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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 convergence and divergence that implies that the various loops are interacting.

A previous BG model was developed by Martin Guthrie. This model was built of interacting bloc-diagram based on rate-models and 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. This should allow us to:

1. highlight structure-function relationship and circuitry emerging properties
2. Investigate cell-scale mechanisms impact on the whole model capacities (learning and decision-making)

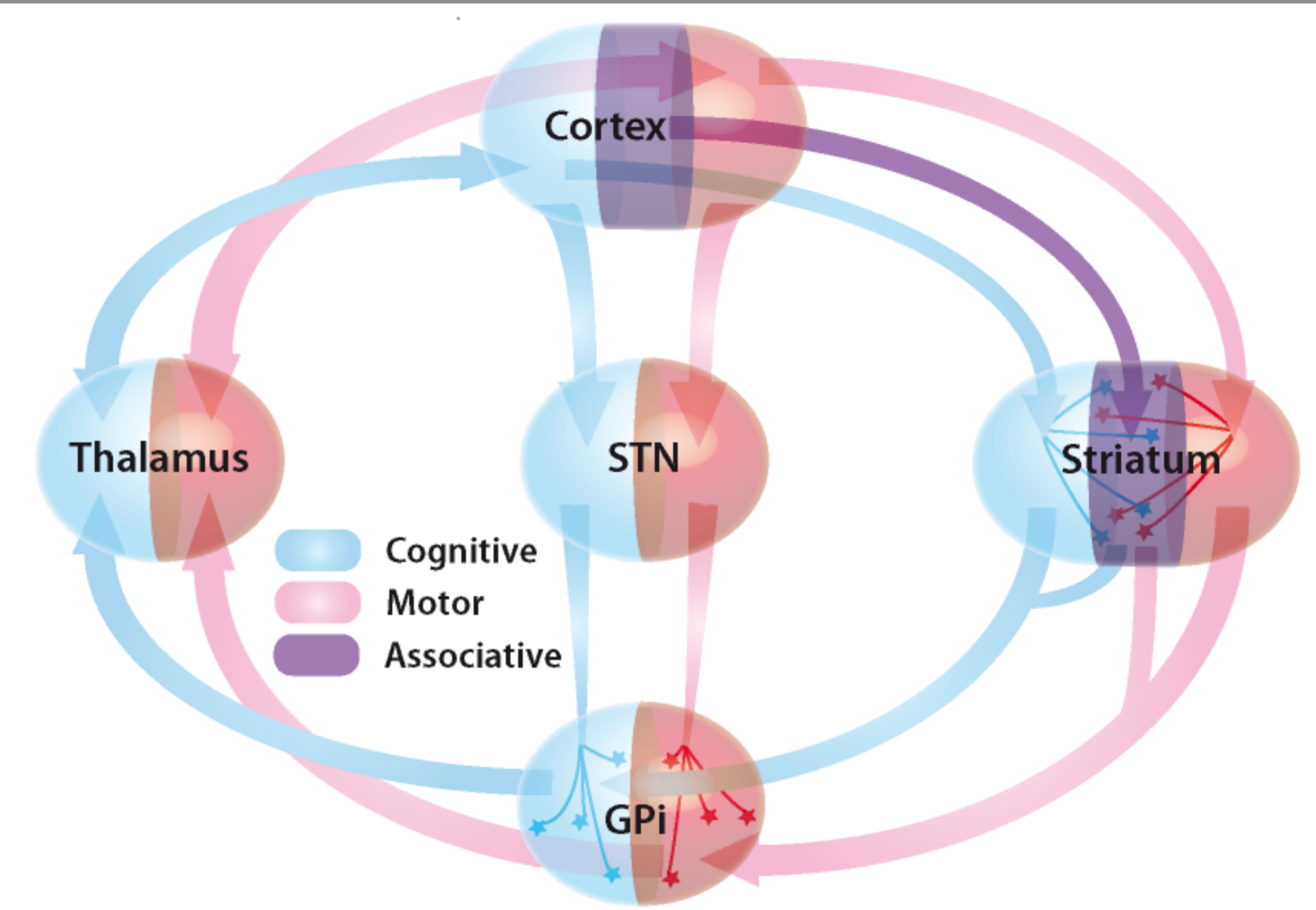


Figure 1. Overview of model architecture\*.

## Material and Method

### Behavioral task

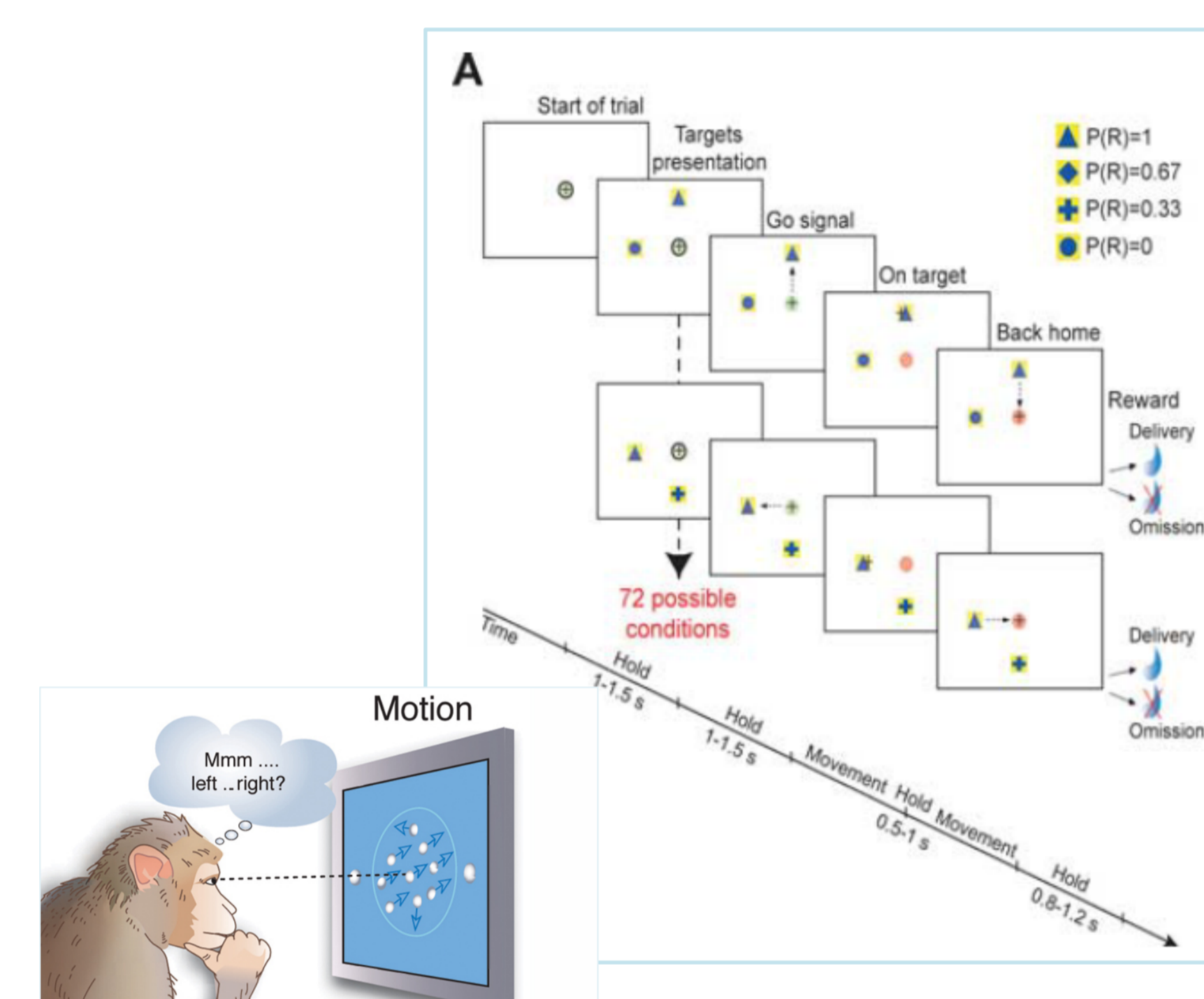


Figure 2. Task design\*\*

4 target shapes are associated with different reward probabilities. At each trial, 2 targets, randomly chosen among the 4, are presented in random positions.

A choice is made by the model and the reward is given or not according to its own reward probability (probabilistic learning task).

The model aim is to learn to choose the optimum target on each trial, which is the target with the higher probability of reward.

### Implementation

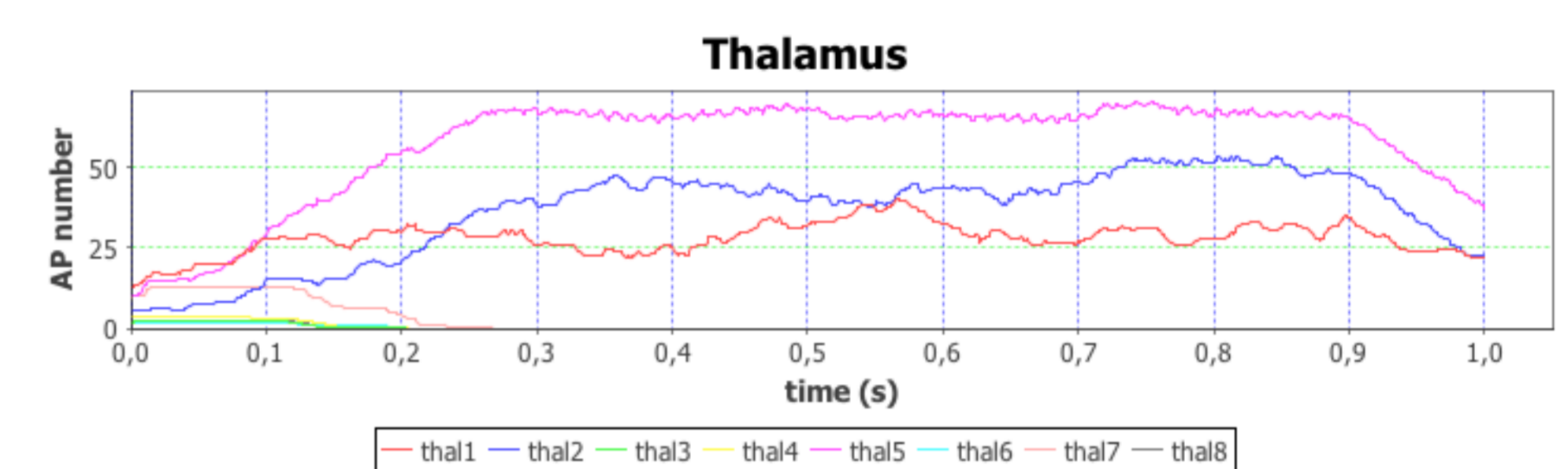
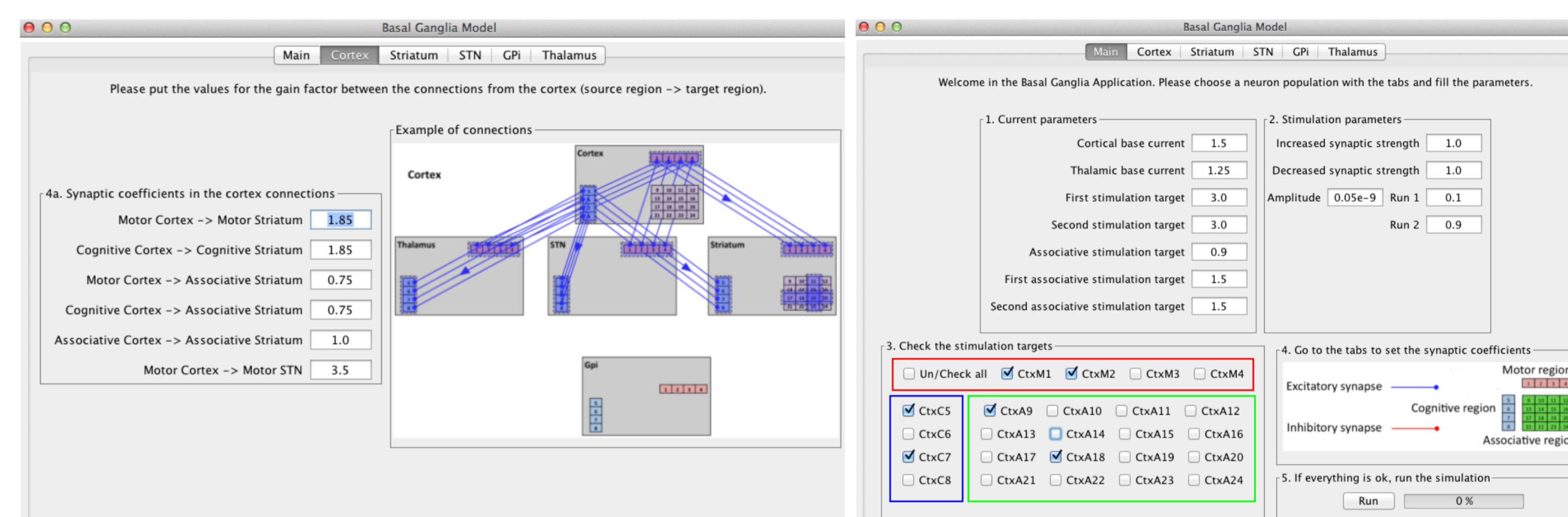


Figure 3. Modeling tool java implementation

## Network architecture

The model is designed in a manner consistent with known anatomy and electrophysiology in three main areas.

Each neuron is implemented by a leaky integrate-and-fire model:

$$C_m \cdot \frac{dV_m(t)}{dt} + \frac{V_m(t)}{R_m} = I(t)$$

Each subpopulation is composed of a cell assembly which size is related to the respective cell ratios.

Learning is modeled as an increase in cortico-striatal cognitive projections (synaptic plasticity).

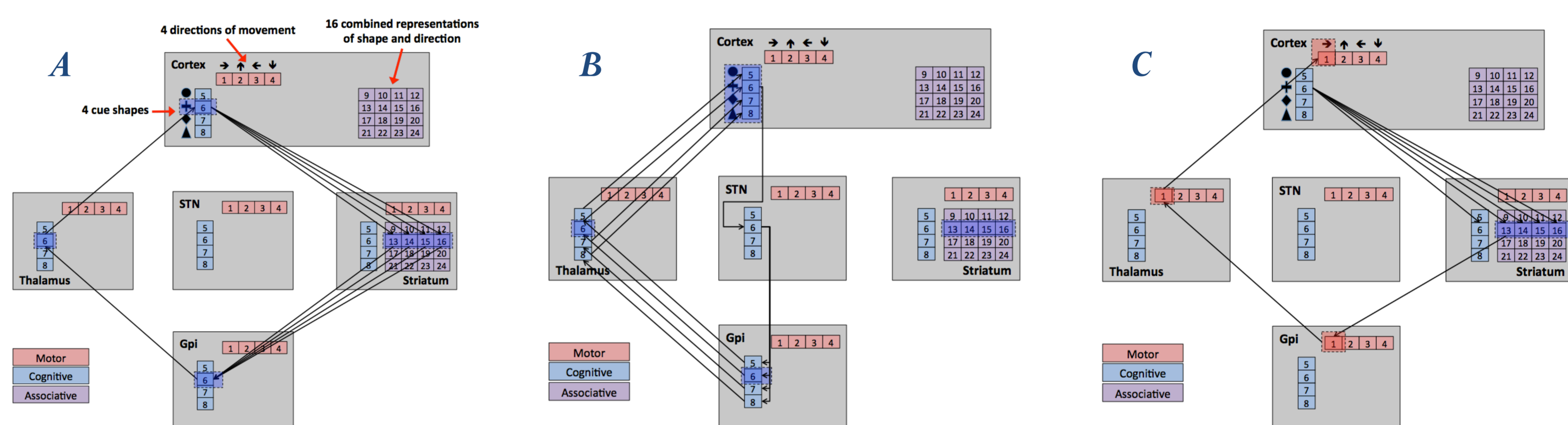


Figure 4. Model pathways. A) Direct pathway. B) Hyperdirect pathway. C) Pathway crosstalk

## Results

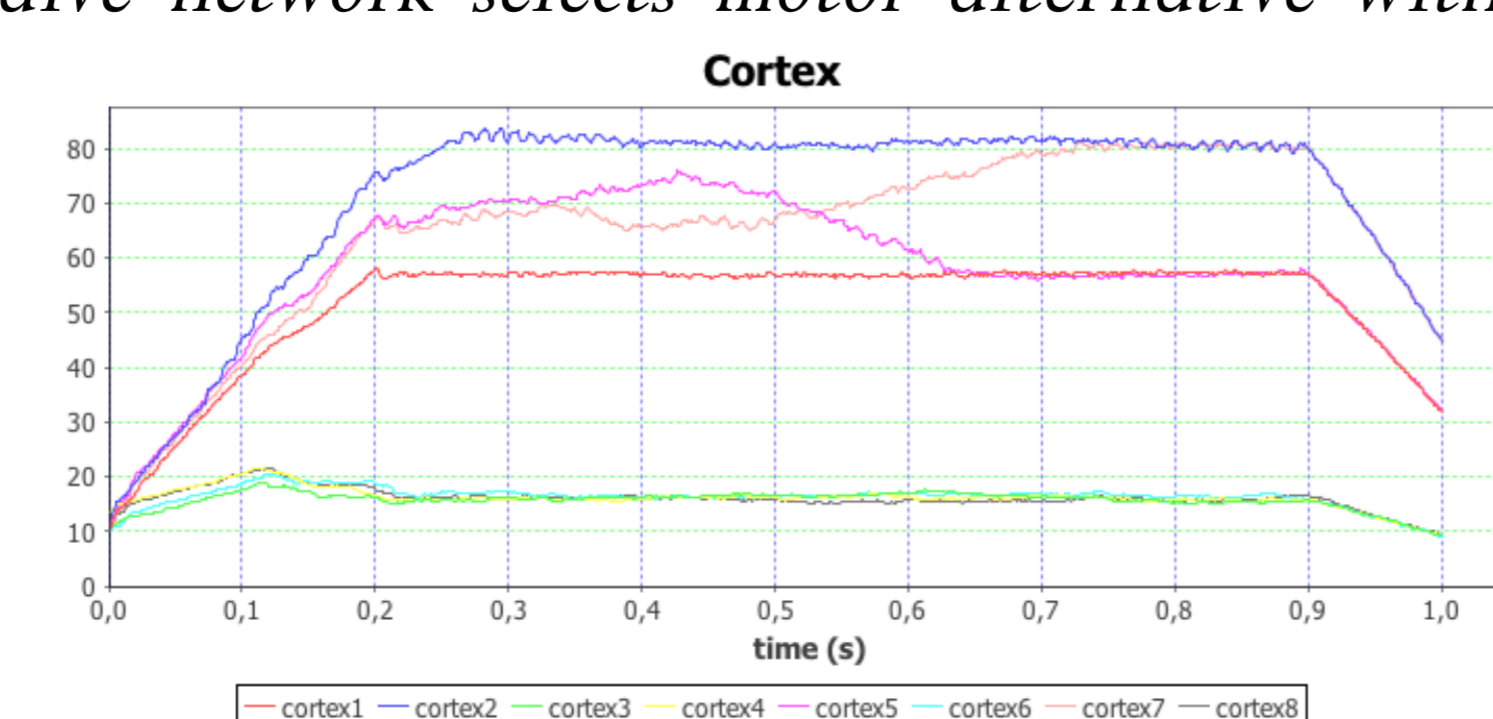
### Global network properties

A manual tuning of the strength of the different projections has provided a model which is robust to noise and consistent regarding (i) the average and relative levels of activity of each cell assembly and (ii) the interactions between each subpopulation.

### Feed-forward inhibition and action selection

Thanks to the architecture and the noise, the model spontaneously selects an action (defined here by the highest motor cortex activity) which breaks the symmetry. During this "exploration" phase, the naïve network selects motor alternative with equal probabilities.

Figure 5. Cortical subpopulations recordings (Hz)



### Cognitive bias of motor selection

The symmetry breaking occurs with equal probabilities regarding the motor and cognitive activation in a naïve model but with a superior probability for motor-cognitive coupled pairs.

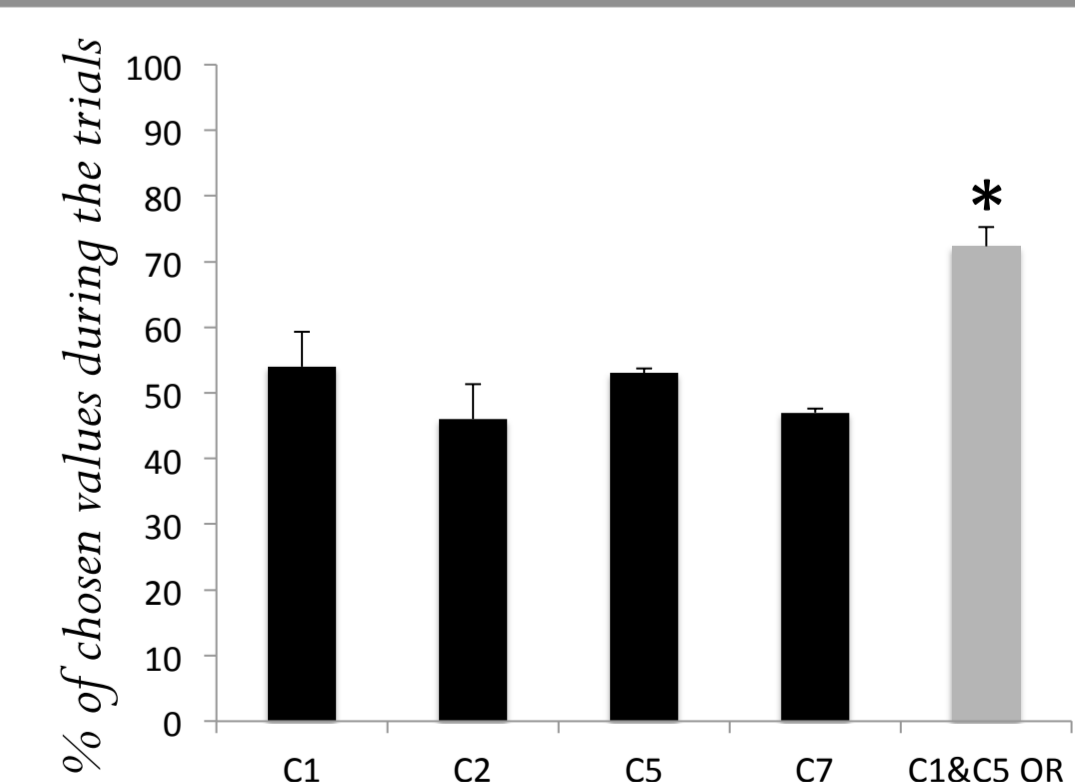


Figure 6. Average of chosen values

## 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. 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. To achieve this study two steps have to be reached:

- role of the cognitive bias on action selection as a function of learnt reward values.
- implementation of a dopamine modulated STDP to reproduce a complete learning process with a bottom-up and model-free paradigm.