



# Results from a Clinical Evaluation of a New DSP Hearing Aid Using an Optimized Platform

Victor H. Bray, Jr.  
Michael J. Nilsson  
Robert M. Ghent, Jr.  
Jeannette S. Johnson

## ABSTRACT

Clinical evaluation of a new digital signal processing (DSP) hearing aid is presented. The aid processes sound based upon a nonlinear model of the cochlea. A multi-clinic trial compared performance with the new aid versus subjects' own "state-of-the-art" multi-channel analog and digital devices. Performance was evaluated subjectively and objectively in the clinic. Comparisons are made between devices using speech measures in quiet and in noise, as well as APHAB questionnaire data.

## INTRODUCTION

Multi-site studies of the NATURA™ DSP hearing aid<sup>1, 2</sup> were conducted in 1998 throughout the United States. A common protocol was used at eleven clinics, including standardized data collection procedures for functional gain, speech intelligibility, and questionnaires. All subjects had bilateral sensorineural hearing losses. They had been successfully wearing programmable high-technology hearing aids of which 39% were digital and 61% were analog. Sixty-five percent of the aids utilized 2-channel compression and 35% utilized 3-channel or 4-channel compression. Sixty of the 62 subjects (97%) were fit binaurally with NATURA CIC or ITC aids and the other two subjects were fit monaurally. In almost all cases, the ears and style of the investigational aids matched the reference aids. The NATURA aids used in the study were for evaluation purposes only (not for sale) and the subjects were paid a small stipend for their participation. The study duration was approximately 60 days.

Complete data sets were obtained for 61 subjects enrolled in the investigation. Their mean age was 64 years with a range of 31 to 88 years. Thirty-nine subjects were male and 23 were female. Mean audiograms for the CIC and ITC subjects in the study are shown in Figure 1. Because the average audiograms for the two subject groups are nearly identical, the data for the two groups were combined for this analysis. This data

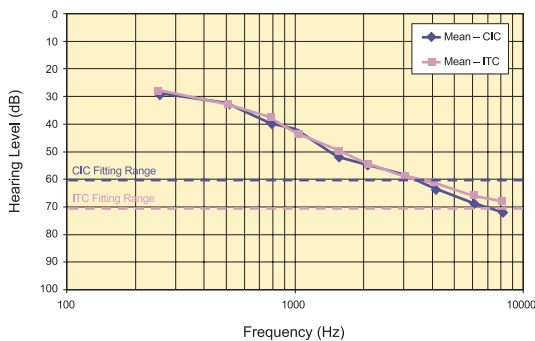


Figure 1. Mean Audiograms (n=56 CIC ears and 66 ITC ears)

treatment is appropriate given that the NATURA CIC and ITC hearing aids use the same transducers and electronic assembly and share the same EXPRESSfit™ fitting algorithm.

## OBJECTIVE DATA

Binaural soundfield functional gain using warble tones was obtained with the subjects' own aids and the NATURA aids. Mean functional gain measures for all subjects were pooled and are shown in Figure 2. On this task,

the NATURA aids provided less low-frequency gain and more high-frequency gain than the subjects' own aids. Two reasons

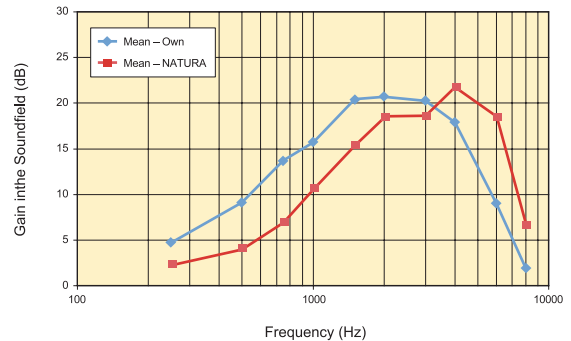


Figure 2. Functional Gain (n=61 subjects)

for the low-frequency effect were observed in the study. The first is that Expansion<sup>3</sup> in the EXPRESSfit fitting algorithm de-emphasizes gain for low-frequency signals below 50 dB SPL. The second reason is that the high-resolution (one-half octave) frequency shaping capability with NATURA allows for frequency-specific amplification to be on target<sup>4</sup> without overamplification at adjacent frequencies. A reason for the high-frequency effect is the enhanced control of independent wide dynamic range compressors at 4, 6, and 8 kHz.

Binaural soundfield speech intelligibility scores using the SIN test<sup>5</sup> were obtained at two presentation levels (40 and 70 dB HL) across four signal-to-noise ratios (0, +5, +10, and +15 dB). Performance was measured unaided, with the subjects' own aids, and with the NATURA aids. Pooled data are presented

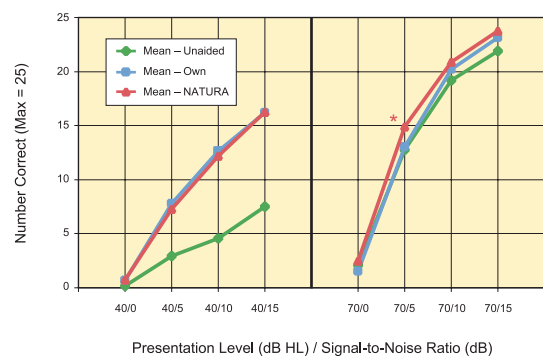


Figure 3. Speech-in-Noise [SIN] Test (n=61 subjects)

in Figure 3. An ANOVA shows significant main effects for presentation level, signal-to-noise ratio, and listening condition. Performance in the two aided conditions was found to be superior to the unaided condition. Post hoc analysis of performance comparing the aided conditions revealed a

significant difference in SIN test scores at 70 dB HL with +5 signal-to-noise ratio, where the NATURA aid outperformed the comparison aids ( $p < .01$ ). This documents that high-technology hearing aids, including NATURA, can provide benefit for speech intelligibility, even in noisy environments.

## SUBJECTIVE DATA

Subjects completed the Abbreviated Profile of Hearing Aid Benefit (APHAB)<sup>6</sup> for their own aids at the beginning of the study and for the NATURA aids at the end of the study. Benefit scores across the four subscales were pooled and are plotted in Figure 4 for the two aided conditions. Compared to the subjects' own aids, significant additional benefit was obtained with NATURA hearing aids for Ease of Communication (EC) ( $p < .01$ ), Reverberation (RV) ( $p < .01$ ), Background Noise (BN) ( $p < .05$ ), and Aversiveness (AV) ( $p < .01$ ). Reasons for improved

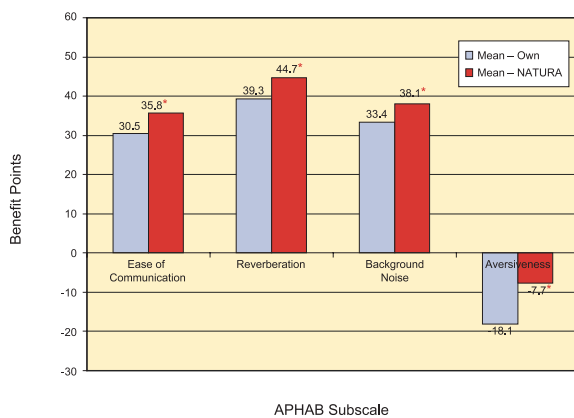


Figure 4. APHAB Comparison (n=62 subjects)

EC are the use of Expansion<sup>3</sup> and advanced compression-shaping with the NATURA aid. Reasons for the improvement in AV are the *in situ* dynamic range verification and advanced intensity-shaping with the NATURA aid. Reasons for the improved RV and BN are the 9 parallel and independent compression channels that react to complex auditory stimuli with narrowband resolution.

## ANALYSIS

At first glance, these data could appear contradictory. How could functional gain be less than expected (Figure 2), speech intelligibility scores equal or exceed the performance of other high-technology aids (Figure 3), and APHAB scores exceed the performance of the competitive devices (Figure 4)? A likely answer is the way **SONIC innovations** combines Expansion, WDRC, and Limiting across 9 compression

channels in the NATURA DSP hearing aid and EXPRESSfit fitting algorithm. Figure 5 is a 3-D plot of gain

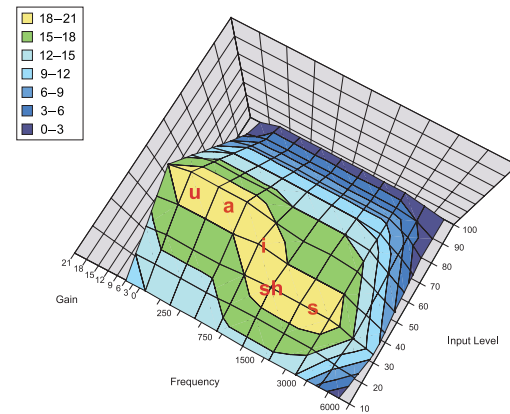


Figure 5. 3-D View of Gain Algorithm

[z-axis] with respect to frequency [x-axis] and input level [y-axis], whereby gain is controlled with 1-dB precision in narrowband frequency slices. The result is maximum WDRC gain for the long-term-average speech spectrum (yellow + green region), reduced gain using Expansion for low-level input (light-blue region at bottom of graph), and reduced gain using Limiting for high-level input (dark-blue region at top of graph). Thus, the fitting algorithm not only concentrates amplification inside the individual's dynamic range, but provides preferential gain for signals at conversational speech levels.

## SUMMARY

Sixty-one subjects completed data collection in field trials comparing the new NATURA DSP hearing aids against multi-channel analog and digital hearing aids. Results were that the NATURA aids equalled or exceeded objective measures for speech intelligibility and exceeded subjective measures for all four APHAB subscales. Final subject preference ratings were grouped according to whether the subject's own devices used analog or digital signal processing. For previously satisfied analog device wearers, 5% of the subjects preferred their own aids, 29% had no preference, and 66% preferred NATURA. For previously satisfied digital device wearers, 17% of the subjects preferred their own aids, 29% had no preference, and 54% preferred NATURA.

## REFERENCES

---

1. Bray, V., Chabries, D., Davis, K., & Johnson, J. (1998). Digital signal processing (DSP) derived from a nonlinear auditory model. Poster presented at AAA - Los Angeles, California.
2. Nilsson, M., & Bray, V. (1999). The application of a cochlear model to hearing aid design. Presented at AAA - Miami Beach, Florida.
3. Ghent, R., Nilsson, M., Bray, V. & Johnson, J. (1999). Expansion as a sound processing tool in hearing aids. Poster presented at AAA - Miami Beach, Florida.
4. Bray, V., Harris, R., & Johnson, J. (1998). Optimized target matching: Demonstration of an adaptive nonlinear DSP system. Poster presented at AAA - Los Angeles, California.
5. Speech In Noise (SIN) Test from Etymotic Research, Elk Grove Village, Illinois.
6. Abbreviated Profile of Hearing Aid Benefit (APHAB) from Hearing Aid Research Laboratory (HARL) of the University of Memphis, Tennessee.

Presented at the American Academy of Audiology 11th Annual Convention on April 29 – May 2, 1999, in Miami Beach, Florida.

