Speech Discrimination and Spatial Release from Masking in Toddlers with Cochlear Implants

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ABSTRACT

Bilateral cochlear implants (BiCIs) have been shown to promote the development of spatial hearing skills in children and adults, but little is known about the role of bilateral stimulation in enhancing language and speech reception in infants and toddlers. In addition, the difference in performance between toddlers with unilateral cochlear implants (UCIs) and BiCIs remains unexplored. We tested two hypotheses: (1) Toddlers with BiCIs will discriminate minimal pair contrasts that differ in voice and/or place of articulation with higher accuracy than toddlers with UCIs because they receive "two looks" at the speech signal. (2) Toddlers with BiCIs will show more spatial release from masking than toddlers with UCIs.

Toddlers with UCIs and BiCIs (ages 24-36 mo.) were tested. Experiment 1: In a novel "Reaching for Sound" paradigm, toddlers were trained to reach for an object and were reinforced for correct responses with a toy, snack, sticker, etc. The stimulus consists of the carrier phrase "I'm hiding under," followed by one of the three test words (bee, pea, or key). The locations for the discrimination set are randomized within each group of toddlers (e.g., pea-Left vs. bee-Right and vice versa), and percent (%) correct was recorded. Experiment 2: Using a computerized 4 alternative forced choice (AFC) task, we adaptively measured speech reception thresholds (SRTs) in quiet and in the presence of a masker whose location was varied between 0° and 90°.

Preliminary results indicate that in Experiment 1, normal hearing (NH) toddlers have high %correct scores, i.e., clear discrimination of all speech contrasts, while toddlers with BiCI or UCI have low %correct scores. As hypothesized, toddlers with CIs discriminate voicing contrasts with higher accuracy than place contrasts, potentially due to temporal information being presented more reliably than spectral cues by CI processors. In Experiment 2, NH toddlers demonstrate a benefit when target and masker are spatially separated, while toddlers with BiCIs and UCIs are highly variable in their performance on this task.

Speech discrimination results to date suggest that: (1) In implanted toddlers, speech discrimination abilities develop faster for temporally-based speech cues than spectrally-based cues, but thus far, there is no measurable difference between UCI and BiCI users. (2) The rate of development in NH toddlers is unknown because they perform equally well with all stimuli. NH toddlers show a benefit when the target and masker are spatially separated, while toddlers with BiCIs and UCIs have not.

PARTICIPANTS

Nine children who use CIs:
- At least 1 year of experience with CI1 at first visit
- Native English speaker
- Primary communication mode=oral, any CI device
- No diagnosed developmental disabilities
- Mean age: 31.6 mo.

Thirteen 24-36 mo. old toddlers with NH:
- Mean age: 30.8 mo. (8 Male, 5 Female)
- No history of hearing loss, ear infections, or other developmental delays
- Tympanomic and hearing screening performed

Subjects	Sex	Age @ Test	Age-CI1	Age-CI2	CI1Exp	CI2Exp
BiCIFI	M	32	7	7	25	25
BiCIFJ	M	30	14	14	16	16
BiCIFK	M	30	14	14	16	16
BiCIFN	M	34	13	13	21	21
BiCIFO	F	34	9	15	25	19
BiCIFQ	M	28	7	13	21	15
BiCIFT	M	36	8	8	27	27
UCIFM	M	26	16	N/A	10	N/A
UCIFS	M	33	11	N/A	22	N/A

SPEECH DISCRIMINATION: METHOD
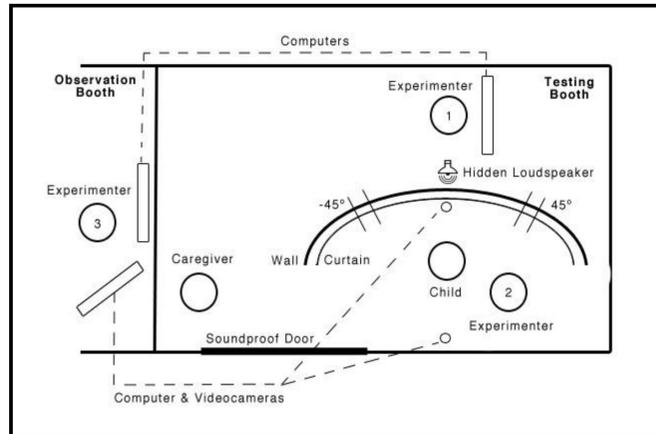
> Testing is conducted using the novel "Reaching for Sound" method depicted above.
> Testing is conducted in a standard IAC sound booth (2.743m x 3.658m). The testing apparatus was a semi-circular table (radius of 0.6m) with nine holes spaced 15° apart from -60° to 60°. Each hole had a an 11cm diameter. A speaker was positioned under each hole at ear level when the child was seated. The child sat in a chair facing the center of the apparatus, and curtains above and below the table hid an experimenter behind the apparatus. Two video cameras were used to record the child's responses. One video camera was positioned behind the child to track the child's behavior, while the other was positioned above the speaker at 0° to track eye gaze and head orientation.
> We collected % correct, looking time, and latency data for each child across conditions.
> **Stimuli:**

		Endpoint Value	Intermediate Value*
BEE	Voiced bilabial plosive	5 ms	15 ms
PEA	Voiceless bilabial plosive	45 ms	35 ms
KEY	Voiceless velar plosive	45 ms	N/A

> The length of time between the release of the consonant and the beginning of vocal fold vibration is known as voice onset time (VOT). Along a continuum, a clear /b/ (5ms) is located at one end, and a clear /p/ (45m) is located at the other end. In the middle of this continuum (25ms), there is an identification boundary, where a bilabial stop with a shorter VOT is perceived as /b/ and a bilabial stop with a larger VOT larger is perceived as /p/. NH 1 month old infants can discriminate /b/ from /p/.

METHOD (cont.)

> **Familiarization**: Before entering the sound booth, the child receives exposure to the words and pictures used in the study through a live-voice familiarization. The experimenter presents each picture card to the child, while saying the accompanying phrase. The experimenter then places one picture on a puppet show game, so that the child learns to reach for a hidden toy when he/she hears, "I'm hiding under (stimulus)".
> Presentation of stimulus on R/L is counterbalanced and randomized

| Block	Contrast		Criterion
T	Training	Pea or Key vs. Bye	4/5 correct
2	Voice + Place	Key vs. Bee	18 trials
3	Place	Key vs. Pea	18 trials
4A	Voicing (easy)	Bee vs. Pea	18 trials
4B	Voicing (hard)	Bee* vs. Pea*	18 trials

SPEECH DISCRIMINATION: HYPOTHESIS

> Voice + Place contrast (Bee vs. Key) should be easiest to discriminate because it differs in 2 features.
> Voicing (Bee vs. Pea) will be easier to discriminate than Place (Pea vs. Key) because temporal cues are relatively intact while spectral domain is degraded in CIs.
> Endpoint stimuli (Bee vs. Pea) will be easier to discriminate than the stimuli closer to the boundary (Bee* vs. Pea*).
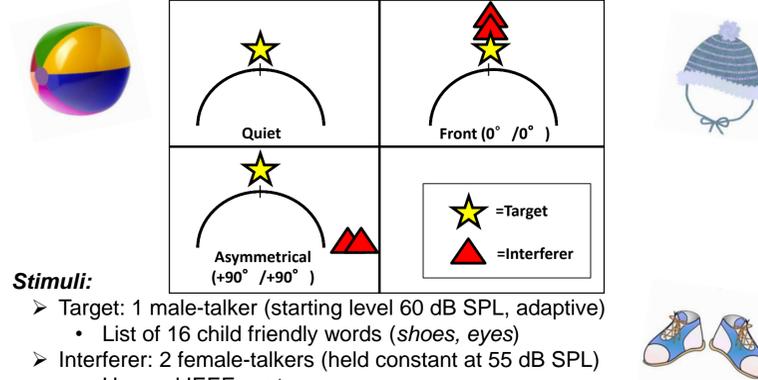
SPEECH DISCRIMINATION: RESULTS

> Individual results on 4 contrasts by toddlers with CIs:
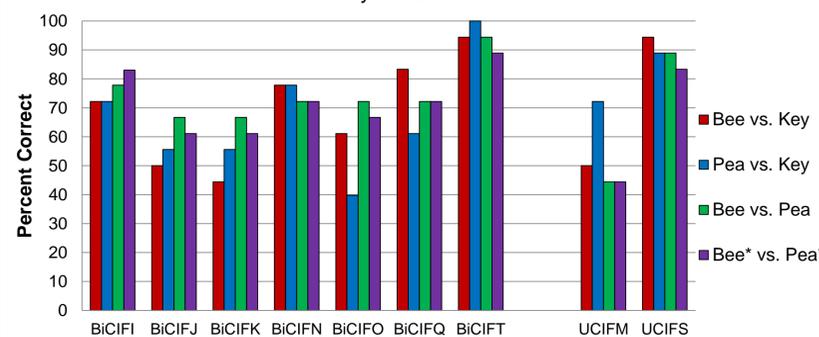
> Group averages for BiCI, UCI, and NH toddlers on the 4 speech contrasts:
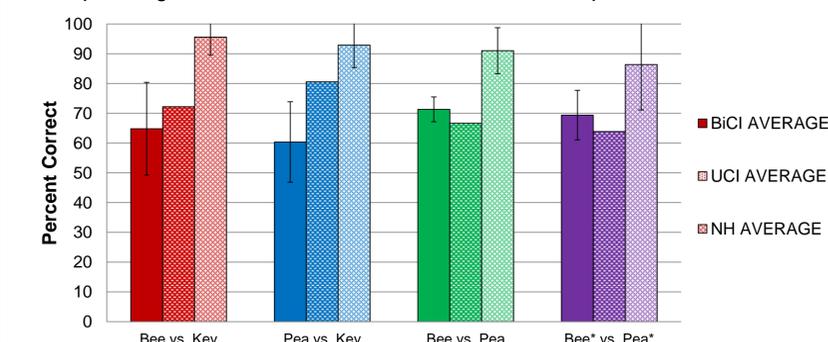
SPATIAL UNMASKING: METHOD

Stimuli:
> Target: 1 male-talker (starting level 60 dB SPL, adaptive)
>   - List of 16 child friendly words (shoes, eyes)
> Interferer: 2 female-talkers (held constant at 55 dB SPL)
>   - Harvard IEEE sentences

Procedure:
> 4 AFC task- Identify target in the presence of interfering speech
> Speech reception thresholds (SRTs) measured using an adaptive tracking algorithm (hybrid PEST/3-down, 1-up (Litovsky, 2005); Threshold determined at 80% correct; computed using MatLab and psignifit (Wichmann & Hill, 2001)

SPATIAL UNMASKING: HYPOTHESIS

> Toddlers with BiCIs will have lower SRTs in the presence of a competitor than toddlers with UCIs
> If toddlers with BiCIs can utilize binaural cues, they will show more benefit when the competitor is spatially separated than toddlers with UCIs

SPATIAL UNMASKING: RESULTS

> SRTs in three conditions for individual toddlers with CIs and mean results for BiCI and NH toddlers:
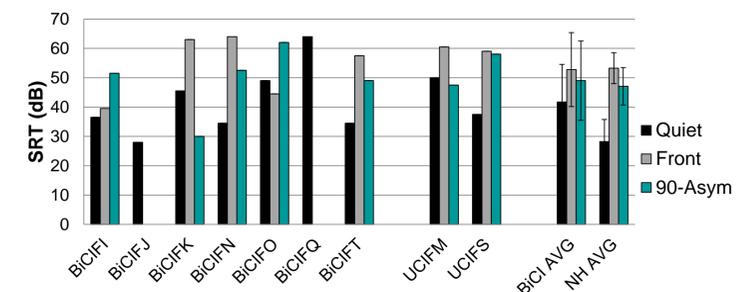
CONCLUSIONS

> Both methods used here are successful for testing 24-36 mo. old toddlers. While toddlers with NH perform near ceiling on speech discrimination and show benefit from spatial release of target and masker, toddlers with both BiCIs and UCIs are extremely variable in their performance.
> The three highest performers on both the Speech Discrimination and Spatial Unmasking tasks were implanted before 12 months of age and perform similarly to their NH peers.
> In implanted toddlers, speech discrimination abilities develop faster for temporally-based speech cues than spectrally-based cues, but thus far, there is no measurable difference between UCI and BiCI users.