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A Model of Hearing Aid Benefit Based on Performance Measures with Hearing Aid Users

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Abstract

Speech-recognition-in-noise measurements have been obtained on several hundred hearing aid subjects over several years. The research sites followed a standardized protocol and utilized a standardized test platform.1,2,3 Performance measures were obtained on all styles of hearing aids (CIC through BTE), on subjects with varying degrees of sensorineural hearing loss (mild through severe), with various hearing aid technologies selectively engaged (multi-channel compression, directional microphones, and digital noise reduction).

This 'large-n' database is being analyzed to determine hearing aid benefit for speech-recognition-in-noise as a function of unaided hearing loss in quiet, unaided hearing loss in noise, and hearing aid technologies. It is hoped that the results will lead to a predictive model for hearing aid benefit for speech- recognition-in-noise with hearing aids. Preliminary results lead to interesting correlations between unaided thresholds in quiet and aided thresholds in noise (R2 ranging from .10 to .17) and unaided thresholds in noise and aided thresholds in noise (R2 ranging from .37 to .50), with respect to the various hearing aid technologies.

METHODS

Product development with data collection is ongoing at the Hearing Aid Research Laboratory at Sonic Innovations in Salt Lake City, Utah. In this retrospective analysis, data collection notebooks were reviewed from the years 2000 - 2005 for hearing aid fittings using the Natura 2 and Natura 3 hearing aids in all styles (CIC through BTE). All subjects had come into the studies with bilateral, sensorineural hearing loss and had been fitted binaurally.

The notebooks yielded 540 individual hearing aid trials for which speech recognition scores were obtained with the HINT. Of these, approximately 200 hearing aid trials contained scores for the conditions needed in this analysis: unaided speech understanding in quiet and in noise, and aided speech understanding in noise in the Listening Conditions of omni-directional, omni-directional + noise reduction, directional, and directional + noise reduction.

Of these, 187 hearing aid trials were accepted, after rejection of fringe cases for unaided hearing in quiet (< 25 dBA or > 70 dBA) or statistical outlier cases for aided performance in noise. All of the 187 cases included information on aided omni-directional and omni-directional + noise reduction. Of these, a subset of 82 cases included the additional information of directional and directional + noise reduction.

RESULTS

Data are plotted in Figures 1-4. Figures 1 and 3 are scatterplots for Unaided Hearing Levels in Quiet (HLQ) versus Unaided and Aided Hearing Levels in Noise (HLN). Figures 2 and 4 are scatterplots for Unaided HLN versus Aided HLN. The

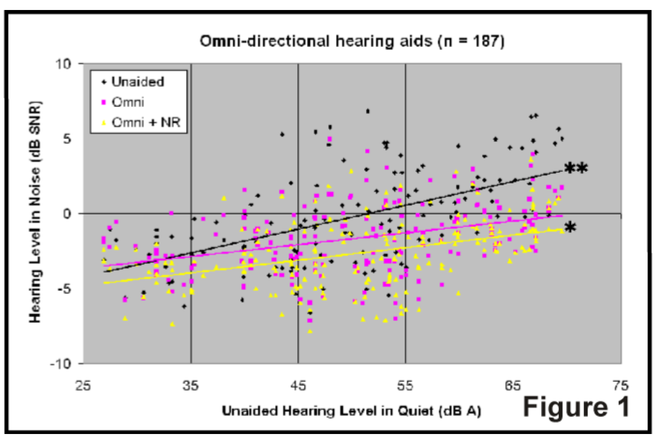

Figure 1

omnidirectional data in Figure 3 are included in Figure 1 and the omni-directional data in Figure 4 are included in Figure 2. The table summarizes the linear regression equations and associated statistics. The analysis from Figures 1 and 3 reveals that the relationship between the Unaided HLQ and

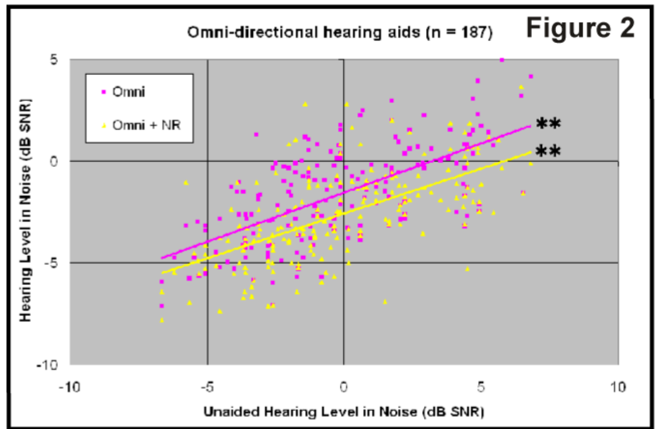

Figure 2

Unaided HLN is mild and positive (R^2 ranges from 0.32 and 0.27), and significant ($p < .001$). The rate of change of Unaided HLN, with respect to Unaided HLQ, is about 1.5 dB SNR for each 10 dBA increase in HLQ (slopes of 0.16 and 0.15).

The analysis from Figures 1 and 3 reveals that the relationship between the Unaided HLQ and Aided HLN is weak and positive

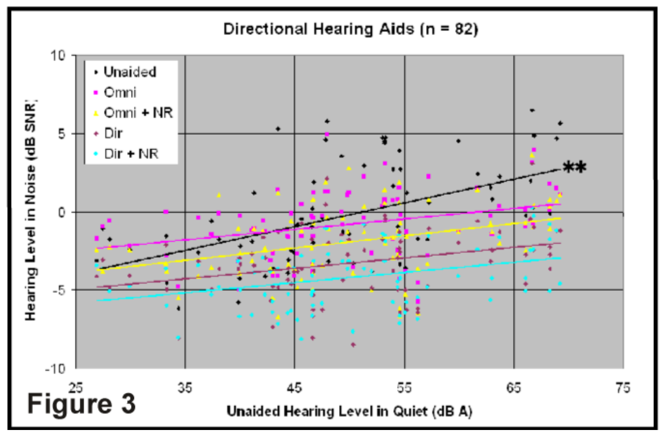

Figure 3

(R^2 ranges from 0.10 to 0.17), with varying significance, depending on the technology employed in the Listening Condition and the sample size. The only significant correlation is between Unaided HLQ and Aided HLN for the omni-directional + noise reduction condition in the larger sample size in Figure 1 ($p < .05$), but the significance is lost in the

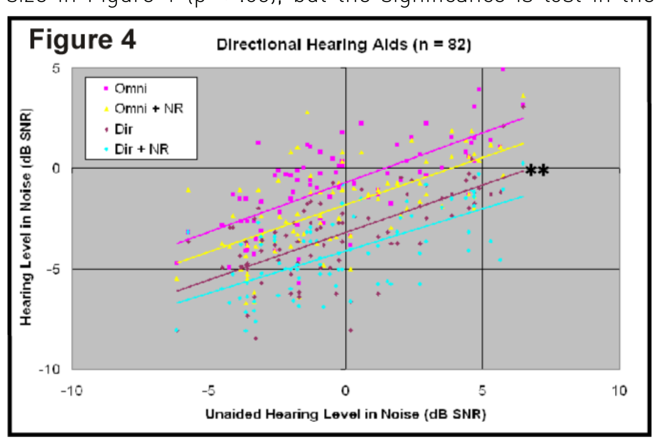

Figure 4

smaller sample size in Figure 3 ($p = .26$). For the two aided conditions in Figure 1 and the four aided conditions in Figure 3, the parallel regression lines indicate step-wise improvements in Aided HLN tied to the technology employed in the various Listening Conditions.

Condition	Figure	Linear Regression Equation	R2 value	p value	
Unaided	F1	HLN unaided = (0.159 x HLQ unaided) - 8.20	R2 = 0.316	p < .001	**
Unaided	F3	HLN unaided = (0.152 x HLQ unaided) - 7.77	R2 = 0.265	p < .001	**
Omni	F1	HLN aided = (0.079 x HLQ unaided) - 5.61	R2 = 0.138	p = .204	
Omni	F3	HLN aided = (0.067 x HLQ unaided) - 4.14	R2 = 0.107	p = .183	
Omni + NR	F1	HLN aided = (0.085 x HLQ unaided) - 6.92	R2 = 0.172	p = .035	*
Omni + NR	F3	HLN aided = (0.078 x HLQ unaided) - 5.81	R2 = 0.131	p = .259	
Dir	F3	HLN aided = (0.067 x HLQ unaided) - 6.62	R2 = 0.103	p = .979	
Dir + NR	F3	HLN aided = (0.064 x HLQ unaided) - 7.41	R2 = 0.115	p = .877	
Omni	F2	HLN aided = (0.481 x HLN unaided) - 1.55	R2 = 0.411	p < .001	**
Omni	F4	HLN aided = (0.494 x HLN unaided) - 0.69	R2 = 0.503	p = .235	
Omni + NR	F2	HLN aided = (0.440 x HLN unaided) - 2.57	R2 = 0.371	p < .001	**
Omni + NR	F4	HLN aided = (0.470 x HLN unaided) - 1.81	R2 = 0.408	p = .215	
Dir	F4	HLN aided = (0.474 x HLN unaided) - 3.18	R2 = 0.445	p = .005	**
Dir + NR	F4	HLN aided = (0.422 x HLN unaided) - 4.11	R2 = 0.428	p = .098	

The analysis from Figures 2 and 4 reveals that the relationship between Unaided HLN and Aided HLN is positive and moderate (R2 ranges from 0.37 to 0.50), also with varying significance, depending on the Listening Condition and sample size. Significant correlations occur between the Unaided HLN and Aided HLN for the omni-directional and omni-directional + noise reduction conditions with the larger sample size in Figure 2 ($p < .001$), but not the smaller sample size in Figure 4 ($p = .24$ and $p = .22$, respectively). A significant correlation occurs between the Unaided HLN and Aided HLN for the directional condition with the smaller sample size in Figure 4 ($p < 0.01$), whereas the correlation between Unaided HLN and Aided HLN for the directional + noise reduction condition with the smaller sample size in Figure 4 was not significant ($p = .10$). Again, for the two aided conditions in Figure 2 and the four aided conditions in Figure 4, the parallel regression lines indicate step-wise improvements in Aided HLN tied to the Listening Condition.

DISCUSSION

Regression Equations: Both linear and non-linear modeling were evaluated in the data analysis. Linear modeling was utilized as it produced slightly higher correlation coefficients.

Slope Coefficients: In Figures 1 and 3, the Unaided HLN values have a different slope than the Aided HLN values. The skewed nature of the Unaided HLN line and Aided HLN Omni line indicate an interaction, whereby subjects with greater Unaided HLQ obtain greater benefit for HLN with basic amplification (e.g. digital multi-channel compression). The parallel pattern of the multiple Aided HLN lines indicate additional benefit for HLN is dependent on technology (omni, omni + noise reduction, directionality, directionality + noise reduction) and independent of the Unaided HLQ. The parallel lines are also seen in Figures 2 and 4, further supporting a model whereby benefit for speech-recognition-in-noise is a function of hearing aid technology.

Correlation Coefficients: The correlations between Unaided HLN and Aided HLN are larger than between Unaided HLQ and Aided HLN.

Clinical Application: While many of the correlations are significant and could be utilized to establish a predictive model for hearing aid benefit, the correlation coefficients are, at best, moderate, and often weak. The statistical significance, where found, is dependent on the large sample size. This means that while a predictive model could be used clinically to recommend hearing aid technology, verification for speech-recognition-in-noise performance should be conducted for every client.

Future Work: More extensive modeling should be evaluated, including the incorporation of both the Unaided HLQ and Unaided HLN values to jointly predict the Aided HLN.

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