

# Dopamine-based reinforcement learning of virtual arm reaching task in a spiking model of motor cortex George L. Chadderdon<sup>1</sup>, Samuel A. Neymotin<sup>1,2</sup>, Cliff C. Kerr<sup>1,3</sup>, Joseph T. Francis<sup>1</sup>, William W. Lytton<sup>1,4</sup> Dept. of Physiology and Pharmacology, SUNY Downstate Medical Center; <sup>2</sup> Dept. Of Neurobiology, Yale Univ. School of Physics, Univ. of Sydney, Australia;<sup>4</sup> Kings County Hospital, Brooklyn, NY

### Introduction

Our goal is to model learning and performance in a target-reaching task. We use a spiking model of primary motor cortex to direct a virtual arm toward a target. The model learns by shaping noise-driven "motor babble" into directed motions using a reward / punisher algorithm based on mechanisms from the dopaminergic reward system. The spiking network model effectively implements Thorndike's Law of Effect: the proposition that rewards (punishers) make stimulus->response mappings more (less) likely to be triggered in the future.

### Methods



Environment

Overview of model and virtual arm system. Only the forearm is allowed to rotate to move the hand toward the target. The arm is driven by a motor controller Actor which is trained by a reward / punisher Critic to learn a proprioceptive sensory->motor command mapping.



Thorndike Law of Effect: Reward makes behaviors more likely. Punishment makes them less likely.

## ♦ Results

### **Reaching performance best** for reward + punisher



A. Error vs. learning condition. B. Reward + Punisher error vs. % poorly connected neurons.

# **Dopamine signaling**



Dopamine signals are given at discrete times allowing error to move towards 0.

## **Reward / punishment effects** on synaptic weights



Weight gains change monotonically unless have both reward and punishment.



Reach performance on 135 (top), 35 (middle), and 0 (bottom) degrees. A. Good; B. Bad wiring random seed.



**Raster plot** 

Raster plot during 5 s simulation under no-learning condition.

# **Reach to different targets** successful, but wiring-dependent



### Successful target switching performance



A. 35->0 degree switch. B. 0->35 degree switch.





A. Motor command for trained model vs. arm angle. B. EM cell spiking at 25°. C. EM cell spiking at 65°.

### Conclusions

• Both reward + punishment are needed for adequate learning Babble allows trial-and-error learning – plan to improve with adaptive noise mechanism Plan extending model to include cortical laminar structure

### References

 Chadderdon GL, Neymotin SA, Kerr CC, Lytton WW. In press. Reinforcement learning of targeted movement in a spiking neuronal model of motor cortex. PLoS ONE.

 Izhikevich EM. 2007. Solving the distal reward signaling. Cereb. Cortex. 17:2443-2452. Schultz W. 1998. Predictive reward signal of dopamine neuron. J Neurophysiol. 80:1-27.

### Acknowledgements

This work was supported by DARPA grant N66001-10-C-2008.