Pupil Size at Encoding Predicts the Temporal Structure of Memory

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Introduction

Episodic memories are temporally organized[1,2].

Event boundaries are an important mechanism for shaping temporal contexts[3,4]. These event boundaries could be internal states[5,6], such as fluctuations in attention.

Surprisingly, we previously found that the temporal organization of memory is *not* influenced by attentional fluctuations – as indexed by RT-based measures[7].

How do pupil-based measures of attention at encoding relate to the temporal organization of memory?

Alternative Hypotheses

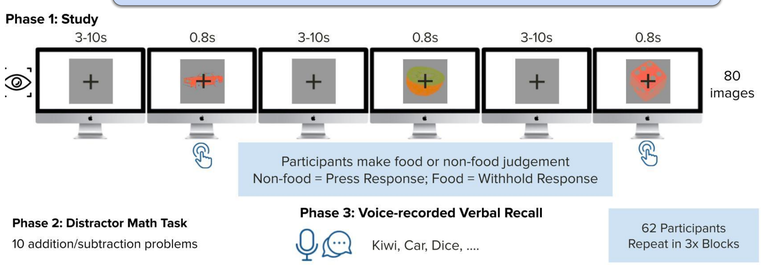
Hypothesis 1: Temporal organization of memory is robust.

Prediction: No differences in recall organization by pupil size at encoding.

Hypothesis 2: RT-based measures do not capture the kinds of attentional fluctuations that predict memory organization.

Prediction: Temporal organization varies by pupil diameter at encoding[8].

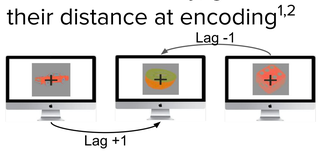
Task Overview



Recall Organization: Lag-CRP

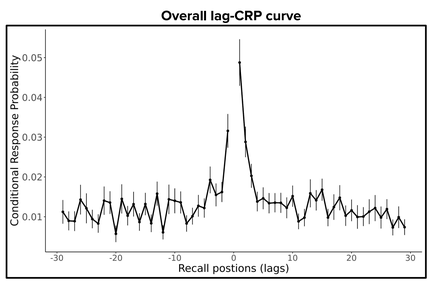
Lag-CRPs quantify & visualize temporal organization in recall

Probability of recalling two items successively, given their distance at encoding[1,2]

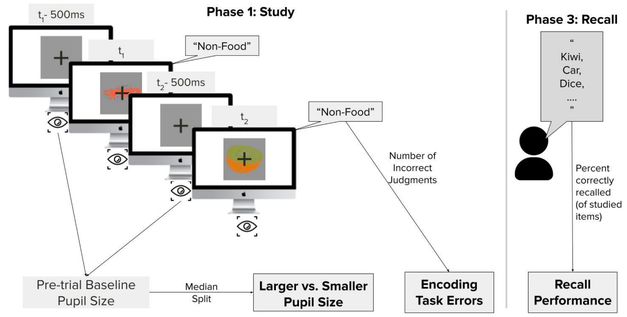


Two properties:

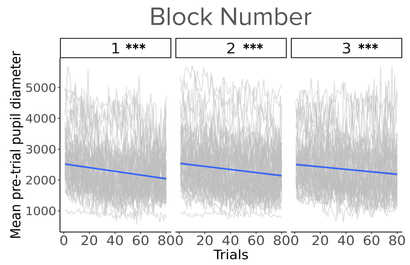
- Temporal contiguity
- Forward asymmetry



Pupil Measures of Attention

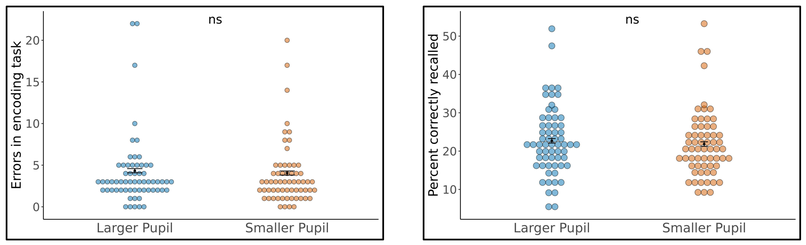


Pupil Size, Task Errors, and Recall

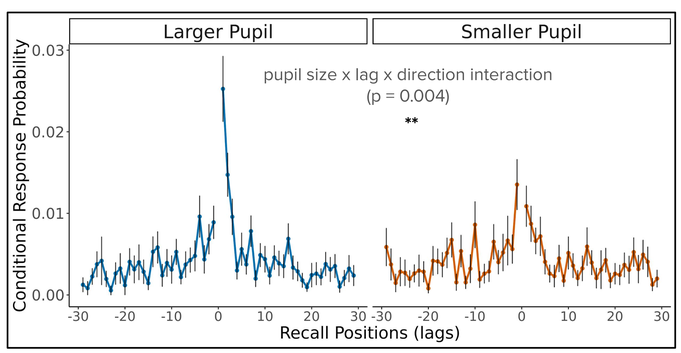


ns = not significant, p > 0.05
* p < 0.05,
** p < 0.001
*** p < 0.0001

Pupil size decreases over trials within a block

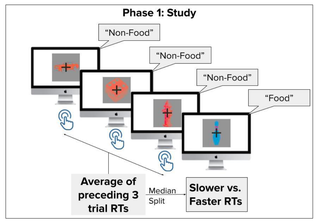


Pupil-based measures of attention do not predict task errors (*left*) **or subsequent recall performance** (*right*)

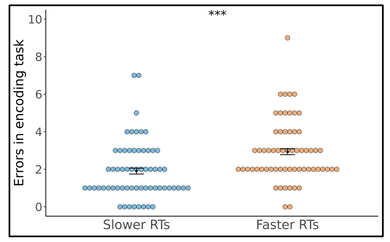


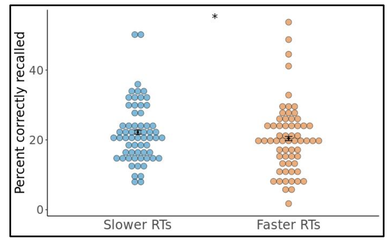
Pupil-based measures of attention predict the temporal organization of recall

Selective to Pupil Measures?



RT-based measures of attention[9] *(left)* **predict task errors** *(bottom left)* **and subsequent recall performance** *(bottom right)*, **but do *not* predict temporal organization of recall – replicating our prior work[7]**





Summary of Results

	Response Time	Pupil Diameter
Encoding Judgement ("Not Food")	✓	✗
Recall Performance	✓	✗
Temporal Organization of Recall	✗	✓

Behavioral and physiological measures of attentional fluctuations yield complementary insights into cognition.

Conclusion

Larger pupil size at encoding is associated with more temporally organized memory at recall.

Behavioral and physiological measures of attention capture distincts aspects of online behavior and memory.

RT measures may be indexing the current allocation of resources to a task; pupil-based measures may be indexing relational encoding.

[1] Howard, & Kahana (2002). A Distributed Representation of Temporal Context. *Journal of Mathematical Psychology*, 46(3), 269–299.
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[9] Wakeland-Hart, et al., (2022). Predicting visual memory across images and within individuals. *Cognition* 227, 105201.