The striatal feedback response reflects goal updating

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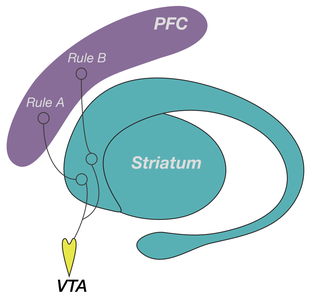
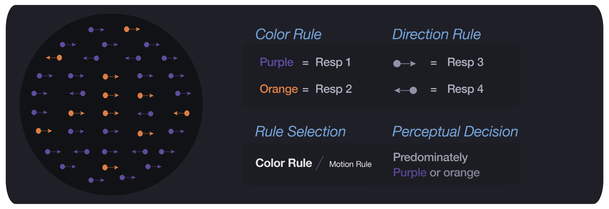
Motivation

1) The striatum is thought to gate the entry of information into cortical circuits[1].
2) Regions of the striatum targeted by prefrontal cortex could gate abstract goals and rules based on their reward values[2]
3) Testing this hypothesis is challenging because, in most tasks, gating is confounded with prediction error[3]



Task

Key Idea: The task dissociates rule updating from reward prediction error



Trial Structure

Stimulus + Response

Reward Feedback

Possible Feedback

"Incorrect"

Task Instructions **Actual sequence of reward feedback was identical between tasks*

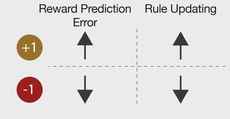
Switch Task

There is a good rule and a bad rule. The good rule always gives coins and the bad rule always loses coins. Unpredictably, the identity of the good and bad rule switches. When a good rule starts losing coins, that means that it is no longer good and you should switch rules.

Learn Task

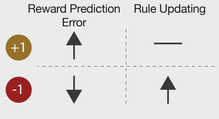
There is a better rule and a worse rule. The better rule usually wins gold coins but sometimes loses gold coins, and the bad rule usually loses coins but sometimes wins coins. Select the rule that earns you more coins more often, and loses you fewer coins less often. The better rule now may not be the better rule later.

Learn Task



****Prediction Error and Rule Updating are confounded***

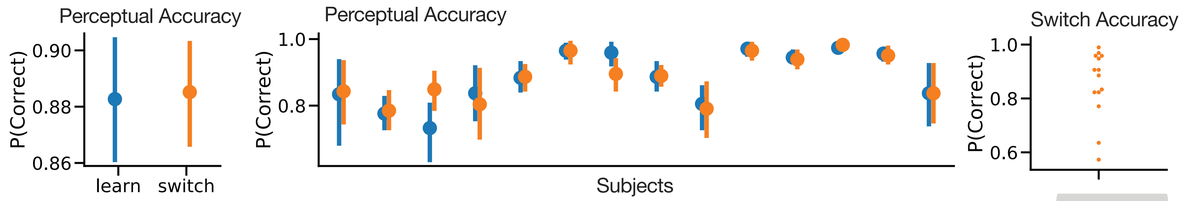
Switch Task



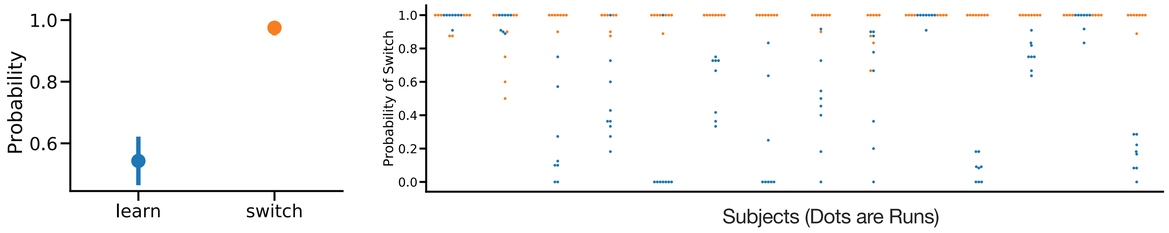
****Prediction Error and Rule Updating are dissociable***

Behavioral Results

Accuracy



Probability of Switching Rules After Negative Feedback



Neural Results

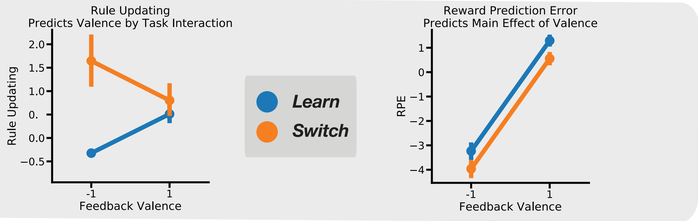
Model Based Predictions

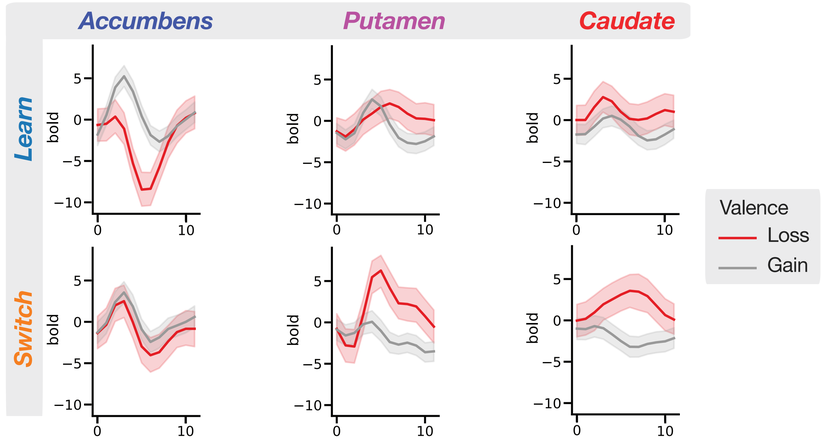
Q-learning model fit to task

$\alpha_{switch} = .8 \quad \alpha_{learn} = .2$

Rule confidence $= | Q_{color} - Q_{motion} |$

Rule Updating $= \Delta$*Rule Confidence*





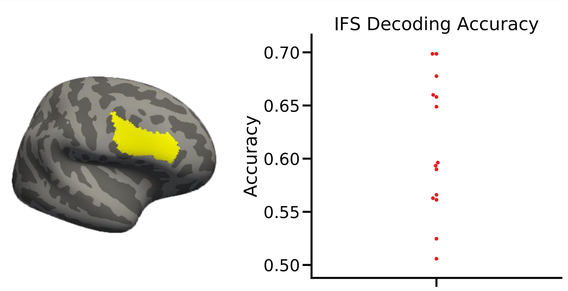
Conclusions

1) Apparent reward prediction error BOLD responses in the nucleus accumbens are better described as updating responses

2) Heterogeneity of response patterns in different striatal nuclei suggests that deterministic and stochastic learning engage partially distinct learning circuits

Future Directions

Outstanding Question: Does the striatal response to feedback predict changes in rule representation in the inferior frontal sulcus, the region of prefrontal cortex that most strongly represents rules in this task[4]?



References

1) Alexander G.E., Crutcher M.D. and DeLong, M.R. (1991) Basal ganglia and thalamocortical circuits. The Prefrontal Cortex: Structure, Function and Pathology.

2) Collins, A. G. E., & Frank, M. J. (2013). Cognitive control over learning: creating, clustering, and generalizing task-set structure. Psychological Review.

3) Ballard I.C., et al (2017). Beyond reward prediction errors: the striatum updates rule values during learning. Cerebral Cortex.

4) Waskom, M.L, Frank M.C., Wagner, A.D. (2014) Frontoparietal Representations of Task Context Support the Flexible Control of Goal-Directed Cognition. Cerebral Cortex.

Acknowledgements

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