

# The Neural Correlates of Aversive to Appetitive Counterconditioning

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## 1.) Introduction

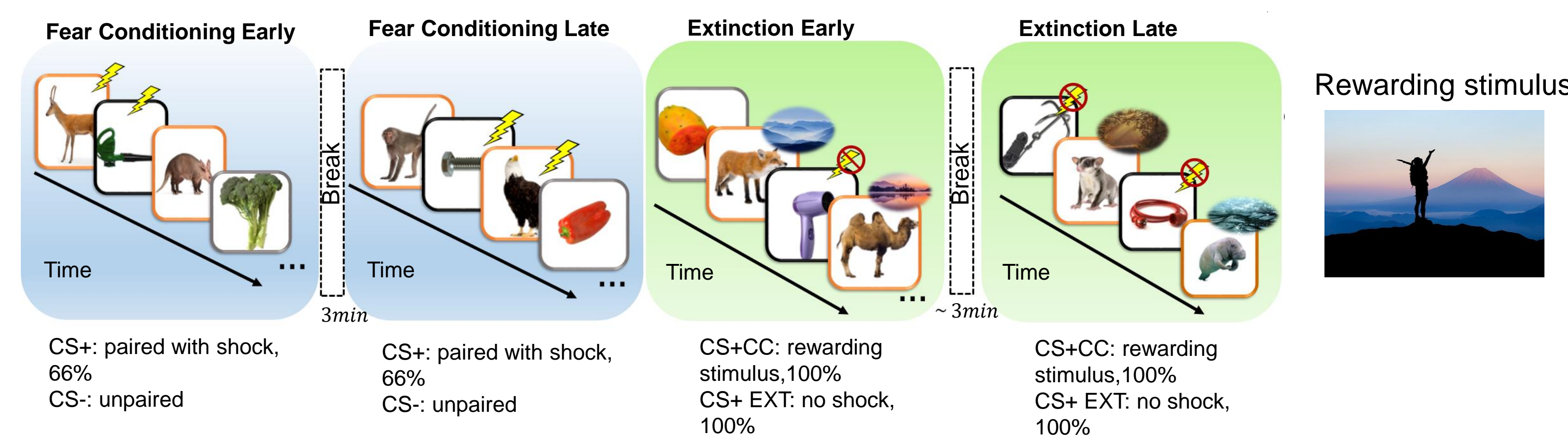
- Fear extinction is not unlearning, and extinguished behaviors can re-emerge through spontaneous recovery, contextual renewal or fear reinstatement.
- Previous studies in rodents have shown that pairing reward with fear extinction training reduces the return of fear that normally follows extinction training (Correia et al, 2016).
- A within-subjects study in humans found that reward enhanced explicit episodic memory of extinction and reduced conditioned fear renewal relative to standard extinction (Keller et al, 2019).
- Despite the fact that a lot is known on the neural correlates of fear extinction, very little is known on the neurobiology counterconditioning (CC) in the brain.
- **Research goal:** using fMRI in humans, investigate if reward reduces fear more effectively than standard extinction and determine the correlates of counterconditioning, in comparison to extinction.

## 2.) Methods N=25

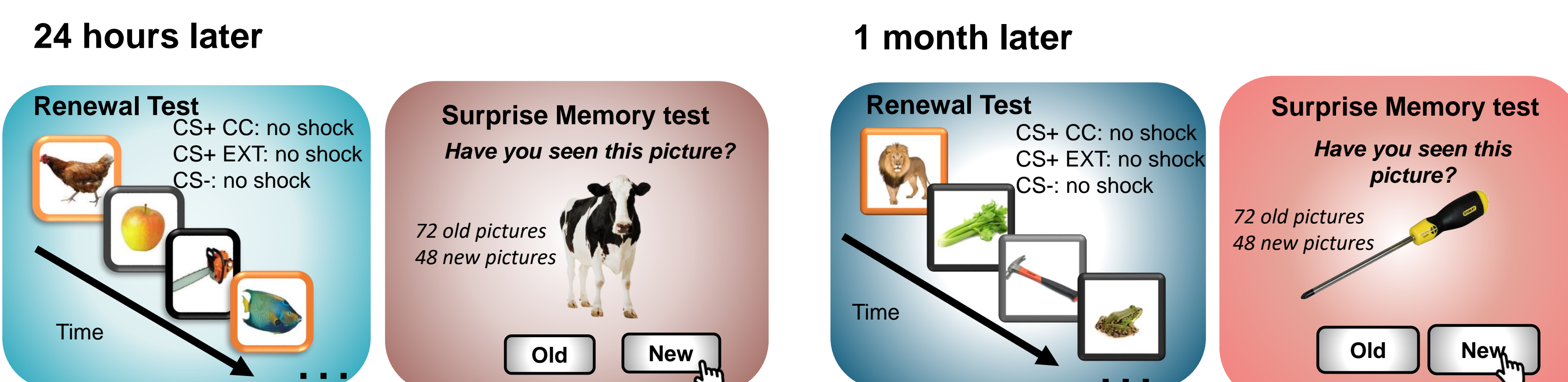
**Task: three session Pavlovian fear conditioning design**



**Day 1: Fear Conditioning and Extinction/Counterconditioning**



**Day 2 and ~ 1 month later: Fear Renewal Test and Episodic Memory**

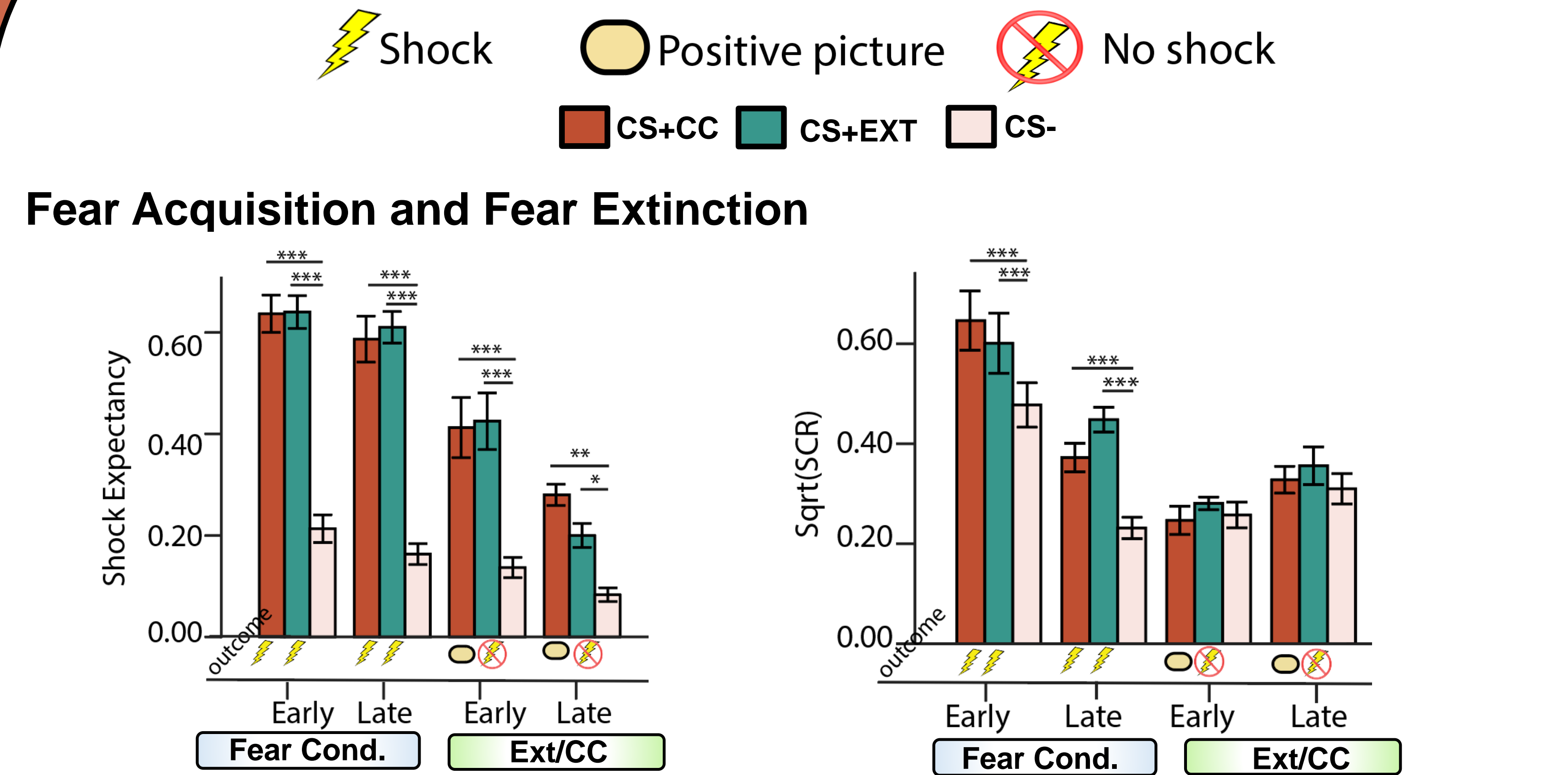


**Stimulus material:** 144 basic-level exemplars of animals and tools and food (72 each). Animals and tools as CS+, food as CS- (6 s duration). CS+ CC and CS+ EXT, counterbalanced (animals and tools). CS+CC: fear conditioned exemplars that were paired with a rewarding stimulus in lieu of shock during extinction. CS+EXT: fear conditioned exemplars that were paired with no shock during extinction. CS-: unpaired category.

**fMRI acquisition:** Scanning was completed using the Siemens Vida 3T MRI scanner. Functional data were acquired with a 64-channel head-coil. Functional image resolution was 2.5mm isotropic voxels (TR = 1s).

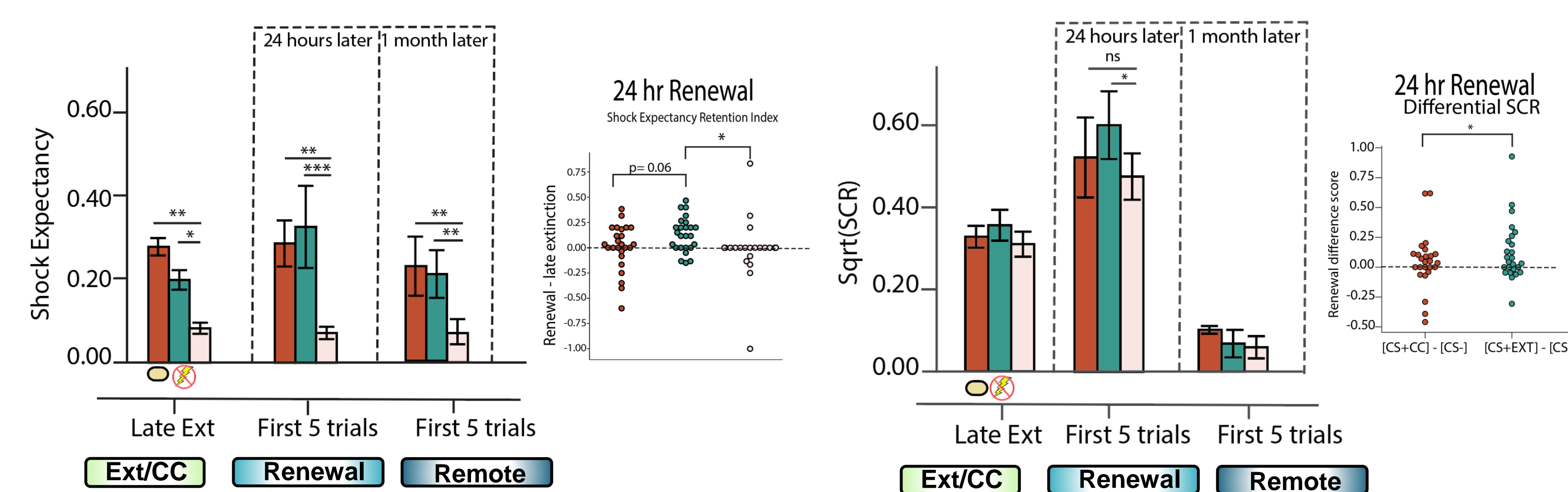
**GLM analysis:** Analysis of the preprocessed data included GLMs with separate regressors for each stimulus presented (CS+CC, CS+EXT and CS-) during fear acquisition, fear extinction, and fear renewal 24 hours later and 1 month later.

## 3.) Behavioral Results



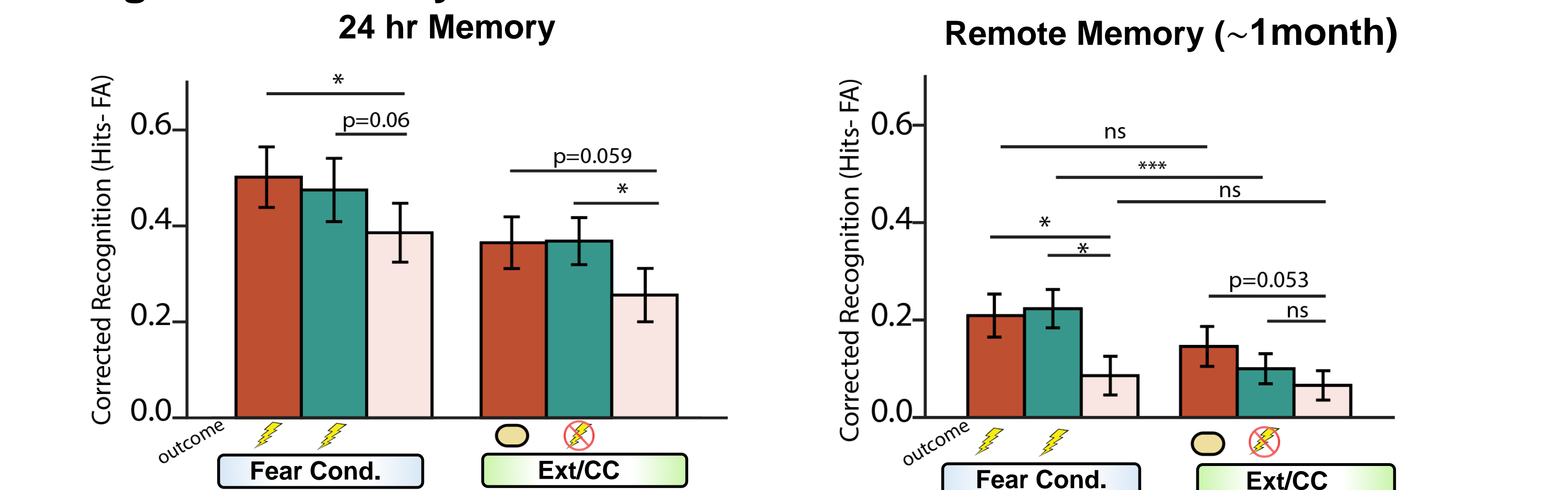
**Take home:** Mean shock expectancy ratings, and SCRs of CS+ vs. CS- during fear conditioning confirmed successful acquisition and extinction of fear.

**Fear Renewal: 24 hrs and ~1 month later**



**Take home:** 24 hrs later, implicit (SCR) and explicit (shock expectancy) fear renewal was reduced for CC stimuli in comparison to EXT. 1 month later there was no fear renewal to any stimuli.

**Recognition Memory**



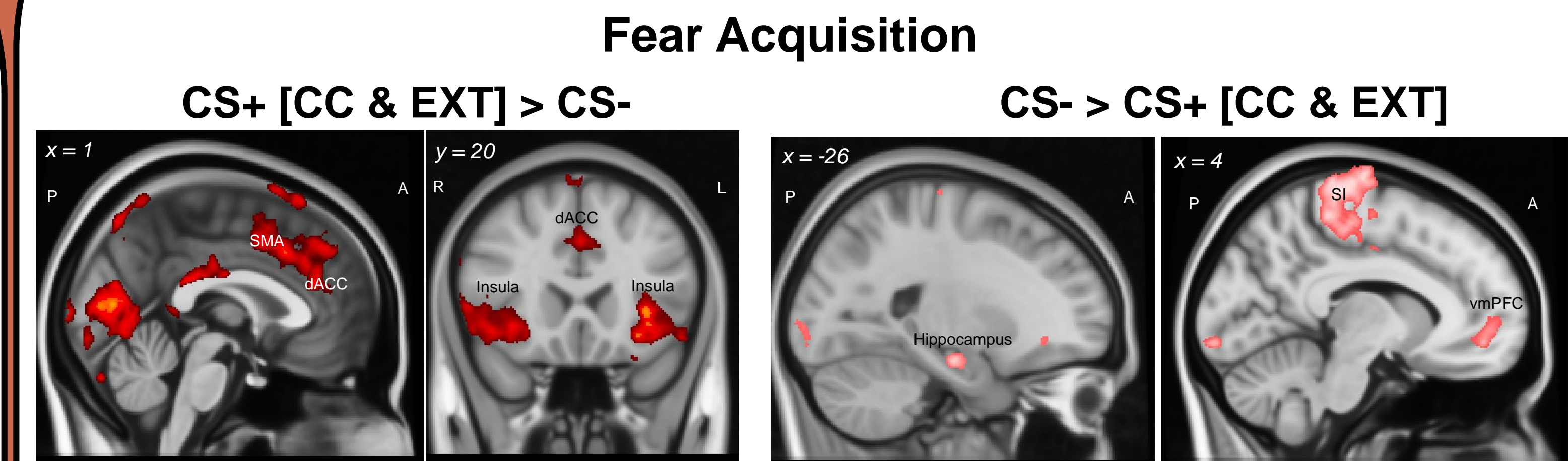
- **Take home for 24 hr memory:** there is selective enhancement of memory for CS+ items during fear conditioning, replicating previous findings.
- **Take home for remote memory:** reward mitigated the drop in memory from fear conditioning to extinction.

## 4.) Conclusion

- **Behavior:** Counterconditioning reduced the return of fear more effectively than standard extinction.
- **Memory:** Reward mitigated the drop in memory from fear conditioning to extinction at a long term memory test.
- **fMRI:** fMRI results reveal that compared to standard extinction, rewarded extinction mitigates the involvement of brain areas traditionally involved in threat acquisition, and activates the amygdala, parahippocampal gyrus and occipital fusiform gyrus during renewal, areas implicated in extinction recall.

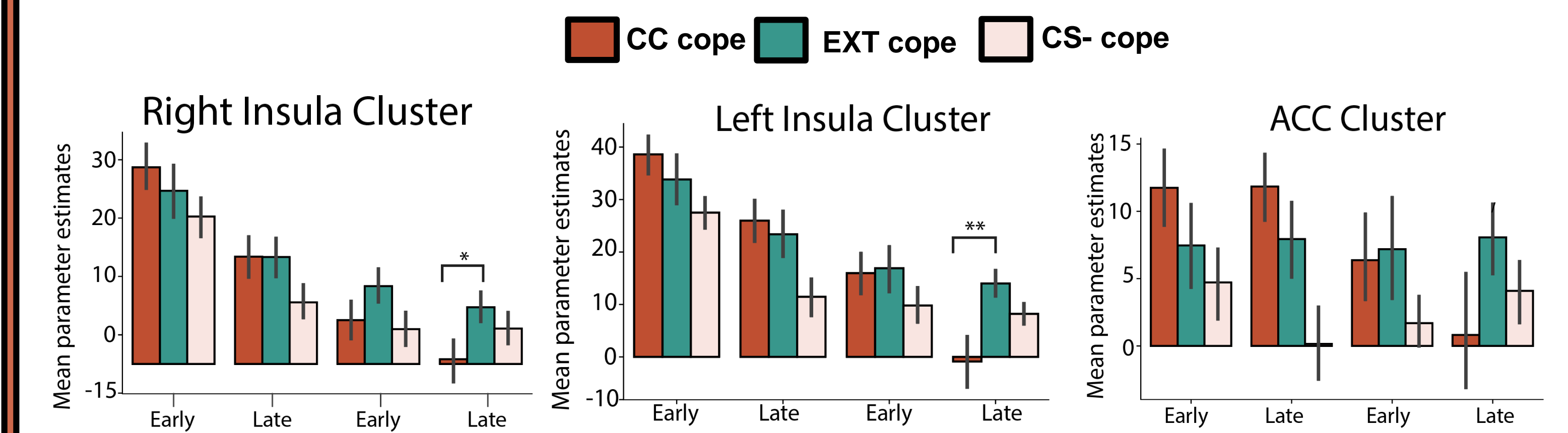
## 4.) Whole-brain fMRI Results

Single-Group Average (One-Sample T-Tests); Threshold  $p < 0.001$ , uncorrected



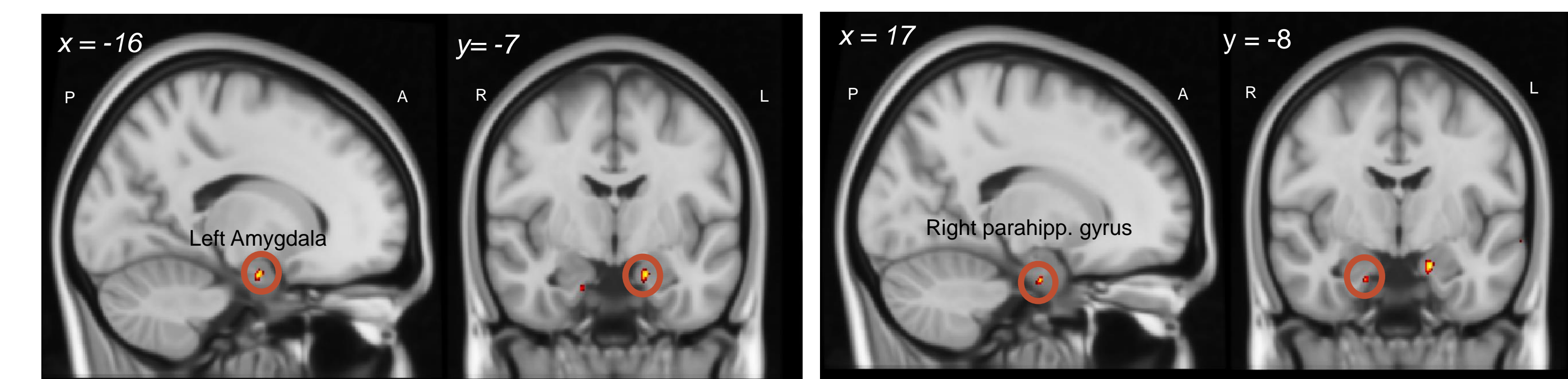
**Take home:** Threat conditioning [CS+ > CS-] and the inverse contrast [CS- > CS+] revealed activity in regions which are consistently implicated in fMRI studies of human conditioning (Sehlmeyer et al., 2009; Mechias et al., 2010; Fullana et al., 2016).

**Regions involved in threat acquisition (CS+>CS-)**



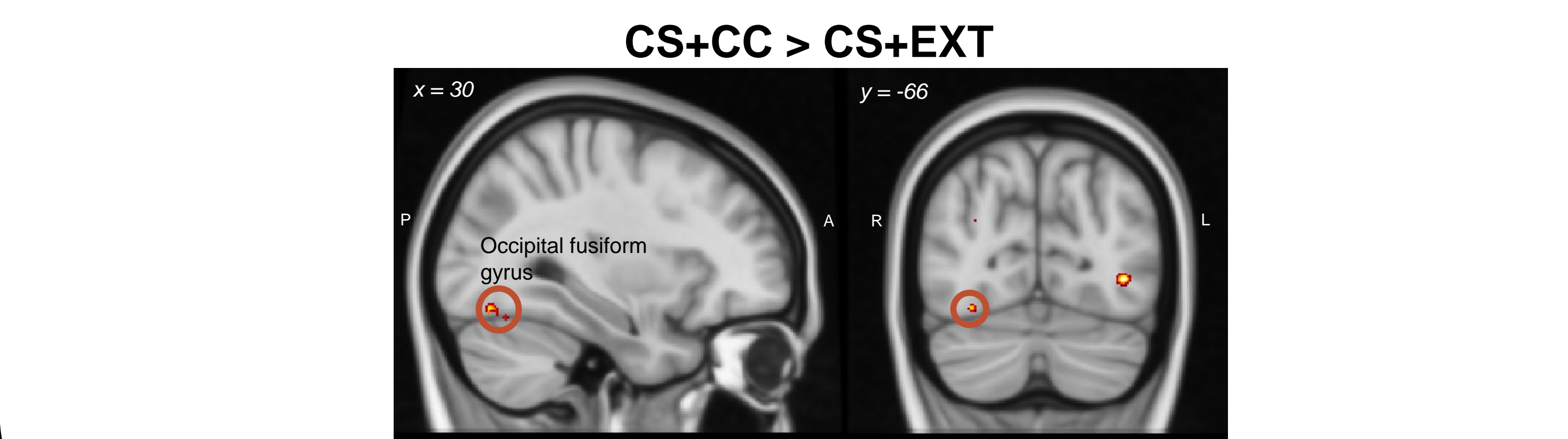
**Take home:** A parameter estimate analysis using regions active during fear conditioning revealed lower activity for CC items in comparison to EXT items during late extinction.

**CS+CC > CS+EXT Fear Renewal-24 hours later**



**Take home:** During fear renewal, a contrast of novel stimuli from the CC category - EXT category revealed activity in the amygdala and parahippocampal gyrus.

**Fear Renewal-1 month later**



**Take home:** One month later, stimuli from counterconditioning category activated the left fusiform gyrus significantly more than stimuli from the standard extinction category.

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