VENTRAL STRIATAL PATHWAY DETERMINES ACTIONS EMPLOYED

A Computational Model

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What is our goal? To develop a neurocomputational model demonstrating that ventral evaluation path modifies dorsal action selection.

How do we model? Modulatory effects of dopamine is considered and an interconnected action selection circuit containing most of the related brain structures is realized as a 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 using modified Hodgkin-Huxley neuron model.
- Conductance-based computational model shows the impact of nucleus accumbens related dopamine secretion on the motor regions of the basal ganglia.

Our Model

- Demonstrates modulatory effects of dopamine in ventral and dorsal pathways taking role in action selection.
- If dorsal and ventral decisions are consistent, the output 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.
- Cortical stimulus input I=16mA
- Conductance based model with additional ion channel currents in Str, SNc, THL, GPe, GPi, STN, NAc, VTA
- Output of GPi/SNr defines action

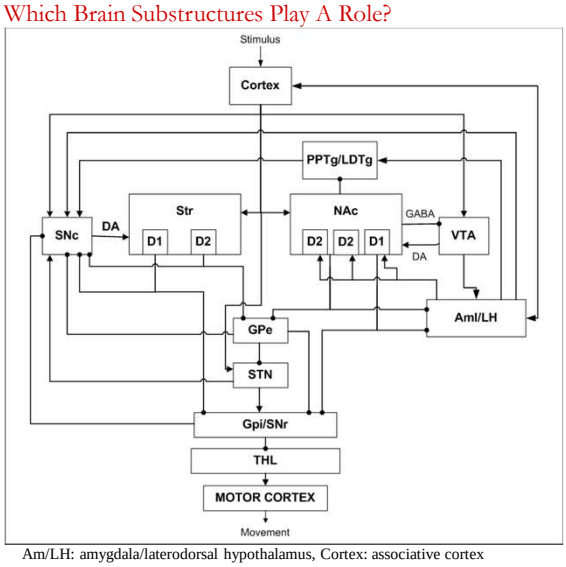
Dorsal Action Selection Loop

- 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.
- The modifying effect of dopamine is modeled by ion channel currents.

Ventral Action Selection Loop

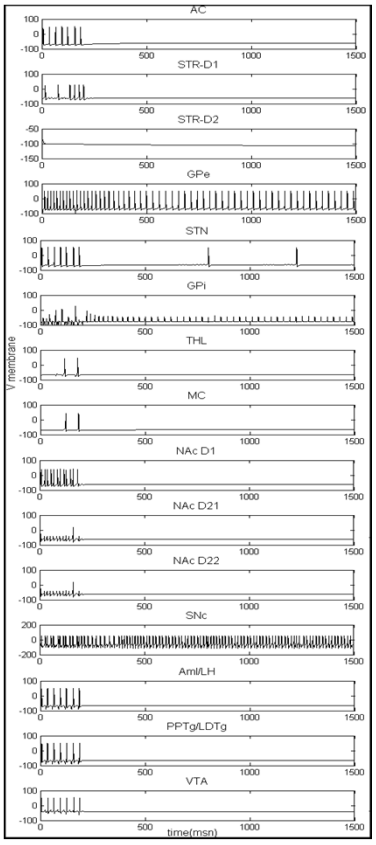
- Cortex-Ventral Striatum (Nucleus Accumbens)-Ventral Pallidum-Substantia Nigra pars reticulata-Thalamus-Motor Cortex
- Ventral pathway contains more D2 type neurons.
- Similar to dorsal loop, direct path excites and indirect path inhibits.
- Denotes value. Even if a certain action's salience is not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

Which Brain Substructures Play A Role?

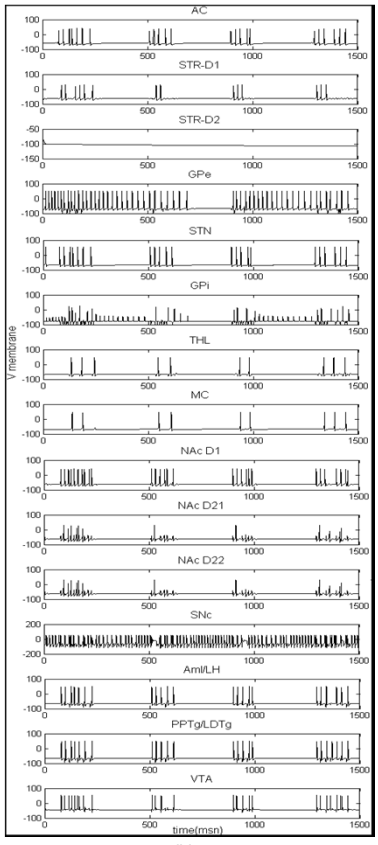


Am/LH: amygdala/laterodorsal hypothalamus, Cortex: associative cortex
D1/D2: D1/D2 type dopamine receptor neurons, GPe: globus pallidus externus
THL: thalamus, GPi/SNr: globus pallidus internus/substantia nigra pars reticulata
MC: motor cortex, SNc: substantia nigra pars compacta, NAc: nucleus accumbens
PPTg/LDTg: pedunculopontine tegmental nucleus/laterodorsal tegmental nucleus
STN: subthalamic nucleus, Str: striatum, VTA: ventral tegmental area

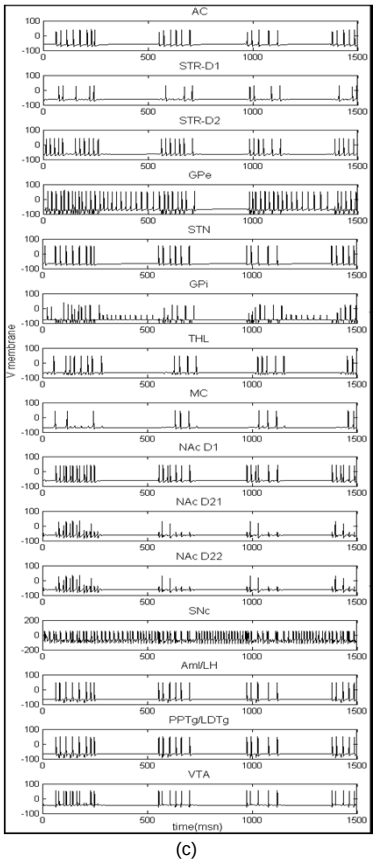
Results



(a)



(b)



(c)

(a) There is no stimulus input to the cortex. The short term activity (<250ms) is due to rebound spikes. Action is suppressed.

(b) Dorsal indirect loop inhibits and ventral loop promotes action selection. Although dorsal loop suppresses (STR-D2), ventral evaluation loop selects the unwanted action. THL-MC outputs show bursting activity.

(c) Dorsal inhibition caused by SNc dopamine projection to StrD2 neurons is removed by modifying ion channel current conductances. Ventral loop promotes action selection while bursting is observed in StrD2. Action selection is amplified w.r.t. (b).

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Conclusion & discussion

- A conductance based model including almost all brain structures employed 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 dynamically changing ion channel current conductances of striatal and nucleus accumbens neurons according to dopamine level modifications.

References

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