Adding nucleo-olivary inhibition to a bottom-up computational model of the vestibulo-ocular reflex to control gaze stabilization

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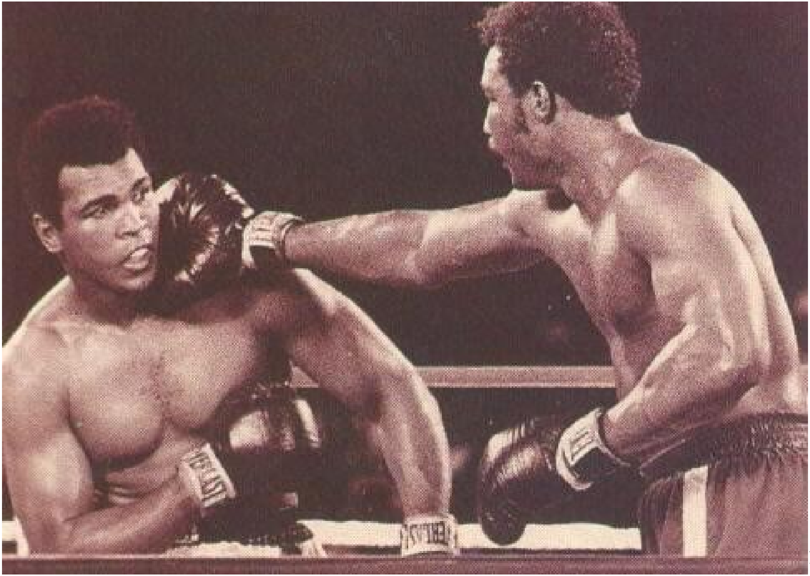
Trade-offs in avoidance actions

 [1]

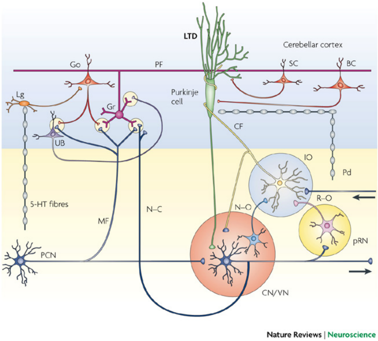
[1] http://bit.ly/1OyIoEI

Optimization of aversive reflexes

- Avoid aversive stimuli with minimum necessary effort
- How we behave carries a cost: What we fail to prevent + preventing action itself
- The ideal actions are those that minimize the overall cost

(Brandi, Herreros, and Verschure 2014)

Nucleo-olivary inhibition (NOI)



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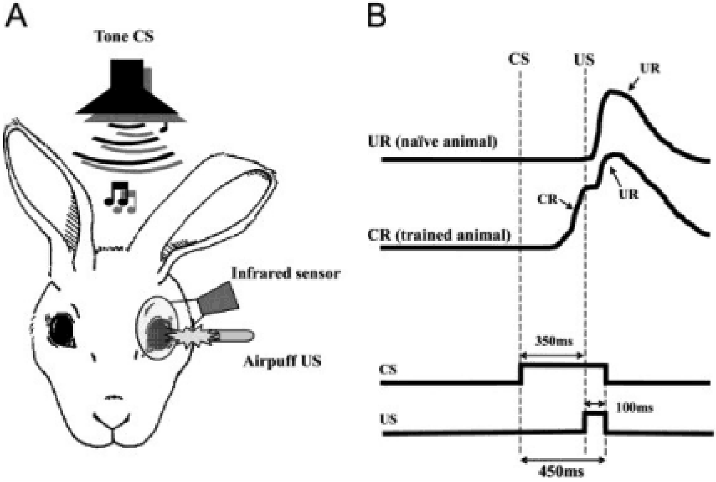
(Herreros and Verschure 2013)

- Cost-optimization
- Error-based learning
- Acquired conditioned responses are extinguished once they become no longer necessary
- The gain of the NOI is what determines the amplitude of the response on adaptive reflexes

[2] http://bit.ly/1AVg1qX

Eye-blink reflex conditioning



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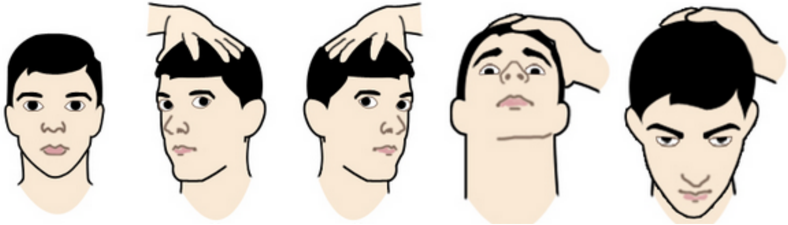
[3] http://bit.ly/1CXvsoK

NOI on eye-blink reflex

- Perceiving an air-puff in the unprotected cornea has a cost
- Two types of costs
  - Failing to avoid: error-based learning
  - Avoiding when not necessary
- Extinction of unnecessary conditioned responses

(Herreros and Verschure 2013)

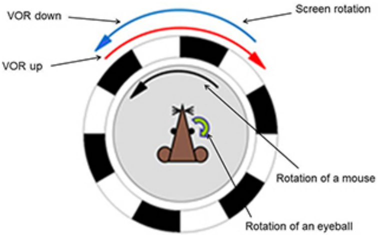
Vestibulo-ocular reflex (VOR)

 [4]

This reflex functions to **stabilize images** on the retinas during **head movement** by producing **eye movements** in the direction opposite to head movement, thus preserving the image on the center of the visual field.

[4] http://bit.ly/19GjJOA

Vestibulo-ocular reflex (VOR) adaptation



[5]

- VOR adaptation is one of the most studied cerebellar dependent motor learning tasks
- It is used to provide insight about the connections and the coding of the circuitry of the cerebellum

[5] http://bit.ly/10x3Qd6

Problem statement

Computational models of the vestibulo-ocular reflex don't take into account the role of the nucleo-olivary inhibition

Research question

What's the role of the nucleo-olivary inhibition in the vestibulo-ocular reflex?

Fingerprints

- NOI has a role in the eye-blink reflex
- There is extinction of the adaptive response in the absence of peripheral error
- VOR adaptation has a non-perfect performance, with a residual error proportional to the amount of cerebellar action required

(Herreros and Verschure 2013)

Hypothesis

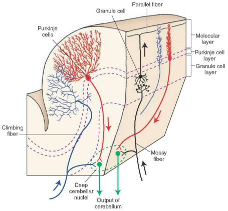
Adding nucleo-olivary inhibition on a detailed bottom-up state of the art vestibulo-ocular reflex computational model would offer a more parsimonious explanation of the experimental behavior of the reflex.

Computational models of the VOR

Models of the cerebellar microcircuit

- Marr-Albus-Ito classical models
- Plasticity on the brainstem
- A detailed bottom-up model

Cerebellar cortex



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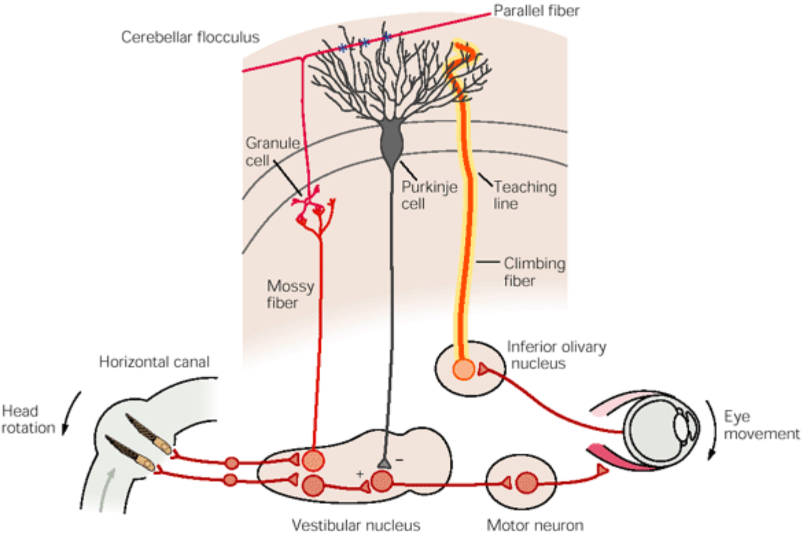
- Uniform structure throughout the cerebellum
- Composed of repeated modules or microzones
- Same cell types and connectivity
- Functional units
- Different inputs, different targets
- Cerebellar algorithm

[6] `http://bit.ly/1CioLvp`

Marr-Albus-Ito classical models



[7]

(Ito 2006)

[7]http://bit.ly/1ED2SEc

Plasticity on the brainstem

- Plasticity in both cerebellar cortex and the brainstem
- Cerebellar cortex for quick adaptation
- Brainstem as long-term memory
- Brainstem learns a simple gain

(Ke, Guo, and Raymond 2009)

A detailed bottom-up model

This computational model is made bottom-up from physiological and behavioral observations.

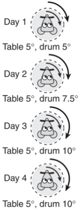
- Plasticity on the cerebellar cortex
- Plasticity on the brainstem
- Delayed error signal
- White noise on the signals
- Contribution of interneurons

(Clopath et al. 2014)

Methods

- Implementation of the detailed model (Clopath et al. 2014) of the VOR
- Reproduction of the results of the paper
- Add the NOI to the detailed model
- Simulation of adaptation, extinction and readaptation of the VOR

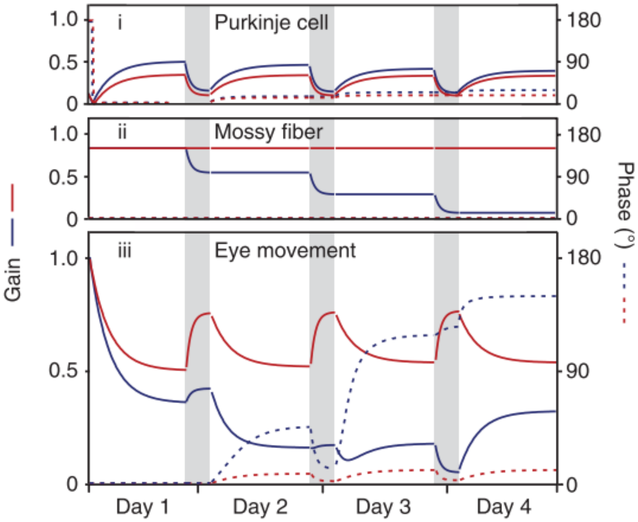
Experimental setup



(Wulff et al. 2009)

- Day 0: Normal VOR
- Day 1 and 2: VOR cancellation (gain decrease)
- Day 3 and 4: Phase-reversal learning

Reproduction of the results

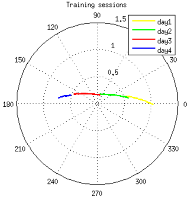


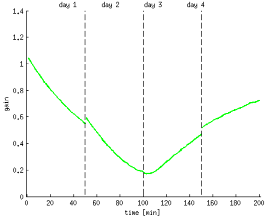
(Wulff et al. 2009)

Reproduction of the results

Evolution of the gain of the VOR on the different training sessions

(Clopath et al. 2014)





Adding the NOI to the detailed mode

Modulation in the dark of the teaching signal

- Modulated by vestibular information (Clopath et al. 2014)

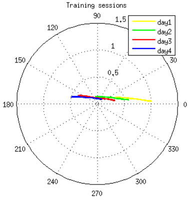
$$C(t) = \nu_{CF} - L(V(t-\delta) - V_t(t-\delta)) - H(M(t) - M_0)$$

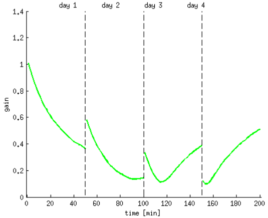
- Modulated by cortical information

$$C(t) = \nu_{CF} - L(V(t-\delta) - V_t(t-\delta)) - H(kP(t))$$

Preliminary results

Evolution of the gain of the VOR on the different training sessions (arbitrary k)





Project planning

- 10/2014 to 02/2015: State of the art review
- 10/2014 to 11/2014: Implement Clopath's minimal model
- 11/2014 to 12/2014: Implement Clopath's detailed model
- 12/2014 to 02/2015: Reproducing experimental results
- 02/2015 to 03/2015: Add NOI to the model
- 03/2015 to 04/2015: Validating the model
- 04/2015 to 05/2015: Analyze results
- 03/2015 to 06/2015: Writing the report

Future work

- Analyze detailed model assumptions
  - What are the effects of clipping weights on the PF-PC synapses?
  - Identify other assumptions of the detailed model
- Comparing detailed and NOI models
  - Do they show linear or exponential decay after one week light deprivation?
  - What does maintaining the training to the cortex-nuclei memory balance?

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