PS #351

Robust Spatial Unmasking of Speech in Children with Bilateral Cochlear Implants by Harnessing Interaural Time and Level Cues with Large Angular Separation between Target and Maskers

Z. Ellen Peng & Ruth Y. Litovsky
University of Wisconsin-Madison, USA
e-mail: z.ellen.peng@wisc.edu; litovsky@waisman.wisc.edu

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INTRODUCTION

- In spatial unmasking of speech, children with bilateral cochlear implants (BiCIs) receive intelligibility benefits mainly from head shadow, by attending to the ear with better signal-to-noise ratio (SNR) of the target speech
- Most children with BiCIs do not seem to benefit from interaural difference cues, i.e., interaural time and level differences (ITD and ILD), and some even demonstrate an "anti-benefit" or interference when a spatial separation between the target and masker is introduced
- Previous work on spatial unmasking is limited to using 90^0 angular separation between target and masker to quantify benefits from head shadow and inteaural differences
- In this study, we enlarged the target-masker angular separation to 180^0 in virtual auditory space (VAS) and systematically assessed intelligibility benefits from individual and co-occurring auditory cues in spatial unmasking

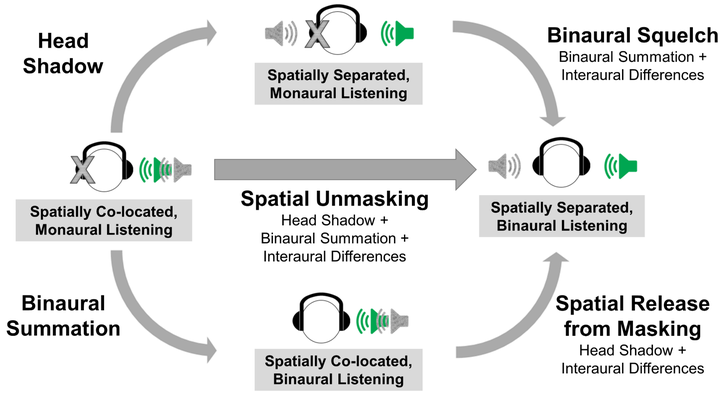


Fig. 1. Schematics of test conditions and the corresponding monaural and binaural cues available for target intelligibility benefit.

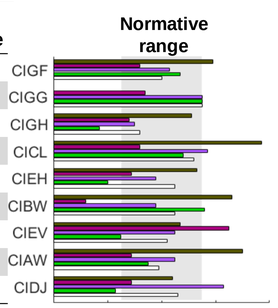
Individual Cues	Formula to Calculate Intelligibility Benefit
Head Shadow	$SRT_{Co-located,\ Monaural} - SRT_{Separated,\ Monaural}$
Binaural Summation	$SRT_{Co-located,\ Monaural} - SRT_{Co-located,\ Binaural}$
Binaural Squelch	$SRT_{Separated,\ Monaural} - SRT_{Separated,\ Binaural}$
Spatial Release from Masking (SRM)	$SRT_{Co-located,\ Binaural} - SRT_{Separated,\ Binaural}$
Interaural Differences SRM – Head Shadow or Squelch – Summation	$(SRT_{Co-located,\ Binaural} - SRT_{Separated,\ Binaural}) - (SRT_{Co-located,\ Monaural} - SRT_{Separated,\ Monaural})$
Full Cues	$SRT_{Co-located,\ Monaural} - SRT_{Separated,\ Binaural}$

METHODS

- Participants
  - BiCI group: 9 children; all Cochlear N5 or N6 users with ACE strategy
  - NH group: 19 children; age-matched to bilateral experience among BiCI group between 6 to 12.5 yrs old. All had ≤20 dB HL from 125-8000 Hz.
- Speech reception thresholds (SRT) measured at 50% correct adaptively
  - **Target**: AuSTIN sentences [3]; **Masker**: 2-talker babble (e.g., science news)
- Test Conditions
  - Target-masker **spatially co-located** vs. **180° angular separation**
    - VAS created with individual head-related transfer functions (HRTF) recorded behind-the-ear (BTE) from BiCI users and with KEMAR HRTFs recorded in-the-ear (ITE) for NH children
  - **Binaural** vs. **Monaural**
    - Direct audio input to CI processors or circumaural headphones for NH children: Stereo vs. better-ear (BiCI) or left-ear (NH) only

Subject ID	Chronological Age [yr; mo]	Age at 1st CI	Bilateral Experience
CIGF	10;10	1; 1	9; 9
CIGG	9; 10	0; 10	9: 0
CIGH	11; 9	1; 5	10; 3
CICL	12; 11	1; 5	10; 1
CIEH	13; 2	1; 1	12; 1
CIBW	15; 2	1; 0	11; 4
CIEV	16; 2	2; 8	5; 2
CIAW	17; 11	1; 2	12; 5
CIDJ	17; 2	1; 7	12; 2

Table 1. Demographics of children with BiCIs. Age and experiences in years; months.



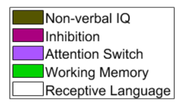
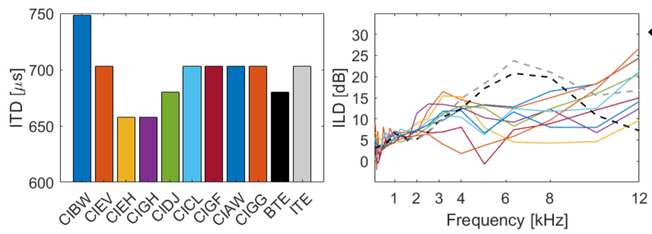


Fig. 2 Standardized test outcomes of children with BiCIs. Most BiCI users have IQ, executive functions and language skills within the range (85-115) of chronologically age-matched, typically developing children (gray box)

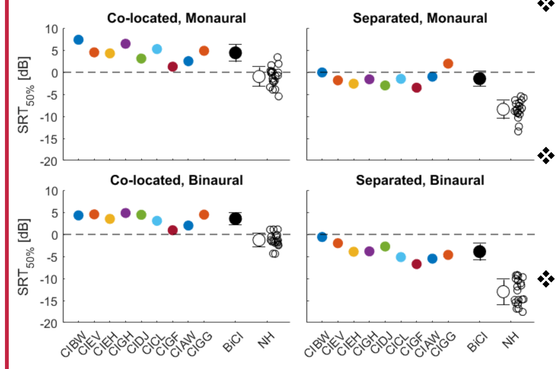
RESULT 1: ITD and ILD Calculated from Individual HRTFs



- BiCI users had similar ITD (<1.5 kHz) from BTE HRTFs as NH children tested with KEMAR HRTFs, but smaller ILDs between 4-8 kHz

Fig. 3 ITD and ILD calculated from HRTFs from individual children with BiCIs and from KEMAR HRTFs. Sound source located at +90^0 azimuth to listener's right. All BiCI HRTFs measured BTE.

RESULT 2: Speech Intelligibility in Each Test Condition



- Elevated SRTs by 5-10 dB among children with BiCIs when perceiving speech in noise across all test conditions
- With co-located target-maskers, all BiCIs users needed positive SNR to reach 50% accuracy
- With 180° separation between target and masker, SRT ≤ 0 dB among most children in the BiCI group

Fig. 4 Individual data and group means (±1 SD) of SRT at 50% accuracy

RESULT 3: Intelligibility Benefit from Unmasking Cues

- All children in the BiCI group showed a head shadow benefit > 2 dB
- Very small benefit from summation likely due to intensity in the added ear
- In the BiCI group, interaural differences provided up to 6 dB benefits except for one child who demonstrated an "anti-benefit"
- The ranges of intelligibility benefits from monaural and binaural cues are similar between BiCI and NH groups

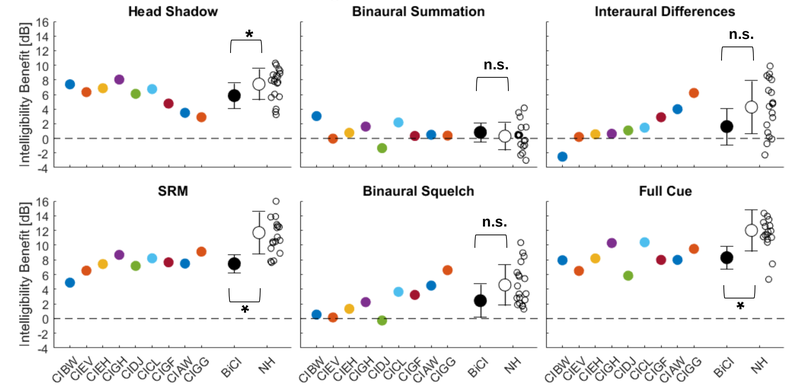


Fig. 5 Intelligibility benefit from individual monaural and binaural cues, and from combinations of multiple cues. Individual data and group mean (±1 SD) shown for both groups. Between-group difference compared using Wilcoxon rank sum tests, * p<.05, n.s. = non-significant.

DISCUSSION

- Spatial unmasking from individual auditory cues was quantified using VAS and compared between NH children and children with BICIs
- With sufficiently large angular separation, some children with BiCIs may benefit from interaural difference cues
- Children with BiCIs who benefited more from head shadows seem to receive smaller intelligibility improvement from interaural differences

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