



Cochlear implant plus hearing aid: measuring binaural benefit in children

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Abstract. Two children who wear a cochlear implant (CI) in one ear and a hearing aid (HA) in the other ear completed a test battery designed to measure speech perception in noise and localization abilities. The children had different lengths of device use for both the CI and the HA (S1 having more CI experience than S2). General trends indicate that the use of an HA in the non-CI ear may benefit localization of sound sources and may degrade ability to understand speech in noise. Due to individual variability on specific conditions, data on more children is necessary to derive conclusions regarding the binaural benefit of combining a CI with an HA. The current test battery may be a useful clinical tool for individual assessment in children. © 2004 Elsevier B.V. All rights reserved.

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1. Introduction

Until recently, children who received a cochlear implant (CI) generally did not use a device on the non-CI ear. As CI candidacy criteria have changed, more children who have residual hearing in the nonimplanted ear have received a CI. This fact, combined with studies showing that continued neural stimulation may have long-term advantages [1], has caused many professionals to recommend continued use of a hearing aid (HA) in the non-CI ear. However, few clinical or research methods exist for use in validating the benefit of using two devices (CI+HA). This study used a new test battery that assesses the ability of young children to understand speech in quiet and in noise, and to localize sounds, with their CI alone and with their CI+HA.

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Table 1
Subject characteristics

Subject	Gender	Chron. age	Etiology of hearing loss	Length of CI use	Length of HA use
1	Male	10 years	Waardenburg syndrome	7 years	10 months—due to discovery of residual low-frequency hearing
2	Female	6 years	Unknown	7 months	5 years—with strict Auditory–Verbal Therapy

2. Methods

2.1. Subjects

This work consists of case studies on two children. Both children wore a CI on the left ear and a behind-the-ear (BTE) HA on the right ear. Each child was diagnosed with hearing loss and initially fit with bilateral HAs near their first birthday. The two children differed in etiology and length of device use as listed in Table 1.

2.2. Testing apparatus

All testing was completed in a large sound-treated booth (2.8×3.25 m). Loudspeakers were positioned on a horizontal arc spanning $\pm 90^\circ$ azimuth. Subjects were seated at the center of the arc at a distance of 1.5 m from the loudspeakers, and were instructed to hold their heads facing front center at the onset of each trial. The test booth was designed to be attractive to children. Colorful pictures attached below the speakers and an interactive computer interface provided response alternatives and reinforcement that maintained the children’s attention for the duration of the testing sessions (Fig. 1).

3. Test battery

3.1. Right/Left Discrimination

A Right/Left Discrimination task was used to estimate Minimum Audible Angle (MAA) by way of a 2-AFC interactive computer game. The target stimulus was a male-voice recording of the spondee “baseball”, repeated three times. The child reported

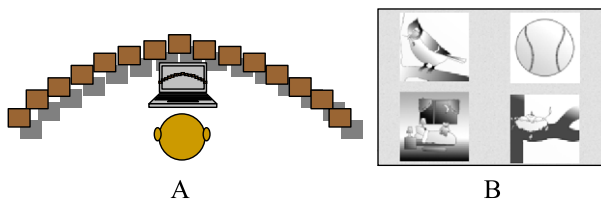


Fig. 1. Test apparatus used for Localization (A) and Speech Intelligibility (B) testing.

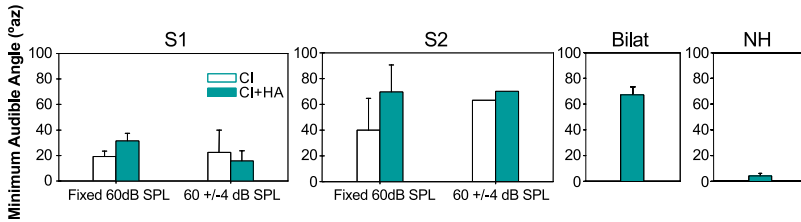


Fig. 2. R/L discrimination threshold (MAA) is compared for S1 and S2 with the average of 4 bilateral-CI children tested by Litovsky et al. [2] and average data from 20 normal-hearing children ages 5–9 tested by Agrawal et al. [3]. Note that smaller values depict better discrimination performance.

whether the target came from the right or left side of the room by selecting from R/L icons on the computer screen. R/L presentations were random and the angle was varied adaptively using a 3-down/1-up decision rule. MAA thresholds were defined as the angles at which discrimination performance reached 80% correct. Presentation level was either fixed at 60 dB SPL or roved at 60 ± 4 dB SPL (uniform distribution). Children were tested in two listening modes: CI alone and CI+HA.

Results are displayed in Fig. 2. In general, all CI children had higher MAAs than normal hearing children. That is, they required larger source separations in order to discriminate between the R/L hemifields correctly. However, S1 had the lowest MAA thresholds (best performance) of all CI children tested to date, including children with bilateral CIs. Note that S1 can be differentiated from the other CI subjects in several ways. First, the fact that he has residual low-frequency hearing may have played an important role in his sound localization discrimination. Second, S1 has had a CI for 7 years compared with S2 who received a CI less than 1 year prior to testing. This suggests that the combined effects of listening experience as well as the potential role of low-frequency residual hearing should be explored further in a larger population of children.

3.2. Speech Intelligibility

Speech Intelligibility in noise was tested using the 4-AFC CRISP test [4], an interactive computer “listening” game. Target Stimuli were male-voice recordings of 25 child spondees. Interferers were two female-voice recordings of Harvard IEEE sentences played simultaneously. The target was always located at the front (0°) while the location of the interferers was either -90° (left), 0° (front) or $+90^\circ$ (right). The interferers were presented

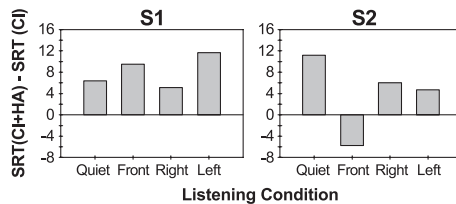


Fig. 3. Effect of HA in non-CI ear: SRT. Differences in SRTs obtained in the CI+HA and the CI listening modes are shown for S1 and S2. High values represent larger SRTs (poorer performance) in the CI+HA than CI mode.

at a constant 60 dB SPL and the level of the target was varied adaptively according to a 3-down, 1-up rule in order to obtain an SRT at 79% correct.

Fig. 3 shows difference scores [SRT (CI+HA)–SRT (CI)]. S1 showed increased SRTs (average 8.2 dB) in all listening conditions when using CI+HA compared with the CI alone condition. S2 showed increased SRTs (average 7.3 dB) in 3 of 4 CI+HA listening conditions compared with the CI alone. This child demonstrated benefit from the added HA only when the target and interferers were presented from the same location (front, 0°). Even in the Quiet condition (no interferer), both children required a higher target level when using CI+HA than the CI alone.

4. Conclusions

(1) Although hearing aids are being recommended for use in the nonimplanted ear of many children, overall, the two subjects tested here showed degraded performance on speech intelligibility with the CI+HA compared with the CI alone. (2) S1 achieved higher performance than S2 on all tasks. This may be due to longer experience with the CI. More residual hearing in HA ear may also be a factor. (3) Overall level cues were important for sound localization for S1; hence, it is recommended that measures of bilateral hearing be utilized with roved stimulus levels. (4) Use of an HA in the non-CI ear improved R/L discrimination abilities for one of the two subjects, and may be an important predictor of HA benefit. (5) Binaural benefit from wearing an HA in the non-CI ear may be task dependent and may vary by individual. Thorough assessment via a test battery, such as the one presented here, is recommended.

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