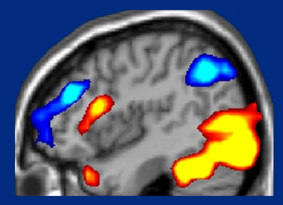
# Bridging Space and Time in Relational Memory: Behavioral and ERP Evidence of Enhanced Spatiotemporal Integration by Emotion

ILLINOIS
Beckman Institute for Advanced Science & Technology

Jacob S. Faibishenko, Paul C. Bogdan, Sanda Dolcos, & Florin Dolcos

Department of Psychology, College of Liberal Arts and Sciences, University of Illinois at Urbana-Champaign



Social, Cognitive, Personality, and Emotional (*SCoPE*) Neuroscience Lab

## I. Introduction

**Background:** Emotion's impact on relational memory (RM) remains a topic of ongoing debate: some studies report enhancing effects, whereas others report impairing or no effects [1, 2, 3].

- By adopting a more nuanced approach toward assessing emotion-RM interactions, we recently demonstrated that emotion enhances both subjective (recollection-based) RM and the likelihood of being confirmed by accurate objective (spatial foreground-background match) RM (Double-Hit) [4].
- The present studies sought to extend this RM framework by investigating emotion's impact across temporal and spatial associative contexts of episodic memory (i.e., spatiotemporal integration), building off earlier evidence that emotion specifically enhances memory for associations encoded in a Negative-to-Neutral temporal order[5]. Behavioral-only data were collected in Study 1, and EEG data were collected for Study 2.

**Hypotheses**:

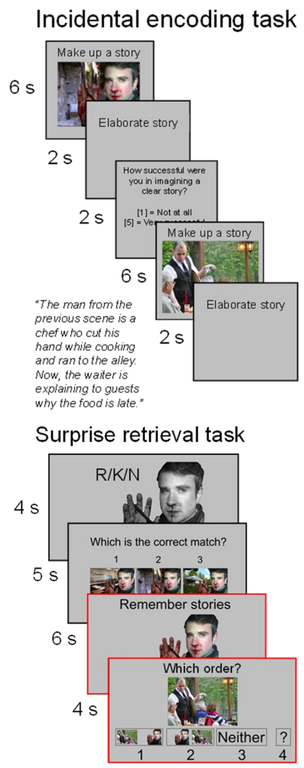
1. *Emotion enhances subjective RM confirmed by objective RM accuracy (Emo Double-Hit > Neu Double-Hit).*
2. *Emotion enhances Negative-to-Neutral temporal RM, preceded by subjective and accurate objective RM (Emo Triple-Hit > Neu Triple-Hit).*
3. *The effects of negative arousal on RM are mediated by attention-related mechanisms, as reflected in heightened centroparietal positivity in posterior event-related potential (ERP) components.*

## II. Methods

**Participants and General Procedures.** A total of 150 subjects participated in Study 1 (17 participants excluded for low response rates). An additional 57 subjects participated in Study 2 (18 excluded due to poor data quality).

**Encoding Task.** Participants viewed 240 images and imagined a story connecting each image to the previous one. Next, participants rated their success in crafting a story.

**Retrieval Task**. First, participants completed a Remember/Know test for the FG component of an encoding image or a foil (120 old trials in total). Second, if the FG was not a foil, participants were asked to match the FG with its corresponding BG component. Third, temporal associations were also tested using FG as a cue image followed by a target image (see the two screens in red), and participants had to indicate whether the latter image was originally shown: (1) immediately before the cue, (2) immediately after the cue, (3) neither immediately before nor immediately after, or that they (4) had no memory of the order. This design allowed us to probe the link between subjective, objective, and temporal RM — i.e., to test if subjective RM is confirmed by objective RM accuracy (Double-Hit), as well as by enhanced temporal RM (Triple-Hit).

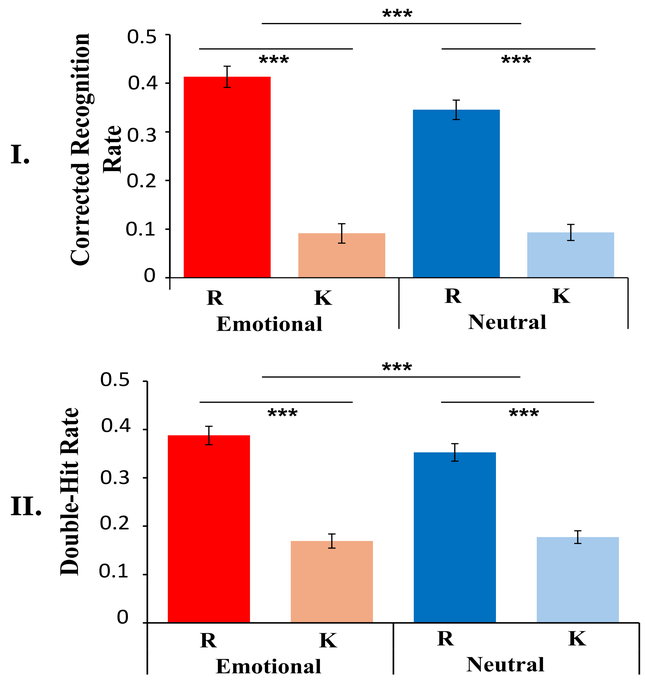



## III. Results

### Study 1 (Behavioral)

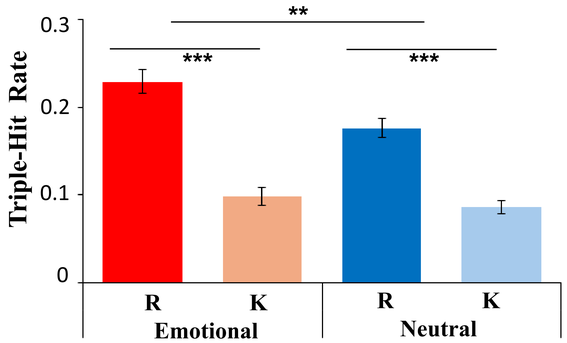
#### *A. Enhanced Subjective Confirmed by Objective RM (Double-Hit) by Emotion*

- (I) Emotional images yielded higher rates of accurate recollection-based responses (subjective RM) and (II) higher rates of subjective confirmed by accurate objective relational memory. R = Remember; K = Know. ** p <.01; *** p < .001.

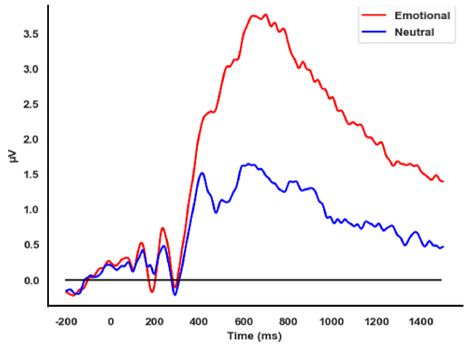


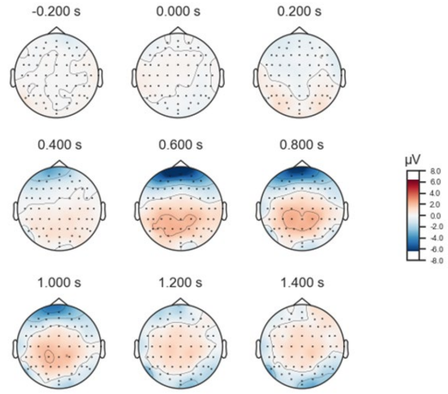

#### B. *Enhanced Spatiotemporal Integration (Triple-Hit) by Emotion*

- Negative-to-Neutral ordered pairs exhibited higher rates of spatiotemporal integration for accurately recollected emotional stimuli that were also confirmed by accurate FG-BG matches.




### Study 2 (Encoding ERPs)




- An early and sustained increase in centroparietal positivity emerged around 300-350ms, with a more pronounced effect for negative stimuli.
- These differences in centroparietal activity peaked around 600–800 ms, followed by a shift in ERP activity from parietal to frontocentral regions at a later epoch (800–1200 ms), where negative amplitudes remained significantly greater than neutral.
- Overall, these results replicate established ERP evidence on emotional encoding [6] and suggest a modulation of attentional mechanisms by emotion.

## IV. Conclusion & Future Directions

- These findings further speak to the importance of using complementary measures to capture the richness of RM, and they validate our framework for reconciling the opposing effects of emotion on RM.
- This demonstration of integration across spatial and temporal elements is valuable and contributes to a more holistic understanding of emotion's specific impact on episodic memories.
- Given earlier findings linking centroparietal positivity to working memory and attention mechanisms, the ERP results from Study 2 may reflect neural processes underlying the behavioral patterns observed in Study 1
- These results are relevant for understanding maladaptive memory processes in post-traumatic stress disorder (PTSD), which is characterized by the rupturing of memories, such that they are involuntarily retrieved in inappropriate contexts – e.g., a veteran retrieving a war memory by hearing a loud noise outside a combat context.

**References:**

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