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Can Omni-Directional Hearing Aids Improve Speech Understanding In Noise?

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Editor's Note: In response to inquiries generated by the Sonic Innovations' press release regarding the NATURA® 2 SE speech-intelligibility-in-noise claim, the principal investigators have released this preliminary report with the data corresponding to the claim. These data are from the first stage of a multi-stage, multi-site investigation. The authors intend that the final results will be submitted to a peer-reviewed journal next year.

—Editor, Audiology Online

ABSTRACT

A multiple-site research investigation was conducted to determine if speech intelligibility in noise could be improved using a new, omni-directional digital signal processing (DSP) hearing aid. Subjects were 48 adults with bilateral, symmetric, sensorineural hearing loss. All subjects had prior experience with amplification and were fit binaurally for this experiment. The test instrument was a modified version of the Hearing In Noise Test (HINT) using a single loudspeaker presentation. A significant benefit was determined for aided speech intelligibility in noise conditions, as compared to the unaided condition. These results demonstrate that well-fit, omni-directional hearing aids can improve speech understanding in noise.

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INTRODUCTION

Many audiologists believe that omni-directional hearing aids, including the new generation of digital signal processing (DSP) aids, cannot improve speech understanding in noise. This belief is supported by recent research on DSP hearing aids evaluated in multiple field trials. For example, Knebel and Bentler (1998), using a single loudspeaker design and the Hearing In Noise Test (HINT) with the noise fixed at 65 dBA, did not find a significant difference from unaided performance for omni-directional two-channel or three-channel DSP aids. Ricketts and Dhar (1999), using a five loudspeaker array in “anechoic” and “living room” environments, and a modified HINT with the noise fixed at 65 dBA, did not find a significant difference from unaided performance for omni-directional three-channel or four-channel DSP aids. Walden et al. (2000), using a four loudspeaker array and a modified Connected Speech Test (CST) presented at 60 dB with 0 dB S/N and at 75 dB with +2 dB S/N, did not find a significant difference from unaided for an omni-directional fourteen-channel DSP aid. The present study was undertaken to evaluate speech-in-noise performance with a new, nine-channel DSP hearing aid.

METHODS

Research Sites: Site 1 was the Hearing Aid Research Laboratory at Sonic Innovations in Salt Lake City, Utah. Site 2 was the Adult Audiology Clinic at Washington University School of Medicine in St. Louis, Missouri.

Subjects: All subjects were adults with bilateral, symmetric, sensorineural hearing loss. All subjects had prior experience with binaural amplification for greater than six months before being enrolled in this study.

The 28 subjects at Site 1 were experienced users of DSP amplification. The 20 subjects at Site 2 were experienced users of analog amplification.

Hearing Aids: The hearing aid under evaluation at both research sites was the NATURA® 2 SE. This DSP hearing aid utilizes nine narrowband compression channels, with very fast and symmetric attack and release times. All subjects were fit binaurally with the test DSP aids. Site 1 used CIC, ITC and ITE styles. Site 2 used only CIC and ITC style aids. Subjects at Site 2 were also evaluated using their own, well-fit, CIC or ITC multi-channel analog hearing aids (the “reference aids”).

Test Conditions: The subjects at Site 1 were evaluated unaided and in four aided conditions: DSP without noise reduction (NR), DSP with low NR, DSP with medium NR, and DSP with high NR. The subjects at Site 2 were evaluated unaided and in three aided conditions: analog, DSP without NR, and DSP with low or medium NR.

Test Instrument: Speech intelligibility in noise was measured using the HINT. The HINT uses an adaptive procedure to determine the 50% intelligibility threshold for sentences in noise. The results are reported as dB signal-to-noise ratio (S/N) with lower scores indicating better performance. The HINT sentences are digitized recordings of a male talker (Nilsson, Soli & Sullivan, 1994).

The HINT masker is steady-state noise filtered to match the long-term average spectrum (LTAS) of the sentences and presented at 65 dBA. In order to allow the digital noise reduction algorithm to engage, the HINT masker was modified so that the noise onset was 5 seconds before the sentence onset. The HINT sentences and noise were delivered from a single loudspeaker placed 1 meter distance from the subject at 0° azimuth. This test configuration was very challenging, as the matched LTAS of the sentences and noise limit spectral cues and the single loudspeaker configuration eliminates spatial cues.

Procedure: Subjects were fit with the test hearing aids, in a style that matched the reference hearing aids, when appropriate. Initial fittings were conducted using the manufacturer's recommended protocol and appropriate modifications were made based on an *in situ* dynamic range mapping procedure, probe microphone measurements, and subjective comments. After the fittings were determined to be satisfactory by both the subject and the investigator, the subjects wore the hearing aids for a minimum of 30 days prior to testing. Performance evaluations with the HINT were conducted in an audiometric test room during a single, two-hour test session. The presentation order of the unaided and aided conditions was counterbalanced across subjects.

RESULTS[1]

The subject audiograms for Site 1 and Site 2 are shown in Figures 1 and 2, below. The data are plotted as the mean values, with standard deviation and range of thresholds. Comparison of the mean audiograms shows that the subjects at Site 2 had better low-frequency hearing than those at Site 1.

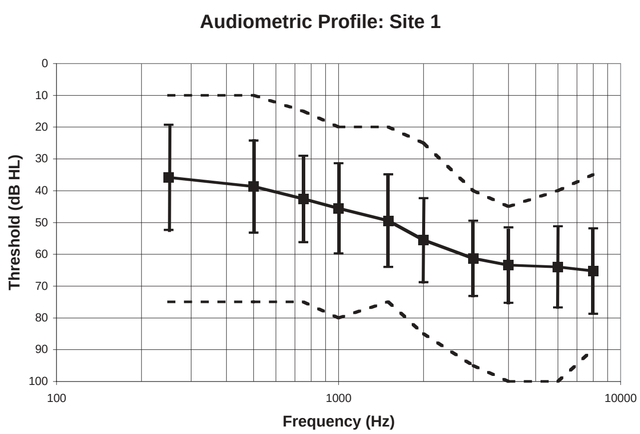

Figure 1: Audiometric profile for Site 1 showing the mean audiogram, 1 standard deviation and range for 28 subjects.

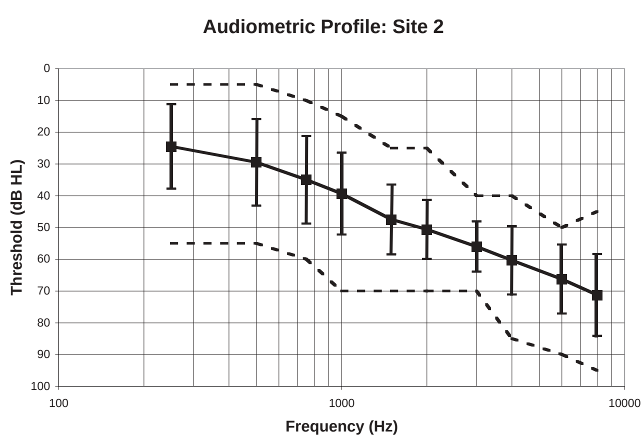

Figure 2: Audiometric profile for Site 2 showing the mean audiogram, 1 standard deviation and range for 20 subjects.

The mean HINT reception threshold for sentences (RTS) for Site 1 and Site 2 are shown in Figures 3 and 4, below. The data show a significant benefit for all aided conditions tested at both Site 1 [F(4,108) = 34.55, $p < .001$] and Site 2 [F(3,57) = 13.26, $p < .001$]. For the Site 1 data, post hoc analysis revealed (a) a significant difference between unaided and aided DSP without NR ($p < .01$), (b) a significant difference between aided DSP without NR and aided DSP with low, medium, or high NR ($p < .01$), and (c) no significant differences between the aided DSP conditions using the three NR settings. For the Site 2 data, post hoc analysis revealed (a) a significant difference between unaided and aided analog ($p < .01$), (b) a significant difference between aided analog and aided DSP without NR ($p = .02$), and (c) no significant difference between aided DSP with or without NR.

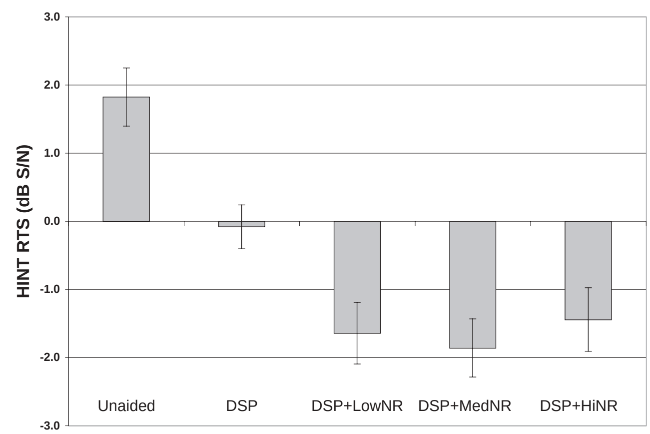

Figure 3: Mean HINT RTS values with standard error (n = 28) from Site 1. Conditions are Unaided, Aided DSP without Noise Reduction (NR), and Aided with Low, Medium, and High NR.

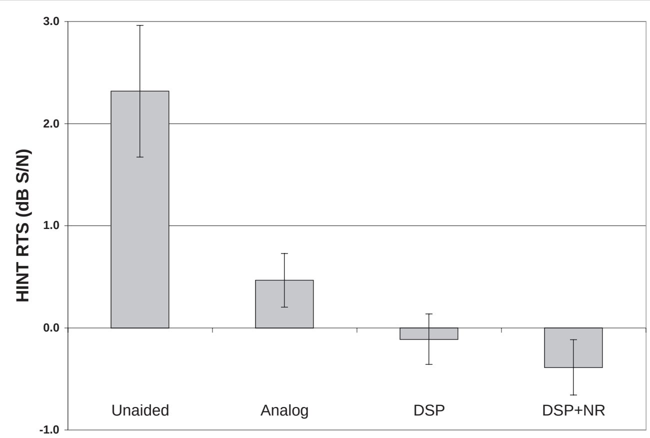

Figure 4: Mean HINT RTS values with standard error (n = 20) from Site 2. Conditions are Unaided, Aided Multi-Channel Analog, Aided DSP without NR, and Aided with NR.

[1] A portion of the Site 1 results were previously published by Bray & Nilsson (2000) in *The Hearing Review*.

The individual HINT RTS values for Site 1 and Site 2 are shown in Figures 5 and 6, below. The individual thresholds in the scatterplot are shown with the unaided values on the x-axis and the aided values on the y-axis. If there was no difference in speech intelligibility in noise between the unaided and aided conditions, the data would fall on the diagonal line. Data points above the diagonal line indicate better unaided performance; data points below the diagonal indicate better aided performance. Note: almost all of the data points in Figures 5 and 6 fall below the diagonal lines. This shows that use of the test hearing aid improves speech understanding in noise.

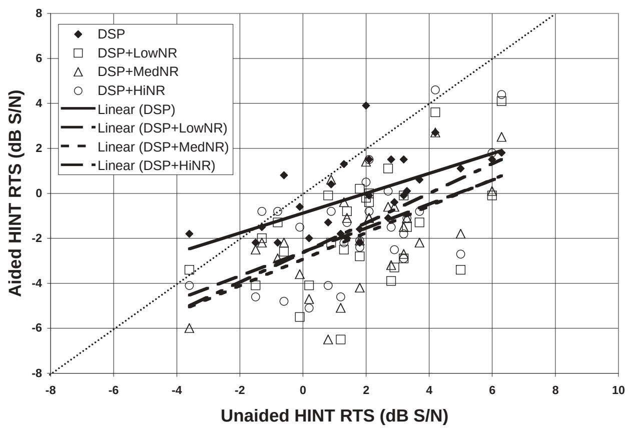

Figure 5: Individual HINT RTS values from Site 1. The dotted, diagonal line represents equal RTS scores unaided and aided. Regression lines are linear best-fit lines for the four aided conditions, with respect to the unaided condition.

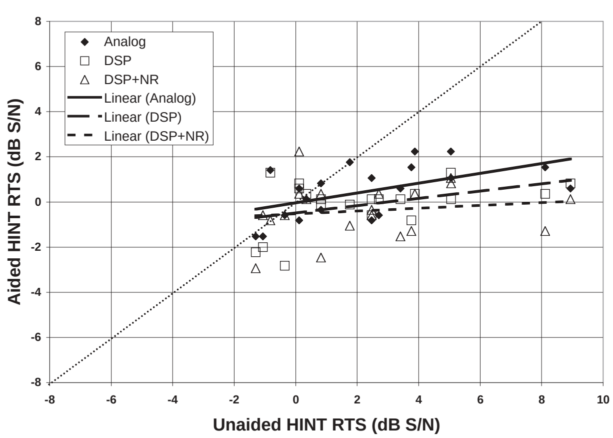

Figure 6: Individual HINT RTS values from Site 2. The dotted, diagonal line represents equal RTS scores unaided and aided. Regression lines are linear best-fit lines for the three aided conditions, with respect to the unaided condition.

Figures 5 and 6 also show linear best-fit regression lines corresponding to the aided conditions. The distance between the regression lines and the dotted, diagonal line is the expected benefit from that specific aided condition. For example, in Figure 5, for a subject with an unaided HINT RTS at 0 dB S/N, the expected aided threshold would be about –1 dB S/N for the DSP without NR condition, and about –3 dB S/N for the DSP with NR condition.

DISCUSSION

Multi-Site Data: At both sites, the test DSP hearing aids provided significant improvement for speech understanding in noise, as compared to the unaided condition. The mean benefit for the 48 subjects was 2 dB S/N for the digital without NR condition and 3 dB for the digital with NR condition. A 2-dB S/N improvement on the HINT corresponds to an 18% increase in speech intelligibility in noise; a 3-dB improvement is equivalent to a 27% increase.

The results of this multiple-site study clearly demonstrate that use of the omni-directional DSP NATURA 2 SE hearing aids, with or without noise reduction activated, improved speech understanding in noise.

Single-Site Data: At Site 2 there was a significant difference between the unaided performance and aided performance with analog hearing aids (1.86 dB S/N). These results indicate that well-fit, omni-directional, multi-channel analog hearing aids can also improve speech intelligibility in noise.

At Site 2 there was a significant difference between the aided multi-channel analog and the aided DSP conditions, with or without NR activated (0.85 and 0.57 dB S/N, respectively). These results indicate that better speech intelligibility in noise was achieved with the multi-channel DSP hearing aid, when compared to the reference well-fit, multi-channel analog hearing aids.

At Site 1 there was a significant difference between the DSP with and without NR conditions (1.56 dB S/N). However at Site 2 there was not a significant difference between the DSP with and without NR conditions (0.28 dB S/N). It is not understood why there was a difference across the two sites for this condition. Several hypotheses are being evaluated, including the possible impact of the low frequency hearing loss differences across the test sites.

CONCLUSION

The results of this multiple-site investigation demonstrate that it is possible to improve speech intelligibility in noise using the NATURA 2 SE omni-directional hearing aids, even in a challenging test environment where there are no spatial cues and only limited spectral cues.

Work is in process to enroll subjects at a third research site and to continue data collection at all sites. The additional objective measures will include analysis for the effects of (a) slope and degree of hearing loss, (b) presence or absence of masker spatial separation, and (c) presence or absence of masker temporal modulation. The subjective measures include the Client Oriented Scale of Improvement (COSI), the International Outcome Inventory for Hearing Aids (IOI-HA), and the Profile of Hearing Aid Benefit (PHAB). Use of the subjective measures will help to determine to what degree laboratory benefit translates into clinical benefit, as perceived by the research subjects.

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