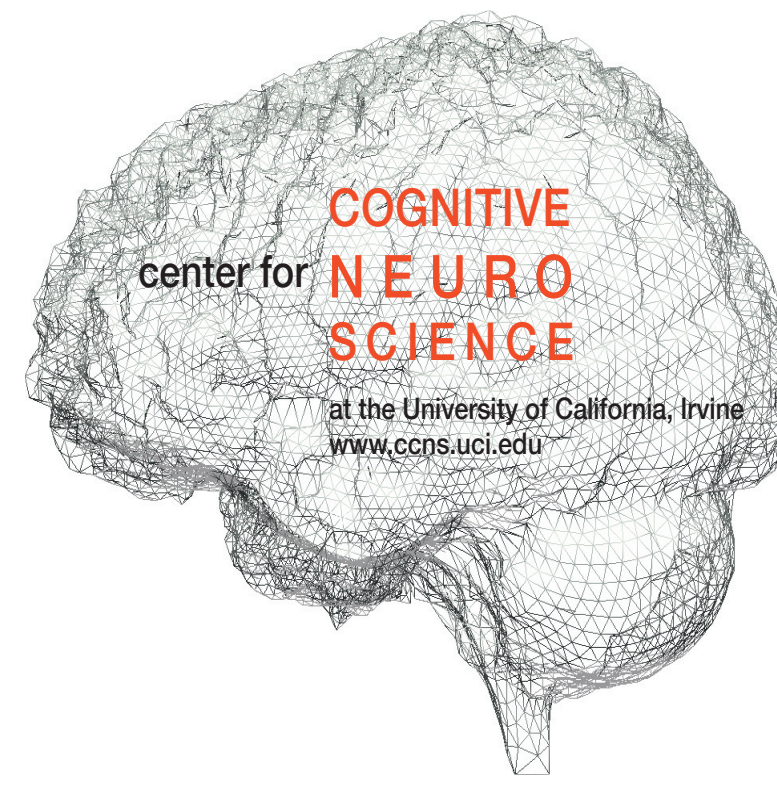


# Effect of Neuromodulation on Performance in Game Playing: A Modeling Study



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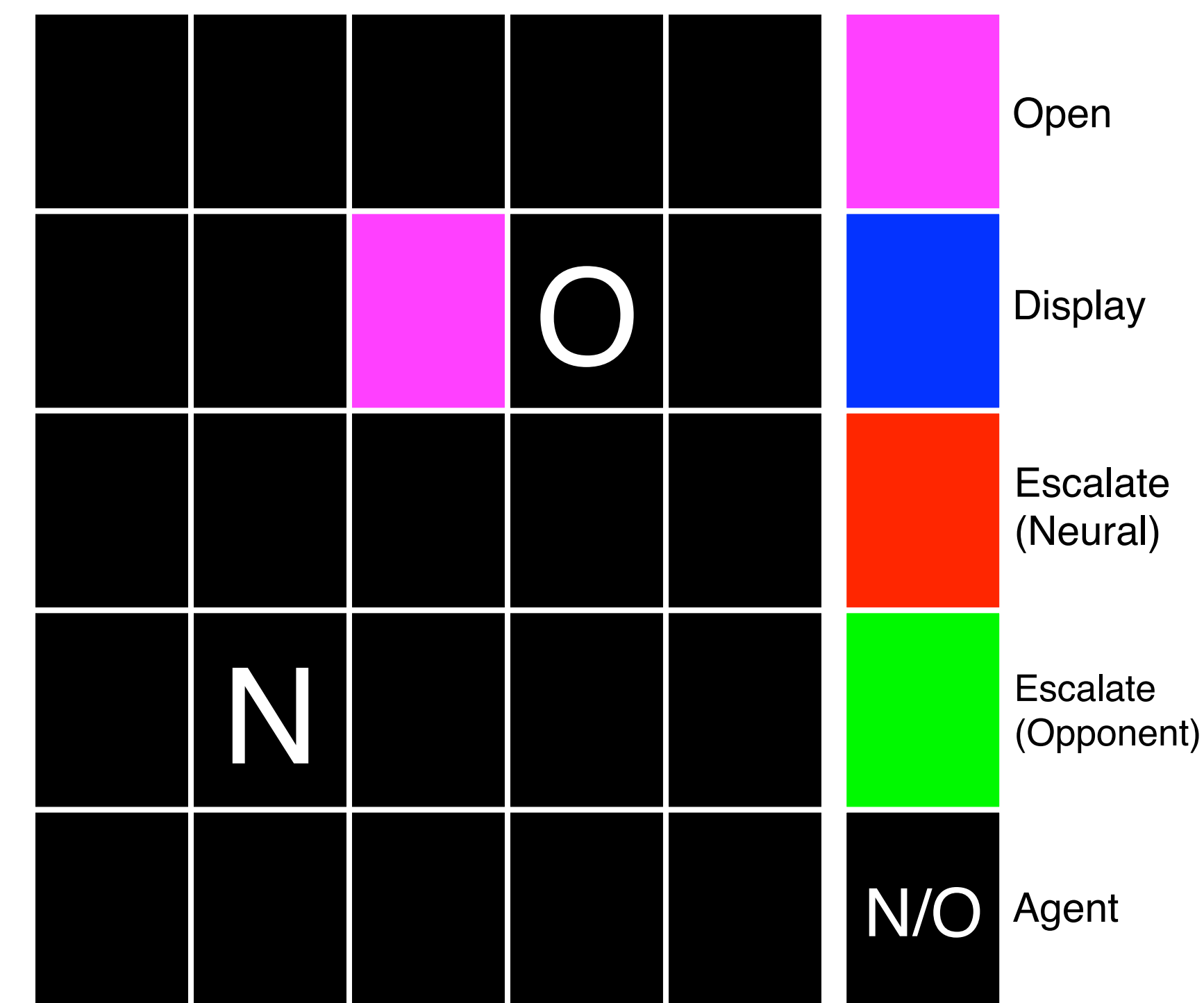
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## INTRODUCTION

- Neuromodulators, such as dopamine (DA) and serotonin (5-HT), are known to be important in predicting rewards, costs, and punishments.
- Dopamine, which originates in the ventral tegmental area (VTA) and the substantia nigra (SN), appears to be linked to expected reward [1], and incentive salience or “wanting” [2].
- Serotonin, which originates in the Raphe nucleus, appears to be related to cognitive control of stress, social interactions, and risk taking behavior [3], [4].
- Game theory has been useful for understanding risk-taking and cooperation [5].
- 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 [5], [6].

## METHODS

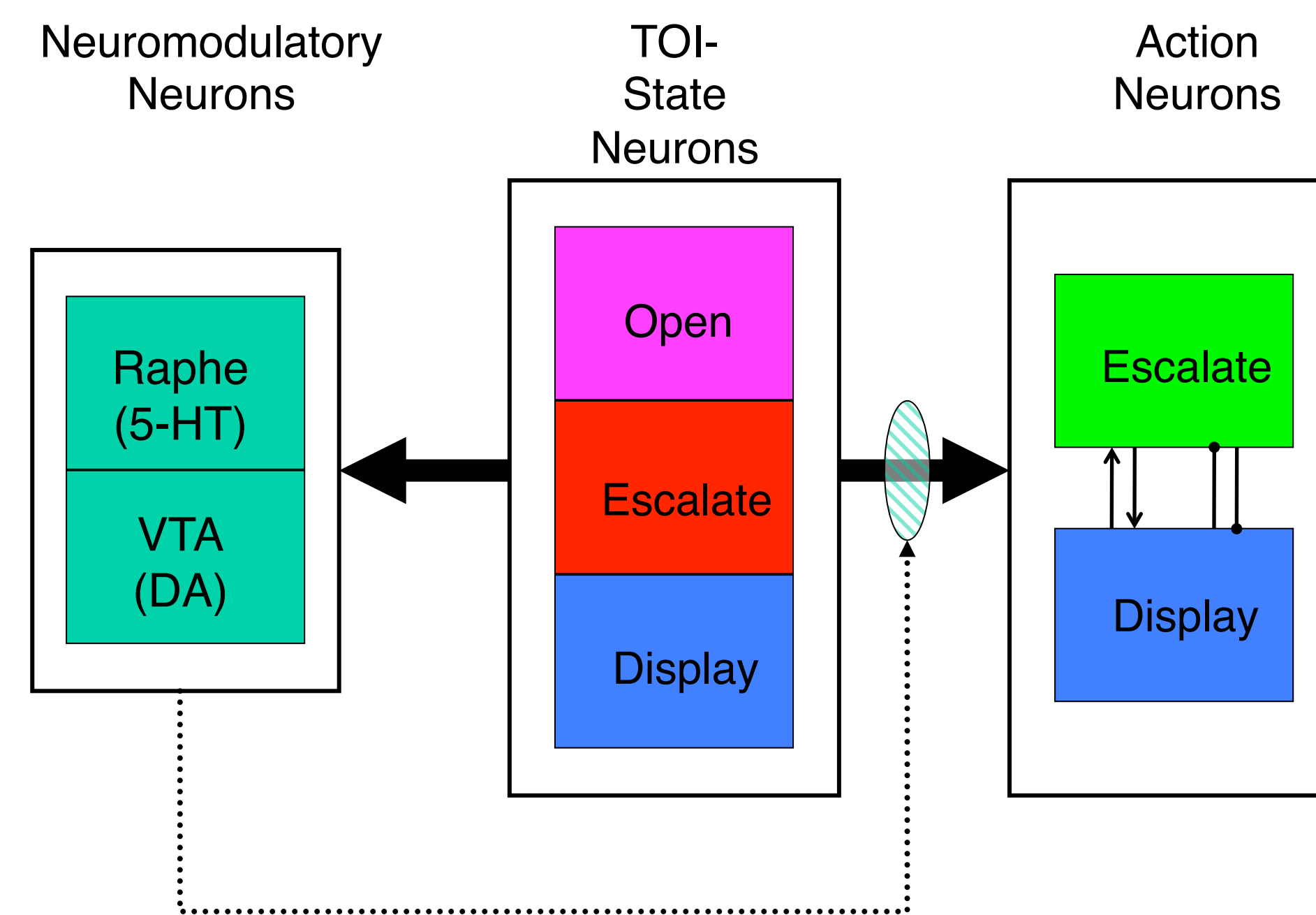
### Game Playing



### Payoff Matrix

		Opponent	
		Hawk	Dove
Neural	Hawk	(V-D)/2, (V-D)/2	V, 0
	Dove	0, V	V/2, V/2

### Network Model



### Neural Agent

TOI State Learning Rule

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

$$\Delta w_{ij} = \alpha * nm(t-1) s_j(t-1) (s_i(t-1) * R)$$

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

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

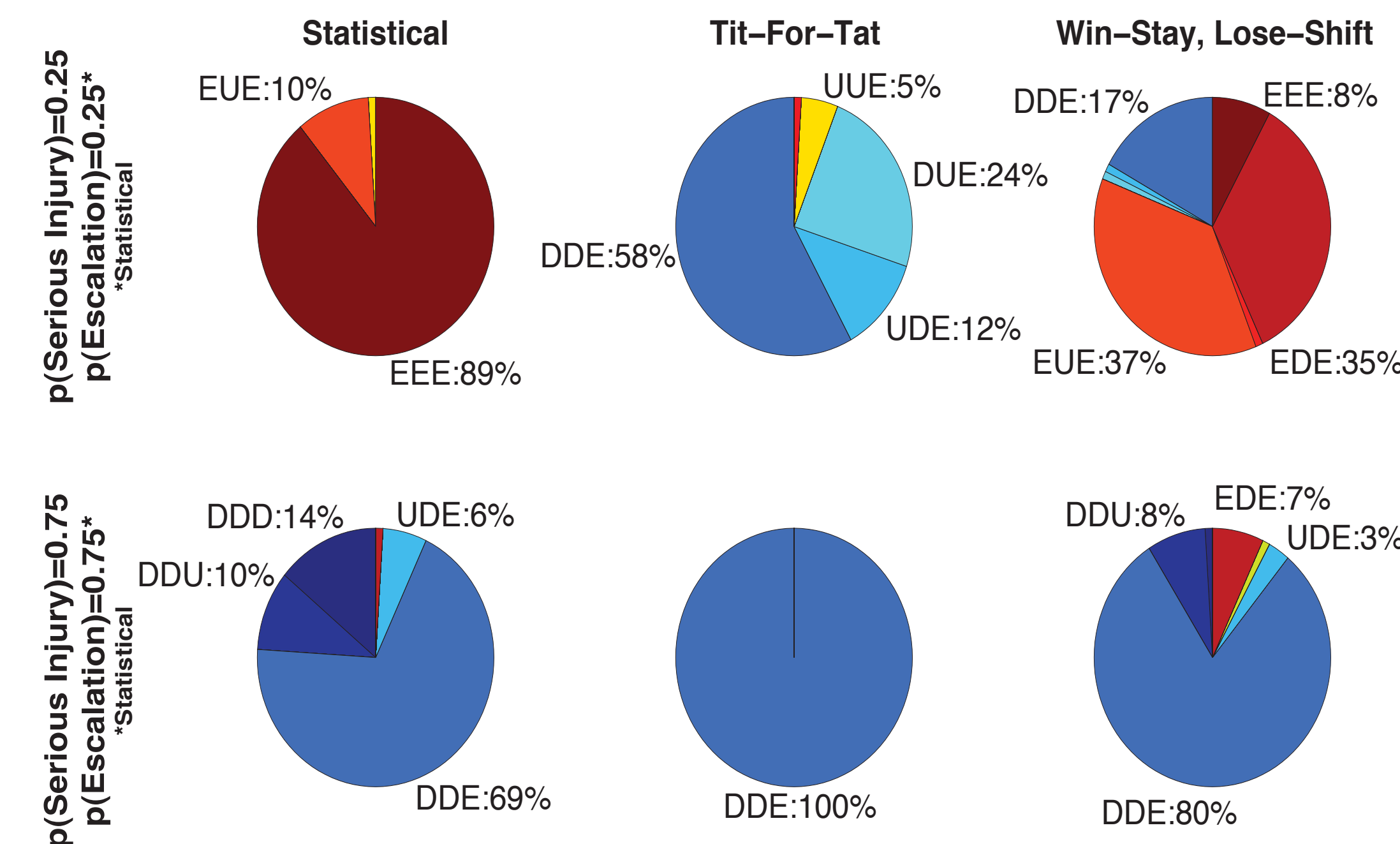
$$I_i(t) = \text{rnd}(-0.5, 0.0) + \sum_j nm(t-1) w_{ij}(t-1) s_j(t-1)$$

### Opponent Agent

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

## RESULTS

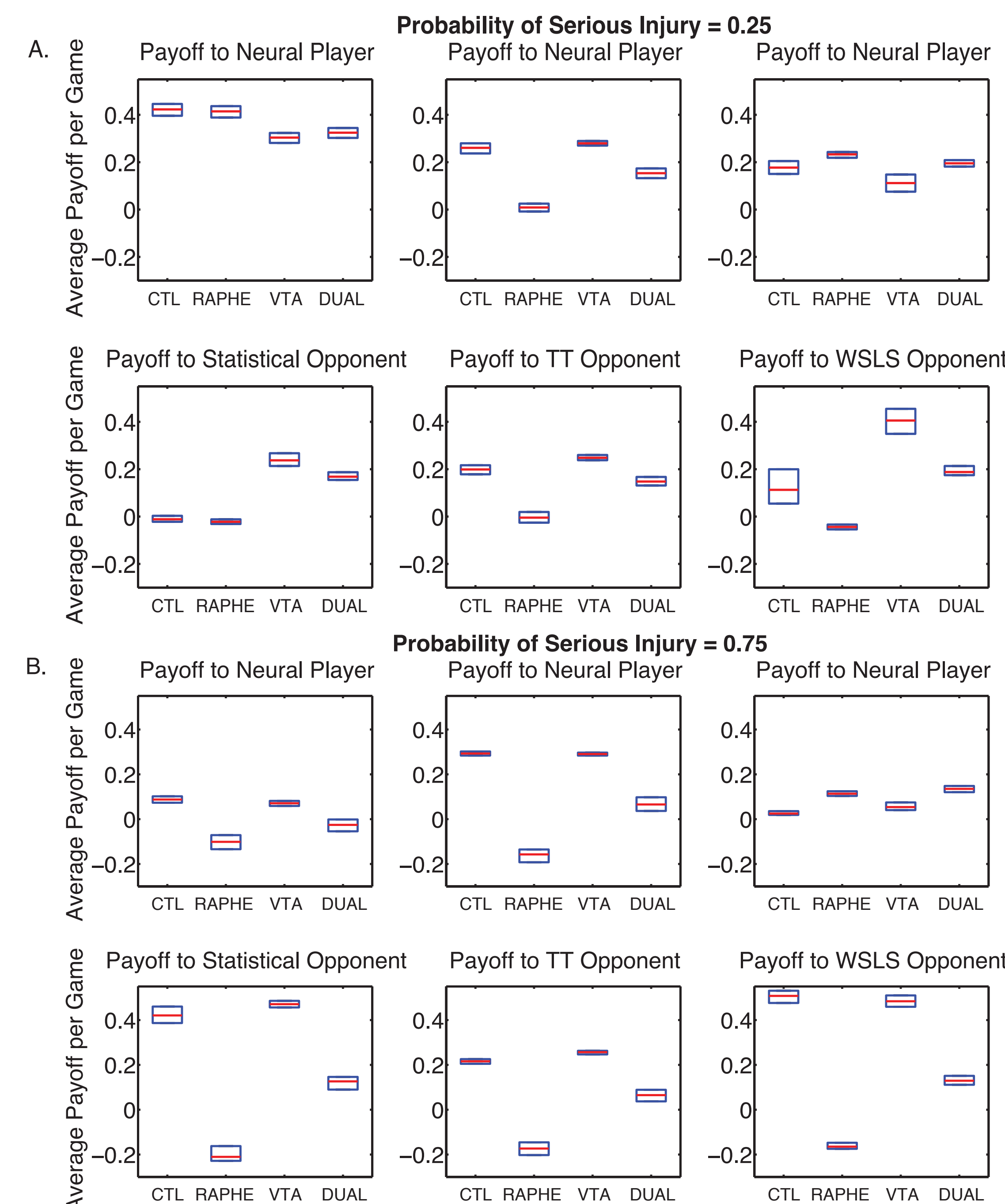
### Statistically Defined Actions



### 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%
WLS	93.22%	9.09%	96.88%	96.88%	20.93%	8.22%

### Average Payoff per Game



## CONCLUSIONS

- We showed that an agent, whose behavior was guided by a computational model of the neuromodulatory system, learned to adjust its strategy appropriately depending on environmental conditions and its opponent's strategy in the Hawk-Dove game.
- The model makes the following predictions:
  1. The interaction between the DA and 5-HT neuromodulatory systems allows for appropriate decision making in games of conflict.
  2. Impairment to either the dopaminergic or serotonergic system will lead to perseverant, uncooperative behavior.
  3. 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.

## REFERENCES

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## ACKNOWLEDGEMENTS

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