Neural Mechanisms Underlying the Impact of Pavlovian Observational Learning on Decision Making

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Abstract

Increasingly, modern humans encounter threats indirectly, through social networks and media, affecting their behavior significantly which can increase anxiety and affect subsequent decision making. However, the underlying neural mechanisms are unclear. This study investigates how observational threat learning shapes instrumental decision-making (threat avoidance learning) and its neural basis. During neuroimaging 44 participants observed others experiencing threats, which enhanced subsequent instrumental learning, especially when observational Pavlovian cues aligned with instrumental outcomes—an effect absent without observational learning. Computational modeling indicated arbitration between observational Pavlovian and instrumental values. Neuroimaging revealed that periaqueductal gray (PAG) activity correlated with observational aversive prediction errors, which in turn affected subsequent decision-making. These findings suggest that the PAG plays a critical role when socially acquired threat information shapes instrumental threat avoidance.

Keywords: Social aversive learning; fMRI

Introduction

Modern humans increasingly learn about fear eliciting events (e.g., terrorist attacks) in a second-hand fashion, through social networks and mass media, and adjust behavior based on vicarious experience (Neria & Sullivan, 2011). Such observational threat learning can facilitate or impede subsequent decisions aiming to avoid threat (Lindstrom et al., 2019). The underlying neural mechanisms remain to be investigated. In this study, we used neuroimaging and investigated how Pavlovian observational threat learning impacts subsequent instrumental threat avoidance at the behavioral and neural level.

Methods

We scanned 44 participants in an Experimental and a Control condition. In the Experimental condition, Social Threat conditioning preceded Decision-Making (Figure 1). Social Threat conditioning consisted of Pavlovian observational threat learning where participants watched videos in which a demonstrator was probabilistically subjected to electric shocks after one conditioned stimulus (CS+), while another stimulus (CS−) was not followed by shock. Next, they performed an instrumental threat avoidance task (Decision-Making), where they instrumentally learned associations between the previously observed stimuli and an aversive outcome (i.e., electric shock) for themselves.

The Decision-Making part was further divided into a Congruent (n=22 participants -No Change group- experienced this phase in the initial Transfer block) and an Incongruent phase. In the Congruent phase, the previously observed CS+ was associated with a higher probability of shock than the previously observed CS-, such that Pavlovian and instrumental learning were aligned. In the Incongruent phase (the other n=22 participants -Change group- experienced this phase in the initial Transfer block), the previously observed CS− was associated with a higher probability of shock than the previously observed CS+, such that Pavlovian and instrumental learning were misaligned. Regardless of which phase was experienced first, they were reversed halfway through the Decision-Making part (Reversal block).

In the Control condition, the structure of the Decision Making part was identical, but not preceded by observational threat learning. Instead, participants were exposed to the two stimuli as often as in the Experimental condition prior to the Decision-Making part. This allowed us to compare instrumental learning with and without previous observational threat learning.

Results

Behavioral: We found that Pavlovian observational threat learning affected subsequent instrumental threat learning (Figure 3). In the Experimental condition, instrumental learning performance in the Congruent phase was higher than in the Incongruent phase during the Transfer block, but this difference diminished during the Reversal block (Congruent/Incongruent x Transfer/Reversal: Z=3.47, p=0.001). By contrast, this pattern was not found in the Control condition (Z=-.22, p=0.63). Thus, prior Pavlovian observational threat learning preferentially affected the initial Transfer phase of subsequent instrumental threat avoidance learning.

Computational modelling: The computational model (Figure 2) combined Pavlovian observational threat learning and instrumental learning. It assumes that the two forms of learning are arbitrated by weight (ω) and thereby commonly affect decision making. This model explained behavior well, and better than alternative models using only instrumental learning($\Delta DIC = 58$).

Neuroimaging: Prediction errors during Social Threat conditioning correlated with periaqueductal gray (PAG) activity (Figure 4). Importantly, this activity was associated with the weight given to Pavlovian versus instrumental values during Decision Making (r = 0.429, p < 0.01): the more sensitive PAG activity was to aversive prediction errors during observational threat learning, the more strongly Pavlovian values affected subsequent instrumental threat learning. Together, these findings suggest that the PAG is centrally involved in the social learning of threat and the subsequent use of the learned information for threat avoidance decisions.

Conclusion

We demonstrate that observational aversive learning impacts subsequent decision making. At the neural level, PAG activity encodes observational aversive prediction errors and the extent to which Pavlovian values influence subsequent instrumental threat avoidance learning. Our data suggest that PAG activity plays an important role in the transfer of observational threat to instrumental decision making.

Figures

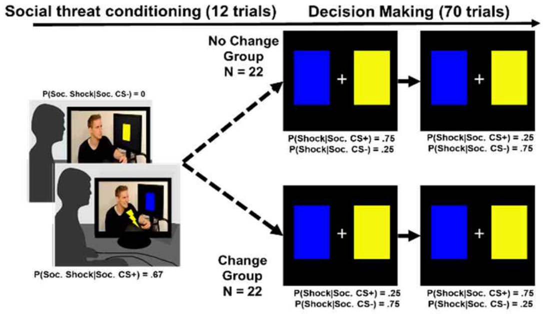

Figure 1: Experimental condition (Social Threat learning precedes Decision Making).

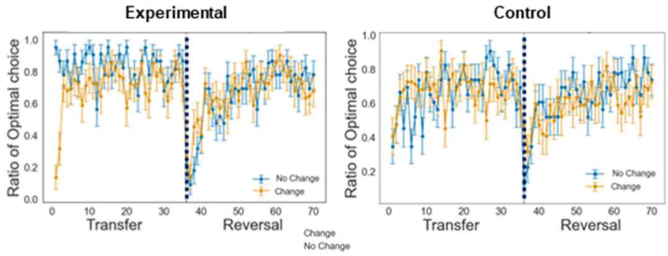

Figure 2. Learning performance in Experimental and Control conditions.

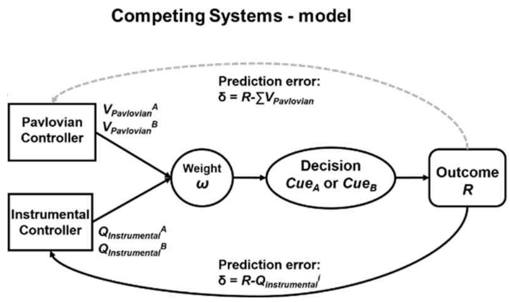

Figure 3. Computational model, where weight (ω) determines relative contribution of Pavlovian values to instrumental learning.

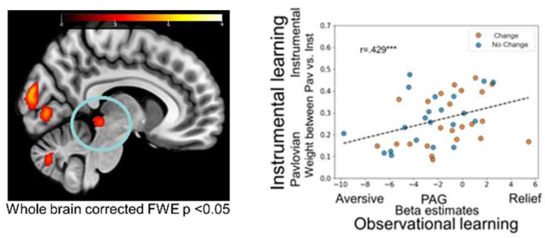

Figure 4. PAG activity associated with negative signed observational threat prediction errors during Social Threat Learning and correlated with weight (ω) parameter during Decision Making.

References

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