Attending to a Single Ear Using Bilateral Cochlear Implants
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INTRODUCTION
- People with two cochlear implants (CIs) often report having a “good” ear and a “bad” ear. The reasons for this include:
  o Hearing history
  o Quality of surgery
  o Subjective impression
- Humans are very good at selectively attending to one ear and ignoring the other (Cherry, 1953)
- Question: Do bilateral CI users demonstrate asymmetrical abilities to attend to a single ear depending on whether they are attending to their good ear or bad ear?

METHOD
- Stimuli
  o BUG word corpus (Kidd Lab, Boston University)
  o 5 keyword sentences
  o Closed set of 8 possibilities per keyword
  o Target Speaker: Female
  o Interfering Speaker: Male
- Reference Level = 70 dB SPL (A)
- Target-to-Masker Ratio (TMR)
  o Positive TMRs: Masker reduced in level
  o Negative TMRs: Target reduced in level
- Volumes in each ear was adjusted by listener to produce equal loudness
- Subject’s good ear was self-reported
- Subject’s good ear was most often the ear first implanted (7 of 9 cases)

RESULTS
- Individual Psychometric Functions
  - The percentage of correct responses ($P_c$) was calculated for each condition
- Conditions
  o Thresholds were calculated as $P_c = 50\%$ from a logistic fit (pignistic: Wichmann and Hill, 2001)

SUBJECTS
- 9 bilateral CI subjects
  o Listened to stimuli via direct line
  o Used clinical maps and automatic gain control was on
  o Volume in each ear was adjusted by listener to produce equal loudness
  o Subject’s good ear was self-reported
  o Subject’s good ear was most often the ear first implanted (7 of 9 cases)

Subjects: Age CI use (Yrs) Good
<table>
<thead>
<tr>
<th>Subject</th>
<th>Age</th>
<th>CI use (Yrs)</th>
<th>Good Ear</th>
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<tbody>
<tr>
<td>IAJ</td>
<td>65</td>
<td>14 7 Left</td>
<td></td>
</tr>
<tr>
<td>IBD</td>
<td>82</td>
<td>13 13 Right</td>
<td></td>
</tr>
<tr>
<td>IBM</td>
<td>71</td>
<td>1 7 Left</td>
<td></td>
</tr>
<tr>
<td>IBM</td>
<td>57</td>
<td>1 5 Right</td>
<td></td>
</tr>
<tr>
<td>IBO</td>
<td>46</td>
<td>1 3 Right</td>
<td></td>
</tr>
<tr>
<td>IBR</td>
<td>57</td>
<td>2 7 Left</td>
<td></td>
</tr>
<tr>
<td>IBY</td>
<td>48</td>
<td>4 &lt;1 Right</td>
<td></td>
</tr>
<tr>
<td>ICA</td>
<td>52</td>
<td>2 9 Right</td>
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<table>
<thead>
<tr>
<th>Number</th>
<th>Symbol</th>
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<tbody>
<tr>
<td>1</td>
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<td>Single ear</td>
</tr>
<tr>
<td>2</td>
<td>(L)</td>
<td>Single talker (Baseline)</td>
</tr>
<tr>
<td>3</td>
<td>(T)</td>
<td>Selective attention</td>
</tr>
<tr>
<td>4</td>
<td>[T]</td>
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<tr>
<td>5</td>
<td>[T]+[T]+</td>
<td>Dual ear</td>
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<tr>
<td>6</td>
<td>[T]+[T]</td>
<td>Energetic masking</td>
</tr>
<tr>
<td>7</td>
<td>[T]+[T]+</td>
<td>Single ear</td>
</tr>
<tr>
<td>8</td>
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<tr>
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<td>Single ear</td>
</tr>
<tr>
<td>10</td>
<td>(L)[T]+</td>
<td>Single ear</td>
</tr>
</tbody>
</table>

- Procedure
  o Single condition run at one time
  o Order randomized
  o Trials/condition = 10 sentences/block, 3 blocks = 30
  o CI subjects: Used clinical processors and adjusted level of stimuli in each ear to be equally loud. Performed all ten conditions.
  o NH subjects: Performed only odd or even number conditions.

- NH Subjects
  - There was no difference between the odd (attended to left ear) and even (attended to right ear) conditions, so data was pooled.
  - Thresholds 7.8 dB higher for selective attention (conditions 3 & 4) compared to baseline (single-ear, single-talker (conditions 1 & 2)).
  - Thresholds 24.8 dB higher for all conditions with energetic masking (conditions 6-10) compared to baseline (conditions 1 & 2), with no differences between those conditions.

- CI Subjects
  - CI subjects showed large individual variability compared to NH subjects.
  - Some CI subjects showed asymmetry in thresholds across ears.
    o Equal: IBM, IAJ
    o Good ear: IAJ (mostly), IBK, IBM, ICA
    o Bad ear: IBM, IAJ (mostly)

DISCUSSION
1. There was no difference in performance between attending to the right or left ear for NH subjects (Fig. 3). In contrast, CI subjects showed large and individual differences, consistent with many previous CI studies (Figs. 2 and 4).
2. Thresholds increased in selective attention conditions by 7.8 dB for NH subjects, 4.2 dB for CI subjects in their good ear, and 11.6 dB in their bad ear (Fig. 5). Caution should be taken in this comparison because of: A. Vastly different TMRs used between NH and CI subjects

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REFERENCES

For all subjects, all conditions showed an increase in threshold from baseline.
- On average, CI subjects show a 4.2 dB increase in threshold for selective attention in the good ear and a 11.6 dB increase in the bad ear (6 dB if IBR omitted).
- CI subjects also showed larger increases in threshold in the bad ear for conditions with energetic masking (conditions 5-10).

What could cause some bilateral CI listeners (see IBM, Fig. 2) to have difficulty attending to a particular ear? Perhaps the auditory system has a problem ignoring more robustly encoded signals. Future studies simulating asymmetric degradation in NH listeners may provide insight into this explanation.