Capacity of Consonant Recognition in Normal Hearing and Cochlear Implant Users
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Background

- Listeners often need to understand more than one talker at the same time.

- Listeners are not always listening to one talker at a time, or listening to two talkers simultaneously.

- But it is not impossible for normal hearing (NH) listeners to understand two short speech tokens in a limited context (e.g., monotonic words, digits or colors (Miller and Licklider, 1957) and as seen in dichotic listening experiments.

- In the present study, we approach this with the information theory in terms of channel capacity. What is listener’s capacity of identification of concurrent phonemes (particularly, consonants)?

Hypotheses (when two consonants are given):
The biggest challenge in CIs is peripheral separation of signals. Once they are separated, their performance of concurrent identification should be similar to that of NH.

CI users will show far poorer performance than NH in monaural listening but comparable performance in dichotic listening condition.

Methods

Presentation of “Double Consonants”

- Consonants from Shannon et al. (1999), [b p d t g k m n v f z s ð ð v j l r] in /Ca/ format, 6 talkers (3♂ 3♀) chosen

- Duration of the consonant portion: 50 — 150 ms

Presentation with temporal onset delay

- Two sounds were presented with either 0, 100, or 200 ms of temporal onset delay.

- Baseline condition: single consonants

- Number of trials: 1836 for double consonants (306 trials per ear × delay), 216 for single consonants

Subjects: 8 NH, 4 bilateral CI users (Nucleus)

Testing mode:

- NH in a sound booth with headphones.

- CI with direct stimulation with NIC2

Data Analysis:

- Relative Information Transmission (RIT) calculated for the baseline condition.

\[ R.I.T = \sum p_i \log \frac{P_i}{p_i} \]

(Miller, 1953)

- For double consonant conditions, two RITs from the constituent consonants were calculated and then summed. Perfect performance with double consonants would lead to RIT of 2 in this calculation.

Results

Table 1: Average Double Consonant RITs and their ratios to Single RITs (0-ms delay only)

<table>
<thead>
<tr>
<th></th>
<th>NH</th>
<th>CI</th>
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</thead>
<tbody>
<tr>
<td>Single RIT</td>
<td>0.92</td>
<td>0.70</td>
</tr>
<tr>
<td>Monaural RIT</td>
<td>1.19</td>
<td>0.77</td>
</tr>
<tr>
<td>B/A</td>
<td>1.29</td>
<td>1.09</td>
</tr>
<tr>
<td>Dichotic RIT</td>
<td>1.46</td>
<td>0.83</td>
</tr>
<tr>
<td>C/A</td>
<td>1.58</td>
<td>1.18</td>
</tr>
</tbody>
</table>

*Results for this study coincide with an earlier study with different materials and listeners (Kwon, 2001).

Fig 1. Raw consonant identification scores

Fig 2. RITs calculated from Fig 1

Fig 3. Dichotic advantage in RIT

Discussion

- NH listeners have an average capacity of identification about 1.3 consonants (when presented monaurally with 2 consonants having no onset delay).

- CI users seem to have less capacity to identify multiple consonants.

- This limited capacity does not seem solely due to difficulty in peripheral separation, as the capacity in dichotic listening is still poorer than NH.

- The cognitive process of speech perception in CIs might impose a higher load due to severely impoverished input at the periphery.

- Two issues in listening to speech with CI in competing sounds: 1) segregation and 2) higher cognitive load.

References


