TECHNISCHE UNIVERSITÄT CHEMNITZ

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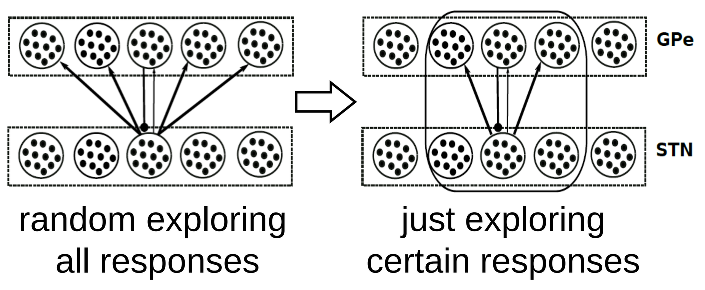
Exploration biased by former stimulus-response associations due to plasticity in the STN – GPe loop of the basal ganglia

Introduction

The basal ganglia (BG) may contribute to reinforcement learning [1]. A phasic dopamine signal, that encodes a reward prediction error [2], modulates the plastic BG connections [3].

There is little information about the possible function of the strong bidirectional connections between the subthalamic nucleus (STN) and the external globus pallidus (GPe) [4].



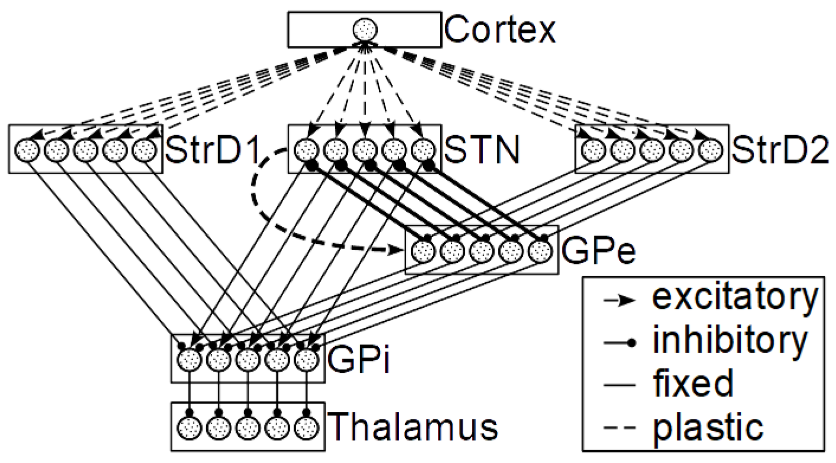
It was shown that these connections can bias exploration after an environmental change, depending on the connectivity pattern [5].

Hypothesis: The STN-GPe loop biases exploration towards solutions that worked well in the past [5].

Goal of this work: Implement plastic STN-GPe connections which allow the loop to store information of rewarded responses and bias exploration towards this responses.

Materials and methods

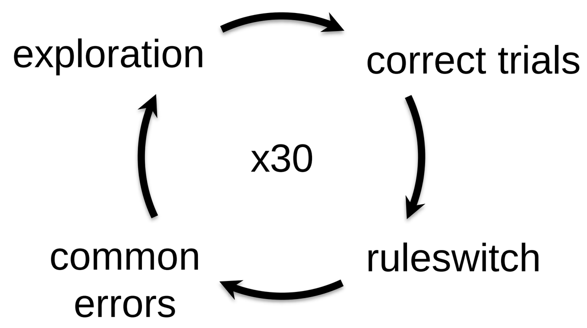
The model:



- Nuclei = 5 populations for 5 actions
- Izhikevich spiking neurons [6]
- Direct, indirect, hyperdirect pathways
- Stimulus = cortex population neurons fire
- Response = integrated thalamus population activity reaches threshold
- Dopamine modulated STDP

The simulations:

A - cluster experiment: only 3/5 actions can get rewarded, equally often



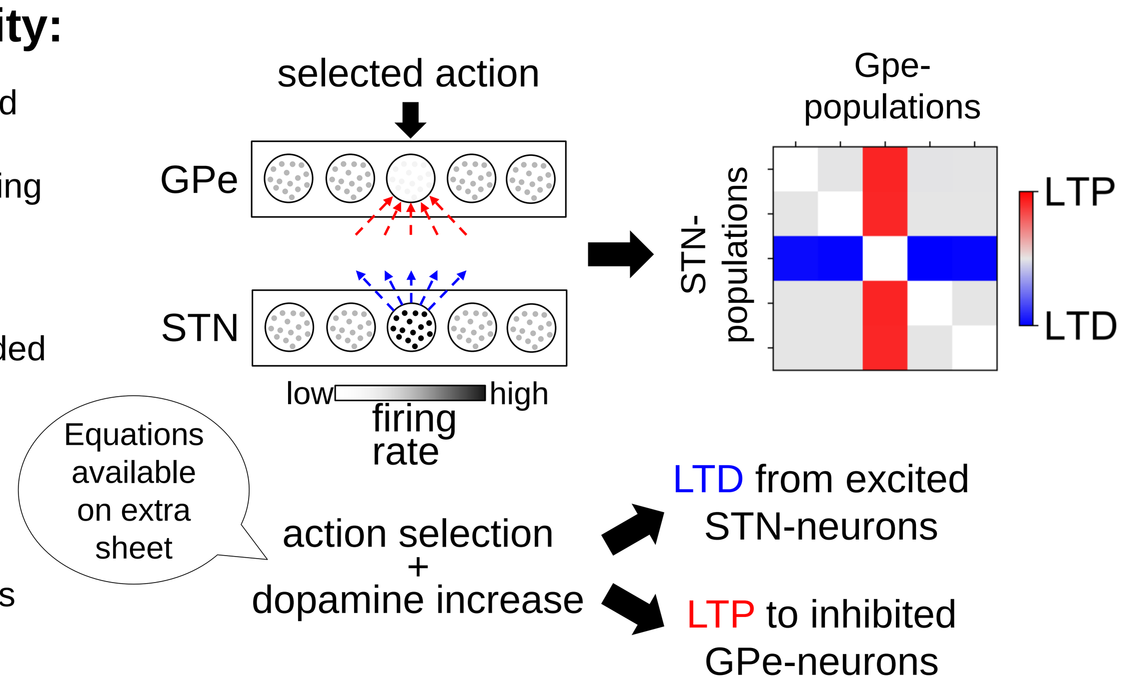
B - frequency experiment: 3 rarely (20%) rewarded actions and one frequent (40%) rewarded action

The STN-GPe plasticity:

Certain GPe-neurons are inhibited and certain STN-neurons are excited by thalamic feedback during and after action selection.

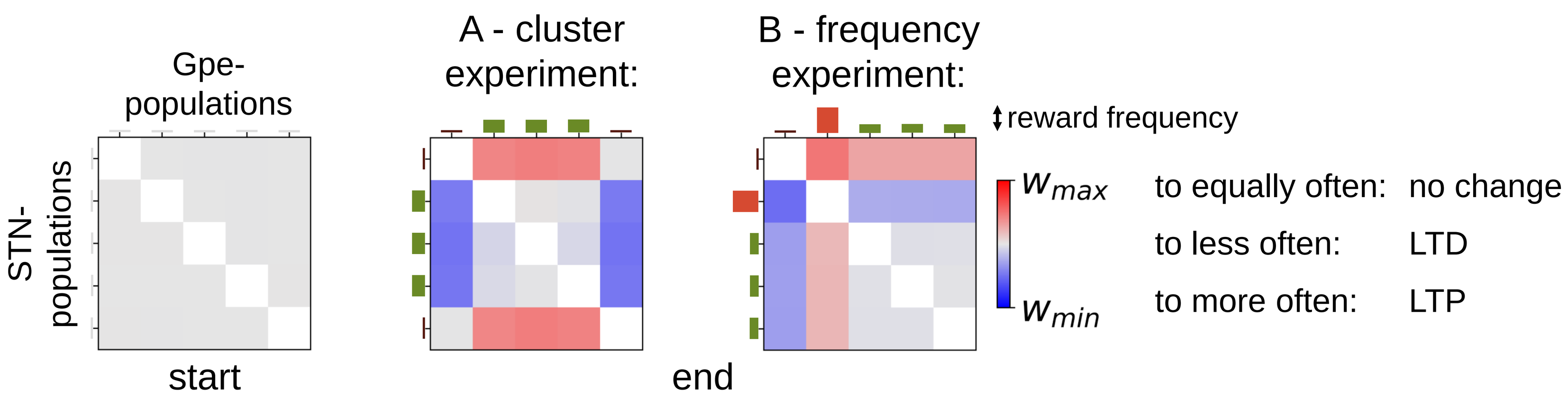
This activity changes and a dopamine increase after a rewarded response cause changes of the STN→GPe weights (see right).

If the selected action has been rewarded, the learning rule facilitates future exploration of this action.



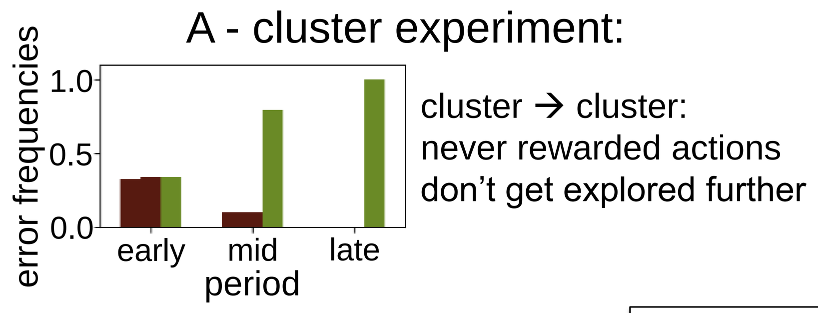
Results

Mean weights:



Errors during exploration:

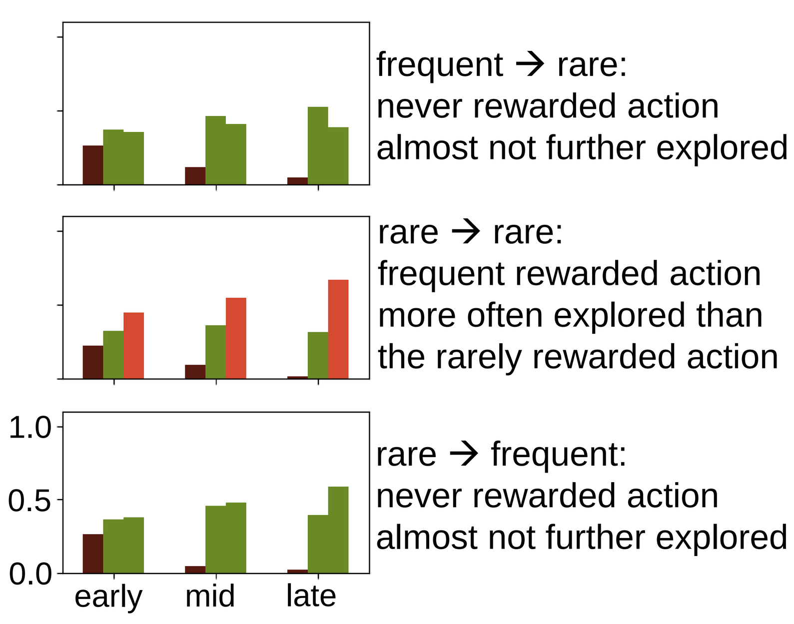
A - cluster experiment:



cluster → cluster: never rewarded actions don't get explored further

in cluster / rare
in cluster / frequent
out cluster

B - frequency experiment:



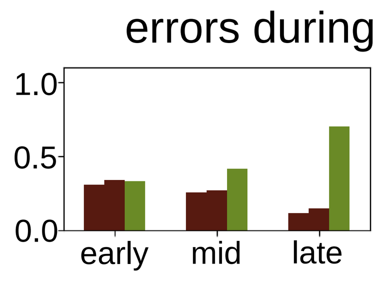
frequent → rare: never rewarded action almost not further explored

rare → rare: frequent rewarded action more often explored than the rarely rewarded action

rare → frequent: never rewarded action almost not further explored

Preliminary psychophysics results:

errors during exploration:

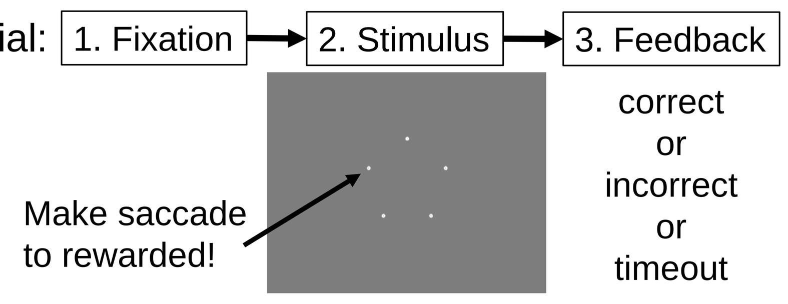


cluster → cluster: frequencies of 10 subjects, the subjects also learn to explore the rewarded actions more often than the never rewarded actions

The experimental setup:

Corresponds to **A – cluster experiment**.
Actions = eye movements to distinct target positions
1 pre-training block: all targets can get the rewarded
2 cluster blocks: only 3/5 targets can get the rewarded
The rewarded target changes after 8±1 trials, 23 times per block.

Trial: 1. Fixation → 2. Stimulus → 3. Feedback



Conclusions

The implemented plastic STN-GPe connections indeed allow the STN-GPe loop to store information of rewarded responses and bias exploration towards this responses.

Furthermore the information of the reward frequency of responses is stored. Therefore the STN-GPe loop biases exploration towards the most often rewarded action in the past.

The experiments provide testable behavioral data of changes in selection frequencies during exploration periods.

A part of the predicted behavior could already be replicated in psychophysics experiments.

Of interest for future research could be:

- the effects of the STN-GPe plasticity in experiments with more than one stimulus
- further investigation of the STN-GPe plasticity with regard to Parkinson's disease
- relate the learning rule to physiological findings of plasticity in the STN-GPe [7]

Literature

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Acknowledgements

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