Fast Reacquisition and Renewal in Human Category Learning

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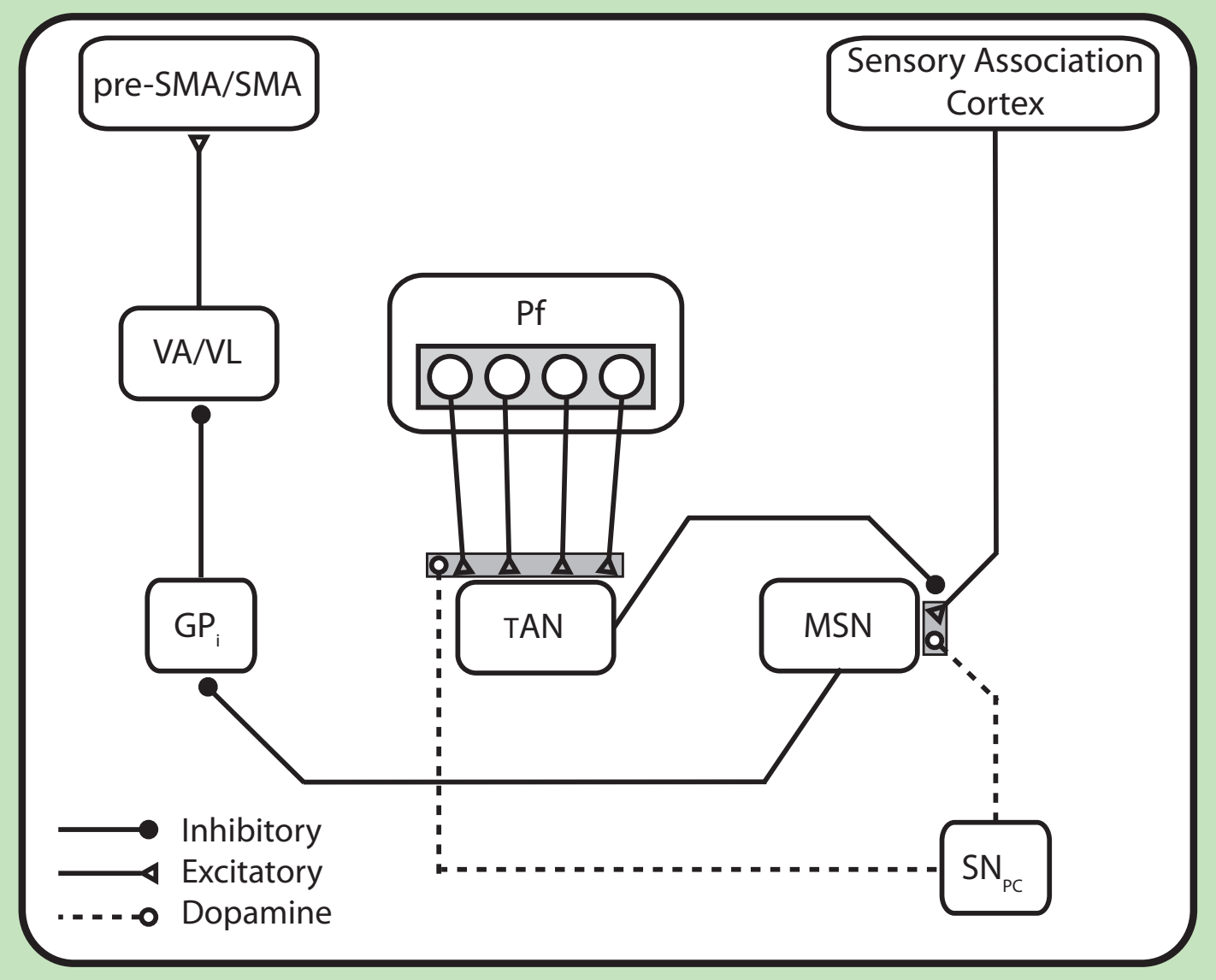
Background

A neurobiologically detailed computational model is described in which procedural skill acquisition is gated by the tonically active neurons of the striatum (TANs). The TANs are driven by cells in the parafascicular nucleus of the thalamus, which in turn are broadly tuned to features of the environment. The model accounts for recently collected fast reacquisition and renewal data in human category learning.



Critical Features

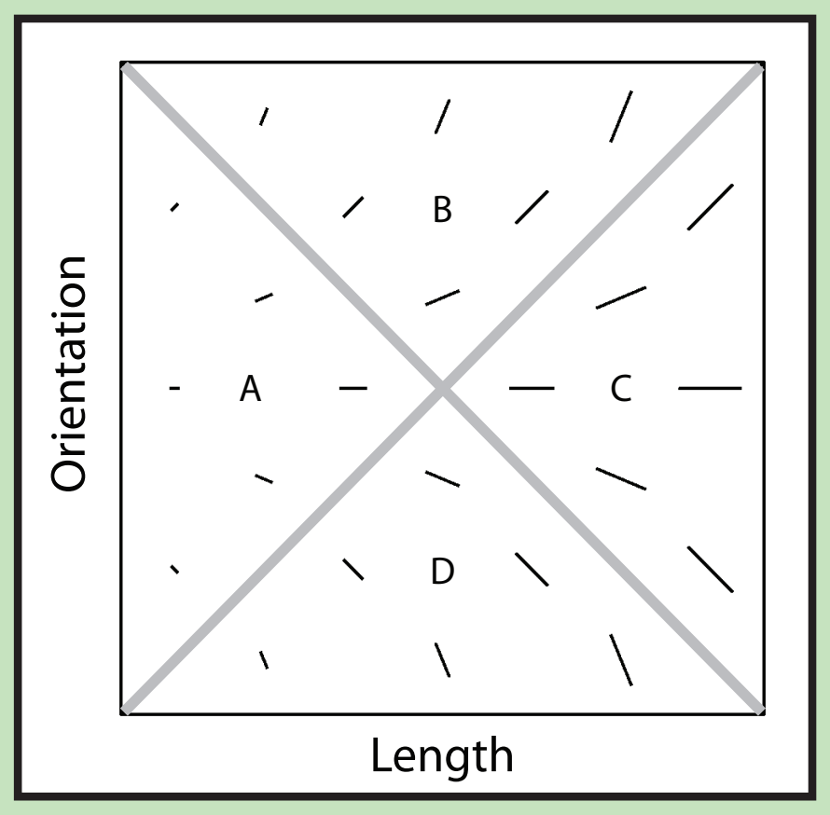
Category associations are learned at Cortical-MSN synapses

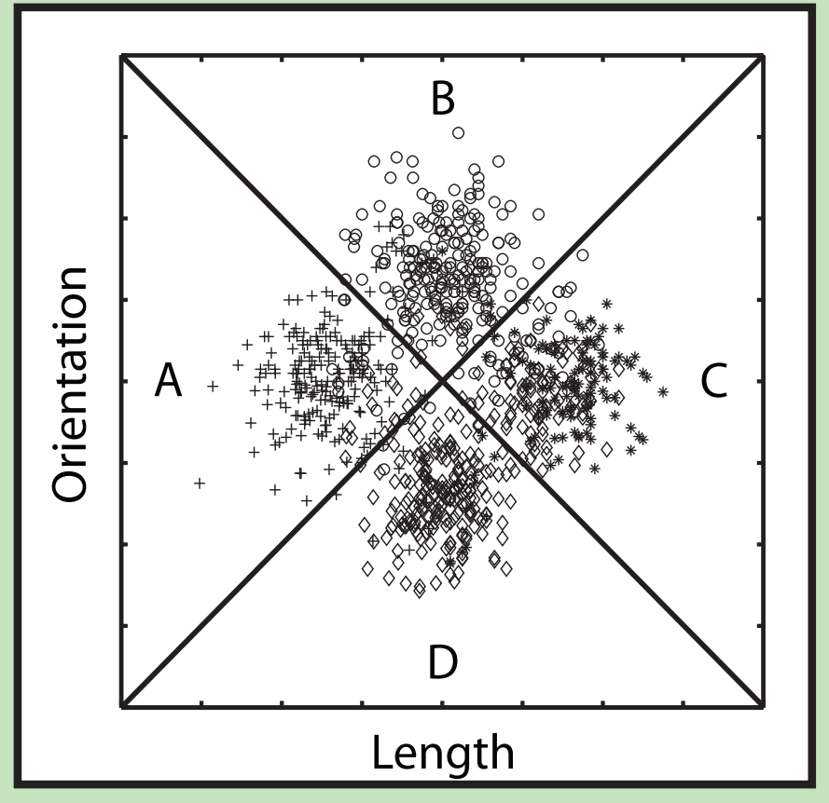
Context associations are learned at Pf-TAN synapses

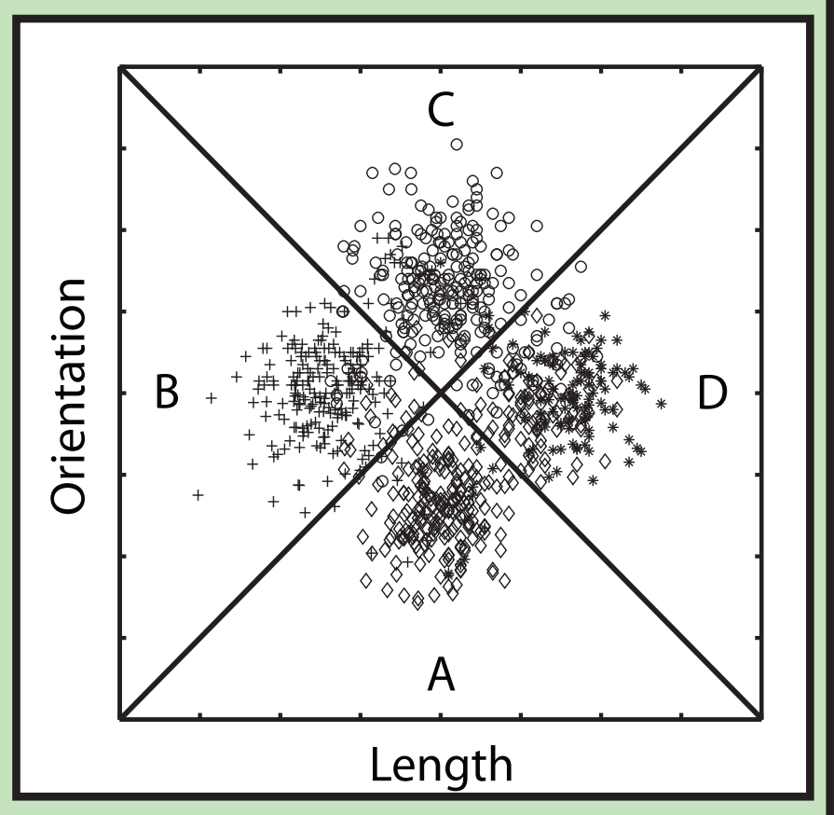
Pf cells respond uniquely to environmental cues

Dopamine-dependent learning occurs at all cortical-striatal and Pf-TAN synapses.

The Tasks







Random Feedback

3 Phases: Acquisition, Extinction, and Reacquisition

Veridical feedback during Acquisition and Reacquisition

Random feedback during Extinction

Uncertainty Response

3 Phases: Acquisition, Extinction, and Reacquisition

Earn points for correct responses, lose points for incorrect responses

Lose points for correct and incorrect responses during extinction

Never lose or gain points for uncertainty response

Renewal

3 Phases: Acquisition, Extinction1, and Extinction 2

Veridical feedback during Acquisition

Random feedback during both Extinction phases

Phases take place in different contexts (i.e., with different background colors)

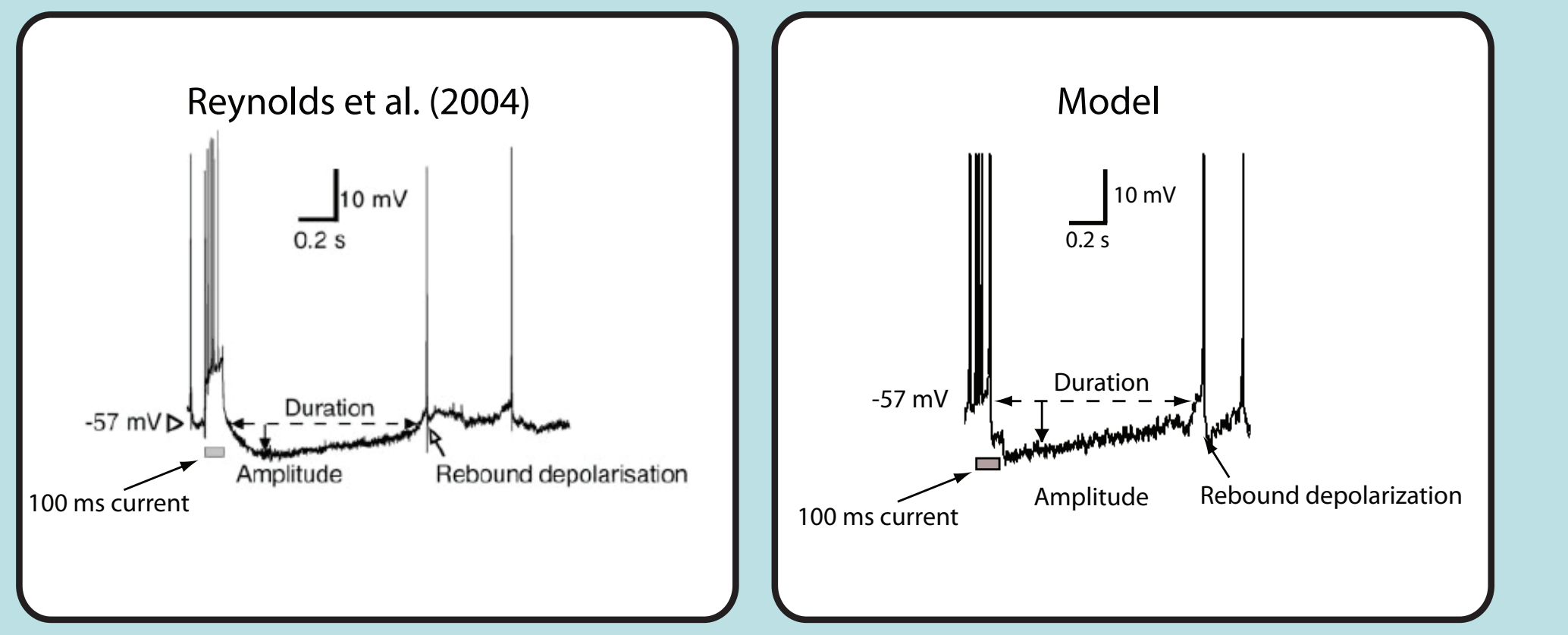
The TANs

Firing Properties

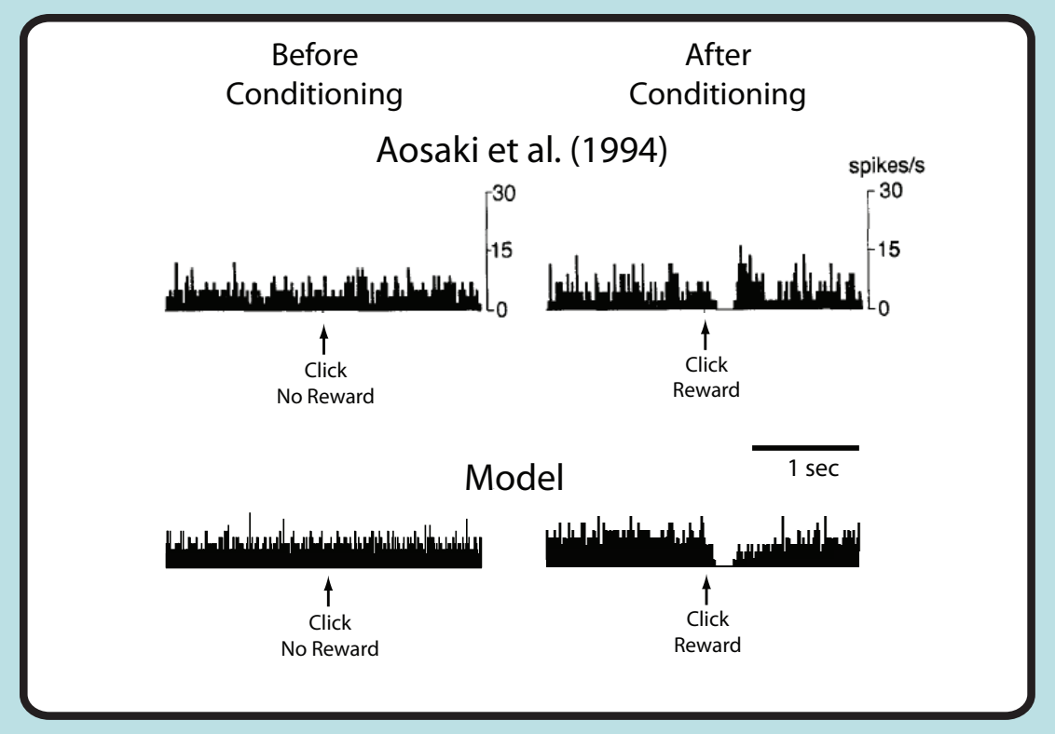
Presynaptically inhibits striatal output neurons (Pakhotin & Bracci, 2007).

Pause to stimuli from multiple modalities (Matsumoto et al., 2001).

Pause to excitatory input (Reynolds et al., 2004).



Learn to pause to stimuli that predict reward.
(Apicella, 1991; Kimura, 1992; Aosaki et al., 1994)

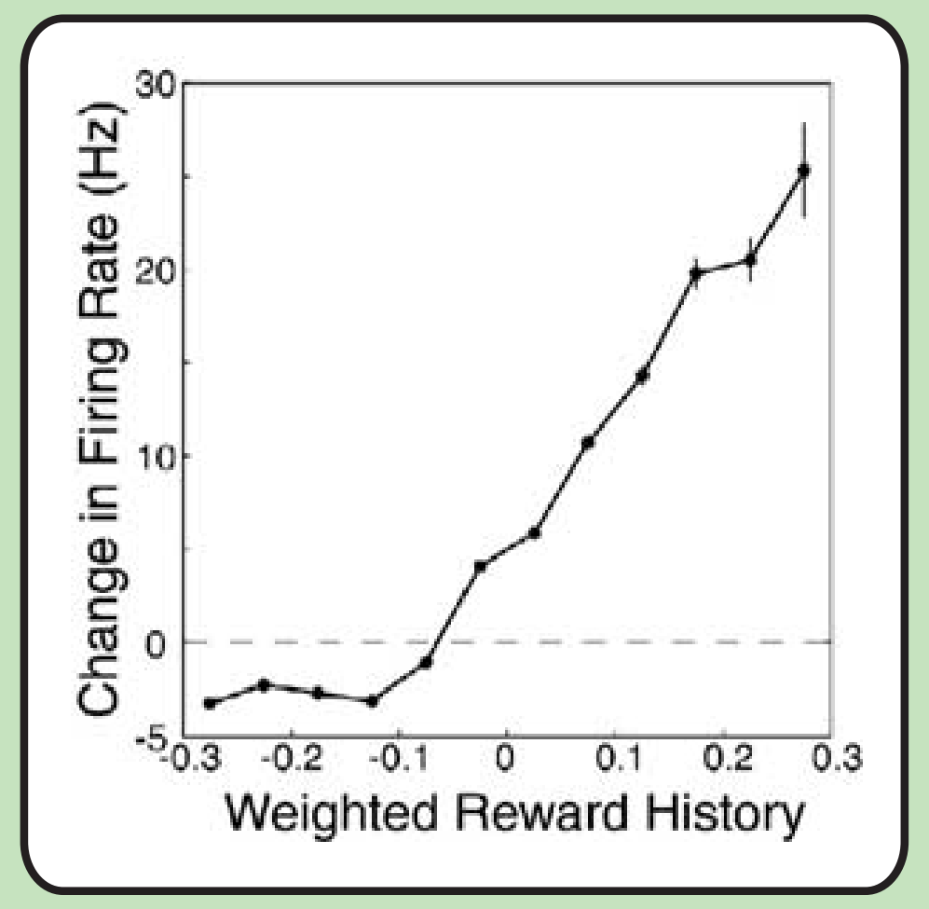


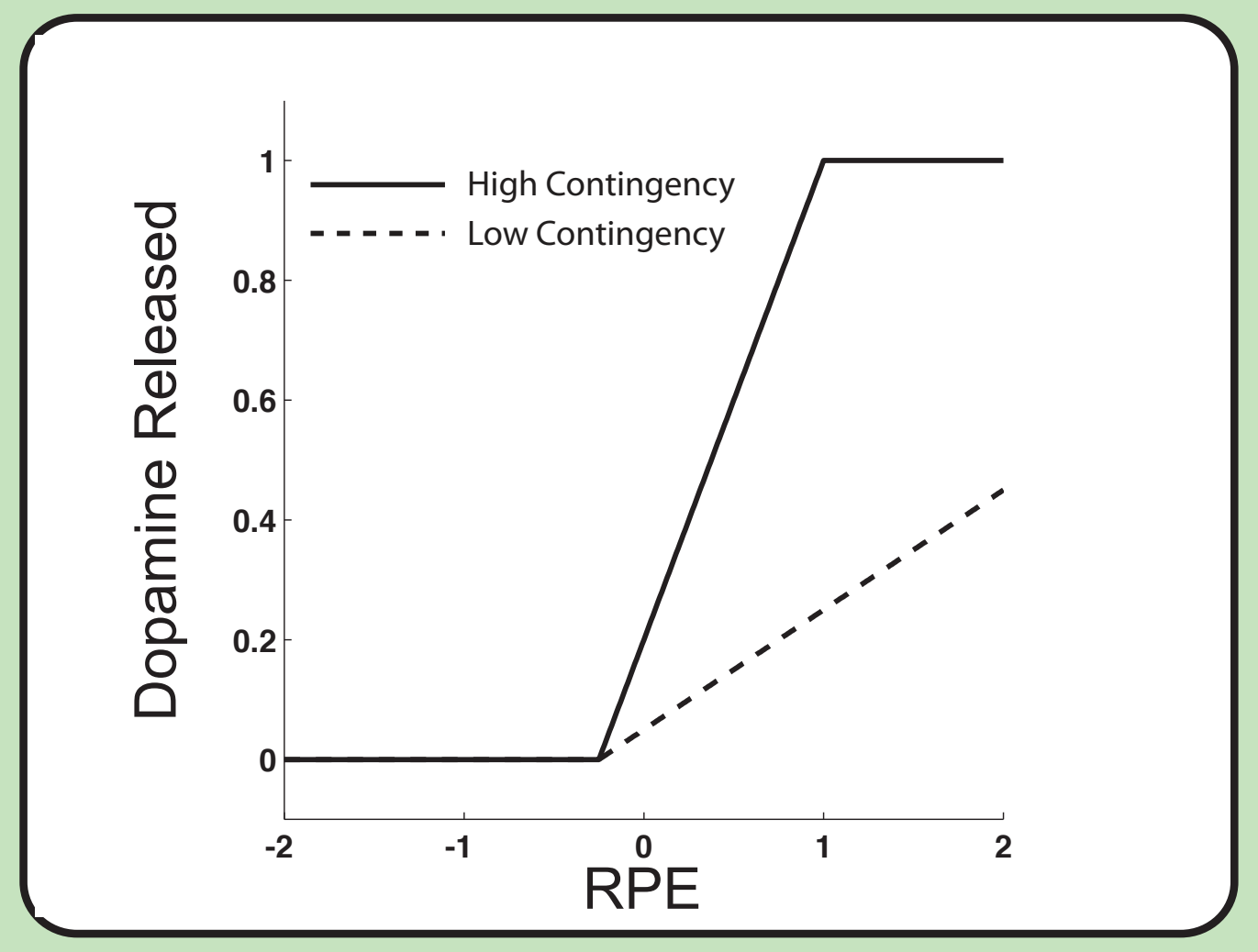
A New Dopamine Model

Dopamine (DA) levels vary as a function of reward prediction error (RPE) (Bayer and Glimcher, 2005).

We assume DA release is large when feedback is contingent on behavior and small when feedback is not contingent on behavior (O'Doherty et al., 2004; Harunu & Kawato, 2005).

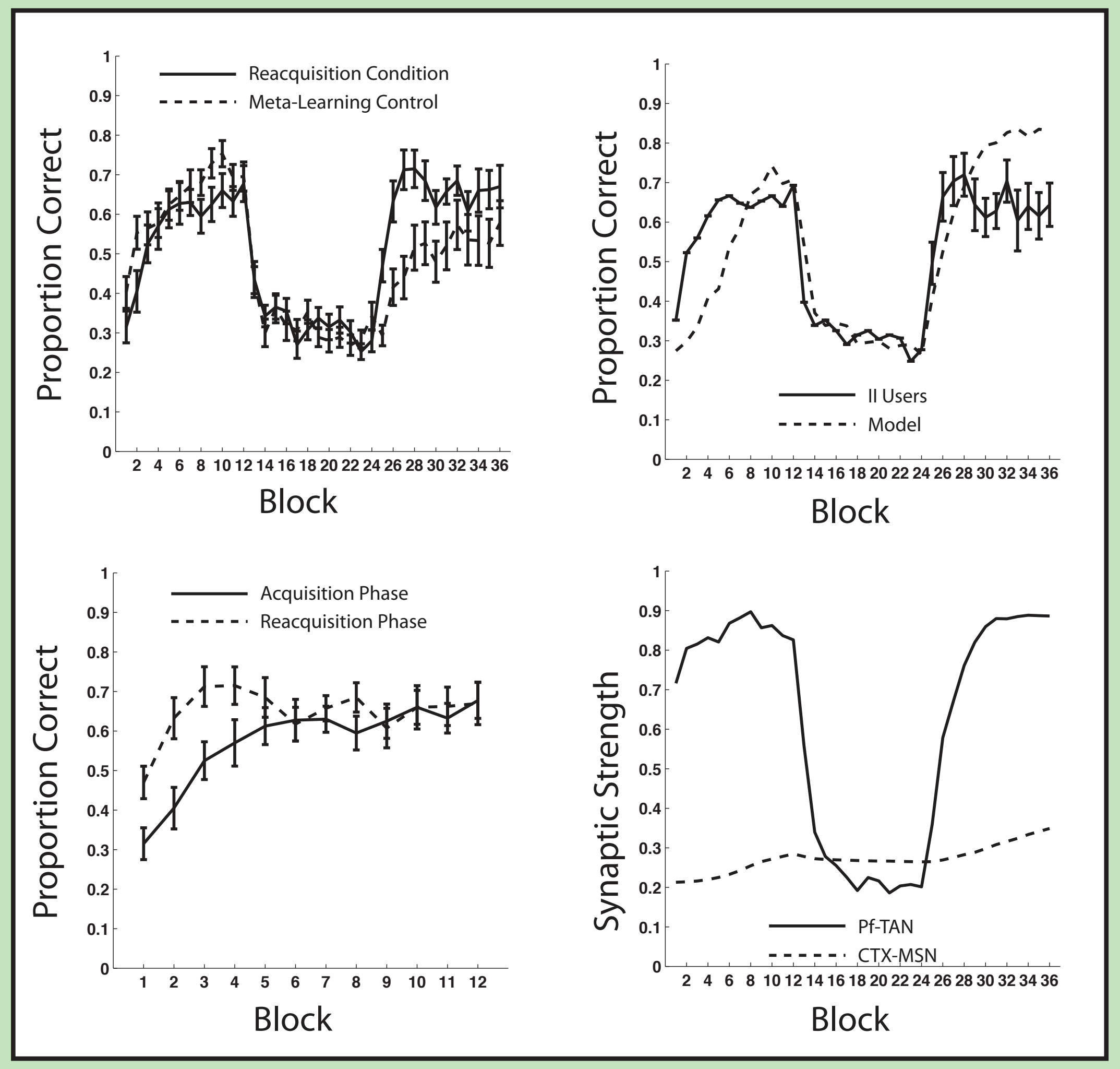
$$D(n)=\begin{cases}\min[r(RPE+0.25),1] & \text{if RPE} > -0.25\\ 0 & \text{if RPE} \le -0.25\end{cases}$$





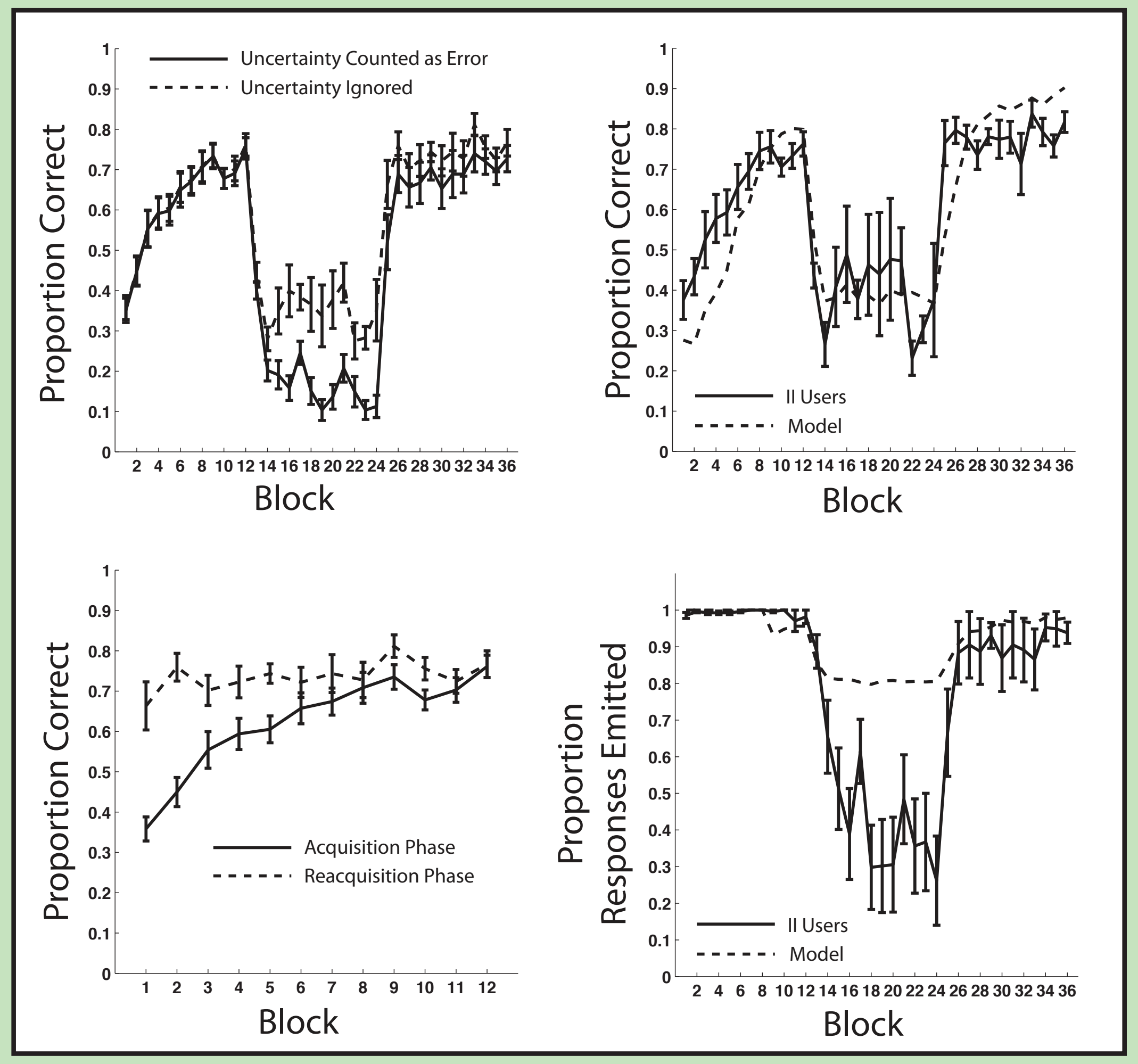
Contingency is measured by the correlation between response confidence (the absolute value of the difference between the two most active motor units) and feedback.

Random Feedback



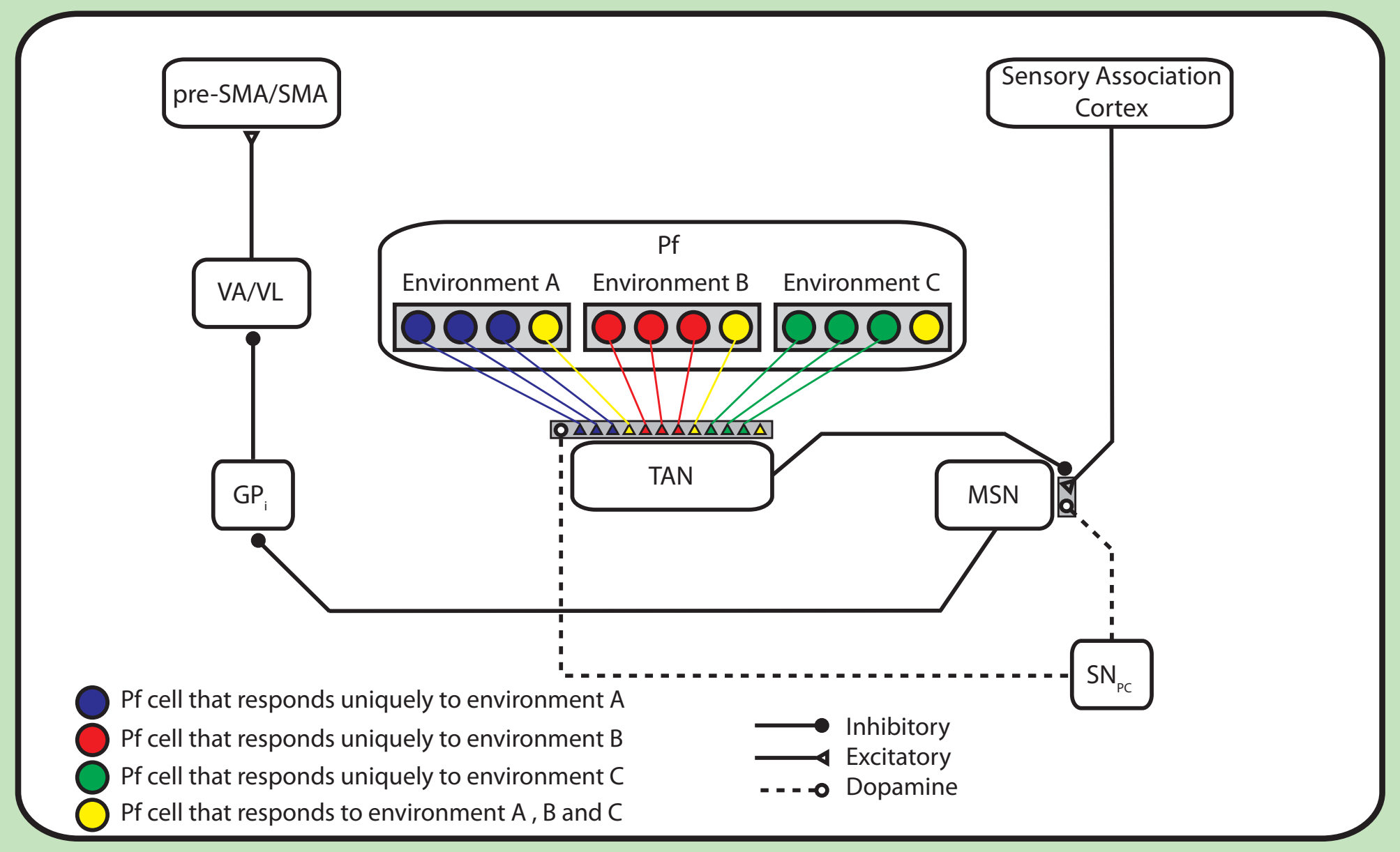
Reacquisition performance is better than acquisition performance in the Reacquisition condition and worse in the Meta-Learning Control condition. This implies that Extinction did not erase the original learning.

Uncertainty Response

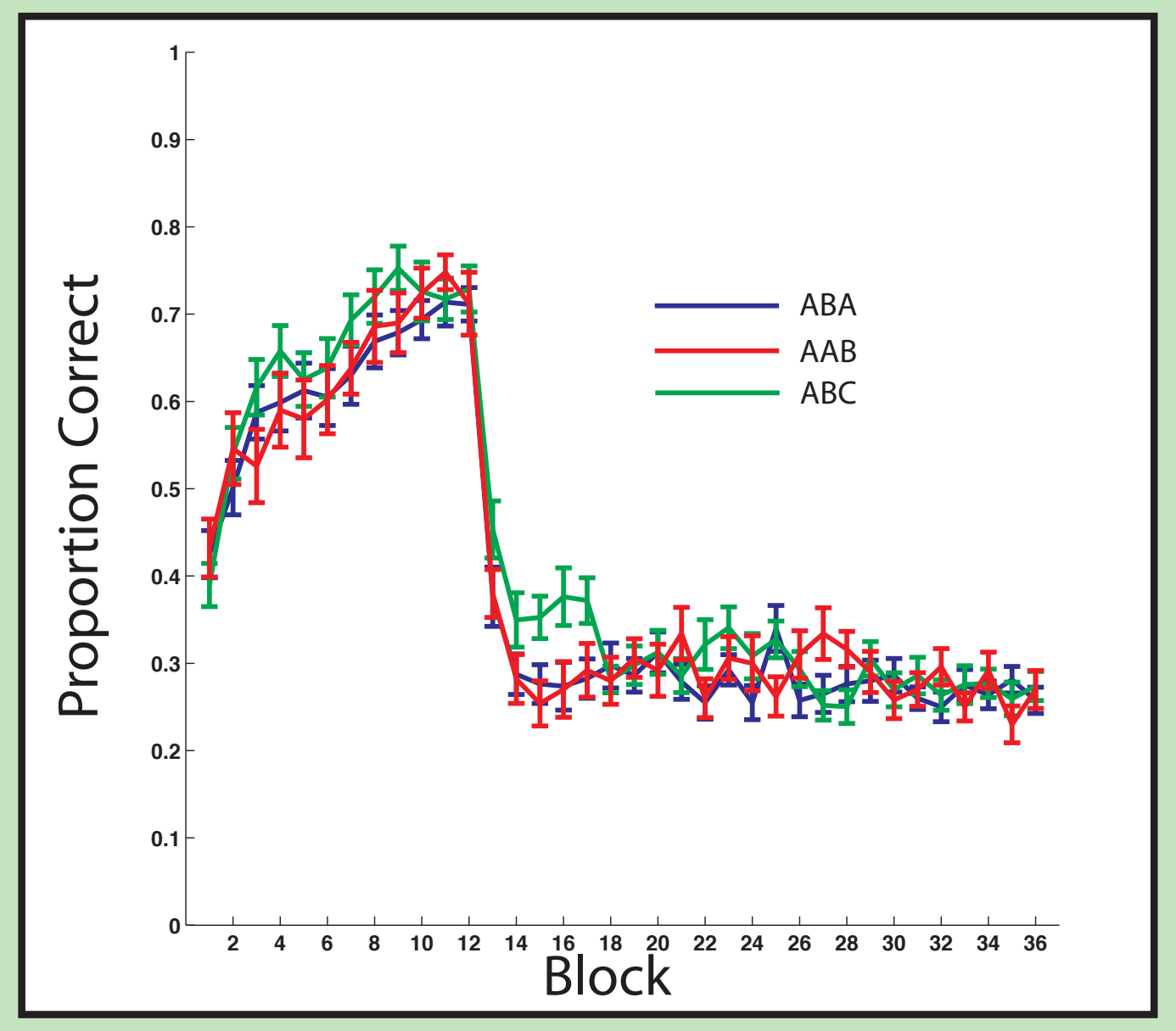


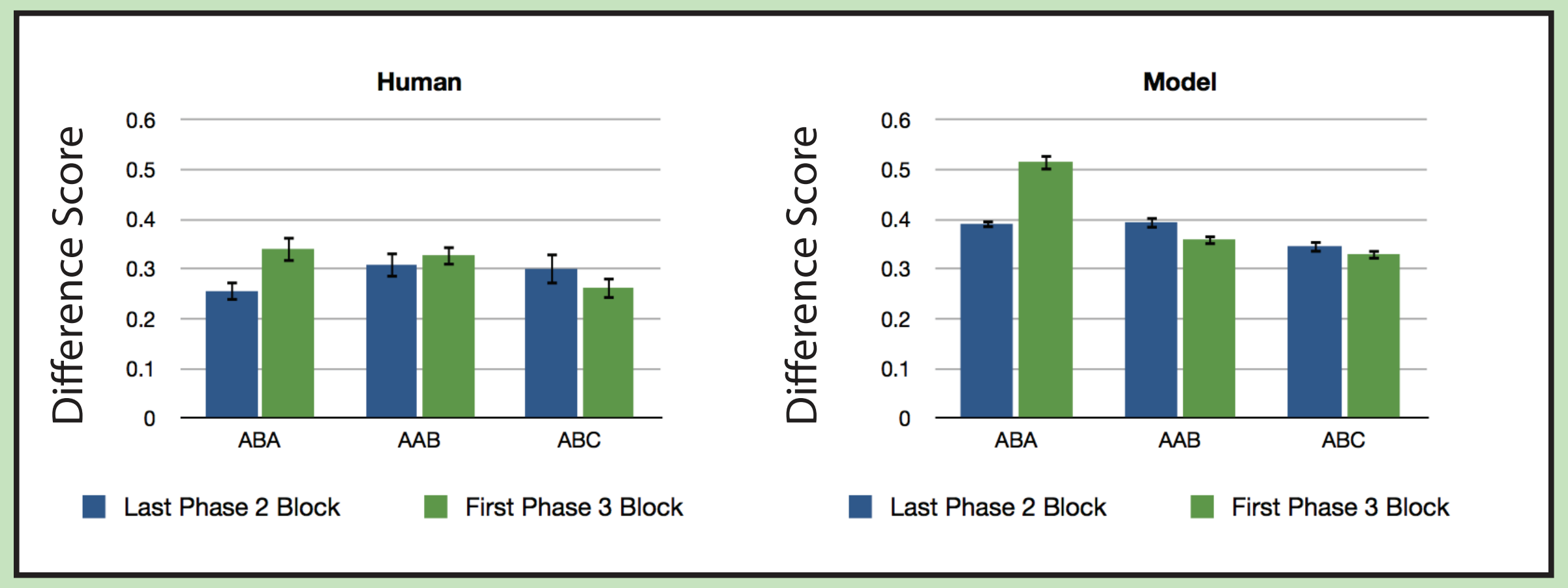
Reacquisition is again better than Acquisition. The original learning was again preserved through the extinction phase.

Renewal



- 🔵 Pf cell that responds uniquely to environment A
- 🔴 Pf cell that responds uniquely to environment B
- 🟢 Pf cell that responds uniquely to environment C
- 🟡 Pf cell that responds to environment A , B and C





There is some, although weak, evidence that responding was briefly renewed in the ABA condition

Conclusion

We observed fast reacquisition and renewal with two different extinction protocols. This implies that extinction training did not erase original learning. Since the TANs gate cortico-striatal synaptic plasticity and thereby protect cortical-striatal synapses when context changes, they are a potential target in the search to induce true unlearning.

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