A new functional role for lateral inhibition in the striatum: Pavlovian conditioning

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Summary

The striatum has long been implicated in reinforcement learning and has been suggested by several neurophysiological studies as the substrate for encoding the reward value of stimuli. Reward prediction error (RPE) has been used in several basal ganglia models as the underlying learning signal, which leads to Pavlovian conditioning abilities that can be simulated by the Rescorla-Wagner model.

Lateral inhibition between striatal projection neurons was once thought to have a winner-take-all function, useful in selecting between possible actions. However, it has been noted that the necessary reciprocal connections for this interpretation are too few, and the relative strength of these synaptic connections is weak. Still, modeling studies show that lateral inhibition does have an overall suppression effect on striatal activity and may play an important role in striatal processing.

Neurophysiological recordings show task-relevant ensembles of responsive neurons at specific points in a behavioral paradigm (Barnes et al., 2005), which appear to be induced by lateral inhibition (see Ponzi &Wickens, 2010). We have developed a similarly responding, RPE-based model of the striatum by incorporating lateral inhibition. Model neurons are assigned to either the direct or the indirect pathway but lateral connections occur within and between these groups, leading to competition between both the individual neurons and their pathways. We successfully applied this model to the simulation of Pavlovian phenomena beyond those of the Rescorla-Wagner model, including negative patterning, unovershadowing, and external inhibition.

References

Barnes, T. D., Kubota, Y., Hu, D., Jin, D. Z., & Graybiel, A. M. (2005). Activity of striatal neurons reflects dynamic encoding and recoding of procedural memories. Nature, 437(7062), 1158–1161.
Ponzi, A., & Wickens, J. (2010). Sequentially switching cell assemblies in random inhibitory networks of spiking neurons in the striatum. Journal of Neuroscience, 30(17), 5894–5911.

Acknowledgements

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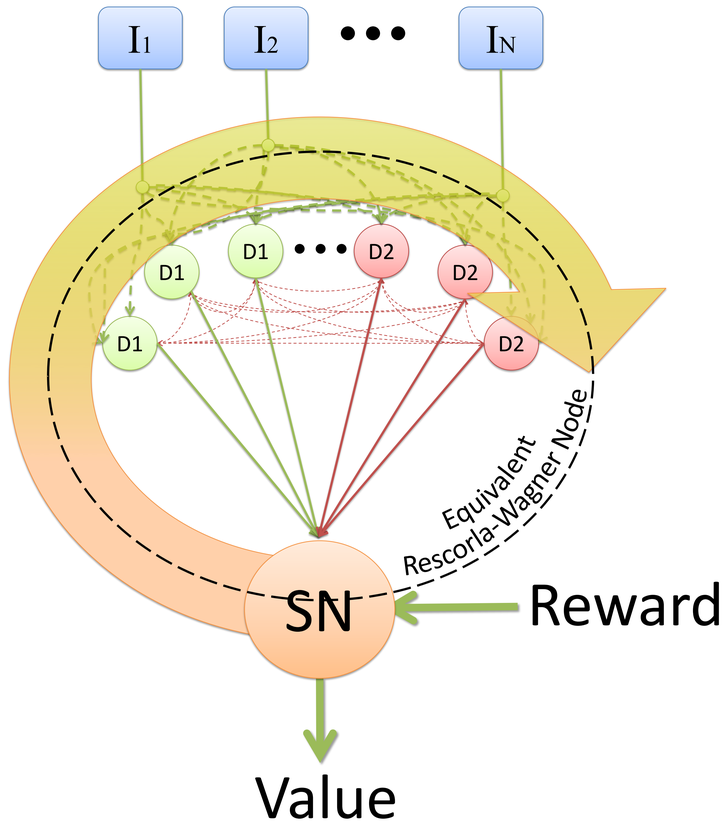
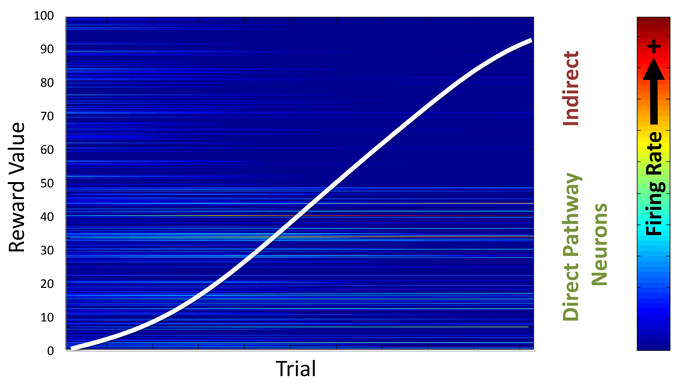
The Striatal Model

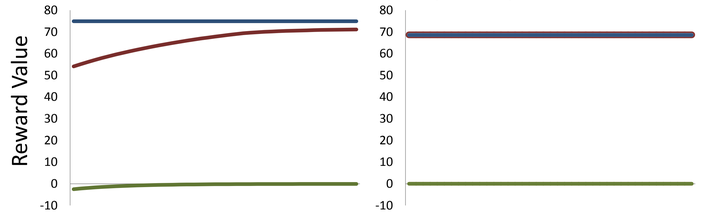


Task-relevant Development of Neural Activity During Excitatory Conditioning

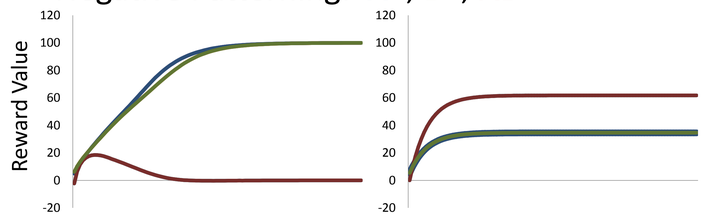


Pavlovian Simulations

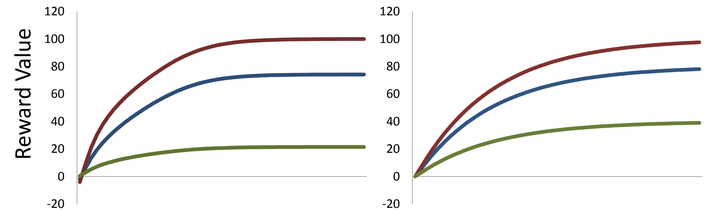
External Inhibition: **A+**; **B-**, **A=?**, **AB=?**



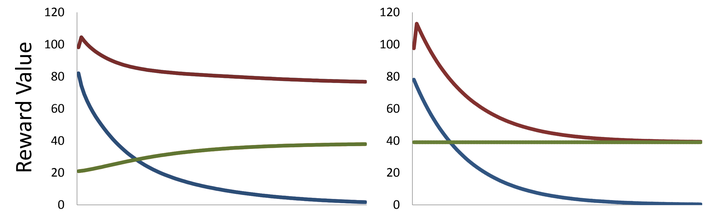
Negative Patterning: **A+**, **B+**, **AB-**



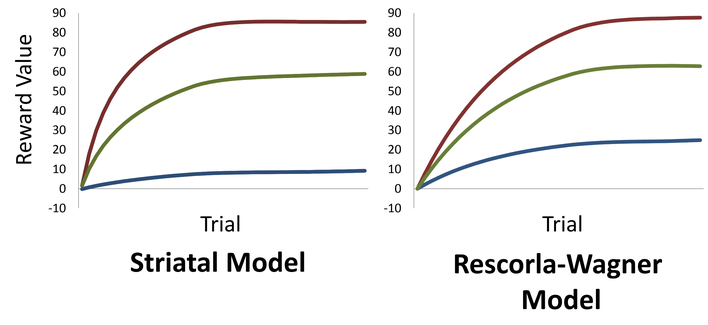
Overshadowing: **AB+** (B has half salience)



Unovershadowing: **AB+; A-**, **B=?**, **AB=?**



Latent Inhibition: **A-**; **AB+**, **A=?**, **B=?**



Striatal Model **Rescorla-Wagner Model**