



Effects of Noise Reduction & Directionality in ITEs

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ABSTRACT

This presentation focuses on how directionality and noise reduction change speech intelligibility in a quasi-free field with uncorrelated noise. The HINT Thresholds of 14 subjects were measured and the effects of various combinations of NR and directionality in a directional ITE were compared. Results demonstrate a statistically significant improvement in the Reception Threshold for Sentences with NR and directionality over the unaided and aided, omnidirectional condition.

INTRODUCTION

A universal complaint of hearing aid users is difficulty hearing in noise. One solution to this problem has been the incorporation of directional microphones into hearing devices. Although effective, directionality can only minimize those noises arriving at or near the directional nulls. Given that real-world noises often surround the listener, the potential Signal-to-Noise Ratio (SNR) improvement allowed by directionality is inherently limited unless the offending noise happens to conveniently fall within the directional null(s). To counter this problem, "adaptive" directional technology has been introduced to automatically direct the directional null towards the greatest noise source. Although this solution can improve the usefulness of directional hearing aids, the problem nevertheless remains about what to do about those noises originating from many sources, including the same direction as the speech signal.

This limitation of directional microphones can be offset by pairing this technology with SONIC innovations Personalized Noise Reduction™ which has been demonstrated to improve speech intelligibility in noise (Bray & Nilsson, 2000). Unlike directionality, Noise Reduction (NR) attenuates steady-state noises arriving from all locations around the listener, and minimizes the inherent "circuit" noise associated with directional microphones. It is proposed that NR and directionality may have additive or combined benefits that extend beyond those provided by each respective technology. This study examines these potential benefits on hearing-impaired subjects using directional ITE devices.

DEVICES

The SONIC innovations NATURA 2 SE ITE-D device features an encapsulated omnidirectional and directional microphone that can be selected by the user via a switch on the device. The instrument processes sound in 9 independent compression channels centered on the audiometric test frequencies. These channels use very rapid and symmetric attack and release times to ensure a natural listening experience for the listener as well as maximize the effectiveness of the NR signal processing.

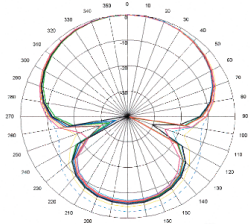


Figure 1. ITE-D Polar Pattern

Additionally, the hearing care professional can easily adjust the frequency response, compression, expansion, and NR levels to ensure maximum speech intelligibility while retaining optimal listening comfort, even in noise. The directional response of the device is a hypercardioid which has been chosen to maximize directional sensitivity with an AI-DI of 5.9 dB (see Figure 1).

METHOD

Subjects: Fourteen hearing impaired subjects wearing ITE-D devices participated in this study (see Figure 2 for audiometric data). All subjects were experienced hearing aid users and included 9 males and 5 females with an average age of 66 years. All device fittings were binaural, appropriately vented to minimize occlusion.

Procedure: HINT performance was measured under two different noise conditions. The "Noise Front" condition included both the HINT sentence material and the noise

Figure 2. Mean Audiogram (n=14) arriving from the same loudspeaker one meter in front of the listener. In the "Diffuse Noise" condition, the uncorrelated noise originated from four loudspeakers located at 45, 135, 225, and 315 degrees while the sentence material was presented in front of the listener. This quasi-free field (QFF) was intended to approximate real-world conditions where noise often originates from multiple locations around the listener. The spectrally-matched noise source was calibrated at 65 dB

A in both the noise front and noise diffuse conditions. Subjects were tested unaided, aided using the different microphones modes without NR, and aided using both microphone modes with NR enabled.

RESULTS

As shown in Figure 4, amplification provided a statistically significant improvement in HINT performance in both the Noise Front (NF) and in the Quasi-Free Field (QFF) conditions [$F(1,13)=9.129, p<.01$]. The QFF noise environment helped improve absolute HINT performance by slightly more than 2 dB SNR [$F(1,13)=31.390, p<.001$]. This performance benefit could be attributed to the spatial separation between the noise sources and the sentence material inherent in the QFF condition.

A main effect of NR was calculated [$F(1,13)=10.960, p<.01$] where HINT performance improved by a modest 0.6 dB in the NF and QFF conditions. Once again, absolute HINT scores were improved by as much as 2.2 dB in the QFF listening condition [$F(1,13)=97.885, p<.001$]. No interaction between NR and noise condition was obtained suggesting that the SNR benefit afforded by NR was independent of the listening

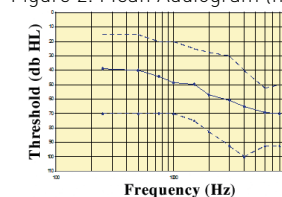


Figure 3. Experimental Setup

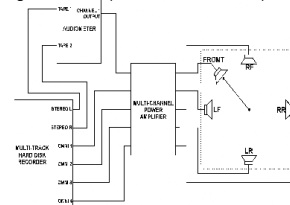


Figure 4. Unaided vs. Aided HINT Performance

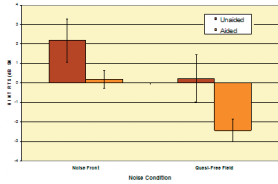


Figure 5. Effects of NR on HINT performance

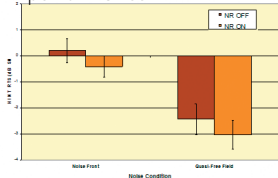
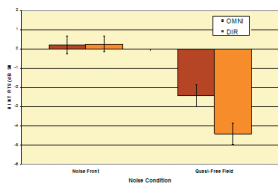


Figure 6. Mic. Mode and HINT Performance



condition.

A statistically significant main effect of microphone mode was obtained [F(1,13)=13.091, p<.01]. As shown in Figure 6 this HINT performance improvement was only obtained in the QFF condition which is exemplified by the significant interaction between microphone mode and noise condition [F(1,13)=23.345, p<.001]. This later outcome is consistent with the proposition that directional improvements are only possible when there is spatial separation between the HINT sentence material and the noise sources.

effects of NR and directionality in ITEs did not summate to provide additional speech intelligibility benefits. Despite this lack of additional performance improvement, enabling NR in the directional mode reduced the audibility of the inherent microphone noise to barely perceptible levels as shown in figure 8. This additional NR benefit makes the directional mode more usable, as we can deliver maximum audibility (full equalization) while significantly reducing the level of background noise in a spatially selective manner. In effect, Directionalplus™ maximizes the benefits afforded by directionality while retaining an open vent, minimal circuit noise along with a completely equalized frequency response.

REFERENCES

Bray, V., & Nilsson, M. (2000). Objective Test Results Support Benefits of a DSP Noise Reduction System. *Hearing Review*, 7(11), 60-65.

Nilsson, M. & Bray (2002). Benefit from Noise Reduction and Directionality in BTEs. Poster presented at the AAA 14th Annual Convention, Philadelphia, Pennsylvania.

SUMMARY

- 1- Digital Amplification alone (without NR or directionality) improves the SNR by as much as 2 dB. This accounts for half of the total SNR improvement possible with this device model.
- 2- Noise Reduction is effective at improving intelligibility in noise by 0.6 dB over amplification alone in both the Noise Front and in the Quasi-Free Field conditions. Unlike directionality, NR does not require spatial separation to improve speech intelligibility in noise.
- 3- Directionality improves speech intelligibility by over 2 dB SNR whenever there is spatial separation between the signal and noise sources.
- 4- The QFF inherently provides improved absolute HINT scores over the NF condition. This indicates that the subjects made use of spatial separation cues when listening in the sound field with the multiple noise sources.
- 5- Unlike the results obtained in a companion poster using directional BTEs. (Nilsson and Bray, 2002), the combined

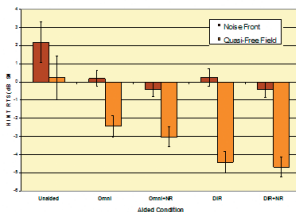


Figure 7. Combined Effects of Amplification, NR, and Directionality on HINT Performance

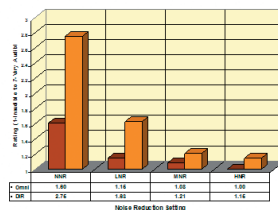


Figure 8. Effects of NR and Expansion on the Audibility of Microphone Noise.

