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Auditory motion perception in normal hearing listeners and bilateral cochlear implant users

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1. Introduction

- Bilateral cochlear implant (**BiCI**) users have poorer localization ability than normal hearing (**NH**) listeners [1,2].
- NH listeners have access to a full range of acoustic cues, such as interaural time and level differences (ITDs and ILDs) [3].
- However, BiCI users have limited access to interaural cues (specifically ITDs), which is likely to degrade localization abilities [4,5].
- Traditionally, localization experiments have utilized mainly static sounds, which does not test the ability of BiCI users to localize a moving sound.

The aims of the present study were:

1) To investigate the auditory motion perception abilities of BiCI users.
2) To compare the auditory motion perception abilities of BiCI users and NH listeners.

2. Stimulus

Binaural Recordings

- Auditory motion was simulated across an array of loudspeakers (Fig. 1) using Vector Base Amplitude Panning techniques [6].
- Stationary and moving sounds were white noise tokens similar to the input range of the Cochlear Ltd processors.
- Recordings were made with binaural microphones placed in the ears of a KEMAR manikin at 19 target locations in azimuth spanning -90° to +90° in 10° intervals.
- Dynamic ITDs were verified by performing short duration cross-correlation functions on binaural recordings (Fig. 2).

Stimulus conditions

Duration	Motion
2000 ms	40º range at 20º/s
	20º range at 10º/s
	10º range at 5º/s
	Static
1000 ms	40º range at 40º/s
	20º range at 20º/s
	10º range at 5º/s
	Static
500 ms	40º range at 80º/s
	20º range at 40º/s
	10º range at 20º/s
	Static

Fig. 1. An array of 37 loudspeakers separated by 5° in azimuth (-90° to +90°).

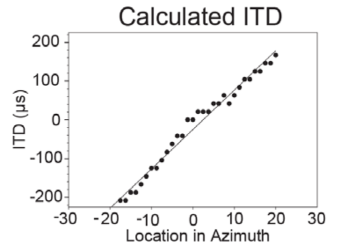


Fig. 2. Calculated ITDs for a sound moving from -20° to 20° across the midline. The solid line represents a linear regression (R^2 = .98).

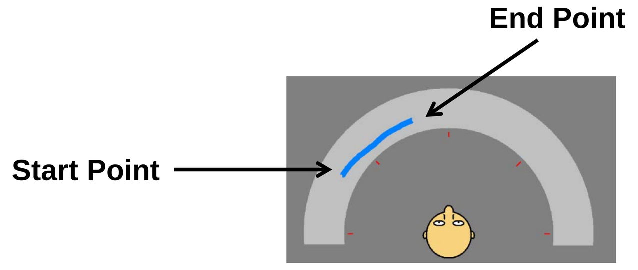
3. Auditory Motion Perception Experiment

NH Testing

- Five NH listeners were presented the stimuli via Sennheiser HD 600 circumaural headphones.

BiCI Testing

- Four BiCI users were tested using their everyday processor settings.
- Prior to testing, processor volumes and sensitivity were set to ensure a perceived centered auditory image at 0° azimuth.
- Binaural stimuli were presented directly to auxiliary input ports.



ID	Age (yrs.)	Sex	Bilateral CIs (yrs.)	Processors	
				Left	Right
IBL	68	F	10	N5	N6
ICD	57	F	7	N6	N6
ICP	52	M	3	N5	N5
ICZ	20	M	7	N5	N5

Instructions

- Participants were asked to indicate the perceived trajectory of the stimuli on a graphical user interface.
- Moving responses were denoted as a line (as seen to the left). A static response would be denoted as a single touch on the screen where the location of the sound source was perceived.
- Static and moving sounds for the same duration were presented randomly within a single block.

4. Results

Localization Performance

- The NH listener's localization ability was comparable for the start and end point locations of the moving sounds, and static sounds (Figs. 3a & 3b).
- In comparison to the NH listener, the BiCI user had larger localization errors when indicating the start and end locations for a moving sound compared to their static conditions (Figs. 3a & 3b).

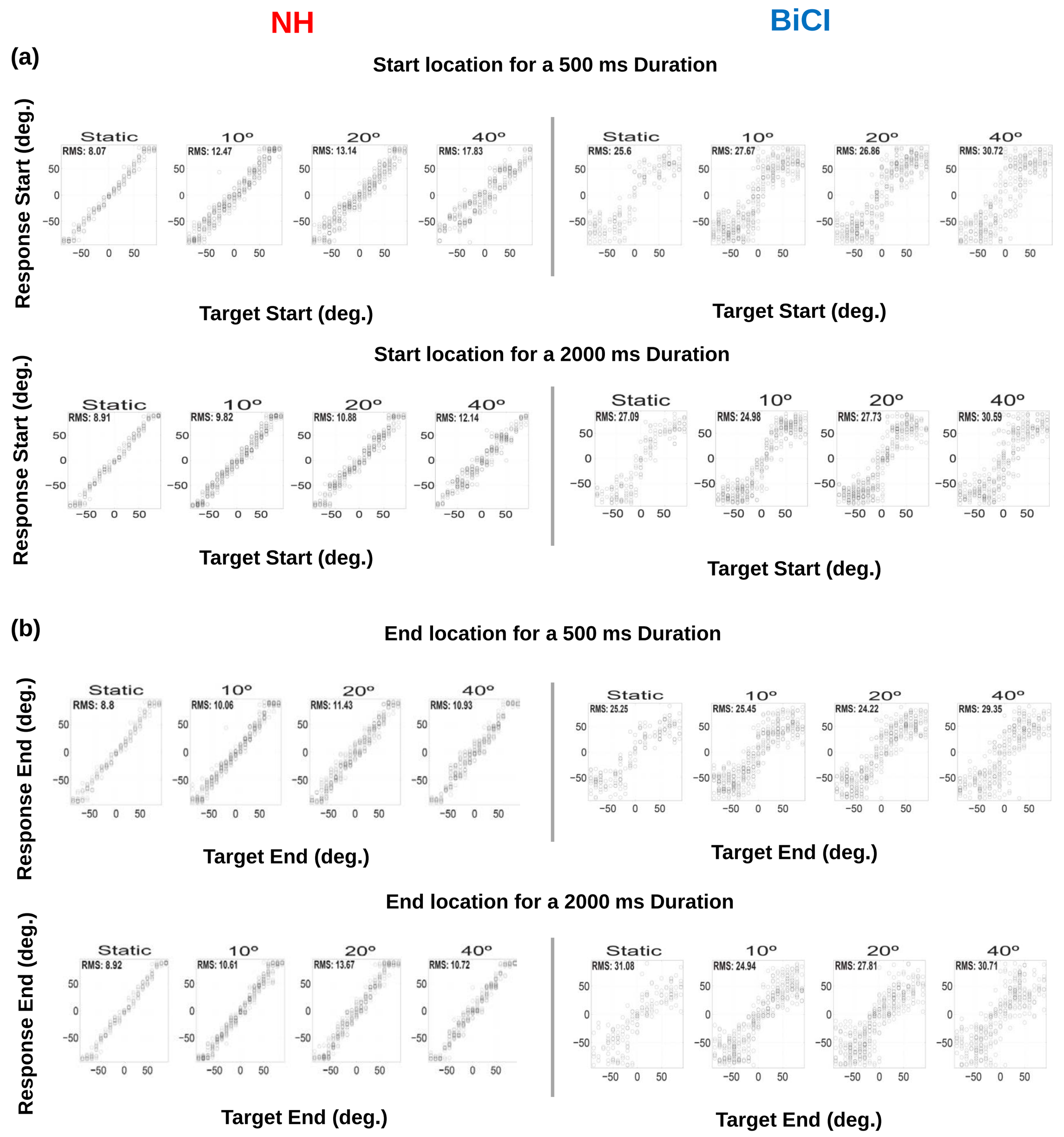


Fig. 3. Shows one NH listener's and one BiCI user's localization of the (a) start and (b) end locations for two different durations. Root mean square (RMS) errors are shown in the corner of each plot.

Directional Response Performance

- Static sounds were perceived as mostly static by the NH listener but not the BiCI user.
- At short angular ranges (10° and 20°), the NH listener was confused as to whether the sound was static or moving. In contrast, the BiCI user was confused about both direction and motion.
- At long angular ranges (40°), the NH listener was able to report the correct direction, regardless of duration. In contrast, some confusion still occurs for the BiCI user.

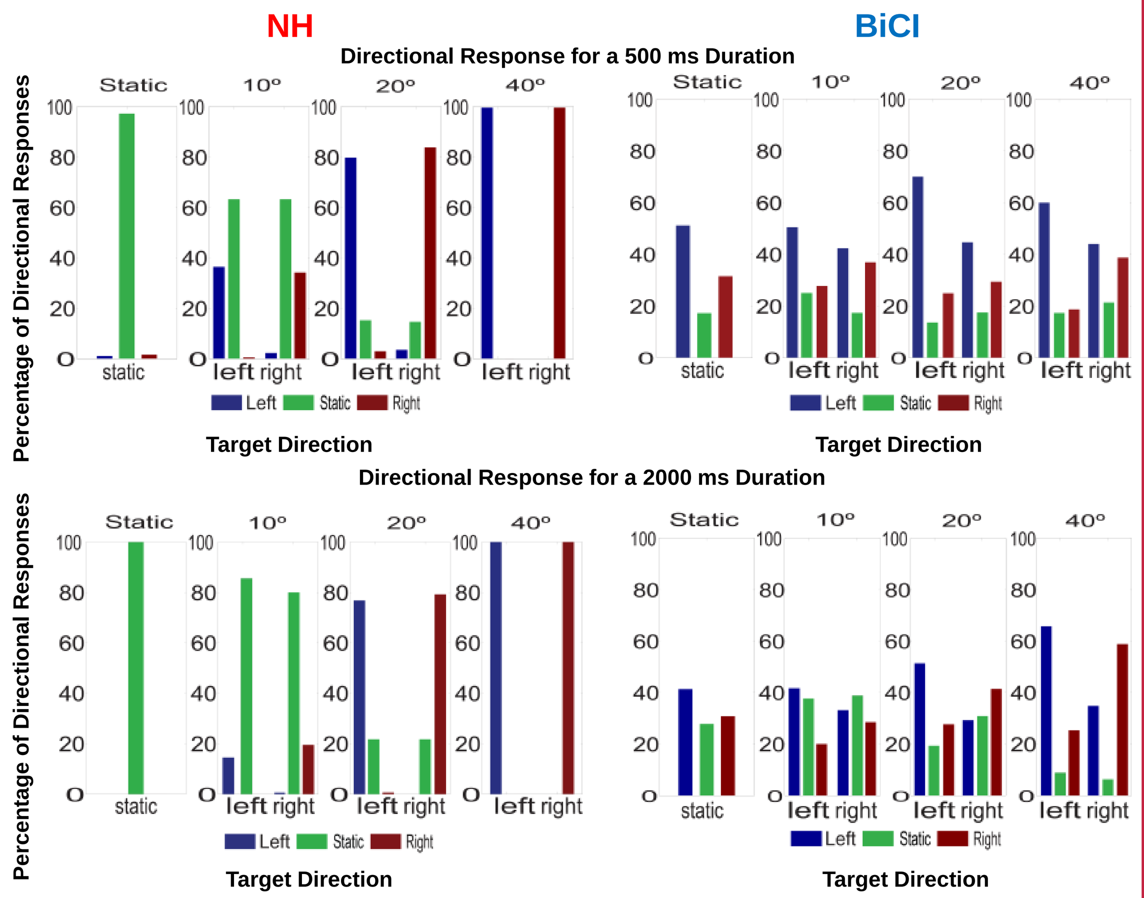


Fig. 4. Shows one NH listener's and one BiCI user's data plotted as a percentage of the directional responses reported for two different durations.

Angular Range Error Performance

- The NH listener had small angular range errors when indicating the location of a static sound across both durations.
- As the angular range increases for a moving sound, the BiCI user undershoots the sound source with larger error than the NH listener across the durations shown in fig. 5.
- At the longest angular range and duration, the BiCI user had a larger error when indicating the trajectory of the moving source compared to the NH listener. This is likely due to the confusion in the movement of the sound.

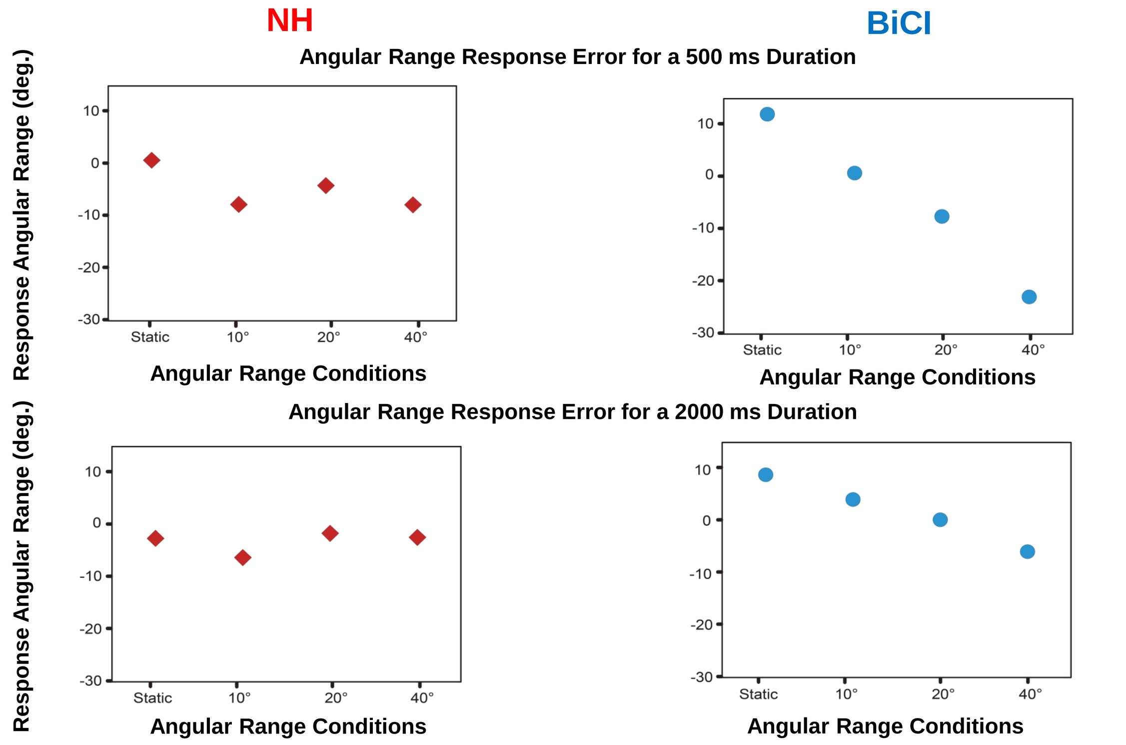


Fig. 5. Shows one NH listener's and one BiCI user's data for the error in angular range response for two different durations.

5. NH vs BiCI: Group Comparisons

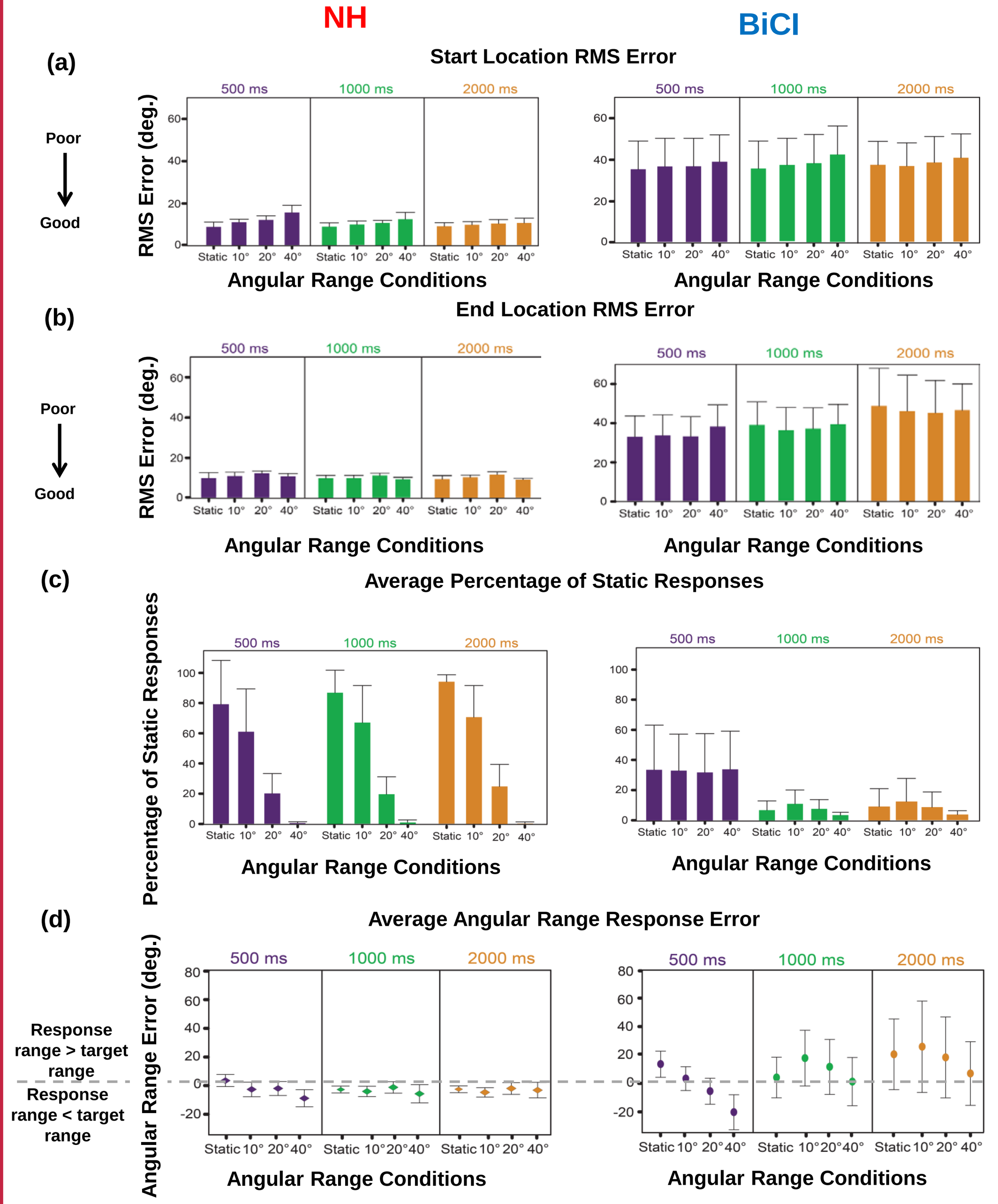


Fig. 6. Bar graphs and scatter plots represent group averages for (a) start location RMS error, (b) end location RMS error, (c) percentage of static responses, & (d) angular range response error. All error bars indicate standard deviations.

Summary

- At the shortest duration and increasing angular range, NH listeners showed higher error in locating the start of the sound compared to the end of the sound (Fig. 6a).
- RMS errors for start and end locations of moving sounds were similar to RMS errors of static sounds in both groups (Figs. 6a & 6b).
- Compared to NH listeners, BiCI users had larger RMS errors for the start and end locations across all angular range conditions and durations (Figs. 6a & 6b).
- Across durations, NH listeners had a higher number of static responses for static sounds compared to BiCI users (Fig. 6c).
- BiCI users reported the highest percentage of static responses for all angular range conditions at a duration of 500 ms. This could be due to the short duration of exposure to the sound source (Fig. 6c).
- At a duration of 500 ms, both groups responded with a decreasing average angular range error when presented a moving sound compared to a static sound. This is likely due to the high angular velocity of the sound (Fig. 6d).

6. Conclusions

- For both NH listeners and BiCI users, localization of moving sounds was comparable to their respective localization performance with static sounds.
- BiCI users have more difficulty judging whether a sound was static or moving, and confuse the direction of sound movement more often than NH listeners.
- On average, BiCI users had larger angular range response errors than NH listeners.
- Experiments with moving sounds reveal more information about the ability of BiCI users' to locate sound sources compared to experiments with static sounds.

7. References

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8. ACKNOWLEDGEMENTS

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