Predicting Hearing Aid Benefit from Speech Recognition Measures

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INTRODUCTION

A common reason cited in the literature for limited use and non-use of hearing aids is inadequate improvement in speech understanding, particularly when listening in noise (e.g., Kochkin, 2000). However, objective measures of unaided and aided speech recognition obtained in laboratory settings are generally poor predictors of subjective hearing difficulties and hearing aid outcomes in real-world settings. One reason for this disconnect may be that in some studies speech recognition is assessed in only a small number of test environments in a laboratory. These conditions may fail to capture the wide range of situations experienced in real-world settings. To address this limitation we measured unaided and aided word recognition at multiple levels and SNRs. Aided testing was completed using the participants own "as fit" hearing aids. Additionally, in an attempt to estimate understanding in the wide range of conditions experienced in real-world settings, we used the Speech Intelligibility Index (SII: ANSI S3.5, 1997) to predict unaided/aided sentence recognition in conditions not tested in the laboratory. A modified SII (mSII) procedure, incorporating individual proficiency factors derived from measured speech recognition ability obtained in the laboratory, was also used. The purpose of this study was to examine relationships between these various measures of unaided/aided speech recognition ability and subjective measures of unaided/aided hearing outcomes.

METHODS

Participants: Fifteen adults (52 to 85 years, 8 male, 7 female) with mild- moderate SNHL hearing loss. All were existing bilateral hearing aid wearers and had worn their current hearing aids for at least 10 months (median: 24 months, range: 10-42). The majority of participants used open fit digital BTE aids.

Hearing Aid Assessment: Hearing aid output was quantified using a concatenated mixture of NU-6 monosyllables (Auditec version, male talker). This modulated signal had the same long term spectrum as the NU-6 materials used during speech testing. Hearing aid output was measured for input levels of 55, 65, and 75 dB SPL. These measures were used to calculate real ear compression ratios for later use in SII calculations.

Subjective Assessments: Unaided and aided hearing outcomes were obtained using the Glasgow Hearing Aid Benefit Profile (GHABP; Gatehouse,1999) and the Profile of Hearing Aid Benefit (PHAB; Cox and Gilmore,1990). Unaided/aided Global Scores (mean of Ease of Communication, Reverberation and Background Noise subscales) were used to characterize hearing outcomes on the PHAB. The Initial and Residual Disability subscales were used to characterize unaided and aided hearing outcomes on the GHABP.

Speech Recognition Testing: Unaided and aided word recognition was assessed using the Auditec version of the NU-6 materials in 8 (4 unaided/4 aided) test conditions. Words were presented at 55 and 65 dBA in quiet, and in a 55 dBA steady-state speech-shaped background noise (0 and +10 dB SNR). Two hundred words were presented in each test condition.

METHODS (con't)

Speech Intelligibility Index (SII) Predictions

SII predictions of intelligibility were made for each participant for a variety of SNRs (up to 483). SNRs were based on estimates of common speech/noise levels (Pearsons et al., 1977; See Figure 1).

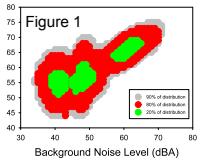

FIG. 1. Estimates of common speech and noise levels based on means, standard deviations, and correlations of speech and noise levels in and around the home reported by Pearsons et al. Simulations were used to identify the range of SNRs corresponding to various proportions of the distribution. Analyses reported here use only the 80% range of most common SNRs.

Unaided and aided SIIs were calculated assuming an average speech spectrum and a spectrally-matched background noise. Aided SIIs were calculated using gain provided by each individual's own hearing aid. In addition, modified SIIs (mSIIs) were calculated for using individual estimates of speech proficiency. Proficiency factors (PFs) were calculated using measured scores and SIIs from each of the 8 test conditions (Studebaker et al., 1995; See Equation 1).

$$PF = \text{Measured SII}/\text{Apparent SII} \quad (Eq1)$$

Proficiency was plotted as a function of measured SII and a best fit was obtained using linear regression (See Figure 2). These regression functions were used to estimate proficiency when calculating the modified SIIs (See Equation 2).

$$mSII = PF*SII_{measured} \quad (Eq2)$$

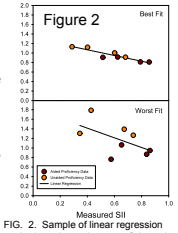

FIG. 2. Sample of linear regression method used to estimate proficiency in modified SII calculations (PF= Measured SII/Apparent SII)

The transfer function for "Unfamiliar Sentences" (Sherbecoe and Studebaker, 1990) was used to convert SIIs to predicted intelligibility at each SNR (See Figure 3).

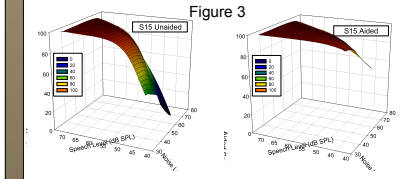

FIG. 3. Unaided and aided SII predicted scores as a function of speech and noise level for a single participant.

RESULTS

Relationships between summary measures of unaided and aided speech recognition and unaided and aided subjective reports (PHAB and GHABP) were explored using correlation analysis. Summary measures of speech recognition ability included: 1) mean unaided and aided measured scores, 2) mean unaided and aided SII and mSII predicted scores from various ranges of speech and noise distributions (data from the 80% range shown), 3) Percentage of SII and mSII predicted scores above a criterion amount (i.e., >30, 50, 70, or 90% correct). Additional summary measures were examined but yielded similar findings and are not reported here.

	Unaided		Aided	
	PHAP	GHABP	PHAP	GHABP
Measured Scores				
Mean	-0.63*	-0.41	-0.52*	-0.78*
Unmodified SII Predictions				
Mean	-0.60*	-0.62*	-0.02	-0.38
>30% correct	-0.67*	-0.67*	-0.06	-0.37
>50% correct	-0.69*	-0.70*	-0.06	-0.37
>70% correct	-0.59*	-0.66*	-0.04	-0.36
>90% correct	-0.33	-0.38	0.03	-0.34
Modified mSII Predictions				
Mean	-0.63*	-0.51*	-0.44	-0.68*
>30% correct	-0.67*	-0.60*	-0.06	-0.37
>50% correct	-0.64*	-0.55*	-0.09	-0.4
>70% correct	-0.60*	-0.49	-0.31	-0.55*
>90% correct	-0.48	-0.33	-0.52*	-0.72*

Table 1. Correlations between various measures of speech recognition and subjective measures of unaided and aided hearing outcomes. Asterisks denote a significance level of at least $p < .05$.

Results in Table 1 suggest a negative correlation between speech recognition ability and subjective measures of unaided and aided hearing outcomes. The strongest correlations appear to be between average, behaviorally measured speech recognition ability and unaided PHAB/ aided GHABP scores (See Table 1 and Figure 4).

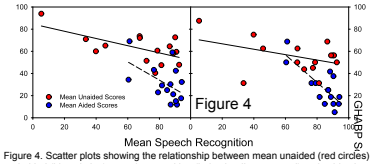

Figure 4. Scatter plots showing the relationship between mean unaided (red circles) and aided (blue circles) speech recognition (behaviorally measured) and subjective ratings of hearing outcome on the PHAB (left panel) and GHABP (right panel). Solid and dashed lines show best fit linear regression to the data.

Summary measures of unaided speech recognition ability based on SII and mSII predictions, in general, showed a similar pattern. However, except for the unaided GHABP, the strength of the correlation was never greater than that observed using behavioral measures (See Table 1). Summary measures of aided speech recognition based on the unmodified SII, were not correlated with subjective measures of hearing outcomes.

RESULTS (con't)

However, the relationship between isolated aided mSII predictions (e.g. >90% correct) and subjective outcomes was similar to, but not stronger than, those observed using behaviorally measured data (See Figure 5 and Table 1).

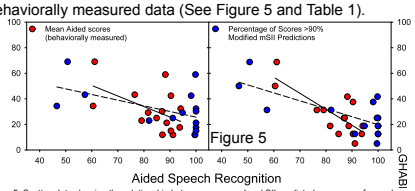

Figure 5. Scatter plots showing the relationship between measured and SII predicted measures of speech recognition and subjective ratings of hearing outcome on the PHAB (left panel) and GHABP (right panel). Red circles show mean, behaviorally measured, aided speech recognition. Blue circles show SII estimates of the percentage of predicted aided scores in 483 conditions that are >90% correct. These SII estimates incorporate individual measures of proficiency (mSII). Solid and dashed lines show best fit linear regression to the behavioral and mSII data, respectively.

Primary Findings/Discussion

- ❑ Results suggest a negative correlation between speech recognition ability and subjective measures of hearing outcomes (both aided and unaided).
- ❑ In general, the use of SII predictions over a broad range of conditions, compared to actual measured performance in a few conditions, did not strengthen correlations with subjective ratings of hearing outcomes on the PHAB or GHABP.
- ❑ Potential factors affecting study outcomes:
  - ❑ Similarities in participant hearing loss and speech recognition abilities, particularly aided, may reduce the role of speech recognition plays in subjective outcomes for this group
  - ❑ The listening situations chosen for SII predictions may not have been representative of important listening situations for our participants
  - ❑ Factors other than speech recognition ability are known to affect ratings of subjective outcomes
  - ❑ Additional data will allow the use of more variables for additional analyses (e.g. multiple regression).

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