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Benefit from Noise Reduction and Directionality in BTEs

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Abstract

The combined effects of multi-channel compression, noise reduction, and directional microphones were evaluated in BTE aids for 20 experienced users of amplification. Speech recognition with the HINT was used to evaluate all combinations of technology. In order to measure the benefits of directionality, a quasi-free field was created for HINT testing. Data demonstrate significant speech recognition benefit from multi-channel compression, noise reduction, and the directional microphone. The additive benefit from the various features is highlighted.

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INTRODUCTION

As digital hearing aids provide more complex and improved signal processing, the ability to evaluate the individual contribution of these advancements becomes more important. Inappropriate testing conditions can falsely inflate or deflate the measured benefit from separate features. A combination of multi-channel compression, switchable directional technology, and active noise reduction (NR) was evaluated using speech recognition measures. Unaided and aided measures, as well as the separate contribution of individual signal processing features, were evaluated to calculate any additive benefits among features.

DEVICES

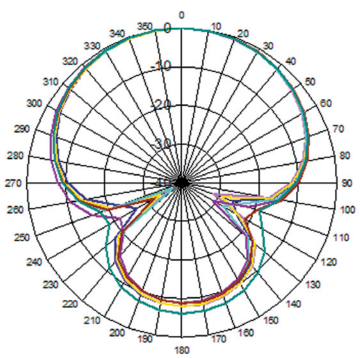

Figure 1: Polar pattern of directional mic

BTE devices with two microphones (one omni-directional microphone and one dual-port directional microphone) were fit on all subjects. Devices were SONIC innovations' NATURA 2 SE BTE-Ds with two memories (separate programs for the omni and directional microphones). The directional response of the device is hypercardioid, as seen in Figure 1, with an AI-DI of 5.8 dB.

The DSP processes sound in nine independent compression channels centered on audiometric half-octaves using very-fast and symmetric time constants1. In addition, the system implements NR in each channel2. Noise detectors determine the portion of the entire signal that is noise based upon the modulation rate of the envelope. From this, the signal-to-noise ratio in each channel is calculated which, in turn, determines the specific amount of NR applied within the channel.

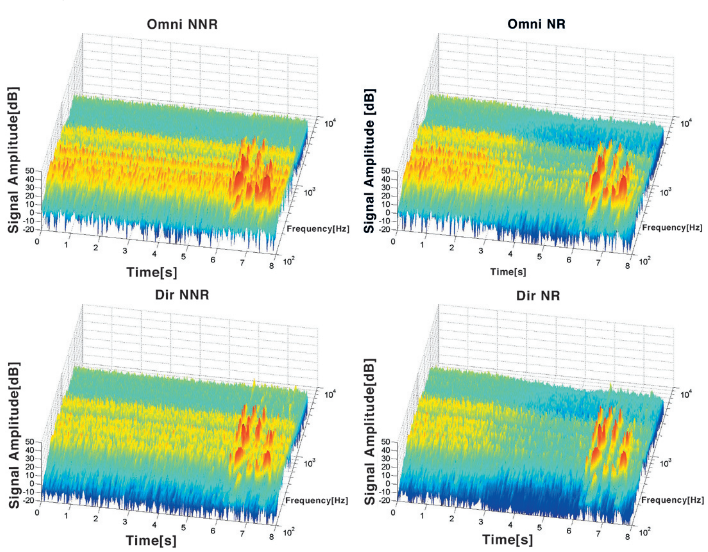

Figure 2: BTE recordings of HINT sentence in Noise at 0 dB SNR

Recordings of the output of one of the devices connected to a Zwislocki coupler are presented in Figure 2. The materials were recorded at a SNR of +0 dB using one HINT sentence and spectrally matched HINT noise. Time is on the horizontal axis, while frequency is shown on the right axis. Amplitude is signified by color, with red showing the peaks in the signal. As the signal processing is combined, the level of the noise is reduced, leaving the peaks of the speech signal intact.

METHODS

Subjects: Twenty subjects were fit binaurally with BTE devices with a switchable directional microphone and programmable NR. Audiometric data are summarized in Figure 3. Subjects included 16 male and 4 female subjects with a mean age of 64 years. All subjects were diagnosed with bilateral, symmetrical sensorineural hearing loss.

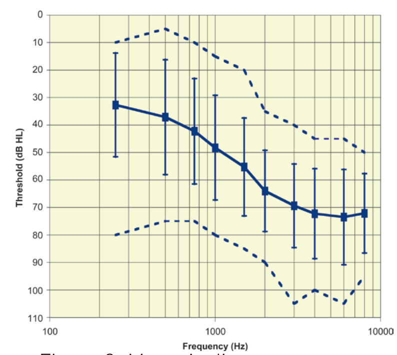

Figure 3: Mean Audiogram

Apparatus: The current study used a modified Hearing In Noise Test (HINT)3 because of its control of materials and listening conditions. Subjects were tested using two scenarios: noise presented from a single front speaker (as specified by the HINT), and the same noise presented simultaneously from four speakers positioned at 45o, 135o, 225o, and 315o azimuths (time-shifted to make the noise uncorrelated).4 This multi-loudspeaker setup meets the ISO standard for a "quasi-free field" (QFF).5 The HINT consists of a set of recordings of short English sentences spoken by a male talker accompanied by white noise filtered to match the long-term average spectrum of the sentences. The noise is presented at a fixed level (65 dB A or 10 dB SL, whichever is higher) and the level of the sentences is adjusted in an adaptive method to estimate the level at which the sentences can be repeated correctly 50% of the time. The test materials were modified by increasing the noise-onset time from one-half to five seconds to allow any adaptive signal processing to stabilize before the beginning of the sentence.

RESULTS

An Analysis of Variance (ANOVA) was run on the HINT thresholds looking at several within-subject variables. To evaluate the benefit from multi-channel compression, an ANOVA was run comparing unaided to aided performance using the omni-directional microphone without any additional signal processing (Figure 4, left). A main effect of amplification was found [F(1,19)=23.5, p<.01] as well as a main effect of type of noise (noise-front versus QFF) [F(1,19)=17.6, p<.01]. No interaction was found.

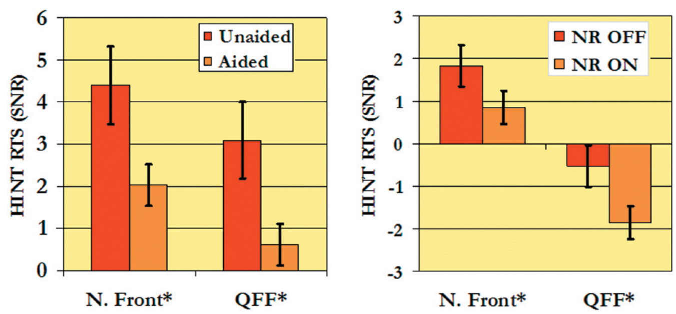

Figure 4: Plot of main effects of amplification (left) and NR (right)

To evaluate the benefit from noise reduction, an ANOVA was run comparing aided performance using the omni-directional microphone with noise reduction turned off or on (Figure 4, right). A main effect of noise reduction was found [F(1,19)=24.7, p<.01] as well as a main effect of type of noise [F(1,19)=21.0, p<.01] with no significant interaction.

To evaluate the benefit of the directional microphone, an ANOVA was run comparing performance with the omni-directional microphone to performance with the directional microphone (Figure 5). A main effect of microphone type was found[F(1,19)=23.3, p<.01) as well as a main effect of type of noise [F(1,19)=129.7, p<.01] and an interaction between microphone and noise [F(1,19)=13.2, p<.01]. The benefit from the directional microphone is found in the QFF condition where the noise is separated from the speech, but not in the noise-front condition where the directional microphone cannot separate the two signals.

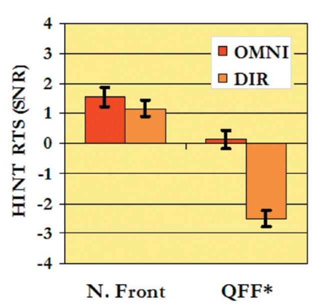

Figure 5: Interaction between microphone and type of noise.

In order to see how the various features combine, Figure 6 shows absolute performance across conditions (noise reduction on and off in the omni and directional microphones measured in the noise-front and QFF conditions). Significant main effects were found [F(4,76)=41.9, p<.01; F(1,19)=92.1, p<.01] as well as the more interesting interaction [F(4,76)=12.1, p<.01], with post-hoc comparisons revealing significant differences between all conditions in the QFF, but no differences between the omni-directional and directional modes in the noise-front environment.

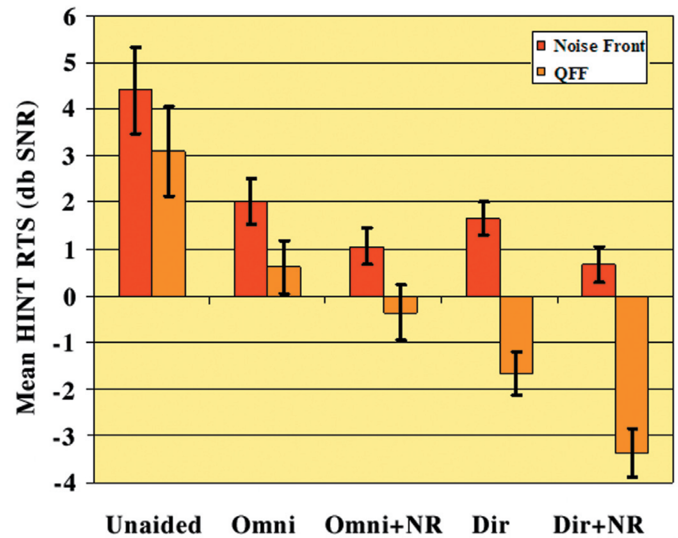

Figure 6: Combined effects of amplification, noise reduction, and directionality in the noise front and QFF conditions.

DISCUSSION

Significant speech-recognition-in-noise benefit re: unaided from multi-channel compression (2.5 dB), NR (1.7 dB), and directional microphones (2.3 dB) combine to show an overall benefit from the devices of 6.5 dB. The separate contributions of individual components each provide significant improvements in speech recognition in noise, leading to a threshold shift associated with over 50% change in intelligibility in noise.

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