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The effect of stationary and moving sounds in localization for normal hearing listeners and bilateral cochlear implant users

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1. Introduction

- Bilateral cochlear implant (BiCI) users have poor localization ability compared to normal hearing (NH) listeners [1, 2].
- Normal hearing 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 stationary sounds, which may overestimate the ability of BiCI users to localize in realistic listening environments.
- No study to date has investigated localization of moving sounds in BiCI users, nor has there been an evaluation of the importance of particular cues.
- The aims of the present study were:

1) To investigate localization of moving sounds in bilateral cochlear implant users.
2) To determine whether reducing access to a particular binaural cue decreases localization of moving sounds for NH listeners.

2. Methodology

❖ Binaural Recordings

- Auditory motion was simulated using Vector Base Amplitude Panning techniques.
- Stationary and moving sounds were white noise recordings made with binaural microphones placed in the ears of a KEMAR manikin (Fig. 1).
- Dynamic ITDs were verified by performing short-duration cross-correlation functions on the binaural recordings (Fig. 2).

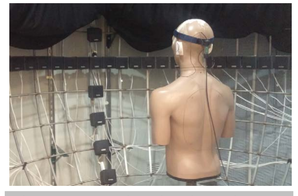

Fig. 1. Array of 37 loudspeakers separated by 5° in azimuth (-90° to +90°). Recordings were made at 11 target locations spanning -50º to +50º in 10º intervals.

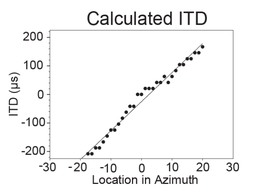

Fig. 2 Calculated ITDs for a sound moving across the midline. The solid line represents a linear regression (R^2 = .98).

❖ Stimulus conditions

Stationary sounds

Duration
1. 2000ms
2. 1000ms
3. 500ms

Moving sounds:

Ang. range,	Ang. Velocity,	Duration
1. 40º	20º/s	2000ms
2. 20º	10º/s	2000ms
3. 40º	40º/s	1000ms
4. 20º	20º/s	1000ms
5. 10º	10º/s	1000ms
6. 20º	40º/s	500ms
7. 10º	20º/s	500ms

3. Sound Localization Task

❖ Normal Hearing Testing

- Presented via Sennheiser HD600 circumaural headphones.
- Three frequency ranges:

1. Control:	**.150**	**–**	**6 kHz**
2. Low pass:	**.150**	**–**	**1.5 kHz**
3. High pass:	**2**	**–**	**6 kHz**

❖ Bilateral CI Testing

- A BiCI listener used their own everyday processor settings.
- Prior to testing, processor volumes and sensitivity were set to ensure a perceived centered auditory image at 0º azimuth.
- Binaural stimuli were presented via direct audio input ports in CI processors.
- Input frequency range was similar to the NH "Control" range.

Subject	Age (yrs.)	Sex	Bilateral CIs (yrs.)	Left Processor	Right Processor
IBK	74	Male	5	N6	N5

❖ Instructions

- Participants were asked to indicate the perceived location at end of stimulus on a touch screen monitor.
- Participants were notified before a stationary or moving stimulus condition was presented.

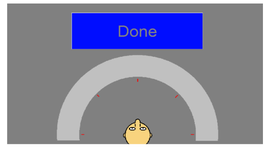

Fig. 3. Touch screen used to indicate perceived location at end of stimulus.

4. Results

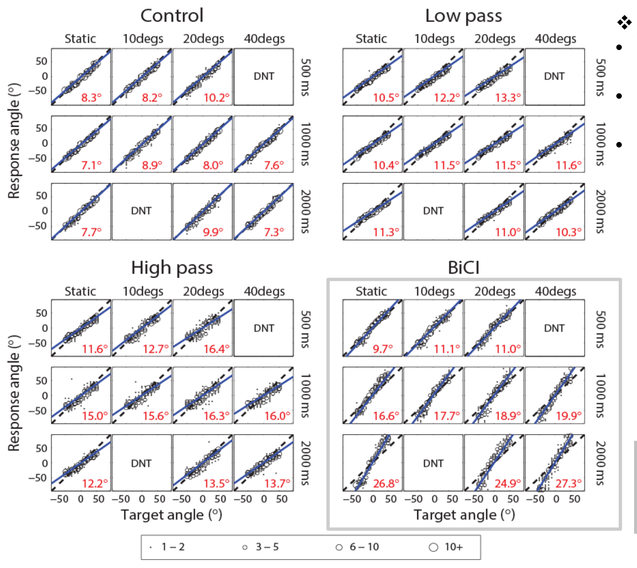

Fig. 4. Localization Data. Response angle is plotted as a function of target angle. The red value at bottom right of each subplot indicates the root-mean-square (RMS) error for the particular condition. The blue line represents linear fit of data. Responses have been binned to the nearest 5° and the size of the points reflect the number of responses within each bin. Each group of subplots are data from a different NH listener and the BiCI data is boxed in grey.

❖ Localization Performance

- All NH listeners and the BiCI user were able to localize moving sounds.
- Localization performance in the NH listeners was consistent across durations (Fig. 5).
- The BiCI user performed within the range observed in the NH listeners, for all conditions with a duration of 500 ms (Fig. 6).

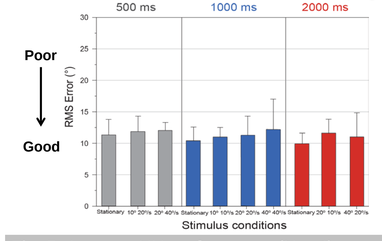

Fig. 5. Average NH performance (N = 4). Overall RMS errors for each of the ten stimulus conditions. Each color represents stimuli with the same duration.

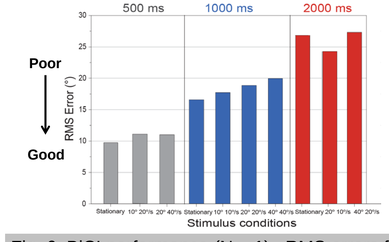

Fig. 6. BiCI performance (N = 1). RMS errors for each of the ten stimulus conditions. Each color represents stimuli with the same duration.

5. Across Group Comparisons

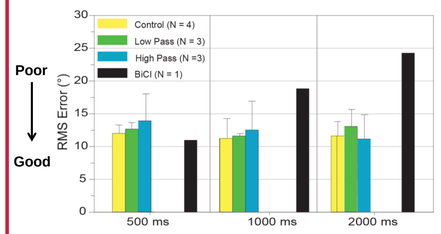

Fig. 7 plots performance for NH listeners compared with the BiCI user for a fixed angular range of 20°.

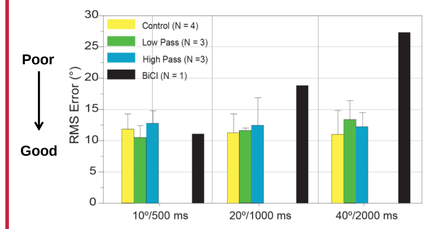

Fig. 7 plots performance for NH listeners with the BiCI user for a fixed angular velocity of 20°/s.

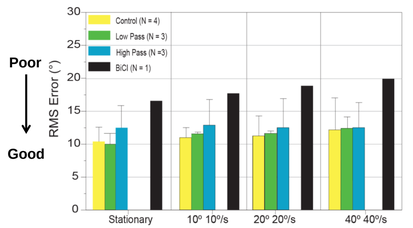

Fig. 9 plots performance for NH listeners with the BiCI user for all stimuli with a 1000 ms duration.

❖ Summary

- The BiCI user exhibited broad localization error when presented a moving sound at the largest angular range (40°) and fastest angular velocity (20°/s) (Fig. 7).
- An angular range of 20° and angular velocity of 20°/s did not affect localization error of a moving source for NH listeners (Figs. 6 & 7).
- Localization for moving sounds in NH listeners did not show an increase in RMS error when compared to stationary sounds (Fig. 9).
- For the BiCI user, errors increased with larger stimulus duration for all conditions (Fig. 9).

6. Conclusions

- The presence of a particular binaural cue in the low and high pass conditions for NH listeners exhibited a similar performance to the control condition for all stimuli.
- Dynamic cues do not appear to aid in the localization of moving sounds compared to stationary sounds for this BiCI user or in NH listeners.
- The BiCI user displayed the best localization when the stimulus duration was 500 ms. This could have been due to the subject not perceiving the moving conditions as motion but rather stationary since short angular ranges of 10° and 20° were employed.
- Future studies may need to access the effect of stimulus duration on localization error in BiCI users by testing angular ranges and angular velocities not used in this experiment.

References

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