# Does degree of speech asymmetry modulate bilateral speech intelligibility and listening effort in adults with bilateral cochlear implants and adults with normal hearing?

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*2019 Conference on Implantable Auditory Prostheses, Lake Tahoe, CA*

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## INTRODUCTION

- Many bilateral cochlear implant (BiCI) listeners demonstrate asymmetries in speech intelligibility across ears.
- **Dynamic range** (DR) is influenced by degree of hearing loss and electrode array insertion, and across-ear differences in DR could contribute to these performance asymmetries.[4,5]
- Additionally, BiCI users report elevated listening effort, which gives rise to stress, fatigue, and social withdrawal.[1,2,3]

## PURPOSE

**Experiment 1:** Determine impact of asymmetric speech intelligibility on bilateral *speech intelligibility* and *listening effort* in individuals with BiCIs.

**Experiment 2:** Explore role of asymmetric DR on *speech intelligibility* and *binaural performance* in normal hearing (NH) individuals listening to vocoded speech.

## METHODS

### Participants

- 12 adults with BiCIs; 4 adults with NH

### Stimuli

- Target (T): Harvard IEEE sentences spoken by a woman.
- Masker (M): AzBio sentences spoken by a woman or modulated speech-shaped noise (SSN).
- Stimuli were presented at 65dB SPL-A.

### Task

- Listeners repeated target sentences and responses were scored by an experimenter.
- Each sentence had five key words, which were scored individually.
- Participants completed 30 trials per condition.

*"The juice of lemons makes fine punch."*

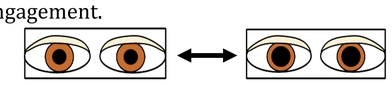
Example of target sentence with key words underlined.

| Subject ID | Age (yrs) | Better ear | Inter-implant delay (yrs) | BiCI experience (yrs) |
|---|---|---|---|---|
| IDI | 52 | Right | 0.6 | 4.6 |
| ICW | 25 | Right | 18.6 | 4.9 |
| ICP | 56 | Left | 3.1 | 7.0 |
| ICK | 75 | Left | 1.0 | 7.2 |
| IBY | 55 | Right | 4.2 | 7.3 |
| IDG | 70 | Right | 2.0 | 7.7 |
| ICJ | 69 | Right | 0.0 | 8.8 |
| IBK | 78 | Left | 6.0 | 9.8 |
| ICD | 61 | Left | 6.0 | 10.0 |
| IBZ | 51 | Right | 1.3 | 11.0 |
| IBL | 72 | Right | 4.8 | 12.8 |
| ICB | 67 | Left | 2.8 | 12.9 |

Table 1. BiCI participant demographics (ordered by years of bilateral experience).

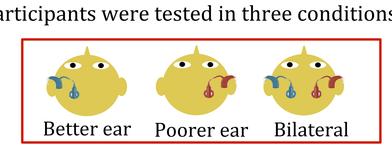
### Experiment 1 procedure: BiCI listeners

- Speech intelligibility and pupil dilation were measured.
- Pupil size is a correlate of listening effort/ engagement.



Less effort or engagement — More effort or engagement

- Stimuli were presented from a loudspeaker at 0° azimuth in quiet.
- Ear with higher word recognition score was labeled the "better ear." If there was no difference, preferred ear was labeled the "better ear."
- Participants were tested in three conditions:




- Pupil data was analyzed as proportion change from baseline (moment before stimulus onset).
- Peak pupil dilation during post-stimulus wait period was used to compare effort across conditions (blue region on Fig. 1).[6]

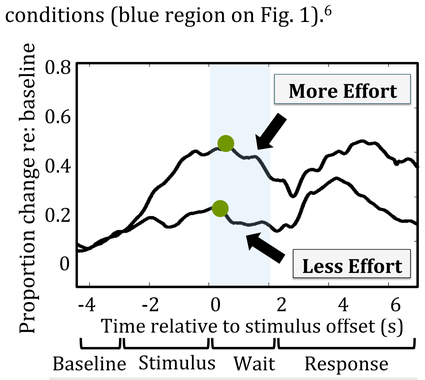
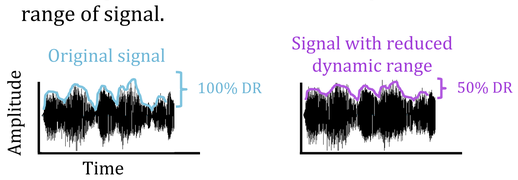



Figure 1. Example of two pupil tracks. Green dots indicate peak during wait period for each track.

### Experiment 2 procedure: NH listeners

- Speech intelligibility was measured.
- Stimuli were processed with a 16-channel sine wave vocoder and presented over headphones.
- All masker/noise conditions were presented at a signal-to-noise ratio (SNR) of +5 dB. Two subjects (TPA & TZV) were also tested at 0 dB SNR on three conditions.
- Temporal envelope of signal in one or both ears was compressed in Praat to reduce dynamic range of signal.




- Participants were tested in ten conditions:

| Conditions | | |
|---|---|---|
| | DR target ear | DR contra ear |
| Unilateral target  | 100%, 75%, 50% | x |
| Unilateral target/masker  | 100%, 75% | x |
| Unilateral target +bilateral masker  | 100%, | 100%, 75%, 50% |
| | 75% | 75% |
| Unilateral target/masker + contralateral SSN (control)  | 100% | 100% |

- Binaural unmasking (squelch) was calculated in order to examine the effect of asymmetric DR on binaural performance in NH listeners.

## EXPERIMENT 1: BiCI RESULTS

Does speech asymmetry influence bilateral speech intelligibility and/or pupil dilation in quiet?

| Subject ID | IBY | IBZ | IDI | IBK | ICD | IDG | ICB | ICP | ICK | IBL | ICW | ICJ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Speech Asymmetry=**% correct better ear - % correct poorer ear | 0% | 3% | 4% | 7% | 10% | 12% | 12% | 21% | 22% | 45% | 53% | 55% |

**Red=no** significant difference across ears
**Purple=**significant difference across ears

Table 2. Speech asymmetry across ears. Differences across ears were determined using 95% confidence intervals for each ear within-subjects.

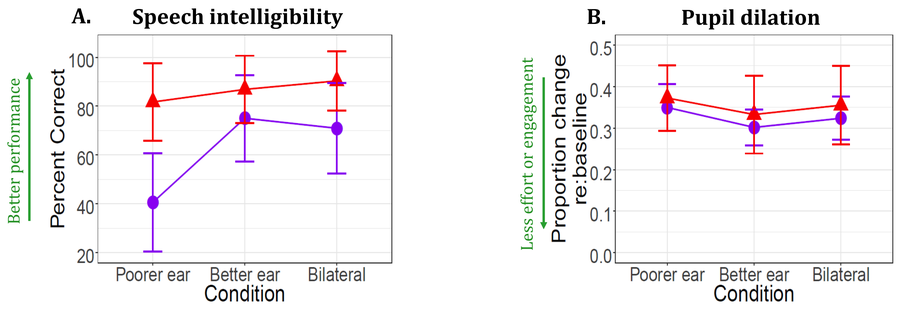



Figure 2A: Mean speech intelligibility and 2B: mean peak pupil dilation for red and purple groups. Error bars represent standard error (SE).

**Figure 2A:**
- Red group: High performance in all listening conditions.
- Purple group: Lower performance in poorer ear and bilateral conditions compared to red group; worst performance in poorer ear condition.

**Figure 2B:**
- No differences in pupil dilation across any conditions within or between groups.

## EXPERIMENT 2: NH RESULTS

Does reduced DR contribute to performance asymmetries or influence binaural performance?

**Unilateral conditions: reduced DR resulted in decreased intelligibility in quiet and with masker**

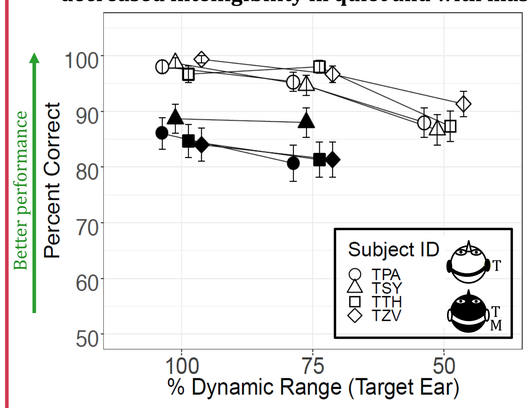



Figure 3. Individual subject intelligibility scores for unilateral conditions. Error bars represent SE.

**Figure 3:**
- *Target only:* Intelligibility decreased when DR was reduced from 75% to 50%.
- *Target/Masker*: Performance was worse with masker; intelligibility decreased with reduced DR.

**Figure 4:**
- Performance was high for all bilateral conditions at +5 dB SNR.
- Contralateral presentation of SSN resulted in lowest intelligibility.

**Bilateral conditions: intelligibility was high for all masker conditions (+5 dB SNR)**

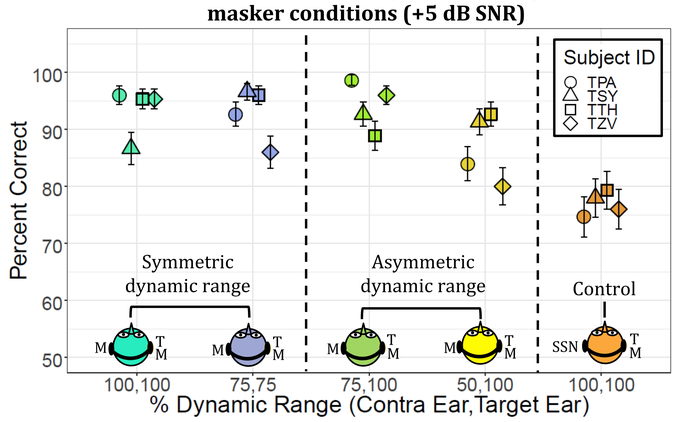
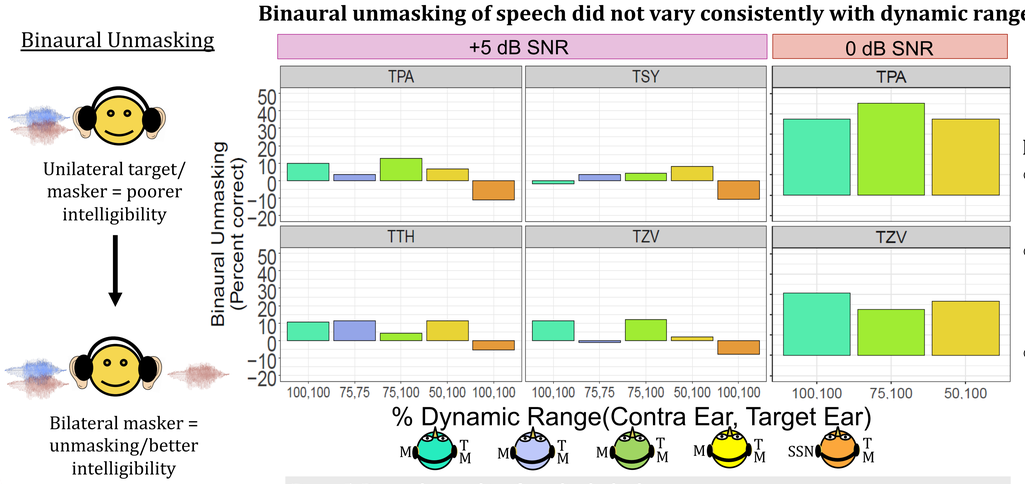



Figure 4: Individual subject intelligibility scores for each masker condition. Error bars represent SE.

**Binaural unmasking of speech did not vary consistently with dynamic range**




**Binaural unmasking** = M/N

Figure 5: Binaural unmasking for individual subjects.

**Figure 5:**
- *0 dB SNR*: Substantial unmasking for all conditions; degree of DR asymmetry did not affect amount of unmasking.
- *+5 dB SNR:* Less unmasking with reduced DR in both ears (purple) compared to asymmetric DR (yellow & green).
- When contra noise is not coherent with ipsi noise (see SSN results), there is *increased* masking rather than unmasking.

## SUMMARY

**Experiment 1:**
- BiCI listeners with large asymmetries (purple group) demonstrated worse performance in the poorer ear and bilateral conditions than those with small asymmetries, while better-ear performance was similar for both groups. This suggests that the benefits of BiCIs may depend on the difference in performance across ears or possibly how poor the worse ear is.
- The poorer ear condition elicited the largest pupil dilation for both groups, but the difference was not significant. This task did not reveal a clear relationship between asymmetric speech intelligibility and pupil dilation in BiCI listeners.

**Experiment 2:**
- Preliminary results from four NH listeners suggest that reduced dynamic range can impair speech intelligibility, but performance was still very high (~90% correct) even when the dynamic range of the signal was reduced to 50% of the original signal (Figure 3).
- The condition with the largest asymmetry elicited sizeable unmasking, but when dynamic range was decreased to 75% in both ears, the amount of unmasking was smaller (Figure 5). This may suggest that overall degradation of the signal affects unmasking more than asymmetries across ears.

[1]Litovsky, R., Parkinson, A., Arcaroli, J., & Sammeth, C. (2006). Simultaneous bilateral cochlear implantation in adults: a multicenter clinical study. *Ear and hearing*, *27*(6), 714-31.
[2]Hughes, S. E., Hutchings, H. A., Rapport, F. L., McMahon, C. M., & Boisvert, I. (2018). Social connectedness and perceived listening effort in adult cochlear implant users: A grounded theory to establish content validity for a new patient-reported outcome measure. *Ear and hearing*, *39*(5), 922-934.
[3]Edwards, B. (2007). The future of hearing aid technology. Trends in amplification, 11(1), 31-45.
[4]Bierer, J. A. (2010). Probing the electrode-neuron interface with focused cochlear implant stimulation. Trends Amplif., (14(2), 84-95.
[5]Oxenham, A. J., & Bacon, S. P. (2003). Cochlear compression: Perceptual measures and implications for normal and impaired hearing. Ear Hear., 24(5), 352-366.
[6]Winn, M. B., & Moore, A. N. (2018). Pupillometry reveals that context benefit in speech perception can be disrupted by later-occurring sounds, especially in listeners with cochlear implants. *Trends in hearing*, *22*, 2331216518808962.

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**ACKNOWLEDGEMENTS**: We would like to thank all of the individuals who participated in this study. This work was supported by NIH-NIDCD (R01DC003083 to RYL) and in part by NIH-NICHD (U54HD090256 to Waisman Center).