Cognitive Load in Normal Hearing Individuals Listening to Cochlear Implant Simulations

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INTRODUCTION

Benefits of listening with two ears

1) Head shadow effects allow listeners to take advantage of the ear with the better signal-to-noise ratio in order to benefit ("better-ear benefit").
2) Binaural hearing mechanisms provide benefits to listeners through the integration and comparison of signals between ears.

Single-sided deafness (SSD)

SSD refers to patients having one normal hearing ear and one deaf ear.

- Patients with SSD are at a disadvantage because they cannot readily access the better-ear benefit or binaural cues.
- Numerous studies have shown that individuals with SSD who receive a **cochlear implant (CI)** in their deaf ear can benefit from head shadow effects.[8]
- Recently, Bernstein et al. (2016) demonstrated that they can also re-gain access to ***some*** binaural hearing benefits, resulting in improved speech perception in noise.[2]

Listening effort

"Listening Effort is a component of auditory perception involving cognitive processing or cognitive load." [9]

- As tasks get harder (e.g. sentence complexity increases, maskers are more similar to target) and cognitive load increases, pupil size also increases.[5, 10]

Individuals with hearing loss experience elevated amounts of effort when listening and trying to understand speech, and this is associated with adverse effects, like fatigue and early retirement.[1,3,4,9]

Pupillometry can be used to objectively quantify changes in listening effort during cognitively demanding tasks (e.g. listening to speech in noise) by capturing changes in pupil dilation.

PURPOSE OF THIS STUDY

To explore whether binaural hearing can facilitate a release from listening effort and improve speech understanding in:

1) Individuals listening to two normal hearing ears.
2) Individuals listening to one normal hearing ear and a CI-simulation in the other ear to simulate the experience of individuals with SSD.

METHODS

Normal hearing (NH) participants

- TGQ (25 y/o), TOD (25 y/o), TQF (23 y/o), TQJ (20 y/o)

*Participants passed a hearing screening (20 dB HL at octave frequencies from 250-8000Hz).

Stimuli

- Target (T): Harvard IEEE sentences[6] spoken by a female.
  - E.g., "The juice of lemons makes fine punch."
- Maskers (M): AzBio sentences[7] spoken by a different female than targets.
  - E.g., "You must live in a gingerbread house."

Procedure

- Participants sat in a soundproof booth with their head in a chin rest.
- They were instructed to fixate their gaze on a small cross in the center of the computer screen and repeat target sentences.
- Stimuli were presented over circumaural headphones.

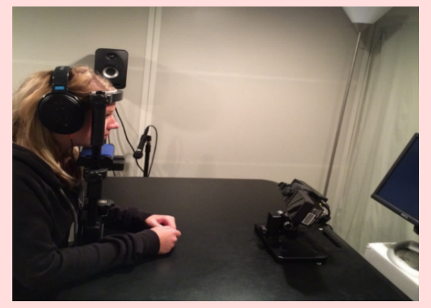


Fig. 1. Participant's head in chin rest.

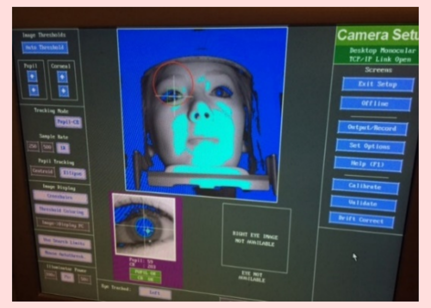


Fig. 2. Examiner's view of EyeLink's infrared camera.

- Auditory stimuli were presented in 1 of 3 conditions at a signal-to-noise ratio of -5 dB SPL.
- Speech intelligibility and pupil dilation were recorded 5 seconds before the stimulus onset until the offset of the listener's response.
- 32 trials were collected per condition and were averaged together to create pupil tracks.

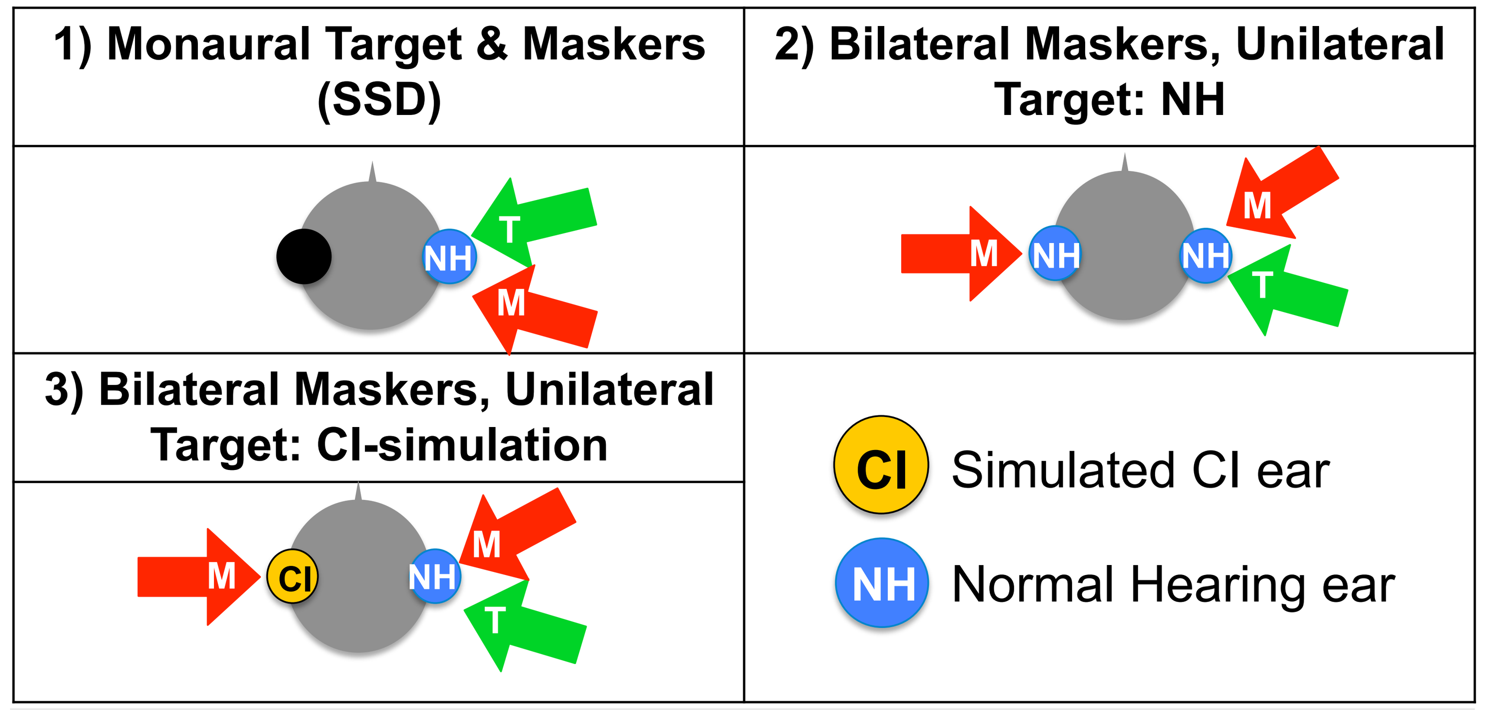


Fig. 3. Listening conditions

- Bilateral conditions (2 & 3 above): maskers were presented to both ears simultaneously.
- CI condition (3 above): maskers presented to non-target ear were processed using a CI-simulation (8-channel noise vocoder).
- This paradigm ensured that any improvement in speech understanding could only be attributed to binaural hearing and not to better-ear benefit.

RESULTS

Improvement in speech understanding from binaural hearing

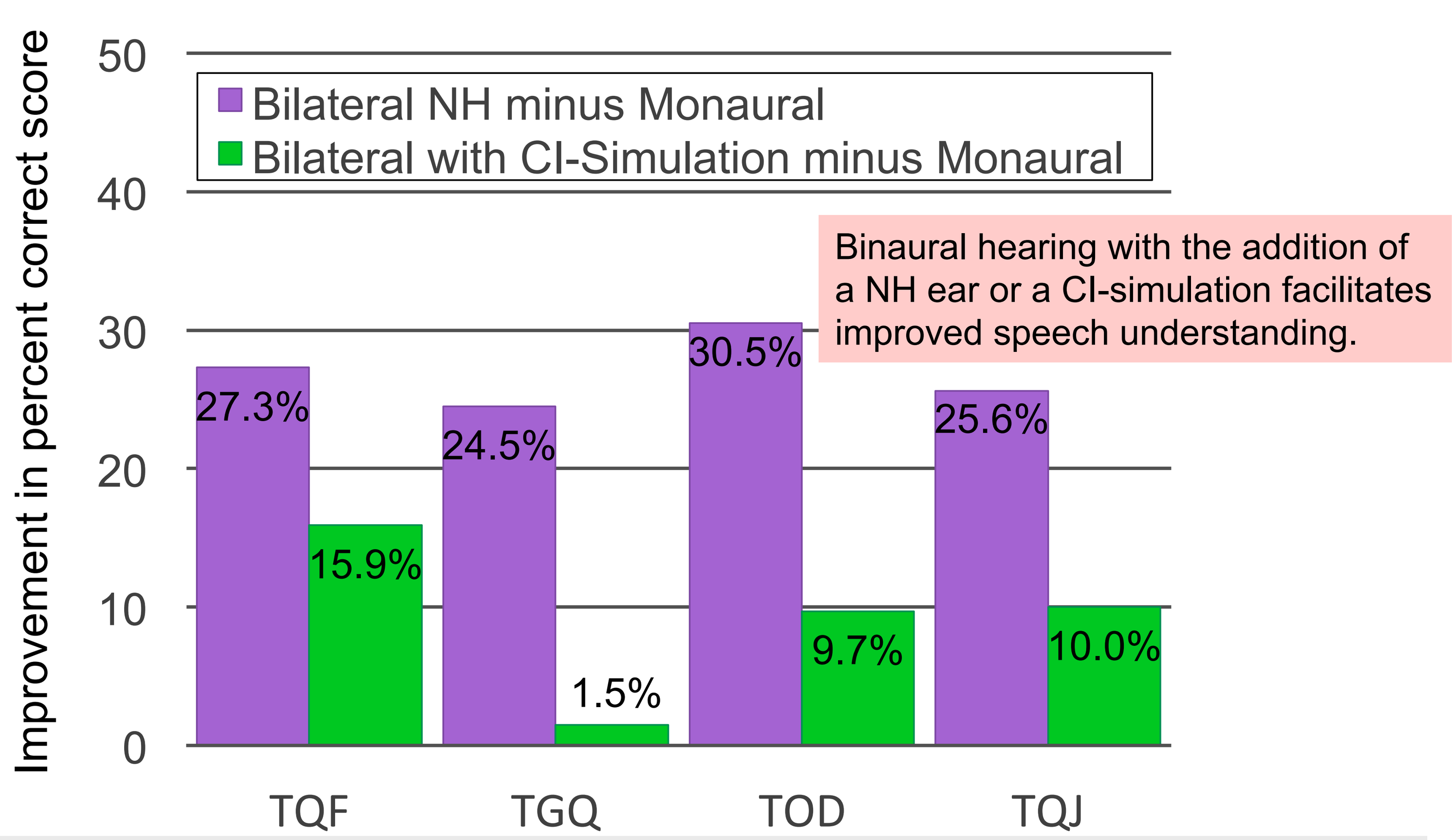
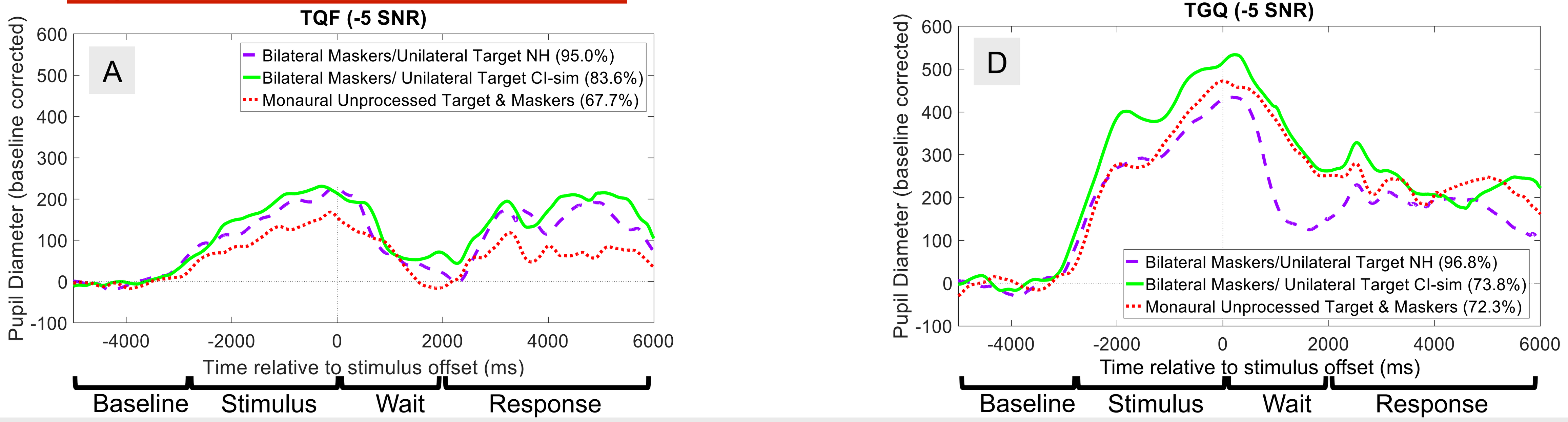


Figure 4. The amount of improvement in speech intelligibility (percent correct) from the monaural condition to each bilateral condition for each participant.

Pupil dilation as a function of time



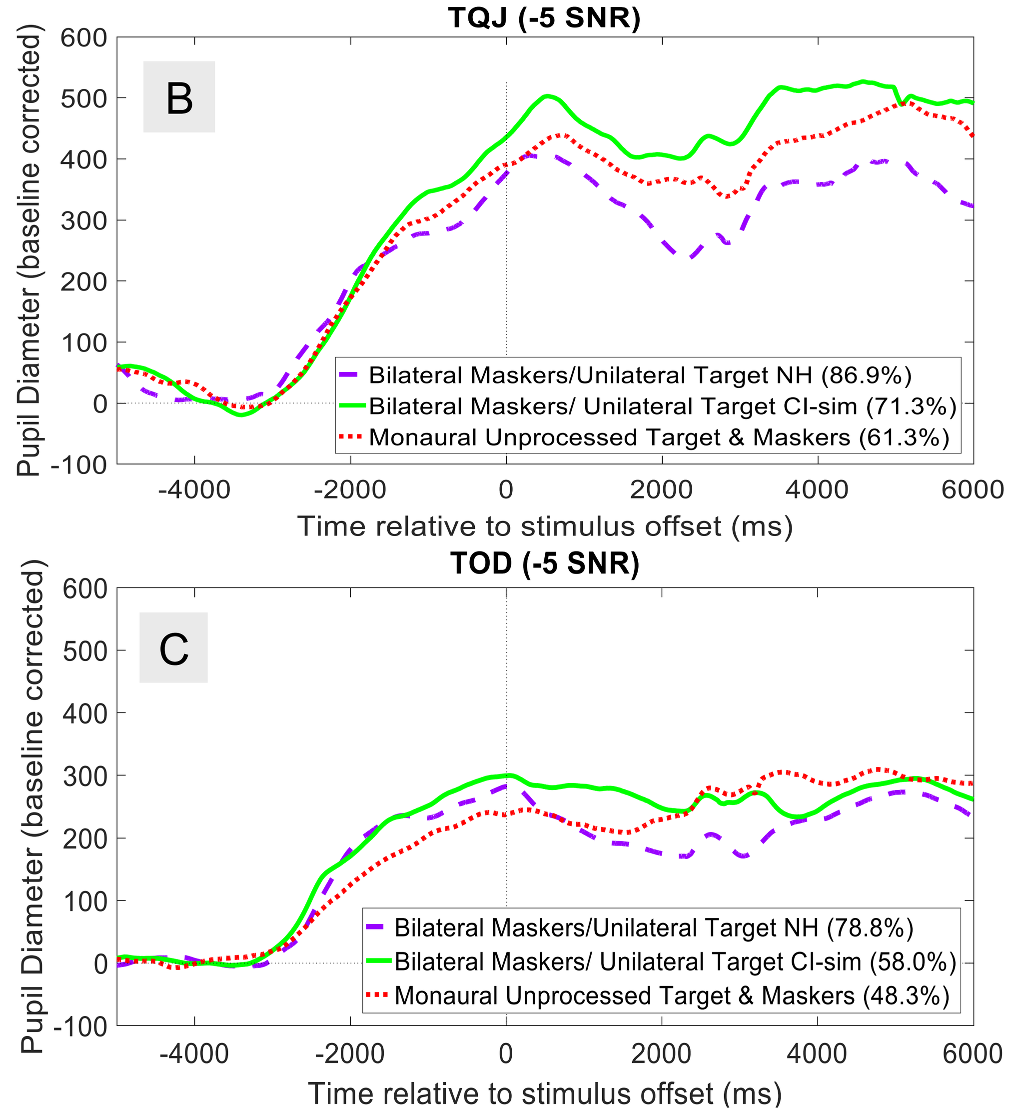


Figure 5 (Panels A-D). Changes in pupil dilation averaged across trials for each condition. Raw percent of correctly identified words are shown in parentheses for each participant.

DISCUSSION

- Results indicate that adding a copy of the maskers to the second ear improves speech intelligibility scores in both bilateral conditions.
  - However, improvement decreases when the input to the second ear is degraded with a CI-simulation.
- All 4 participants exerted the most effort in the bilateral CI-simulation condition, suggesting that integrating input from a NH ear and a CI-simulation may require additional cognitive load than listening with either two NH ears or just one ear alone.
- 3 out of 4 participants (TQJ, TOD, TGQ) showed a release from effort in the bilateral NH condition compared to the monaural, suggesting that listening to speech-in-noise with two NH ears requires less effort than just one ear alone.

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