W41 – 1037

A Binaural Advanced Combination Encoder Strategy for Sound Localization with the CCi-Mobile Research Platform

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WAISMAN CENTER

Binaural Hearing and Speech Laboratory

Conference on Implantable Auditory Prostheses (CIAP)

Lake Tahoe, CA

July 15-19, 2019

INTRODUCTION

- Bilateral cochlear implants are not coordinated across ears. Consequently, the Advanced Combination Encoder (ACE) strategy independently selects different channels in each ear [1].
- Binaural cues, which are computed in the brain on a frequency-by-frequency basis, may not be transmitted on the same electrodes across ears, resulting in poor representation of those cues.
- Recent data from our lab has shown that BiCI listeners have difficulty distinguishing between stationary and moving sounds, an ability with implications for safety and spatial hearing [2].

RESEARCH AIM

This study was developed to test whether the selection of independent channels in each ear and synchronization of time-clocks across ears contribute to the perception of moving versus stationary sounds.

For this purpose, we developed a Binaural ACE processing strategy.

BINAURAL ACE

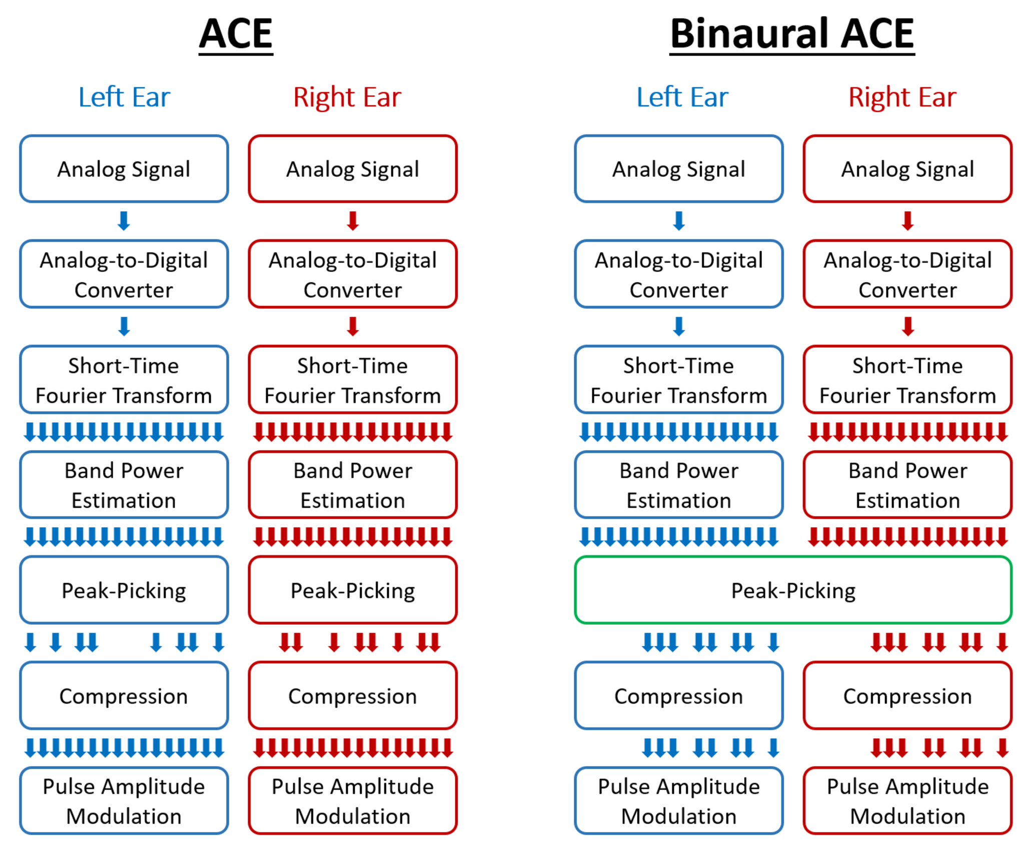

Figure 1: Signal processing chains for regular ACE and Binaural ACE. The green box highlights where the peaks from both ears are picked by the algorithm.

- Standard ACE: the N highest peaks in each time frame are chosen for stimulation. Each ear picks peaks independently from the other.
- Binaural ACE (bACE): all $2N$ peaks from both ears are pooled and highest peaks are selected from this pool. Once peaks are picked, the same electrodes are stimulated on both sides.
  - Example: 8 highest channels differ, sorted with increasing intensity,
    Left [16, 1, 19, 20, 17, 14, 3, 4]
    Right [1, 2, 3, 4, 16, 5, 6, 7].
    The union of the set of peaks is [20, 19, 17, 16, 14, 7, 6, 5, 4, 3, 2, 1], and Binaural ACE chooses the first 8 of these to stimulate.

METHODS

Task

- Five bilateral Cochlear listeners were presented both moving and stationary sounds via a loudspeaker array (37 speakers spanning 180° at 5° intervals) attached to a 1.4 m radius matrix.
- Participants responded using a laser pointer; OptiTrack motion-capture system recorded responses. Listeners indicated a stationary sound by pressing a button on the laser pointer once and indicated a moving sound by tracing the perceived trajectory of the sound.

Stimuli

- 1000 ms white-noise tokens moved at angular ranges either 0°, 20°, or 40° per second, with a balanced number of stationary and moving trials, presented in a pseudo-random block design across three signal processing conditions (see Table 1).
- Delivered with Tucker Davis Technologies RP2 units.

Equipment: CCi-Mobile Research Platform

- The CCi-Mobile is a portable research platform developed at UT-Dallas. One central processor controls both implants, effectively synchronizing the delivery of stimulation across ears [3, 4].
- bACE is only possible with a device like the CCi-Mobile, as the design and testing of real-time bilateral signal processing strategies is not possible with current research processors that directly stimulate the electrode array.

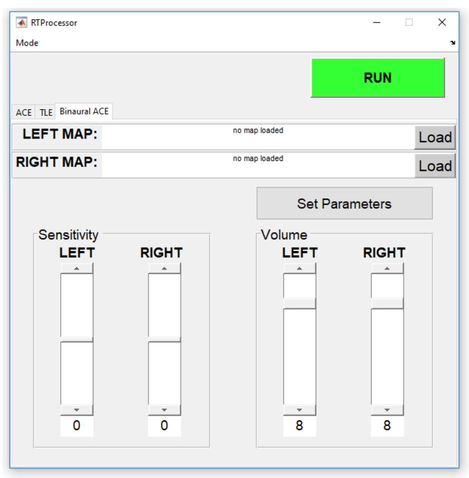

Figure 2: GUI used to control signal processing strategy on the CCi-Mobile.

Signal Processing Conditions

Strategy	Device(s)	Time Synchronized?	Binaurally Coordinated?
Clinical (Clin.)	Cochlear N6	*No*	*No*
ACE	CCi-Mobile	**Yes**	*No*
bACE	Cci-Mobile	**Yes**	**Yes**

Table 1: Processing strategies compared in this study.

ID	Age	Etiology	Years Bilateral	Pulse Rate (pps)
IAJ	73	Progressive	16	1200
IBO	54	Otosclerosis	9	1200
ICM	63	Progressive	4	900
IDA	52	Progressive	5	900
IDH	20	Unknown	14	1200

Table 2: CI participant information.

RESULTS I: How did Binaural ACE impact auditory motion discrimination?

Total proportion correct:

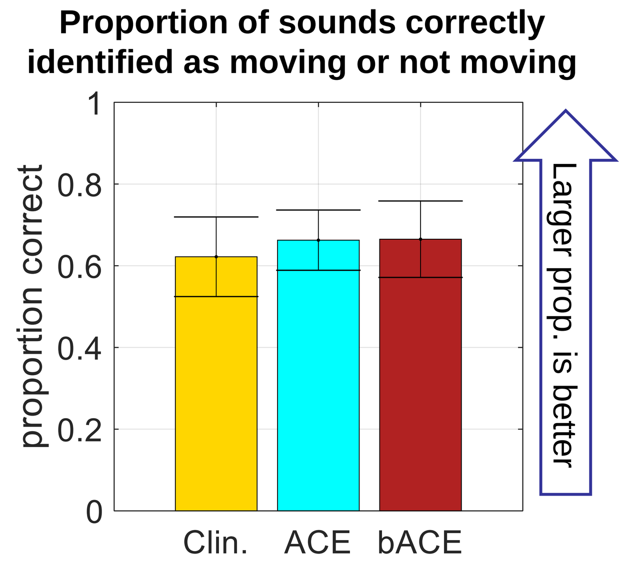

Figure 3: Average total proportion correct for identifying if a sound was moving or not. Error bars show standard deviation.

- The average proportion correct was slightly larger with ACE and bACE than with Clinical.
- Three subjects performed better with ACE and bACE than with Clinical. The other two subjects performed best with ACE.
- One-way ANOVA determined no statistical difference across signal processing conditions.

Auditory motion sensitivity and bias:

- Auditory motion sensitivity (d') and bias (c) calculated using proportion of stationary stimuli correctly identified and proportion of moving stimuli incorrectly identified.

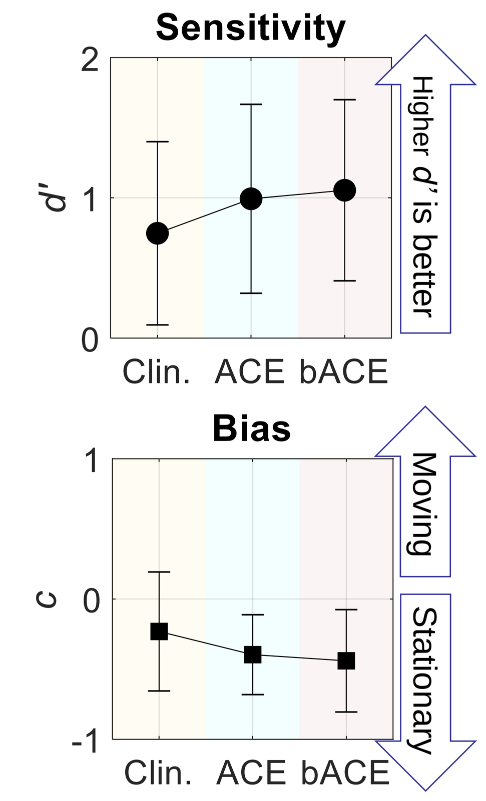

Figure 4: Mean sensitivity (d') and bias *(c)* for discriminating between moving and stationary sounds. Error bars show standard deviation.

- Average sensitivity increased with ACE and bACE as compared to Clinical, with a further marginal increase with bACE when compared to ACE.
- Overall, sensitivity was larger than previously reported for BiCI listeners, with mean d' scores near 1 instead of 0 [2].
- With ACE and bACE, listeners were more biased to report moving sounds as stationary than with the clinical processors.
- One-way ANOVA determined no statistical difference between signal processing conditions.

Sensitivity and bias for different velocities:

- Sensitivity (d') and bias (c) calculated using proportion of stationary stimuli correctly identified and proportion of 20° or 40° moving stimuli incorrectly identified.

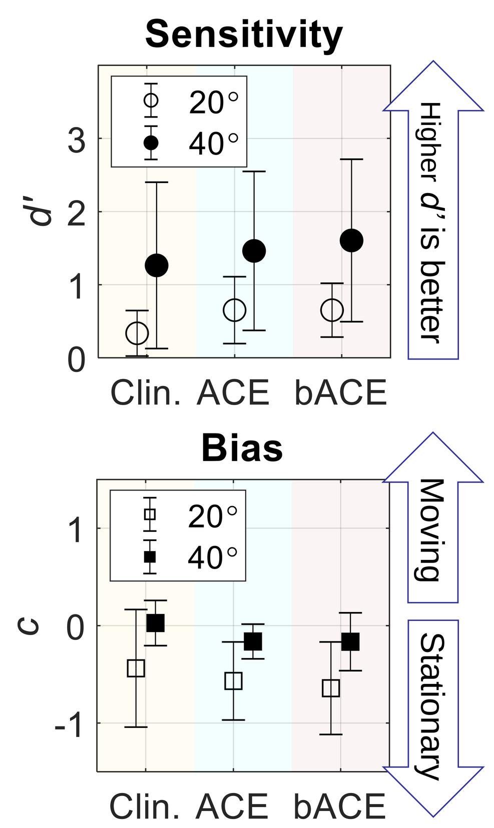

Figure 5: Mean sensitivity (d') and bias *(c)* for discriminating between static and moving sounds at different velocities. Error bars show standard deviation.

- Separating by stimulus condition reveals listeners were more sensitive when stimuli moved 40° instead of 20°.
- Three of five subjects improved to d' scores above 1 when responding to stimuli moving 40°.
- Listeners had less bias when sounds moved 40° as compared to 20°.
- One-way ANOVA determined no statistical difference between signal processing conditions for both 20° and 40° moving stimuli.

RESULTS II: How did Binaural ACE impact localization accuracy?

Stationary localization accuracy:

- Root mean square (RMS) error was calculated for trials that were correctly identified as stationary.

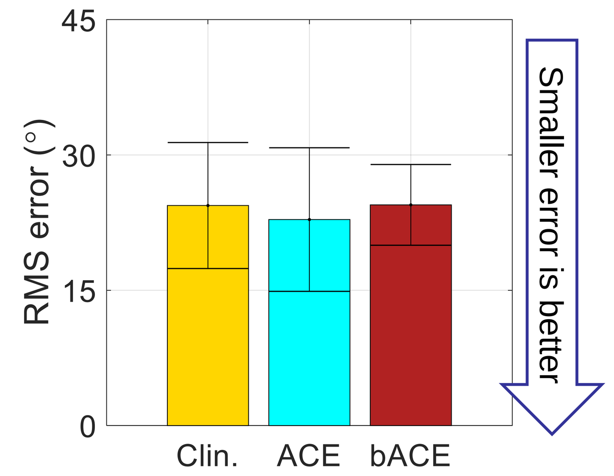

Figure 6: Average root mean squared error for correctly identified stationary trials. Error bars show standard deviation.

- On average, there was no improvement in RMS error across signal processing conditions for stationary stimuli.
- Average RMS error was 24.4° for the clinical processors, lower than previously reported [2].
- One-way ANOVA determined there was no statistical difference between conditions.

Angular trajectory accuracy:

- Trajectory is the absolute angular distance that a stimuli moved. Subjects responded with the perceived trajectory of a moving sound.

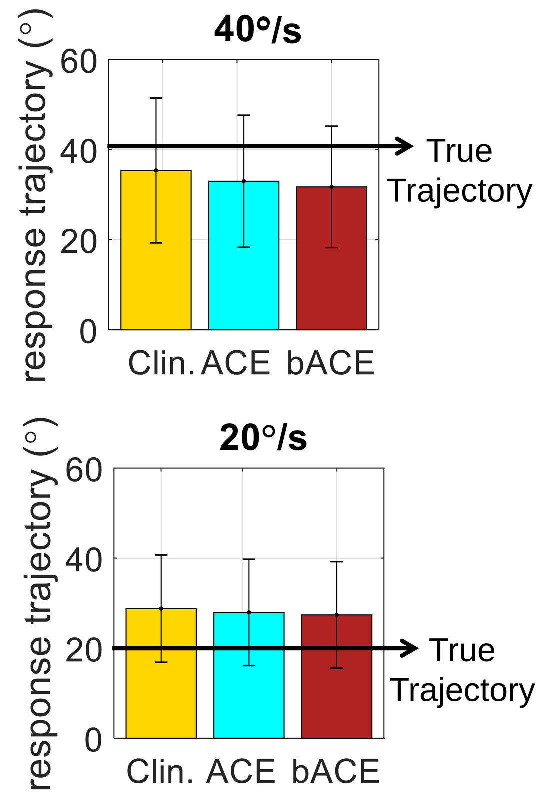

Figure 7: Average trajectory (absolute difference between start and end position) per each condition and signal processing strategy. Error bars show standard deviation.

- Listeners underestimated the extent of 40° stimuli and overestimated the extent of 20° stimuli.
- For 40° sounds, listeners responded with slightly smaller trajectories when using ACE and bACE conditions as compared to Clinical.
- Listeners responded with smaller trajectories for the 20° stimuli than the 40° stimuli.
- One listener (ICM) never reported hearing a sound moving more than 10°.
- One-way ANOVA determined there was no statistical difference between conditions.

SUMMARY

- **Effect of signal processing on motion perception:**
  - Binaural ACE gives similar auditory motion discrimination performance as clinical processors, and may give some listeners a slight improvement.
  - Listeners on average perceived smaller trajectories for all angular ranges of moving sounds with Binaural ACE than with clinical processors.
- **Effect of matching channels:**
  - Since Binaural ACE did not significantly improve performance, this implies that independent selection of channels across ears may not be a meaningful factor in auditory motion discrimination.
- **Effect of synchronizing time-clocks:**
  - CCi-Mobile ACE condition did not yield a statistically significant improvement in auditory motion discrimination or sound localization as compared to the clinical processors.
- Other considerations, such as interaural mismatch from unequal electrode array insertion depth, poor survival of neurons at the electrode-neuron interface, or delayed activation times across ears [6] could be mitigating the improvements offered by Binaural ACE.

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ACKNOWLEDGEMENTS

This work was supported by NIH-NIDCD R01DC016839 to Hansen, Litovsky, and Svirsky, NIH-NIDCD R01DC03083 to RYL, NIH-NIDCD R03DC015321 to AK, and NIH-NICHD U54HD090256 to the Waisman Center.
Thanks to William Sethares and Michaela Warnecke for help with analysis of data.

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Printing courtesy of the Friends of the Waisman Center