

An adaptive role for anhedonia following early-life unpredictability

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Abstract

Early-life unpredictability (ELU), a form of early-life adversity, is often followed by anhedonia in adulthood. Formal models show that efficient coding of ELU leads to asymmetrically greater sensitivity to negative, rather than positive, outcomes during learning, while models of consummatory anhedonia suggest that the experience of reduced pleasure can arise from “warping” internal representations of environmental states, so that goals seem more distant. Here, we use simulations to examine whether adopting an anhedonic belief about the state space adaptively reduces the hedonic asymmetry that results from ELU. Combining these two computational frameworks, we show that warping both substantially reduces perceived hedonic experience but, critically, with the benefit of reshaping the valence between gains and losses. While belief-space warping attenuates both positive and negative prediction errors, it disproportionately suppresses negative outcomes and alters the tradeoff structure. Further, we found that distinct forms of belief-space warping can confer different adaptive advantages across environments. Taken together, these results suggest that anhedonic belief representations may alleviate the subjective impact of negative outcomes under ELU while also critically shaping behavior in threat-rich settings, offering a computational account of why anhedonia may be prevalent after unpredictable early-life experience.

Introduction

Anhedonia is often modeled as reduced reward sensitivity, and is a central transdiagnostic construct in affective disorders (Pizzagalli, 2022). A recent computational account models consummatory anhedonia as “belief-space warping.” In this framework, the experience of pleasure depends on perceived progress toward goals within an internal belief structure (i.e. pleasure is minimal when goals feel distant or unreachable, and increases when goals are near) (Hall et al., 2024). As a result, movement in any direction of a “warped” space provides little change in the expectation of eventual reward,

resulting in reduced hedonic prediction errors. This view connects anhedonia to work showing that momentary affect tracks recent reward expectations and prediction errors (Eldar et al., 2016; Rutledge et al., 2014).

We ask why such warping might be common following early-life unpredictability (ELU). ELU is a measurable dimension of adversity that involves fragmented and unpredictable early experience, and has been linked to adult neuropsychiatric symptoms, including anhedonia (Baram et al., 2012; Glynn et al., 2019; Hunt et al., 2026; Spadoni et al., 2022). We model ELU using a recent account in which temporal unpredictability produces elevated sensitivity to negative outcomes and reduced sensitivity to positive outcomes (Harhen & Bornstein, 2024). Motivated by recent evidence that anhedonia can buffer the effects of ELU in threat-reward foraging (Leonard et al., 2026), we tested whether belief-space warping can be adaptive given ELU-induced hedonic asymmetry, and whether this depends on environmental structure.

Methods

Agents performed goal-directed learning in a gridworld using temporal-difference updates, $V(s_t) \leftarrow V(s_t) + \alpha^\pm \delta_t$, where $\delta_t = r_t + \gamma V(s_{t+1}) - V(s_t)$. ELU was controlled by asymmetry A and learning-rate mass S , with $\alpha^+ = S/(1 + A)$ and $\alpha^- = A * S/(1 + A)$. Reward was defined as progress toward the goal, $r_t = d(s_t) - d(s_{t+1})$, where d is the distance from current state to goal state. We compared three belief spaces: Control, Dim-add, and Rejection. Dim-add increased representational distance to the goal; Rejection introduced repeated setbacks during goal pursuit (Fig. 1A). For each condition and $[A, S]$ pair, 3000 agents were simulated. Hedonic experience was measured from accumulated normalized prediction errors. We then repeated the simulation in a hazardous 10×10 environment where half of states carried large penalties.



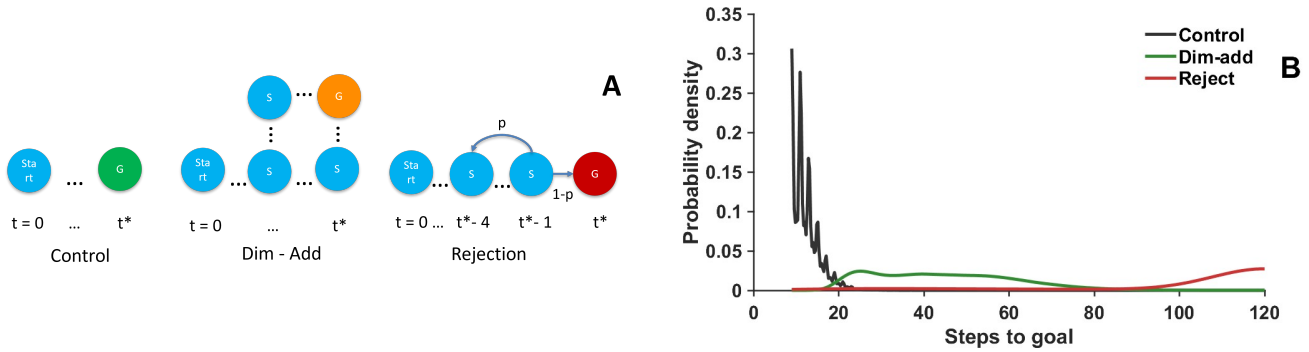


Figure 1: **Belief-space manipulation.** Dim-add and Rejection increased effective steps to the goal, operationalizing anhedonic warping as reduced reachability of rewarding states.

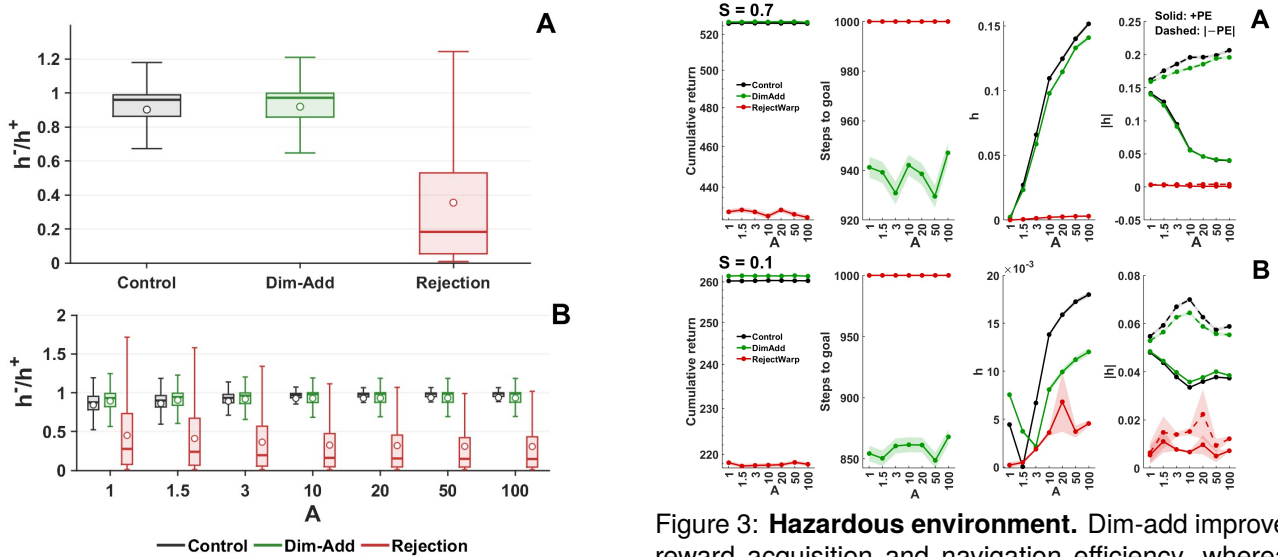


Figure 2: **Valence-specific effects.** Rejection reduced the negative-to-positive hedonic ratio.

Results

Belief-space warping increased perceived distance to goal: Control agents reached the goal quickly, Dim-add increased path length, and Rejection produced the longest trajectories, often reaching the step limit (Fig. 1B). Warping also altered hedonic balance. Rejection markedly reduced the negative-to-positive hedonic ratio (Fig. 2A), indicating stronger suppression of negative than positive experience; this effect persisted across the levels of ELU asymmetry, while control showed stronger negative hedonic dominance as A increased (Fig. 2B). In addition, both Dim-add and Rejection flattened the relation between positive and negative hedonic magnitude, suggesting that warping changed the structure of affective evaluation rather than simply scaling reward up or down.

In the hazardous environment, Dim-add improved cu-

mulative reward while reducing steps to goal, implying safer and more efficient navigation. Rejection, by contrast, primarily muted hedonic signals without improving behavior (Fig. 3).

Conclusion

Anhedonic belief-space warping was not uniformly adaptive or maladaptive. Given early-life unpredictability, warping reduced subjective impact of negative prediction errors conditioned on the form of warping and the environment. Rejection-like warping buffered negative experience in simple reward pursuit, whereas dimensional addition improved efficiency under hazard. This yields a testable prediction: anhedonia could be locally adaptive when its representational distortion matches current environmental structure, but pathological when it generalizes broadly and makes rewarding goals feel unreachable. Future work can examine belief-space warping using theory-guided tasks and neural measures of belief-state geometry (Schuck et al., 2016).

Acknowledgements

This work was supported by NIMH R01MH128306 (AMB; PI: MA Yassa) and R01MH061285 (AMB; PI: SJ Pollak).

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