Listening to dopamine: A corticostriatal circuit model of auditory hallucinations

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↑ striatal dopamine → Neural mechanism? → ↑ hallucinations

reward learning

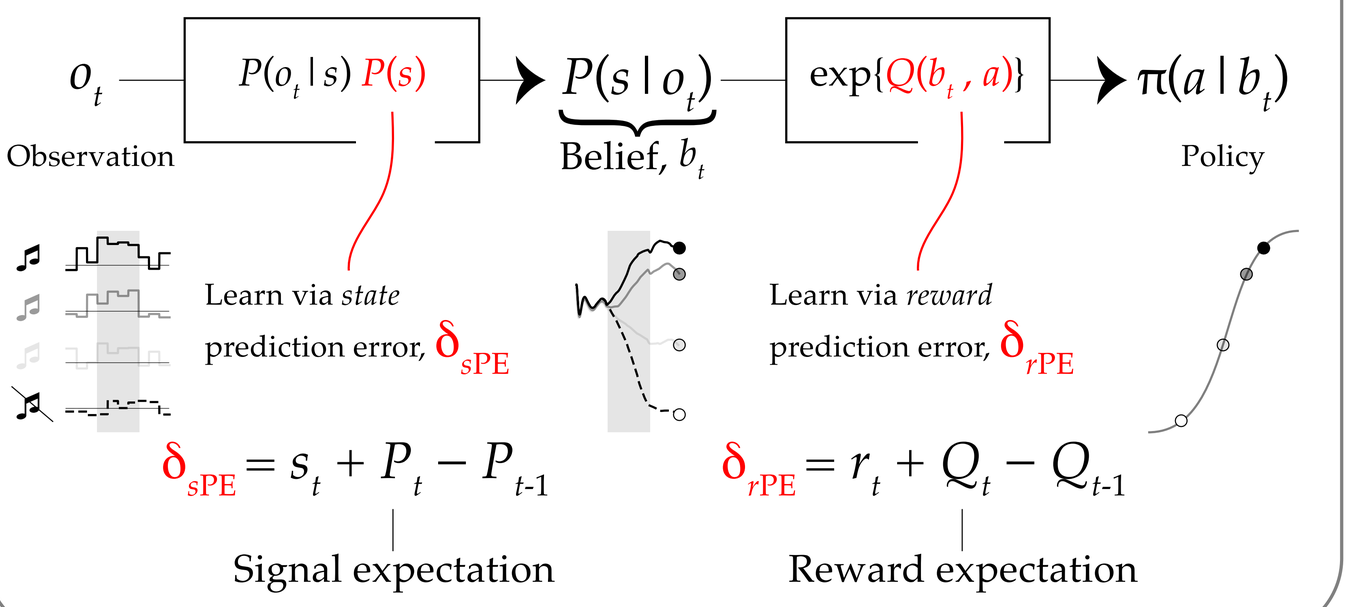
perceptual learning

Question: Striatal dopamine is thought to facilitate learning by encoding prediction errors. How could excess dopamine lead to hallucinations?

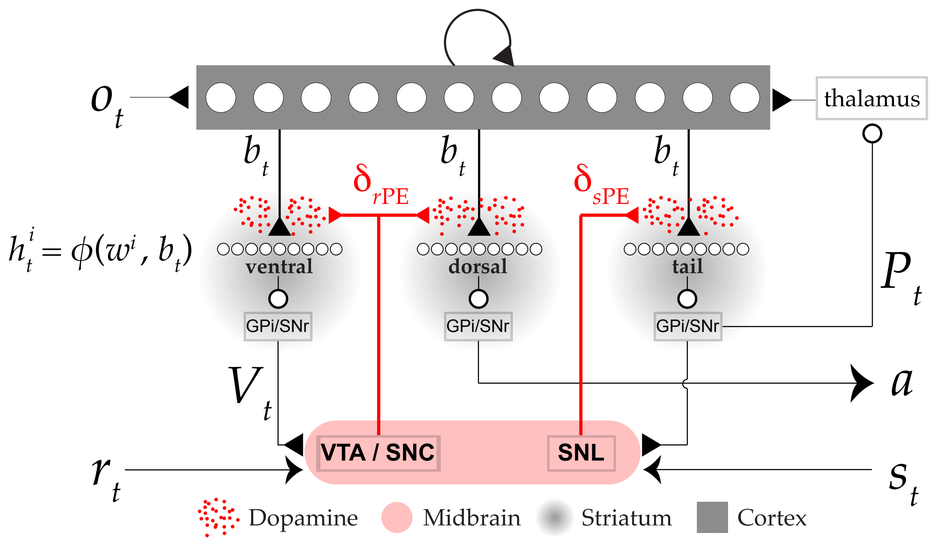
Hypothesis: Hallucinations arise specifically from excess dopamine in the pathway conveying prediction errors needed for learning to perceive.

Approach: Simulate a model of dopamine-mediated corticostriatal plasticity to combine traditional ideas on reward learning with evidence implicating dopamine in perceptual learning (Cassidy et. al. 2018, Schmack et. al. 2021)

Computational theory

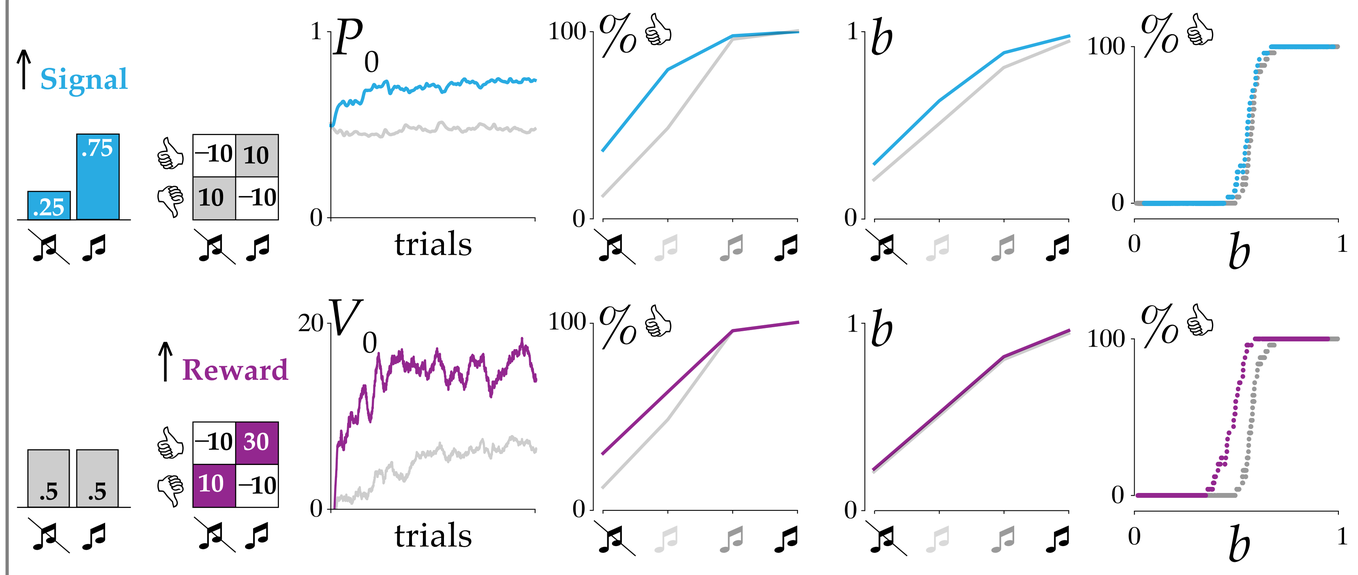


Neural implementation



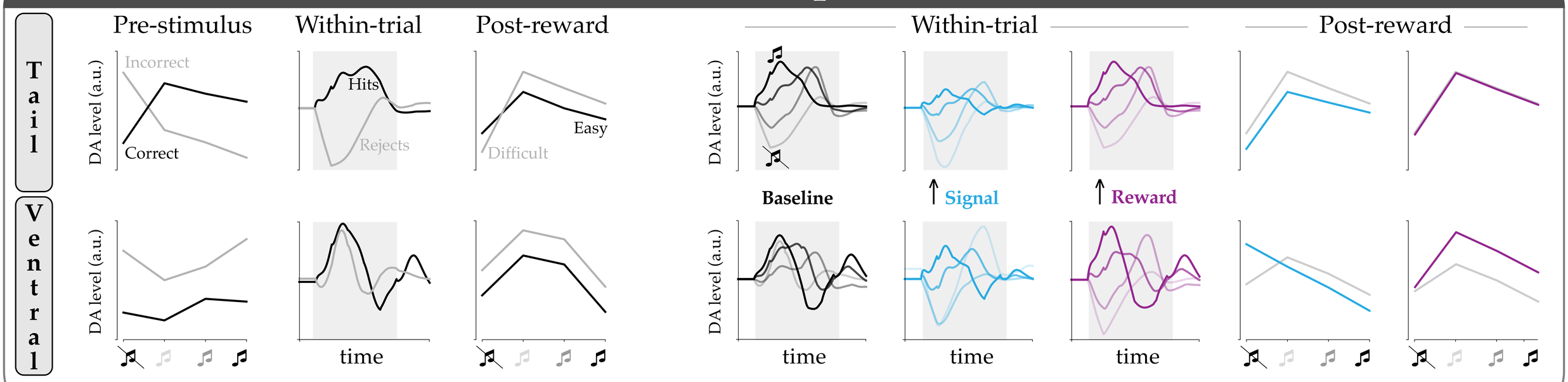
Corticostriatal plasticity rule : $\Delta w^i \propto \delta\ b_t\ \phi_i'$

Model performance



Biasing signal/reward statistics induces false alarms by changing beliefs/policy respectively

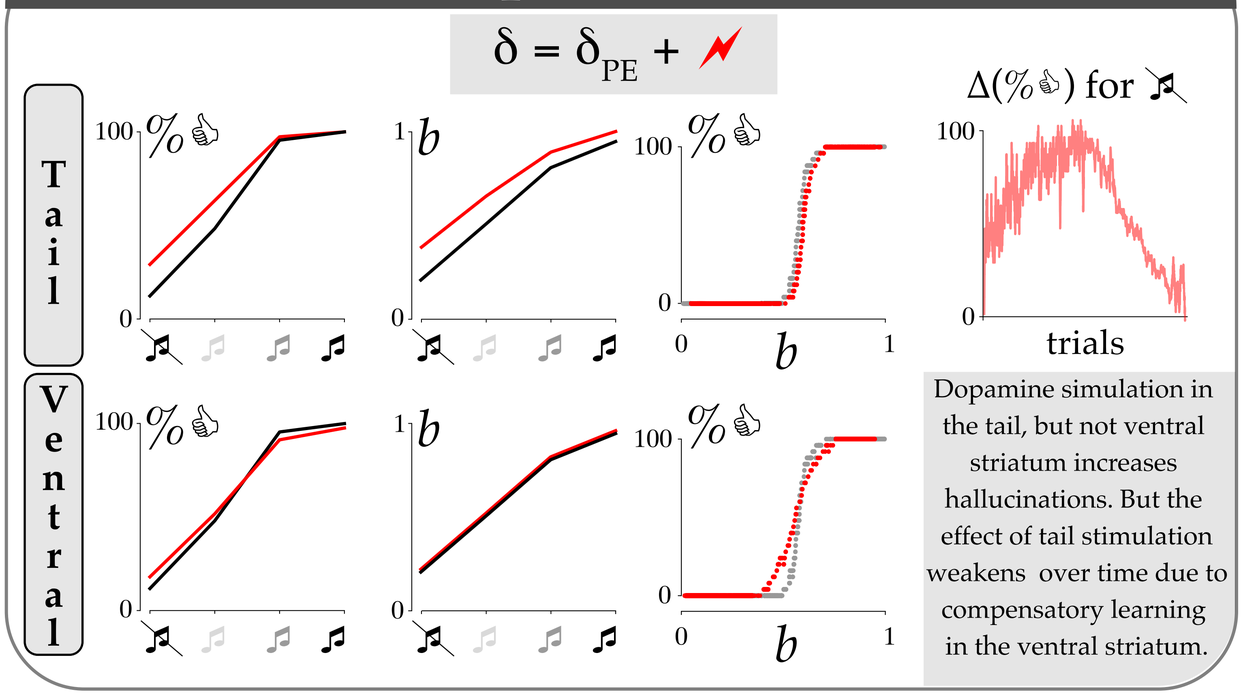
Functional dissociation between dopamine levels across the striatum



Dopamine in the tail/ventral striatum promote signal/win-stay choices

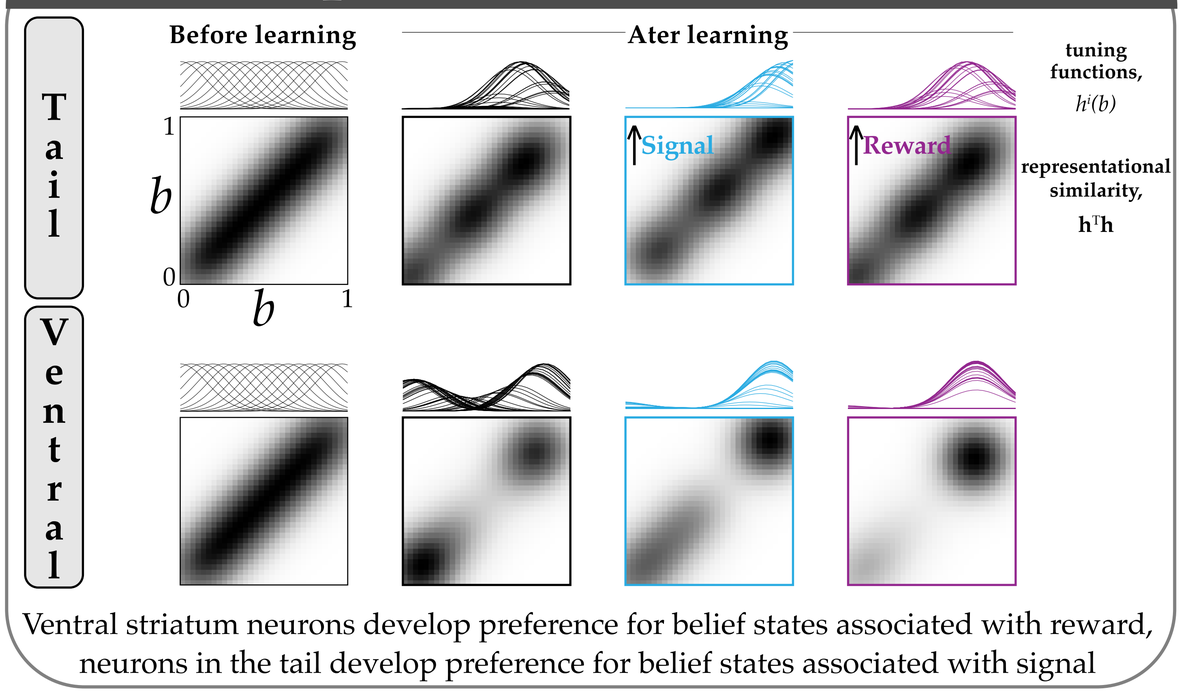
Unlike ventral striatum, dopamine in the tail is sensitive to signal but not reward manipulation

Effect of dopamine stimulation



Dopamine simulation in the tail, but not ventral striatum increases hallucinations. But the effect of tail stimulation weakens over time due to compensatory learning in the ventral striatum.

Neural representation in the striatum



Ventral striatum neurons develop preference for belief states associated with reward, neurons in the tail develop preference for belief states associated with signal

We simulated a biologically plausible corticostriatal model for learning an auditory detection task in which dopamine contributes to learning both signal statistics and reward statistics by mediating plasticity in the tail and ventral striatum respectively. The model recapitulates empirical data implicating excess dopamine in the tail in auditory hallucinations. The model makes concrete predictions for how learning should shape neural representations in the ventral and tail regions of the striatum.