



Published in final edited form as:

*Ear Hear.* 2010 April ; 31(2): 296–298. doi:10.1097/AUD.0b013e3181c12383.

## Bilateral and Unilateral Cochlear Implant Users Compared on Speech Perception in Noise

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### Abstract

**Objective**—Compare speech performance in noise with matched bilateral (CICI) and unilateral (CI-Only) cochlear implant users.

**Design**—Thirty CICI and 30 CI-Only subjects were tested on a battery of speech perception tests in noise that utilize an 8-loudspeaker array.

**Results**—On average, CICI subject's performance with speech in noise was significantly better than the CI-Only subjects.

**Conclusion**—The CICI group showed significantly better performance on speech perception in noise compared to the CI-Only subjects, supporting the hypothesis that bilateral cochlear implantation is more beneficial than unilateral implantation.

### Keywords

adult; bilateral cochlear implants; localization; speech perception; binaural summation

### Introduction

Much of the literature on benefits of bilateral cochlear implantation seeks to demonstrate benefits of having two devices by having bilateral users de-activate one of their implants. Comparisons are then made between performances using one implant to performances using bilateral devices. There is little research comparing the performance of those who have only one implant to that of users with two implants. Dunn, Tyler, Oakley, Gantz, & Noble (2008) studied the benefits of bilateral implantation (CICI) as compared to unilateral implantation (CI-only) using listeners matched by age at implantation and duration of deafness. Their results showed that the CICI group scored significantly higher on sentences and words in quiet and on a localization test compared to the CI-Only group. A limitation of this study was that listening to speech in noise was not tested. Therefore, the purpose of the present study was to assess speech perception in noise on matched bilateral and unilateral cochlear implant subjects. A set of tests that reflect a more dynamic and challenging listening environment was used.

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Speech perception in noise was evaluated on 30 bilateral cochlear implant subjects (CICI) and 30 subject unilateral (CI-Only) cochlear implant subjects. CICI performance was significantly better on words presented in noise. The results showed that it is likely that some CICI subjects can make use of selecting between one of two ears with a more favorable signal-to-noise ratio which is not possible for listeners with only one implant.

## Materials and Methods

### Subjects

Thirty simultaneously implanted CICI and 30 CI-Only subjects who had used their cochlear implants for at least six months participated in this study. None of the CI-Only subjects regularly used hearing aids in the opposite ear in their everyday lives and thus did not use hearing aids during this study. The CICI and CI-Only subjects were matched for age at implantation, duration of profound deafness, and preoperative pure tone average hearing loss (.5, 1, 2k Hz) in the right and left ears. On average, subjects were matched for age and duration within one year and for pre-operative hearing level within 5 dB HL and 6 dB HL for the left and right ears, respectively. No significant differences between groups were found between these matching criteria. A summary of the demographic information is presented in Table 1.

Fifty-eight subjects participated in the Cueing-the-Listener test; 48 participated in the Multiple-Jammers test; and 52 subjects participated in the Cognitive Load test. Due to time constraints not all subjects completed all testing or completed all testing at the same session. Details of each of the tests are described below.

### Procedure

All speech perception in noise tests were randomized as to the order of presentation and were presented in the sound field in a sound-treated booth. In addition, for each test, an array of eight loudspeakers spanning a horizontal arc of 108° was used. Loudspeaker one and loudspeaker eight were placed 54° to the left and to the right of the straight-ahead (0°) position (Figure 1). Each test used a closed set of 12 spondee words (female voice) randomly selected as the target. The listener used a touch screen to select which spondee word was heard amongst the background noise. The level of the background noise was varied adaptively with the level of the spondee word remaining constant. The signal-to-noise ratio (SNR) yielding 50% correct was obtained with a 2-up and 2-down adaptive rule with a total of 14 reversals. Each test consisted of five runs and the SNR was calculated based on the average threshold of the last three runs.

**Cueing-the-Listener**—This test represented a situation where a listener might hear a talker, turn to face them, and then recognize their message. An auditory cue (“hey I’m over here”) was played in quiet (at the same level as the target word) to orient the listener to the location of the loudspeaker that the target word would be played from. After the auditory cue was played, there was a 1 second delay, followed by initiation of the background noise and 0.8 seconds later the target word was played. The loudspeaker location of the target words was randomly selected on each trial and the background of competing speech noise (a male and a female each repeating a different sentence from the same loudspeaker; Turner, Gantz, Vidal, Behrens, & Henry, 2004) was presented from one loudspeaker that was either +/- 4 loudspeakers from the location that the target word was played. For example, if the target word was played from loudspeaker 3, the competing speech noise would be played from loudspeaker 7.

**Multiple-Jammers**—In everyday settings, listeners are also often faced with competing sounds in the form of several other voices at spatially discrete locations (Hawley, Litovsky, & Colburn, 1999; Culling, Hawley, & Litovsky, 2004). To represent this situation with this test, the target spondee word was presented from one of two loudspeakers placed at +/-8° from 0°-azimuth (loudspeakers 4 or 5). In addition, two separate loudspeaker combinations were used to play simultaneous randomly selected male and female sentences (jammers). The jammers were located either at +54° and -38° azimuth (loudspeakers 1 and 7) or at +38° and -54° azimuth (loudspeakers 2 and 8). The sentences as well as the location of the male and female talkers saying the sentences varied from trial-to-trial.

**Cognitive Load**—This test assesses a listener's ability to divert attention between two tasks, such as listening to a speech signal while simultaneously engaged in a different task, for example, with a different modality such as vision. The loudspeaker location of the target words and location of the background of competing speech noise was the same as described in the Cueing the Listener test. With this test, however, the background noise consisted of one talker repeating one of several randomly selected sentences. The sentence was randomized on each trial. At the same time, a brief visual display was presented on the touch screen with varying numbers of three sets of colored shapes. The arrangement and number of the shapes varied from trial-to-trial. The listener had to judge which set of colors was more numerous or if they were equal while at the same time identifying the target word that was played. The visual display was turned on simultaneously with the background noise and turned off simultaneously with the target word being spoken. The subject had to make a judgment on the visual display first and then chose the target word they heard.

## Results

In Figure 2 the averaged results for the speech perception in noise tests for the CICI and CI-Only subjects are shown as SNR. For each of the tests, a t-test revealed that the CICI subjects were able to listen against significantly higher noise levels to identify the words 50% of the time compared with the CI-Only group. For the Cueing-the-Listener test, the CICI subjects could withstand 9 dB more noise than the CI-Only subjects ( $t(56) = -6.74, p < .00001$ ). The CICI subjects performed 5 dB better than the CI-Only group ( $t(50) = -2.66, p < .05$ ) on the Multiple-Jammer test. For the Cognitive Load test, the CICI subjects outperformed the CI-Only group by an 11 dB S/N ratio ( $t(46) = -4.87, p < .00001$ ).

An additional analysis showed that the CICI group had used their implants an average of 71 months and the CI-Only group had used their implants an average of 128 months. In order to determine relevance to our study results of the CICI group having more recent cochlear implant technology, we evaluated this variable using HINT sentence and CNC word performance on 20 CICI subjects and 20 CI-Only subjects matched on age at implantation, duration of deafness, and type of internal device. Results for both tests showed better performance with the CICI group compared to the CI-Only group indicating that implanted hardware is not likely to be a factor in the difference shown between the groups in the present study. Also noteworthy, the CI-Only group had their implants for a significantly longer period of time, potentially favoring their tested performance.

## Discussion

We evaluated the benefit of bilateral versus unilateral implantation by comparing speech perception in noise in CICI and CI-Only listeners matched for age at implantation, duration of profound deafness, and pre-operative residual hearing on a battery of tests which utilize an 8-loudspeaker array.

Results of the Cueing the Listener test suggest that listeners with two cochlear implants are presumably better able to quickly identify where a sound is coming from in comparison to a listener with only one implant. This could be due to a greater ability to take advantage of localization in the ear with the better SNR.

The Multiple Jammer test arguably introduces informational masking (Kidd, Mason, Rohtla, & Deliwala, 1998; Stickney, Zeng, Litovsky, & Assmann, 2004) in multiple locations that is acoustically and structurally similar to the target signal. Thus, it evaluates a listener's ability to segregate the target signal from the masker. Our results suggest that listeners with two

implants are better able to attend to a target while being challenged with multiple signals with a similar spectrum and content to the target.

The results of the Cognitive Load test suggest that listeners with two cochlear implants are presumably better at processing speech while attending to other simultaneous tasks, perhaps because they are able to segregate the signal from the background noise. In addition, listening with two ears can potentially provide these listeners with an ease of listening which aids in separating their attention between two modalities as found by Noble, Tyler, Dunn & Bhullar (2008) where CICI users self-rated listening effort significantly lower than CI-Only users. Also noteworthy, the CICI users performed 14% better than the CI-Only on the visual component of this test, possibly indicating that they might be better at dividing attention between sources.

## Conclusion

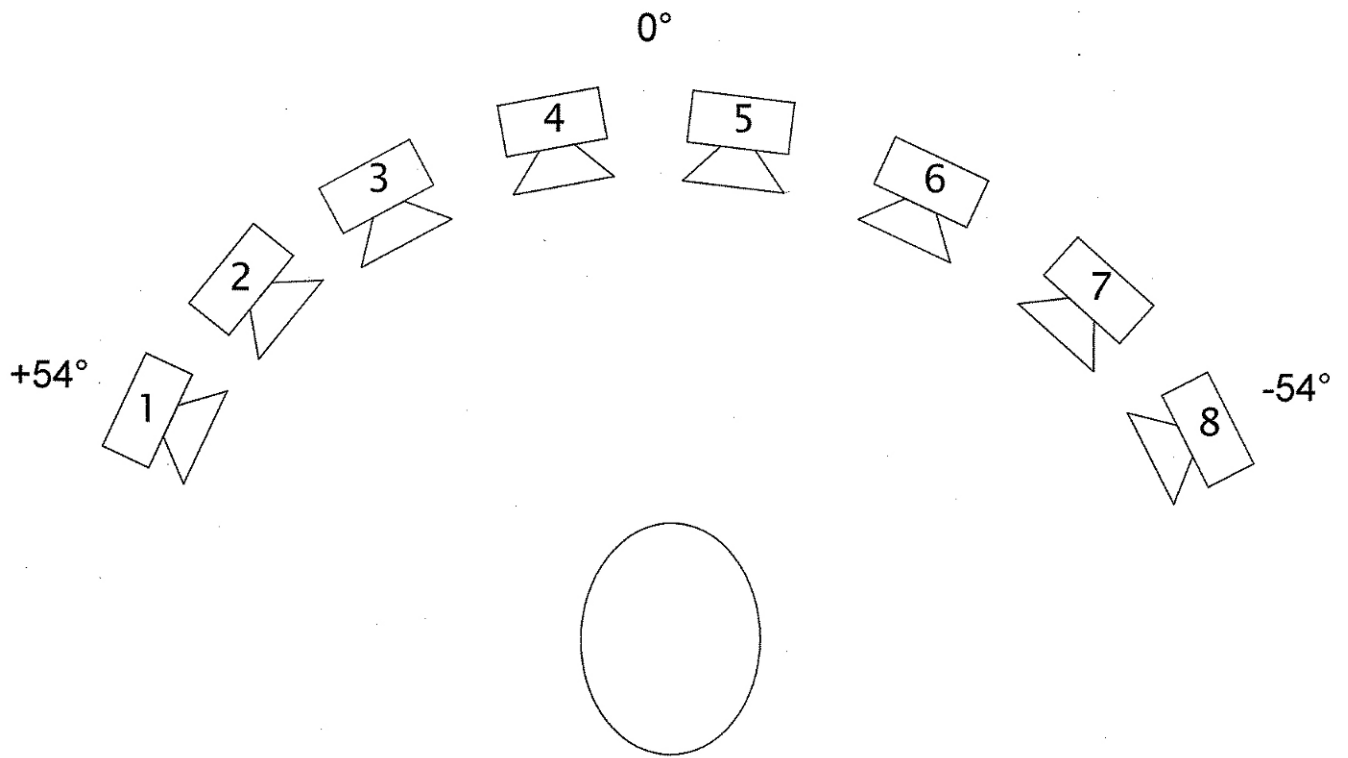
Our results support the hypothesis that bilateral cochlear implantation is materially more beneficial than unilateral implantation due to binaural benefits. The improved performance of CICI users relative to CI-Only users observed here may reflect several factors, including (1) assurance that the better-functioning ear is always implanted; (2) assurance that the ear receiving the favorable SNR is implanted; and (3) true binaural benefits related to localization and squelch.

## Acknowledgments

This research was supported in part by research grant 2 P50 DC00242 from the National Institutes on Deafness and Other Communication Disorders, National Institutes of Health; grant RR00059 from the General Clinical Research Centers Program, Division of Research Resources, National Institutes of Health; the Lions Clubs International Foundation; and the Iowa Lions Foundation. We would like to thank Beth MacPherson, Ann Perreau, and Shelley Witt for all of their hard work and dedication to collecting data for this project.

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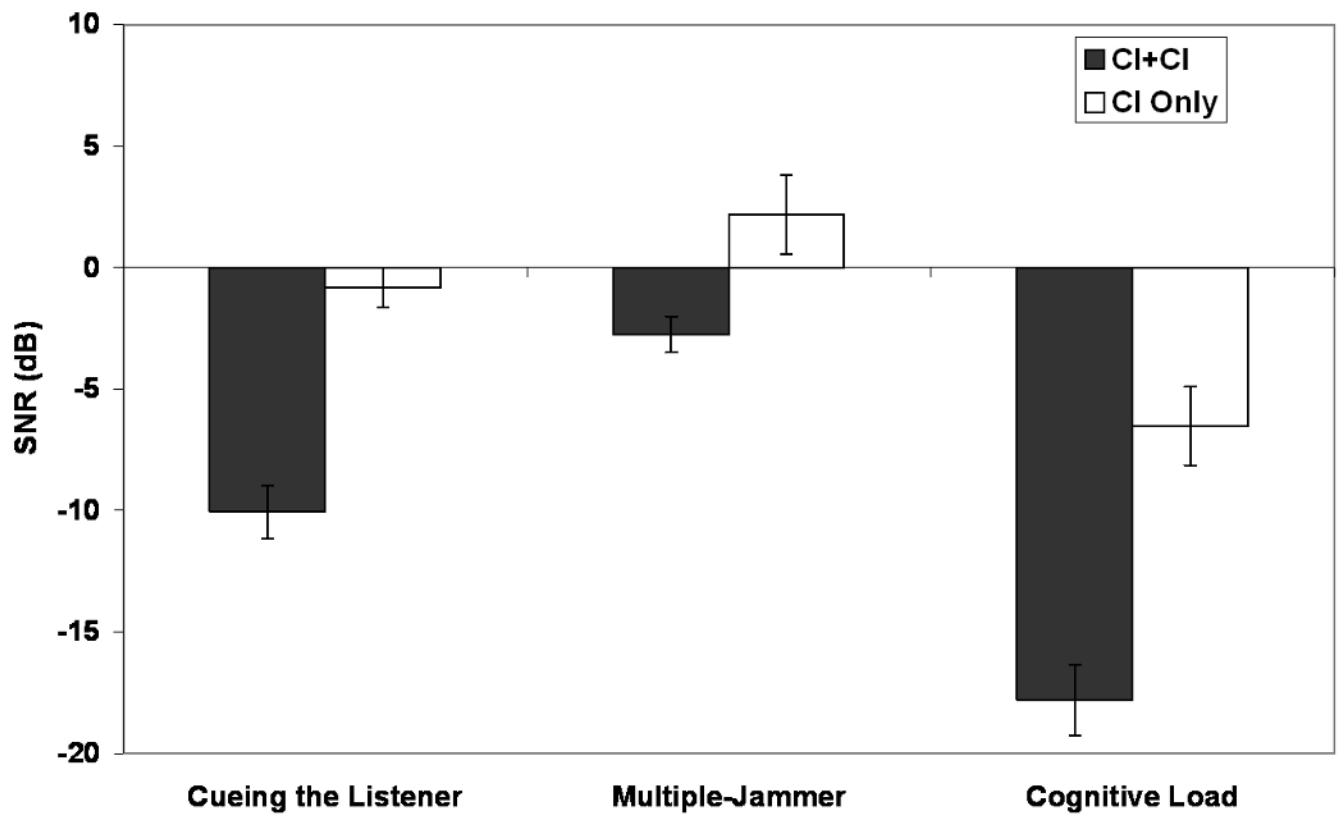
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**Figure 1.** Visual schematic of the eight loudspeaker array which spanned a horizontal arc of  $108^\circ$ . Loudspeaker one and loudspeaker eight were placed  $54^\circ$  to the left and to the right of the straight-ahead ( $0^\circ$ ) position.

## Spatial Hearing Tests in Noise

Age at Implantation, Duration of Deafness, and Pre-Op Hearing Matched  
(N= 58 Cueing; N= 52 Multi-Jammer; N= 48 Cognitive Load)



**Figure 2.** Signal-to-Noise (SNR) ratio scores for Cueing-the-Listener, Cognitive Load, and Multiple Jammer tests for CICI and CI-Only subjects. Average scores are shown with +/-1 standard error bars.

**Table 1**

Summary of demographic information.

	Age at Implant (yrs)	Years Deaf (yrs)	Left Pure-Tone Average (dB HL) (.5, 1, 2k)	Right Pure-Tone Average (dB HL) (.5, 1, 2k)	Nucleus Devices (N=)	Clarion Devices (N=)
CI/CI	55 (SD=14.4)	6.5 (SD=8.4)	100	96	16	14
CI-Only	56 (SD=14.7)	7.2 (SD=9.3)	105	102	21	9