Electrophysiological evidence for dissociation between covert spatial attention and working memory gating

Brecken Marome[1], Henry Jones[1], William Thyer[1], Edward Vogel[1], Edward Awh[1]
[1]The University of Chicago

Background

To be successful at visual tasks in cluttered environments, observers must process information using **covert spatial attention**, which selects specific regions of space [1], **and working memory (WM) gating**, which selectively encodes items into limited-capacity storage [2,3].

Although these systems interact, recent work suggests that covert spatial attention and WM gating are distinct forms of attentional control [1-5].

This project aims to elucidate the timing of covert spatial orienting and working memory encoding during visual working memory tasks.

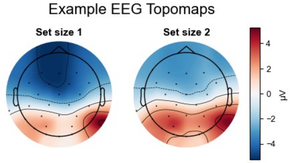
Methods & Analysis

Participants encode a memory array (150-200ms) of set size 1 (ss1) or set size 2 (ss2), maintain item(s) across a delay period (~1000ms), and respond to a spatially identical test item.

EEG and eye-tracking are recorded; trials with eye movements during encoding or maintenance are rejected and requeued.

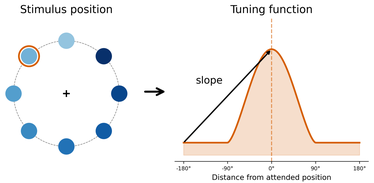
WM gating

A linear classifier learns to distinguish ss1 from ss2 EEG [2,3].



Covert spatial attention

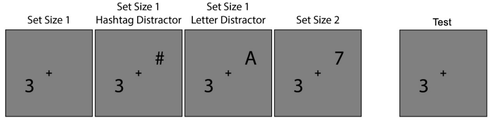
Alpha-band (8-12 Hz) EEG activity is converted into spatial channel responses using an inverted encoding model (IEM) [1].



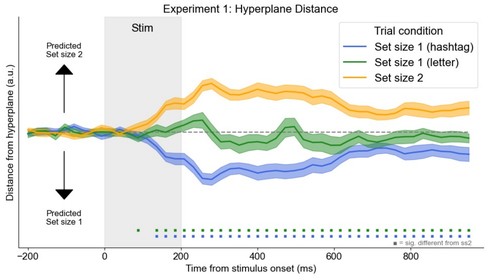
Experiment 1 (n = 22)

Question: Does the ability to discriminate distractors from targets entail working memory storage?

Task: Remember digits, ignore hashtags and letters. Single-probe test; indicate same/different.

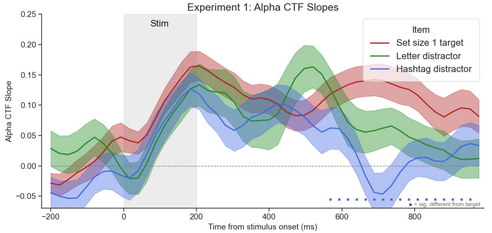


WM rejects hashtags and letters by ~125ms



Although distractors must be actively discriminated from targets, they do not always elicit a WM load signal. This suggests a post-perceptual gate into WM.

Covert spatial attention is similarly allocated to targets and distractors until ~575ms

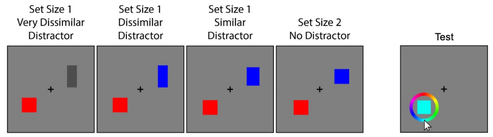


Although alpha quickly tracks the engagement of covert spatial attention, it lingers at distractors long after WM rejects them.

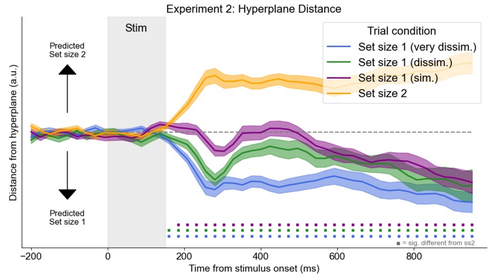
Experiment 2 (n = 24)

Question: Is the post-perceptual locus of WM gating observed for shape discrimination?

Task: Remember squares, ignore very dissimilar, dissimilar, and similar distractors. Continuous color recall of a single item.

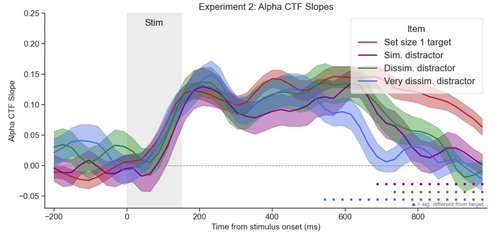


WM rejects distractor shapes by ~150ms



Decoding of ss1 + distractor conditions diverges rapidly from decoding of ss2 but as distractors grow more similar to targets, there are more intrusions into WM.

Covert spatial attention disengages from the most dissimilar distractors at ~550ms

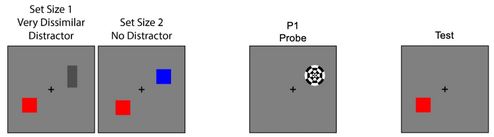


Again, covert spatial attention lingers at distractors long past WM gating; attention disengages first from very dissimilar distractors.

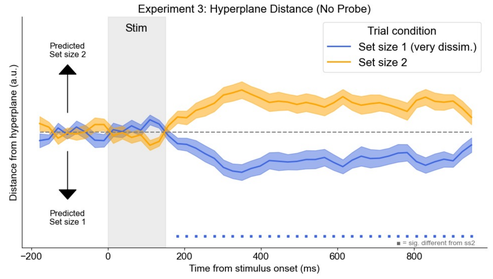
Experiment 3 (n = 20)

Question: Are alpha CTFs sluggish in tracking covert spatial attentional disengagement?

Task: Remember squares, ignore very dissimilar distractors. P1 probe appears during delay on 80% of ss1 trials. Same/different.

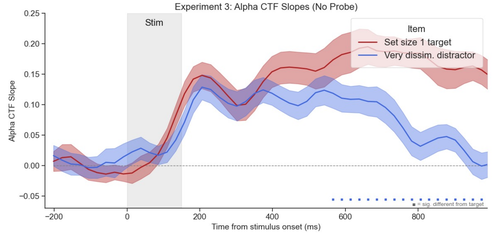


Replicating the timecourse of WM gating



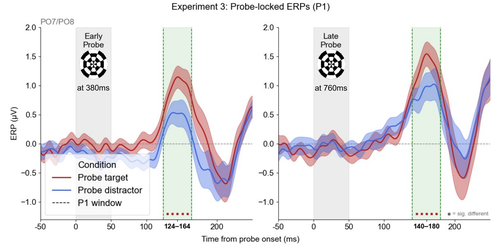
The classifier learns to distinguish between EEG data for ss1 trials with very dissimilar distractors and ss2 trials by ~175ms.

Replicating the timecourse of covert spatial attention for target and distractor items



Covert spatial attention allocated to target and distractor locations cannot be discriminated until ~575ms.

P1-probed covert spatial attention is biased toward target locations ~200ms before alpha-band activity suggests



Subtracting the no-probe condition from probed conditions isolates the effects of the probes [4], indicating a preference for target locations over distractor locations at both probing timepoints [5].

Conclusions & Future Directions

Together, these results reveal a striking temporal dissociation: alpha-based covert spatial attention lingers on distractor locations for hundreds of milliseconds after WM rejects distractors.

P1 probes indicate that covert spatial attention is biased towards target locations over distractor locations by a 380ms SOA, which is **~200ms before alpha CTFs** track this bias.

Even as distractors grow more similar to targets, WM load decoding suggests that **high similarity comparisons do not obligate WM encoding**. This motivates future research to explore what types of comparisons indeed obligate WM encoding.

Our findings show that **covert spatial orienting and WM gating are distinct attentional control processes.** While spatial attention modulates very early stages of visual processing, WM gating may operate during the post-perceptual stages of information processing. Resolving the precise timecourses of covert spatial orienting and WM encoding would provide important insight into the nature of each cognitive process and how they interact.

References

[1] Foster, J. J., Sutterer, D. W., Serences, J. T., Vogel, E. K., & Awh, E. (2017). *Psychological Science.*
[2] Thyer, W., Adam, K. C., Diaz, G. K., Velázquez Sánchez, I. N., Vogel, E. K., & Awh, E. (2022). *Psychological Science.*
[3] Jones, H. M., Thyer, W. S., Suplica, D., & Awh, E. (2024). *Psychological Science.*
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Acknowledgments

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