Evaluation of Automatic Directional Processing with Cochlear Implant Recipients

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Abstract

Background For cochlear implant (CI) recipients, speech recognition in noise is consistently poorer compared with recognition in quiet. Directional processing improves performance in noise and can be automatically activated based on acoustic scene analysis. The use of adaptive directionality with CI recipients is new and has not been investigated thoroughly, especially utilizing the recipients' preferred everyday signal processing, dynamic range, and/or noise reduction.

Purpose This study utilized CI recipients' preferred everyday signal processing to evaluate four directional microphone options in a noisy environment to determine which option provides the best speech recognition in noise. A greater understanding of automatic directionality could ultimately improve CI recipients' speech-in-noise performance and better guide clinicians in programming.

Study Sample Twenty-six unilateral and seven bilateral CI recipients with a mean age of 66 years and approximately 4 years of CI experience were included.

Data Collection and Analysis Speech-in-noise performance was measured using eight loudspeakers in a 360-degree array with HINT sentences presented in restaurant noise. Four directional options were evaluated (automatic [SCAN], adaptive [Beam], fixed [Zoom], and Omni-directional) with participants' everyday use signal processing options active. A mixed-model analysis of variance (ANOVA) and pairwise comparisons were performed.

Results Automatic directionality (SCAN) resulted in the best speech-in-noise performance, although not significantly better than Beam. Omni-directional performance was significantly poorer compared with the three other directional options. A varied number of participants performed their best with each of the four-directional options, with 16 performing best with automatic directionality. The majority of participants did not perform best with their everyday directional option.

Conclusion The individual variability seen in this study suggests that CI recipients try with different directional options to find their ideal program. However, based on a CI recipient's motivation to try different programs, automatic directionality is an appropriate everyday processing option.

Keywords
- cochlear implants
- speech perception
- directional microphones

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Introduction

A cochlear implant (CI) notably improves speech recognition for the majority of recipients. Individual benefit varies between recipients, but speech recognition in noise is consistently poorer compared with speech recognition in quiet.[1] One option to improve performance in noise is the use of directional microphones which are available in both hearing aids and CIs. Research shows that directional processing improves speech recognition in noise compared with Omni-directional processing.[2,3] Directional processing can vary in the azimuth of the null, as well if the null is fixed or adaptive. All three CI manufacturers (Advanced Bionics, Cochlear Americas, and MED-EL) offer both fixed and adaptive directional options in their current speech processors. Cochlear Americas' devices were used in this study, therefore their directional processing will be described in detail.

Cochlear Americas' fixed directional option is called Zoom[4] and adaptive directional option is called Beam.[5,6] Zoom uses a set hypercardioid pattern with maximum suppression at 120 degrees. Wolfe and colleagues [7] compared Zoom to Omni-directional processing with 35 adult CI recipients using sentences presented from the front with multitalker babble presented at 90 degrees toward the implanted ear. Mean scores significantly improved with Zoom compared with Omni-directional. Beam is the adaptive directional processing option with maximum noise suppression varying between 90 and 270 degrees depending on the azimuth of the noise. Brockmeyer and Potts[8] evaluated Beam and Omni-directional processing with 30 adult CI recipients using hearing-in-noise test (HINT) sentences [9] in diffuse restaurant noise. Speech recognition was significantly better with Beam compared with Omni-directional processing. Similarly, Gifford and Revit[10] evaluated 20 adult CI recipients with and without Beam (i.e., Omni-directional) and found the best performance in noise with Beam active. The authors suggested an expected range of improvement anywhere from 32 to 66 percentage points for speech understanding in noise when Beam is active.

The benefit of Beam and Zoom is also affected by additional signal processing options including adaptive dynamic range optimization (ADRO), automatic sensitivity control (ASC) and signal-to-noise-ratio noise reduction (SNR-NR).[11] ADRO is a multichannel input gain adjustment across the frequency range which aims to match the signal processing to specified targets in the upper part of the 30-dB input range. ASC automatically adjusts the sensitivity level at which sound is processed according to the background noise floor. SNR-NR estimates the SNR for each channel and maintains those with higher SNRs and attenuates those channels with poorer SNRs. Please see the cited references for a detailed description of these processing options. Speech recognition in noise has been shown to be affected by the combination of signal processing options and directional filtering options. The way these processing options interact is very dependent on the environment, including the level and type of background noise. In addition, it may also be the case that individual preferences or experience with signal processing options could affect an individual's performance, especially in research testing.

In the past, hearing aid and CI recipients had to manually switch programs to change between directional options. The majority of recipients do not, however, routinely change programs in different environments.[10,12] To address this issue, automatic directionality was developed where the hearing device analyzes the environment and automatically implements different directional filtering options. In hearing aids, automatic directional processing has been shown to provide improvement in speech recognition in noise across a variety of environments.[13] Automatic directional processing is relatively new in cochlear implants.

All three CI manufacturers have automatic directionality which changes the directional filtering based on the environment. These directional filtering options can switch the processor between Omni-directional, fixed directionality, and/or adaptive directionality. SCAN, developed by Cochlear Americas was the first automatic processing available for CI recipients. SCAN analyzes the acoustic scene to decide which directional filtering option to activate. Advanced Bionics has Auto UltraZoom and MED-EL has Adaptive Directional, both of which also utilize a scene analysis to implement directional filtering options automatically.

Initial studies have shown SCAN to improve speech recognition in noise for CI recipients. Wolfe and colleagues [14] evaluated 81 adult and 12 pediatric CI recipients with different directional filtering. AzBio Sentences[15] were presented at 60 dB SPL (decibel sound pressure level) with speech-weighted noise (SWN) + 10 dB SNR presented toward the implanted ear. The average score with SCAN was significantly better compared with Omni-directional. Mauger and colleagues [16] tested 21 CI recipients using an Australian sentence test in adaptive noise (SWN and four-talker babble) in two spatial configurations: signal at 0 degrees and noise at 0 degrees (S0N0) and signal at 0 degrees and noise simultaneously from 90, 180, and 270 degrees (S0N3). Directional options included SCAN, Beam, Zoom, and Omni-directional. For the sentences presented in SWN at S0N0, average group scores were significantly improved by approximately 2 dB SNR with SCAN compared all other options. Average group scores in four-talker babble at S0N0 did not reveal any significant differences. With SWN and four-talker babble at S0N3, average group scores showed a significant improvement with SCAN compared with Omni-directional. This study illustrates how differences in noise type and azimuth can affect performance with directional processing.

De Ceulaer and colleagues[17] compared various microphone settings, including SCAN, using sentences presented from the front and multitalker babble presented from six loudspeakers. The conditions tested were: Omni-directional with the participants' everyday signal processing, SCAN + ASC + ADRO + SNR-NR, and wireless microphone(s) all tested at distances of 1, 2, and 3 m. Among the 13 participants, the median within-subject differences between SCAN and Omni-directional were not significant. Like previous studies, however, the SCAN condition did not utilize recipients' preferred or everyday use speech processing options.

The current study utilized the CI recipients' preferred everyday signal processing to evaluate the directional processing options in a diffuse noisy environment. The R-SPACE is a testing configuration that simulates an everyday real-life restaurant environment by using a 360-degree array.[18] The purpose of this study was to compare SCAN to different directional options (Zoom, Beam, and Omni-directional) to determine which directional option provides recipients with the best speech recognition.

Methods

Inclusion Criteria

CI recipients with the following criteria were recruited for this study: between ages 18 and 99 years, implanted with a Cochlear Nucleus internal device, everyday users of the CP900 processor, sound-field thresholds lower than 30 dB HL from 250 to 6,000 Hz, consonant-nucleus-consonant (CNC) [19] scores of 20% or higher, and minimum of 3 months' CI experience. Approval for this study was obtained from the Washington University School of Medicine Human Research Protection Office.

Participants

For this study, 26 unilateral (13 right ear/13 left ear) and 7 bilateral recipients were recruited from Washington University's Adult Cochlear Implant and Aural Rehabilitation Program. Participants included 15 females and 18 males, with a mean age of 66 years (range: 32–92 years). Duration of hearing loss prior to implantation was an average of 28 years (range: 1–60 years). Average CI experience was just over 4 years. See ►**Table 1** for individual data.

Each participant's everyday preferred signal processing was determined via data logging. Signal processing options used included: six participants with ADRO only, 3 with ASC + ADRO, 6 with ASC + SNR-NR, and 18 with ASC + ADRO + SNR-NR. Directional option use showed 22 participants with SCAN, 0 with Beam, 2 with Zoom, and 9 with Omni-directional in their primary everyday program. See ►**Table 2** for each participant's everyday preferred signal processing and directional option.

Equipment

Testing was completed with the participant seated in a double-wall sound-treated booth (8'3" × 8'11" × 6'6"). To run the R-SPACE test environment, an Apple iMAC 17 personal computer with professional audio mixing software (MOTU Digital Performer 5) and audio interface (MOTU 828mkII, 96-kHz fire wire interface) sent the output to four amplifiers (ART SLA-1, two-channel stereo linear power amp with 100 W per channel) and then to eight loudspeakers (Boston Acoustic CR67) that surrounded the listener. The eight loudspeakers are arranged in a 360-degree arc, with 45-degree increments between each loudspeaker, at a distance of 24 inches from the center of the participant's head (►**Supplementary Material** R-Space noise as recorded in sound booth; available in the online version).

Testing

R-SPACE testing was completed with HINT sentences presented at 0 degrees azimuth and R-SPACE restaurant noise presented at 70 dB SPL from eight loudspeakers in a 360-degree array. For each condition, two HINT lists (10 sentences per list) were presented. Reception threshold for sentences (RTS) scores were calculated using an adaptive procedure. List number and presentation order of testing conditions were randomized for each participant.

Each of the four directional options (SCAN, Beam, Zoom, and Omni-directional) were tested with participants' everyday use signal processing options active (ASC, ADRO, and/or SNR-NR) at their preferred volume and sensitivity levels. Consignment CP900 speech processors were programmed and used for testing to ensure proper equipment function. The unilateral recipients were tested with their CI only. The nontest ear was plugged and muffed when there were thresholds less than 70 dB HL. Bilateral recipients were tested with both CIs.

Statistical Analysis

A mixed-model analysis of variance (ANOVA) was used in which the four directional options (SCAN, Beam, Zoom, and Omni-directional) were the main effect. Pairwise comparisons were performed between the directional options. Main effects and all two-way interactions were included in the analysis.

A descriptive overview was performed to find any extrapolative patterns between potential predictive factors and participants' results. Specifically, examining any underlying patterns between recipients' best performing directional option and recipients' level of speech recognition. For this analysis, recipients' past clinical evaluations that were completed between 1 and 18 months prior to the research testing were utilized. The clinical evaluations were completed with the CI recipient's everyday use processing options. The clinical testing included CNC Words and AzBio sentences in quiet presented at 0-degree azimuth which should not have utilized or activated any directional filtering. For these speech recognition tests, the median score was used to separate recipients in two groups of higher (better) and lower (poorer) scores (Iacobucci et al).[20,21] CNC words were divided using 76% as the separating criterion, with 16 recipients in the lower score group and 17 recipients in the higher score group. AzBio sentences were divided using 83% as the separating criterion, with 16 recipients in the lower score group and 17 recipients in the higher score group. See ►**Table 3** for individual participants' CNC and AzBio scores.

Results

Directional Options

Average RTS scores for each of the four-directional options are shown in ►**Fig. 1**. A lower RTS score indicates better performance. SCAN resulted in the best performance, with an average RTS score of 5.77 dB followed by Beam (6.48 dB), Zoom (7.05 dB), and Omni-directional (9.04 dB). SCAN and

Table 1 Participant demographic and audiologic information

Participant	Gender	Age (y)	CI ear	Years of HL	Years of severe to profound HL	Years of CI use
1	F	57	R	17	1	10
			L	18	18	9
2	M	68	R	17	1	1.5
3	M	63	L	2	2	1
4	F	66	R	40	9	0.25
5	F	73	R	28	9	1.25
6	F	54	L	28	1	6
7	M	58	R	31	4	0.75
8	M	32	R	1	1	19
			L	27	27	2
9	F	59	R	47	47	3
10	F	52	L	11	6	2
11	M	60	R	39	6	1.25
12	M	67	L	2	1	7
13	M	74	L	58	Unknown	10
14	M	80	R	53	5	0.5
15	M	60	L	26	14	0.25
16	F	92	R	20	2	6
17	M	81	R	20	2	1
18	M	69	L	14	4	1.75
19	M	69	L	16	2	1.5
20	F	44	L	38	10	1
21	M	76	L	49	15	8
22	F	81	R	11	8	2
23	M	80	L	35	7	1
24	M	80	R	58	4	0.75
25	F	68	R	53	2	0.5
26	F	24	R	20	20	2.75
27	M	91	L	20	0	1.25
28	F	64	R	49	49	6
			L	42	42	12
29	F	70	L	8	1	2
30	M	60	R	24	6	0.5
			L	24	6	4
31	F	56	R	33	8	0.75
			L	33	32	6
32	M	72	R	55	0	14
			L	60	0	9
33	F	62	R	9	3	4
			L	11	3	2
Mean		66		28.68	9.70	4.31
SD		15		17.08	12.88	5.41

Abbreviations: CI, cochlear implant; F, female: L, left, M, male; R, right; SD, standard deviation; HL, hearing loss.

Table 2 Preferred processing and directionality along with RTS scores (in SNR) for each directional condition tested for individual participants

Participant	Processing preference	Directional preference	SCAN RTS score	Beam RTS score	Zoom RTS score	Omni RTS score
1	ASC, ADRO, SNR-NR	SCAN	2.11	−0.7	4.7	2.6
2	ASC, ADRO, SNR-NR	SCAN	8	9.6	7.05	10.11
3	ASC, ADRO, SNR-NR	SCAN	4.47	7.53	5.18	8.94
4	ASC, SNR-NR	SCAN	7.76	7.29	9.18	13.53
5	ASC, ADRO, SNR-NR	SCAN	6.59	8.94	10.94	8.71
6	ADRO, SNR-NR	Omni	0	0.94	2.35	4.24
7	ASC, ADRO	SCAN	1.88	1.88	3.53	4.24
8	ASC, ADRO SNR-NR	SCAN	10.47	12.24	12.47	12.47
9	ASC, ADRO, SNR-NR	SCAN	2.35	5.88	7.06	6.82
10	ASC, ADRO, SNR-NR	SCAN	4.47	4.47	3.29	7.53
11	ASC, SNR-NR	SCAN	10	11.53	12.59	8.47
12	ADRO	Omni	5.18	6.59	9.29	11.76
13	ASC, SNR-NR	SCAN	8.71	11.88	12.71	12
14	ASC, SNR-NR	SCAN	9.29	4.71	10.7	10.59
15	ASC, ADRO, SNR-NR	SCAN	9.41	11.53	11.41	12.35
16	ASC, ADRO, SNR-NR	SCAN	12.47	12.82	10.59	12.82
17	ASC, ADRO, SNR-NR	Zoom	13.53	12.71	12.24	13.53
18	ASC, ADRO	Omni	4.94	1.41	0.94	7.29
19	ASC, ADRO, SNR-NR	SCAN	3.53	5.18	5.41	9.18
20	ASC, ADRO, SNR-NR	SCAN	0.24	−0.47	2.35	5.41
21	ADRO	Omni	2.35	7.76	11.29	12.35
22	ASC, ADRO, SNR-NR	SCAN	8	8	9.53	12.59
23	ASC, SNR-NR	SCAN	10.59	8.24	10.59	7.76
24	ASC, ADRO, SNR-NR	SCAN	4.24	7.53	8.47	9.41
25	ASC, ADRO, SNR-NR	SCAN	4	6.35	1.88	11.18
26	ADRO	Omni	12	9.65	7.06	13.41
27	ASC	Omni	10.35	13.76	13.41	13.53
28	ADRO	Omni	11.29	10	10.35	11.65
29	ASC, ADRO	Omni	4.47	3.76	3.76	6.35
30	ASC, ADRO, SNR-NR	SCAN	2.82	3.29	0.94	4.24
31	ASC, ADRO, SNR-NR	Omni	2.59	4.94	5.88	8.71
32	ADRO	Omni	−3.76	−3.06	−4.71	2.35
33	ASC, ADRO, SNR-NR	SCAN	−4	−2.35	0.24	2.35
Mean SD			5.77 4.49	6.48 4.57	7.05 4.54	9.04 3.55

Abbreviations: ADRO, adaptive dynamic range optimization; ACS, automatic sensitivity control; RTS, reception threshold for sentences; SNR-NR, signal-to-noise-ratio noise reduction.

Beam's average RTS scores were only 0.71 dB apart which was not a significant difference. SCAN and Zoom's average RTS scores had a 1.28-dB difference and was significantly different ($p \leq 0.01$; [F (3, 96) = 8.24, $p = 0.03$]). The use of SCAN, Beam, and Zoom significantly ($ps \leq 0.01$) improved performance compared with Omni-directional (SCAN: [F (3, 96) = 53.73]; Beam: [F (3, 96) = 32.83]; Zoom: [F (3, 96) = 19.89]). The average RTS score with Omni-directional was 2 to 3 dB poorer compared with all other options.

►**Fig. 2** shows the directional option with the best RTS score for each recipient. A varied number of individuals had their best (lowest) RTS scores with each of the four-directional options. See ►**Table 2** for individual RTS scores for each directional option. Overall, 16 recipients had their lowest

Table 3 Individual recipients' speech recognition scores from clinical evaluations

Participant	CNC words (%)	AzBio sentences (%)
1	30	75
2	36	89
3	41	51
4	44	97
5	48	88
6	50	99
7	52	88
8	54	63
9	54	87
10	56	97
11	58	76
12	64	73
13	66	30
14	68	89
15	68	78
16	53	69
17	72	65
18	74	85
19	76	71
20	76	93
21	76	77
22	76	83
23	76	84
24	78	92
25	78	93
26	78	52
27	78	49
28	84	73%
29	84	30
30	86	92
31	86	77
32	86	95
33	88	97
Average	90	77
Median	92	83
Range	30–90	12–97

Abbreviation: CNC, consonant-nucleus-consonant.

RTS score with SCAN, 6 with Beam, 9 with Zoom, and 2 with Omni-directional. Across recipients, an average difference of 4.64 dB was seen between their best and poorest option. Participant 21 showed the greatest difference of 10 dB between his best (SCAN) and poorest (Omni-directional) performing options. Interestingly, this participant used Omni-directional as his everyday directional option. Participant 17 showed the smallest difference of 1.29 dB between his best (Zoom) and poorest (SCAN) RTS scores. This participant used Zoom as his everyday directional option. The majority of recipients did not perform best with their everyday directional option. Only 12 of 33 participants performed best with their preferred or everyday processing combination. Eleven of the 12 recipients used SCAN on a daily basis and 1 used Omni-directional. Results varied and were inconsistent for the remaining 21 recipients who did not perform best with their preferred directional option.

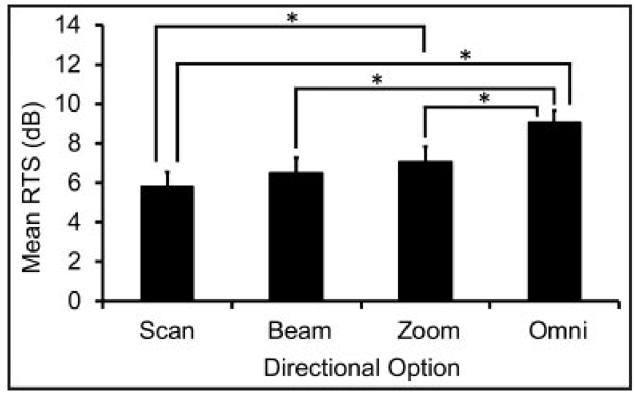

Fig. 1 Average performance for directional options. Overall, recipients RTS score was best (lowest) with SCAN followed by Beam, Zoom, and Omni-directional. RTS scores with SCAN were significantly lower ($p < 0.05$) compared with Zoom but not Beam. SCAN, Beam, and Zoom had significantly lower RTS scores ($ps < 0.01$) than Omni-directional. Asterisk represents significance between options. RTS, reception threshold for sentences.

Unilateral and Bilateral Performance

Mean RTS scores for each directional option for bilateral ($n = 7$) and unilateral ($n = 26$) recipients are shown in ►**Fig. 3**. No statistical analyses were performed due to the uneven group sizes. Bilateral recipients showed better RTS scores compared with unilateral recipients, with bilateral recipients' average RTS score being approximately 3.5 dB better than unilateral participants' RTS score for each directional option. Bilateral recipients' average RTS score with SCAN was 3.07 and 3.82 dB with Beam, 4.27 dB with Zoom, and 6.34 dB with Omni-directional. Unilateral recipients had an average RTS score of 6.49 dB with SCAN, 7.29 dB with Beam, 7.80 dB with Zoom, and 9.77 dB with Omni-directional. Both groups had the same performance trends with the best performance with SCAN and the poorest performance with Omni-directional. The improvement in SNR from Omni-directional to SCAN was approximately 3.3 dB for both groups.

Clinical Data Relation to Individual Best Performing Directional Option

There was no clear predictor for recipients' best performing directional option from clinical speech recognition tests. The majority of recipients in both the higher and lower scoring groups, however, did best with SCAN. For the 17 recipients with lower CNC word scores, 9 performed best with SCAN, 1 with Beam, 6 with Zoom, and 1 with Omni-directional. For

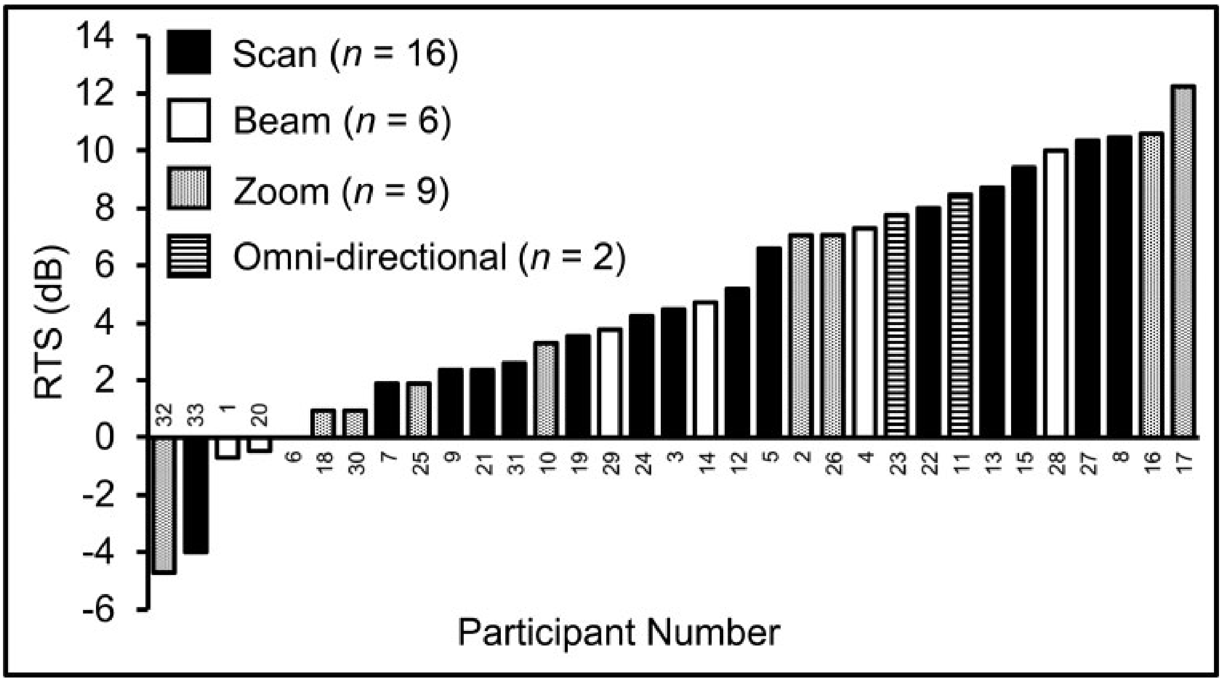

Fig. 2 Individual participants' best (lowest) RTS scores and corresponding directional options are shown. Performance is organized in order of participants from the lowest (−4.71 dB) to highest (12.24 dB) RTS score. A varied number of individuals performed best for each of the four conditions. Overall, 16 recipients performed best with SCAN, 6 with Beam, 9 with Zoom, and 2 with Omni-directional. RTS, reception threshold for sentences.

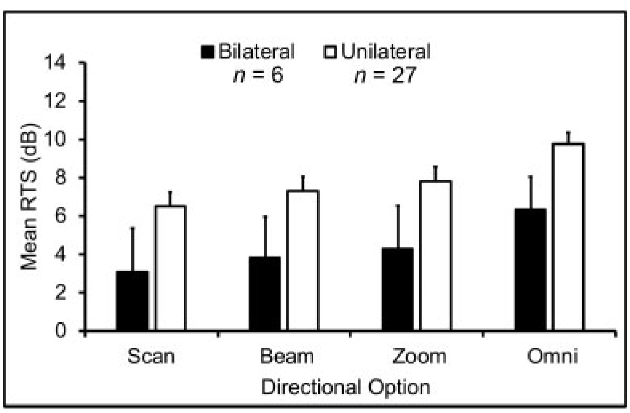

Fig. 3 Unilateral and bilateral recipients showed a parallel trend in in RTS scores across the four-directional options. The decrease in RTS score from Omni-directional to SCAN was ~3.27 dB for both groups. Bilateral recipients' RTS score was ~3.5 dB better than unilateral participants in each test condition. RTS, reception threshold for sentences.

the 16 recipients with higher CNC scores, 7 performed best with SCAN, 4 with Beam, 4 with Zoom, and 1 with Omni-directional. For AzBio Sentences in quiet, of the 17 recipients with lower sentence scores, 9 performed best with SCAN, 2 with Beam, 4 with Zoom, and 2 with Omni-directional. Of the 16 recipients with higher AzBio scores, 8 performed best with SCAN, 3 with Beam, and 5 with Zoom.

Discussion

Automatic processing can eliminate the need for recipients' to manually switch programs in different environments, providing the opportunity to improve performance in noisy environments. Cochlear Americas recommends activation of SCAN as recipients' everyday program. However, automatic directional processing has not been evaluated thoroughly to understand how it benefits CI recipients in combination with their everyday processing options in a diffuse restaurant-type environment.

Automatic directional processing is dependent on the speech processor's accurate analysis of the environment and apt selection of processing option(s). This can be complex since real-life situations are not typically static as noise levels and sources can change quickly. The R-SPACE test provides an opportunity to evaluate how accurately the processor is analyzing an environment that has fluctuations in azimuth of noise sources, as well as varying intensities and configurations. In the current study, SCAN and Beam were not significantly different. SCAN was, therefore, most likely implementing Beam's adaptive directionality during R-SPACE testing. This is consistent with previous research that identified Beam as the most effective directional option in the R-SPACE compared with Zoom and Omni-directional,[22] which supports previous research showing the benefits of directional processing for CI recipients.[7,10] Specifically, adaptive directionality is an appropriate processing option for a noise program.

The best directional option varied across patients which may suggest that the choice of directionality can influence a recipient's performance and not all recipients benefit equally from the same directional option. In addition, the analysis of clinical speech recognition scores showed no distinct pattern between speech recognition in quiet and the best directional option in noise. It is possible that the analysis method used for dividing the recipients into two groups (higher and lower performers) using the median score was not sensitive enough as the participants in this study were fairly homogenous, in that all were postlingual and had open-set speech recognition.[23–25] The majority of recipients in this study performed best with SCAN, therefore, the use of automatic directionality may be an appropriate everyday option for CI recipients regardless of their speech recognition performance. The use of automatic directionality for CI recipients who do not use Cochlear Americas devices may not be the same as the results found in this study.

In this study, an overall improvement in speech recognition of approximately 3.5 dB was found for bilateral recipients which is notable, but smaller than the 9 dB improvement for bilateral CI recipients found previously.[8] This could be due to the additional signal processing (ASC, ADRO, and SNR-NR) used by many participants in this study, thereby enhancing performance with a unilateral CI. Lastly, the difference between bilateral and unilateral performance, may be different if individuals were tested bimodally. Ernst and colleagues [26] found both bilateral and bimodal CI recipients performed better with directional options compared with unilateral CI recipients. Future research should test the benefit of bimodal devices with automatic directional processing.

For the current study, recipients' everyday processing options (ASC, ADRO, and SNR-NR) were active for testing which could optimize recipient performance because of the familiarity with the processing. The use of different processing options by the participants, however, did create variability in the study that could also affect the results. The majority of participants had all processing options active in their everyday program ($n = 18/33$). This is the signal processing combination recommended by Cochlear Americas. Future studies should compare SCAN to other directional options (Beam, Zoom, and Omni-directional) with various processing option combinations (ASC, ADRO, and SNR-NR) held constant between participants.

Conclusion

Past programming recommendations have encouraged CI recipients to experiment with several programs entailing different directional options to find their ideal everyday program. The individual variability seen in this study suggests that this is still an appropriate recommendation. However, based on a CI recipient's motivation to try different programs and depending on the available programming time, automatic directionality is an appropriate everyday processing option. The results of this study support the recommendation by Cochlear Americas for CI recipients to use SCAN as their everyday processing option.

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Conflict of Interest

None declared.

Disclaimer

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