>
</tbody>
</table>

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### Vocabulary Then and Now Test (VTNT)

#### Performance (proportion correct)

<table>
<thead>
<tr>
<th>PTA (dB HL)</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-20</td>
<td>49</td>
</tr>
<tr>
<td>21-40</td>
<td>18</td>
</tr>
<tr>
<td>41-60</td>
<td>15</td>
</tr>
<tr>
<td>81-100</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>94</td>
</tr>
</tbody>
</table>

**Marzan & Hutton (2018)**
When/where do adults and children learn new words?

<table>
<thead>
<tr>
<th>Children</th>
<th>Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>School</td>
<td>Second language learning</td>
</tr>
<tr>
<td>Home</td>
<td>Medical terminology</td>
</tr>
<tr>
<td>Friends</td>
<td>Meeting new people</td>
</tr>
<tr>
<td>Activities</td>
<td>Traveling to new places</td>
</tr>
<tr>
<td>Social Media</td>
<td>On the job training</td>
</tr>
</tbody>
</table>

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Auditory Learning Tasks

- **Word Recognition**: How well they can recognize words they already know.
- **Lexical Decision Task**: How well they can recognize words they don’t know.
- **Non-Word Detection**: How well they can detect words they don’t know in context.
- **Rapid Word Learning**: How well they can learn new words.
To determine if differences in device output (like bandwidth) improve performance for auditory tasks important to learning new information.
Air-Conduction Devices

Oticon miniAlta RITE

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (yrs)</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children w/NH</td>
<td>8-12</td>
<td>20</td>
</tr>
<tr>
<td>Children w/HL</td>
<td>8-12</td>
<td>21</td>
</tr>
<tr>
<td>Adults w/NH</td>
<td>50-67</td>
<td>15</td>
</tr>
<tr>
<td>Adults w/HL</td>
<td>52-78</td>
<td>17</td>
</tr>
</tbody>
</table>

4 kHz

sothnud

doztul

fosnush

stomun

homtul

10 kHz
Bone-Conduction Devices

Participants
17 children
10 boys, 7 girls
7 – 15 years
14 bilateral conductive
1 unilateral conductive
2 unilateral profound
Method

Test Parameters
- 53 dB SPL in quiet
- 0° azimuth

Data collection
- Computer interface
- Digital audio recordings
Word Recognition

Word Recognition

Aided Sound-Field Thresholds

- Skin Drive
- Direct Drive

Difference (Skin-Direct)

Group | Age (yrs) | n
---|---|---
Bilateral | 7-15 | 14
Unilateral | 7-15 | 3

Direct Drive (% Correct)

Δ7%
“Swim”

<table>
<thead>
<tr>
<th>Repeat</th>
<th>Categorize</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swim</td>
<td>Real</td>
</tr>
<tr>
<td>Swim</td>
<td>Not Real</td>
</tr>
<tr>
<td>Srim</td>
<td>Real</td>
</tr>
<tr>
<td>Srim</td>
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</tr>
<tr>
<td>Whim</td>
<td>Real</td>
</tr>
<tr>
<td>Whim</td>
<td>Not Real</td>
</tr>
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</table>

“Glat”

<table>
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<th>Repeat</th>
<th>Categorize</th>
</tr>
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<tbody>
<tr>
<td>Glat</td>
<td>Not Real</td>
</tr>
<tr>
<td>Glat</td>
<td>Real</td>
</tr>
<tr>
<td>Glad</td>
<td>Not Real</td>
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Auditory Lexical Decision

Auditory Lexical Decision

Aided Sound-Field Thresholds

-20 -15 -10 -5 0 5 10 15 20 25

Level (dB HL)

Skin Drive
Direct Drive

Difference (Skin-Direct)

-25 -20 -15 -10 -5 0 5 10 15 20 25

Frequency (kHz)

0.25 0.5 1 2 4 8

Unilateral (Conductive, SSD)
Bilateral (Conductive)

Group | Age (yrs) | n
--- | --- | ---
Bilateral | 7-15 | 14
Unilateral | 7-15 | 3
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 <em>rike</em> long worms.</td>
</tr>
<tr>
<td>2</td>
<td><em>Dats</em> catch slow <em>bice</em>.</td>
</tr>
<tr>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
</tr>
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Non-Word Detection 2.0

Non-Word Detection 2.0

Aided Sound-Field Thresholds

- Skin Drive
- Direct Drive

Difference (Skin-Direct)

Group | Age (yrs) | n
--- | --- | ---
Bilateral | 7-15 | 14
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Sensitivity via Direct Drive ($d'$)

Sensitivity via Skin Drive ($d'$)

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Rapid Word Learning

Performance (% Correct)

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

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

Rapid Word Learning

- **Oticon miniAlta RITE**

- **Graph:**
  - Frequency (kHz) range: 0.25 to 8
  - Hearing Level (dB re: ANSI 1989) range: -20 to 120
  - Data points for **CHILDREN** and **ADULTS**

- **Bar Chart:**
  - Learning Speed (log 1000/n) for **NH** and **HL**
  - **NH**:
    - Children: 18
    - Adults: 12
  - **HL**:
    - Children: 16
    - Adults: 47

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Rapid Word Learning


Group | Age (yrs)  | n  
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Children w/HL | 8-12 | 21 
Adults w/HL | 52-78 | 17
Rapid Word Learning

Aided Sound-Field Thresholds

- Skin Drive
- Direct Drive

Difference (Skin-Direct)

Group | Age (yrs) | n
--- | --- | ---
Bilateral | 7-15 | 14
Unilateral | 7-15 | 3

Skin Drive (log 1000/n)

Direct Drive (log 1000/n)

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Speech Perception vs. Word Learning

**Graphs:**
- **Hearing Level vs. Frequency (kHz):**
  - Children with Hearing Loss (HL)
  - Adults with HL
- **Rapid Word Learning vs. Word Recognition (% correct):**
  - Adults
  - Children

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Pittman et al. (2017) Detecting and Learning New Words: The Impact of Advancing Age and Hearing Loss, AJA, 26, 318-327.
# Modeling and Predicting Hearing Aid Outcome

## Data Sets

<table>
<thead>
<tr>
<th>n</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>173</td>
</tr>
<tr>
<td>2</td>
<td>53</td>
</tr>
<tr>
<td>3</td>
<td>333-338</td>
</tr>
</tbody>
</table>

## Outcome Measures

<table>
<thead>
<tr>
<th>Domain</th>
<th># of Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hearing aid usage</td>
<td>2-3</td>
</tr>
<tr>
<td>Subjective benefit</td>
<td>5-7</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>2-3</td>
</tr>
<tr>
<td>Speech Recognition</td>
<td>6-8</td>
</tr>
</tbody>
</table>


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Results:

Predictors of hearing aid use (15% of variance)
- Previous experience with hearing aids
- Perceived sound quality
- Marital status
- Loudness discomfort level
- Perceived distortion
- Duration in primary occupation
- Verbal IQ

None of the speech recognition measures predicted hearing aid use/satisfaction.

Conclusions

Vocabulary is dynamic.

New words are created rapidly.

Word learning is like riding a bike.

Uncorrected hearing loss impedes learning, limits vocabulary size, reduces knowledge.

Correcting hearing loss with amplification improves learning for both children and adults.