First HBP Tea & Slides event

23rd April 2020
The cerebellum: building multi-scale computational models

Alice Geminiani

Department of Brain and Behavioral Sciences
University of Pavia
Italy

alice.geminiani@unipv.it
The cerebellum and motor learning

Sensory inputs → Motor control → ADAPTATION
- Reflexes
- Multi-dimensional coordination
- Balance control

PERTURBATIONS

- MOLECULAR layer
- PURKINJE layer
- GRANULAR layer
- CEREBELLAR NUCLEI
- INFERIOR OLIVE

Adapted from [D’Angelo et al, 2013]
The cerebellum and motor learning

What are the neural bases of cerebellar function?

Adapted from [D'Angelo et al, 2013]
Modelling the cerebellum

What are the neural bases of cerebellar function?

DATA

VS

VALIDATION

NEW INSIGHTS INTO CEREBELLAR FUNCTIONING

COMPUTATIONAL MODELS: Multi-scale Spiking Neural Networks

SIMULATED BEHAVIOR during cerebellum-driven tasks

closed-loop system

[Amunts et al, 2019]
Single neuron modelling

Neuron model from Generalized Leaky Integrate and Fire: E-GLIF point neuron model

- modelled properties:
  - autorhythm
  - sub-threshold oscillations
  - resonance
  - phase reset
  - spike-frequency adaptation
  - rebound bursting

- biological plausibility
- neuron-specific electroresponsive phenotype
- reduced computational load

Adapted from [Geminiani et al, 2018; 2019]
Network modelling

Topologically organized Spiking Neural Network:
- different cerebellar layers
- geometry-based neuron positioning
- geometry-based connectivity
- conductance-based synapses

Single neuron properties and network connectivity cause network bursting activity

Adapted from [Geminiani et al, 2019]
Motor behavior modelling

We need the Spiking Neural Network in a closed-loop control system, where we embed:

- Distributed plasticity in the network
- Sensorimotor signal encoding/decoding
- Learning protocol

Eye closure

Unconditioned Stimulus (US)

Conditioned Stimulus (CS)

Eyelid closure (CR)

Unconditioned Stimulus (US)

Conditioned Stimulus (CS)

Eyeblink conditioning

We need the Spiking Neural Network in a closed-loop control system, where we embed:

- Distributed plasticity in the network
- Sensorimotor signal encoding/decoding
- Learning protocol
Simulating cerebellar pathologies

**COMPUTATIONAL MODELS:**
Multi-scale Spiking Neural Networks

The model predicted and suggested hypotheses on:
- *damage amount* generating the misbehaviors
- evolution of behavior on *different time scales*
- altered *underlying neural* mechanisms
- possible *compensatory* mechanisms
Thanks for your attention!

UNIPV
Egidio D’Angelo (DIRECTOR)
Neurocomputation lab
Claudia Casellato
Robin De Schepper
Alberto Antonietti
Stefano Casali
Stefano Masoli
Martina Rizza
Alessandra Ottaviani
Neurophysiology lab

Neuroimaging lab
POLIMI, Neuroengineering Lab
Alessandra Pedrocchi
ERASMUS-MC

For more questions, contact me at:
alice.geminiani@unipv.it