Neural Correlates of Learning Models in a Dynamic Decision-Making Task

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Introduction
Recent work has highlighted the value of using learning models in fMRI analyses. A common approach in decision-making tasks has been to use prediction errors from reinforcement learning (RL) models as regressors. Recently we have found that a heuristic win-stay-lose-shift WSLS model can often provide a better fit to the data than a RL model. This is especially true in dynamic decision-making tasks where participants must learn how current choices affect future outcomes. Our goal is to investigate how prediction errors from RL and WSLS models correlate with neural activity.

Method
We used a reward structure where the option that provides larger immediate rewards is sub-optimal. The Increasing option provides smaller immediate rewards but increases delayed rewards.

Increasing-Optimal Task
We performed task in GE 3T scanner. Third level statistics were run cluster corrected -z threshold 2.3 -cluster p threshold .05.

Learning Models
Data were fit with a Baseline model, RL model, and a WSLS model. The Baseline model assumes fixed choice probabilities (no learning) and has one free parameter, p(increasing). The RL model updates Expected Values of each option based on a prediction error:

\[ E_{V_{rl}} = E_{V_{rl}} + a \cdot [r(t) - E_{V_{rl}}] \]

to develop probabilities for selecting each option (a) using a Softmax decision rule:

\[ P(a_t) = \frac{e^{r_{V_{rl}}}}{\sum_{a} e^{r_{V_{rl}}}} \]

WSLS has two free parameters, probability of staying with the same option if reward is ≥ reward on previous trial, and probability of shifting if reward is < the previous trial.

Model-Based Predictions
RL Model – Prediction errors may correlate with striatal activity. WSLS Model - Prediction errors may correlate with frontal activity.

Results
We subtracted the fit of each learning model from the fit of the Baseline model. Higher values indicate a better fit.

fMRI Results
Activation Modulated by Prediction Errors
Despite providing a better fit we did not find activation that correlated with prediction errors from the WSLS model.

Correlates of RL model’s prediction errors
Prediction error’s from the RL model corresponded with activation in left parietal, left frontal pole, and in the left cerebellum.

Comparison when accounting for WSLS prediction errors
We examined activity when prediction errors from the RL model were greater than prediction errors from the WSLS model.

When WSLS prediction errors were accounted for neural activity in the left cerebellum was modulated by the RL model’s prediction errors.

Discussion
Striatal activation was not modulated by the RL model’s prediction errors. We could not identify areas that were modulated by prediction errors from the WSLS model. Activity in the medial and lateral left cerebellum corresponded with prediction errors from the RL model. Some recent work also supports a role for the cerebellum in decision-making under uncertainty. The neo-cerebellum may monitor the consequences of actions by tracking prediction errors from an RL model.