

Increased Spectral Resolution Enhances Listening Benefit in Cochlear Implant Users

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INTRODUCTION

In 2006, Advanced Bionics introduced HiRes with Fidelity™ 120 (HiRes 120) sound processing. The goal of the HiRes 120 strategy is to build on the strengths of standard HiRes sound processing by improving representation of the stimulus spectrum in the electrical stimulation pattern. In standard HiRes processing, the incoming sound is filtered into 16 spectral bands. The energy of each band is extracted and its envelope modulates a high-rate pulse train that is delivered to a single corresponding electrode. In HiRes 120 processing, the input signal is analyzed in greater spectral detail than with standard HiRes to achieve a maximum of 120 spectral bands. HiRes 120 first analyzes the incoming sound signal using a 256-bin Fast Fourier Transform. Next, a detailed analysis of temporal and spectral information is processed in parallel. The temporal detail is extracted using a Hilbert transform while a navigator locates the spectral maximum for each electrode pair across the 120 spectral bands. The estimated frequency of the spectral maximum is used to compute the rate of the pulse train and to continuously select the optimal location for delivering stimulation.

In HiRes 120 sound processing, the spectral bands are created by precisely varying the proportion of current delivered simultaneously to adjacent electrodes in each electrode pair through the implementation of active current steering (Donaldson et al. 2005, Firszt et al. submitted, Koch et al. in press). For each electrode pair, there are eight spectral bands. When all 16 electrodes are enabled, 120 total spectral bands are created—that is, 15 electrode pairs times 8 spectral bands.

HiRes 120 should allow many implant users to take advantage of their residual place-pitch perception capabilities by delivering spectral information in higher resolution than standard HiRes processing. The increased spectral resolution, in combination with the fine temporal resolution already implemented in HiRes, may lead to better speech perception in noise and improved music appreciation.

STUDY PROTOCOL

The aim of this multicenter clinical study was to document the listening benefits of HiRes 120 sound processing in adult Bionic Ear® users (CI or HiRes 90K® implants). Performance with standard HiRes was assessed at a baseline visit and compared with HiRes 120 performance after one and three months of use. Then subjects were refit with standard HiRes and tested again. The outcome measures in the Table below were used at each test interval. All speech signals were delivered directly from a PC to the subject's sound processor using a direct connect system developed in collaboration with Sigfrid Soli and colleagues at the House Ear Institute (Soli et al. 2005). This poster summarizes the results from 34 subjects who have completed the three-month protocol.

Test Type	Outcome Measure
Words	CNC word test (60 dB SPL)
Sentences in Quiet	HINT sentences (60 dB SPL)
Sentences in Noise	HINT sentences (60 dB SPL, speech-spectrum noise, +8 dB SNR) HINT sentences (speech-spectrum noise, adaptive paradigm)
Self-Reported Listening Benefits	Listening Benefits Questionnaire (Lbqt scale 0-5, 5 = best) • Clarity for 13 listening situations • Ease of listening for 11 listening situations • Sound, voices, and music for 7 listening situations
Music Ratings	0-10 pleasantness scale (0 = extremely unpleasant, 10 = extremely pleasant) 0-10 distinctness scale (0 = extremely indistinct, 10 = extremely distinct) Ensemble size identification
Preference Questionnaire	Preference for HiRes 120 vs. standard HiRes • Strength of preference rating (0 = weak to 10 = strong) • 15 aspects of sound/music that are better with preferred processing

Participating Study Sites

- House Ear Clinic, Los Angeles, California
- Houston Ear Research Foundation, Houston, Texas
- Johns Hopkins University, Baltimore, Maryland
- Northwestern University, Chicago, Illinois
- Ottawa Hospital (Civic Campus), Ottawa, Ontario
- Midwest Ear Institute, Kansas City, Missouri
- Washington University, St. Louis, Missouri

References

Donaldson GS, Kuhl HA, Litvak L. (2005) Place-pitch discrimination of single- versus dual-electrode stimuli by cochlear implant users. *Journal of the Acoustical Society of America*, 118(2), 623-628.
Firszt J, Koch D, Dowling M, Litvak L. Current steering enables additional pitch percepts in adult cochlear implant recipients. *Otology and Neurotology*, submitted.
Koch DB, Osberger MJ, Dowling M, Litvak L. (2007) Using current steering to increase spectral resolution in CI and HiRes 90K users. *Ear and Hearing*, in press.
Koch DB, Osberger MJ, Sager P, Kessler DK. (2004) HF-resolution and conventional sound processing in the HiResolution Bionic Ear: using appropriate outcome measures to assess speech-recognition ability. *Audiology and Neurotology* 2:124-129.
Soli S, Chen J, Vannicola A, Freed D, Kessler DK. (2005) Assessment of spatial uncoupling and sound localization in bilateral implants using direct input. Poster presentation at the Conference on Intractable Auditory Disorders, Pacific Grove, CA, July 20-August 4, 2005.

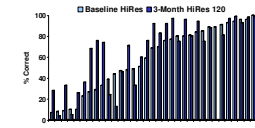
RESULTS

Speech Perception

Mean speech perception scores were higher for HiRes 120 compared to baseline with HiRes. Subjects who showed the lowest scores at baseline appear to exhibit the greatest gains when using HiRes 120, particularly for the HINT sentences in quiet and noise.

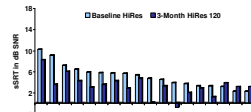


Mean scores for three speech tests at baseline with HiRes, at three months with HiRes 120, and after being refit with HiRes (* = p < .05, HiRes 120 compared to baseline HiRes).

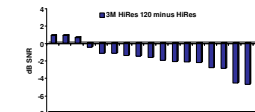


Individual HINT-in-fixed-noise scores at baseline with HiRes and at three months with HiRes 120, rank ordered from lowest to highest HiRes scores.

The adaptive HINT paradigm proved to be sensitive to differences in sound processing for high-performing subjects. Sentence reception thresholds (sSRTs) represent the SNR in dB at which subjects hear 50% of HINT sentences in 52 dB SPL speech-spectrum noise. sSRTs were lower (better) for HiRes 120 than for HiRes for 16 of 19 subjects who scored better than 70% on the HINT-in-fixed-noise test. For the other three subjects, sSRTs were similar between HiRes and HiRes 120 (within 1 dB).



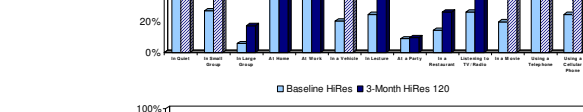
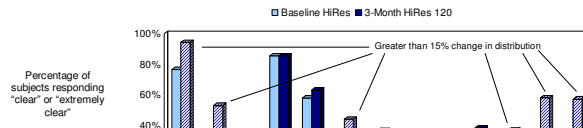
Adaptive HINT sSRTs for 19 subjects at baseline with HiRes and at three months with HiRes 120. Scores are rank ordered from worst to best sSRT with standard HiRes. A lower SNR indicates a better score.



HiRes 120 sSRT minus HiRes sSRT for 19 subjects. Scores are rank ordered from smallest to greatest difference in sSRT. A more negative SNR indicates greater improvement in benefit with HiRes 120.

Everyday Listening Benefits

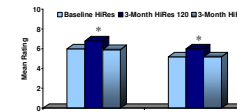
After three months of HiRes 120 use, a greater proportion of subjects rated their experience as "clear" or "very clear" for all but one listening situation (at home). There was over a 15% shift in the proportion of adults reporting "clear" or "very clear" for 6 of 13 situations. Similarly, a greater proportion of subjects rated their experience as "easy" or "very easy" for all situations after using HiRes 120. There was over a 15% shift in the percent of subjects rating their experience as "easy" or "very easy" for 5 of 11 listening situations.



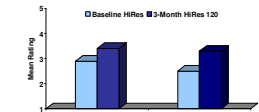
RESULTS (continued)

Music Appreciation

Ratings of music pleasantness and distinctness were significantly higher for HiRes 120 compared to baseline with HiRes. Mean ratings for frequency of listening to music (1 = never to 5 = very often) and satisfaction with listening to music (1 = very dissatisfied to 5 = very satisfied) were higher with HiRes 120 than with standard HiRes.



Music pleasantness and distinctness rated on a 0-10 scale (* = p < .05).



Frequency of listening to music and satisfaction in listening to music rated on a 0-5 scale.

Preference Ratings

Subjects indicated their preferred sound-processing option (HiRes 120 or standard HiRes) and their strength of preference on a scale from 1 (weak preference) to 10 (strong preference). Of the 34 subjects, 28 (82%) preferred HiRes 120. The strength of preference was 8.3 (range: 1-10). The strength of preference was rated as 8 or higher by 19 of the 28 subjects and 14 subjects rated it as 10. In addition, subjects indicated those aspects of sound that were better with their preferred processing mode using the scale: *strongly disagree, disagree, neutral, agree, strongly agree*.

Preference Item	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Agree or Strongly Agree
Quality is Better	0.0%	0.0%	14.3%	39.3%	46.4%	85.7%
Speech is more natural	0.0%	3.6%	14.3%	39.3%	42.9%	82.1%
Speech is easier to understand in noise	0.0%	10.7%	25.0%	32.1%	32.1%	64.3%
Environmental sounds are easier to distinguish	0.0%	0.0%	14.3%	35.7%	50.0%	85.7%
Environmental sounds are more distinct	0.0%	3.6%	7.1%	46.4%	42.9%	89.3%

Distribution of preference ratings on items involving speech and environmental sounds for subjects who preferred HiRes 120 (n = 28)

Preference Item	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Agree or Strongly Agree
Music sounds better	0.0%	3.6%	25.0%	28.6%	42.9%	71.4%
Music sounds more natural	0.0%	0.0%	33.3%	22.2%	44.4%	66.7%
Music sounds richer	0.0%	3.6%	25.0%	28.6%	42.9%	71.4%
Melody is more enjoyable	0.0%	3.6%	25.0%	39.3%	32.1%	71.4%
Rhythm is more noticeable	0.0%	0.0%	28.6%	32.1%	39.3%	71.4%
Can distinguish singer's voices from instruments	0.0%	3.6%	25.0%	46.4%	25.0%	71.4%
Singer's voices sound more distinct	0.0%	7.1%	39.3%	28.6%	25.0%	53.6%
Can recognize lyrics	0.0%	14.3%	39.3%	28.6%	17.9%	46.4%
Can distinguish individual instruments	0.0%	10.7%	21.4%	53.6%	14.3%	67.9%
Individual instruments sound more distinct	0.0%	7.1%	21.4%	50.0%	21.4%	71.4%

Distribution of preference ratings on items involving music for subjects who preferred HiRes 120 (n = 28)

CONCLUSIONS

To date, this clinical study shows that HiRes Fidelity 120 is a viable sound-processing option that may improve benefit appreciably for some CI and HiRes 90K recipients in a variety of listening environments. The reported benefits can extend beyond speech perception, and encompass everyday sounds and music appreciation. These study results, as well as subjective feedback from subjects, indicate that new methods are necessary for assessing the wide range of hearing benefit that now can be experienced by cochlear implant recipients. Innovative speech and environmental tests and questionnaires may prove useful as technology continues to evolve.