Title: **Effects of neuromodulation and adaptive behavior on reciprocity during human-robot interactions**

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Abstract: Game theory has been useful for understanding risk-taking, cooperation, and social behavior. However, in studies of the neural basis of decision-making during games of conflict, subjects typically play against an opponent with a predetermined strategy. The present study introduces a neurobiologically plausible model of action selection and neuromodulation, which adapts to its opponent's strategy and the environmental conditions. The neural model is based on the assumption that the dopaminergic and serotonergic systems track expected rewards and costs, respectively. The neural model controlled both simulated and robotic agents that played a series of Hawk-Dove and Chicken games against human subjects. The human subjects underwent a dietary manipulation called the acute tryptophan depletion procedure (ATD), which subtly and transiently alters the levels of serotonin in the brain via a decrease in blood plasma tryptophan. A corresponding simulated version of ATD was applied to the neural agent through a simulated lesion of its serotonergic system. When human subjects played against an aggressive version of the neural model with such a simulated lesion of its serotonergic system, there was a significant shift in the human subjects' strategies from Win-Stay-Lose-Shift to Tit-For-Tat, regardless of their tryptophan levels or whether they were playing against a simulated versus robotic opponent in the human robot interaction (HRI) paradigm. It may be that iterative interactions with a responsive, adaptive agent outweighed the effects of ATD and HRI on behavior. Thus, human subjects became retaliatory when confronted with an agent that tended to adopt risky behavior by fighting for resources. These results highlight the important interactions between human subjects and an agent that can adapt its behavior. Moreover, they reveal neuromodulatory mechanisms that give rise to cooperative and competitive behaviors.

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