# Mental context reinstatement may underlie successful retrieval of extinction memories

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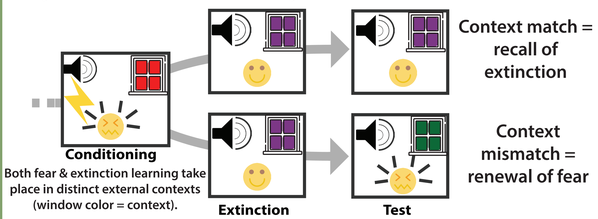
## 1. INTRODUCTION

### Background

*Context refers to the many facets of information that characterize the situation in which an episodic memory occurs, and place our memories in space and time.*

#### Specificity of Extinction Learning.

- Extinguishing learned fear involves both new learning of extinction and successful retrieval of these extinction memories rather than the fear.
- Successful retrieval of extinction memories is contextually specific (Bouton, M. E., 2004).
- Fear learning, unlike extinction, readily generalizes to novel contexts; and the over expression of generalized fear is a hallmark of neurobiological disorders such as PTSD (Maren et al., 2013).




Both fear & extinction learning take place in distinct external contexts (window color = context).

#### Mental Context

- Recent models of episodic memory in humans highlight the importance of mental context for the successful encoding and retrieval of memories (Sederberg et al., 2008).
- Mental context is defined as the running average of recent perceptual and mnemonic experiences at any given moment.

**Conditioning**: Memories formed during conditioning and extinction are temporally separated, and are encoded in distinct mental contexts.

**Test**: The mental context reinstated at test could influence the renewal of fear or the successful recall of extinction.

***QUESTION: Is mental context reinstatement associated with the successful retrieval of extinction memories?***

### Hypothesis

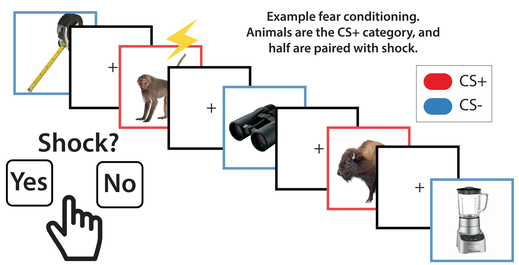
- **We predict that the successful retrieval of extinction memories will be associated with the reinstatement of the mental context in which extinction learning occurred.**
- **If extinction behaviors are exhibited, then we should be able to decode the neural pattern of activity associated with the extinction mental context.**

## 2. METHODS

| | I. Baseline | II. Category Fear Conditioning | III. Extinction with Mental Context Tag |
|---|---|---|---|
| **Day 1** | Category identity decisions are made about images from categories to be used in conditioning, animals and tools. | Pavlovian conditioning. Images from one category are paired with a mild electric shock to the finger (50% reinforcement rate). | Pavlovian extinction - no shocks are delivered. ITIs are filled with scene images in order to build the mental context tag. |
| **Day 2** | **IV. Extinction Recall** Subjects are told that a shock is still possible, but receive none. | **V. Recognition Memory** Surprise recognition confidence memory test is given for all objects seen during day 1, plus novel foils. | **VI. Localizer** N-back task used to train the MVPA classifier. Categories include animals, tools, scenes, and rest. |

### Category Fear Conditioning

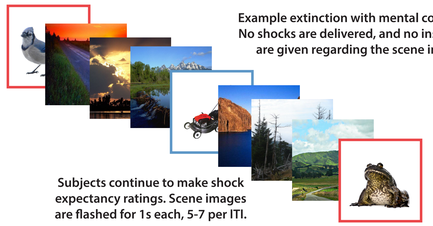
- Half the images from a single category are paired with an electric shock; 12 shocks total.
- No images are repeated; emotional learning generalizes to an entire category rather than specific exemplars (Dunsmoor & Murphy, 2015).




Example fear conditioning. Animals are the CS+ category, and half are paired with shock.

### Day 1: Extinction with Mental Context Tag

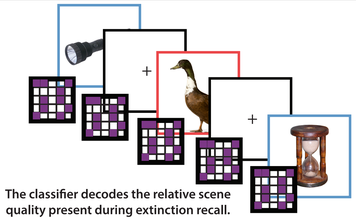
- Mental Context can be tagged by associating trial irrelevant stimuli with an ongoing task (Gershman et al., 2013; Manning et al., 2016).
- Scene images are repeatedly flashed during the ITIs of extinction, and these images are incidentally encoded alongside extinction memories.
- The next day, recall of extinction memories should lead to reactivation of other memories (scene images) encoded within the same mental context.
- The multi-voxel pattern associated with scene images can be decoded the next day, when no scenes are actively perceived. This pattern of activity is a proxy for the reinstatement of the extinction mental context, the only point in time during which scenes were observed.



Example extinction with mental context tag. No shocks are delivered, and no instructions are given regarding the scene images.

Subjects continue to make shock expectancy ratings. Scene images are flashed for 1s each, 5-7 per ITI.

### Day 2: Decoding Mental Context

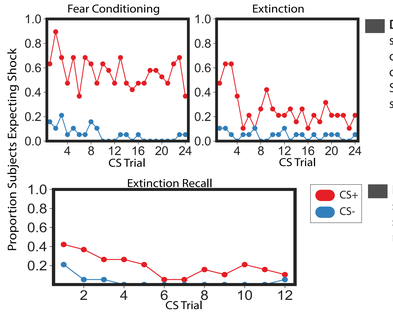


The classifier decodes the relative scene quality present during extinction recall.

MVPA classifier trained on scene images collected during the localizer (end of day 2)

## 3. RESULTS

### Shock Expectancy

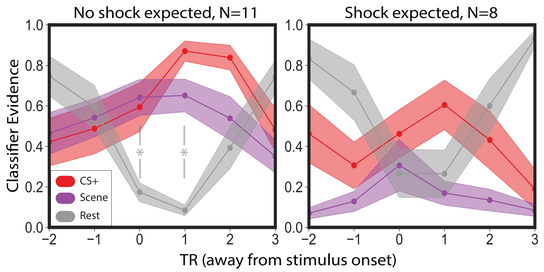



- **Day 1.** During conditioning, subjects quickly gain contingency awareness of contingency on CS+ trials. Subjects then successfully learn safety during extinction.
- **Day 2.** During extinction recall, some subjects again expect a shock, but then quickly re-extinguish.

### Decoding Mental Context - MVPA Neural Results

*A one-vs-all logistic regression classifier was trained on exemplars collected during the localizer and used to decode category evidence during experimental runs. ROI for MVPA analysis included Ventral Temporal Cortex and Lateral Occipital Complex, feature selected at k=1000 voxels.*

**Extinction Mental Context Reactivated During Successful Extinction Recall**



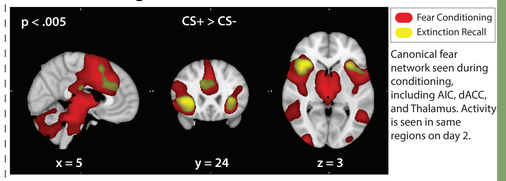

Classifier evidence for the first CS+ trial of extinction recall on day 2, shaded area is +/-1 SEM. ( * indicates TR where scene > rest; p < .005 )

- Subjects who did not expect a shock had significantly higher classifier evidence for scenes compared to rest when no scenes were observed, indicating reinstatement of extinction mental context.
- Subjects who did not expect a shock had significantly higher relative scene evidence during TR=1 of the first CS+.

Lines represent +/-1 SEM. ( * indicates p < .001)

### Future Directions

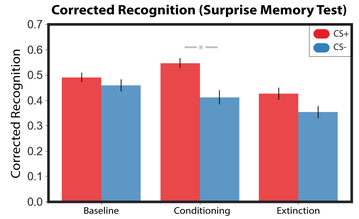
**Re-Emergence of Fear Network for Novel Stimuli**




Canonical fear network seen during conditioning, including AIC, dACC, and Thalamus. Activity is seen in same regions on day 2.

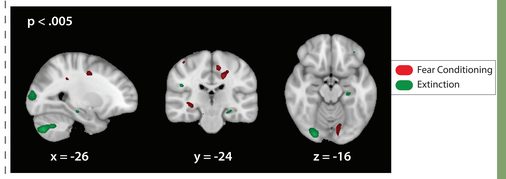
Future analyses will continue exploring how humans generalize fear to novel stimuli and situations, as well as exploring how extinction generalization may be enhanced

**Emotional Subsequent Memory Analysis**




Corrected recognition (high confidence hits - false alarm rate) for items seen during phases on day 1. Lines represent +/-1 SEM. N=17, two subjects excluded as statistical outliers. ( * indicates CS+ > CS-; p < .005 )

**Interaction of Emotion and Memory**




Group level analysis for the interaction (CS+ remembered > CS+ forgotten) > (CS- remembered > CS- forgotten) Preliminary results highlight hippocampal and parahippocampal activity, and future work will expand on the interaction of emotion and encoding success, including emotionally modulated encoding-retrieval overlap.

## 4. SUMMARY

- **A mental context framework of episodic memory can be used to understand how humans learn and remember fear and safety.**
- **Extinction mental context reinstatement was observed in subjects who exhibited conscious extinction recall the following day.**
- **Future directions will explore how fear and extinction contexts compete following extinction, as well as how emotional learning modulates encoding success of episodic memories.**