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Language and speech perception of young children with bimodal fitting or bilateral cochlear implants

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Abstract

Objectives—This paper compares language development and speech perception of children with bimodal fitting (a cochlear implant in one ear and a hearing aid in the opposite ear) or bilateral cochlear implantation.

Methods—Participants were children enrolled in the Longitudinal Outcomes of Children with Hearing Impairment (LOCHI) study. Language development was assessed at 3 years of age using standardized tests. Speech perception was evaluated at 5 years of age. Speech was presented from a frontal loudspeaker, and babble noise was presented either from the front or from both sides.

Results—On average, there was no significant difference in language outcomes between 44 children with bimodal fitting and 49 children with bilateral cochlear implants; after controlling for a range of demographic variables. Earlier age at cochlear implant activation was associated with better outcomes. Speech perception in noise was not significantly different between children with bimodal fitting and those with bilateral cochlear implants. Compared to normal-hearing children, children with cochlear implants required a better signal-to-noise ratio to perform at the same level, but demonstrated spatial release from masking of a similar magnitude.

Conclusions—This study found that language scores for children with bilateral implants were higher than those with bimodal fitting or those with unilateral implants, but neither reached significance level.

Keywords

Children; bimodal fitting; bilateral implants; language; spatial release from masking

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Conflicts of interest
None were declared.

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Introduction

Listening with two ears is better than one. When sounds are audible in both ears, the listener can make use of the difference in the timing and level of sounds reaching the two ears to locate the source of sounds. When listening to speech in noisy situations, the listener can selectively attend to the ear with a better signal-to-noise ratio to hear speech better. Even when the signals reaching the two ears are similar, the auditory system can derive benefits by combining information from both ears. These advantages are possible for people with hearing loss who are aided by either acoustic amplification with hearing aids or electric stimulation with cochlear implants.

Evidence of binaural advantages when hearing-aid amplification in one ear is combined with cochlear implantation in the opposite ear (bimodal fitting) has been summarised in systematic reviews (Ching et al., 2007; Ching & Incerti, 2012). Speech perception is better with bimodal fitting than with unilateral cochlear implantation, for children and for adults. The effect size is larger for speech perception in noise than in quiet. Significant benefits with bimodal stimulation are evident also for locating sound source, listening to music, and functioning in real-world environments.

Evidence on the benefits of bilateral relative to unilateral cochlear implantation is accumulating. Even though the current evidence does not allow robust conclusions about the clinical effectiveness of bilateral cochlear implants for children (Sparrenboom et al, 2010; Ching & Incerti, 2012), this treatment is the only option for providing access to sounds in both ears for those with bilateral profound hearing loss. The current evidence on the relative effectiveness of bilateral implantation and bimodal fitting is even less certain for people who receive a cochlear implant in one ear and who have residual hearing in the other ear due to methodological limitations in previous studies (for a review, see Ching & Incerti, 2012).

Why is the choice between bimodal fitting and bilateral implantation an important question? Firstly, current cochlear implant processing is efficient in providing high-frequency information whereas acoustic amplification is more effective in providing low-frequency information. As such, bilateral bimodal stimulation is better than bilateral cochlear implantation for perception of pitch-related information, including voice-pitch contrasts in speech (Zhang et al, 2010; Cullington & Zeng, 2011) and music perception (McDermott, 2011). Secondly, there is some evidence that acquisition of expressive language is better for children with bilateral cochlear implants who had prior experience of bimodal stimulation than those who did not have such experience (Nittrouer & Chapman, 2009), possibly because bimodal fitting allowed early access to voice-pitch contrasts that are fundamental to early speech perception. For infants and young children with usable residual hearing in at least one ear, is it better for speech and language acquisition to provide bimodal fitting or bilateral implantation? When speech occurs in noisy environments, as in many real-world environments including classrooms where children learn, is either of the treatment options more effective for enabling a child to make use of inter-aural time and level differences to separate target speech from background noise? This spatial release from masking (SRM) has been reported in normal-hearing children (Ching et al. 2011; Litovsky, 2005), but findings remained controversial for children with cochlear implants.

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To address the evidence gap, it appears impossible or ethically unacceptable to conduct a randomised controlled trial of alternative treatments for young children. Rather, we propose to take advantage of the prospective measurement of outcomes in the Longitudinal Outcomes of Children with Hearing Impairment (LOCHI) study (www.outcomes.nal.gov.au) to compare outcomes of children with bimodal fitting to those with bilateral cochlear implants. About 450 children enrolled in the study, drawn from populations in New South Wales, Victoria and Southern Queensland in Australia. The sample size allowed the quantification of the impact of device configuration (bimodal fitting or bilateral implantation) after allowing for the effects of multiple demographic variables.

This paper reports the effect of device configuration on 1) language development of children at 3 years of age; and 2) speech perception at 5 years of age.

Method

This is a prospective cohort study. Participants were 134 children enrolled in the LOCHI study who were using cochlear implants at 3 years of age – 13 used a cochlear implant in one ear only (unilateral CI), 61 children had bimodal fitting (CI+HA), and 60 had bilateral cochlear implants (bilateral CI).

Procedure

Soon after a child turned 3 years of age, a team of trained research speech pathologists conducted assessments using standardized tests. Directly-assessed measures included the Pre-school Language Scale 4th ed. to evaluate receptive and expressive language, the Peabody Picture Vocabulary Test, 4th ed. to evaluate receptive vocabulary, and the Diagnostic Test of Articulation and Phonology to assess production of consonants and vowels. Demographic information and performance ratings were solicited from parents using written questionnaires. Parent-report tools included the Child Development Inventory and the Parents' Evaluation of Aural/oral performance of Children. Custom-designed questionnaires were used to collect demographic information.

In addition, speech perception was evaluated at 5 years of age. Target speech (sentences or words) was presented from a frontal loudspeaker at 0º azimuth. Babble noise was presented either from the same loudspeaker, or from two loudspeakers positioned at ±90º azimuth. The signal-to-noise ratio (SNR) for 50% correct identification was measured using an adaptive procedure with either words or sentences as stimuli. The difference in SNRs obtained with the two listening conditions provided an estimate of SRM.

Statistical analysis

The Statistica software and R with additional R packages were used for analysis. Factor analysis was used to combine test scores from all measures at 3 years into a global outcomes factor score. Multiple linear regression analysis was performed with the factor score as a dependent variable and 13 predictor variables, including device configuration (unilateral CI, CI+HA, bilateral CI), gender, additional disability, ANSD, communication mode at home and in early education, language at home, maternal education, age at first fitting, age at cochlear implant activation, birth-weight, socioeconomic status and severity of hearing loss. Analysis of variance was used to compare speech perception results between device groups.

Results and Discussion

Global outcomes factor scores were available for 106 children with cochlear implants at 3 years of age. Of these children, 49 had bilateral CI, 13 had unilateral CI, and 44 had CI+HA. The overall effect of device configuration was not significant ($p = 0.09$). Table 1 shows the estimated effect size of each device configuration. Relative to bilateral CI, the estimated effect size is in the negative direction. On average, those with CI+HA had 6.6 points lower (95% confidence interval is +/− 7.2 points), and those with unilateral CI had 8.9 points lower (+/− 10.6) outcomes scores, than those who had bilateral CIs. However, neither met the required significance level of < 0.05. It is possible that a larger experiment may show a significant negative effect of device configuration.

Earlier age at cochlear implantation was, on the other hand, significantly associated with better outcomes after allowing for a range of demographic characteristics. Details were described in a separate paper (Ching et al, 2013). Briefly, a delay from 10 to 24 months in cochlear implant activation was associated with a decrease of 8.1 points (+/− 6.4 points) in outcomes scores, which is a decrement of more than one-half of a standard deviation.

At 5 years of age, 70 children with cochlear implants completed speech perception testing. Of these children, 20 were using CI+HA, and 50 were using bilateral CIs. As shown in Figure 1, the SNR was lower when speech and noise were spatially separated (S0N90) than when they were collocated (S0N0), for both groups of children ($p < 0.001$). The difference in absolute SNRs between groups was not significant for both listening conditions ($p > 0.9$). Compared to children with normal hearing (Ching et al, 2011), children with CI+HA and children with bilateral CIs required about 9 dB better SNR for achieving the same level of speech perception. Both groups of children with cochlear implants demonstrated an SRM of about 3 dB, similar in magnitude to that reported for children with normal hearing.

Conclusion

This population-based study found that earlier age at cochlear implant activation was significantly associated with better language outcomes at 3 years of age, after controlling for a range of demographic characteristics. Although mean scores for children with bimodal fitting or unilateral cochlear implants were lower than those for children with bilateral implants, the difference did not reach significance level. Children who used either bimodal fitting or bilateral cochlear implants required better SNR than normal-hearing children but demonstrated abilities of a similar magnitude for using spatial separation between speech and noise to perceive speech.

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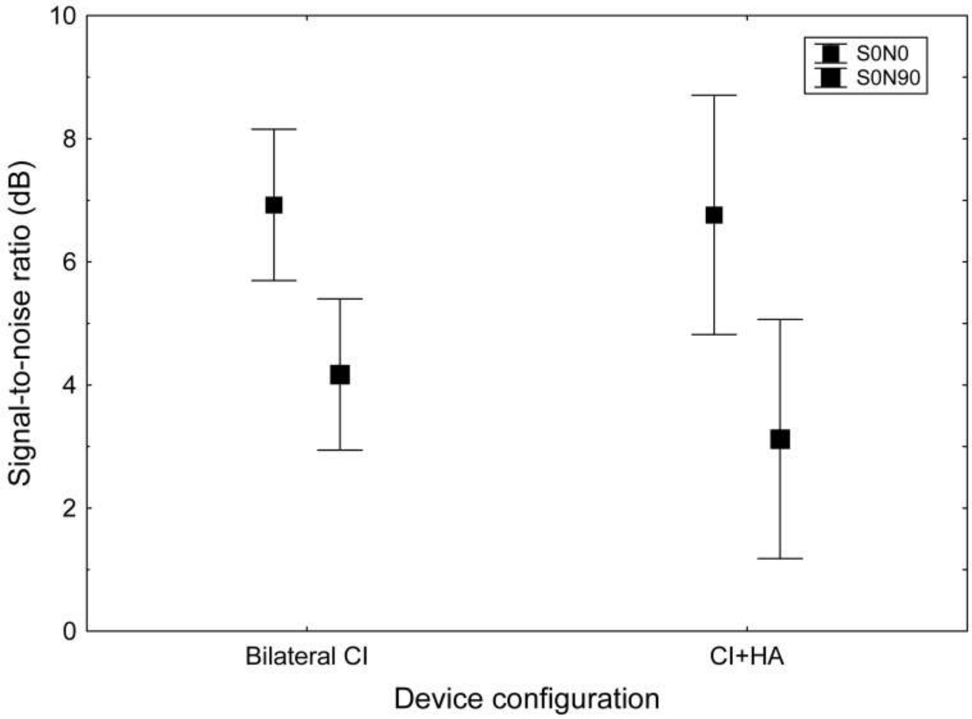

Figure 1.
Mean signal-to-noise ratio in dB of the speech reception threshold at 50% correct, for children with bilateral cochlear implants (Bilateral CI) and children with bimodal fitting (CI +HA). The filled symbols depict mean performance when target speech and babble noise were presented from 0° azimuth (S0N0). The open symbols depict mean performance when target speech was presented from 0° azimuth and babble noise was presented from both sides at ±90° azimuth (S0N90). Vertical bars denote 0.95 confidence intervals.

Table 1

The estimated mean effect size, 95% confidence interval, and p-value for the effect of unilateral cochlear implant (unilateral CI), and bimodal fitting (CI+HA), relative to bilateral cochlear implant (bilateral CI).

Predictor	Estimate (95% confidence interval)	p-value
Unilateral CI	−8.9 (−19.6, 1.7)	0.10
CI+HA	−6.6 (−13.8, 0.7)	0.08