Predictors of Listening Effort Benefits with Directionality and Noise Reduction

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INTRODUCTION

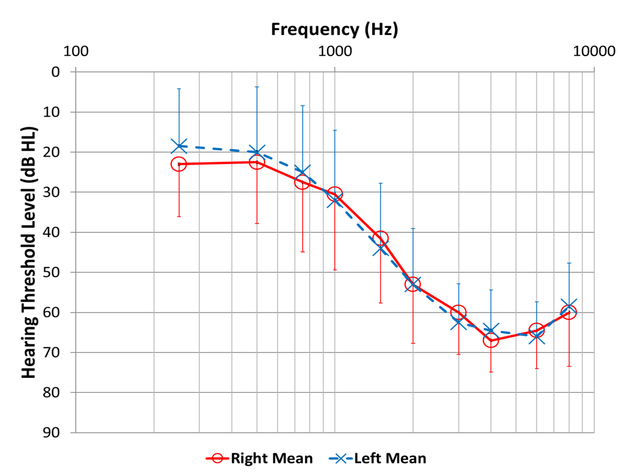
Understanding speech in noise can be effortful for hearing aid users. To reduce listening effort, hearing aid technologies, such as directional microphones (DIR) and digital noise reduction (DNR), have been designed and used to improve signal-to-noise ratios (SNR) and listening comfort. Despite demonstrated effects on listening effort, there is still substantial variation in perceived effort among hearing aid users in different listening environments. It is hypothesized that factors pertaining to individuals using hearing aids, such as demographics, audiological data, cognition, self-reported measures of hearing handicap, effort, and fatigue, may influence the assessment of listening effort.

The purpose of this study was to explore how these characteristics of listeners relate to benefits of using DIR/DNR under different degrees of aided effort measured using the Adaptive Categorical Listening Effort Scaling (ACALES)[1].

METHODS

Participants:

- 20 experienced hearing aid users
- Age: 42 to 85 years (M=70.7, SD=10.5)
- Female: N=10

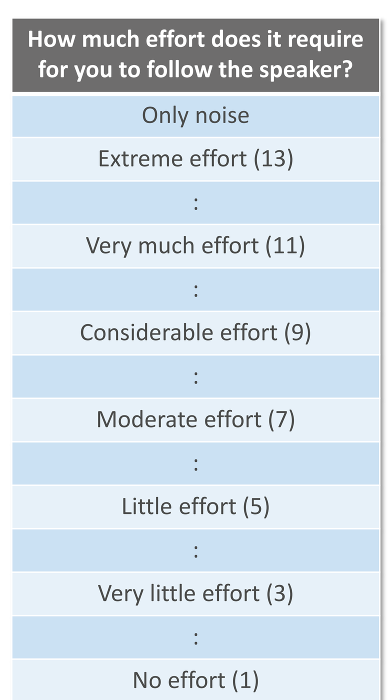


Hearing aids:

- Starkey Genesis AI 24 receiver-in-the-canal (RIC RT) devices, programmed to eSTAT 2.0 fitting formula
- Dome selection based on degree of hearing loss (12 occluded fittings)
- Two conditions were tested: (1) DIR/DNR disabled and (2) DIR/DNR enabled.

Adaptive Categorical Listening Effort Scaling (ACALES):

- Rate listening effort at various SNRs when listening to sentences from the English Matrix Test in a modulated noise (ICRA250)

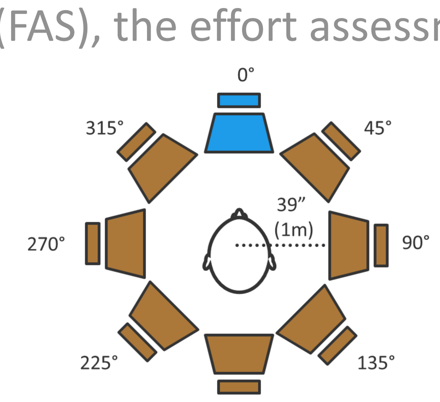


Questionnaires

- The 36-Item Short Form Health Survey (SF-36), Cognitive Self Efficacy Questionnaire II (CSEQ), Revised Hearing Handicap Inventory (RHHI), Vanderbilt Fatigue Scale (VFS), Reading Span Test (RSPAN), Montreal Cognitive Assessment (MoCA), the fatigue assessment scale (FAS), the effort assessment scale (EAS)

Procedures:

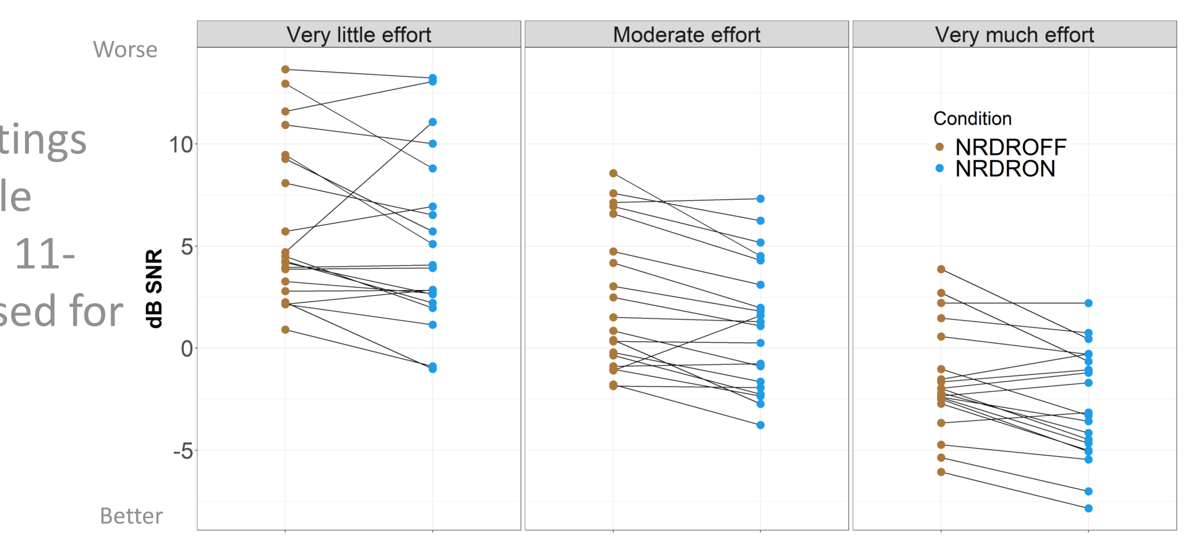
- Completed the questionnaires
- Performed the ACALES listening effort test in a sound treated lab with each of the two hearing aid conditions.



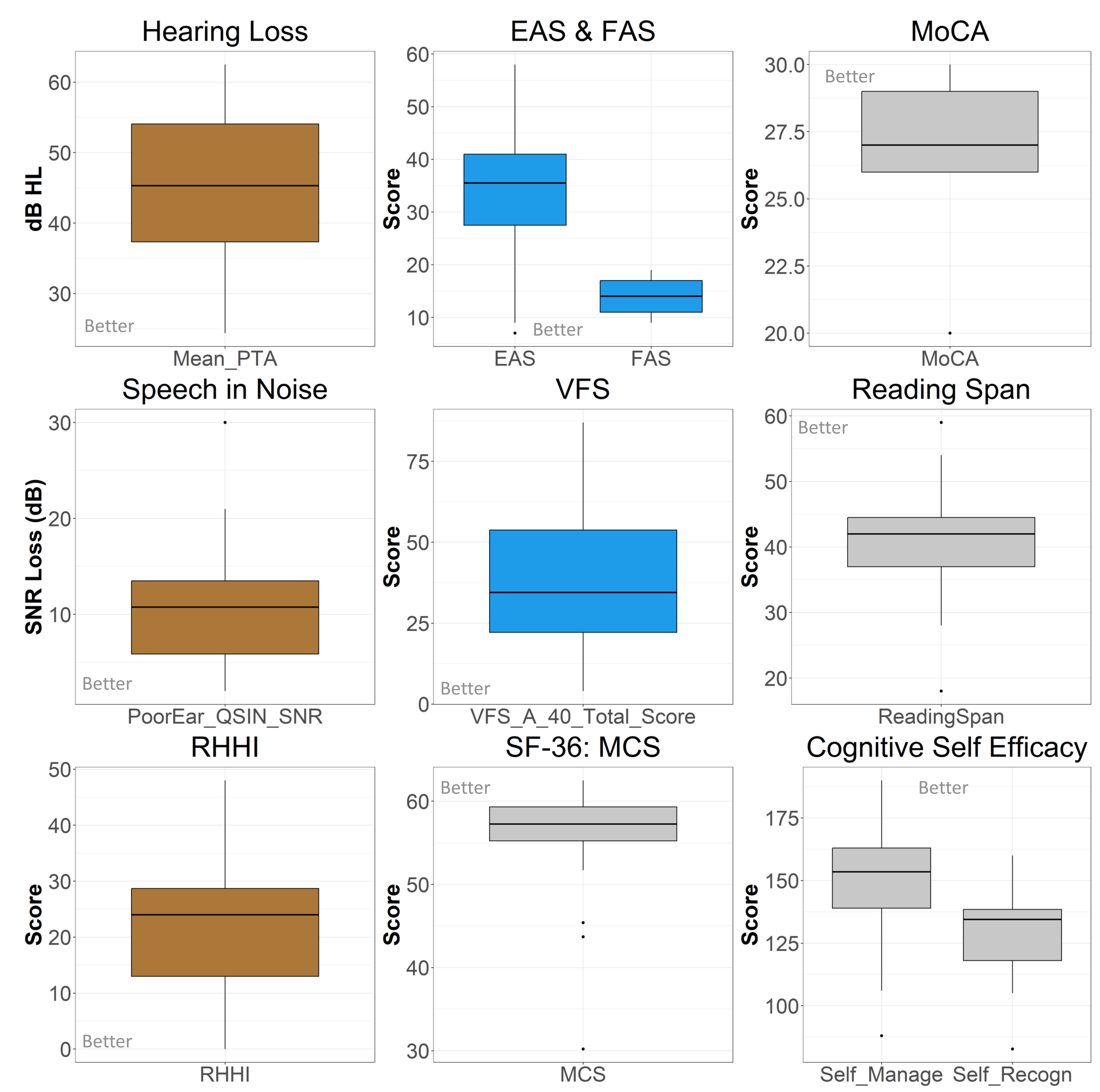
RESULTS

LISTENING EFFORT

SNRs for ACALES effort ratings of 3, 7, and 11 (3-Very little effort; 7-Moderate effort; 11-Very much effort) were used for statistical analyses.



PREDICTORS



ANALYSES

For the three effort ratings, regression models were used to examine the relationship between the predictors (numeric predictors were normalized) and the listening effort measure in the two hearing aid conditions. The `Buildmer`[2] function in R was used to optimize the model for each of the effort ratings.

- Full Model before optimization:

```
SNR ~ Condition*(Fitting_type + Gender + Age + EAS + FAS + MCS +
VFS_A_40_Total_Score + RHHI + MoCA + Mean_PTA + PoorEar_QSIN_SNR +
ReadingSpan + Self_Recognition_Score_1 + Self_Management_Score_2) +(1|ID)
```

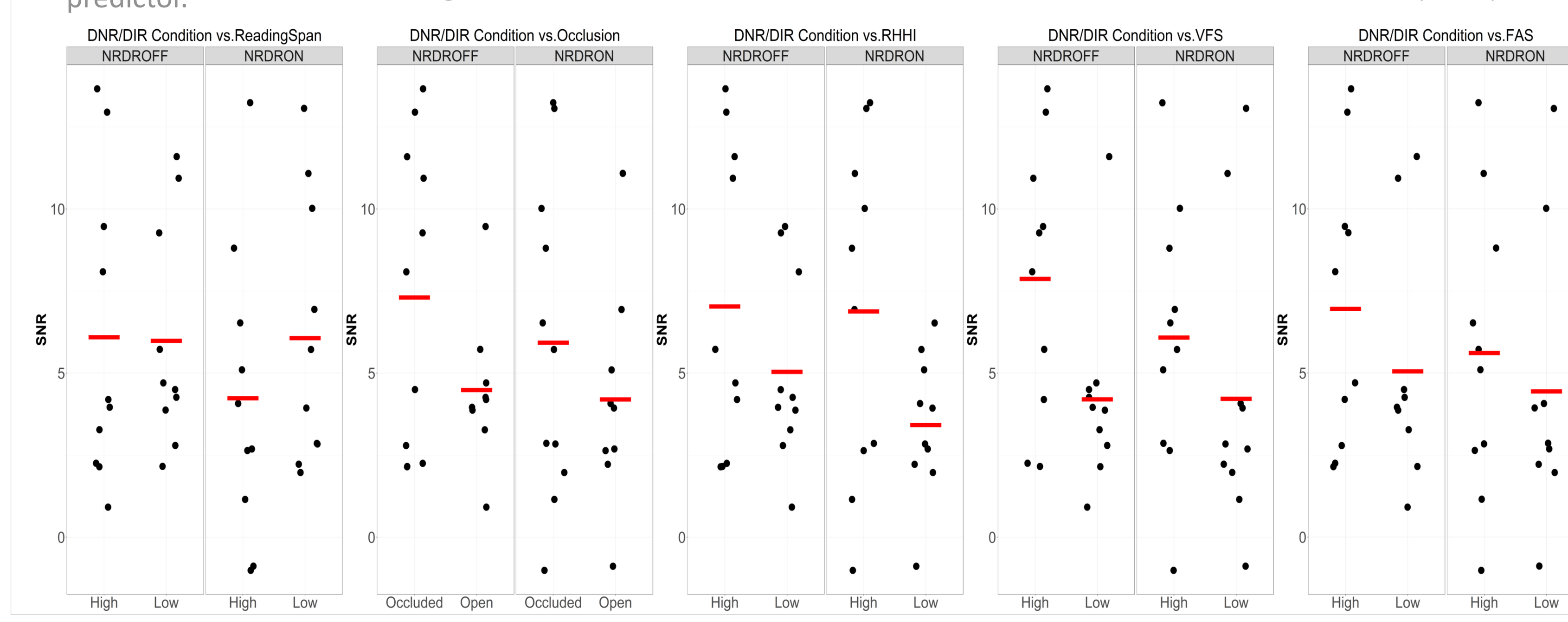
- Linear Mixed effect regression models were optimized for the “Very little effort” and the “Moderate effort” ratings; A linear regression model was optimized for the “Very much effort” rating.

RESULTS (CONT.)

M = significant main effect; I = significant interaction with DNR/DIR condition; β values are listed in parentheses; key interactions and main effects are highlighted in grey.

	Very little effort		Moderate effort		Very much effort
DNR/DIR condition			M (-0.98)		M (-1.08)
COGNITIVE					
Self management	M (1.94)		M (2.46)		M (0.94)
Self recognition			M (-1.48)		
RSPAN	M (2.62)	I (-1.44)	M (1.57)	I (-0.85)	
MCS					M (0.92)
HEARING					
Occlusion	M (4.18)	I (-2.60)	M (4.01)	I (-1.83)	M (occl. -2.82)
RHHI		I (1.51)			
MeanPTA					M (2.87)
QSINSNR					M (0.54)
EFFORT/FATIGUE					
VFS	M (2.53)	I (-1.35)			M (-1.86)
EAS			M (1.62)		M (1.48)
FAS		I (0.94)		I (0.78)	
DEMOGRAPHICS					
Gender				I (1.60)	M (male, -2.91)
Age					M (-0.20)

The plots below are for “**Very little effort**” to demonstrate the patterns (red bars are means). Except for “Occlusion,” the participants were evenly divided into High and Low groups based on the median value of each predictor.



CONCLUSIONS

- Occluded coupling yields greater DIR/DNR benefits, consistent with the literature[3].
- When perceived listening effort is low or moderate, several variables can help predict who benefits most from access to DIR/DNR strategies, including cognition, self-reported fatigue, and acoustic coupling. Specifically, listeners with better cognition, occluded fitting, less hearing handicap, more self-reported fatigue may perceive greater DIR/DNR benefits.
- When perceived listening effort is high, using DIR/DNR strategies provides an overall benefit in reducing listening effort; however, none of the factors pertaining to the user predict benefits of using DIR/DNR strategies.
- This insight can inform study design aimed at assessing listening effort, and the development/evaluation of new hearing aid features for reducing listening effort.

REFERENCES

1. Krueger, M., Schulte, M., Brand, T., & Holube, I. (2017). Development of an adaptive scaling method for subjective listening effort. *The Journal of the Acoustical Society of America, 141*(6), 4680-4693.
2. Voeten, C. C., & Voeten, M. C. C. (2021). Package ‘buildmer’.
3. Jürgens, T., et al. (2023). Closedness Of Acoustic Coupling Is The Strongest Factor For Predicting Speech-in-noise Benefit Induced By Hearing-aid Noise Reduction. Presented at the *International Symposium on Auditory and Audiological Research (ISAAR).*