Minimum Audible Angles in Children who use Bilateral Cochlear Implants
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ABSTRACT

Over 5,000 children worldwide have received bilateral cochlear implants (CI) so that the auditory skills rely on inputs to both ears, such as sound localization, may be improved. In this study, localization acuity was measured with minimum audible angles (MAA), the smallest discriminable distance between two locations in the frontal azimuth plane. It is unclear whether children who use bilateral CIs can attain MAA comparable to their acoustically-hearing peers, and the extent to which exposure to bilateral hearing is necessary. Children having 3-76 months of bilateral experience participated. Stimuli were presented at an overall level of 60 dB (±4 dB) every week. Every child with <5 years of auditory experience performed the task, whereas some of the children with >5 years' experience could not perform the task. In the former group, children with >2 years' bilateral experience were able to perform the best-performance (MAA thresholds >30 degrees), compared to children in the latter group who had completed the task (MAA thresholds >30 degrees). Results suggest that in children who receive bilateral CIs the two overall factors that impact performance are overall “fine in sound” and amount of time with bilateral experience.

INTRODUCTION

• Cochlear implants are being provided to an increasing number of people who are deaf. In particular, bilateral cochlear implants (BICIs) are becoming increasingly more common, especially in children. Previous research suggests that children who use BICIs have better sound localization acuity compared to a minimum audible angle (MAA) than children who are unilaterally implanted (Litovsky et al., 2006). However, their performance is on average, worse than age-matched peers with acoustic hearing.

• Numerous factors can be considered regarding this gap in performance between BICI listeners and typically-developing (TD) children, including the fact that implant speech processors are not coordinated; hence, the extent to which accurate binaural cues are not provided to these listeners is unknown. Additionally, there is a limited number of channel stimuli that are available for use in studying the binaural interaction and the addition of simultaneous sounds to a binaural cue. Further, the extent to which success with BICIs depends on binaural auditory processing is not well understood.

• Gaps in performance between children who use BICIs and TD children could be accounted for by non-auditory factors such as memory and cognition.

• Purpose: (1) to determine whether sound localization accuracy is in children who use BICIs is generally better in children who have had longer periods of bilateral experience. 

• To assess the reliability of sound localization acuity in children who use BICIs is generally better in children who have had longer periods of bilateral experience.

• It was expected that performance for all children would decrease as the task became more challenging (i.e., the number of channels increased). Moving from left/right discrimination to MAA in one hemisphere, and that children with the greatest amount of bilateral experience would have the lowest thresholds across conditions.

METHOD

MINIMUM AUDIBLE ANGLE (MAA) - Smallest discriminable distance between two locations that are spatially separated

Set-up - Left/Right Discrimination:

• Within a block of trials, a pair of loudspeakers was selected from an array of 15 placed along a semi-circle in azimuth, 1.2 meter head position: center of array, facing 0°.

• Sound booth with RT=250 ms.

• Reference speakers were represented by images of stars (green: left; yellow: right).

Stimulus locations:

• Start at ±40°.

• Decrease angle if ±75° correct.

• Increase angles if ±75° correct.

• Make trials more difficult with ±60° (which remained until performance dropped below 75% correct).

• Feedback: Provided visually on a PC monitor placed at 0°.

• Minimum Audible Angle (MAA) = 

Setup - Within Hemifield Discrimination:

Left/Right Discrimination

• Reference at 0° or 50°.

• Initial change in locations: 50°.

• If ±75° correct, decrease angle.

• If ±75° correct, increase angle.

• Testing in clicks of 20 trials; vary angle of comparison location across trials.

• Stimuli presented to side of initial-implemented ear.

Stimulus:

• Target: Spondee spoken by an adult male talker randomly chosen from a list of 25 examples: (‘airplane’, ‘bathtub’) 60 dB SPL = 440° right.

Procedure:

• Left/right: Children reported whether the stimulus was in the left/right ear.

• Observational: Children reported whether the stimulus location remained or changed the same.

• MAA Threshold: determined from psychometric functions a value of the angle that intersected the function at 70.9% correct.

• Testing: Provided visually on a PC monitor placed at 0° (underneath the front speaker), icons flashed to indicate correct answers after responses.

Conclusions: Children who completed left/right discrimination with performance >75% correct proceeded to the more challenging hemifield measures (0°/50° hemifield, respectively).

• Testing concluded if the child could not attain 75% correct performance on any of the MAAs.

STANDARDIZED MEASURES

• Standardized measures were administered to provide descriptive information regarding the sample that may also predict better performance of MAA performance.

• Test of Language Development – Primary, 4th ed. (TOLD-P; Newcomer & Hamblin, 2008)

• Expressive Language

• Core Language Composite

• Receptive Language

• Language: Brief IQ (Non-verbal Intelligence; NIH-NCDC) and Memory Screen Composite

RESULTS: MAA and Bilateral Experience

Table 1. Demographic Characteristics and Results of Standardized Measures for children with 3-36 months (n=25) and 50-76 months (n=5) of bilateral experience

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<th>n</th>
<th>Mdn</th>
<th>Mean</th>
<th>SD</th>
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<tr>
<td>Age (yr)</td>
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<tr>
<td>Hearing Age (yr)</td>
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<td>5.5</td>
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<tr>
<td>Bilateral Experience (yr)</td>
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<td>3.4</td>
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<td>Non-Verbal Intelligence</td>
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<td>85</td>
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<td>Memory Screening Test</td>
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<tr>
<td>Core Language</td>
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<td>55</td>
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<td>Speaking Comp</td>
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<tr>
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<tr>
<td>MAA Left/Right</td>
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<td>2.8</td>
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<td>MAA Handedness</td>
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Table 2. Results of MAA Testing

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CONCLUSIONS

• The emergence of spatial hearing in children who use bilateral cochlear implants occurs in parallel with the age at which the auditory streams are first fully activated.

• Variability within the group of children tested suggests that spatial hearing may depend on a combination of age, hearing age, and bilateral experience.

• Group variance in performance on auditory measures is often attributed to non-sensory factors. Here we examined standardized measures of NVIQ, Memory, and Language. Group means on these measures suggest that these children are, on average, performing well-within (or above) the range of age-matched typically-hearing peers. Lack of statistical correlations of auditory and non-auditory measures should be interpreted with caution, as these children may not be representative of the bilaterally-implemented population of children. Further research in this area is needed to determine whether performance on standardized measures is predictive of spatial hearing abilities.

REFERENCES


ACKNOWLEDGEMENTS

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