A Dynamic and Embodied Environment to Probe the Neural Correlates of Decision-Making and Social Signaling

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INTRODUCTION

•Elucidating the neurobiological basis for decision-making under competitive and conflicting situations is an important step towards understanding reciprocity, social cognition, cooperation, and competition [1,2].

•Game theory has been successful in describing such social behaviors [3,4,5] and has been applied to the investigation of their neural bases [1,6,7,8].

•The raphe nucleus, which is the source of serotonin in the central nervous system (CNS), may underlie cognitive control of stress, social interactions, and risk-taking behavior [9].

•In studies of the neural basis of decision-making during games of conflict, subjects typically play against opponents with predetermined strategies.

•The present study introduces a neurobiologically plausible model of action selection and neuromodulation, which adapts to its opponent's strategy and environmental conditions [10,11]. The model is based on the assumption that dopaminergic and serotonergic systems track expected rewards and costs, respectively.

•The model controlled simulated and robotic agents playing Hawk-Dove against subjects [12, 13].

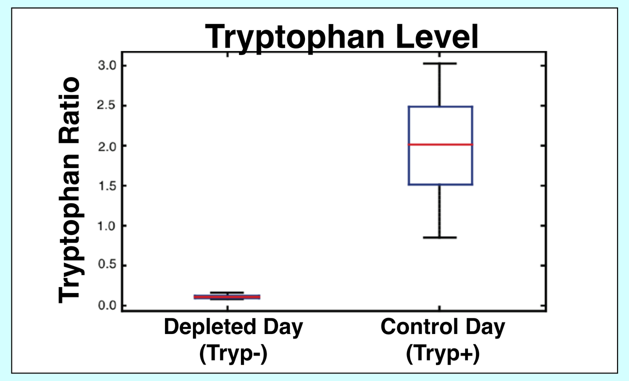
•An actor-critic model controlled simulated agents playing Stag Hunt games against subjects.

METHODS

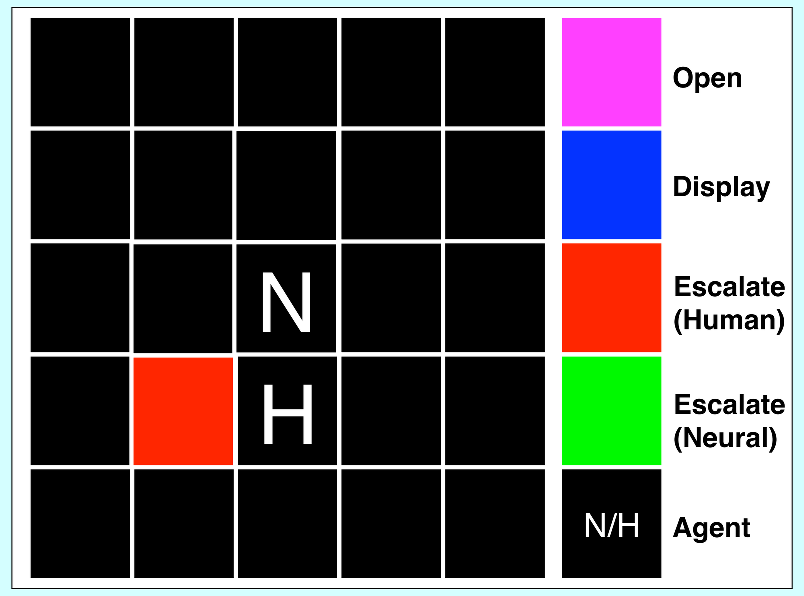
Acute Tryptophan Depletion

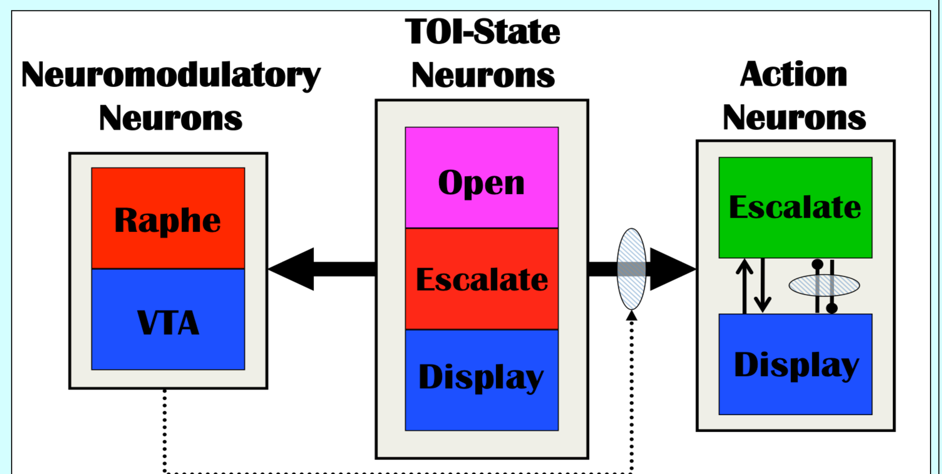
PROCEDURE

- 8 participants
- Double blind study
- 24 hour dietary modification pre-experimental day
- Drink amino acid shake w/ and w/o tryptophan
- 2 experimental days separated by 1 week (7 days)
- Blood draw pre-consumption
- Blood draw 5.5 hours post-consumption
- Game playing

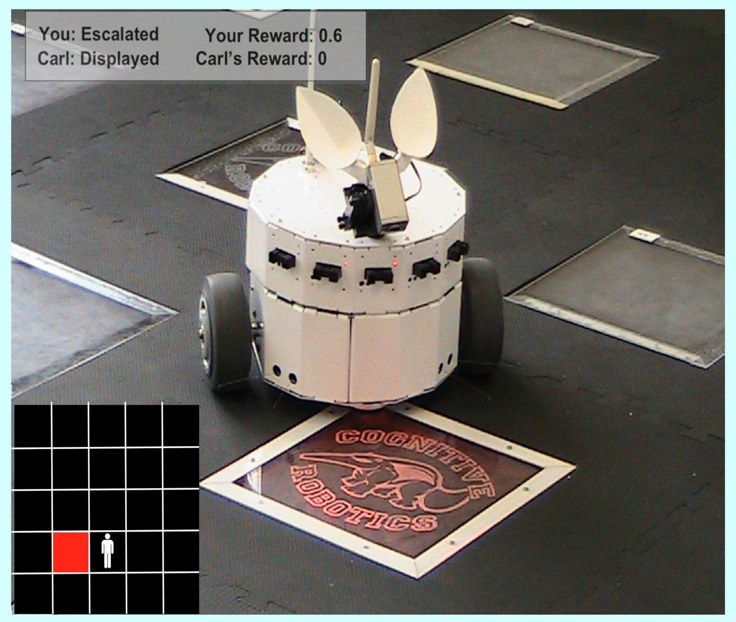


Hawk-Dove Game





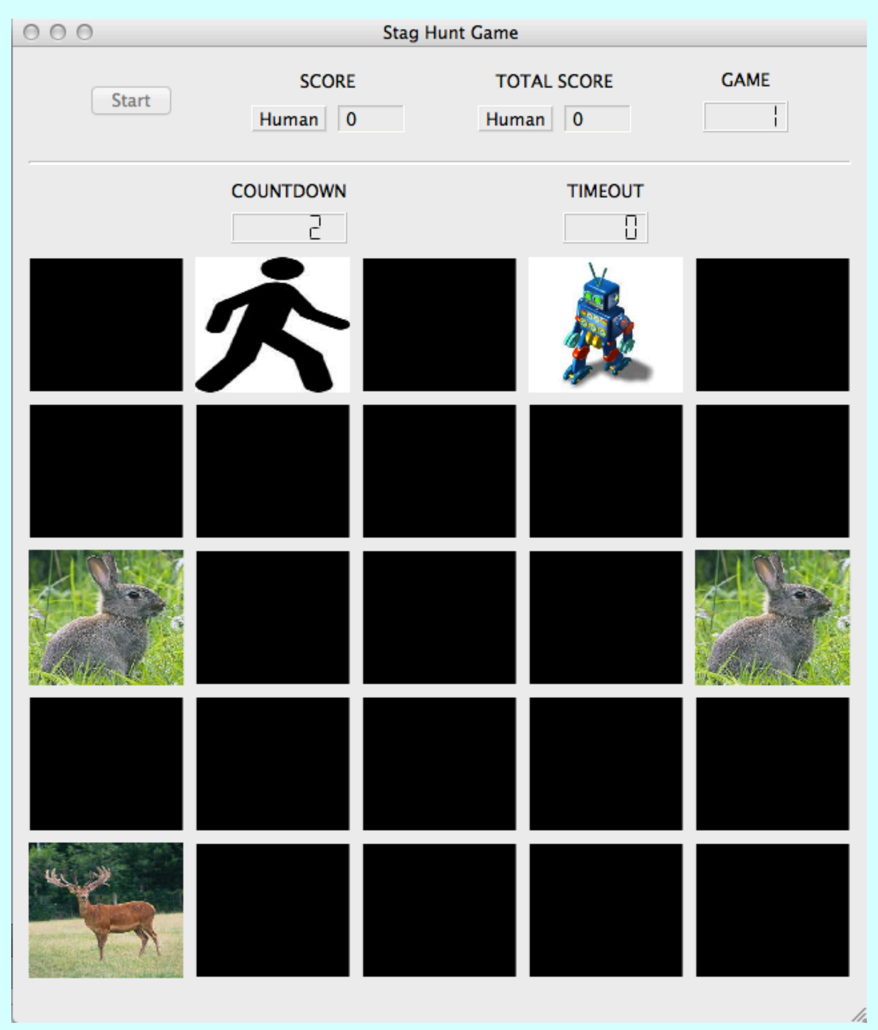
From	To	Initial Weight	Plastic	Phasic Neuromodulation
TOI-State	*Action*	0.1	Y	Y
TOI-State	*Neuromodulatory*	0.1	Y	N
Action-Escalate	*Action-Display*	0.1	N	N
Action-Escalate	*Action-Display*	-0.1	N	Y
Action-Display	*Action-Escalate*	0.1	N	N
Action-Display	*Action-Escalate*	-0.1	N	Y

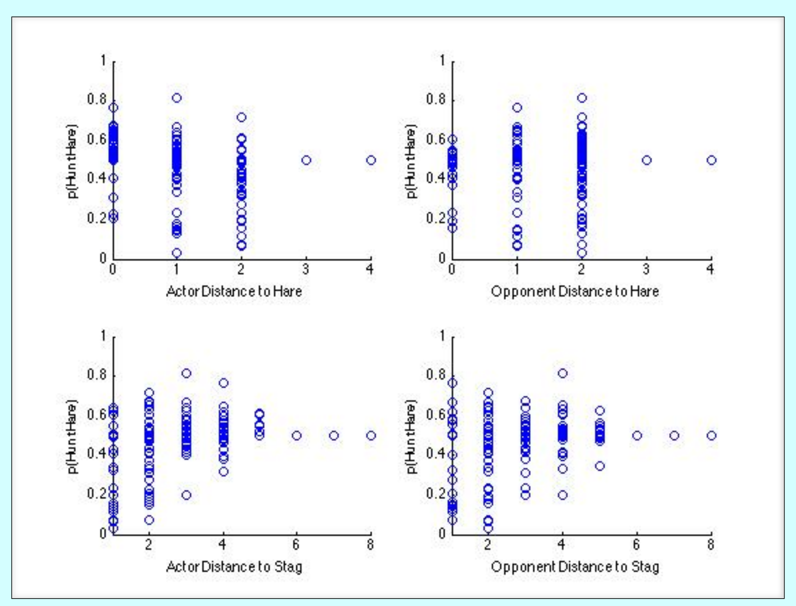


Hawk-Dove Experimental Conditions

Conditions	Control	Raphe	P_{SI} = 0.25	P_{SI} = 0.75	Robot	Sim
A	x		x		x	
B		x	x		x	
C	x			x	x	
D		x		x	x	
E	x		x			x
F		x	x			x
G	x			x		x
H		x		x		x

Stag Hunt Game

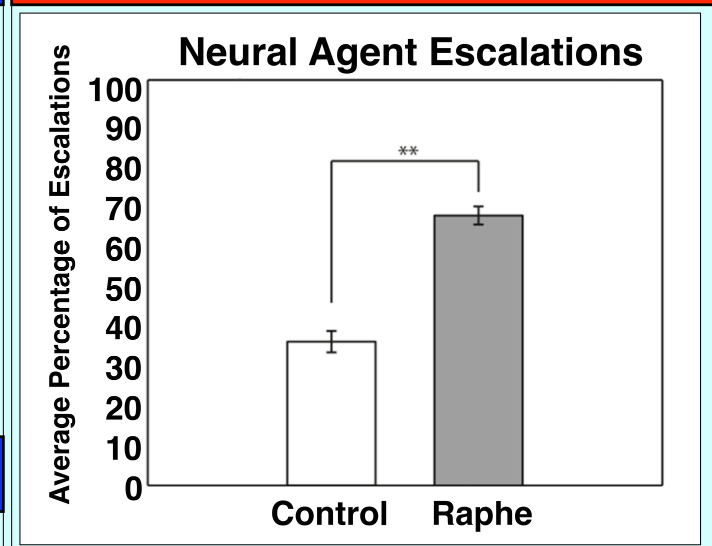


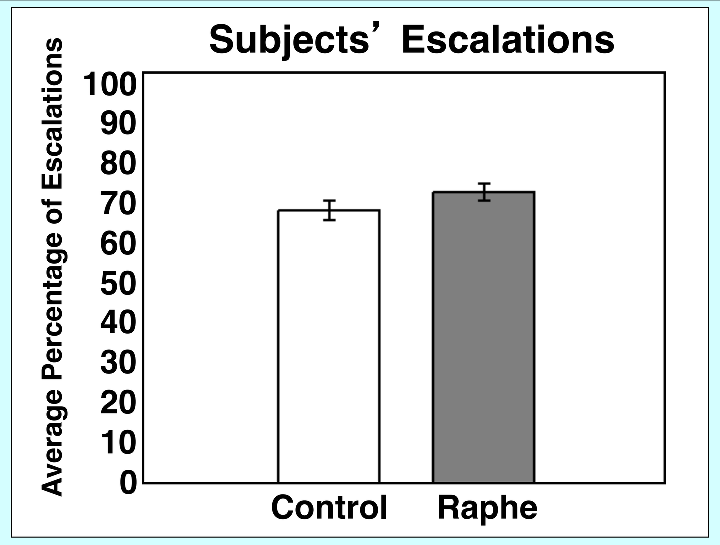


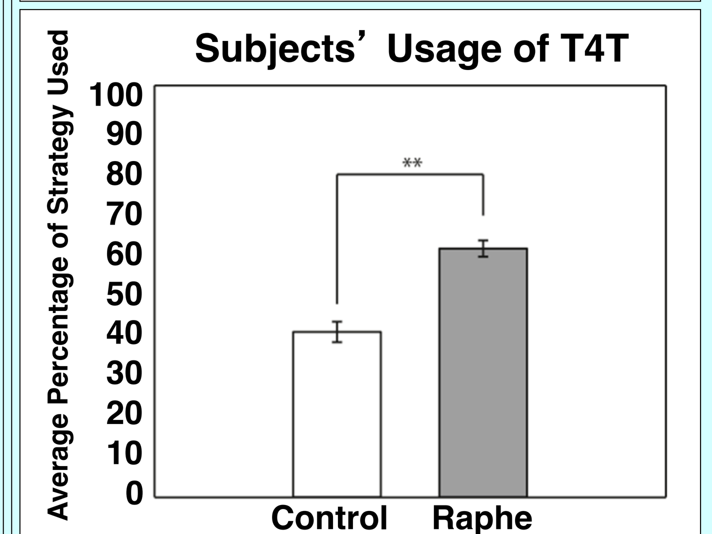
	Agent hunts Stag	Agent hunts Hare
Player hunts Stag	Agent: 4 pts Player: 4 pts	Agent: 1 pt Player: 0 pts
Player hunts Hare	Agent: 0 pts Player: 1 pt	First to catch: 1 pt Other: 0 pts

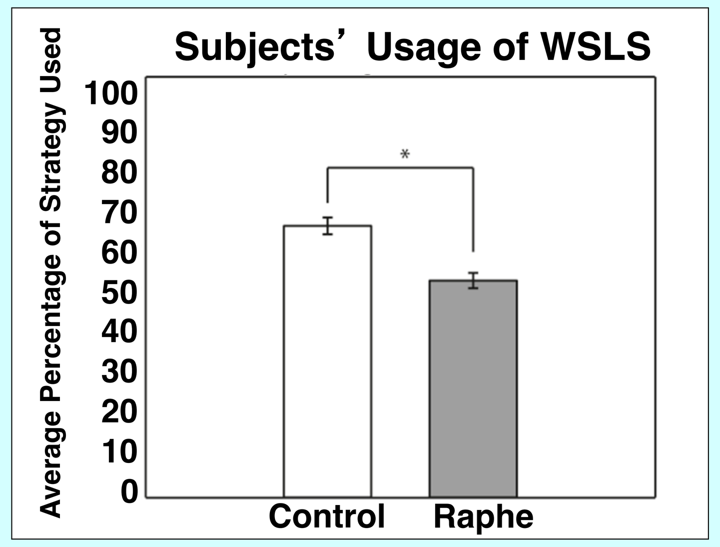
RESULTS

Hawk-Dove Game







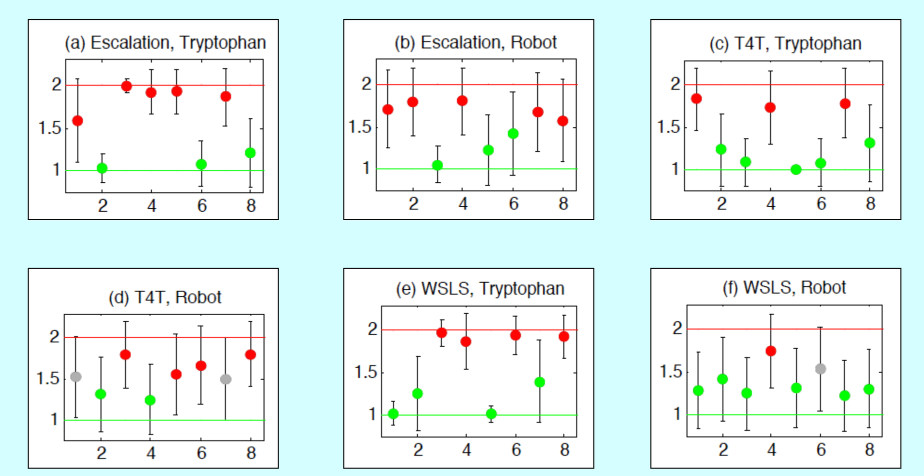


Bayesian Analysis of Hawk-Dove

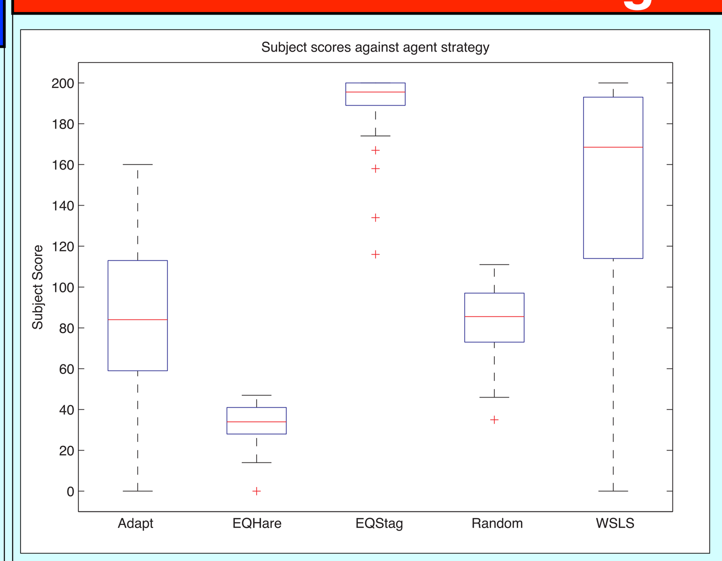
• A hierarchical Bayesian Cognitive Model was utilized to explore the possibility of sub-groups within the subject pool.

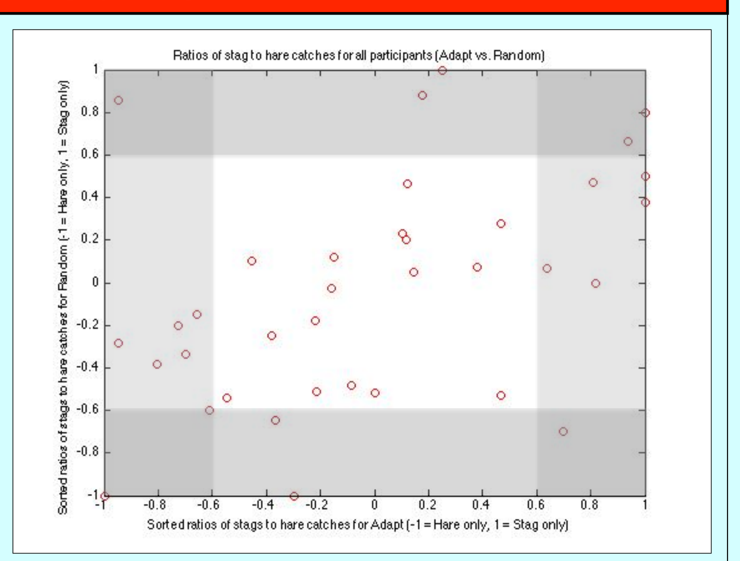
• The model makes a general prediction about a subject's base-rate amount of Escalations independent of tryptophan depletion by assuming the prior to be a flat Gaussian distribution.

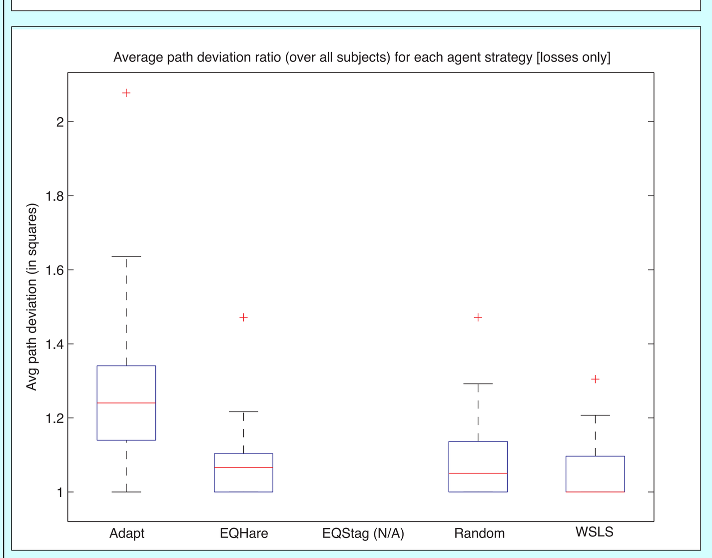
• The model utilizes a Markov chain Monte Carlo (MCMC) approach to approximate the target distributions for the potentially different groups that result from changes in percentage of Escalations when tryptophan depleted.

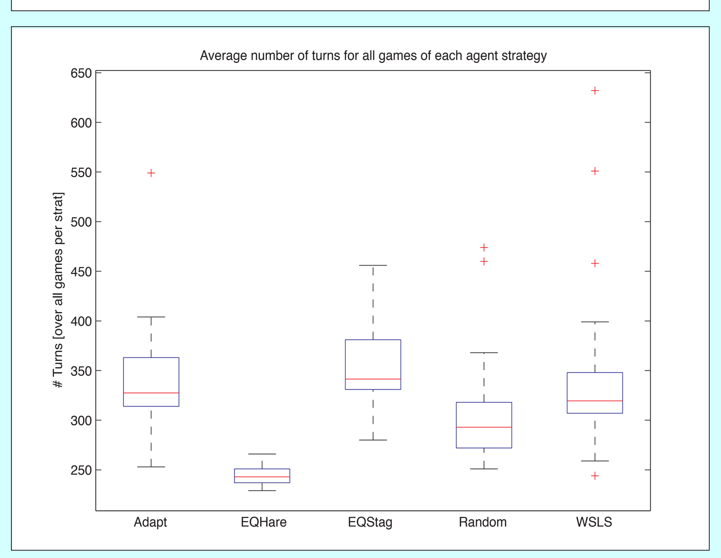


Stag Hunt Game









CONCLUSIONS

•When playing Hawk-Dove against an aggressive version of the model, there was a significant shift in the subjects' strategy from Win-Stay-Lose-Shift to Tit-For-Tat.

•Subjects became retaliatory when confronted with agents that tended towards risky behavior in the Hawk-Dove game.

•In previous studies, treatment with ATD has led to an increased number of defections in the Prisoner's Dilemma [14] and more rejections of offers in the Ultimatum Game [15]. In contrast, we did not observe a decrease of cooperativeness in our subjects due to ATD, but rather the emergence of a significant shift in strategies based on opponent type.

•It may be that iterative interactions with a responsive, adaptive agent outweighed the effects of ATD in our human subjects.

•When playing Stag Hunt against an adaptive model, subjects tended to spend more time thinking about their moves and navigating the board before settling on a target.

•When playing with the adapting agent, many subjects tended to play Stag Hunt with a heavy bias toward either the hare or stag equilibrium.

•These results highlight the important interactions between subjects and agents utilizing adaptive behavior. The Hawk-Dove results reveal neuromodulatory mechanisms that give rise to cooperative and competitive behaviors. The Stag Hunt results reveal distinct differences in subjects when comparing responses to an adaptive agent versus a set-strategy.

•Our study sheds light on how humans interact with others in conflicting situations and assists in the development of neural agents that can respond more naturally in human-robot interactions.

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