Ventral Striatal Pathway Determines Actions Employed: A Computational Model

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In the last decade, there have been complimentary works proposing that the ventral striatum, namely nucleus accumbens, influences the dorsal striatum through midbrain dopamine cells [1]. Nucleus accumbens, especially shell region, has an important function in determining reward value of tasks in goal-directed behavior and the error in expectation [1]. Various works demonstrate the effects of nucleus accumbens in delayed reinforcement on action-outcome learning [2] and there are works showing the nucleus accumbens related dopamine transmission involvement in effort-related decision making processes [3]. It is suggested that through the striato-nigro-striatal pathway, limbic regions have impact on the motor regions of the basal ganglia and also ventral pallidum acts as an integrator between nucleus accumbens and other parts of the brain [1,3]. The value of a stimulus is calculated by the ventral pathway according to its salience to produce an action and if dopamine release triggered by this stimulus is sufficient, then the output of the basal ganglia is modulated to permit a behavior to occur [4].

The computational model proposed in this work focuses on the modulatory effect of nucleus accumbens related dopamine secretion in the dorsal striatal pathway. In the model, both ventral and dorsal basal ganglia circuits are considered and each neural structure is modeled by Hodgkin-Huxley (HH) like conductance neuron models. While deriving model for each structure, ion channel dynamics are integrated and HH neuron model is modified to show the dynamic behavior of the considered neural structure. The simulation results are obtained with in-house built MATLAB® codes where differential equations defining the neuron dynamics are solved.

The simulation results reveal that the model is capable of showing the controversial role of direct and indirect pathways and how the ventral striatal pathway supports the indirect pathway effecting the action selection through cortico-striatal thalamic loop. The proposed model captures not only the connectivity of neural substrates but also the modulatory effect of neurotransmitters which have an important impact on behavior. According to the proposed model, if the dorsal and ventral pathway decisions are consistent, the output of the dorsal loop is amplified. Otherwise, ventral path suppresses the dorsal output. Therefore the model demonstrates that with the existence of dopaminergic ventral striatal pathway, even if an action's salience is not sufficient to be selected, it can be preferred based on its value calculated by the ventral striatal pathway.

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