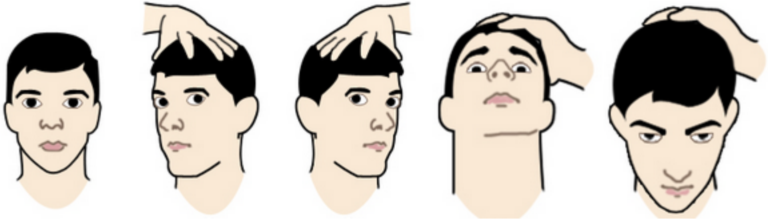
NUCLEO-OLIVARY INHIBITION EXPLAINS EXTINCTION ON A COMPUTATIONAL MODEL OF THE VESTIBULO-OCULAR REFLEX

Xavier Duran, supervised by Ivan Herreros and Paul Verschure

July 7, 2015

Master in Cognitive Systems and Interactive Media

VESTIBULO-OCULAR REFLEX (VOR)

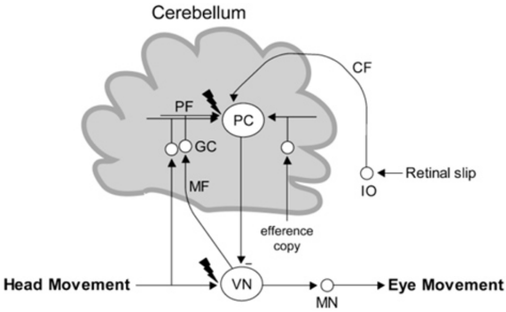


[1]

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.

[1] http://bit.ly/1Ox3Qd6

VOR adaptation is **trained with light** and **measured in the dark** [Boyden et al., 2004]



EXTINCTION OF THE LEARNED ADAPTATION

- **head movements** in the absence of **visual stimulation** cause a loss of the learned **eye movement response**
- changes in the amplitude, or gain of the VOR
- is mediated by an active, extinction-like process (not by passive forgetting)

[Cohen et al., 2004]

State of the art computational models of the vestibulo-ocular reflex don’t define a physiological mechanism for extinction

Inhibition of climbing fibres (retinal slip) serves as a teaching signal for extinction [Medina et al., 2002]

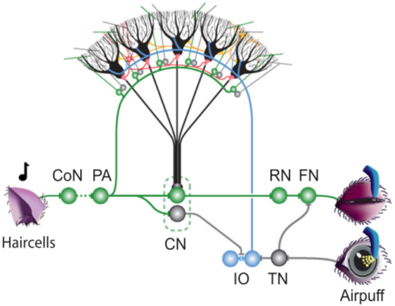


Figure 1: Neuroanatomical circuitry involved in eyeblink conditioning [Schonewille et al., 2010]

Would nucleo-olivary inhibition explain extinction in the vestibulo-ocular reflex computational models?

In direct evidence

- There is extinction of the adaptive response in the absence of peripheral error
- NOI has a role in the eye-blink reflex. The gain of the NOI is what determines the amplitude of the response on adaptive reflexes [Emken et al., 2007, Herreros and Verschure, 2013]

Adding nucleo-olivary inhibition on a vestibulo-ocular reflex computational model would explain extinction as in the experimental behavior of the reflex

METHODS

A BOTTOM-UP MODEL COMPUTATIONAL MODEL OF THE VOR

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

- Plasticity on the cerebellar cortex
  - quick
  - short-term
  - error-based learning
- Plasticity on the brainstem
  - slow
  - long-term

[Clopath et al., 2014]

- learned adaptation at the cerebellar cortex is slowly transfered to the brainstem
- cortical plasticity remains flexible to further adaptations
- savings help faster response on reacquisition

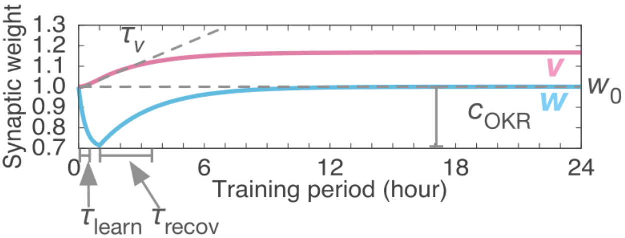


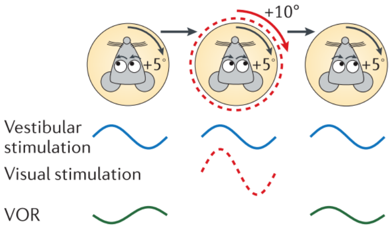
Figure 2: Short and long-term memory on eyeblink reflex adaptation [Yamazaki et al., 2015]

Extinction on Clopath's model

- Weakly modulated by head movement (vestibular signal)
- Weights on cortical plasticity decay linearly to their initial value

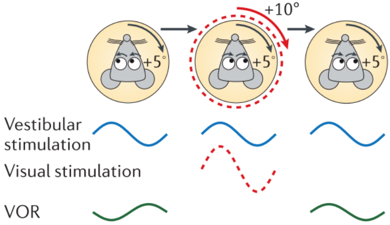
Extinction on NOI model

- Extinction is defined as proportional to cerebellar output
- More simple mechanism



[Gao et al., 2012]

- Day 1: VOR cancellation
- Day 2: VOR reversal with gain -0.5
- Day 3 and 4: Phase reversal with gain -1



[Gao et al., 2012]

- Day 1: VOR cancellation
- Day 2: VOR reversal with gain -0.5
- Day 3 and 4: Phase reversal with gain -1
- One week of light deprivation with vestibular stimulation

RESULTS

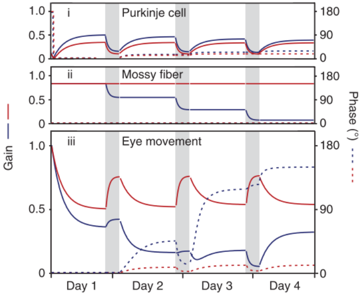
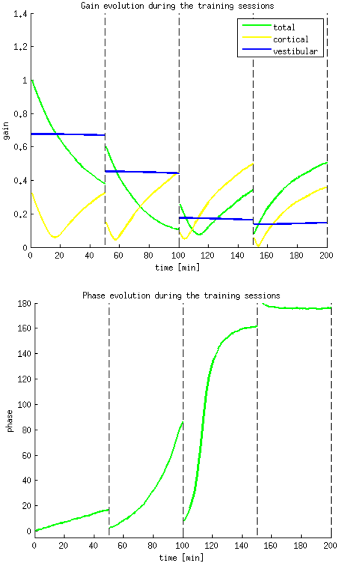


Figure 3: Experimental results (left) and simulations (right)



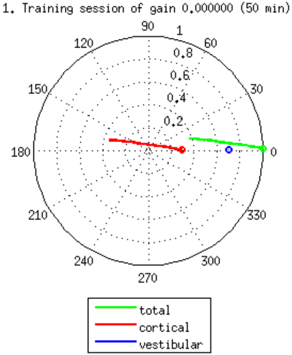


Figure 4: Day 1: VOR cancellation training

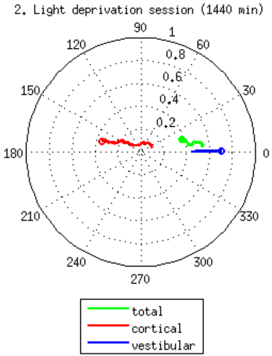


Figure 5: Night 1: partial extinction

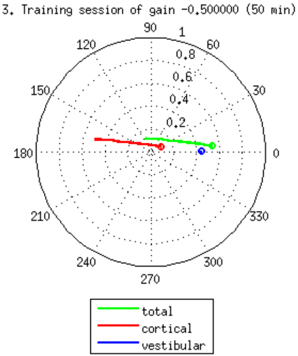


Figure 6: Day 2: VOR phase reversal training

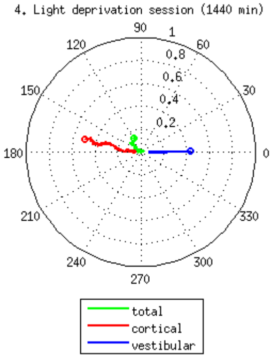


Figure 7: Night 2: partial extinction

WHAT HAPPENS IN THE DARK?

- Cortical
  - Extinguishes progressively to a baseline
- Nuclear
  - Continues transference from cortical memory until it arrives at a nuclear balance
- Total
  - Extinction and transference go in opposite directions
  - On the dark adaptation continues consolidating until an inflextion point where extinction overtakes transference
  - After a long period on the dark, all cortical memory is consolidated on the brainstem and cortical contribution is at its baseline

CONCLUSIONS

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- NOI **explains extinction** on VOR adaptation
- Extinction is triggered when vestibular information is available
- Teaching or error signal is modulated by **cerebellar output**
- Savings

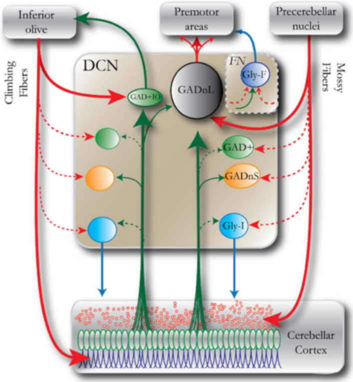

Figure 8: GAD+IO neuron populations receive signals from cerebellar output [Uusisaari and Knöpfel, 2011]

More detailed bottom-up models

- transgenic mouse lines
- better electro-physiological recordings
- models with distributed plasticity

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Thank you