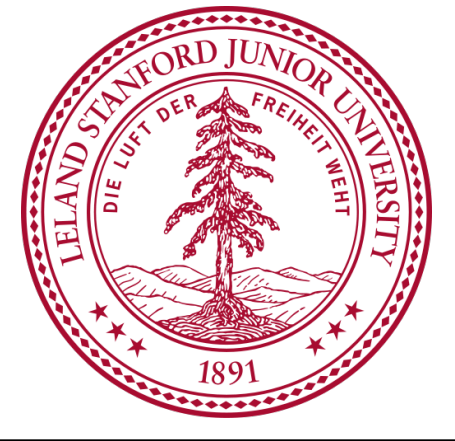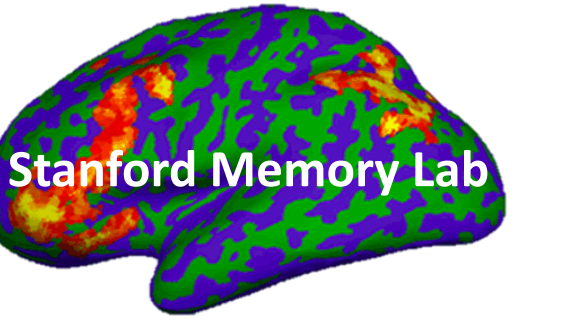# Moment-to-moment and individual differences in spontaneous lapses of attention at encoding predict subsequent memory

Kevin P. Madore[1], Anna M. Khazenzon[1], Anthony D. Norcia[1,2], & Anthony D. Wagner[1,2]

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INTRODUCTION

Attention-control-memory interactions at the trial level
- Pre-trial changes in attention have been related to behaviors in working memory, visual attention, and navigation paradigms.
- Posterior alpha power and pupil diameter can index lapses.
- Trial-level changes in goal states have also been related to behavior, and neural and ERP correlates of control and attention.

Attention-control-memory interactions at the subject level
- Trait differences in constructs related to attention and control, such as sustained attention ability from the gradCPT, may partially account for interactions with learning and memory processes.

Hypotheses

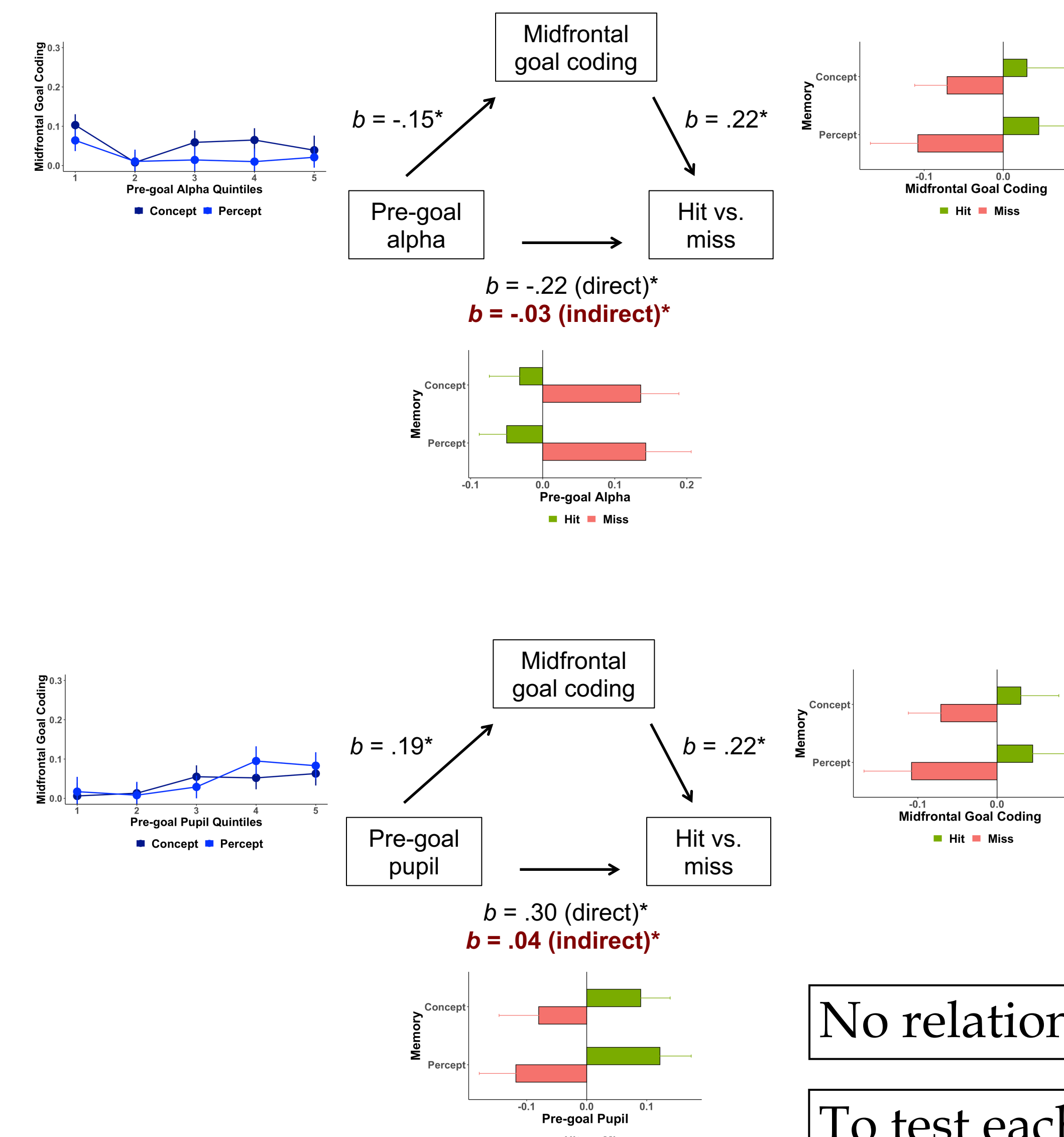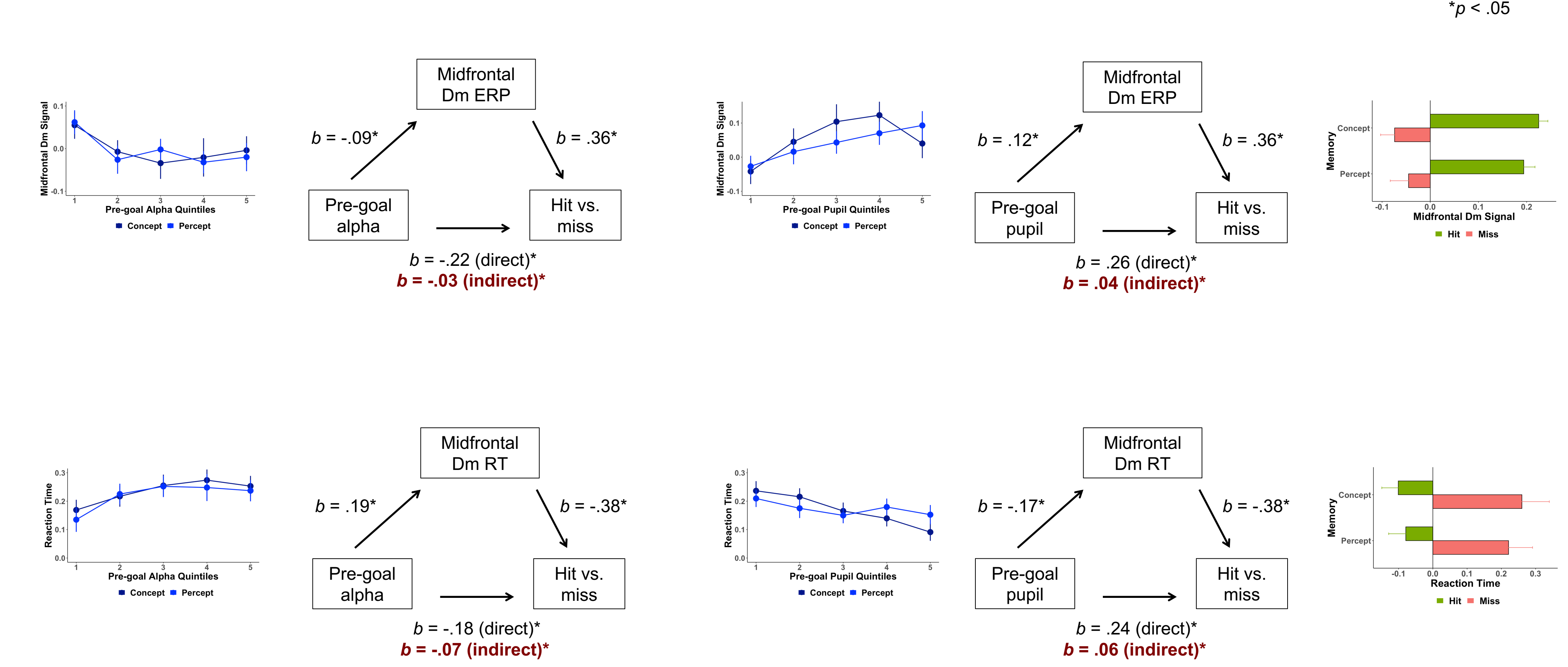INDIVIDUAL DIFFERENCES   MOMENT TO MOMENT
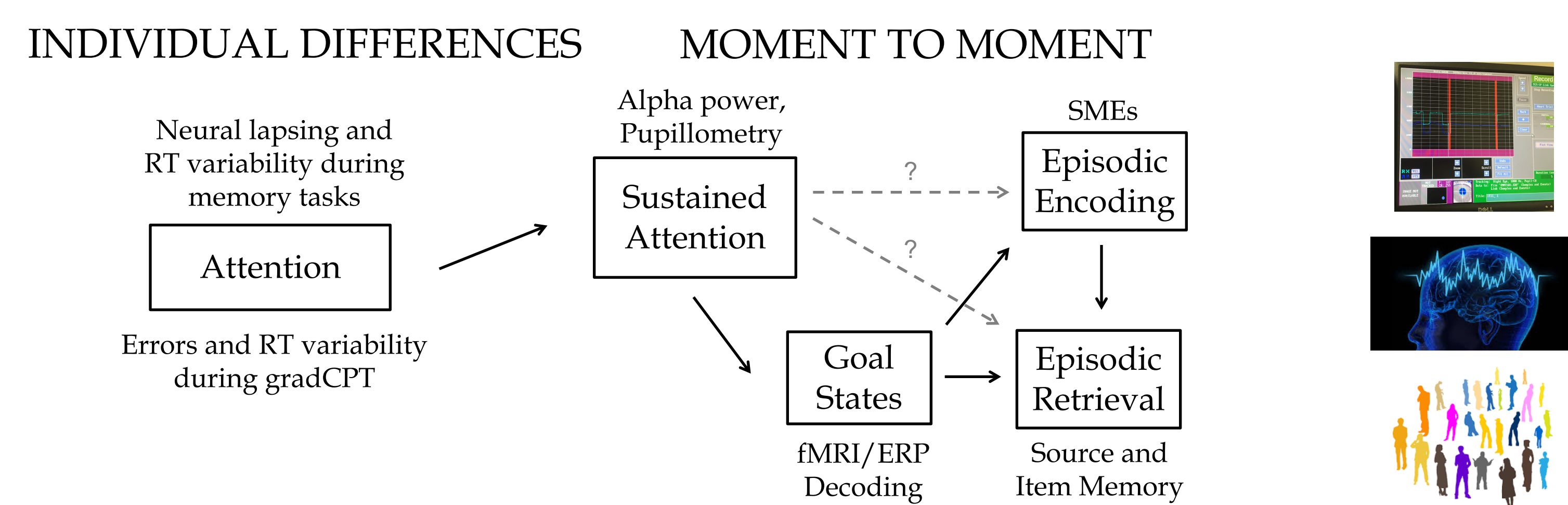
Questions
- How do pre-goal spontaneous attention lapses relate to goal-state coding, learning, and episodic remembering?
- How do subject-level differences in sustained attention ability relate to learning and memory ability?

METHOD

Participants
- 80 healthy young adults (49 female, M_{age} = 21.70 yrs, SD = 3.48)

Experimental Design

A) Encoding / Retrieval

B) L R

- Spontaneous attention lapses
- Manipulation of goal states (Pleasant/Unpleasant vs. Bigger/Smaller)

- Spontaneous attention lapses
- Manipulation of goal states (Concept Before? vs. Percept Before? vs. New Item?)

— Tonic pupil diameter (Attention lapsing)
— Tonic posterior alpha power (Attention lapsing)
— Midfrontal ERP (Goal coding) and Dm ERP (memory)
— Parietal Old/New ERP (Recollection-based memory)

Acquisition
- During memory task: EEG+pupillometry recorded via NetStation and EyeLink 1000 systems.
- SHINE toolbox used to equate luminance and chrominance.
- After memory task, individual differences battery: Questionnaires, and task-based sustained attention (gradCPT).

gradual-onset Continuous Performance Task (gradCPT)

Analyses
- Examined **tonic pre-goal alpha and pupil relationships to goal coding (midfrontal ERP), learning (Dm ERP and RT), and subsequent memory (Hit vs. Miss and Parietal Old/New ERP)**.
- Used trial-level mixed effects models, and trial-wise and trait-wise mediation models. Trial-level assays z-scored by run, and trait-level assays z-scored across subjects.

PRE-GOAL ATTENTION LAPSES PREDICT HITS VS. MISSES, PARTIALLY MEDIATED VIA THE STRENGTH OF GOAL CODING AND Dm SIGNALS
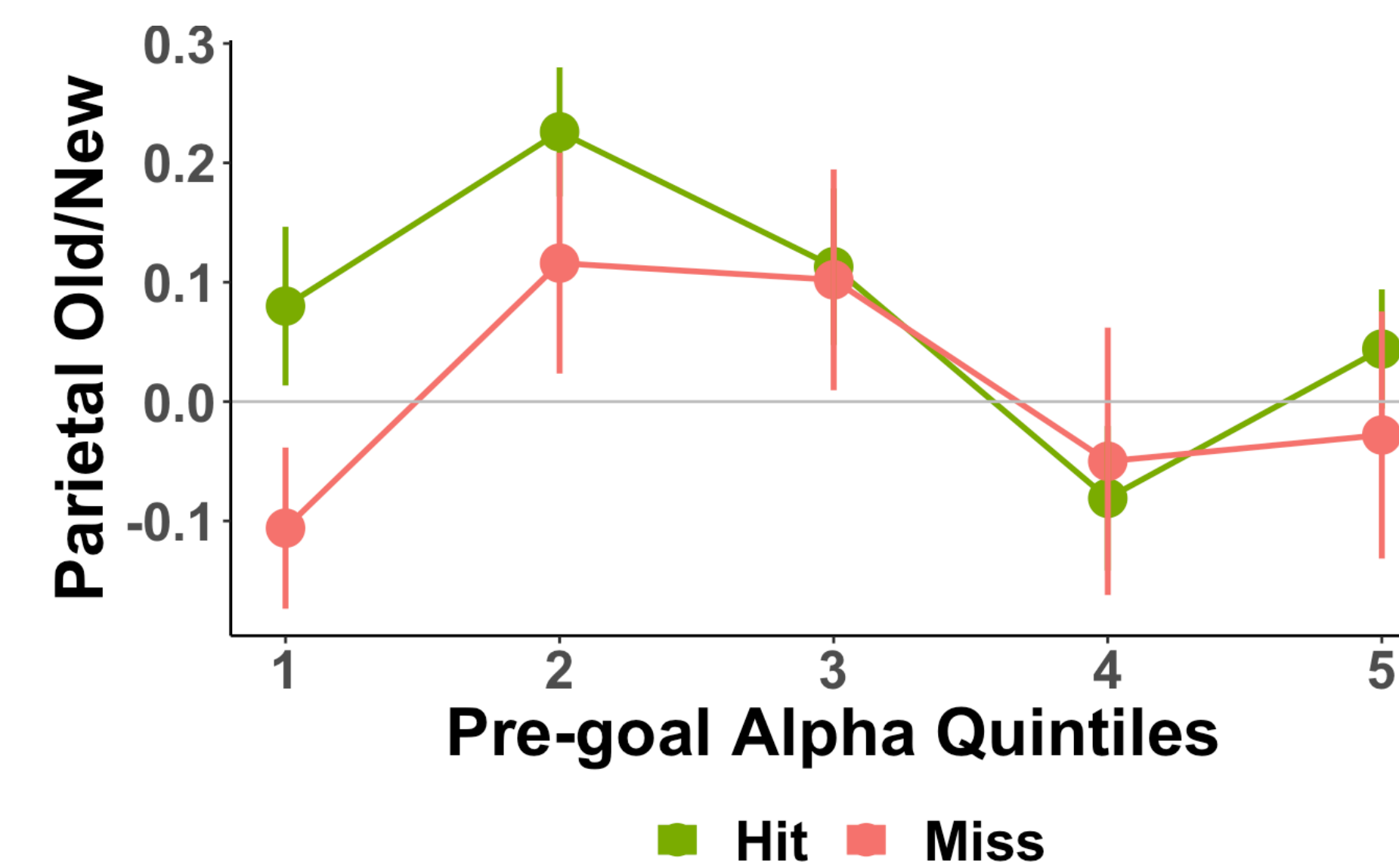
*p < .05

ATTENTION-GOAL CODING-MEMORY

$b = -.15*$ $b = .22*$

$b = -.22$ (direct)*
$b = -.03$ (indirect)*

$b = .19*$ $b = .22*$

$b = .30$ (direct)*
$b = .04$ (indirect)*

ATTENTION-Dm ERP and Dm RT-MEMORY

$b = -.09*$ $b = .36*$

$b = -.22$ (direct)*
$b = -.03$ (indirect)*

$b = .12*$ $b = .36*$

$b = .26$ (direct)*
$b = .04$ (indirect)*

$b = .19*$ $b = -.38*$

$b = -.18$ (direct)*
$b = -.07$ (indirect)*

$b = -.17*$ $b = -.38*$
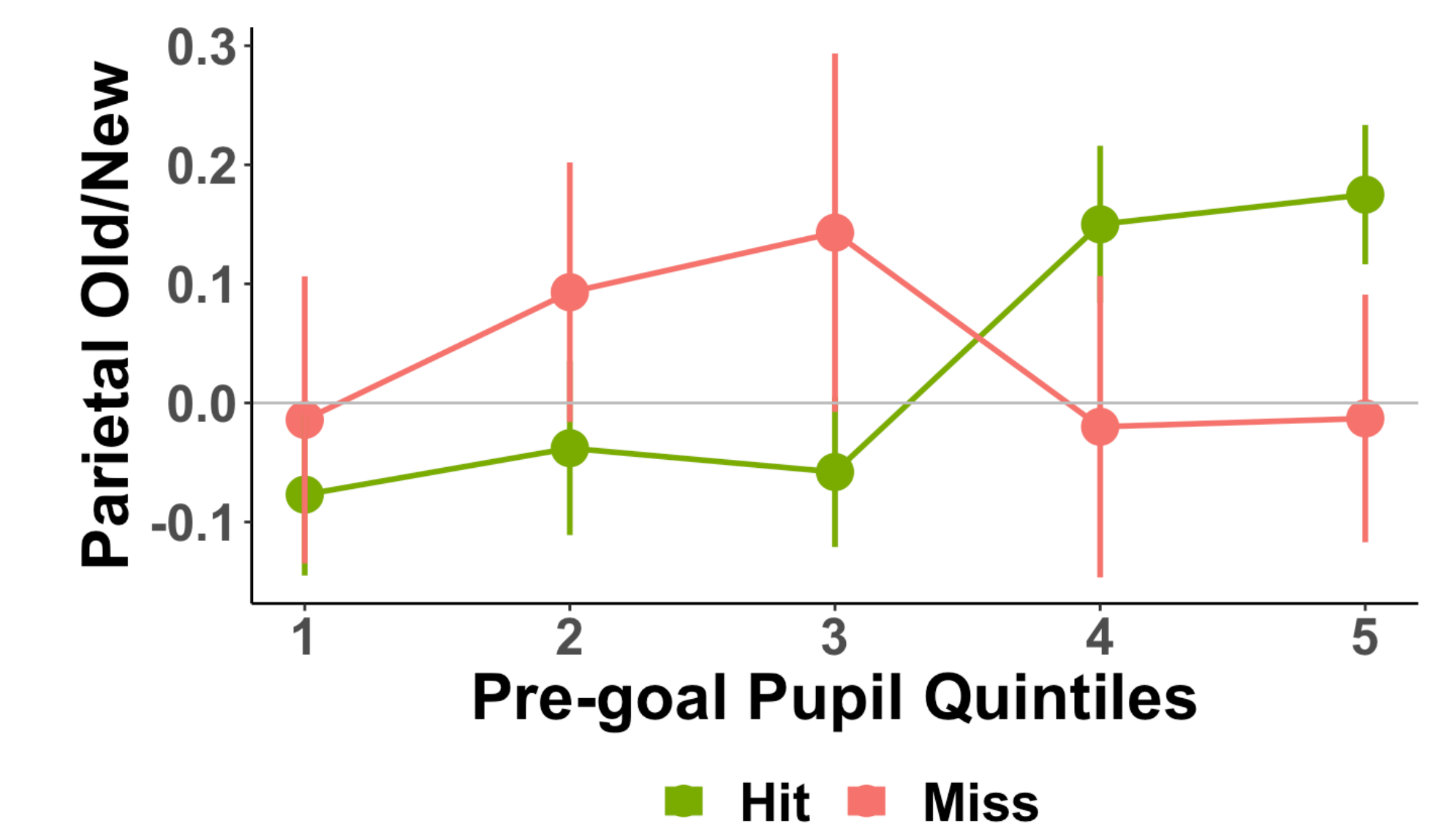
$b = .24$ (direct)*
$b = .06$ (indirect)*

No relationship between pre-goal attention lapsing and memory was observed for correct rejections vs. false alarms.

To test each mediation, we computed the direct path from pre-goal lapsing --> memory, and the indirect path. The indirect paths were lapsing -> goal coding X goal coding --> memory, lapsing --> Dm ERP X Dm ERP --> memory, or lapsing --> Dm RT X Dm RT --> memory. Significance was tested at $p<.05$ via 10,000 bootstrapped samples.

PRE-GOAL ATTENTION LAPSES PREDICT PARIETAL OLD/NEW MEMORY SIGNAL

Pre-goal lapses from alpha power and pupil diameter during learning predict Parietal Old/New signal during retrieval for hit trials in source recognition but not for miss trials.
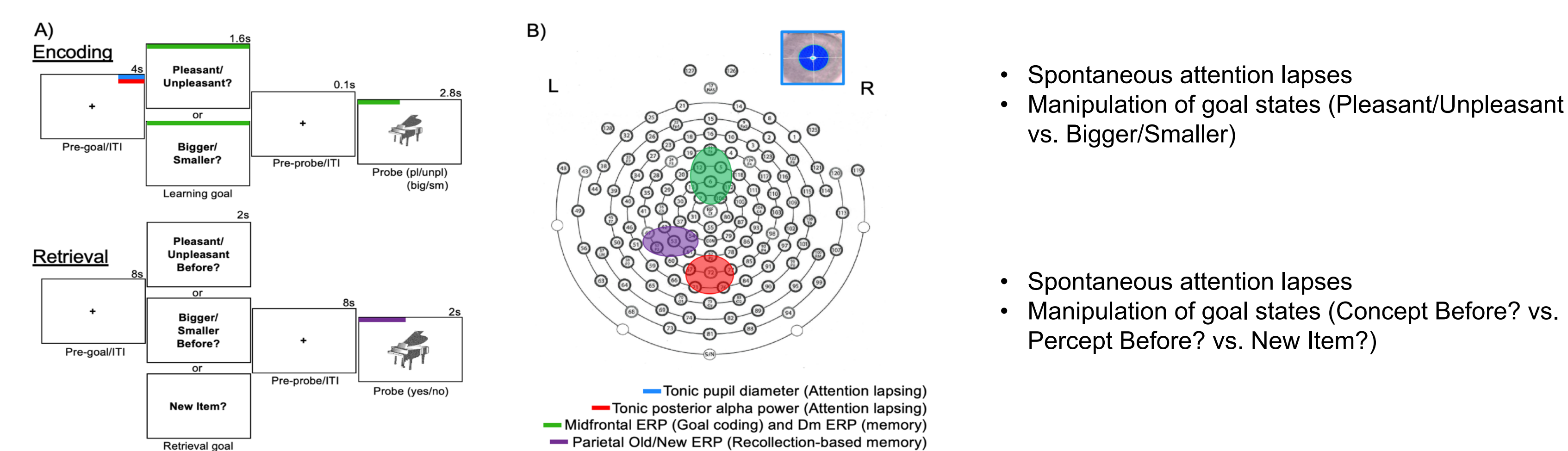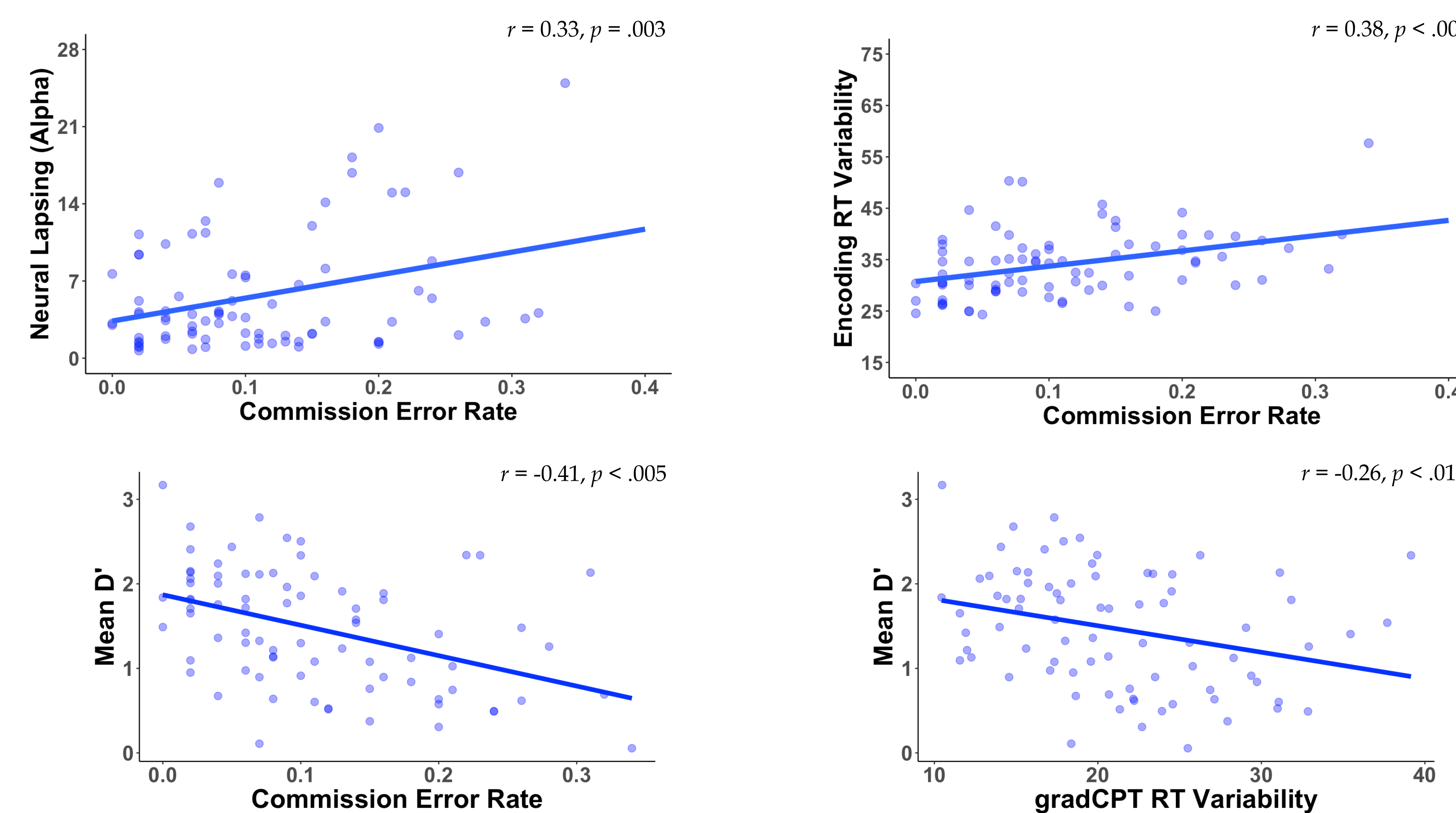
SUBJECT-LEVEL MULTIMODAL ATTENTION IS RELATED TO MEMORY

$r = 0.33, p = .003$

$r = 0.38, p < .001$

$r = -0.41, p < .005$

$r = -0.26, p < .01$

CONCLUSIONS

- Spontaneous lapses in attention at the trial level predict goal coding, learning, and subsequent memory.

- Subject-level differences in sustained attention ability partially account for subject-level differences in learning and memory.

- Ongoing work is focused on concurrent EEG-fMRI assays of attention and goal coding to acquire more sensitive quantitative measures of goal strength and memory.

- Results highlight how preparatory attention and goal-state representation relate to learning and memory processes both in the moment and across individuals.

- These results may have implications for links between memory and real-world behaviors like media multitasking and mind wandering.