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Investigating the effect of competing talkers on speech processing load as shown by task evoked pupil dilation

Dorothea Wendt1, Thomas Koelewijn2, Adriana A. Zekveld2,3, and Thomas Lunner1,3
1 Section Ear & Hearing, Department of Otolaryngology-Head and Neck Surgery and Erasmus MC for Hearing and Care Research, VU University Medical Center, Amsterdam, The Netherlands
2 Linnaeus CENTRE HEAD, Swedish Institute for Disability Research, Linköping University, Linköping, Sweden

Introduction
In everyday communication situations, we have to listen and attend to one (target) speaker in the presence of one or more (competing) speakers. Segregating speech from competing speech required higher cognitive processing demands. Koelewijn and colleagues reported that the type of masker affects processing load especially when the masker contains semantic-linguistic information [1].

Objective of this study was to investigate the effect of competing speech information on cognitive effort during speech perception indicated by task evoked pupil dilation. In contrast to these previous studies [1,2], the effect of masker type on processing load was investigated using Danish sentences.

Methods
- Participants: 19 participants (average age 33 years) with normal hearing, normal or corrected to normal vision (self-reported)
- Stimuli: Danish HINT Sentences
- Task: Listen to the sentence and repeat back the sentence after the noise offset. While listening and remembering to the sentence, fixate the grey dot on the screen.
- Noise conditions: Speech reception thresholds (SRT) were tested at 84% speech intelligibility (SRT84) and at 50% intelligibility (SRT50) with three different noise masker types, i.e. in fluctuating noise masker [3], a single (female) speaker masker, a 4 (two male, two female) talker babble masker.
- Pupil recording: An View X RED System was used with a sampling rate of 60 Hz to monitor participants’ eye fixations.

Data cleaning and analysis
Data analysis of the pupil data was performed similar to [1]:
- First five trials were removed from analysis and averaged pupil dilation was recorded
- Trials with more than 15% of eye blinks were excluded
- For the remaining trials, eye blinks were removed by a linear interpolation method
- High-frequency artifacts were removed with a five-point moving average smoothing filter
- Baseline correction by subtracting a baseline value, i.e. mean pupil size within the 1 s before the onset of the sentence
- Averaged maximum pupil dilation and mean pupil dilation were calculated for each masker type and each intelligibility level

Effect of competing talker
ANOVA on the SRTs revealed:
- Effect of intelligibility level and masker type
- Interaction effect between intelligibility level and masker type

Post hoc (two-tailed t-tests) revealed:
- Higher SRT for 4-talker babble compared to fluctuating noise and to competing speaker condition (p < 0.001).
- Higher SRT for the fluctuating noise compared to the competing speaker condition (p < 0.001).

An ANOVA on pupil dilation revealed:
- Effect of intelligibility level (p < 0.016) indicated a higher peak pupil dilation at 50% intelligibility level compared to 84% intelligibility level [Figure 3]
- Effect for masker type (p < 0.017) at 84% intelligibility level [Figure 4]

Discussion and Conclusion
- Lowest SRTs for speech presented in a competing speaker condition, slightly higher SRTs in a fluctuating noise. Speech recognition performance was poorest in a 4-talker babble
  - Speech recognition data are in line with previous work [1]
- Largest pupil response for the competing speaker condition at SRT84
- Pupil data are in line with [1], i.e. possible to replicate findings in Danish language
- Larger pupil response for the 4-talker masker at SRT50
  - Ignoring the babble-masker becomes more effortful when the babble is more audible
- Effect of lexical-semantic information depended on the speech intelligibility level
  - Activation of cognitive processes to ignore irrelevant speech information
  - Speech recognition performance (indicated by SRTs) and cognitive effort (indicated by task evoked pupil dilation) are independent

References

Figure 1: Mean SRTs averaged across all participants. SRT was measured for 3 different interfering noise maskers, i.e., Fluctuating noise; competing speaker; and 4-talker babble. Speech recognition was measured at 50% intelligibility level (SRT50) and at 84% intelligibility level (SRT84).

Figure 2: Pupil dilation as a function of time for all conditions, i.e. in fluctuating noise (○); in competing speaker (△); in a 4-talker babble (△). Masker onset started 3 s before sentence onset. Time until participants response varied depending on the length of the sentence (7.5 s on average).

Figure 3: Peak pupil dilation at SRT50 and SRT84 for three different masker types averaged across all participants. Error bars show standard deviation. Fluctuating noise; △= competing speaker; ba=4- talker babble. * indicates significant differences in pupil response between intelligibility levels.

Figure 4: Mean pupil dilation [A, C] and maximum pupil dilation [B, D] averaged across all participants. Pupil response was measured at SRT84 [A,B] and at SRT50 [C,D]. Fluctuating noise; ◇= competing speaker; ba=4-talker babble. * indicates significant differences in pupil response. Note that the data of the maximum pupil dilation [D] are also shown in Figure 3.