The effects of noise attenuation on listening effort and arousal

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Introduction

Previous studies have shown that sub-optimal listening conditions may affect listening effort[1] and arousal[2] for individuals with normal hearing[3]. In these studies, speech-in-noise tasks have been used and quantified via speech recognition performance, subjective ratings and pupil responses. The objective of the present study was to investigate the effect of noise attenuation on listening effort and arousal in persons with normal hearing.

Methods

Participants:

- 19 persons with self-reported normal hearing (8 female)
- Aged between 22 and 53 years (mean age = 36, SD = 10)

Study design:

- Within subject design performing pre- and post-load speech-in-noise tasks[3]
- 40 DAT sentences[4], adjusted to SRT80, with and without noise attenuation in the pre- and post-load tasks
- The load task consisted of 14 SWIR lists[5] with -1 dB SNR, half with and half without noise attenuation in random order
- 4-talker babble noise in all speech-in-noise tasks

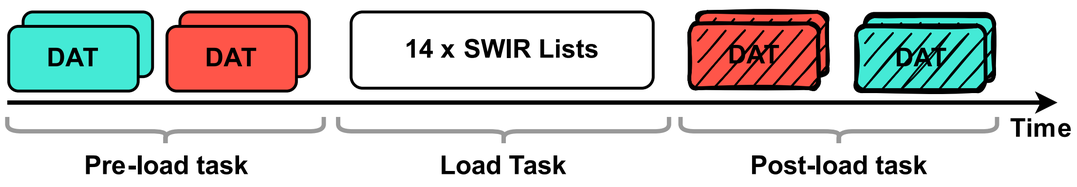

Figure 1: *Diagram of the study design and procedure.*

Metrics:

- Pupil dilation, where peak pupil dilation (PPD) and baseline pupil dilation (BPD) were measured to assess listening effort and arousal, respectively
- Speech recognition performance
- Subjective ratings reported after pre- and post-load tasks for each noise condition:
    1. Invested effort
    2. Perceived performance
    3. Tendency to quit

Results

Speech recognition:

	Pre-load	Post-load
w/o Noise Attenuation	76.2% [±2.1]	75.1% [±3.1]
Noise Attenuation	99.2% [±0.3]	99.4% [±0.3]

Table 1: *Speech recognition score with standard error for each combination of noise conditions and pre/post-load task combinations. Friedman ANOVA revealed a significant difference between the combinations ($p<0.05$). Post-hoc analysis revealed significant differences between combinations that differed in noise condition ($p<0.001$).*

Pupil dilation:

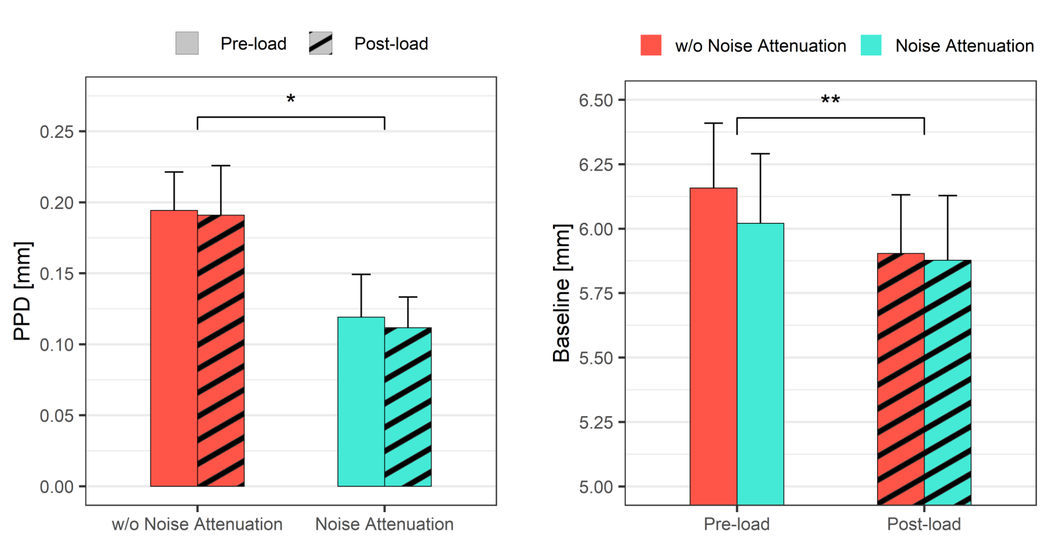

Figure 2: *Pupillometric results, PPD (left) and baseline (right), for each noise condition and pre/post-load task combinations. Error bars show standard errors. ANOVA of PPD revealed significant main effect of noise condition ($p<0.05$), while ANOVA of baseline revealed significant main effect of pre- and post-load task ($p<0.01$).*

Applying the same analysis using mean pupil dilation (MPD) showed the same behavior as in PPD, with a significant main effect of noise attenuation ($p<0.05$).

Subjective ratings:

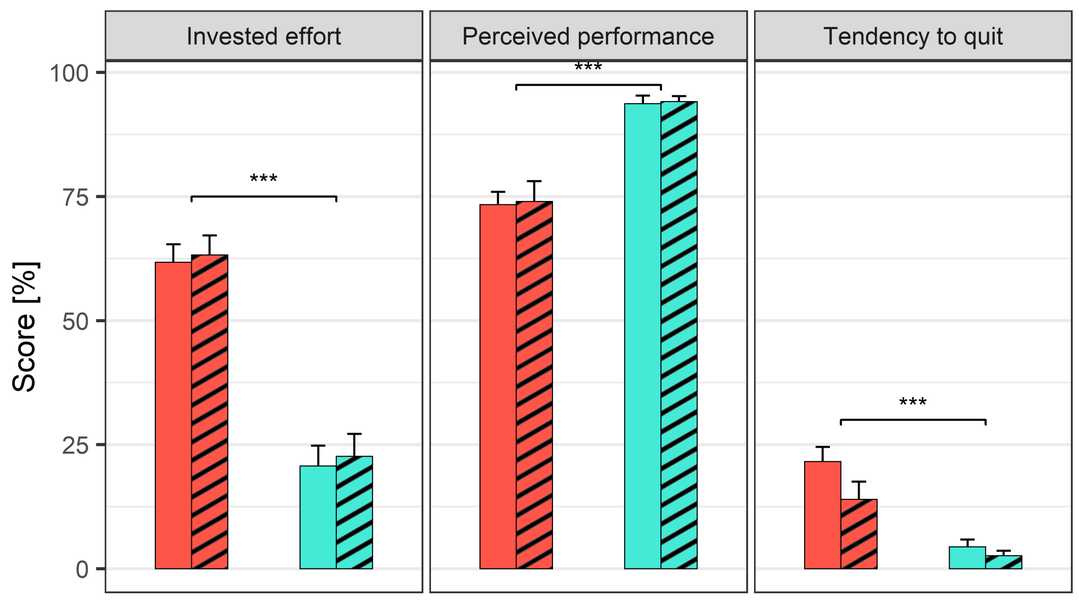

Figure 3: *Subjective ratings for each noise condition and pre/post-load task combinations. Error bars show standard errors. ANOVA of 'Invested effort' revealed significant main effect of noise condition ($p<0.001$). Friedman ANOVA of the combinations in 'Perceived performance' and 'Tendency to quit' showed significant difference ($p<0.05$). Post-hoc analysis revealed significant differences between combinations that differed in noise condition ($p<0.001$).*

Discussion and conclusions

Noise attenuation significantly reduces listening effort.

- Evident from subjective rating of invested effort, the objective measure from PPD, and their agreement.

Baseline significantly decreases from pre- to post-load task.

- Likely not related to fatigue, as speech recognition does not decrease from pre- and post-load tasks.
- Possibly due to heightened anticipatory arousal in the pre-load task, which then may decrease by re-evaluation of task demand or increasing task familiarity.

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This study was funded by EPOS

References:

1 Wendt D, Dau T and Hjortkjær J (2016) Impact of Background Noise and Sentence Complexity on Processing Demands during Sentence Comprehension. Front. Psychol. 7:345.

2 Wang, Y., Naylor, G., Kramer, S. E., Zekveld, A. A., Wendt, D., Ohlenforst, B., & Lunner, T. (2018). Relations between self-reported daily-life fatigue, hearing status, and pupil dilation during a speech perception in noise task. Ear and Hearing, 39(3), 573.

3 Menase, D. A., Richter, M., Wendt, D., Fiedler, L., & Naylor, G. (2022). Task-Induced Mental Fatigue and Motivation Influence Listening Effort as Measured by the Pupil Dilation in a Speech-in-Noise Task. medRxiv.

4 Bo Nielsen, J., Dau, T., & Neher, T. (2014). A Danish open-set speech corpus for competing-speech studies. The Journal of the Acoustical Society of America, 135(1), 407-420.

5 Ng, E. H. N., Rudner, M., Lunner, T., Pedersen, M. S., & Rönnberg, J. (2013). Effects of noise and working memory capacity on memory processing of speech for hearing-aid users. International Journal of Audiology, 52(7), 433-441.