Production of Stop Consonants by Children with Cochlear Implants & Children with Normal Hearing

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Normal Hearing (NH)

- **Who:**
  - Individuals with no HL

- **What:**
  - Acoustic signal
  - Typically functioning auditory system

Hearing Aid (HA)

- **Who:**
  - Mild – Profound HL

- **What:**
  - Amplified acoustic signal

- **Pro:**
  - Amplifies soft speech while reducing background noise

- **Con:**
  - May not benefit individuals with profound HL

Cochlear Implant (CI)

- **Who:**
  - Profound HL

- **What:**
  - Electrical signal

- **Pro:**
  - Replaces function of the cochlea when individual cannot benefit from a HA

- **Con:**
  - Degraded signal
  - Information is lost

Cochlear Implants (NIDCD); Smith (1975); Todd, Edwards, & Litovsky (2011)
What we hear in the speech signal

1.) Temporal Contrasts
   • Differences in **timing**
   • Example: Distinguish between voiced and voiceless sounds - *time* vs. *dime*
   • Easy to distinguish, even for CI users

2.) Spectral Contrasts
   • Differences in **frequency** (Peak ERB)
   • Example: Distinguish between voiceless sounds - *tea* vs. *key*
   • Easy to distinguish with normal hearing, but degraded through a CI

Imperfections of Cochlear Implants

1.) Spectral Information is Lost
   • Difficult to distinguish sounds that differ by spectral, not temporal, contrasts

2.) Delay in Hearing Experience
   • Surgical procedure to receive CI
     • FDA approved at 12 months
     • Hearing age ≠ Chronological age

3.) Reduced Speech Intelligibility
   • Lack of listening and speaking experience
   • Increased need for early speech intervention
   • Heavily studied with “s” and “sh”

Giezen, Escudero, & Baker (2010); Peng, Spencer, & Tomblin (2004); Todd, Edwards, & Litovsky (2011)
Gaps in Current Literature

• Majority of research on fricatives: “s” and “sh”
  • Findings: Children with CIs produce “s” and “sh” differently and less intelligibly than their peers with normal hearing

• Lack of research on voiceless stops: “t” and “k”

Hewlett (1987); Todd, Edwards, & Litovsky (2011)
Why is this important?

- “t” and “k” are typically acquired early in the development of speech
  - Stops are typically developed earlier than fricatives

- Less speaking and listening experience due to time of implantation
  - Earliest implantation = 12 months

- IPA transcription is categorical
  - Acoustic analysis shows fine-grained differences

Hewlett (1987); Holliday et al. (2014); Tyler, Figurski & Langsdale (1993)
Robustness of Contrast (RoC)

More Robust

Less Robust

“k”

“t”

ambiguous
Research Questions

• Based on our perception using IPA transcription, are children with cochlear implants less accurate at producing “t” and “k” than their age-matched peers with normal hearing?

• Do children with cochlear implants have a lower robustness of contrast between the sounds “t” and “k” than age-matched children with normal hearing?
### Participants

64 children; Monolingual speakers of American English

<table>
<thead>
<tr>
<th>Males:Females</th>
<th>Age in months m(SD)</th>
<th>PPVT-4 m(SD)</th>
<th>Maternal Education</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cochlear Implant n=32</td>
<td>14:18</td>
<td>47.5(9.2) range = 31-65</td>
<td>n = 32 91.63(23.1)</td>
</tr>
<tr>
<td>Normal Hearing n=32</td>
<td>16:16</td>
<td>47.6(9.2) range = 31-66</td>
<td>n = 22 116.86(14.3)</td>
</tr>
</tbody>
</table>
Procedure

• Picture Prompted Real Word Repetition Task

• Stimuli: 15-18 “t”-initial and “k”-initial words
  • Followed by front and back vowel contexts
    • “kitty” (front vowel)
    • “comb” (back vowel)
    • “teddy bear” (front vowel)
    • “tooth” (back vowel)
  • “keep” vs. “coop”
Coding: Transcription
Coding in Praat

Consonant: “t”  Vowel

burst Stop t
Data Analysis: Research Question #1

Based on our perception using IPA transcription, are children with cochlear implants less accurate at producing “t” and “k” than their age-matched peers with normal hearing?
Data Analysis: Research Question #1 (CA matches)

<table>
<thead>
<tr>
<th>Target consonant</th>
<th>Accuracy</th>
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<tbody>
<tr>
<td>Back</td>
<td></td>
</tr>
<tr>
<td>Front</td>
<td></td>
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</table>

The figure shows the accuracy of CA matches for target consonants 'k' and 't' for 'Back' and 'Front' positions. The accuracy is represented on the y-axis, with 'kt' on the x-axis. The graphs illustrate the performance of CI and NH groups, indicated by green and purple dots respectively, with error bars for standard deviation.

- **Back**:
  - 'k' and 't' have significant accuracy differences (***P < 0.001***).

- **Front**:
  - 'k' and 't' show a significant accuracy difference (***P < 0.001***).
  - 'k' has a higher accuracy compared to 't' (**P < 0.01***).
Data Analysis: Research Question #2

Do children with cochlear implants have a lower robustness of contrast between the sounds “t” and “k” than age-matched children with normal hearing?

VS.
Robustness of Contrast
Robustness of Contrast

- Children with normal hearing have a significantly more robust contrast in front vowel contexts
Conclusions

• Based on IPA transcription, children with cochlear implants produced “t” and “k” significantly less accurately than their peers with normal hearing
  • Need for early intervention

• Based on acoustic analysis, children with cochlear implants produced a less robust contrast in front vowel contexts compared to children with normal hearing
  • Revealed fine-grained differences within productions that were perceived to be correct
  • Acoustic analysis supplements IPA transcription
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Members of the Learning to Talk Lab
Participants & Families

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References

Cochlear Implants. (2014, August 8). In National Institute on Deafness and Other Communication Disorders (NIDCD).


Thank You!