The role of listening effort in mitigating rollover effects of speech-in-noise perception in cochlear implant users

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Introduction
The current best approach to treating profound hearing loss in older individuals is the cochlear implant, yet they are not perfect solutions for the wide range of auditory processing situations. Challenging listening conditions, such as listening to speech in noise, can vary across signal-to-noise ratio and at different sound intensities. Paradoxically, speech in noise presented at higher intensities may actually worsen behavioral performance, and this is known as the “Rollover” phenomenon. There is some evidence of rollover in CI users, but it is currently unknown how this phenomenon compares to individuals with acoustic hearing. Furthermore, it is unknown how effort plays a key role in listening when sound intensities increase and how it can potentially mitigate the effects of rollover in both acoustic listeners and cochlear implant users. Here we use a combination of pupillometry and behavioral perception paradigms to investigate how CI listeners utilize listening effort to aid speech understanding during rollover.

Background
Previous studies have found that CI users experience word presentation level effects with temporal contrasts. Older CI listeners required longer silence durations to correctly identify the word presented than younger CI listeners. In addition, these age-related differences were dependent on presentation level.

Hypotheses
- YNH listeners experience minimal rollover in noise and can compensate to give the same level of performance by expending effort
- Both OHI and CI listeners will experience perceptual rollover over in noise conditions at high intensities to different extents
- OHI listeners will expend effort for listening in noise to a lesser extent than CI listeners
- CI listeners will expend more effort in listening in noise to mitigate rollover effects at their maximum performance

Methods

**Experimental Task**
- 8 possible word pairs played either in quiet or in 6-talker babble noise (0 dB SNR)
- Presented at 35, 55, 65, 75, and 85 dB SPL
- Listening phase: Participants were asked to remember second word in word pair
- Response phase: Participants were asked to indicate the second word on-screen with key press (1 for Left word, 2 for Right word)
- EyeLink 1000 used to track pupil dilation and E-Prime to record behavioral responses

**Procedure**
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**Listeners**
- Acoustic Listeners:
  - Young (< 45 years, N = 6) and normal hearing (pure-tone thresholds of ≤25 dB HL from 0.25-4 kHz)
  - Older (≥ 45 years, N = 6) and hearing-impaired with mild-to-moderate hearing loss (between 30 dB and 60 dB HL from 0.25-4 kHz)
- CI Listeners:
  - Older (≥ 45 years, N = 10)
  - MoCA score ≥ 26
  - No history of visual-related health issues (e.g. glaucoma, untreated cataracts, etc)
  - No history of neurological disorders

Results

**Figure 1.** Behavioral performance on perceptual task involving discriminating between two words in the word pair presented in quiet (left) and in 0 dB SNR 6-talker babble noise (right). Rollover was not present in quiet, but did occur in noise conditions with an effect of level (p<0.05) for OHI and OCI listeners. Highest performance occurred for YNH (blue), followed by OHI (orange), and lowest performance in OCI (yellow) listeners. Behavioral performance differed significantly between groups (p<0.05) in noise. Dashed line indicates 50% chance performance. Error bars indicate SEM.

**Figure 2.** A) Pupilometry data for YNH listeners across presentation levels ranging from 35 – 85 dB SPL for quiet (orange) and noise (cyan) conditions. Curves are a function of pupillary dynamic range to avoid aging confounds. Note there are two peaks in pupil dilation following the onset of the stimulus (listening) phase and the response phase (grey vertical lines). Shaded error bars indicate SEM. **B** *P* *M* *E* *G* **C** *E* *M* *I* *L* *I* 

Discussion

- **Behavioral data** (Fig. 1) show that CI users struggle much more with speech intelligibility in noise than acoustic listeners despite increased audibility
- **CI users perform above chance level** (Fig. 1) demonstrating that even at 0 dB SNR, they can perform the task
- **Pupillometry results** (Fig. 2) show that CI users expend much more effort to perform the task compared to their acoustic counterparts
  - CI users experience rollover in a different manner than acoustic listeners with potentially different neural and device-related mechanisms
- **OHI listeners experience the largest dropoff in perceptual rollover** and it is unclear whether hearing aids will be beneficial in mitigating rollover (Fig. 1)

Future Directions

- **Test older normal-hearing participants to determine whether there is an aging component**
- **Combine pupillometry with simultaneous EEG cortical recordings to determine neural mechanisms and how they differ across age and hearing status**
- **Distinguish between how different types of word pairs elicit differential behavioral and effort responses**

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