

Pessimism in future action leads to anxious behavior in a model of sequential decision making

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Summary

- Symptoms of anxiety (e.g. fear generalization, avoidance) are puzzling from a decision theoretic perspective.
- Misbeliefs about future action are commonly reported in clinical anxiety.¹
- We propose pessimistic beliefs about future action as a root cause of anxious symptoms, and formalize this in a reinforcement learning model.
- Our model ties together a large range of seemingly disconnected features of anxiety.

The challenge of anxiety

The family of anxiety disorders are characterized by several core symptoms:

- **exaggerated threat appraisals**, or a bias towards evaluating threat as disproportionately greater in likelihood and severity than is warranted;
- **fear generalization**, wherein the primary threat becomes associated with increasingly distal locations, events, and thoughts; and
- **persistent avoidance behavior**, which often occurs well in advance of the materialization of actual threat.

Laboratory studies of learning and decision making in anxious populations have corroborated these observations, but none have offered an explanation as to their cause.

Evaluation requires assumptions about future action

Anxious symptoms are puzzling from a decision theoretic perspective. Fear and avoidance of future threat violates the core logic of evaluation of sequential chains of action. This is because avoidance is by nature protective: **the ability to avoid danger in the future means an agent need not also do so now**.

This is apparent in the standard MDP models of decision making, i.e. agents learn to optimize the expected cumulative reward. Importantly, these formalisms require assumptions about future action, and we typically assume an agent makes the return-maximizing choice at each step in the future,

$$Q^*(s, a) = r(s, a) + \gamma \sum_{s'} p(s' | s, a) \max_{a'} Q^*(s', a')$$

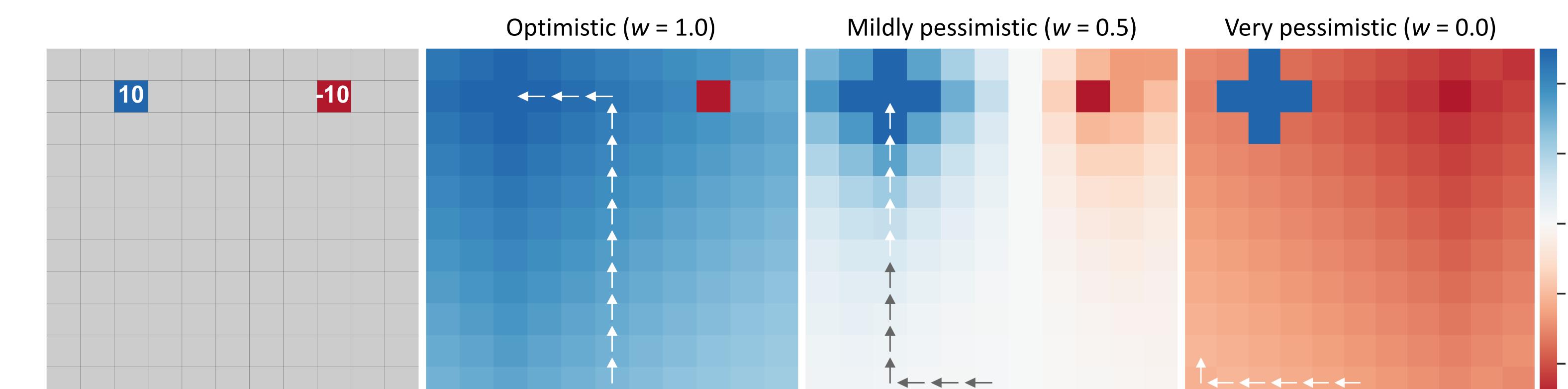
There is considerable evidence, however, that anxious individuals do not endorse such beliefs.¹ Here, we propose **erroneous pessimistic beliefs about future action as a root cause of anxious symptoms**. We adopt the **β -pessimistic** value function to define an expectation of state-action value,

$$Q^w(s, a) = r(s, a) + \gamma \sum_{s'} p(s' | s, a) f^w(Q_{s', :})$$

$$f^w(Q_{s', :}) = w \max_{a'} Q^w(s', a') + (1 - w) \min_{a'} Q^w(s', a')$$

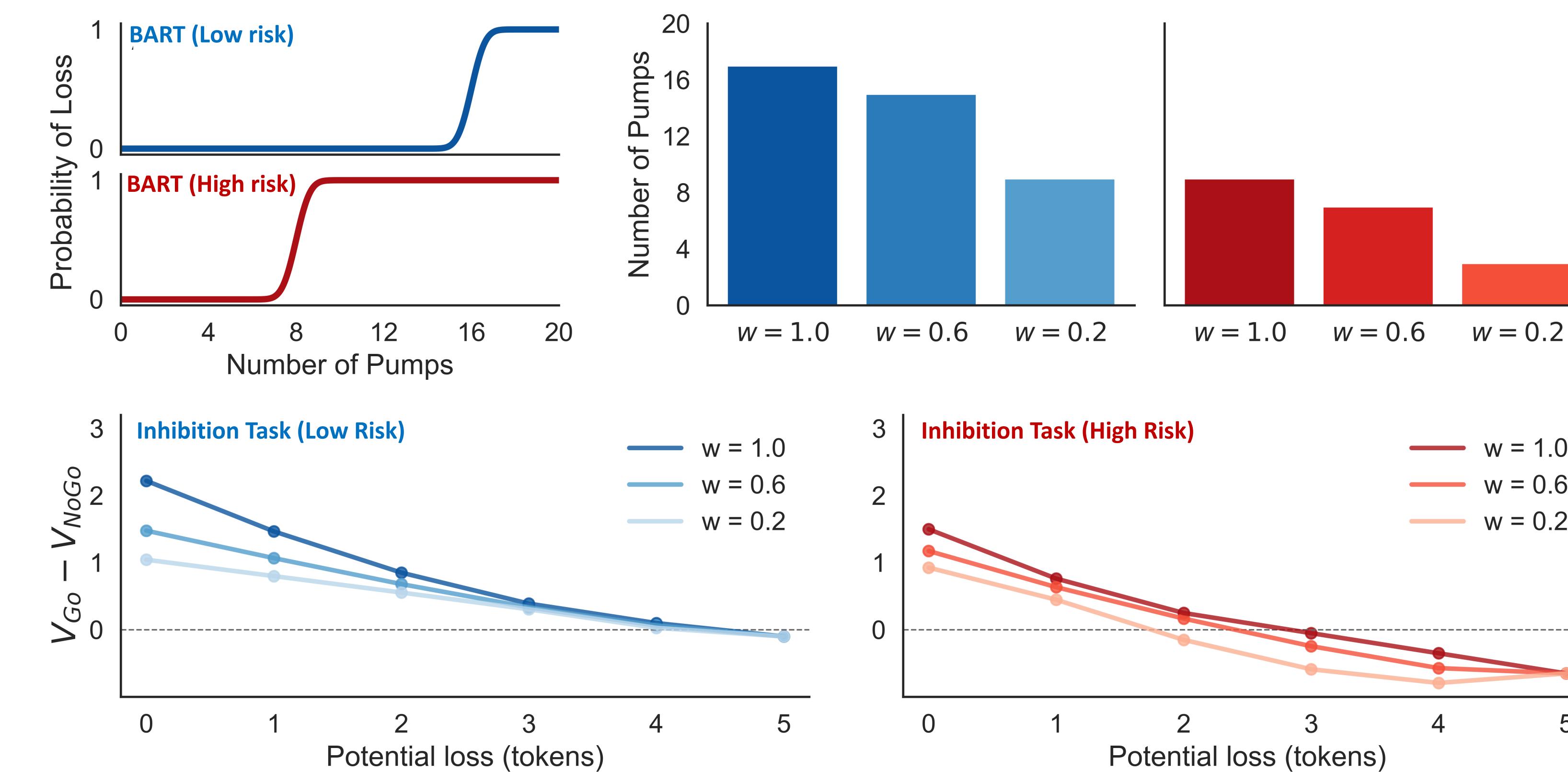
where w allows for weighting between the best (optimistic) and worst (pessimistic) next action.

Threat value spreads when future avoidance is not guaranteed



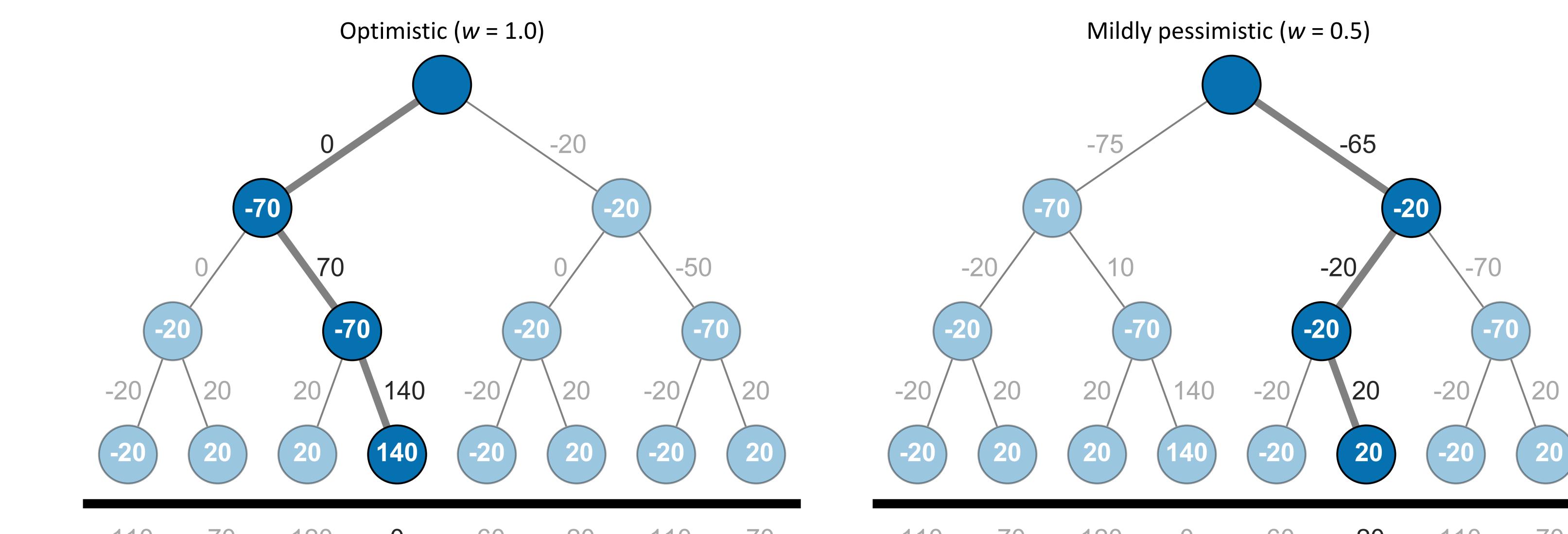
- When an agent believes future self-action is reliable, and successful avoidance guaranteed, threat is isolated and reward value pervades the state space.
- Under pessimistic assumptions, such that the efficacy of future self-action is in doubt, threat value pervades the state space.
- Pessimistic evaluation yields the core symptoms of anxiety: exaggerated threat appraisals, fear generalization, and persistent avoidance.

Pessimistic evaluation results in approach-avoidance imbalance



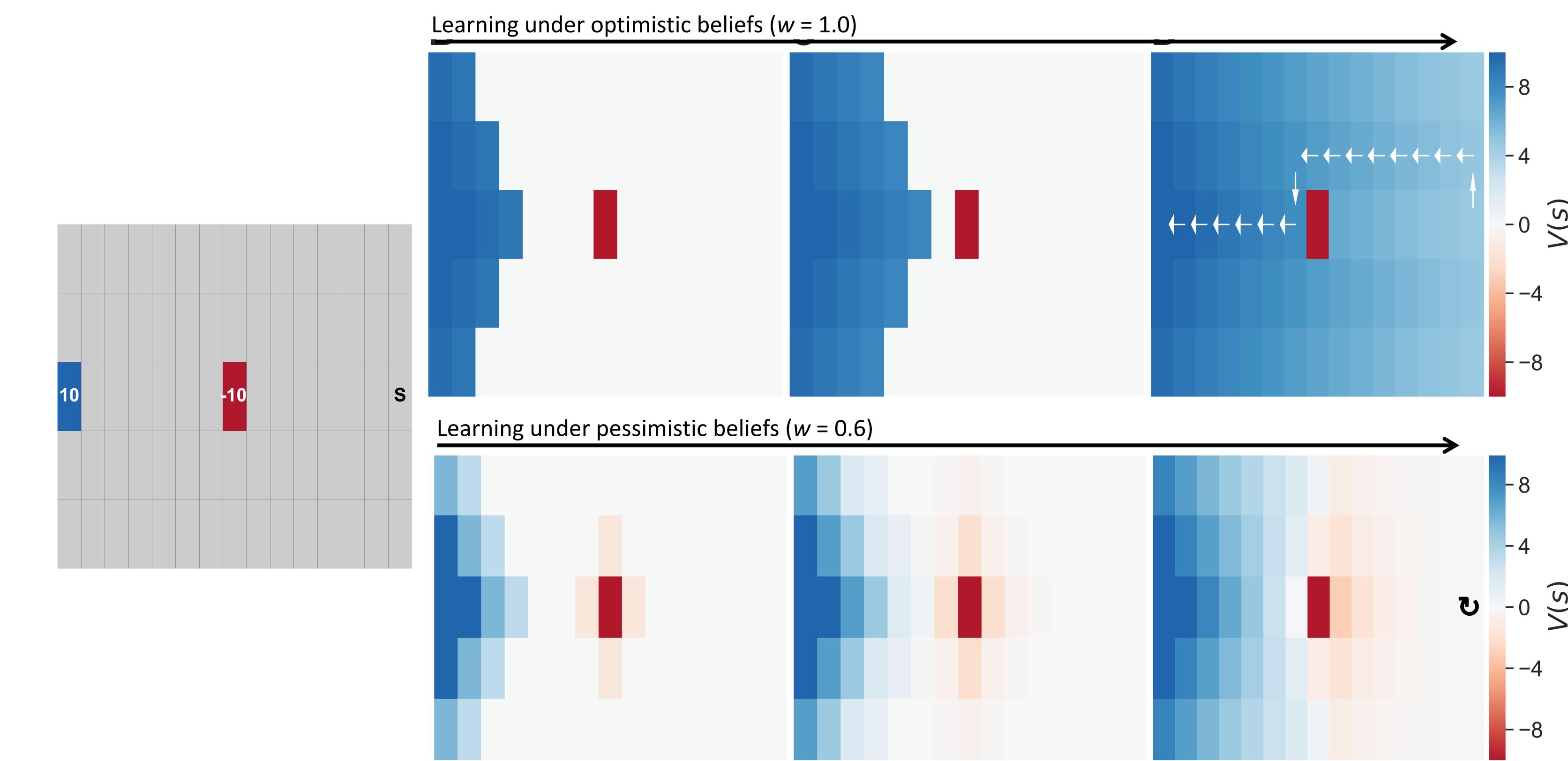
- Anxiety is associated with biased resolution of approach-avoidance conflict, as has been observed in several paradigms.²⁻⁴
- Our model predicts earlier avoidance for anxiety on the balloon analog risk and predator avoidance tasks (top) as it anticipates and avoids future errors in choice which would otherwise result in loss.
- Our model explains prolonged response times for anxiety on the behavioral inhibition task (bottom) as the relative value of approach compared to avoidance is reduced under pessimistic assumptions.

Pessimistic evaluation leads to risk-averse planning



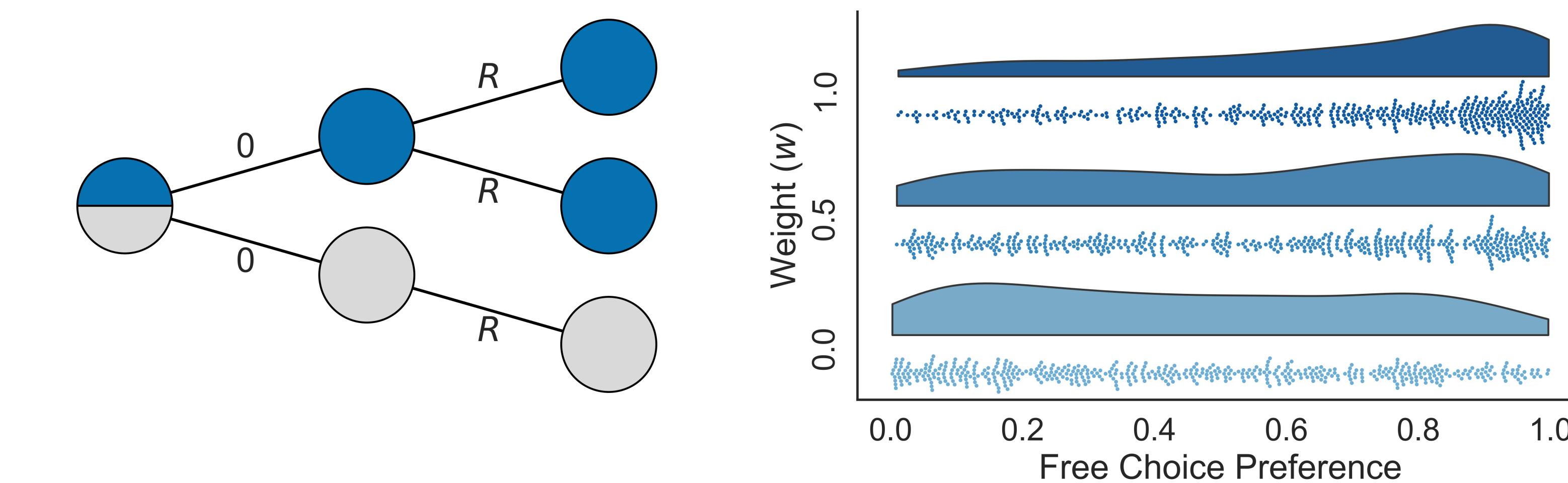
- Anxiety is associated with aversive pruning⁵, or discarding from further evaluation choice sequences involving large losses.
- Our model shows this behavior because, with increasing pessimism, agents increasingly expect to choose poorly after the large loss and fail to recoup the loss.

Pessimistic evaluation yields long-run depressive behavior



- Anxiety and depression are highly comorbid, and evidence suggests clinical anxiety precedes the onset of depression.⁶
- This is supported by our model: As threat value dominates the state space, an agent learns to expect reward is unavailable and subsequently shows depression-like anergic symptoms (bottom row).

Pessimistic evaluation predicts a reduction in the free choice bias



- Multiple studies⁷ have documented a free choice bias, i.e. a tendency to prefer choice options that lead to even more future choice (left).
- Our model predicts a reduction in this effect: If anxiety reflects a misbelief in future reward-maximizing action, then the value of future choice, and the free choice bias, should be diminished (right).
- We plan on testing this hypothesis in anxious populations in the near future.

Discussion and future directions

- Our new model – involving only a single deviation – unites a range of otherwise disconnected anxious behaviors, and formalizes clinical theory on the role of self-efficacy in anxiety disorders.
- The model predicts that pessimistic policies (*and pessimistic state-transition probabilities*) give rise to anxious behavior because successful avoidance of future threat not guaranteed.
- Future plans include integrating the clinical and safe reinforcement learning literatures, e.g. applying theory from robust control to model alternate value functions in anxious learning.

References

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