Semantic Clustering & Semantic Path Length:
Two measures of free recall organization with different functional properties

Felicia M. Chaisson*, Heather D. Lucas, Amber M. Alford, Christopher R. Cox - *Department of Psychology, Louisiana State University*

LSU

BAM LAB Brain and Memory

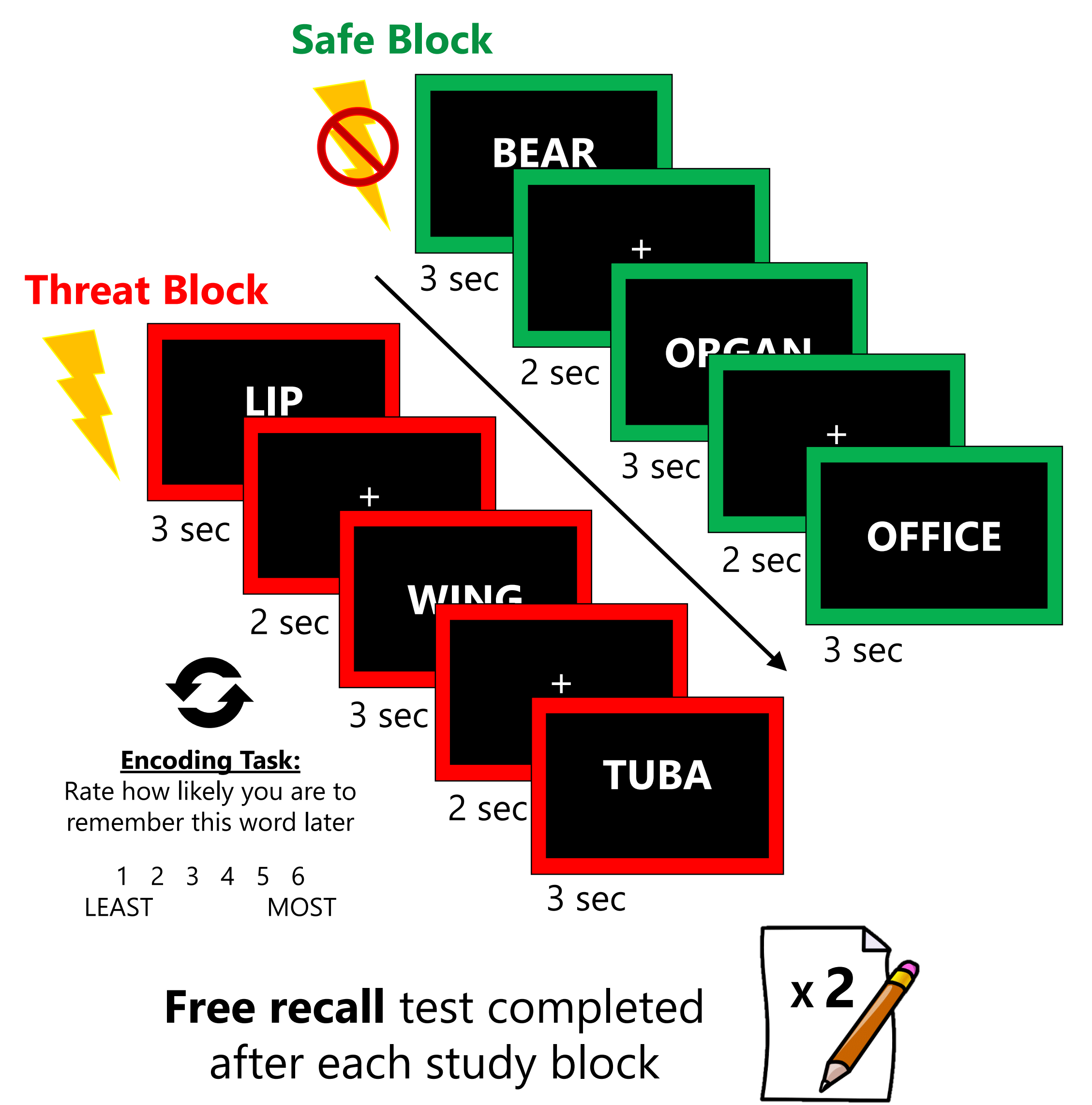## Background and Hypotheses

- In free recall, people exhibit semantic clustering (i.e., sequential recall of related words)

- Often measured by ranking how related each recalled word is to the previously recalled word vs all not-yet-recalled words
  - Potential downside: score given to a recall like "cat"-"milk" will be penalized if words even *more* related to "cat" were studied but poorly encoded

- Can also measure the "distance" traveled during recall compared to other possible recall paths **given only the set of words recalled**

- We applied this "path length" measure as well as a standard clustering measure[1] to recall data from two exps that induced acute anxiety during study

- **Question 1**: Can either measure account for across-person variability in recall accuracy?

- **Question 2**: Can either measure detect differences in semantic organization of recall for words studied with vs without anxiety?

Experimental Design

Experiment 1:
- N = 40, 29 F, ages 18 - 25
- 144 neutral nouns split into study blocks of 72

Experiment 2:
- N = 56, 42 F, ages 18 - 25
- 96 neutral nouns from 4 taxonomic categories split into 2 study blocks of 48

Sample Study Trials

Safe Block
BEAR — 3 sec
ORGAN — 2 sec
OFFICE — 3 sec

Threat Block
LIP — 3 sec
WING — 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

Free recall test completed after each study block   x 2

Measuring Semantic Clustering and Path Length

Semantic Clustering

- Similarity of each just-recalled word to prior word compared to **all not-yet-recalled words**
- Based on percentile observed similarity values relative to those of **all possible recalls**
- Scores **influenced** by similarity of non-recalled to recalled words
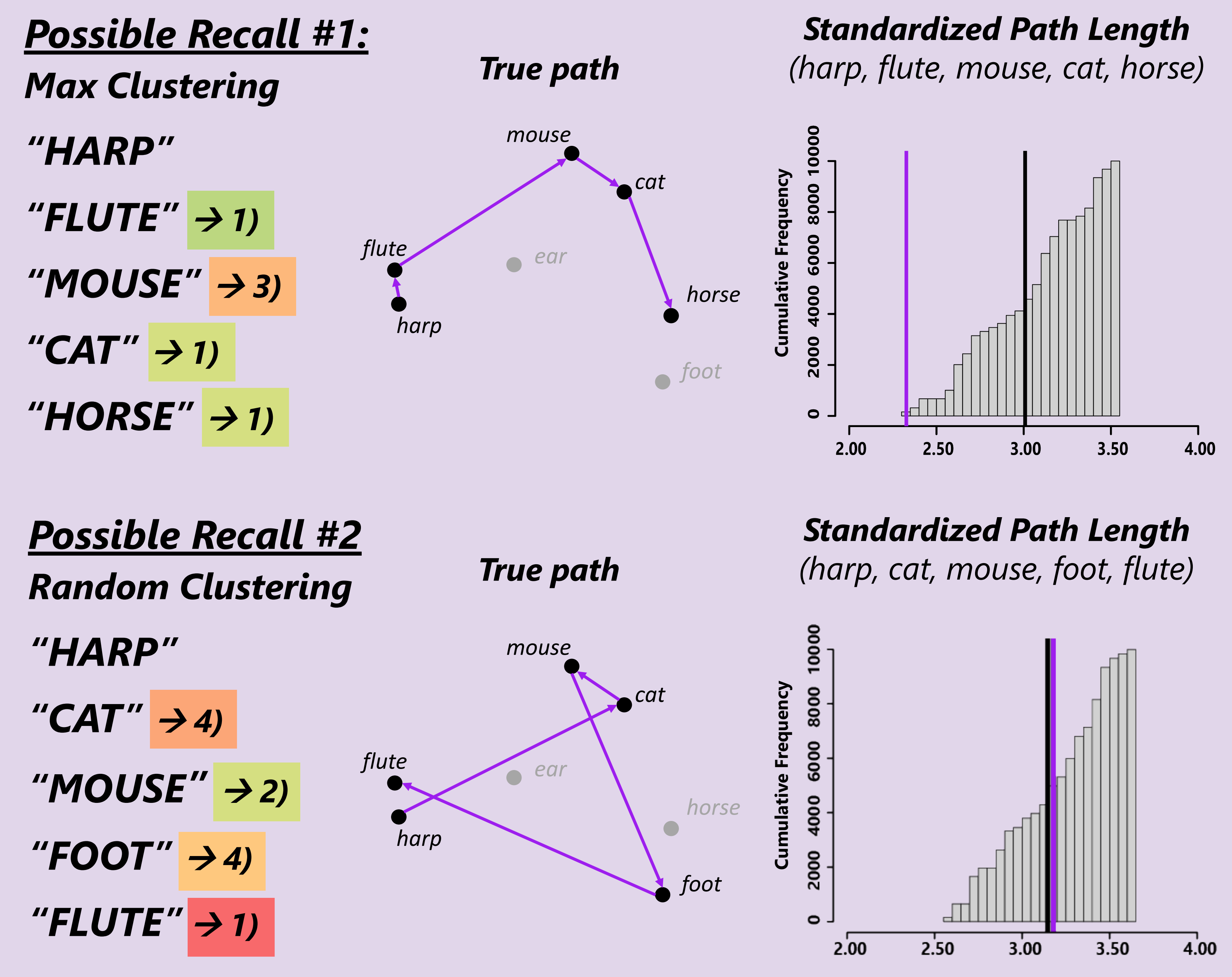
Semantic Path Length

- Similarity of each just-recalled word to prior word compared to **only the set of recalled words**
- Based on percentile of overall "path" travelled to a null mean **specific to recalled words**
- Scores **disregard** similarity of non-recalled to recalled words

Worked Example

Hypothetical study list and matrix of cosine distance scores:

HORSE
FLUTE
EAR
CAT
FOOT
MOUSE
HARP

	HORSE	FLUTE	EAR	CAT	FOOT	MOUSE	HARP
HORSE	0.00	6) 0.92	6) 0.83	1) 0.53	1) 0.64	3) 0.80	5) 0.91
FLUTE	5) 0.92	0.00	5) 0.74	5) 0.84	6) 0.97	5) 0.83	1) 0.42
EAR	4) 0.83	2) 0.74	0.00	3) 0.72	2) 0.74	2) 0.68	2) 0.71
CAT	1) 0.53	4) 0.84	3) 0.72	0.00	3) 0.79	1) 0.55	4) 0.86
FOOT	2) 0.64	5) 0.97	4) 0.74	4) 0.79	0.00	4) 0.80	6) 0.94
MOUSE	3) 0.80	3) 0.83	1) 0.68	2) 0.55	4) 0.80	0.00	3) 0.86
HARP	6) 0.91	1) 0.42	2) 0.71	6) 0.86	5) 0.94	6) 0.86	0.00

Colors and number represents distance such that Six (6) or red = furthest away (least similar) and One (1) or green = closest (most similar)

Possible Recall #1:
Max Clustering
"HARP"
"FLUTE" → 1)
"MOUSE" → 3)
"CAT" → 1)
"HORSE" → 1)

True path

Standardized Path Length (harp, flute, mouse, cat, horse)

Possible Recall #2
Random Clustering
"HARP"
"CAT" → 4)
"MOUSE" → 2)
"FOOT" → 4)
"FLUTE" → 1)

True path

**Standardized Path Length** (harp, cat, mouse, foot, flute)

Behavioral Results: Threat of Shock Harmed Word Recall

- Worse recall overall for threat versus safe blocks in both exps
- Better recall overall in exp 2 due to related word lists

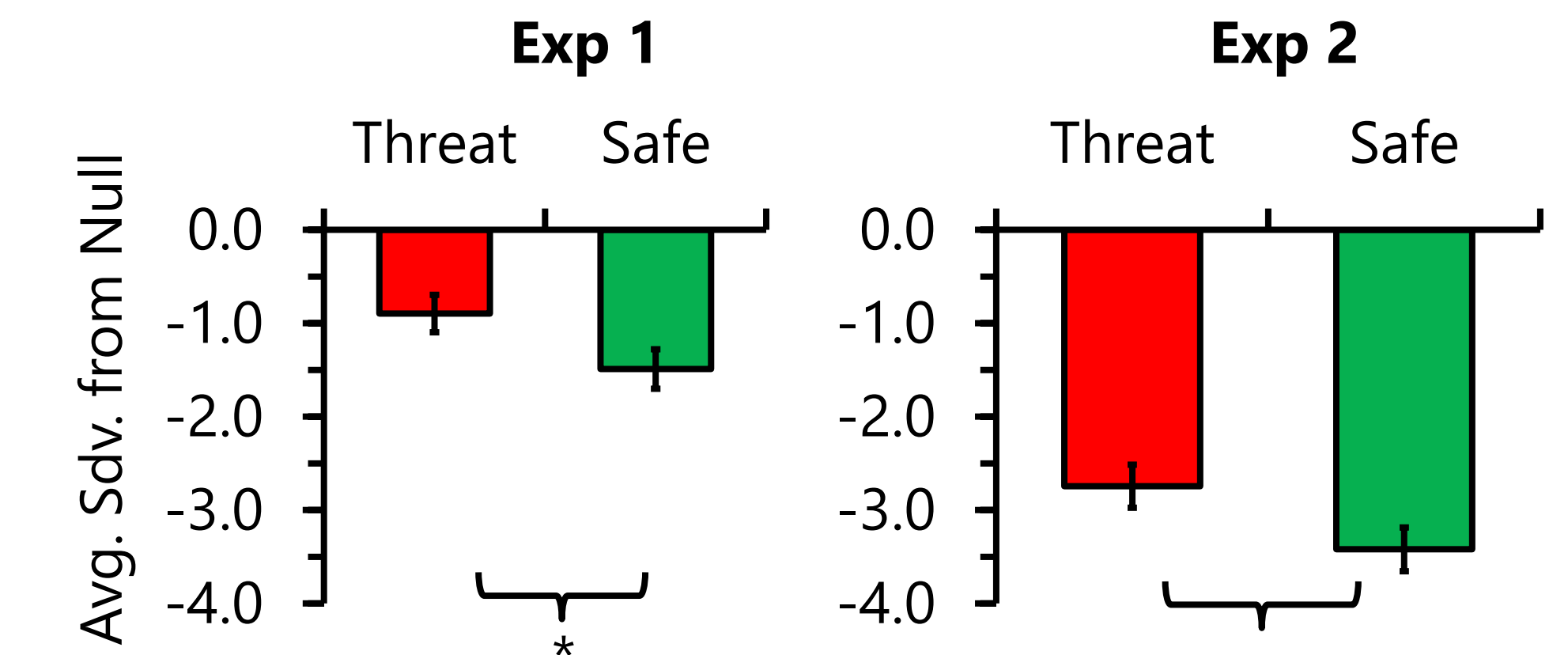Exp 1 / Exp 2 — Prop. Words Recalled — Threat, Safe
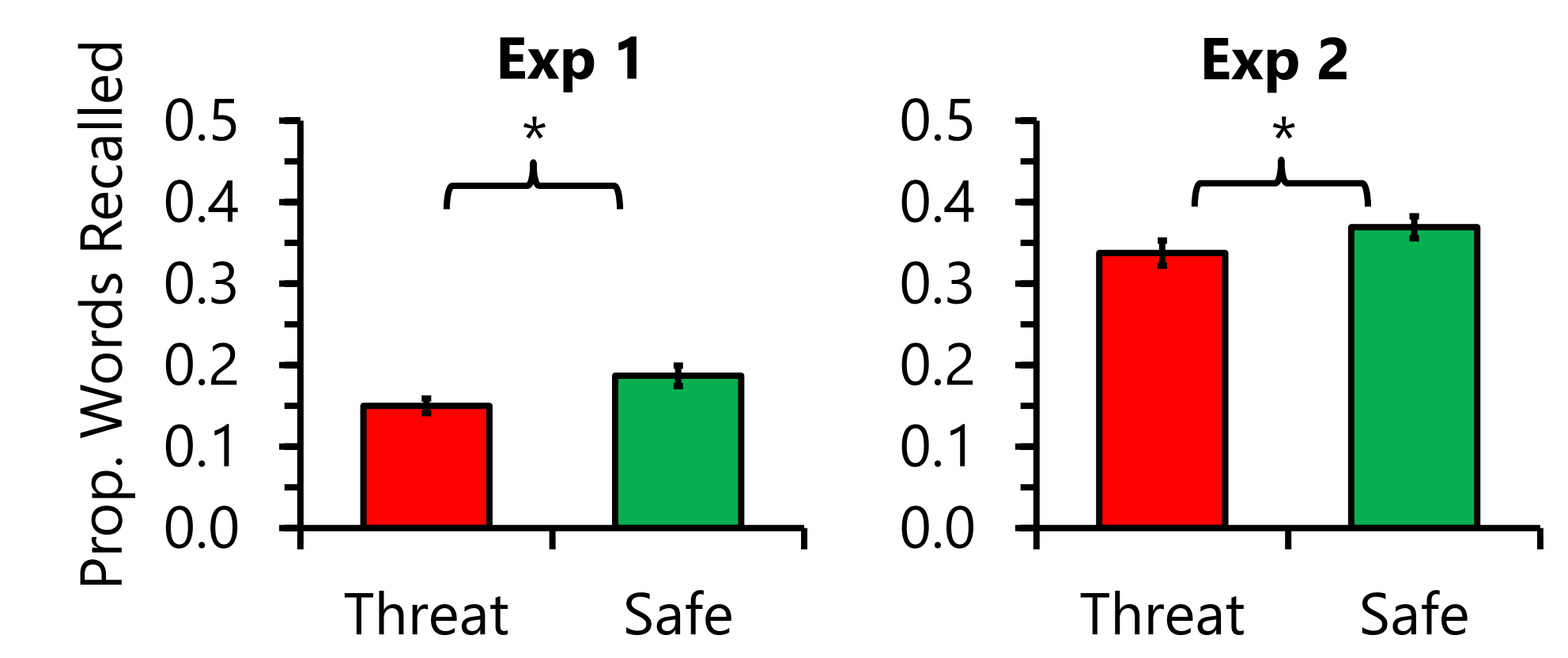
Semantic Clustering Unaffected by Threat of Shock

- No difference in semantic clustering between threat and safe blocks
- More clustering overall in exp 2

* Random chance = 0.50, or 50%

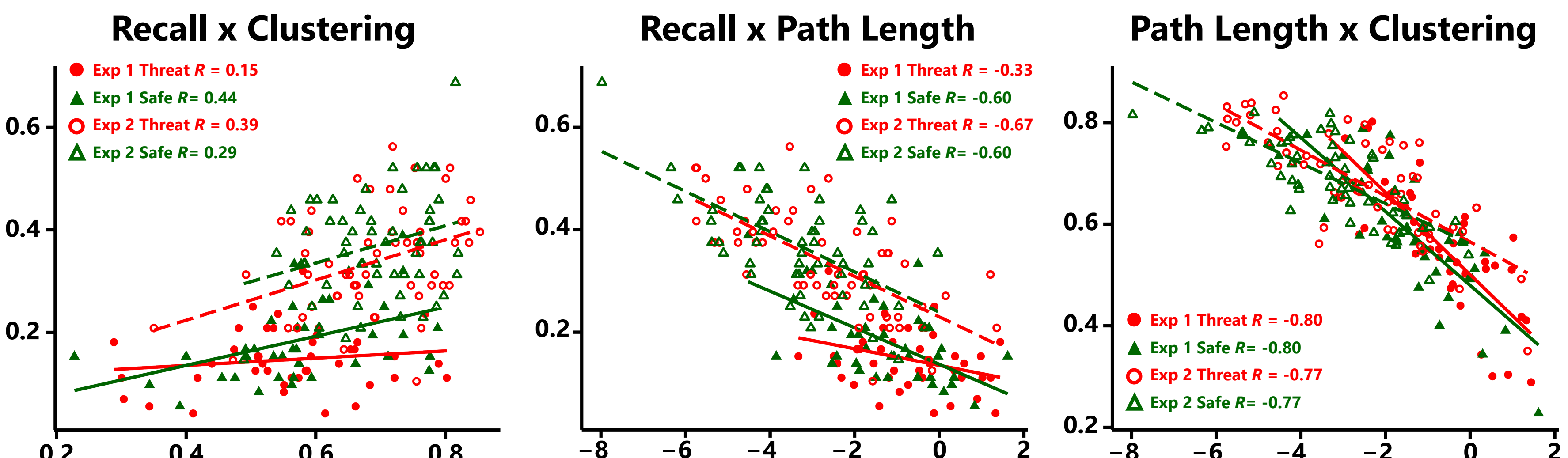Exp 1 / Exp 2 — Avg. Semantic Clustering Score — Threat, Safe (n.s.)
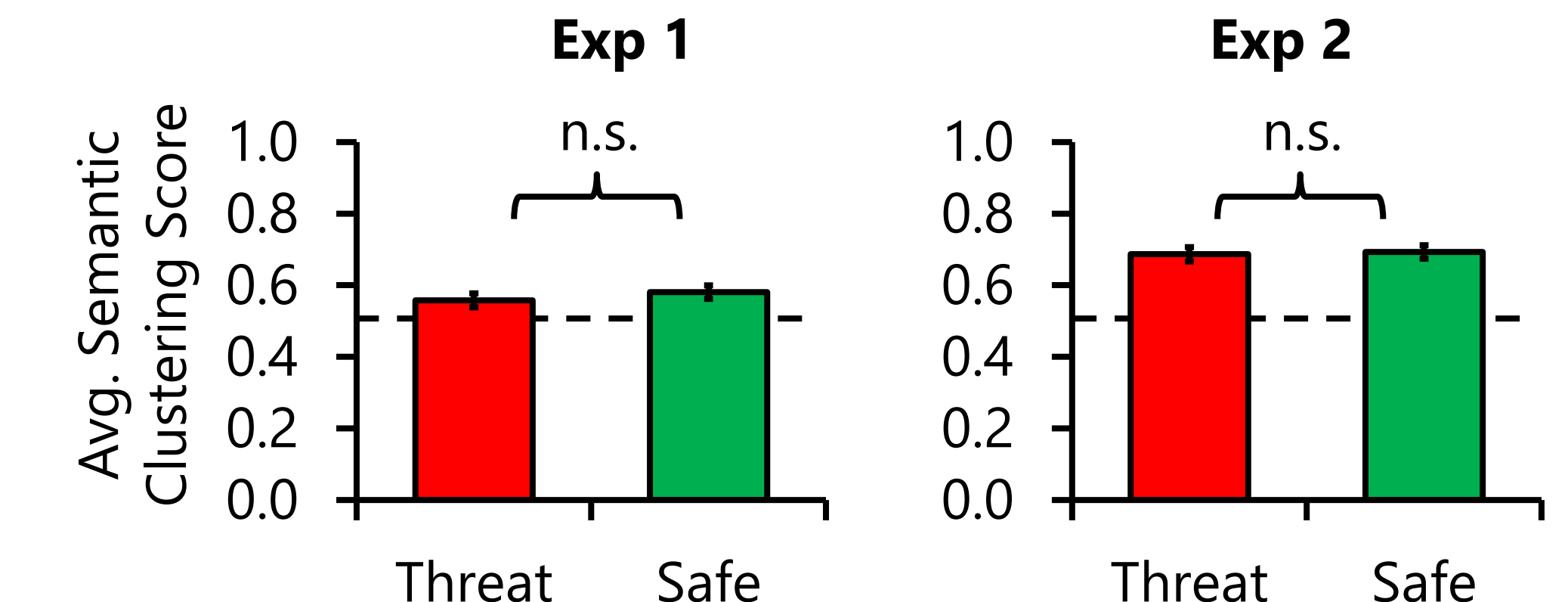
Longer Recall Path Lengths For Words Studied Under Threat

- Path length significantly longer in threat than safe conditions in both exps
- Longer path lengths → less semantic organization

* Random chance = 0

Exp 1 / Exp 2 — Avg. Sdv. from Null — Threat, Safe

Correlations Among Clustering, Path Length, and Recall

Recall x Clustering
- Exp 1 Threat R = 0.15
- Exp 1 Safe R = 0.44
- Exp 2 Threat R = 0.39
- Exp 2 Safe R = 0.29

Recall x Path Length
- Exp 1 Threat R = -0.33
- Exp 1 Safe R= -0.60
- Exp 2 Threat R= -0.67
- Exp 2 Safe R= -0.60

Path Length x Clustering
- Exp 1 Threat R = -0.80
- Exp 1 Safe R= -0.80
- Exp 2 Threat R = -0.77
- Exp 2 Safe R= -0.77

Discussion

- In two experiments, threat during study linked to worse subsequent recall and longer semantic paths lengths, but not less semantic clustering
  - Clustering and path length may provide complementary information about semantic organization in free recall
- Strong across-subject correlations between clustering and path length scores
- Path length scores correlated more strongly with recall accuracy
- Path length may be more sensitive in circumstances where:
  - Attention is likely to fluctuate during study; some words not encoded
  - Learners encode idiosyncratic or more distant associations among words.
    - Consistent with prior research showing that acute stress selectively impairs access to remote, but not close associations in semantic memory[2,3]

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

1. Polyn et al., 2009, *Psychol Rev.*; 2. Alexander et al., 2007, *J. Cogn. Neurosci.*; 3. Marko & Riečanský, 2018, *Cognition*