Vowel discrimination with reduced spectral cues as a function of infant age

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  – Megan Mears
  – Ingrid Gonzalez Owens
  – Christine Silva

• Infants and their families
• Cochlear implants (CI) have reduced spectral resolution, which impacts:
  – Localization of spectral peaks
  – Cues for vowels and consonant place

• Poorer spectral resolution may affect perceptual development of infants.

• Inability to resolve a degraded signal might contribute to outcome variability.

e.g., Geers et al., 2003; Geers et al., 2008; Jusczyk, 1985; Niparko et al., 2010; Rosen, 1992; Saffran et al., 1996.
Cochlear implant simulations

- Divide acoustic signal into discrete frequency channels via multiple bandpass filters
  - Reduces spectral resolution
  - Preserves temporal envelope

- Present CI-simulated signal to individuals with normal hearing
  
  e.g., Baskent, 2006; Eisenberg et al., 2000; Friesen et al., 2001; Shannon et al., 1995.
Effect of age on perception of spectrally degraded signals

Baskent, 2006; Bertoncini et al., 2011; Dorman et al., 1997; Eisenberg et al., 2000; Friesen et al., 2001; Shannon et al., 1995; Warner-Czyz et al., 2014; Xu et al., 2005.
Effect of age on perception of spectrally degraded signals

Baskent, 2006; Bertoncini et al., 2011; Dorman et al., 1997; Eisenberg et al., 2000; Friesen et al., 2001; Shannon et al., 1995; Warner-Czyz et al., 2014; Xu et al., 2005.
Purpose of this study

• What is the effect of chronologic age (6, 9, 12 months) on vowel discrimination with a 16-channel CI-simulated signal?

• What is the effect of number of spectral channels (8, 16) on vowel discrimination in 12-month-old infants?
## Participants

<table>
<thead>
<tr>
<th>Infant age</th>
<th>8 channels</th>
<th>16 channels</th>
<th>32 channels</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 months $^a,^b$</td>
<td>X</td>
<td>$n = 20$ $(n = 16)$</td>
<td>$n = 21$ $(n = 7)$</td>
</tr>
<tr>
<td>9 months $^b$</td>
<td>X</td>
<td>$n = 19$ $(n = 8)$</td>
<td>$X$</td>
</tr>
<tr>
<td>12 months $^b$</td>
<td>$n = 23$ $(n = 6)$</td>
<td>$n = 24$ $(n = 13)$</td>
<td>$X$</td>
</tr>
</tbody>
</table>

**Study 2 (effects of channels)**  
**Study 1 (effects of age)**

$a$ Data from Warner-Czyz et al. (2014)  
$b$ All groups reflect ages ± 1 month of the target age.
Stimuli

- Consonant-vowel stimuli (/ti/-/ta/)
  - 500 ms duration with 500 ms inter-stimulus interval

- CI simulations via noiseband vocoder
  - Semi-logarithmic (mel) spacing
  - 8, 16, and 32 channel
Visual habituation

• **Habituation phase (≤ 16 trials)**
  – One auditory stimulus (/ti ti ti ...) + simple visual stimulus (checkerboard)
  – 50% decrease in look time

• **Test phase (12 trials)**
  – Oddball paradigm (9 familiar, 3 novel)

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Warner-Czyz et al., 2014.
Data analysis

- **Difference in mean looking time**
  - No difference in look time = no discrimination
  - Difference in look time = discrimination

- **Statistical analysis (Two-way ANOVA)**
  - Chronologic age (6, 9, 12 months) (Study 1)
  - Spectral channels (8, 16) (Study 2)
  - Stimulus order (/ti/-/ta/ vs. /ta/-/ti/)
Effect of age on vowel discrimination via a 16-channel CI simulation

Habituation phase

<table>
<thead>
<tr>
<th></th>
<th>6a</th>
<th>9</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Novel</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

Test phase

<table>
<thead>
<tr>
<th></th>
<th>6 m</th>
<th>9 m</th>
<th>12 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Novel</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
</tbody>
</table>

\[ p > .05 \]
\[ p < .05 \]
\[ p < .05 \]

a Data from Warner-Czyz et al. (2014)
Effect of number of channels (8, 16) on vowel discrimination in 12 m/o

Mean duration, looking time (s)

- **Familiar**
- **Novel**

**Habituation phase**

- 8 ch
- 16 ch

**Test phase**

- 8 channels
- 16 channels

\[ p < 0.05 \]
Effect of age on perception of spectrally degraded signals

<table>
<thead>
<tr>
<th>Effect of age on perception of spectrally degraded signals</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of channels to score &gt;90%</td>
</tr>
<tr>
<td>consonants</td>
</tr>
<tr>
<td>6 months</td>
</tr>
<tr>
<td>5-7 years</td>
</tr>
<tr>
<td>10-12 years</td>
</tr>
<tr>
<td>Adults</td>
</tr>
</tbody>
</table>

Baskent, 2006; Bertoncini et al., 2011; Dorman et al., 1997; Eisenberg et al., 2000; Friesen et al., 2001; Shannon et al., 1995; Warner-Czyz et al., 2014; Xu et al., 2005.
Summary

• Age significantly affects discrimination of spectrally degraded (16-channel) vowels
  – Adequate for 9- and 12-month-old infants
  – Inadequate for 6-month-old infants

• 12-month-old infants can discriminate vowels with fewer channels (8 vs. 16)
Discussion

• Should we stop implanting 6-month-old infants?

• One-size-fits-all approach to signal processing may not optimize outcomes for the youngest CI recipients.

• Increased spectral resolution of the CI signal may improve early speech perception skills in young CI users.