RESEARCH BRIEF

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Can Directional Benefit be Predicted from Auditory Threshold?

ABSTRACT

Forty-four research participants completed a study that evaluated speech understanding in noise while wearing S Series™ hearing aids. One of the experimental questions asked if directional benefit in a noisy background — relative to performance with omni-directional microphones — could be predicted from the pure-tone audiogram. While trends within the group data suggest that higher pure-tone thresholds may result in the greatest benefit from directional microphone technology, individual variability in performance suggests that directional benefit should not be attributed to audiometric data alone.

INTRODUCTION

There is great difficulty in predicting an individual's speech understanding difficulties in noisy environments from a pure-tone audiogram[1] or even other speech tests, especially when conducted in quiet.[2, 3] Indeed, many clinicians have seen the patient with a steeply sloping high-frequency hearing loss who, against expectations, excels in noisy conversation, while the next patient they see has a gently sloping hearing loss but has stopped attending social gatherings because the effort to hear is too great. This variability also extends to the benefit that one may receive from directional microphones.

This article explores variability in benefit from directional microphones across a range of hearing loss severity; benefit was documented using a standardized test of speech understanding in noise. While some sources of variability can be identified, others cannot. The clinical implications of this variability will also be discussed.

METHODS

Participants: Data from 44 participants (29 male and 15 female) were analyzed for this study. Participants ranged in age from 22 to 78 years (mean = 59 years). Hearing losses were generally symmetrical, mild to profound, and sensorineural. Mean right and left audiograms with minimum and maximum thresholds are shown in **Figure 1**. Maximum thresholds are at audiometric equipment limits and represent *"no response"* markings on individual audiograms.

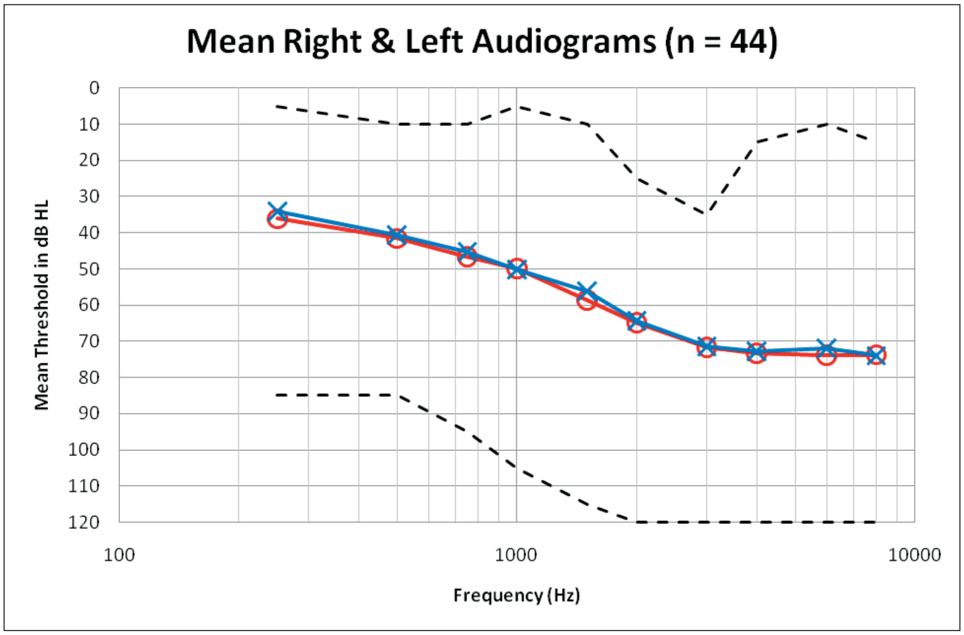

Figure 1: *Mean audiometric thresholds with range (minimum and maximum thresholds). Maximum thresholds shown at 120 dB HL are marked as "no response" on individual audiograms.*

Materials and Equipment: Five hearing aid styles with directional microphones were used, including In-the-Canal (ITC), Behind-the-Ear (BTE) with standard tubing, BTE with thin tubing, and Receiver-in-the-Canal (RIC) in both an "open-ear" configuration and a 70-gain occluded configuration with custom molds. All subjects were fitted bilaterally.

Test materials consisted of the Hearing In Noise Test (HINT). The HINT uses an adaptive procedure to estimate the reception threshold for sentences (RTS) in dB signal-to-noise ratio (SNR) when administered in competing noise at a fixed intensity. The RTS is defined as the correct repetition of 50 percent of the sentences presented.[4]

The sentences were presented from a loudspeaker positioned one meter from the center of the listening position and at 0˚ azimuth. Uncorrelated noise was presented at 65 dBA through seven loudspeakers, located at 45˚ intervals from 45˚ through 315˚ azimuth, also at a distance of one meter, to create a diffuse noise field in the horizontal plane.

RESULTS

For the purposes of this report "directional benefit" is defined as the difference in dB between HINT scores obtained with directional microphones versus omni-directional microphones. **Figure 2** plots directional benefit against the three-frequency (0.5, 1.0, and 2.0 kHz) pure-tone average (PTA) of each subject's hearing loss. The PTA was used to represent each subject's hearing loss as it correlates well with the speech reception threshold (SRT). The trend line in **Figure 2** shows that in general, as hearing loss worsens, more benefit from directional microphones is observed.

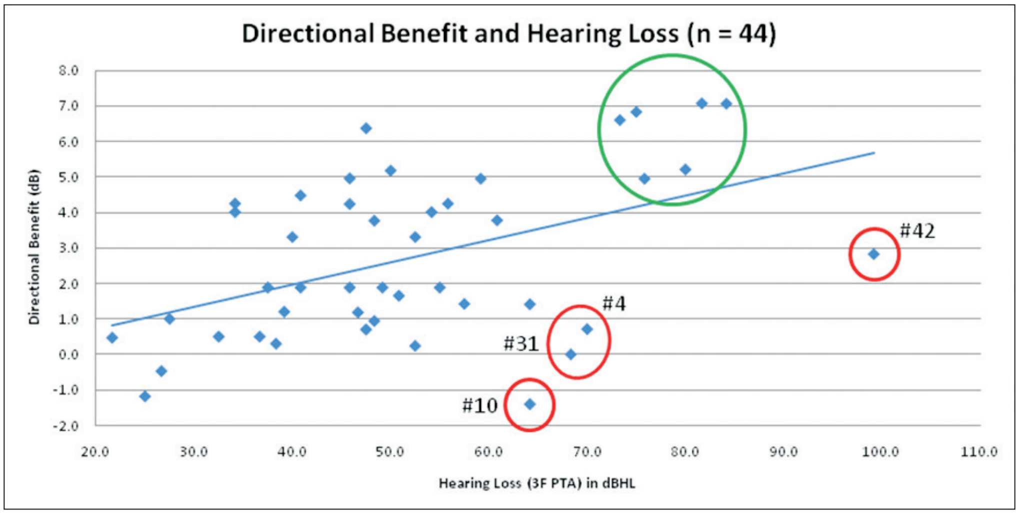

Figure 2: *Scatterplot of directional benefit against hearing loss, given as the 3-frequency pure-tone average (PTA) at 0.5, 1.0, and 2.0 kHz.*

Several other observations can be made from **Figure 2**. Though the graph appears to support the notion that those with the highest thresholds receive the greatest benefit from directional microphones, it is not a foregone conclusion. Each observation will be addressed in turn:

1. The majority of participants—those with PTAs below 70 dB HL—demonstrate a fair amount of variability with regard to directional benefit. These participants show directional benefit that ranges from 0 dB (no benefit) to over 6 dB (extraordinary benefit). Two participants among those with the mildest hearing losses show no benefit from directional microphone use.

2. The next observation is the group of six data points circled together in green. These thresholds are among the most elevated of all of the participants, with PTAs between 75 and 80 dB HL. This group of severe-to profoundly-impaired participants received the most benefit from directional microphones. The idea that greater directional benefit is available to those with the more severe losses seems to be quite evident in this subgroup.

3. The benefit exhibited by the participants circled in green is offset by those circled in red. Participant #42 had the highest of all PTAs, yet received only half of the mean benefit of the sub-group circled in green. For this individual, the "greater-loss, greater-benefit" theory does not hold up. Participant #42's audiogram (**Figure 3a**) reveals profound high-frequency thresholds and no response above 2 kHz.

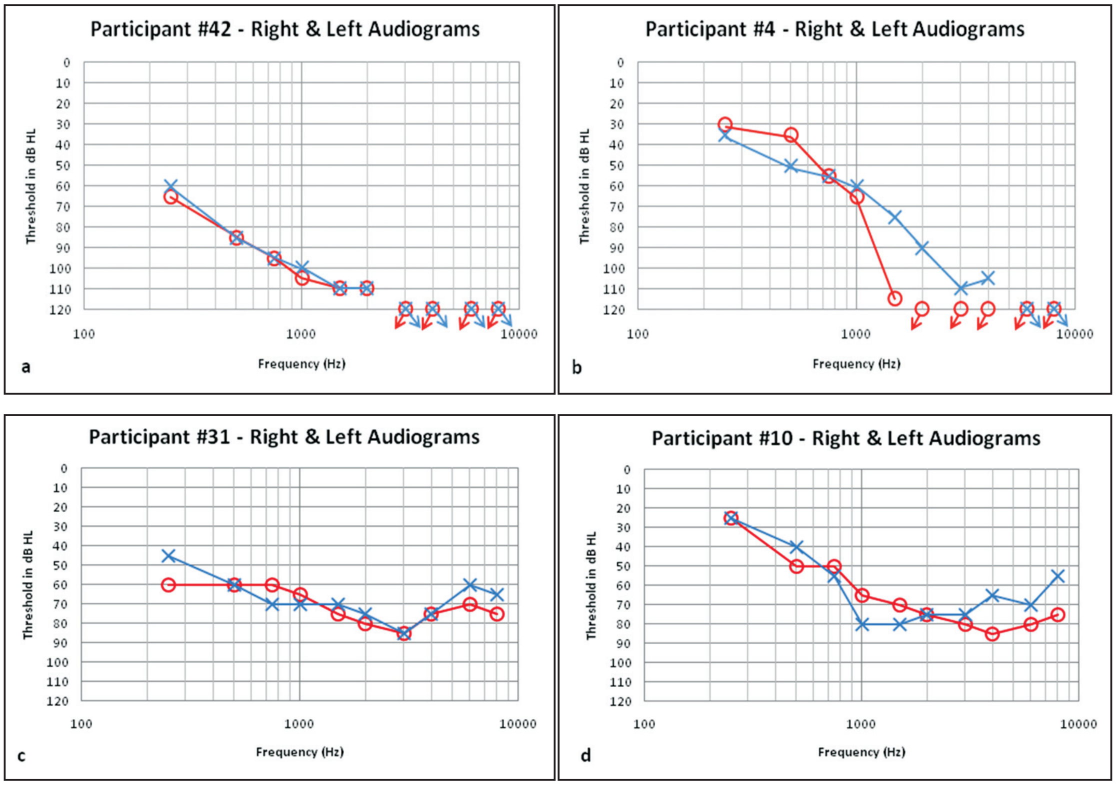

Figure 3: *Individual audiometric thresholds of participants #42, #4, #31, and #10.*

4. The two circled data points in **Figure 2** with PTAs near 70 dB HL (Participants #4 and #31) also do not support the "greater-loss, greater-benefit" theory. These individuals' PTAs are certainly not the most severe, nor are they the mildest, yet they receive far less benefit than the majority of the group. Looking at their individual audiograms, **Figure 3b** reveals that Participant #4 has a hearing loss similar to Participant #42. However, Participant #31 (**Figure 3c**) has a relatively flat audiogram, yet performs not unlike Participant #4.

5. The individual who received the least amount of benefit from directional microphones is represented by the audiogram in **Figure 3d** (Participant #10). This individual has a hearing loss similar to that of Participant #31, but with better low-frequency thresholds. That Participant #10 should receive less directional benefit than Participant #31 would not have been easily predicted.

6. 91 percent of the participants in the present study received some directional benefit, demonstrating that directional microphones should be a consideration for every patient, regardless of hearing loss. Since the performance-intensity function of the HINT yields an average of about nine percent-per-decibel improvement in speech understanding,[4] the importance of this finding cannot be overstated.

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CONCLUSION

Group data appear to suggest that directional benefit will show a concomitant increase with pure-tone threshold. Yet a high degree of variability is evident across all levels of hearing loss severity. Even with stellar performers (those in **Figure 2** circled in green), only 22 percent of the observed benefit is statistically related to the severity of the hearing loss ($r^2 = 0.2192$). It is also apparent that similar hearing loss configurations can result in differences in directional benefit.

Among the data presented here it appears that as the PTAs are elevated, the size of individual variances may also increase. This means that while some individuals with severe hearing loss may benefit from directional microphones more than those with less severe impairments, others with severe hearing loss experience less benefit, making predictions all the more tenuous. On the other hand, the variance among those with less severe hearing impairment, while perhaps smaller, is evenly, randomly, and widely distributed, and without obvious audiometric indicators (e.g., *"no response"* at some frequencies), making predictions equally as difficult among these individuals.

Clinical Implications: At first glance, these group data seem to lend support to a common clinical assumption, that directional benefit increases with PTA. Upon analysis it becomes clear that due to individual variability, the PTA does not predict *how* much benefit can be received from directional microphone technology in noisy listening situations. However, these data clearly show that most hearing-impaired individuals can receive some benefit from directional microphones. If there is aidable hearing available at speech frequencies there is an opportunity that the use of directional microphones can improve speech understanding in noise. Keeping this in mind will guide clinicians in setting realistic expectations for individual fittings.

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