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#### ► To cite this version:

Charlotte Héricé, Radwa Khalil, Maria Moftah, Thomas Boraud, Martin Guthrie, et al.. Decision making mechanisms in a connectionist model of the basal ganglia. The Multi-disciplinary Conference on Reinforcement Learning and Decision Making (RLDM 2015), Jun 2015, Edmonton, Canada. . hal-01206514

#### HAL Id: hal-01206514 https://inria.hal.science/hal-01206514v1

Submitted on 29 Sep 2015

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# Decision making mechanisms in a connectionist model of the basal ganglia

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#### INTRODUCTION

Basal ganglia (BG) are known to hosts mechanisms of action selection and its adaptation to a changing environment. Their architecture consist of several parallel functional loops connecting back to distinct areas of cortex (motor, cognitive and limbic) and processing different modalities of decision making. The picture of parallel loops is complicated by partial convergence and divergence connections that implies that the various loops are interacting.



A previous BG model (developed by M. Guthrie[1]) was built of interacting bloc-diagram based on rate-models. It was able to learn optimized action selection during a probabilistic reward task. The aim of the present work is to refine and extend these results to a cell-synapse level through a bottom-up approach:  $\rightarrow$  Highlighting of the structure-function relationship and cir-

 $\rightarrow$  Investigation of cell-scale mechanisms impact on the whole

model capacities (learning and decision-making)

### **BEHAVIORAL TASK**



Figure 1. Overview of model architecture

## **NETWORK ARCHITECTURE**



cuitry emerging properties

Figure 4. Model pathways. A) Direct pathway. B) Hyperdirect pathway. C) Pathway crosstalk

Leaky integrate-and-fire neuron model:  $C_m \cdot \frac{dV_m(t)}{dt} + \frac{V_m(t)}{B_m} = I(t)$ Learning takes place when a reward is obtained. It is implemented as an increase in the synaptic weights corresponding to the projection from the cognitive cortex to the striatum.

4 target shapes  $\Leftrightarrow$  4 different reward probabilities. At each trial[2]:

- random presentation of 2 targets, at random positions

- choice made by the model

- reward given or not according to the reward probability (probabilistic learning task)

 $\rightarrow$  The model has to learn to choose the optimum target on each trial.

#### IMPLEMENTATION

				Basal Gang	lia Mo	odel	
		Main Cortex Ass	ciative cortex	Striatum	Asso	ociative striatum STN GPi Thalamus	
	Welcon	ne in the Basal Ganglia	Application. Ple	ase choose a	neuro	ron population with the tabs and fill the parameters.	
1. Current p	parameters -		2. Stimu	lation param	ters –	3. Learning parameters	
Current base value (Ampere) 0.05e-9			9	R	ın 1 (s	(seconds) 0.1 Increased synaptic strength	1.0
	- Base curre	nt multipliers				Decreased synaptic strength	1.0
Motor/Cog	nitive corti	cal coefficient 1.5		R	ın 2 (s	(seconds) 0.9	
Assoc	iative corti	cal coefficient 0.9	Motor/C	ognitive Cor	ex co	oefficient 3.0	
	Thalan	nic coefficient 1.25	As	sociative Cor	ex co	oefficient 1.5	
4. Che	eck the stim	ulation targets				<sup>−</sup> 5. Go to the tabs to set the synaptic coefficients —	
	Un/Check	all 🗌 CtxM1 🗌 Ct	xM2 🗌 CtxM	3 🗌 CtxM4		Excitatory synapse	n
	CtxC5	CtxA9 CtxA	0 CtxA11	CtxA12		Cognitive region	6
	CtxC6	CtxA13 CtxA	4 CtxA15	CtxA16		Inhibitory synapse Associative regi	
		0.0.44				rissociative regi	

CtxC8 CtxA21 CtxA22 CtxA23 CtxA24 6. If everything is ok, run the simulation-

#### RESULTS





Figure 6. Example of the cortex activity after learning

Figure 5. Example of the cortex activity in a naive network

#### Naive network

Ability of spontaneous action selection (defined here by a sufficient difference in the activity between two regions of the motor cortex).  $\rightarrow$  Exploration phase  $\Leftrightarrow$  Target selection of the primate.

#### Trained network



	Basal Ganglia Model	
Main Cortex	Associative cortex Striatum Associative striatum STN GPi Thalamus	
Please put the values for	the gain factor between the connections from the cortex (source region -> target region).	
	Example of connections	
Synaptic coefficients in the corte Motor Cortex -> Motor Cognitive Cortex -> Cognitive Motor Cortex -> Associative Cognitive Cortex -> Associative Motor Cortex -> M Cognitive Cortex -> Cogn Motor Cortex -> Motor T Cognitive Cortex -> Cognitive T	x connections Striatum 1.85 Striatum 0.75 Striatum 0.75 Striatum 0.75 otor STN 3.5 Thalamus 1.75 Thalamus 1.75	

## DISCUSSION

The neural network implementation of a BG stochastic model is developed, embedded in a sensory-motor closed-loop environment and applied to an action-selection task. Once finalized, this neuron level description model allows for a better understanding of the information flows dynamics in the BG and for an investigation of the physiopathological models including synapses, cells and neuromodulators properties.

Ability to preferentially select the optimum target (highest reward probability).

 $\rightarrow$  Exploitation phase  $\Leftrightarrow$  Successful learning from the primate.

#### **Before/after learning**

Better percentage of success (chosing the optimum target, p-value<5%) after learning than before.

To achieve this study, an accurate implementation of a dopamine modulated LTP mechanism will be done to reproduce a complete learning. To validate the model, lesional tests and changes in the conditions of the task are planned.

## REFERENCES

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