# Simulating Speech Perception in Bilateral Cochlear Implant Users With Asymmetric Input

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## INTRODUCTION

- ❖ A cochlear implant (CI) is an auditory prosthesis surgically implanted in the skull and inner ear that provides auditory stimulation by means of electrical signals. One of the biggest challenges CI users face is understanding speech in noisy environments (e.g., Nascimento & Bevilacqua, 2005).
- ❖ The ability to understand speech in background noise relies heavily on binaural hearing (hearing with two ears). This provides benefits such as binaural interaction, which allows the listener to perceive spatial separation between the target speech from the interfering sound (Bernstein et al., 2016).
- ❖ The goal of bilateral implantation is to provide the CI user with similar benefits (such as binaural interaction) that a normal-hearing individual would have with their two ears. However, bilateral implantation does not necessarily improve patients' abilities to utilize these binaural advantages. One of the reasons for this is because asymmetries between the devices causes the integration—or fusion—of a single signal across the two devices to be more difficult (Eisenberg & Goupell, 2013).
- ❖ There are several causes of asymmetries in bilateral CIs (BiCI). For the purposes of this experiment we focus on asymmetric levels of signal clarity, which can result from greater nerve damage of one auditory pathway compared to the other due to factors such as uneven durations of deafness (Leake et al., 1999).
- ❖ Data from a recent study examining BiCI users' ability to integrate dichotic alternating speech using their binaural hearing showed that several participants were only preforming as well as the limits of their better ear allow; this suggested that asymmetries across their CIs was significantly limiting binaural benefits (Peng et al., 2019).
- ❖ This project aims to examine how asymmetrical speech clarity across the two ears affects bilateral CI users' speech understanding. Specifically, we examine the extent to which normal-hearing listeners presented with a CI simulation use selective attention when listening to alternating speech and focus on their "better ear" (i.e., the ear provided with better spectral resolution) in asymmetrical speech clarity conditions.
- ❖ **Hypothesis & Predictions**: The hypothesis is that normal-hearing participants will show selective attention to the ear with the clearer signal, and largely ignore information from the ear with the more degraded, less clear signal; this would support the idea that poor performance in alternating speech tasks among CI users may be driven by the effects of asymmetrical bilateral hearing.

## METHODS

**Experimental Conditions**

- ❖ Dichotic: The speech signal is alternated between two ears at various switch rates
  - ➢ Symmetric conditions: Speech presented with 16 channels in the right ear and 16 in the left; 8 channels in the right ear and 8 in the left
  - ➢ Asymmetric conditions: 8 channels in the right ear and 16 in the left and vice versa
- ❖ Monotic: The speech signal is presented to one ear only and is *interrupted* at the same switch rates

**Stimuli**

- ❖ A total of 320 IEEE sentences presented at alternation rates of 0, 4, 8, and 16 cps per subject; 10 sentences per cps condition
- ❖ 8 or 16 channel noise vocoder (0.2 to 4 kHz; low pass filter cutoff at 50 Hz)

**Participants**

- ❖ Young normal-hearing participants were tested (N=6; 20-22 yr)
  - ➢ Audiometric screening at ≤25 dB HL between 125 to 4000 Hz
  - ➢ >22 on Montreal Cognitive Assessment (MoCA)

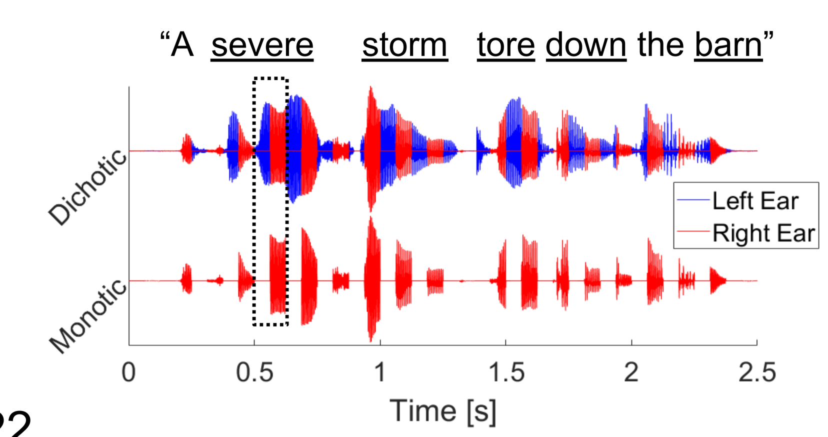


Figure 1. Visualization of the sample sentence with the dichotic (binaural) condition versus the monotic (monaural) right-ear condition. In this example, the switch rate is at 8 cps (adapted from Peng et al., 2019).

## RESULT 1: Control

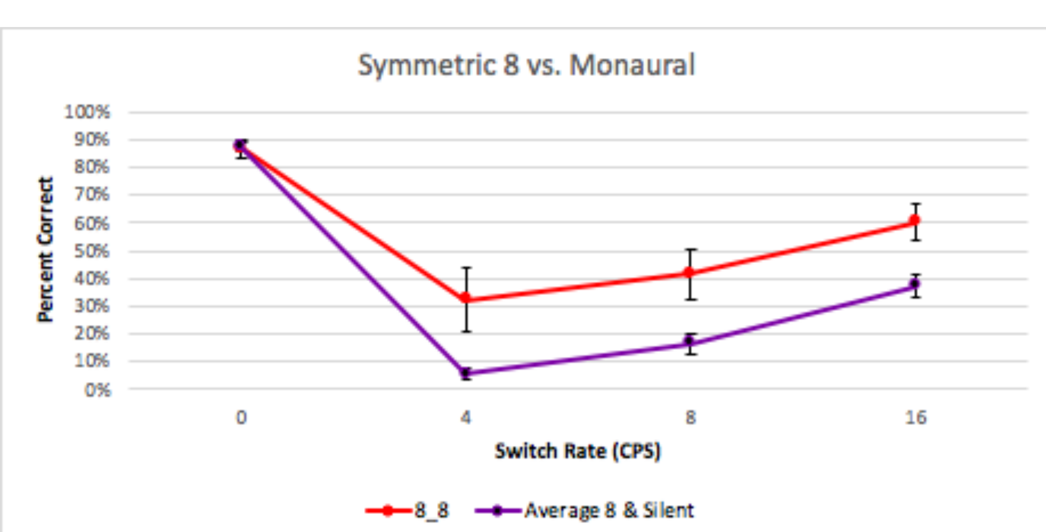


Figure 2. Percent correct results at each switch rate for the symmetric 8 channel condition (red) and the the monaural 8 channel condition (purple) are presented. 8_8 refers to the presentation of 8 channels in the left ear and 8 channels in the right ear. "Average 8 & silent" refers to the average scores between the monaural condition where the right ear receives 8 channels and the left receives no stimuli ("silent") and vice versa. Error bars refer to the standard error

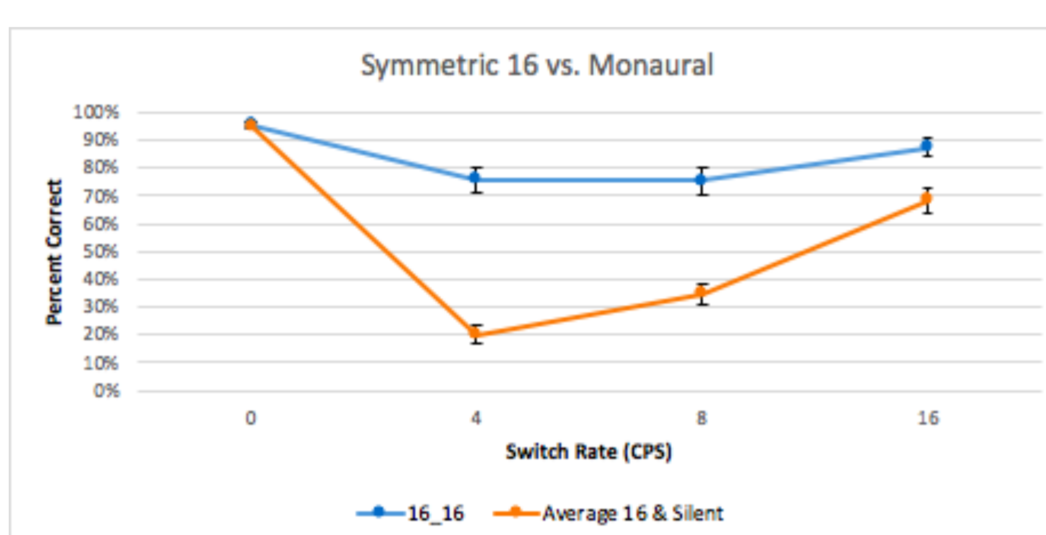


Figure 3. Same as Figure 2 but for the comparison between symmetric 16 channel condition (blue) and the average between the monaural 16 channels and silent condition in both the left and right ears (orange).

- ❖ Averaged across all participants' scores, the symmetric 8 vs. monaural conditions (Figure 2), were not statistically significantly different from each other (p=0.109). However, the symmetric 16 vs. monaural conditions (Figure 3) were statistically significantly different from each other (p<0.001); performance in the symmetric condition was higher overall across switch rates compared to the monaural condition.
- ❖ These two analyses were done to emphasize the poor intelligibility performance that the monaural conditions yield.
  - ➢ Depending on the switching rate, these monaural conditions have missing information of up to half of the speech content within a sentence.
  - ➢ These control conditions are important to note because we want to emphasize that the high intelligibility results from the asymmetric condition (Figures 4 and 5) are not due to participants' ability to simply "fill in the gaps" of what they supposedly cannot hear had they only been attending to the "better-ear".

## RESULT 2: Better Ear vs. Asymmetric

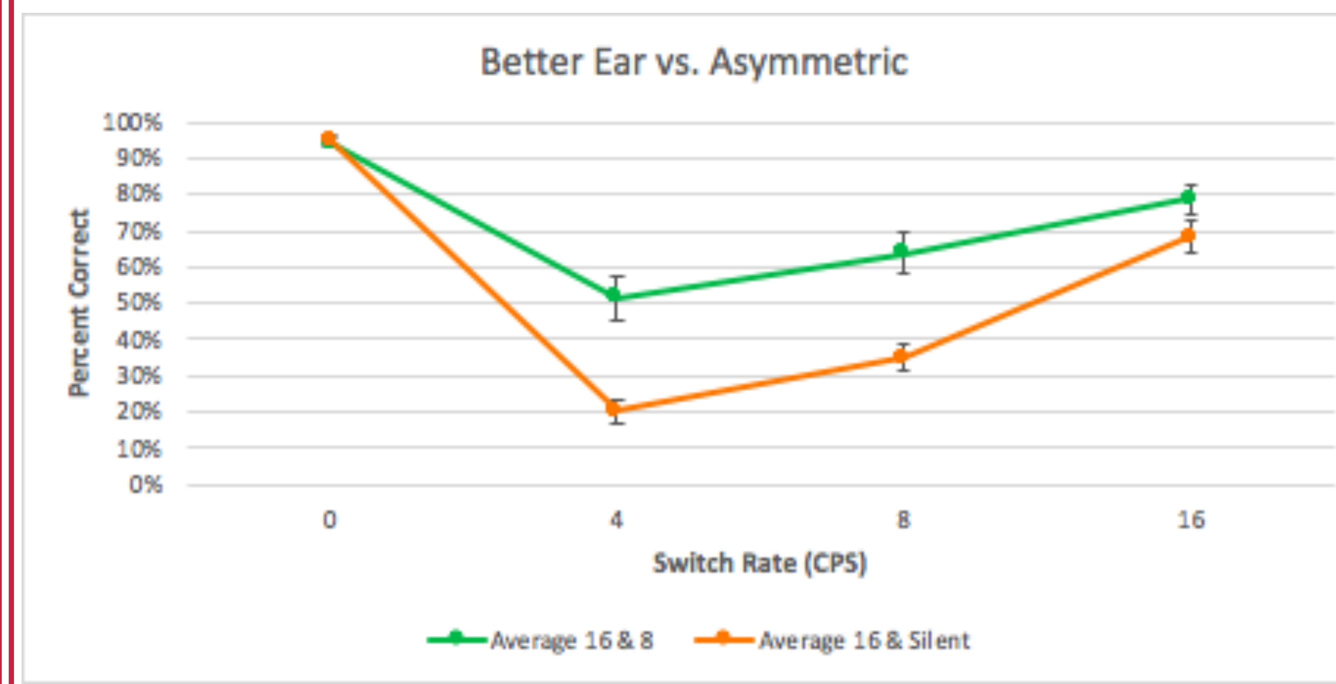


Figure 4. Same as Figure 2 but for the comparison between the average of the asymmetric 16 & 8 channel condition (green) and the average between the monaural 16 channels and silent condition (orange).

- ❖ Primary analysis for experiment.
- ❖ There is substantial gain with the additional eight channels in the asymmetric condition
  - ➢ Performance in the asymmetric condition was higher overall across switch rates compared to the better ear condition (p=0.008).

## RESULT 3: Symmetric vs. Asymmetric

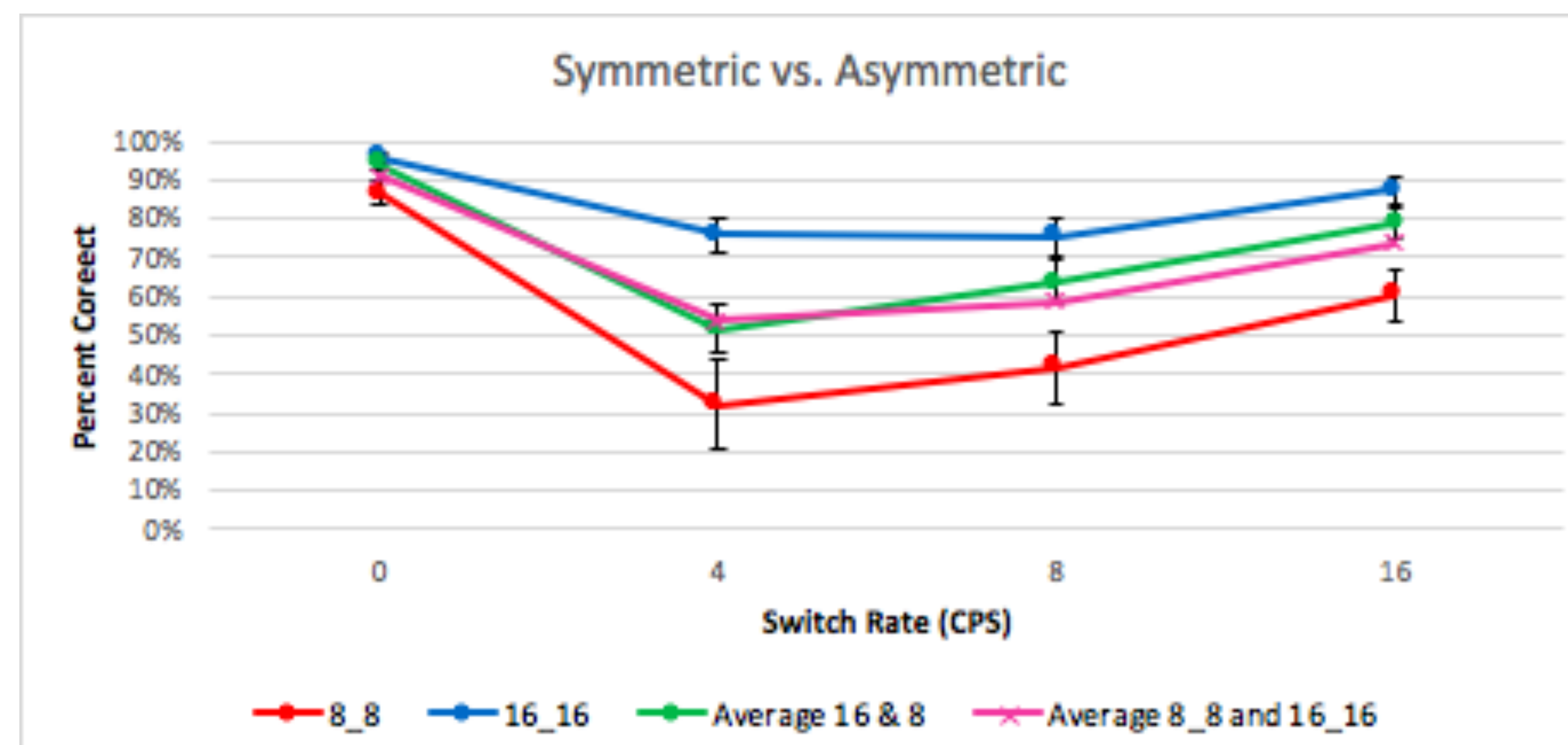


Figure 5. Same as Figure 2 but for the comparison between the symmetric and asymmetric conditions. The two symmetric conditions are indicated in red (8 channels in both ears) and in blue (16 channels in both ears). The asymmetric condition is indicated in green and is the average of 16 channels and 8 channels in either ear. The pink line with the x indicates the calculated average of both symmetric conditions.

Since participants are not selectively attending to their "better-ear", Figure 5 provides more insight into what is actually occurring:

- ❖ The average score of both symmetric conditions is almost precisely the same as the asymmetric condition (green line vs. pink line).
  - ➢ This shows that there is essentially no loss of information due to the switching of attention across different levels of degradation in either ear.
  - ➢ Therefore, participants had no difficulty with this task of integrating asymmetrically degraded signals

## CONCLUSIONS

- ❖ There is no evidence that that the participants are ignoring the more degraded signal and focusing only on the "better ear" (Figure 4); therefore we can reject the hypothesis that participants will largely ignore information from the ear with a more degraded signal.
- ❖ Normal-hearing participants had little to no difficulty integrating the signals with mismatched levels of degradation (Figure 5); therefore we can expect that there are other factors (such as distortion due to frequency-to-place shift, or shifted placement of the electrode) contributing to the perceived deficits seen in CI participants from Peng and colleagues' study.

## Future Directions

- ❖ Based off of this study, I am currently developing a new project for my honors thesis that examines asymmetries caused by interaural mismatch due to unmatched placements of the electrode array across ears. This study aims to establish whether CI programming methods of current standard clinical practice can be adjusted to improve asymmetries across ears, thus improving listeners' ability to integrate dichotic signals and benefit from binaural interaction.

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