CONTRIBUTION OF THE VENTRAL STRIATAL PATHWAY TO DECISION MAKING

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What is our goal? To develop a neurocomputational model to demonstrate the effects of ventral evaluation path over dorsal action selection path.

How do we model? Along with brain substructures, the effects of dopamine as a modulator is considered and an action selection circuit is realized as an interconnected dynamic system of ventral and dorsal basal ganglia pathways.

Abstract

- The model demonstrates the effect of ventral striatal pathway over dorsal striatal pathway for decision making.
- Neural substructures are modeled as nonlinear dynamical systems based on Hodgkin-Huxley type equations.
- Conductance-based computational model shows the impact of nucleus accumbens related dopamine secretion on the motor regions of the basal ganglia.

Dorsal Action Selection Loop

- Cortex-Dorsal Striatum-Globus Pallidus-Substantia Nigra pars reticulata-Thalamus-Motor Cortex
- Action selection results in motor circuits of cortex
- Direct (dopamine D1 receptors) and indirect (dopamine D2 receptors) pathways work simultaneously to decide on an action. Both pathways are balanced at rest state.
- Direct pathway excites motor cortex while indirect pathway results in decreased stimulation of the motor cortex and reduced muscle activity.
- Output of GPi/SNr defines action.

Ventral Action Selection Loop

- Cortex-Ventral Striatum (Nucleus Accumbens)-Ventral Pallidum-Substantia Nigra pars reticulata-Thalamus-Motor Cortex
- There are more D2 type neurons in the ventral pathway.
- Similar to dorsal loop, direct path excites and indirect path inhibits.
- Shows value. Even if a certain action's salience is not sufficient for it to be selected, it can be preferred based on its value.

Our Model

- Demonstrates modulatory effects of ventral pathway over dorsal pathway
- If dorsal and ventral decisions are consistent, the output of the dorsal loop is amplified. Otherwise, ventral path suppresses the dorsal output.
- Dopamine is a modulator acting on D1 and D2 type receptor neurons. Dopamine input inhibits D2 neurons and stimulates D1 neurons.
- VTA and SNc input I=80mA
- Conductance based model based on Hodgkin-Huxley type equations

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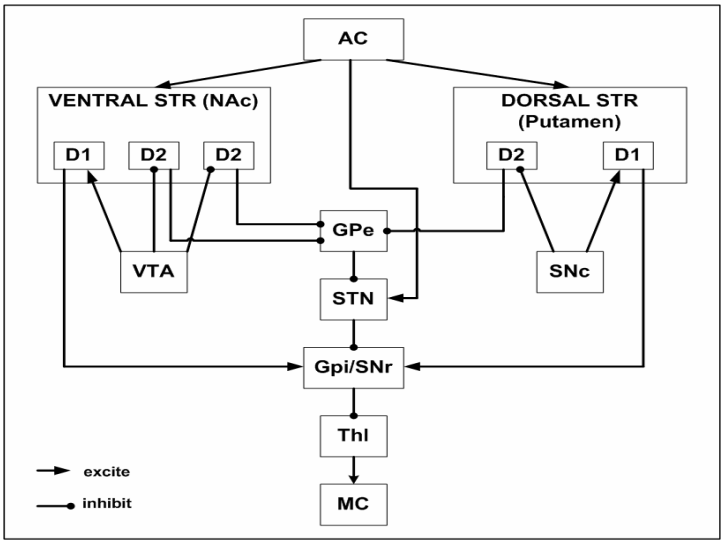
Which Brain Substructures Play A Role?



AC: associative cortex

D1/D2: D1/D2 type dopamine receptor neurons

Thl: thalamus

GPe: globus pallidus externus

GPi/SNr: globus pallidus internus/substantia nigra pars reticulata

MC: motor cortex

NAc: nucleus accumbens

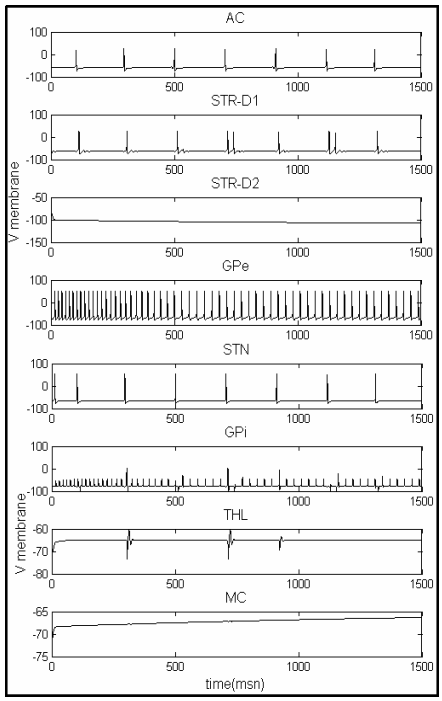
SNc: substantia nigra pars compacta

STN: subthalamic nucleus

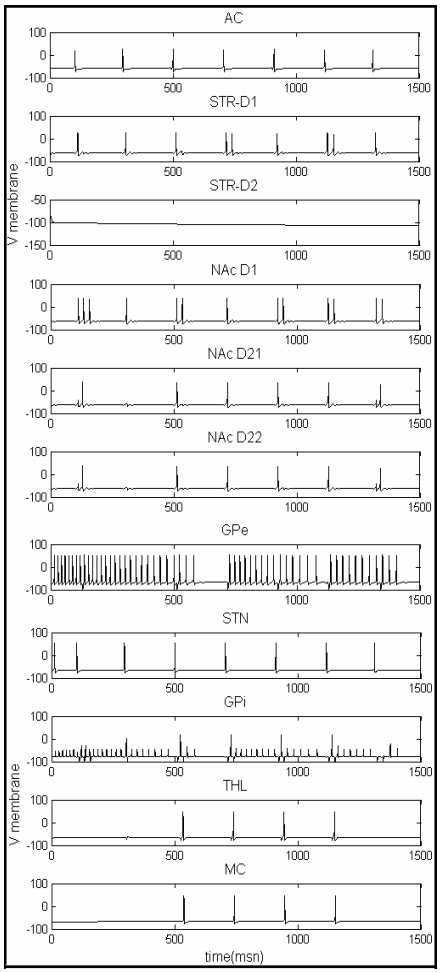
STR: striatum

VTA: ventral tegmental area

Results



Above, only dorsal loop is active. Action is suppressed.



Right, dorsal and ventral loops are both active. Although dorsal loop suppresses (STR-D2), ventral evaluation loop selects the unwanted action (MC).

Conclusion & discussion

- A conductance based model for action selection which shows the effects of ventral striatum over dorsal striatum.
- It is demonstrated that unwanted actions might be preferred due to their values.
- The model can be improved by including a more realistic input to trigger dopamine secretion from VTA and SNc.

References

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