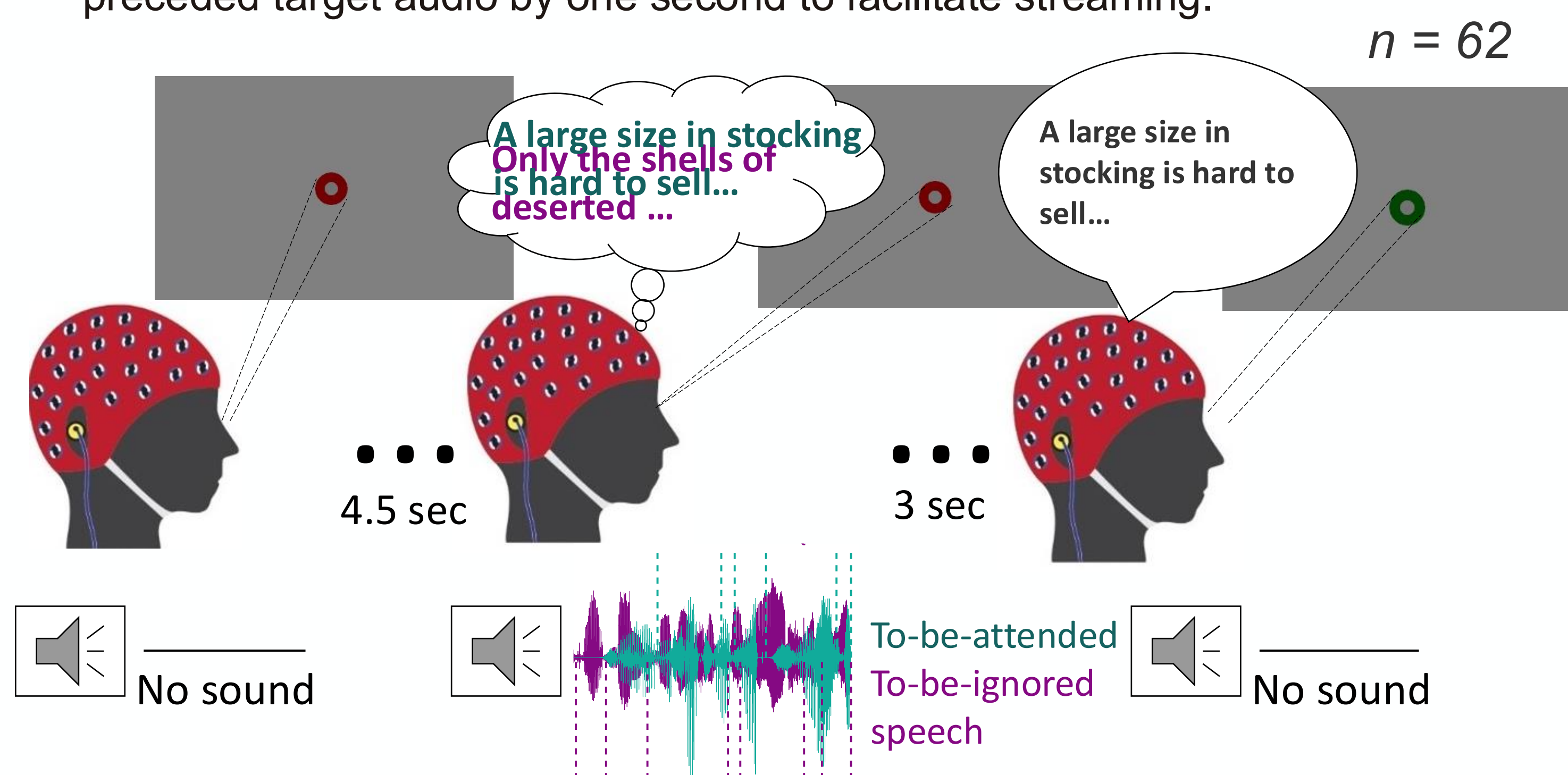


INTRODUCTION

- Pupillometry is commonly used to quantify listening effort (LE) in speech-in-noise perception tasks (Generally, more LE → Higher pupil dilation).
- However, task-evoked pupillometric responses (TEPR) fatigue (i.e., habituate) over the course of the experimental session, introducing (to most researchers) undesirable variance into the data.
- It is unclear if TEPR fatigue modulates effects of experimental manipulations** (e.g., does fatigue interact change of SNR affects TEPR). Such interactions would have important implications for the design choices in pupillometric paradigms (e.g., experiment duration).
- Here we examine this possible interaction effect in the context of a sentence recognition task with speech-on-speech masking and an SNR manipulation of LE.

METHOD

- Paradigm:** Diotic speech-in-speech recognition at four SNR levels (5, 0, -5, and -10 dB SNR) with 50 trials/condition, performed over 10 blocks of 20 trials. SNR varied pseudo-randomly each block such that each SNR was presented an equal number of times.
- Stimuli:** IEEE target sentences with simultaneous audiobook distractor.
- Distractor level was fixed at 65 dB SPL, and in each trial its onset preceded target audio by one second to facilitate streaming.



Behavioral Measures: Speech intelligibility and self-reported LE

Pupillometry Data: Tobii Pro Spectrum with binocular tracking at 300 Hz

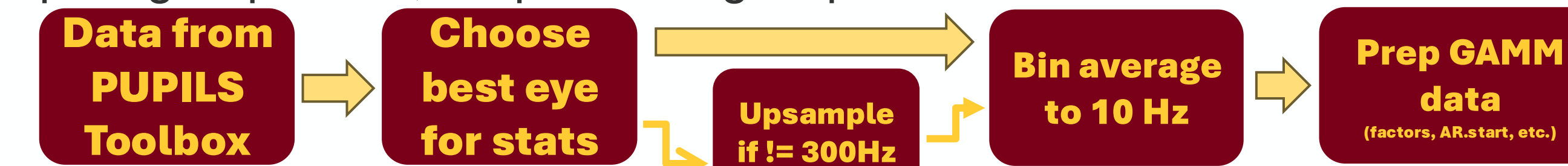
Preprocessing: PUPIL Toolbox (Relaño-Iborra & Bækgaard, 2020) used to preprocess the pupil dilation and correct for eye blink-related distortions.

Each trial was baseline corrected at -1.5 to 0 sec relative to target speaker onset.

Basic Pupil Statistics	
Pupil Mean	0.063
Pupil SD	0.198

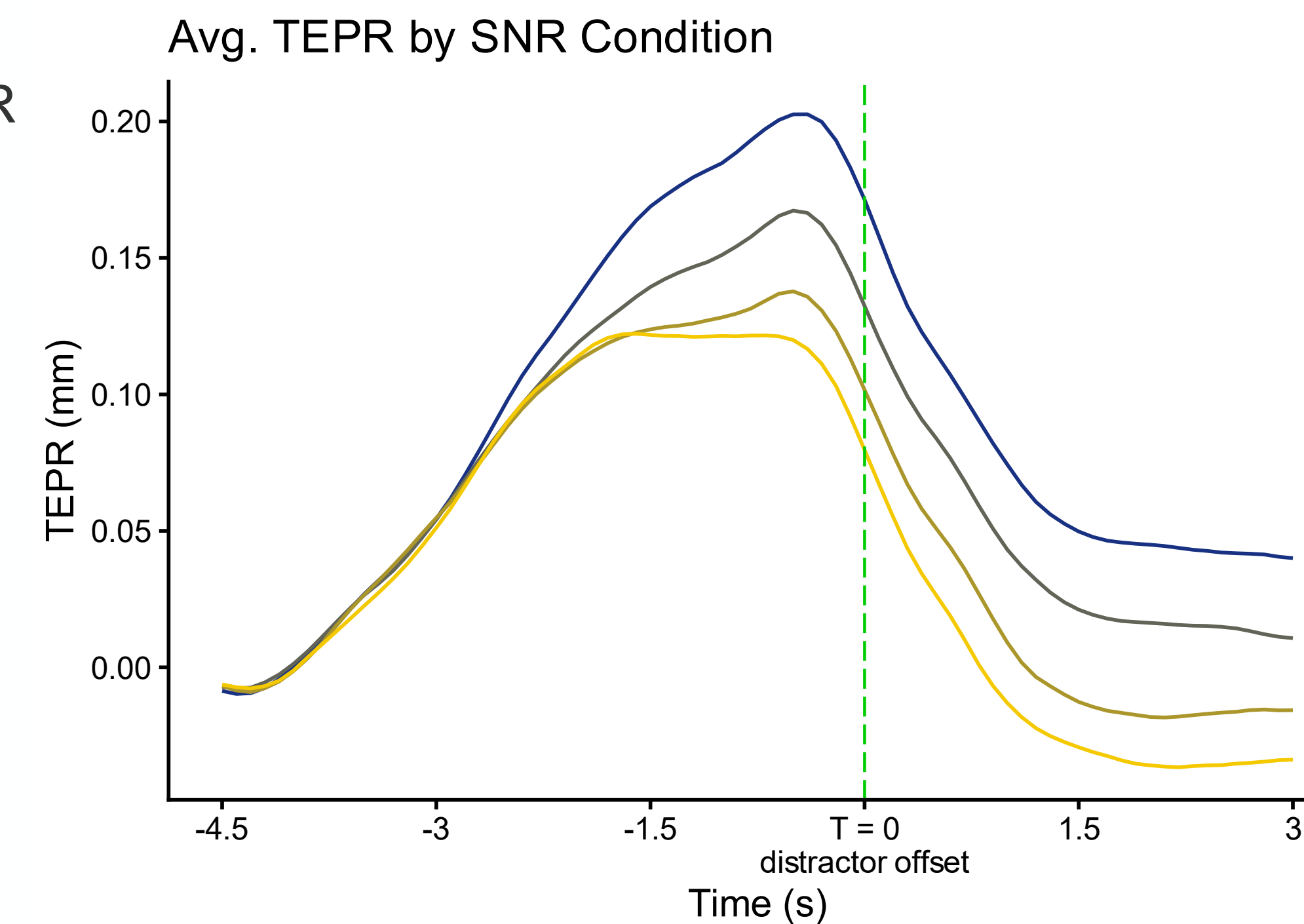
PUPIL DATA; EFFECTS OF SNR & BLOCK

Preparing Pupil Data; Preprocessing steps in R

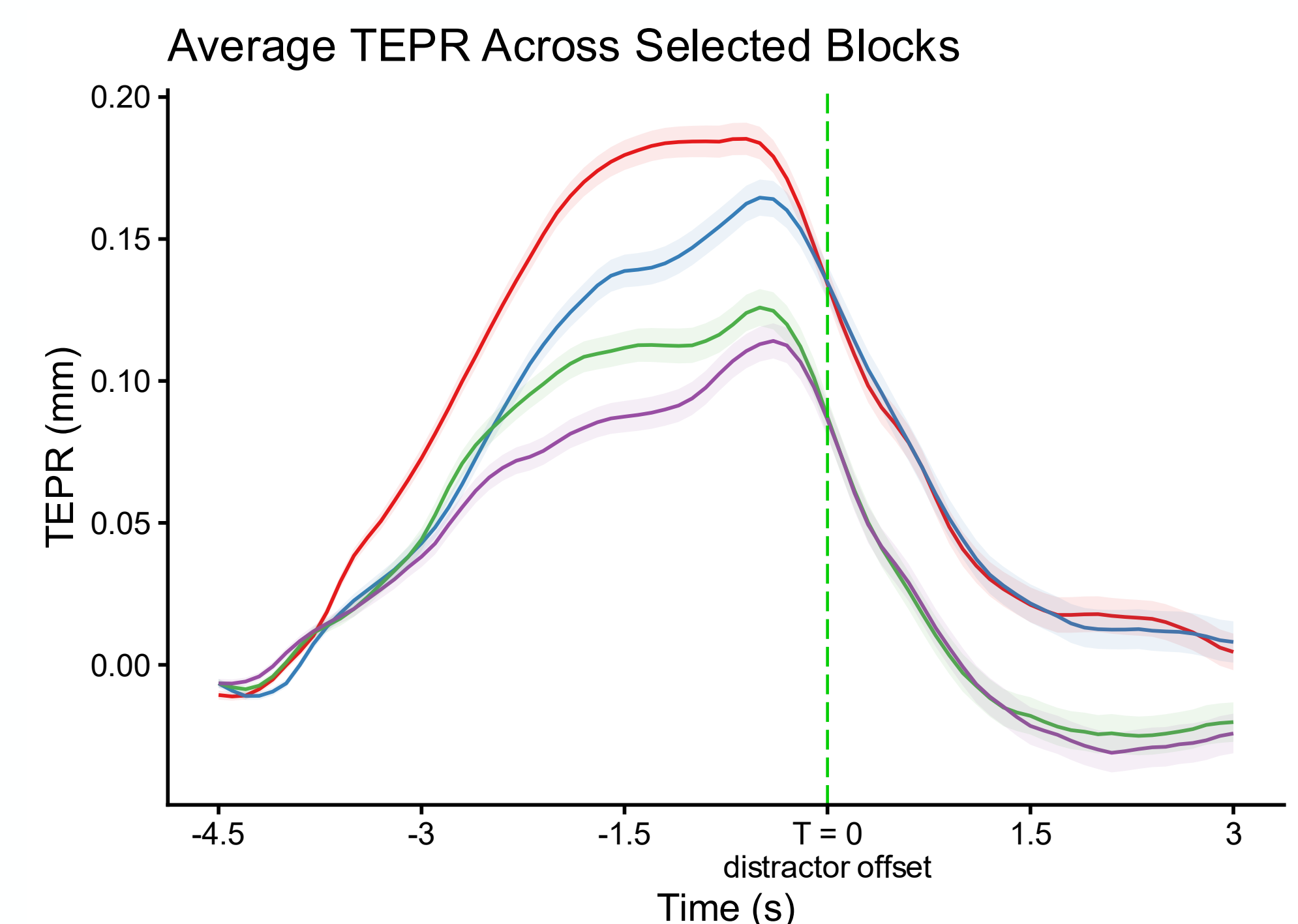


Average Pupil Response by SNR

Basic Statistics by SNR		
	Mean	SD
-10 dB SNR	0.09	0.2
-5 dB SNR	0.07	0.2
0 dB SNR	0.05	0.2
5 dB SNR	0.04	0.2



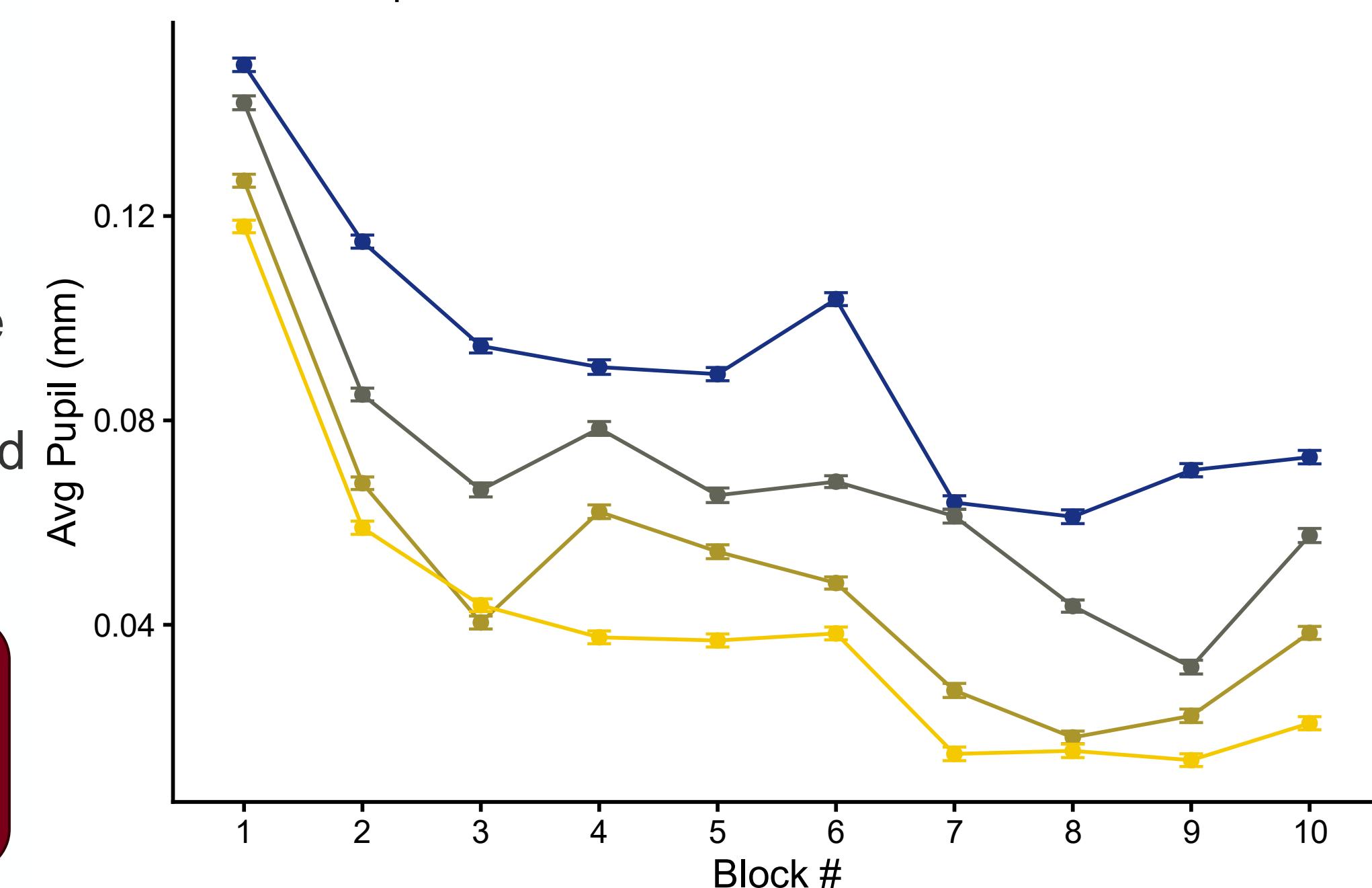
Average Pupil Response in Selected Blocks; Collapsed Across SNR



EFFECT of BLOCK

- Can observe fatigue over block in raw response
- For most, weaker average dilation over time is unwanted variance

Mean Pupil Response Across Experimental Blocks
Error bars represent ±1 Standard Error of the mean



Effect of SNR persists, but does it interact with fatigue?

GAM MODELS

- GAMMs replace the parametric assumptions for GLMs required for linear predictors with a sum of smoothing functions instead
- This method allows construction of unique smoothing functions added together to represent nonlinear data

Our models have four main parts:

PARAMETRICS

- Treat SNR as an ordered factor
- Exclude 1 level for reference treatment

SMOOTH TERMS

- Reference surfaces of time and block
- Difference surfaces of block by each SNR
- Tensor product of time and block by each SNR. Separates interaction of time and block from marginal effects

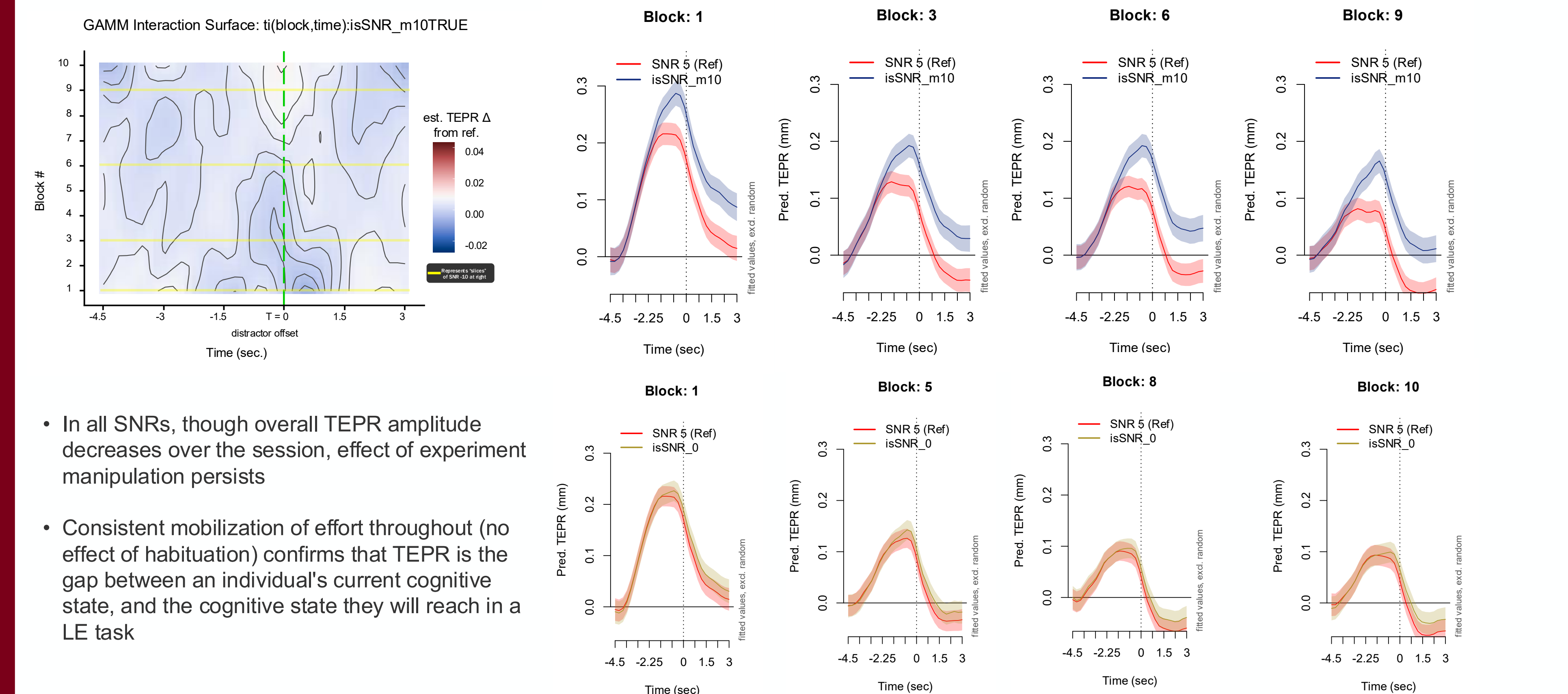
RANDOM EFFECTS

- Random Factor smooths account for high individual subject variability in pupil data; unique shifts in SNR response
- Prevents individual differences from biasing estimates of covariates on LE

AUTOCORRELATION

- Include an AR1 error model, handles the high temporal dependency of pupil data

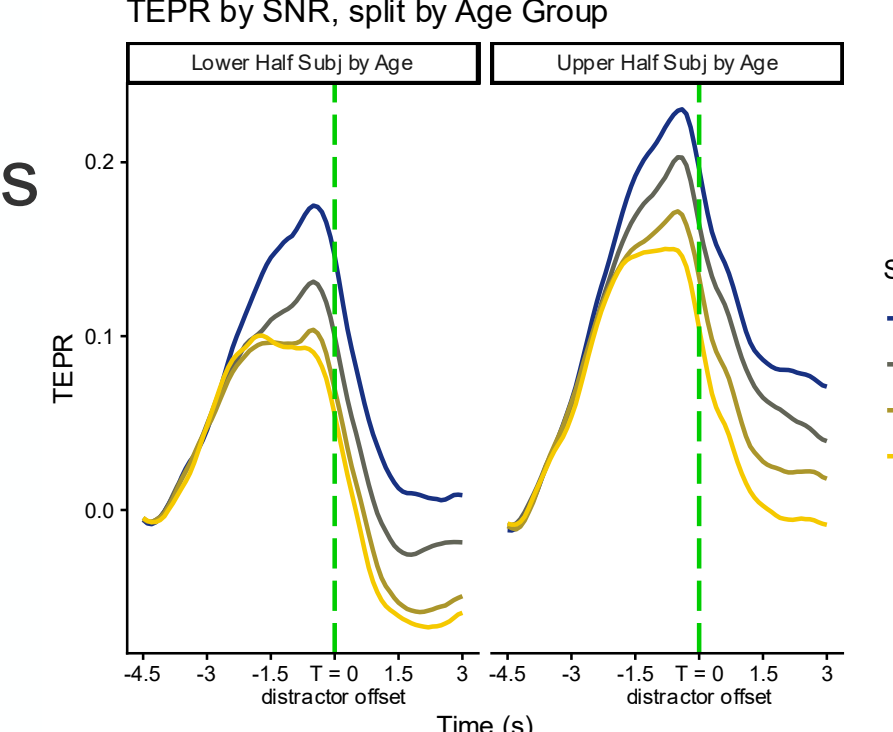
3-Way Interaction Surfaces & Summed Effects



- In all SNRs, though overall TEPR amplitude decreases over the session, effect of experiment manipulation persists
- Consistent mobilization of effort throughout (no effect of habituation) confirms that TEPR is the gap between an individual's current cognitive state, and the cognitive state they will reach in a LE task

DISCUSSION

- Impact of block and SNR on TEPR are both significant. However, they do not interact: the SNR effect remains consistent throughout the experimental session
- It remains to be seen whether TEPR is consistent and unaffected in other experimental paradigms. Work by Widmann et al. demonstrates that TEPR sensitivity may decrease over session in a continuous speech paradigm of longer narrative passages (10+ min)
- Further analyses will explore how including age as a covariate may affect findings
- GAMMs with tensor interactions (t_i) offer a powerful tool for modeling and identification of interactions between variables (e.g., SNR and block) in the context of non-linear timeseries data



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