Updating dopamine reward signals

Wolfram Schultz
Department of Physiology, Development & Neuroscience, University of Cambridge, UK

I will interpret past work and report on current work addressing open questions and using experimental economics to advance the characterisation of dopamine responses in terms of formal economic decision theory.

Experiments have shown for >20 years that the phasic dopamine prediction error signal is composed of two components, resembling two-component responses in main sensory neurons. The early, unselective dopamine response component detects events indiscriminately and is influenced by physical impact, novelty, reward generalisation and reward context. After 50-200 ms, the second component codes the reward prediction error. Although the first component detects punishers by their physical impact, none of the components codes the aversive nature of punishers. These characteristics concern the phasic prediction error response.

Dopamine neurons and voltammetrically measured concentrations show also several slower changes that are inconsistent and not comprehensible by formal behavioural theories. They were not further investigated in our laboratory (beyond 1990) but have generated some recent interest. There is also the much slower, often tonic role of dopamine neurotransmission that has many motor and cognitive enabling functions. It is challenged in Parkinson's disease, modified by pharmacological agents, and again not further investigated in our laboratory.

Our current studies reveal that monkeys are risk seeking with small rewards and risk neutral and then risk avoiders with larger rewards. They have corresponding convex and then concave economic utility functions. The animals' choices are meaningful in satisfying first, second and third order stochastic dominance of the tested gambles. The dopamine reward prediction error response follows closely the utility function and thus can be specified as a utility prediction error response. This response follows first and second stochastic dominance and is suitable to influence postsynaptic neurons involved in economic decision-making. These data unite concepts from animal learning theory and economic decision theory at the level of single reward neurons.