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Bilateral cochlear implants in children

R. Litovsky[a,*], P. Johnstone[a], A. Parkinson[b], R. Peters[c], J. Lake[c]

[a]*University Wisconsin-Madison, Communicative Disorders and Waisman Center, 1500 Highland Avenue, Room 565, Madison, WI 53705, USA*
[b]*Cochlear Americas, United States*
[c]*Dallas Otolaryngology Associates, Dallas, TX, United States*

Abstract. This study investigated the extent to which 9 months of listening with bilateral cochlear implants (CIs) improves the ability of children to hear speech in noise and to localize sounds. Three children ages 8–12 who received sequential bilateral CIs, 3–8 years apart, participated in a series of binaural tasks at 3 and 9 months after activation of the second CI. Each child participated in a battery of tests under unilateral and bilateral conditions. Results suggest that speech intelligibility in noise improves with added bilateral experience, but that speech intelligibility in quiet does not. In addition, the improvement was seen primarily for the two younger children, who had received the second CI at the age of 8, but not for the older child whose second CI was received at the age of 12. None of the children were able to localize sounds well at 3 or 9 months after receiving the second CI. Further research is necessary to establish the importance of age of implantation and duration of bilateral experience necessary in order for maximal performance to be achieved.

Keywords: Bilateral; Cochlear; Implantation; Pediatric; Binaural; Experience

1. Introduction

In recent years, cochlear implants (CIs) have become increasingly more successful, with children's language acquisition and reading skills achieving increasingly higher performance, e.g., Refs. [1,2]. However, adult and children users of CIs share a common complaint regarding their ability to hear in noisy environments and for children this difficulty can be especially problematic in classroom environments. Given the known importance of binaural hearing for speech-in-noise and localization abilities, an attempted

* Corresponding author. Tel.: +1 608 262 5045; fax: +1 608 263 2918.
E-mail address: Litovsky@waisman.wisc.edu (R. Litovsky).

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solution to address this problem in some patients has been bilateral implantation. To date, there is a growing number of bilateral adult CI users, and there is increasing evidence that bilateral CIs improve speech understanding in noise and sound localization for sources positioned in the horizontal plane, e.g., Refs. [3,4]. Bilateral implantation in children is less common than in adults and may remain that way until the benefits of implanting both ears can be objectively quantified and justified. This study focused on measurements of directional and spatial hearing in children who received a second CI several years after having shown success with their first CI. Testing was conducted at 3 and 9 months after activation of the second CI, with a focus on measures of sound localization, right/left discrimination and speech intelligibility in the presence of interfering speech.

2. Methods

2.1. Subjects

Three children 8–13 years of age with at least 3 years of unilateral cochlear implant experience underwent sequential implantation in the opposite ear. It was required that they were engaged in a habilitation/educational program with an emphasis on spoken language adjustment. Subjects S1 and S3 were 8 years old at the time of the second surgery, while S2 was 12 years old. In addition, S1 and S3 had two Nucleus® 24 devices, while S2 had a Nucleus 22 in the first ear and a Nucleus 24 Contour™ in the second ear. The same speech coding strategies were used in both ears, although each ear was independently mapped for best results in that ear.

2.2. Testing protocol

Speech intelligibility was measured using the CRISP [5] test, a 4-AFC test in which the target speech (spondees) was presented from 0° (front). In conditions with interfering speech, the interferer also occurred from 0°. Testing was conducted at fixed signal-to-noise ratios (SNRs) that varied from −25 to 0 dB SPL. Sound localization measures were conducted using an array of 15 matched loudspeakers positioned in a semicircular array at 10° intervals in the horizontal plane, using 3, 25-ms pink noise bursts, presented at 60±4 dB SPL. Stimuli were presented 10 times from each location, in random order.

3. Results and discussion

3.1. Effect of listening experience on speech intelligibility in noise

Measures of speech intelligibility in noise generally revealed that performance was better (higher percent correct) when listening under bilateral conditions compared with either the first- or second-implanted ear alone. Of particular interest here, however, is the effect of listening experience on the ability of children to ignore the interferers and listen to the speech. First, the effect of experience can be evaluated by comparing performance after 3 and 9 months of bilateral listening. Fig. 1 shows performance of the three children at the two time intervals, for the condition in which the target and interferers were both presented from 0° (front). Performance improved over the 6-month interval of additional listening experience for subjects S1 and S3, pointing to the importance of listening experience in

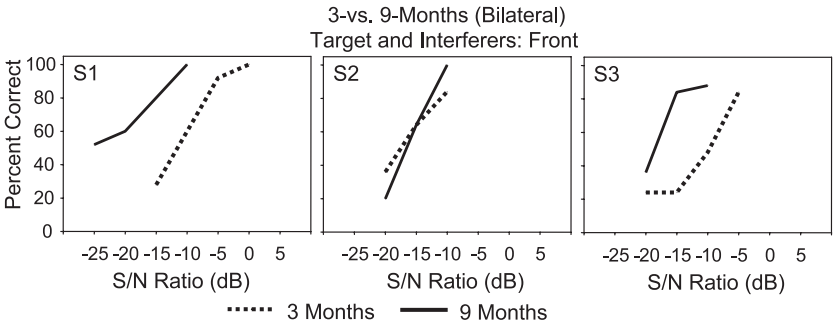

Fig. 1. Measures from the CRISP test are shown for three children with bilateral CIs, tested at 3 and 9 months after activation of the second CI. Percent correct for 25 targets per data point is plotted as a function of signal-to-noise ratio, comparing results from the two testing sessions. In this set of measures, the target and interfering speech were both presented from front and testing was conducted in the bilateral listening mode (with both CIs active).

obtaining the benefit of listening to speech in noise. This was not true, however, for S2, a finding that underscores another component of experience, which is the age at which the implants are received. S2 was the oldest of the three subjects (age 12), and had the longest duration of unilateral deafness (first CI implanted at age 8), as well as being the oldest at the time of the second implantation. These findings suggest that the advantages afforded by bilateral CIs, as measured with speech intelligibility, undergo improvement during the first 9 months (and possibly longer). However, there may be a critical period for the maximization of the benefit. Follow-up measures at longer post-surgical intervals, as well as with a larger number of subjects are necessary in order to obtain a more complete picture of the factors that are most important in contributing to bilateral advantages in children.

3.2. Effect of listening experience on speech intelligibility in quiet

Measures of speech intelligibility in quiet generally revealed that performance did not differ between the 3- and 9-month testing intervals. Fig. 2 shows results for the three

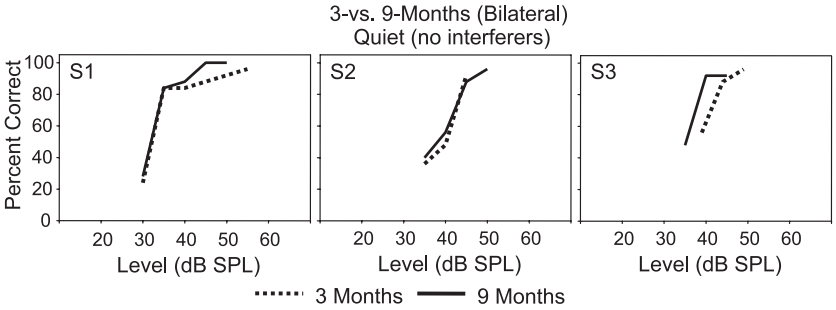

Fig. 2. Measures from the CRISP test are shown for three children with bilateral CIs, tested at 3 and 9 months after activation of the second CI. Percent correct is plotted as a function of sound level for the two testing sessions. In this set of measures, there was no interfering sound and the target was presented from front.

subjects at the two testing intervals. All three subjects reach 100% performance at around 40 dB SPL and only S3 shows slightly higher performance at 9 months compared with 3 months. This finding, in contrast with that shown in Fig. 1, suggests that the bilateral listening mode may be especially important for negotiating complex acoustic environments, such as listening to speech in the presence of interferers. However, bilateral hearing may not be of particular importance for listening in quiet environments. In addition, this result suggests that the improvement observed in noise for S1 and S3 is not merely a test–retest effect with overall improvement on the task, but is specifically indicative of improvement under stringent listening conditions.

3.3. Effect of listening experience on sound localization accuracy

The average RMS error for the three children tested was between 50° and 60°, at both 3- and 9-month intervals, and was no different for unilateral and bilateral listening modes. This is significantly higher than the average RMS of approximately 10° observed in normal-hearing children and values typically reported in adults of 20–30° [3,4,6]. This preliminary observation suggests that the robust effects of bilateral implantation on localization abilities observed in adults is not mirrored in the sequentially implanted children studied here. A notable difference between the adult and child populations is the fact that most adults with bilateral CIs were deafened post-lingually; hence, they had a number of years during which they were exposed to binaural hearing. This early exposure may be necessary for establishing essential neural circuits that mediate localization abilities at a critical time during development.

4. Conclusions

There is evidence that bilateral CIs are beneficial for speech understanding in noisy environments, and that performance improves with added listening experience. Benefit for understanding speech in the presence of competing speech is irregardless of whether the children had been exposed to bilateral hearing during early childhood. In contrast, sound localization abilities are still poor after 9 months of bilateral hearing, and may require further experience to achieve the sort of benefit that has been reported in adults.

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