Simulation of How Neuromodulation Influences Cooperative Behavior

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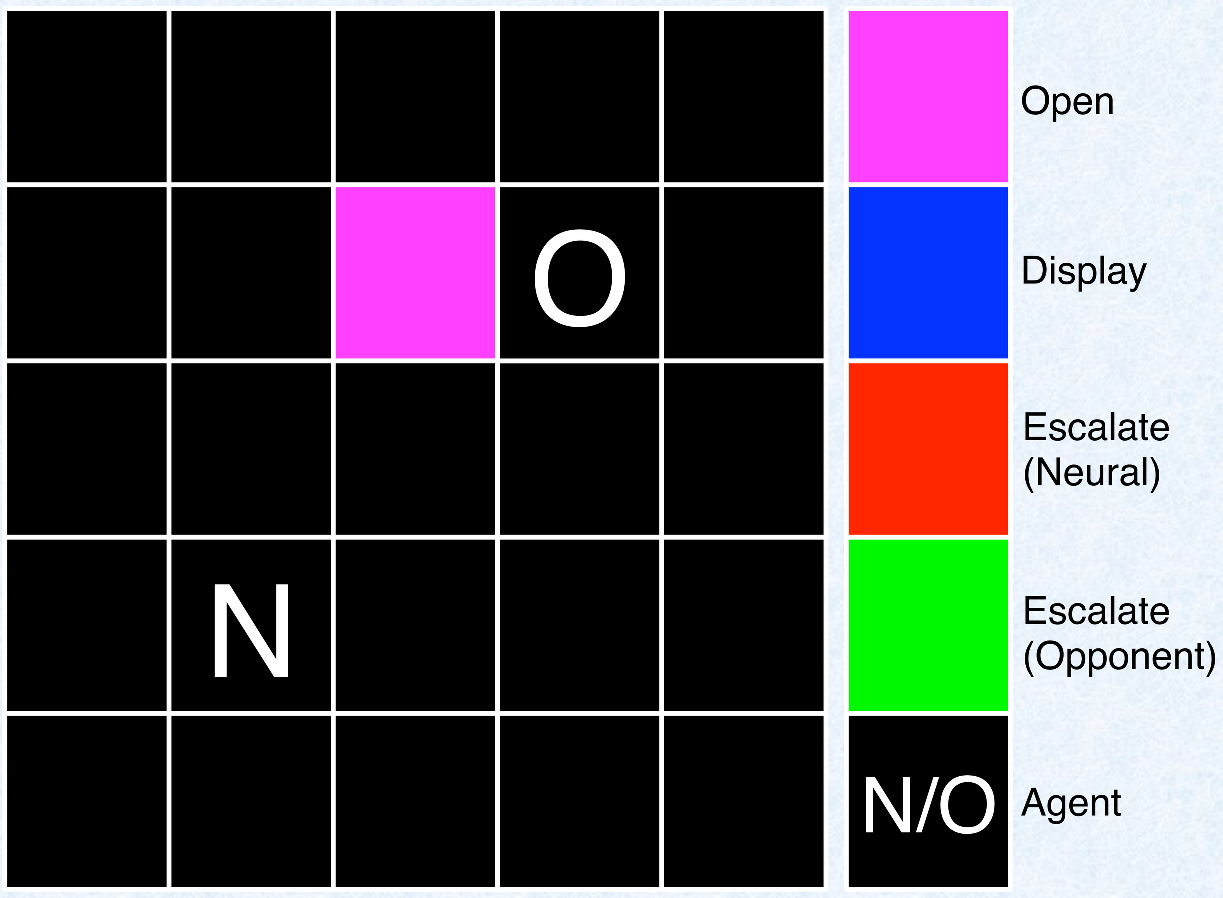
INTRODUCTION

- Neuromodulators, such as dopamine (DA) and serotonin (5-HT), are important in predicting rewards and costs.
- To better understand the roles of dopamine and serotonin during decision-making in games of conflict, we developed a computational model of neuromodulation and action-selection.
- An agent, whose behavior was guided by the neural model, played the Hawk-Dove game, where players must choose between confrontational and cooperative tactics.

METHODS

Game Playing



Payoff Matrix	*Hawk*	*Dove*
Hawk	(V-D)/2, (V-D)/2	V,0
Dove	0,V	V/2, V/2

Neural Agent

TOI State: $n_i = \begin{cases} 0.75 + rnd(0.0,0.25); & i = TOIState \\ rnd(0.0,0.25); & Otherwise \end{cases}$

Neural Activity: $s_i(t) = \rho_i s_i(t-1) + (1-\rho_i)\left(\frac{1}{1+\exp(-5I_i(t))}\right)$

Synaptic Input: $I_i(t) = rnd(-0.5,0.0) + \sum_j nm(t-1) w_{ij}(t-1) s_i(t-1)$

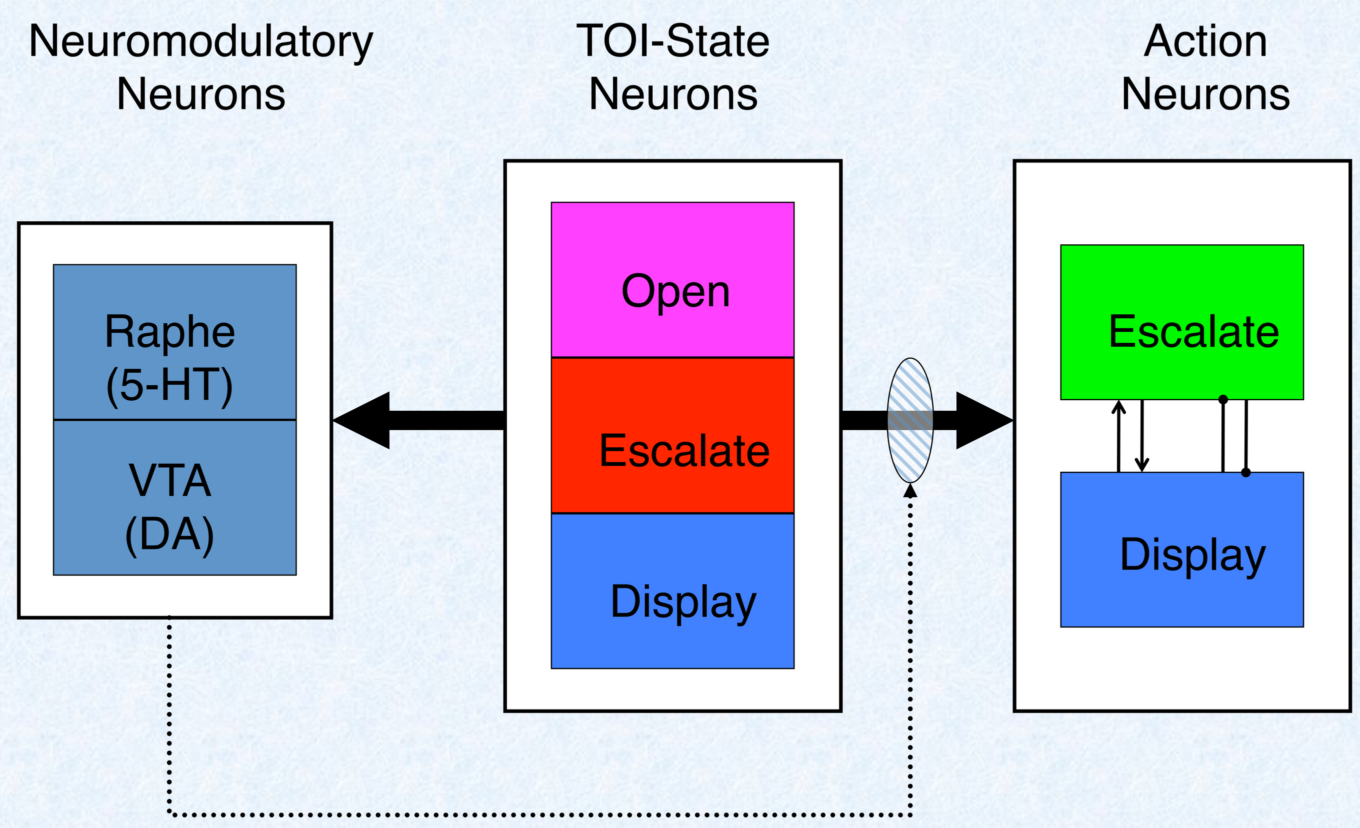
Learning Rule: $\Delta w_{ij} = \alpha * nm(t-1) s_j(t-1)\left(s_i(t-1)\right) * R$

$$R = \begin{cases} (\text{Reward} - VTA) - (\text{Cost} - Raphe) \\ \text{Reward} - VTA \\ \text{Cost} - Raphe \end{cases}$$

Opponent Agent

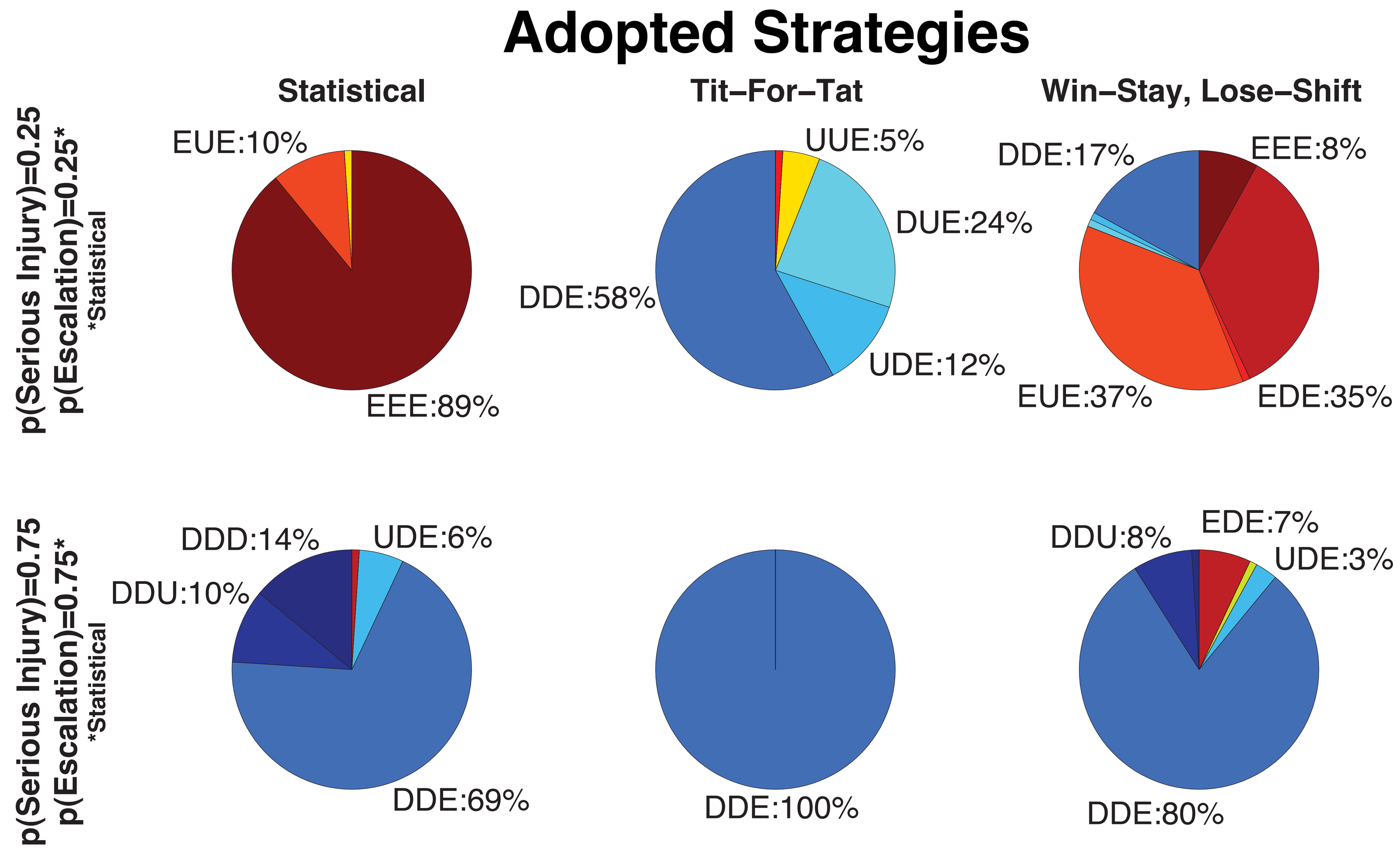
Statistical, Tit-for-Tat, or Win-Stay,Lose-Shift

Network Model



RESULTS

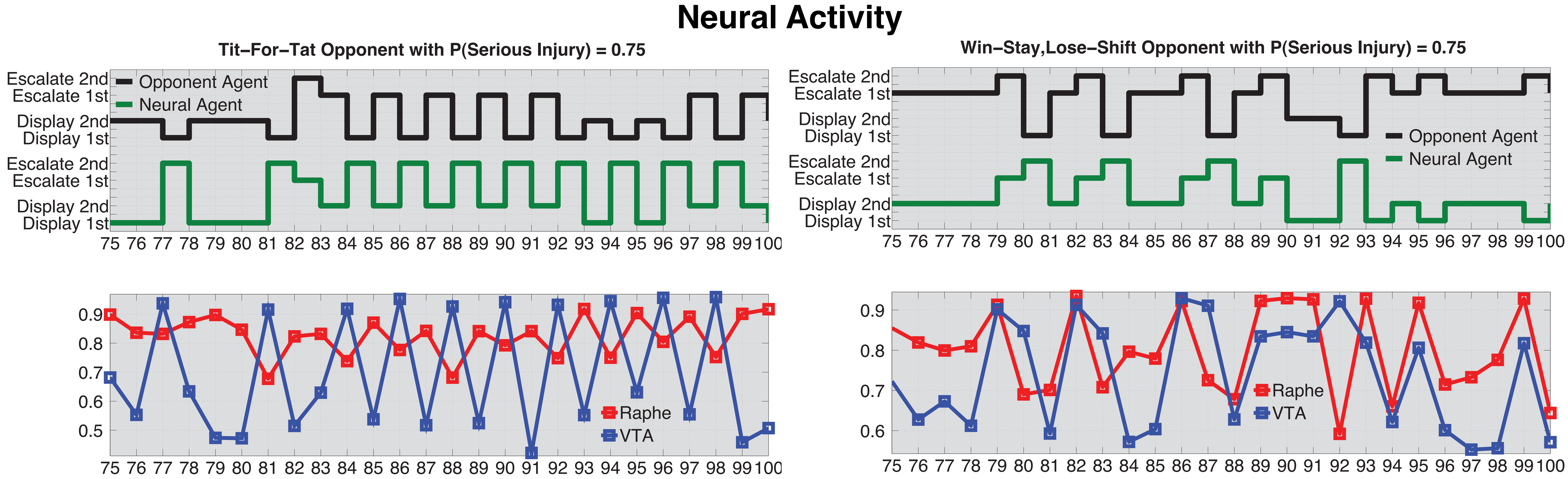
Adopted Strategies



Percentage of Escalation for the Neural Agent

	CTL		Raphe		VTA	
	p(0.25)	p(0.75)	p(0.25)	p(0.75)	p(0.25)	p(0.75)
Statistical	97.65%	10.00%	99.06%	92.86%	34.79%	7.14%
TT	34.15%	13.64%	81.82%	81.82%	24.74%	12.50%
WSLS	93.22%	9.09%	96.88%	96.88%	20.93%	8.22%

Neural Activity



CONCLUSIONS

An agent, whose behavior was guided by a computational model of the neuromodulatory system, adjusted its strategy appropriately depending on environmental conditions and its opponent's strategy in the Hawk-Dove game.

- The interaction between the DA and 5-HT neuromodulatory systems allows for appropriate decision making in games of conflict.
- Impairment to either the dopaminergic or serotonergic system leads to perseverant, uncooperative behavior.
- Although DA and 5-HT activity appears to be related to different expectations (e.g., predictive reward, anticipated cost), the action of these neuromodulators on downstream targets is similar in that it governs decision-making.