

INTRODUCTION

- Listening conditions can be noisy
- Spatial separation of target speech from noise improves intelligibility¹

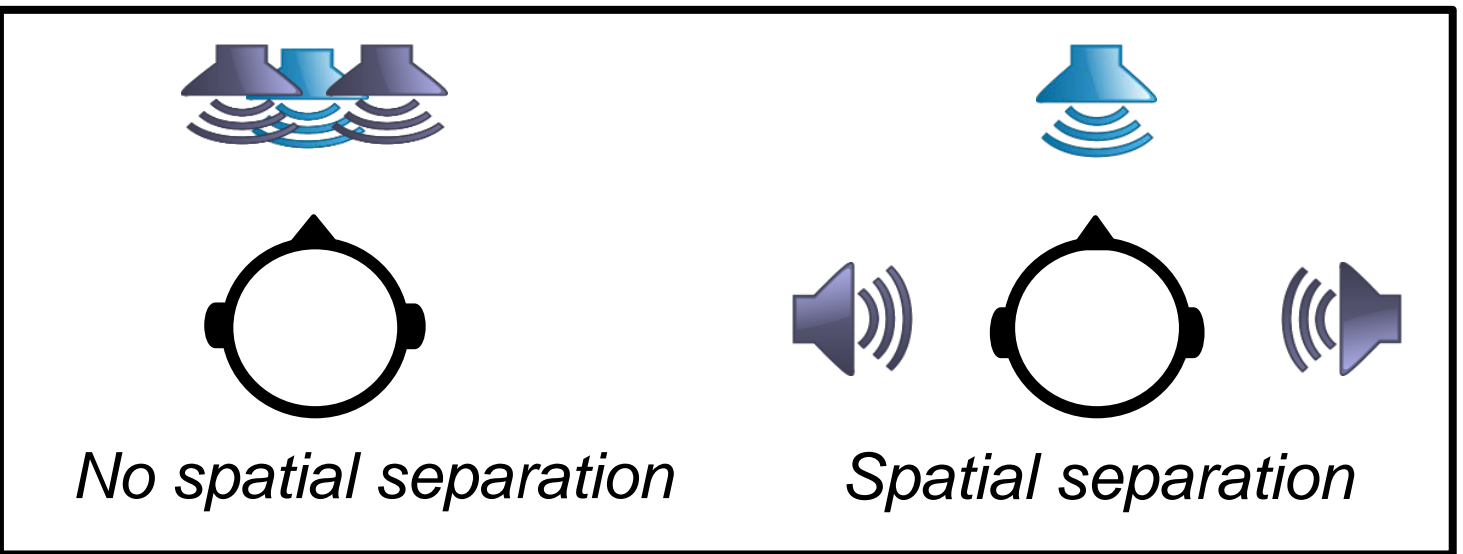


Fig 1. Examples of spatial configurations of target speech (blue) and noise (gray) that can impact speech intelligibility.

- When the target is louder than the noise, the higher signal-to-noise ratio (SNR) can result in improved speech intelligibility
- Purpose of the study: To determine the combined effect of spatial separation and SNR between target & competitor on listening effort and intelligibility

Binaural hearing is the process of integrating sound that the brain receives from the two ears. Binaural hearing provides the ability to localize sound sources and helps improve hearing performance noisy environments.

Listening effort is the allocation of mental resources to overcome obstacles when carrying out a listening task.²

The amount of listening effort required for listening based tasks can be measured with a variety of techniques including dual task performance, reaction time measurement, and subject rating scales.³ One non-invasive, objective measurement technique of listening effort is **pupillometry**: the measurement of task-evoked pupil response (TEPR) over time. **Increased pupil dilation** has been found with increasing cognitive task demands.⁴

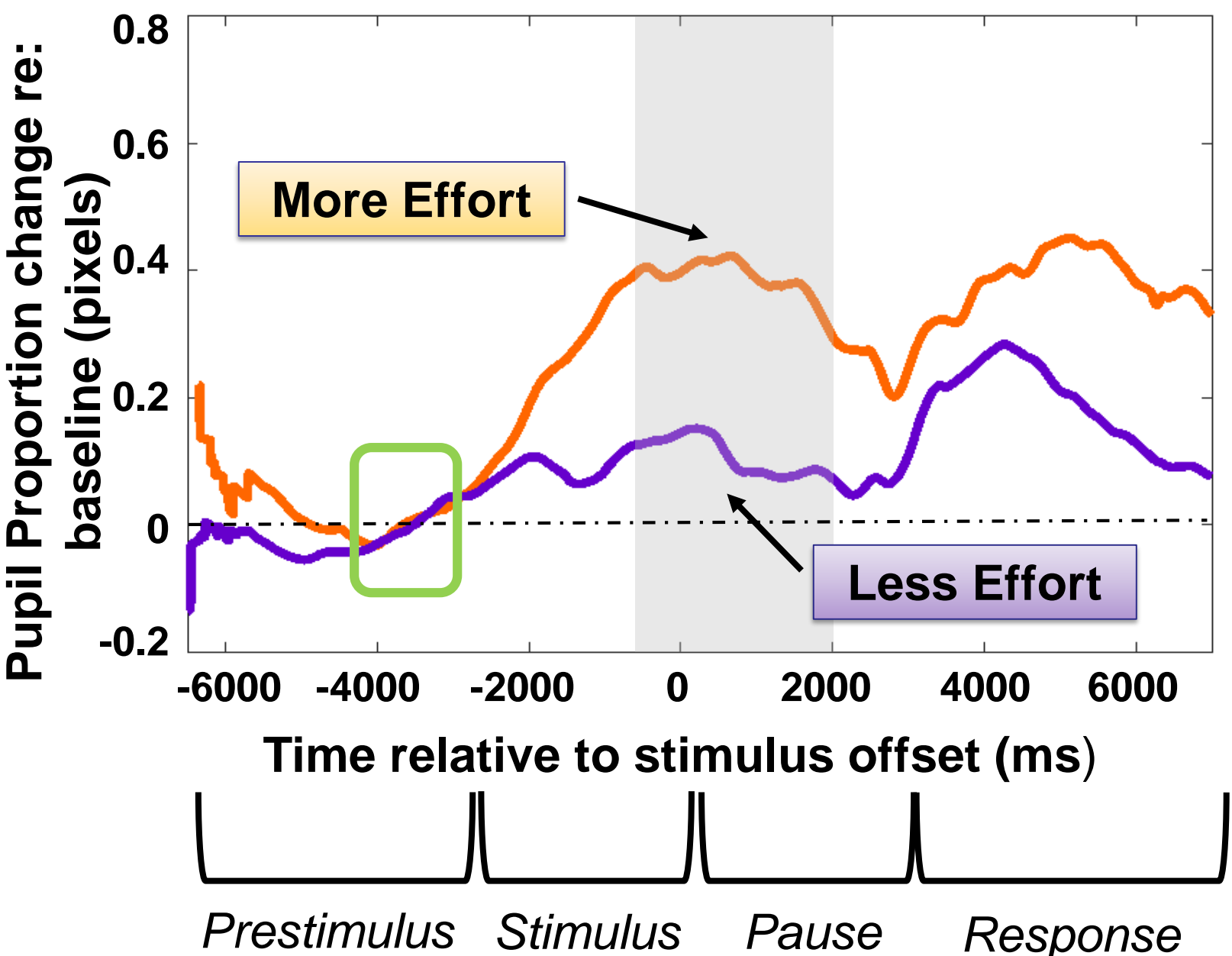


Fig. 2. Example of pupil tracks from two listening conditions. The orange track is from a difficult condition and the purple track is from an easy condition. The green box denotes the prestimulus baseline region. Peak pupil dilation was measured within the shaded region.

Study Goals

- Determine the stimulus parameters for maximizing the TEPR
- Measure the impact of spatial separation and SNR between the target & competitor on speech intelligibility and listening effort

Hypothesis

Peak pupil dilation will be smaller and speech intelligibility will be greater in conditions where the target and competitor are spatially separated than when the target and competitor are co-located.

METHODS

Participants

Subjects: 12 native English speakers; 7 female & 5 male
Mean age: 22.2 ± 7 years

Stimuli

Target: Harvard IEEE male voiced sentences
Competitor: 2 male voiced AZ-Bio sentences spliced into continuous loops
Target/Competitor signal to noise ratios (SNRs): -12 to +9 in 3 dB steps

Listening Conditions

Co-located: Target and competing sentences are presented via the front speaker (Fig. 3A)
Symmetric: Target sentences are presented via front speaker and competing sentences are presented via 2 speakers at ±90° azimuth (Fig. 3B)

Co-located



Fig. 3A. Co-located configuration.



Fig. 4. Participant sitting with head placed in the chin rest.

Symmetric



Fig. 3B. Symmetric configuration.

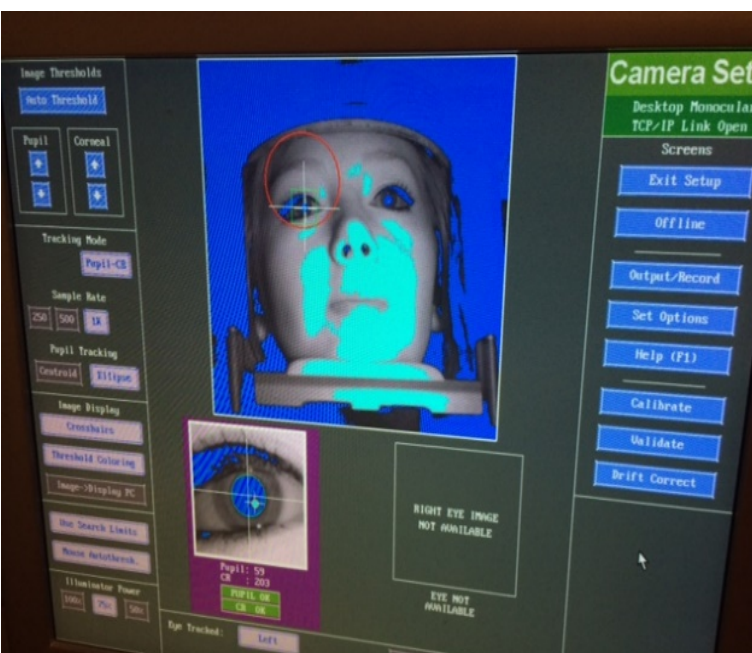


Fig. 5. Examiner's view of the participant's pupil from the EyeLink's infrared camera.

DATA ANALYSIS & RESULTS

- Individual pupil tracings were assessed for inclusion before being averaged into a waveform for each condition. Tracings were excluded based on the following criteria:
 - More than 25% of tracing consisted of eye blink artifact
 - Mean pupil size of the tracing was below the baseline pupil size
- The maximum pupil dilation value for each subject was identified from the averaged waveform between -500 msec to 2000 msec relative to the offset of the sentence
- Speech intelligibility was scored as % correct for all sentences within each SNR & listening configuration

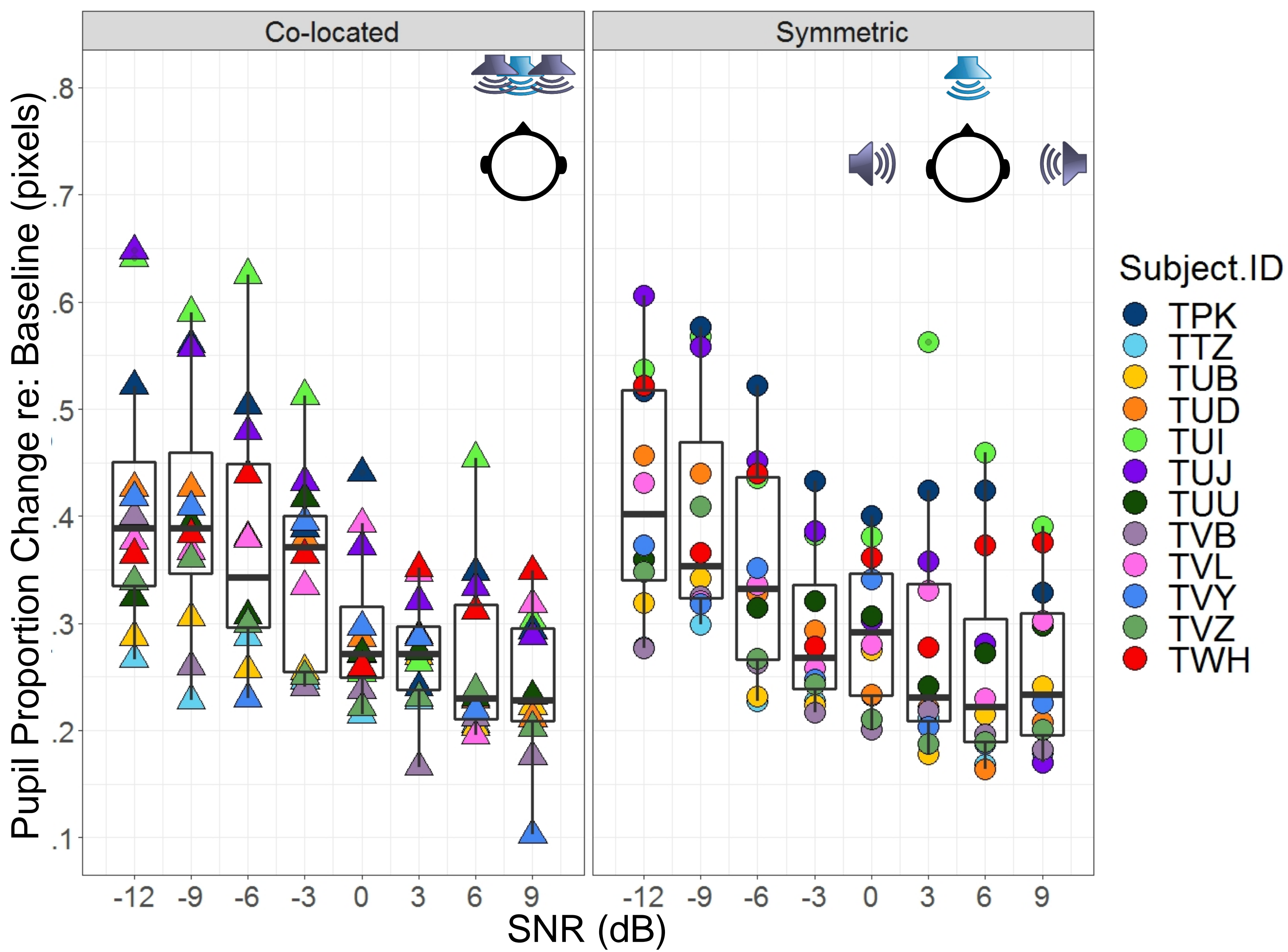


Fig. 6. Peak pupil dilation for all subjects across SNR's. The Boxplots represents the group median and quartiles. The whiskers represent 1.5 of the min and max interquartile range.

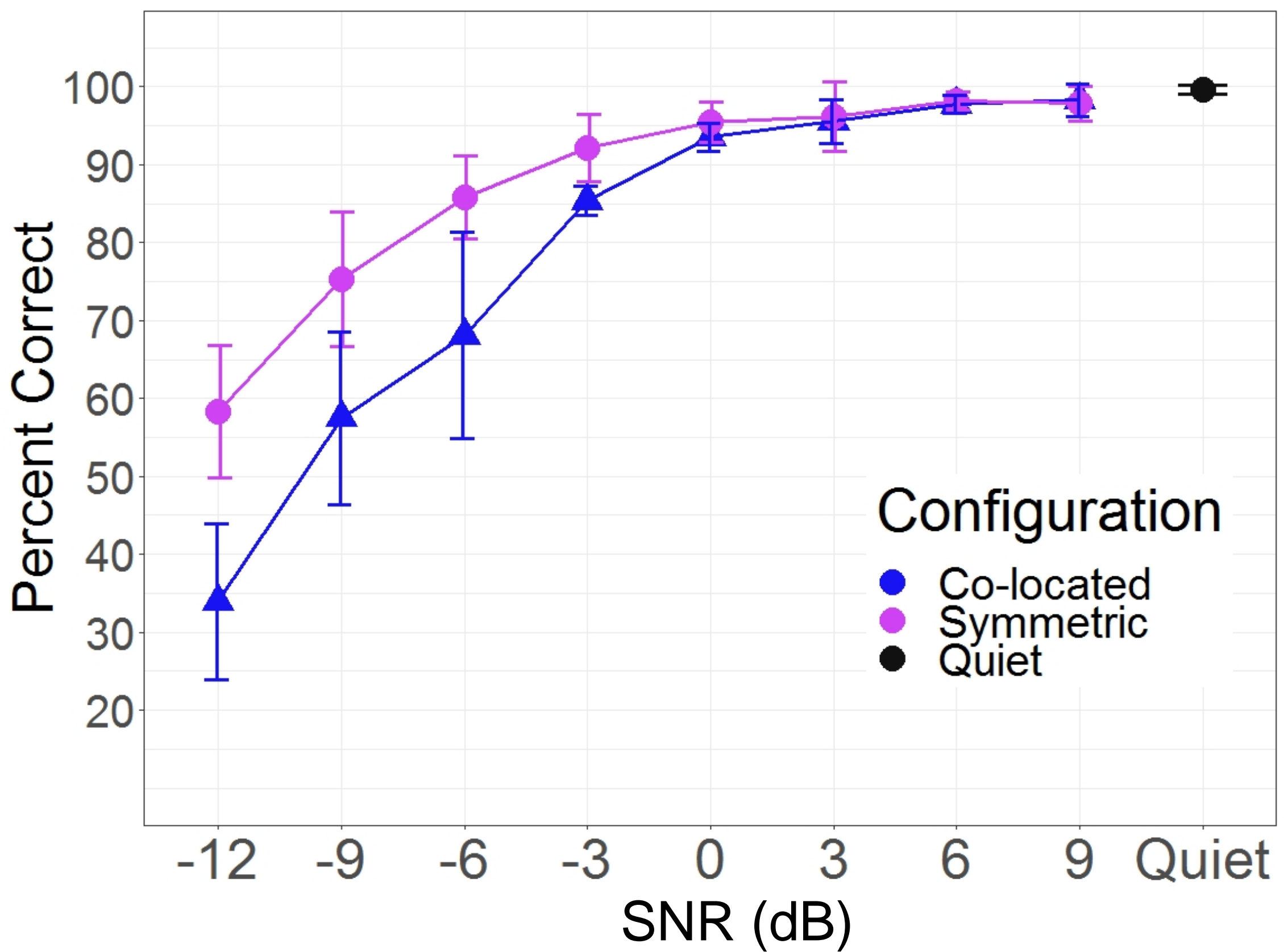


Fig. 7. Subject mean speech intelligibility scores for co-located and symmetric conditions by SNR.

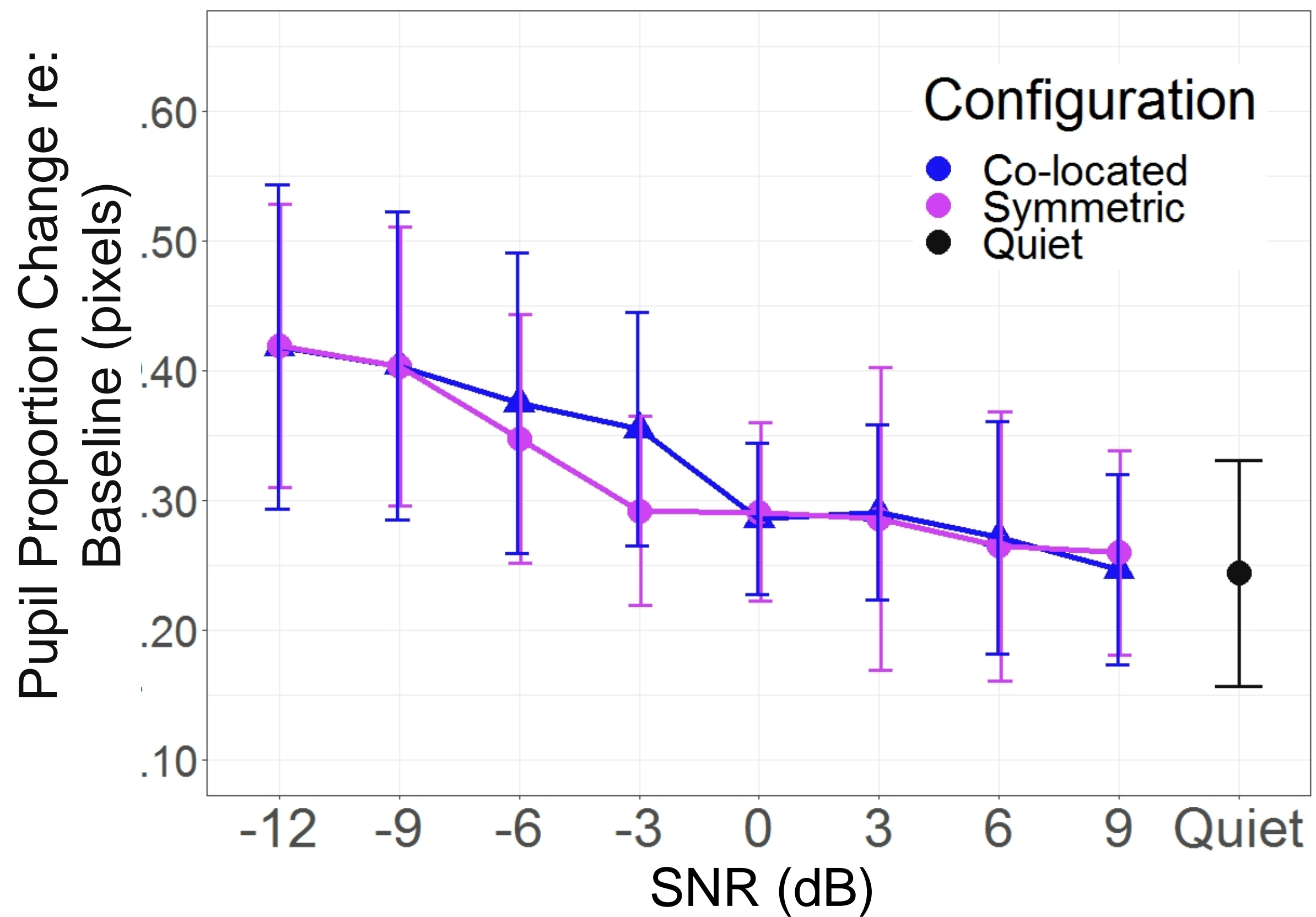


Fig. 8. Subject mean peak pupil dilation for co-located and symmetric conditions by SNR.

DISCUSSION

- The data here demonstrate that binaural hearing has the potential to reduce listening effort for some but not for all SNRs (Fig. 8)
 - A binaural advantage, indicated by a difference in peak dilation between the co-located and symmetric conditions, was observed only at harder (negative) SNRs
- The speech perception data demonstrated a binaural advantage over a similar but wider range of SNRs than did peak pupil dilation (Fig. 7)
- We also observed an inverse relationship between the TEPR and SNR between target and competitors
- These findings suggest that there is a limited range of SNRs where the spatial configuration of sound sources can impact listening effort
- Forthcoming work will determine the impact of hearing loss and the effect of its treatment(s) on the interaction between binaural hearing and listening effort measured above

REFERENCES

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3. Kuchinsky SE, Ahlstrom JB, Vaden KI, Jr et al. Pupil size varies with word listening and response selection difficulty in older adults with hearing loss. Psychophysiology 2013; 50:23-34.
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