Dynamics of pupil response during the Sentence-final Word Identification and Recall test

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IHCON 2022

Introduction

There is a growing interest in learning how listening effort and memory effort are invested during speech understanding. One way to investigate the effort investment is to compare the pupil responses during a speech recognition task that requires recall.

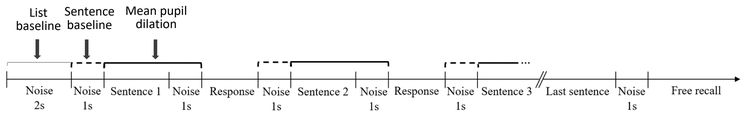
Previous studies suggested that baseline pupil dilation increases when speech recall is required in the task (Bönitz et al., 2021), as well as better overall recall performance suggesting higher memory effort due to speech encoding (see poster *More is more: Physiological markers of successful effort* by Micula et al. presented in this conference). Increase in task-evoked (peak and mean) pupil responses is believed to be associated with increased listening effort.

Noise attenuation technology in hearing solutions can enhance recall performance by freeing up cognitive resources for speech recall (Ng et al., 2013, 2015). However, some recent investigations done among people with normal hearing and hearing loss using the combination of pupillometry and a speech recall task reported mixed results in terms of changes in baseline and task-evoked pupil responses.

Aim: To better understand the effect of noise attenuating technology on the dynamics of pupil responses during a speech recall task, we examined the effect of a preprocessed noise attenuation technology on recall performance and pupil responses.

Methods

- Nineteen adults (8 female) with self-reported normal hearing aged between 22 and 53 years (mean age 36 years, SD 10) were included in the analyses.
- Sentence-final Word Identification and Recall test (SWIR) was administered (Ng et al., 2013) Tasks: 1) identify and verbally repeat the final word after listening to each sentence, and 2) recall all final words when a list finishes.
- Test conditions: with and without noise attenuation. All sentence-in-noise stimuli were preprocessed.
- For each condition, 7 lists of 7 sentences were presented in the a 4-talker babble noise. Sentence stimuli and noise were fixed at 69 and 70 dB SPL respectively.
- Pupil responses:
  - Sentence baseline: State of arousal (including memory effort)
  - Mean Pupil Dilation: Listening effort



Results

1) SWIR performance

- Word identification performance with noise attenuation (mean 99.7%, SD 1.0%) was significantly better than without (mean 96.2%, SD 5.8%) ($p < 0.01$).
- Figure 1 shows the recall performance as a function of word position. When the average recall performance was calculated based on the total number of to-be-recalled words in a list (i.e. 7 words), the performance was significantly better with noise attenuation (mean 73.2%, SD 13.4%) than without (mean 68.8%, SD 12.1%) ($p < 0.05$).
- However, when the average performance was calculated based on the total number of word identified (i.e. word identification performance), the difference in performance between conditions became insignificant ($p = 0.14$).

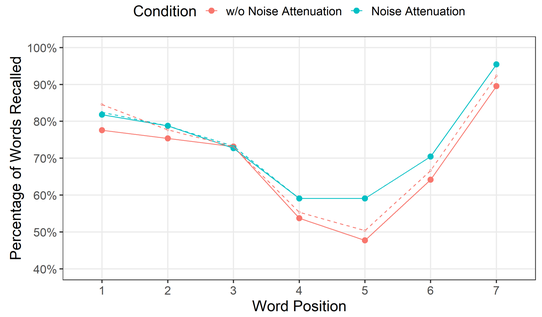


Figure 1. Average recall performance as a function of word position in a 7-sentence list. Solid lines represent recall performance calculated based on 7 final words. Dotted lines represent recall performance calculated based on the word identification performance.

2) Pupil responses

- Figure 2 shows the aggregated pupil traces obtained across all participants.

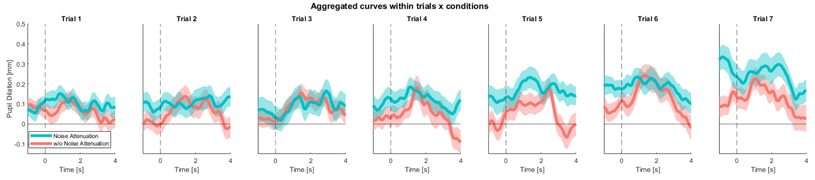


Figure 2. Pupil traces aggregated within trial (sentence) x conditions across participants. The aggregated pupil traces are relative to the list baseline. The shaded area indicates standard error.

- For each trial (sentence), we extracted two features: sentence baseline and mean pupil dilation. We applied linear fits to the data points across a list (7 points) for each feature. The slopes fits of sentence baseline and mean pupil dilation were then obtained for each participant (Bönitz et al., 2021).
  - Baseline slope indicates the modulation of memory effort throughout the list
  - Mean pupil dilation slope indicates the dynamic change in listening effort
- Noise attenuation siginificantly increased the slope fits of baseline (Figure 3) and reduced the slope fits of mean pupil dilation (Figure 4).

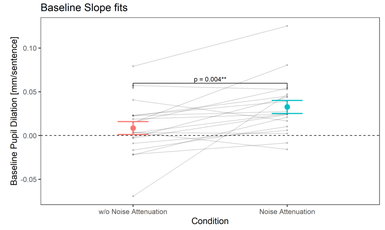


Figure 3. Increased slope fits of baseline dilation with noise attenuation than without.

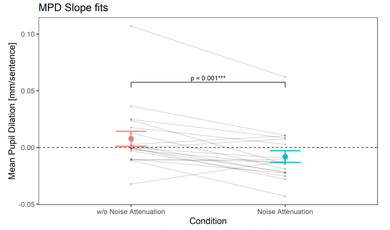


Figure 4. Decreased slope fits of mean pupil dilation with noise attenuation than without.

Discussions

- Speech recall performance was better in the condition when noise attenuation was applied. At the same time, there was a stronger increase in baseline pupil dilation over the course of a SWIR list, indicating higher memory effort.
- A stronger decrease in the mean pupil dilation with noise attenuation, suggests less listening effort throughout a list.
- These findings suggest that reduced listening effort liberates cognitive resources that can be used for speech processing and encoding of speech information into long-term memory (cf. Micula et al.). This can lead to better recall performance.
- The dynamics of the pupil responses also support the notion that working memory is a limited capacity.

References

Bönitz et al. (2021). Ear Hear, 42(4), 846-859.
Ng et al. (2013). Int J Audiol, 52(7), 433-41.
Ng et al. (2015). Ear Hear, 36(1), 82-91.

Acknowledgement

This study is funded by EPOS A/S.

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