The Enhancement of the Reward Prediction Error Signal in the Midbrain Dopamine Neuron by the Cost Paid for the Reward

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Abstract The midbrain dopamine (DA) neuron plays a key role in reward processing and codes signals associated with the reward prediction error (RPE) to update the value of options. Here, we examined whether these RPE signals are modulated by the cost paid to obtain the reward. After focussing a fixation point, two macaque monkeys were required to make a saccade to a condition cue, then a target appeared. In the high cost condition, long fixation to the target was required. In the low-cost condition, only a short fixation was required. After fixation on the target, the subjects made a saccade to the reward cue. Choice trials between condition cues and between reward cues were inserted randomly to test if the subjects showed a preference. Free reward and free air-puff trials were inserted randomly to determine whether each DA neuron was of a salience or motivation subtype. A cue signaling a costly action to be performed triggered less response in DA neurons with respect to a cue signaling a less costly action, but DA neuron responses to cues predicting reward and to the delivery of rewards were found to be enhanced after the monkey had performed a costly action compared to a less costly action. These findings suggest that DA neurons incorporate the cost of performing an action into the prediction error signal, and that RPEs are enhanced following the performance of a costly action. This finding suggested that monkeys would be faster to learn stimulus-reward associations after performing a costly action compared to a less costly action. A subsequent behavioral experiment confirmed this hypothesis. Information about action cost is processed in the DA

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reward system in a manner that amplifies the DA RPE signal, thereby producing more rapid learning under situations of high cost.