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

In a pupillometry experiment, the effect of competing semantic-linguistic information was investigated on cognitive load required for successful speech recognition of Danish HINT sentences. Speech recognition in the presence of a competing talker required higher cognitive load compared to a 4-talker babble or fluctuating noise at high speech intelligibility levels. At lower intelligibility levels, cognitive load is highest for speech perception in a multi-talker babble.



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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, and 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.
- **Pupil recording:** An iView X RED System was used with a sampling rate of 60 Hz to monitor participants' eye fixations.

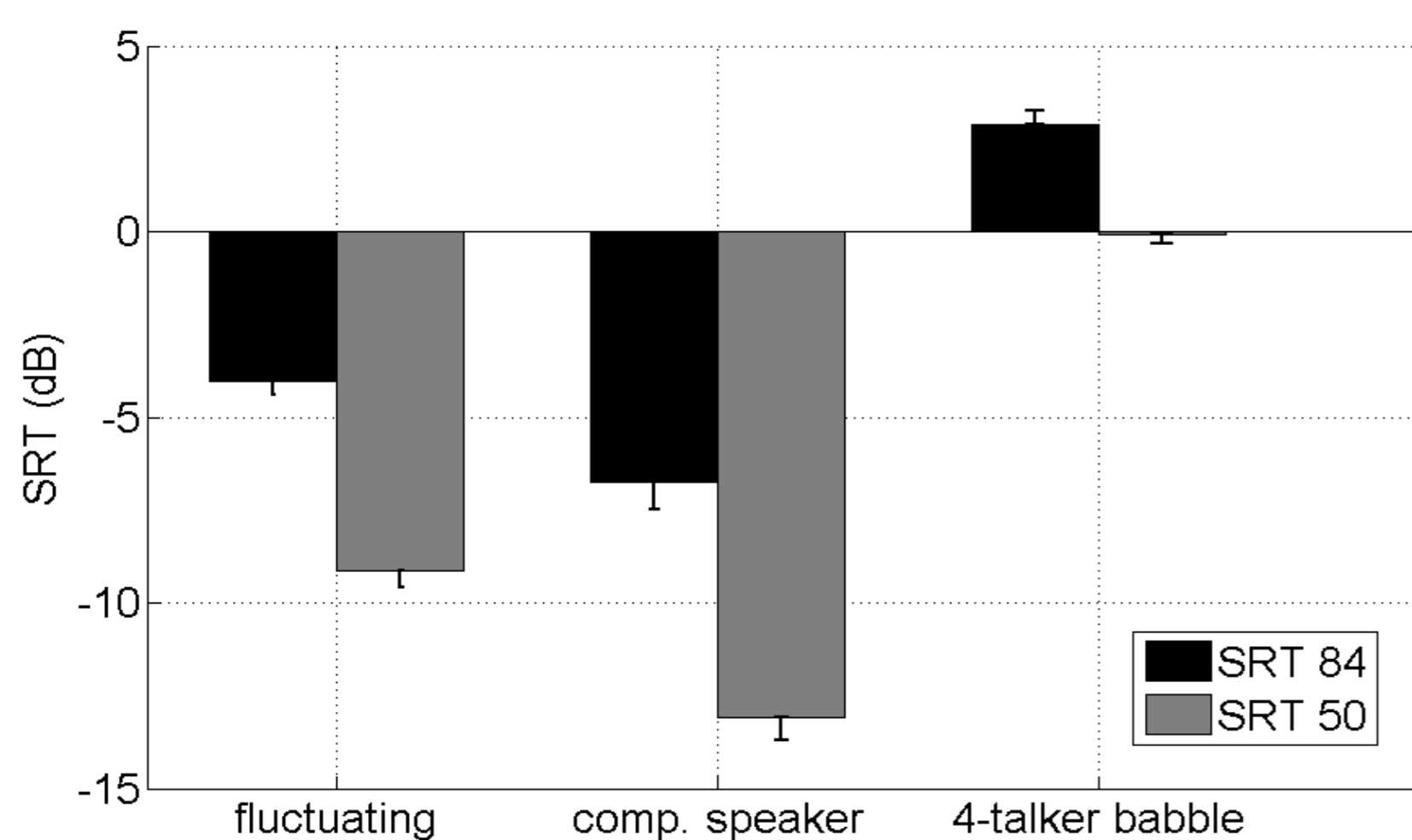


Figure 1: Mean SRTs averaged across all participants. SRT was measured for 3 different interfering noise maskers, i.e. fluctuating noise, competing speaker, and 4-talker babble. Speech recognition was measured at 50% intelligibility level (SRT50) and at 84% intelligibility level (SRT84).

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**
- 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

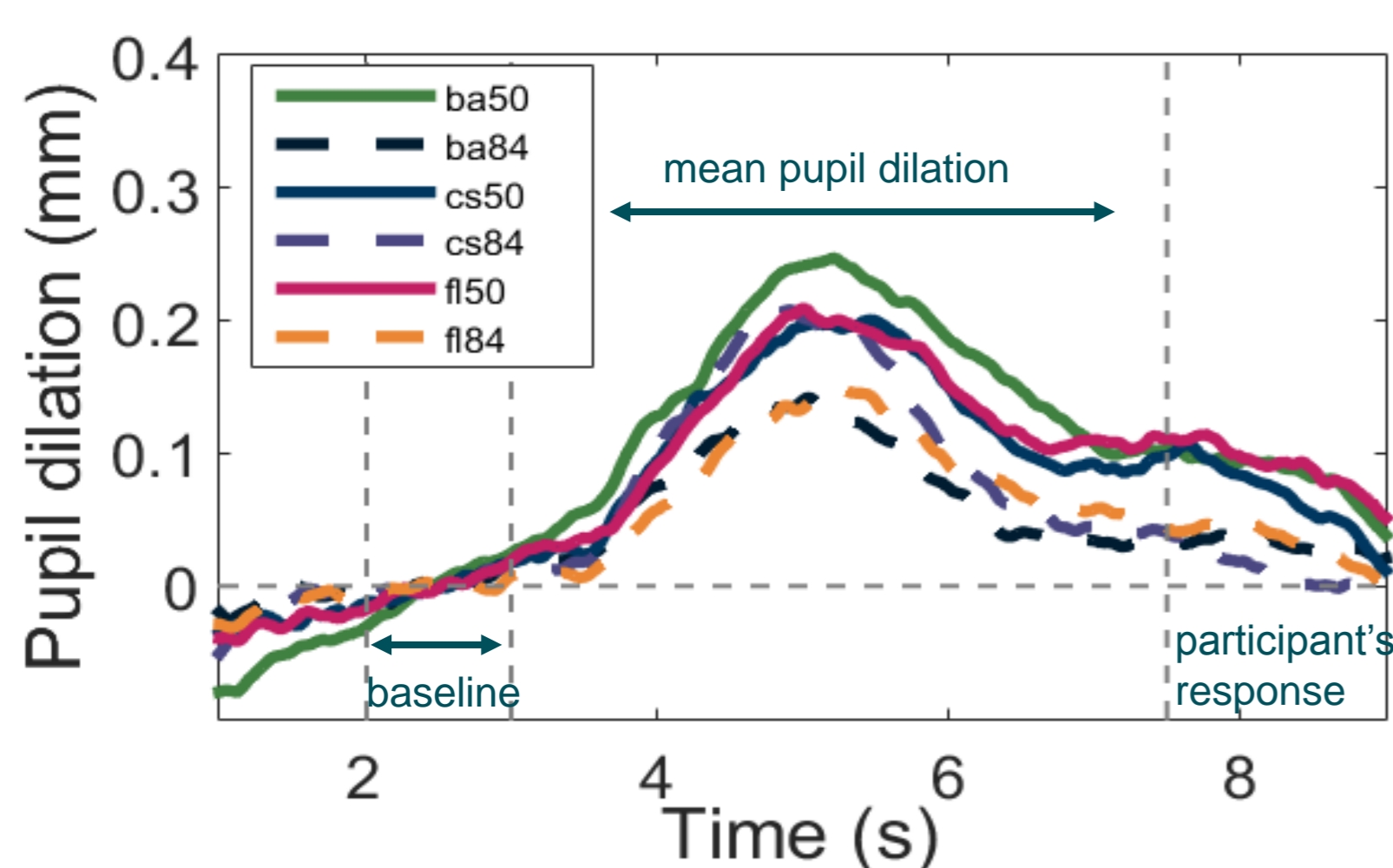


Figure 2: Pupil dilation as a function of time for all conditions, i.e. in fluctuating noise (fl); in competing speaker (cs); in a 4-talker babble (ba). Masker onset started 3 s before sentence onset. Time until participants response varied depending on the length of the sentence (7.5 s on average).

Result

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:

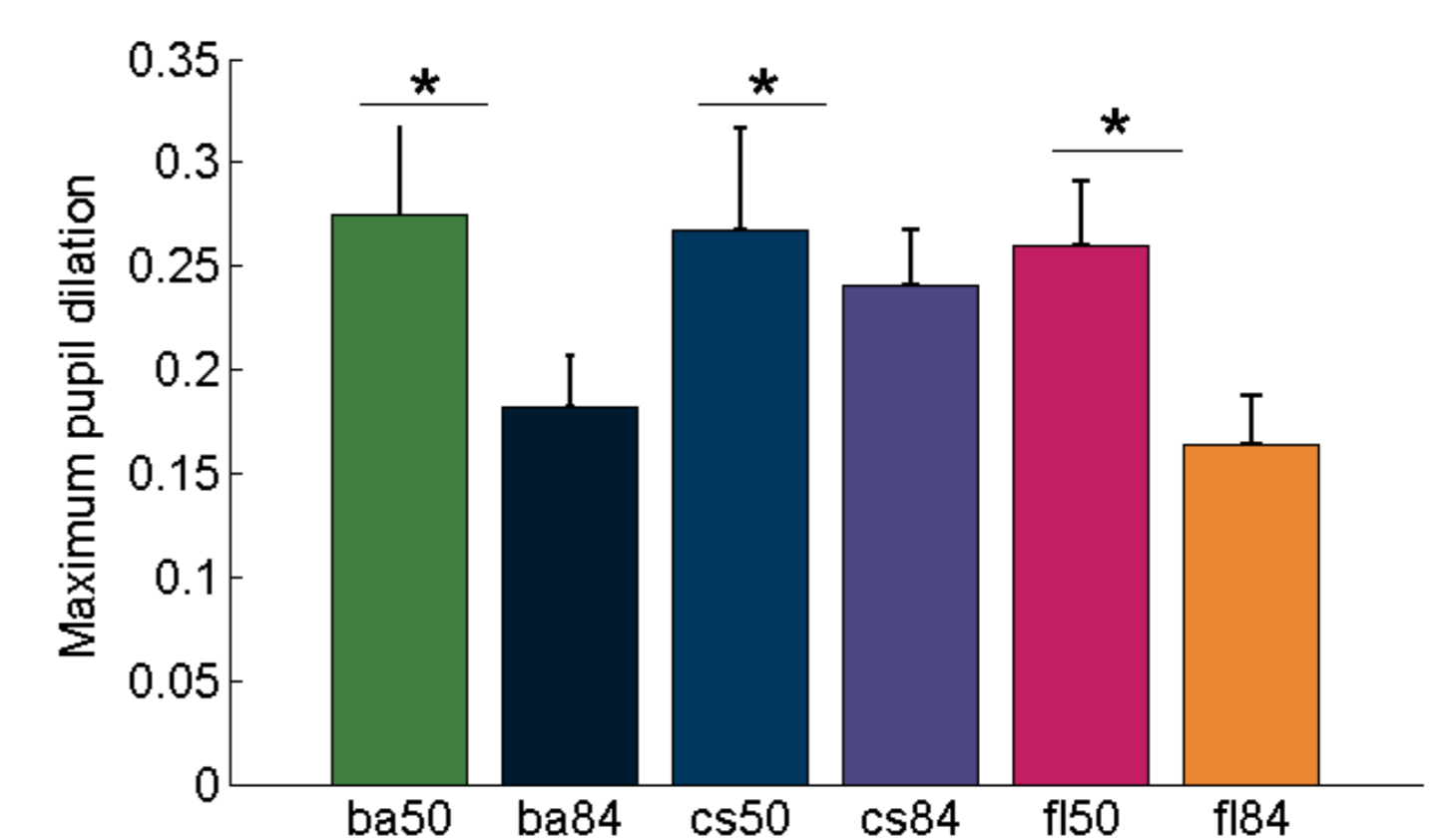
- Higher SRT for 4-talker babble compared to fluctuating noise and to competing speaker condition ($p < 0.001$).
- Higher SRT for the fluctuating noise compared to the competing speaker condition ($p < 0.001$).

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]

Effect of speech intelligibility level

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



Effect of competing talker

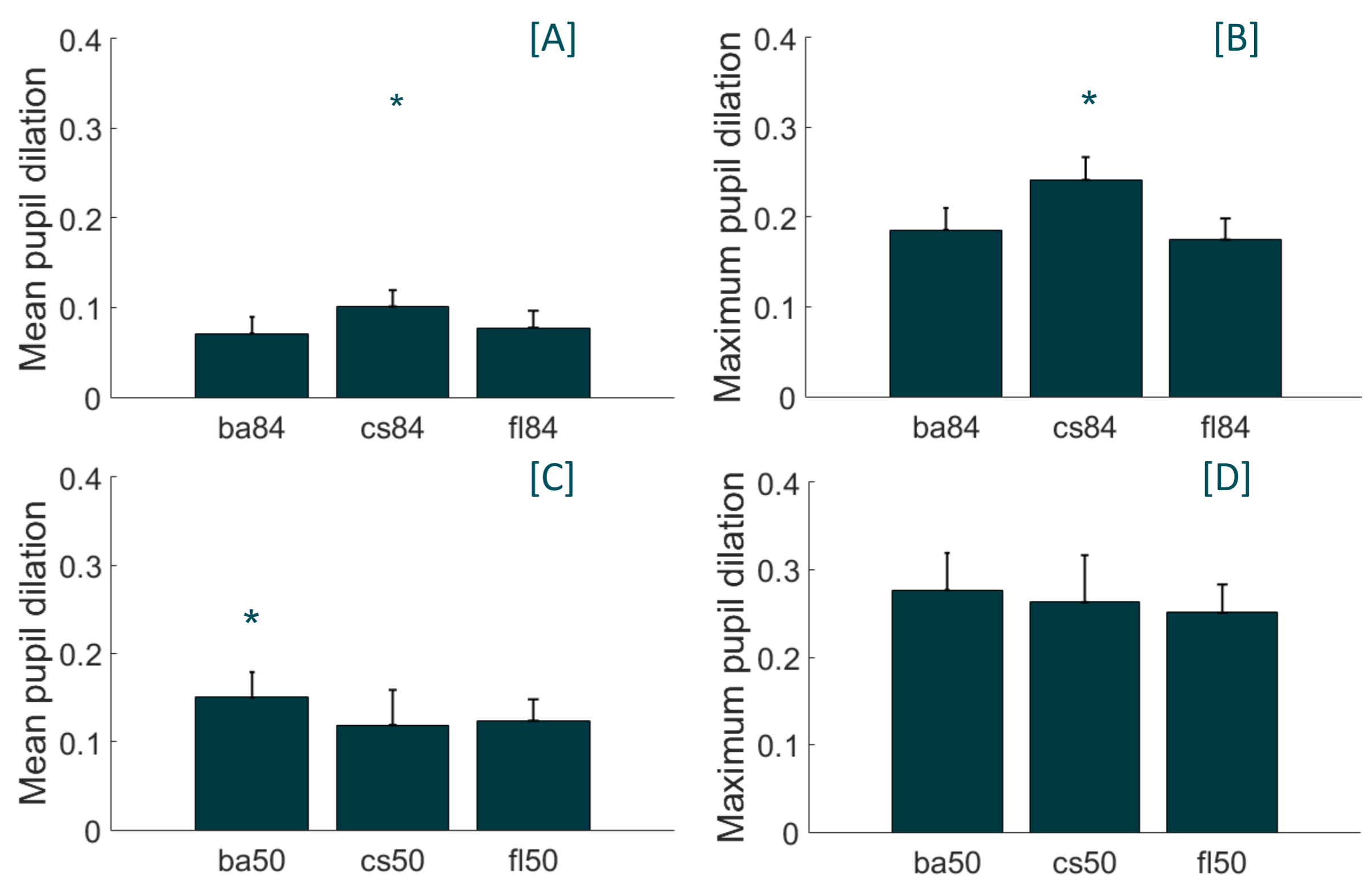


Figure 4: Mean pupil dilation [A, C] and maximum pupil dilation [B, D] averaged across all participants. Pupil response was measured at SRT84 [A,B] and at SRT50 [C,D]. Fl= fluctuating noise; cs= competing speaker; ba= 4-talker babble. * indicates significant differences in pupil response. Note that the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

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:

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