Acute anxiety reduces behavioral and electrophysiological measures of semantic processing during memory formation

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Background and Hypotheses

Research Question:

Does acute anxiety impair memory by reducing spontaneous semantic encoding strategies?

In 3 Exps, participants studied neutral word lists in either a stressful or a non-stressful context

Hypotheses:

1. Recall will be lower for words studied in a stressful vs. a non-stressful context (Exps 1-3)

2. Recall patterns for words learned in a stressful context will show less semantic clustering vs. a non-stressful context (Exps 1-3)

3. During study, a stressful context will impact ERPs linked to semantic processing[1] (N400) and elaborative encoding[2] (late frontal positivity or LFP) (Exp 3)

Experimental Design

Stress Manipulation:

- Stress was induced using the "threat-of-shock" paradigm, in which each participant receives a "safe" block and a "threat" block

- During threat blocks, participants receive infrequent mild shocks via a BIOPAC stimulator

- Condition order and assignment of words to conditions counterbalanced across participants

- Tonic skin conductance levels (SCLs) recorded

Shocks delivered   ***SCLs recorded***
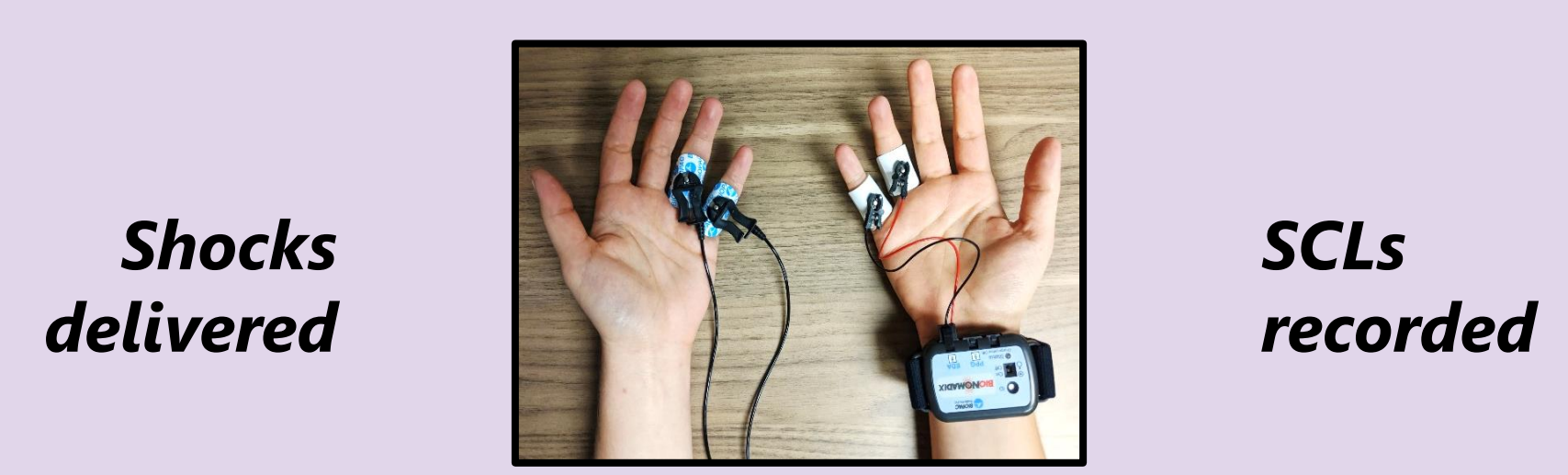
Experiment 1: Behavioral Study

- N = 40, 29 F, ages 18 - 25
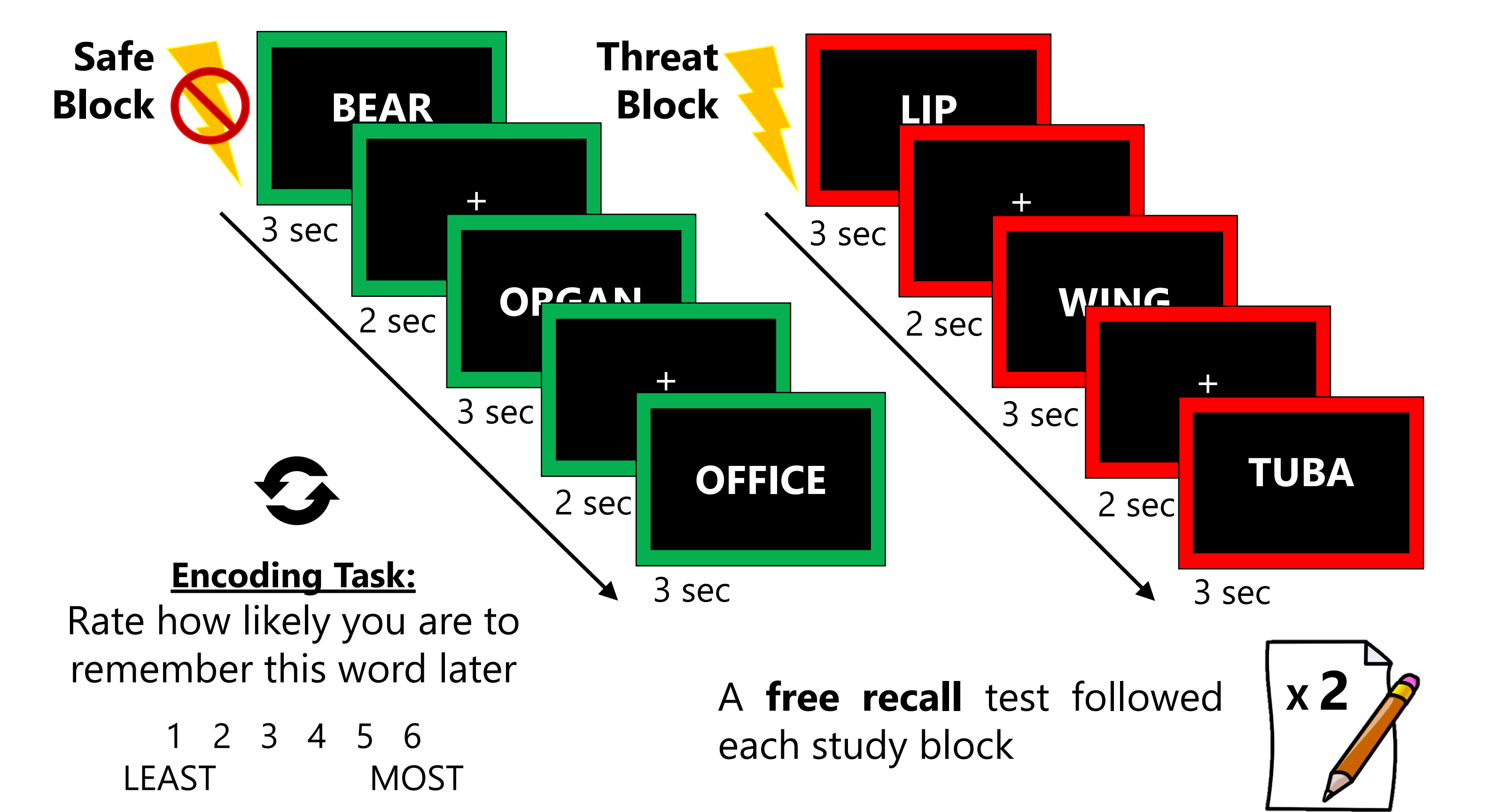- 2 study blocks of 72 neutral nouns,

Experiment 2: Behavioral Study

- N = 56, 42 F, ages 18 - 25
- 2 study blocks of 48 neutral nouns taken evenly from four taxonomic categories
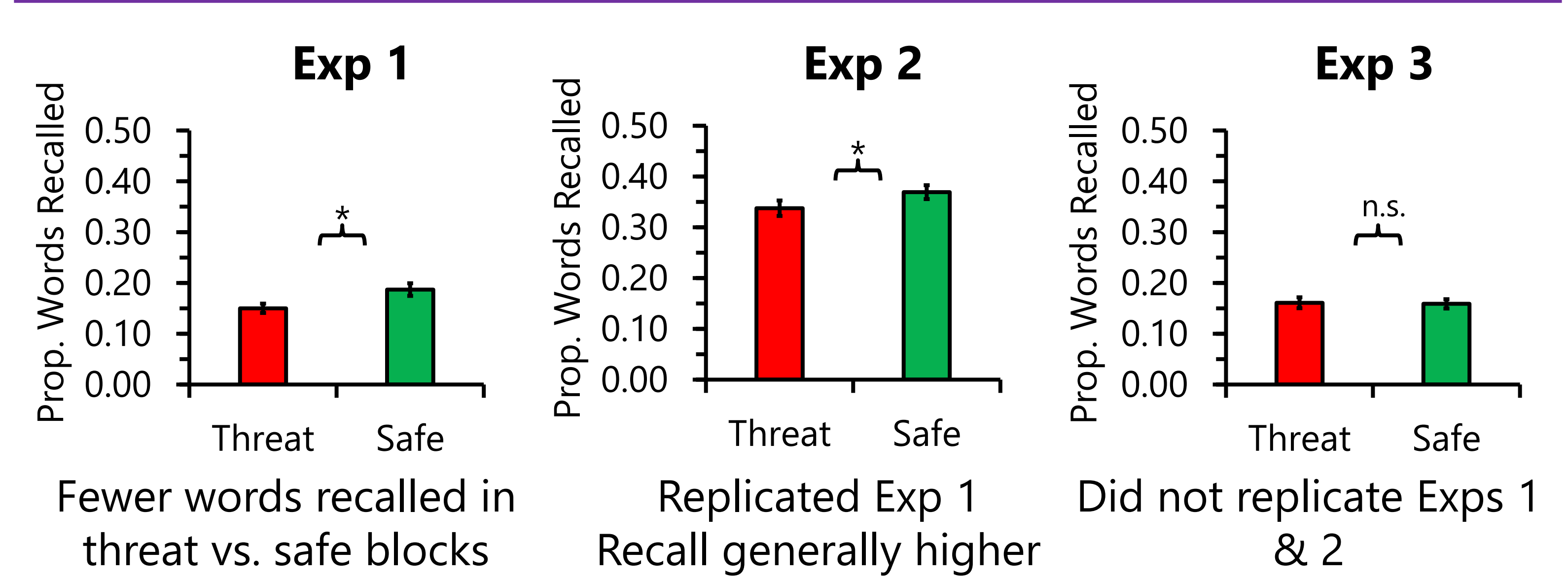- Animals, instruments, building parts, body parts

Experiment 3: Event-Related Potentials

- N = 32, 23 F, ages 18 – 24
- 2 study blocks of 72 neutral nouns
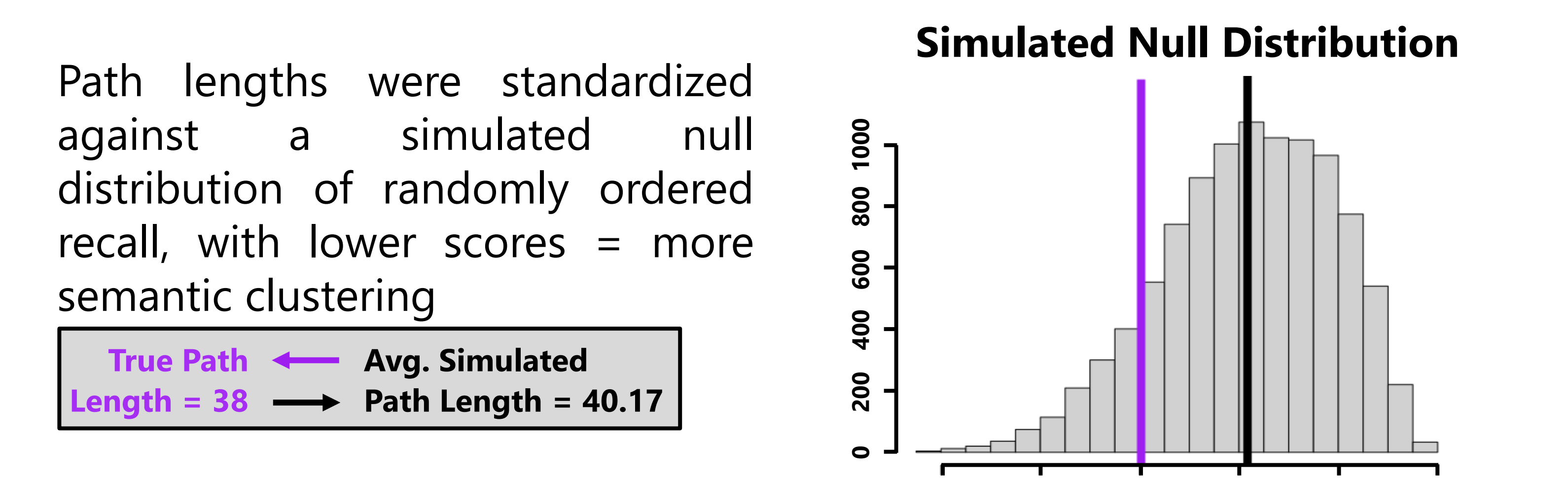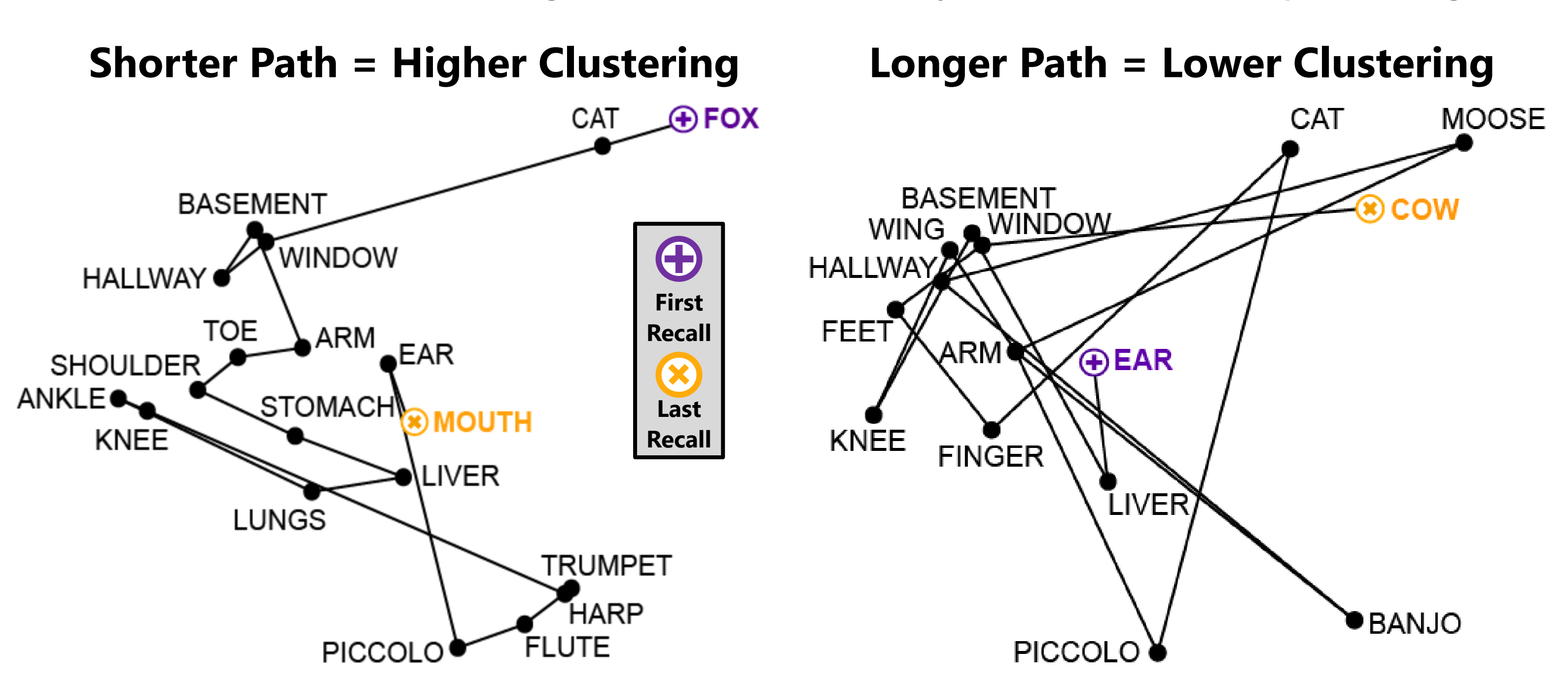- Continuous EEG recorded from 32 channels during the study blocks

Sample Study Trials

Safe Block 🚫   BEAR (3 sec) · + (2 sec) · ORGAN (3 sec) · + (2 sec) · OFFICE (3 sec)

Threat Block ⚡   LIP (3 sec) · + (2 sec) · WING (3 sec) · + (2 sec) · TUBA (3 sec)

Encoding Task:
Rate how likely you are to remember this word later

1 2 3 4 5 6
LEAST   MOST

A **free recall** test followed each study block   x2

Recall Results

Exp 1
Fewer words recalled in threat vs. safe blocks

Exp 2
Replicated Exp 1
Recall generally higher

Exp 3
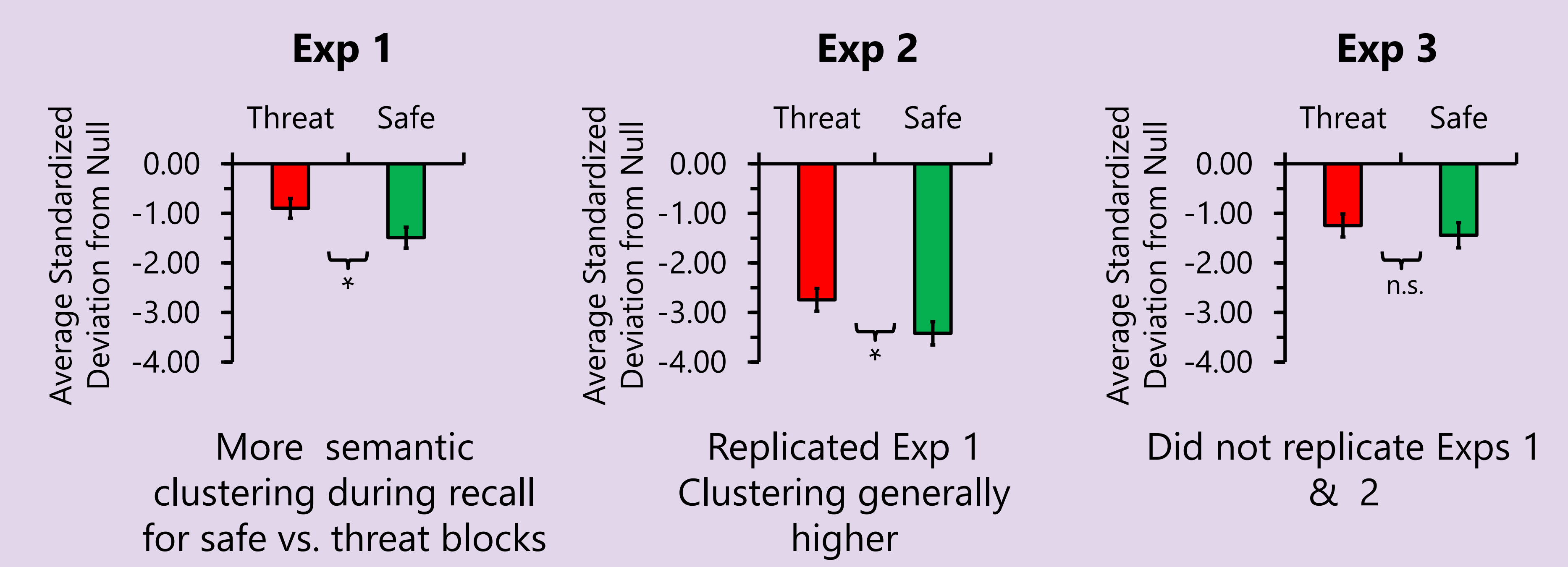Did not replicate Exps 1 & 2

Prop. Words Recalled — Threat / Safe

Clustering Analyses – Methods and Examples

Pairwise similarity distances were calculated for sequentially-recalled words based on word embeddings[3] and summed to yield a semantic "path length"

Shorter Path = Higher Clustering   **Longer Path = Lower Clustering**

⊕ First Recall   ⊗ Last Recall

Path lengths were standardized against a simulated null distribution of randomly ordered recall, with lower scores = more semantic clustering

| True Path Length = 38 | Avg. Simulated Path Length = 40.17 |

Simulated Null Distribution

Semantic Analysis Results

Exp 1
More semantic clustering during recall for safe vs. threat blocks

Exp 2
Replicated Exp 1 Clustering generally higher

Exp 3
Did not replicate Exps 1 & 2

*Average Standardized Deviation from Null — Threat / Safe*

ERP Results

Both N400 and LFP amplitudes were more negative during threat :

- **N400:** linked to difficulty of semantic access
- **LFP:** linked to elaborative encoding strategies

Fz / Cz +3 μV   -200 to 800 ms

- - Safe   — Threat

late frontal positivity (LFP)

N400

500–1000 ms (LFP)
300–500 ms (N400)

+2 / -2 μV

The magnitude of the stress effect on recall correlated across subjects with the magnitude of the LFP effect:

R = 0.37 p = .043

Safe – Threat Recall Difference vs. Safe – Threat LFP Difference (uV)
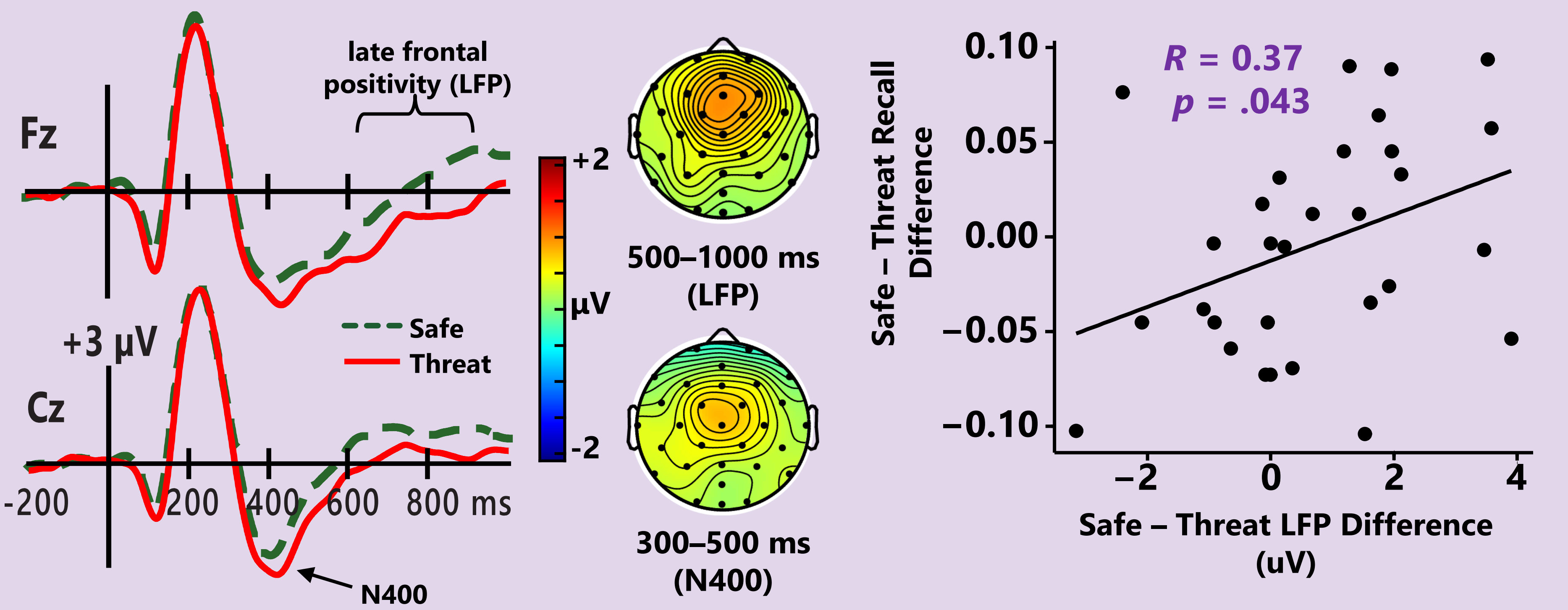
Discussion

- Recall results for Exps 1 & 2 demonstrate that induced anxiety at encoding can negatively impact memory

- More semantic organization was present in free recall patterns following safe relative threat blocks, as evidenced by shorter average semantic path lengths

- Although these behavioral effects did not replicate in Exp 3, analyses of study-phase ERPs are consistent with disruptions to semantic processing (N400) and elaborative encoding (LFP)

- Overall, these results provide evidence that stressful learning contexts reduce spontaneous use of semantic encoding strategies, consistent with models of acute stress that emphasize impairments to controlled processes[4]

Acknowledgements, References, & Contact Information

Scan the link for contact information and a PDF of the poster →

1. Kutas & Federmeier, 2011 *Annu. Rev. Psychol.*; 2. Mangels et al., 2001, *Cogn. Brain Res.*; 3. Mikolov et al., 2013, *In Proceedings of NIPS*; 4. Gagnon & Wagner, 2016, *Ann. N. Y. Acad*