



# The Elusive Effects of Anxiety on Reinforcement-Learning

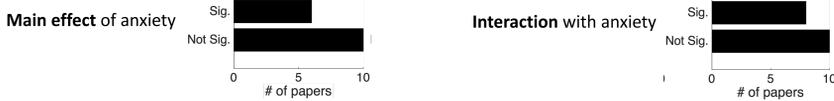
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## Introduction

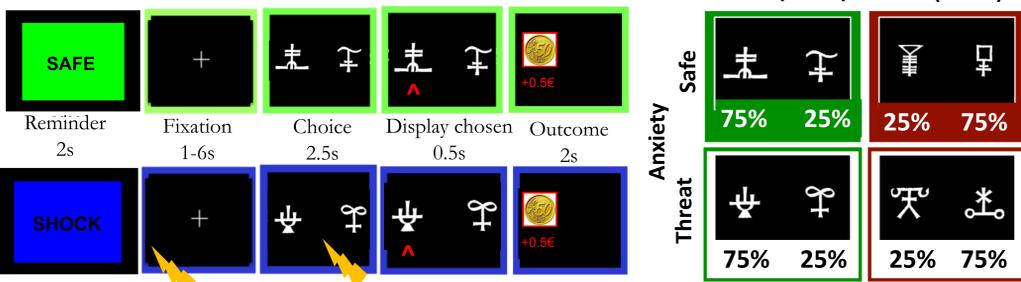
- Anxiety not only represents an emotional state, but is frequently accompanied by alterations in decision-making.
- It is still unclear how anxiety impacts value-updating, such as learning about probabilistic rewards and punishments.
- Prior studies have yielded conflicting effects of anxiety on learning performance.



- Four issues might cause contradictory results in prior research:
  - Most of threat induction paradigms perform at beginning of task. (e.g., Cold pressor Test, Trier Social Stress Test).
  - Focus on either learning or post-learning performance.
  - No separate investigation of reward and punishment learning.
  - Lack of computational characterization to provide parsimonious explanations.

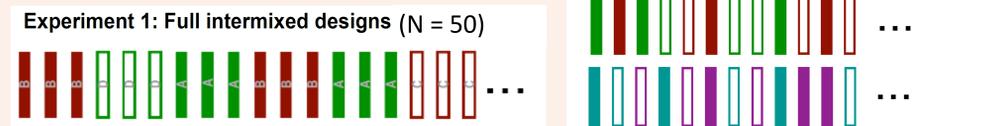
## Experimental design

### Learning task



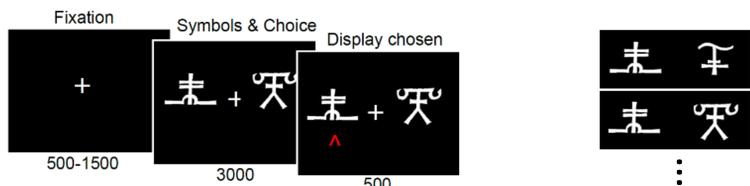
- 100 Subjects completed a probabilistic instrumental learning task in both safe and threat conditions.
- Incidental anxiety was induced through Threat of Shock (ToS) and maintained for the duration of threat condition.
- 2 x 2 within-subject design with 20-24 trials per condition.
- When the safe condition switches to threat condition, or vice versa, the reminder sign was displayed.
- Skin conductance was recorded through the learning task.

### Two variants of the ToS procedure



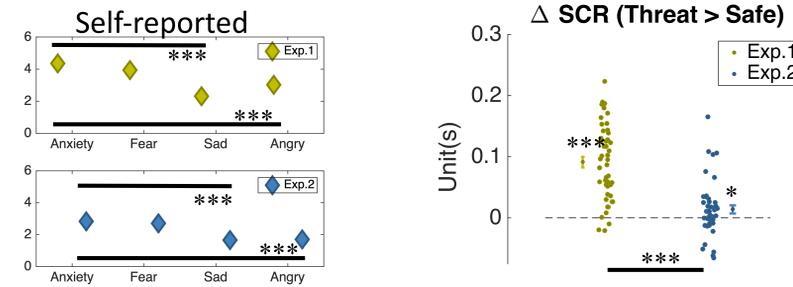
- Anxiety was induced in both short chunks of trials (experiment 1) and full learning session (experiment 2).

### Post-Learning task



- Task: Choose the more advantageous symbol as they can benefit from it.
- Each symbol was combined with other symbols and repeated four times.
- No feedback and no shocks in the post-learning task.

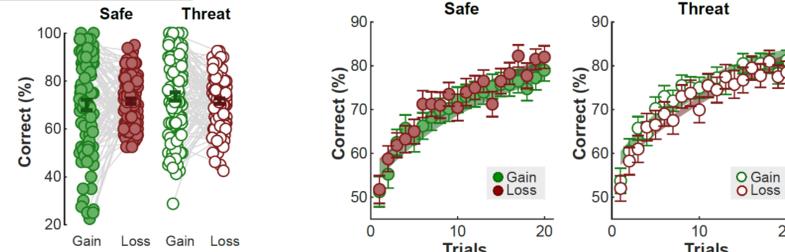
## Manipulation check



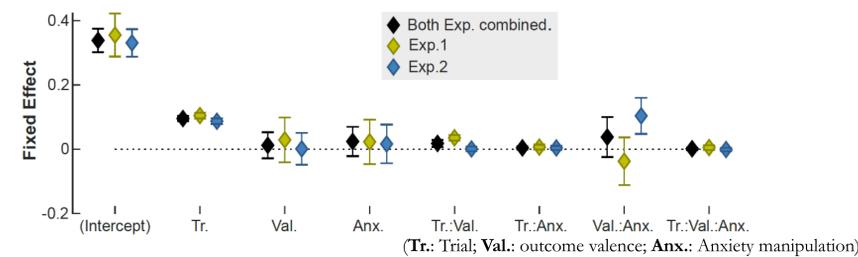
- Threat condition induced higher level of anxiety rather than other negative and high-arousal emotions.
- Skin conductance responses (SCR) results showed higher anxiety in threat condition than in safe condition.
- The results are consistent between two experiment and the anxiety level in Experiment 1 is higher than Experiment 2.

## Results: Model-free analysis

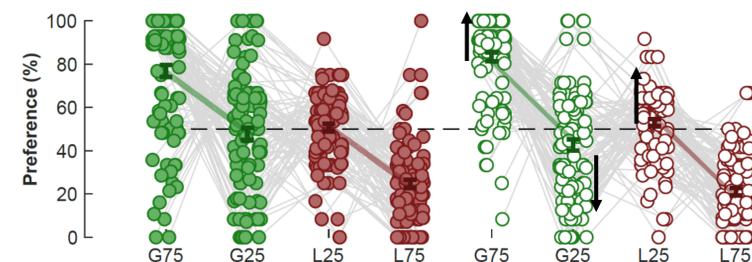
### Learning task



- No main effect of threat of shock, outcome valence nor their interaction on choice ( $P_s > .20$ ).
- Trial-by-trial analysis with generalized linear mixed (GLME) model only found the significant main effect of trial ( $T_{15992}=12.23$ ;  $p < .001$ ).
- Both trait anxiety (i.e., BAI score) and Experiment (i.e., Exp.1& 2) have no significant effect on choice.

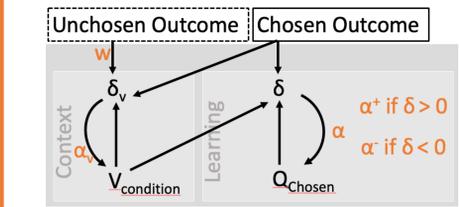


### Post-Learning task



- The symbol with the highest expected value was selected most of the time.
- Anxiety significantly increases preference of the better options.
- Subjects preferred Loss 25% to Gain 25% when symbols were learnt in threat condition.

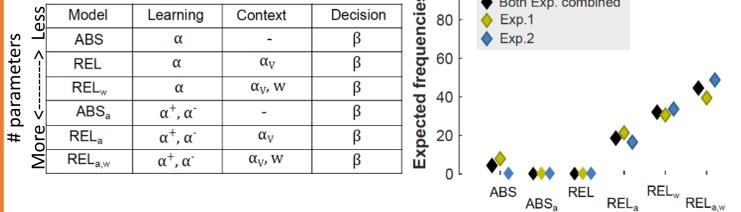
## Results: Model-based analysis



Q = option value  
 V = context value  
 $\delta$  = prediction error  
 $\alpha$  = learning rate

- Two-step computational modelling:
  - **Step1:** Identifying core parameters regardless of anxiety.
  - **Step2:** Dividing each core parameter into safe and threat.
- The winning model was selected through *model comparison*, assessment of *identifiability* and *parameter recovery ability*.

### Step1



- Parameters were estimated by likelihood maximization.
- The winning model (REL<sub>a,w</sub>) is the most complex one, which considers **asymmetric learning rates** and **context value**.

### Step2

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
$\beta$	fixed	S/T	fixed	fixed	fixed	fixed
$\alpha^+$	fixed	fixed	S/T	fixed	fixed	fixed
$\alpha^-$	fixed	fixed	fixed	S/T	fixed	fixed
$\alpha_v$	fixed	fixed	fixed	fixed	S/T	fixed
w	fixed	fixed	fixed	fixed	fixed	S/T

- Inconsistent results from model comparison.
- Some models cannot be perfectly identified.

## Discussions

- Systematically investigated the impact of anxiety on learning by improving experimental design and analyses.
- Limited effect of incidental anxiety on learning *per se*.
- Significant improvement in choosing the better options during the post-learning task.
- The results are in line with theories suggesting salience of reward and memory retrieval might be altered by anxiety.
- The easy learning task requires the most complicated model to explain choices from learning and post-learning.
- The misidentification suggests that those parameters have a small effects on the behavior.

## Reference

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