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Auditory motion perception of individuals with single sided deafness

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1. Introduction

- Recently, individuals with single-sided deafness have been implanted with a cochlear implant (SSD(CI)) as a treatment for tinnitus[1-3].
- Little is known about how these individuals combine their two different hearing modalities (acoustic + CI) for spatial hearing tasks. In particular, this study concerns the ability to perceive movement of sound sources.
- For SSD(CI) individuals, we hypothesize that:
  1. If auditory motion is perceived, then performance will be similar to NH listeners because of access to acoustic cues.
  2. If auditory motion is perceived, then performance will be similar to BiCI users due to interference from the degraded auditory input of the CI.

2. Stimulus

Binaural Recordings

- White noise tokens (100-6000 Hz bandwidth, 500 ms duration) were recorded using binaural microphones placed in the ears of a KEMAR manikin.

Fig. 1. Binaural recording setup.

- Angular ranges of motion: 0° (stationary), 10°, 20°, and 40°.
- 19 target locations, spanning -90° to +90° in 10° intervals.
- Moving sound sources were simulated using Vector Base Amplitude Panning[4] and an array of loudspeakers (Fig. 1).

3. Participants

Table 1. NH adults (**n = 10**)

ID	Age (yrs.)
TCC (◯)	24
TCG (◇)	23
TDN (△)	22
TEC (◁)	21
TEG (▽)	24
TFV (▷)	27
TFX (⬠)	25
TGI (⬡)	20
TGJ (✙)	19
TKG (x)	20

Table 3. Adults with BiCIs (**n = 9**)

ID	Age (yrs.)	Sex	BiCIs (yrs.)
IBF (◯)	64	F	8
IBK (◇)	76	M	6
IBL (△)	69	F	10
ICB (◁)	65	F	10
ICI (▽)	57	F	6
ICP (▷)	53	M	3
ICT (⬠)	22	M	4
ICX (⬡)	75	F	4
ICD (✙)	58	F	7

Table 2. Adults with SSD(CI) (**n = 4**)

ID	Age (yrs.)	Sex	Yrs. of CI experience	Processors	
				Left	Right
MAF (◯)	29	F	2.25	N6	
MAG (◇)	62	F	1		N6
MAH (△)	40	M	1.5	Rondo	
MAJ (◁)	41	M	1	Naida Q70	

4. Auditory Motion Experiment

Testing

- NH adults were presented stimuli via Sennheiser HD 600 circumaural headphones.
- SSD(CI) adults were tested in the free field to assess spatial hearing abilities when listening with two different modalities (acoustic + CI).
- BiCI adults listened to stimuli presented to their clinical sound processors via auxiliary input ports.
- Prior to testing, processor volumes and sensitivity were set to ensure a frontal auditory image.

Task

- Stationary and moving sounds were presented randomly within a single block.
- Participants were asked to report the perceived trajectory of the stimuli on a graphical user interface (Fig. 2).
- Stationary responses were reported by a single dot and moving responses were reported by a line indicating the perceived trajectory.

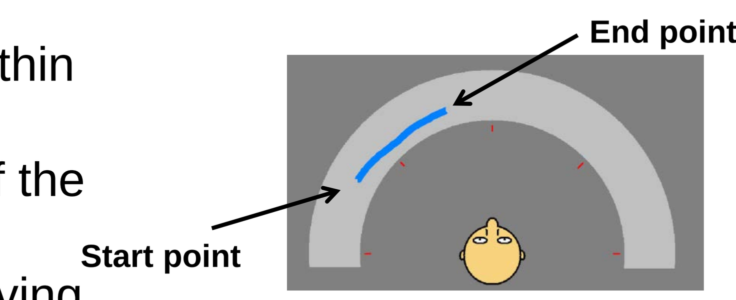


Fig. 2. Graphical user interface showing perceived sound source trajectory as a blue line.

5. Stationary Sound Localization Ability

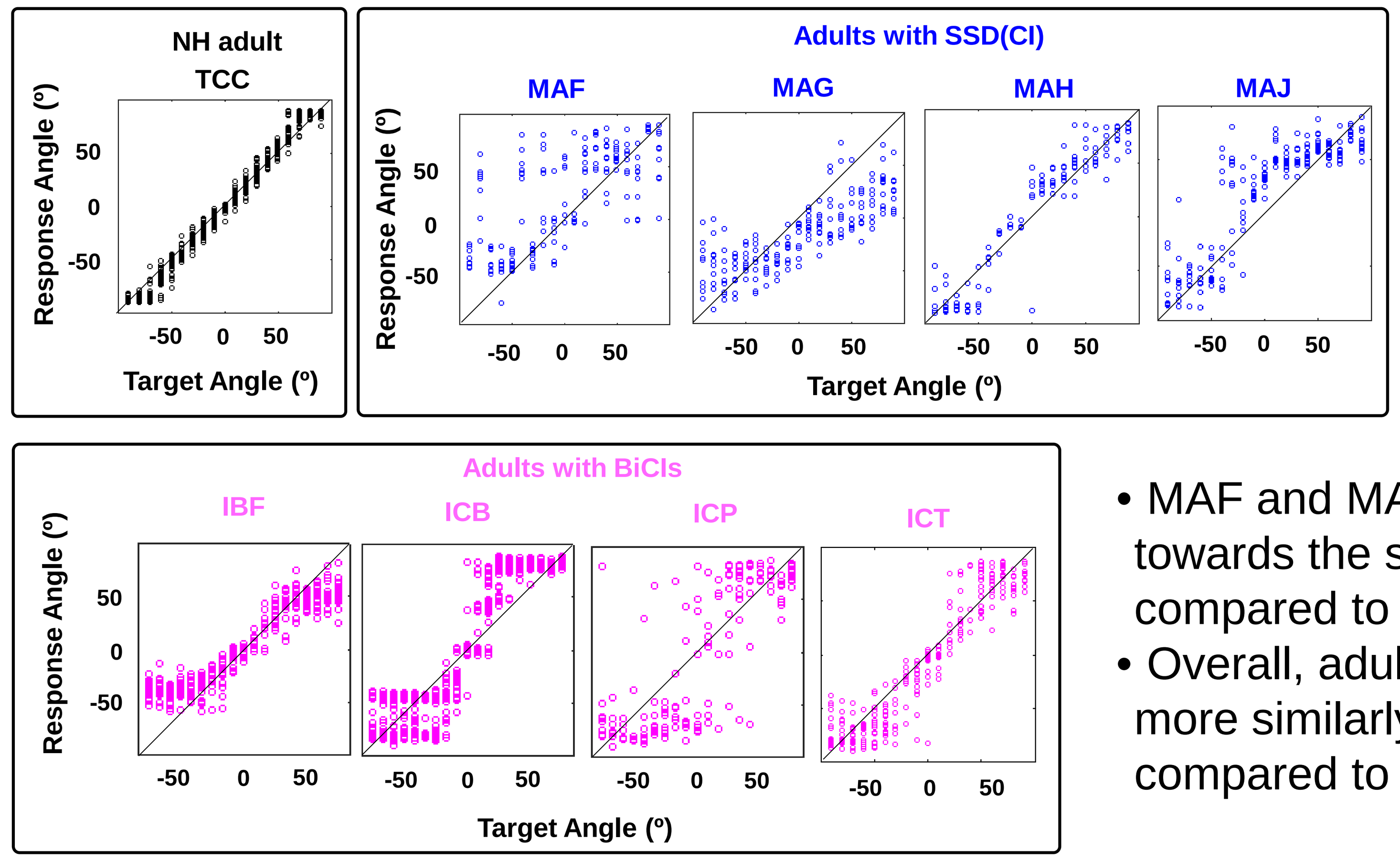


Fig. 3. Stationary sound localization performance when the subject reported detecting a stationary sound.

- Adults with SSD(CI) and BiCIs had a larger spread in their responses compared to NH subject (TCC).
- SSD(CI) and BiCI subjects had more difficulty locating lateral azimuthal positions compared to TCC.
- MAF and MAG responsded more often towards the side of their acoustic ear compared to their CI ear.
- Overall, adults with SSD(CI) performed more similarly to adults with BiCIs when compared to TCC.

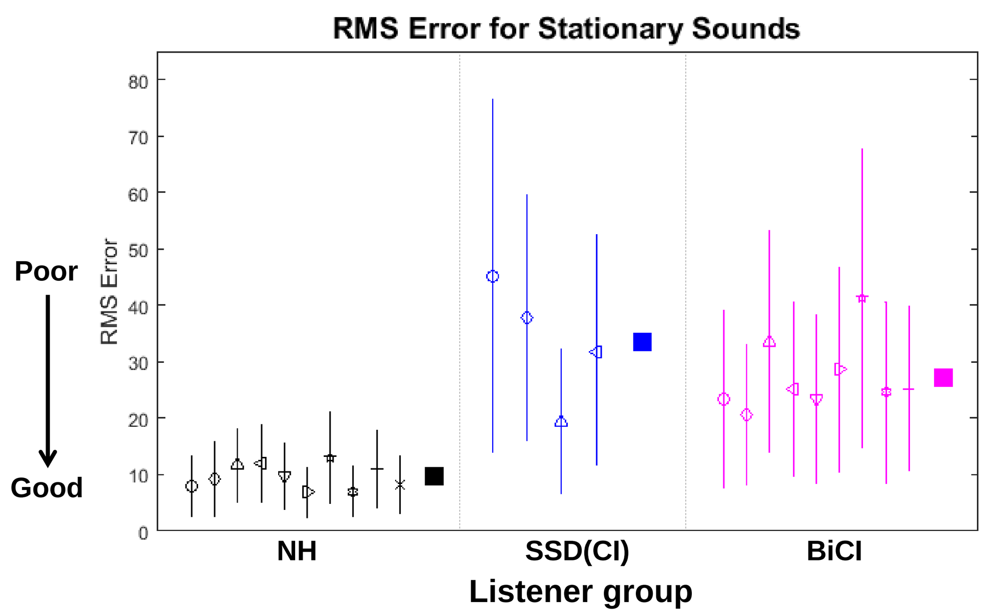
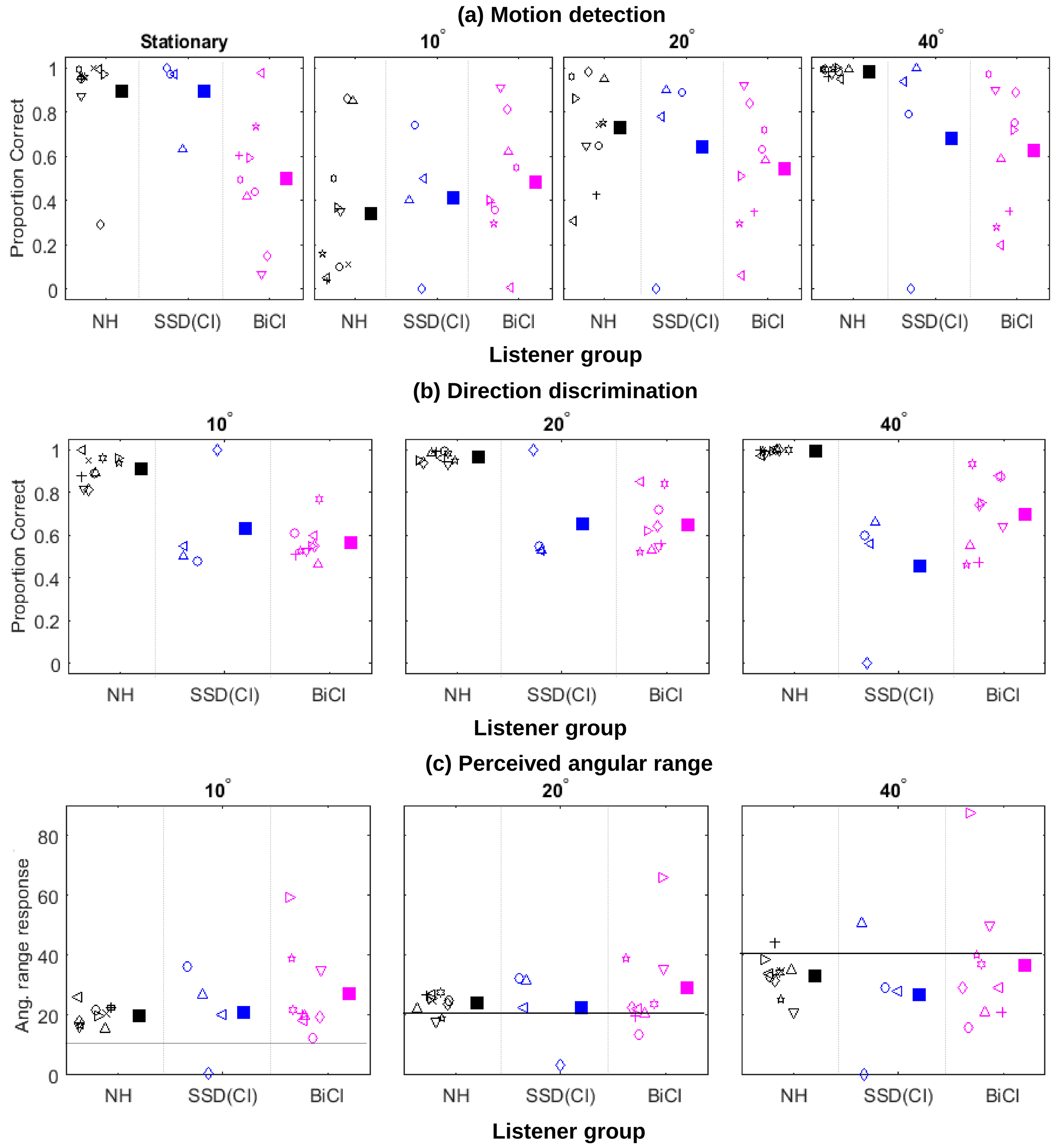


Fig. 4. Individual subjects are represented by their own symbol as seen in tables 1, 2, & 3 for subjects with NH, SSD(CI), & BiCIs respectively. Group means are plotted to the right of the individual data points (black square = NH, blue square = SSD(CI), pink square = BiCI).

- SSD(CI) subject (MAH) had less variability than all of the SSD(CI) and BiCI listeners but still not comparable to the NH adults.
- Most SSD(CI) listeners exhibit similar variability in their sound localization ability compared to the BiCI users.
- On average, adults with SSD(CI) had a similar RMS error compared to the BiCI users but both groups were poorer than the NH adults.

6. Moving Sounds



- Adults with SSD(CI) detected stationary sound sources similarly to adults with NH.
- NH and SSD(CI) adults improved their motion detection as a sound source traversed a wider angular range. This trend did not occur for BiCI users.
- Across all angular range conditions, SSD(CI) and BiCI listeners had similar performance for discriminating the direction of a moving sound.
- The NH adults had the best performance for discriminating the direction of movement, regardless of the angular range condition.
- At a 10° angular range, all groups of listeners overestimated the target angular range.
- When the sound source moved a wider angular range (20° & 40°), SSD(CI) and BiCI listeners were able to track the trajectory of movement but with larger variability than the NH adults.

Fig. 5. Individual subjects are represented by their own symbol as seen in tables 1, 2, & 3 for subjects with NH, SSD(CI), & BiCIs respectively. Group means are plotted to the right of the individual data points (black square = NH, blue square = SSD(CI), pink square = BiCI) for **(a)** proportion of moving trials detected as a moving sound, **(b)** proportion of moving trials detected as moving and discriminated moving in the correct direction **(c)** the perceived angular range response of a moving sound that was detected and discriminated moving in the correct direction. Solid lines represent the target angular range presented.

7. Summary

- SSD patients who were implanted with a CI in their deaf ear could localize stationary sound sources comparable to that of BiCI users.
- The ability to detect sound source movement was better for adults with SSD(CI) than with BiCIs but overall, both of these groups performed poorer than NH adults.
- Use of this novel auditory motion paradigm examined the efficacy of spatial hearing in SSD(CI) individuals, not previously reported in the literature[1-2].

8. References

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9. Acknowledgements

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