Switching from tonic firing to bursting: implications on learning and memory

Kathleen Jacquerie°, Danil Tyulmankov*, Piere Sacré° and Guillaume Drion°

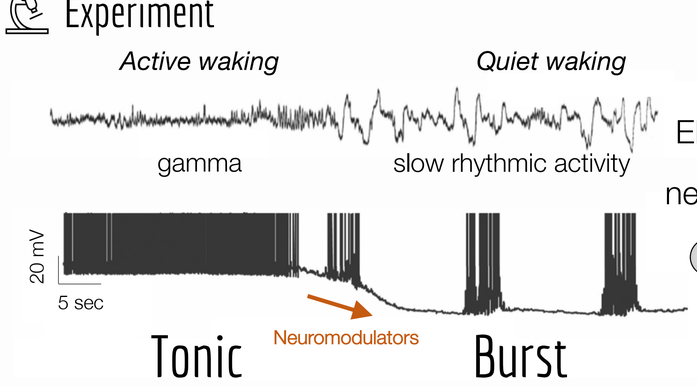
° University of Liege, Belgium; * Columbia University, New-York, USA

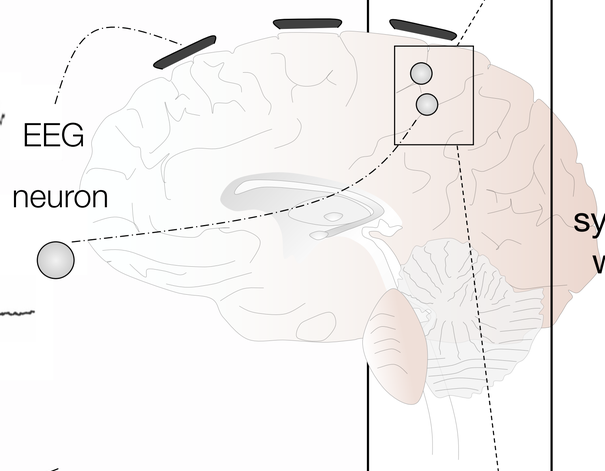
Kathleen.jacquerie@uliege.be

Scan me

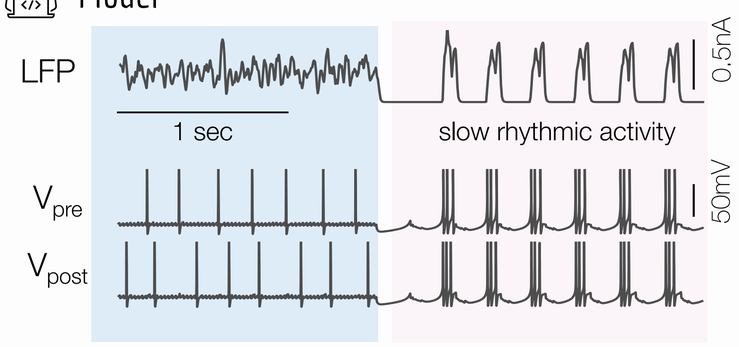
Neurons are switching from tonic to burst

Experiment

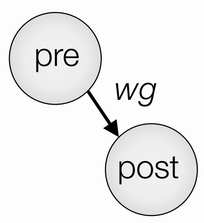




Model



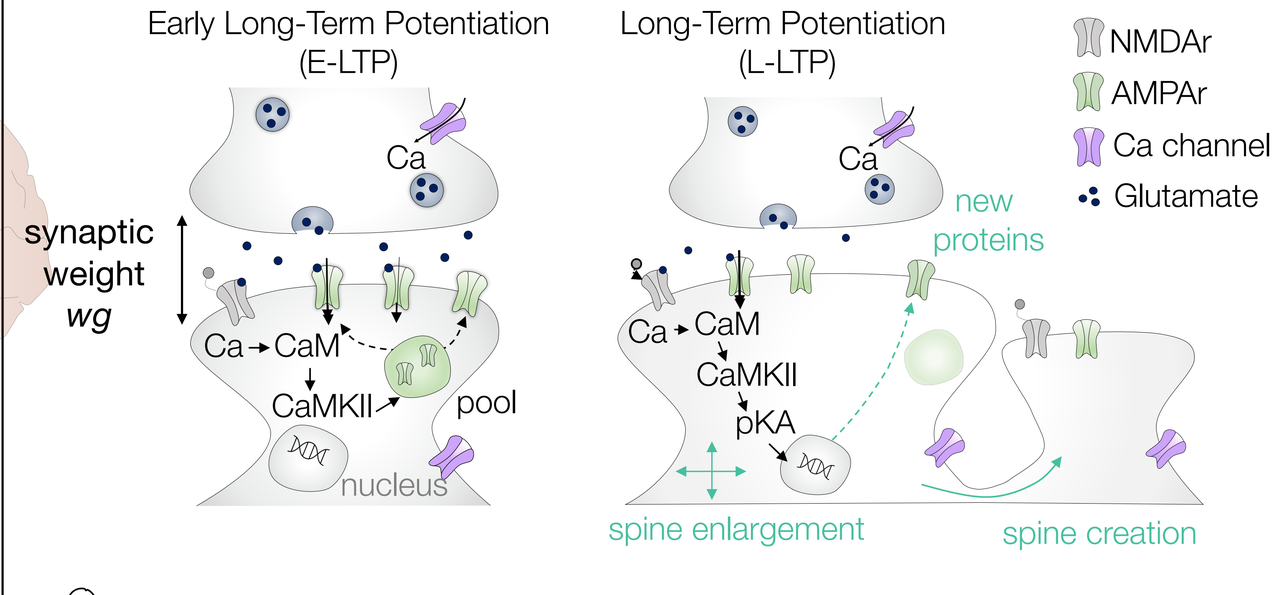
Small circuit



Conductance-based model
Robust to neuromodulation and plasticity

[Jacquerie and Drion,2021]
[McGinley et al., 2015]

Neurons are modifying their connections with each other



Traditional plasticity

synaptic efficacy *w*

- efficacy of postsynaptic receptors
- exocytosis of postsynaptic receptors

STDP, calcium-based rule

Structural plasticity

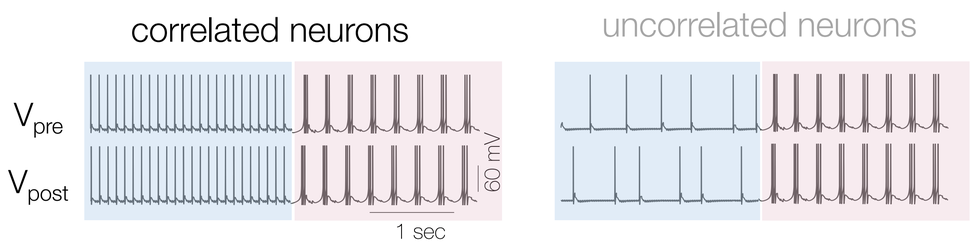
synaptic conductance *g*

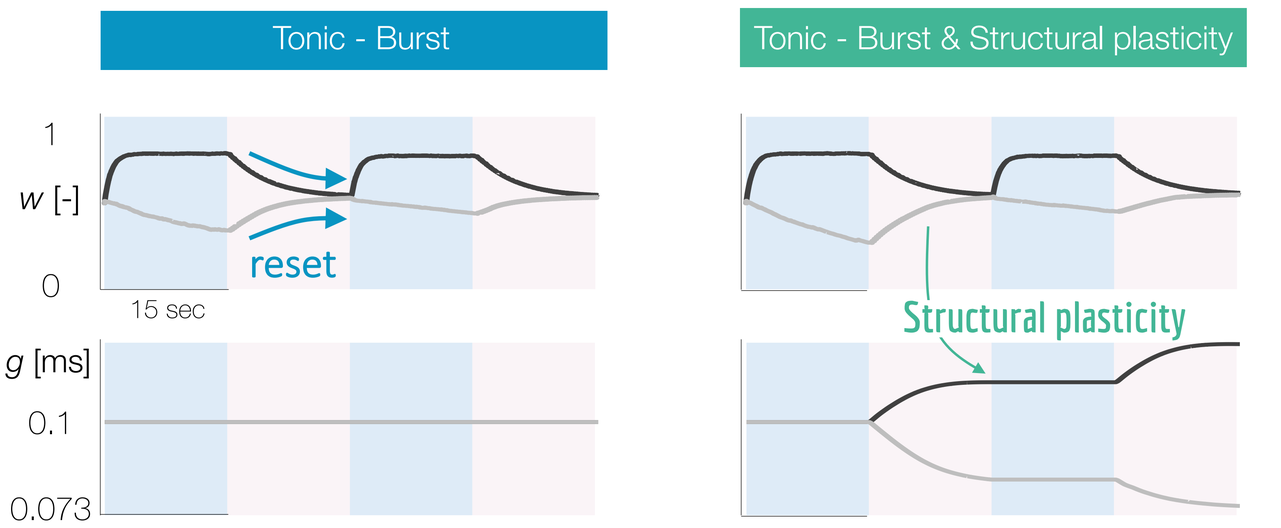
- morphological spine change
- creation of new proteins

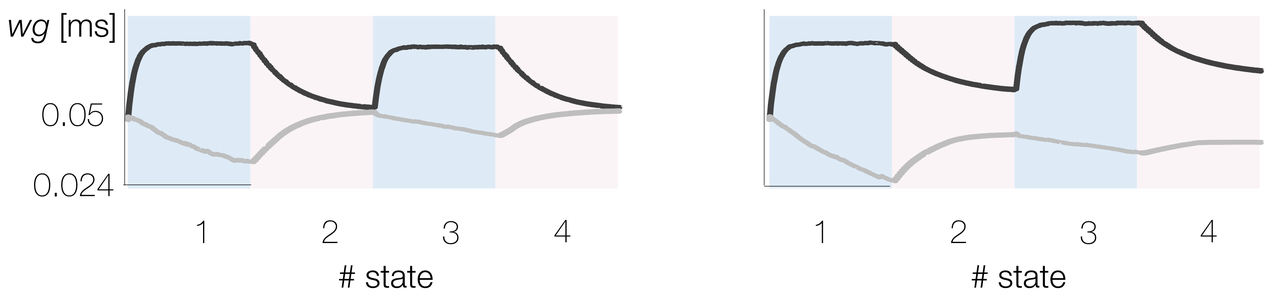
Our model of structural plasticity

What is the evolution of the synaptic weight during switches in firing patterns?

We record the synaptic weight in two circuits with correlated and uncorrelated neurons during switches from tonic firing to bursting







Conclusions

- Bursting leads to a homeostatic reset of synaptic efficacy *w*. The connection returns in its baseline value regardless of its starting point.
- Burst-driven structural plasticity transfers learning acquired during tonic into change on synaptic conductance *g*.

[Jacquerie et al.,2022]

Switches from tonic firing to bursting combined with structural plasticity enhances memory consolidation

Memory task

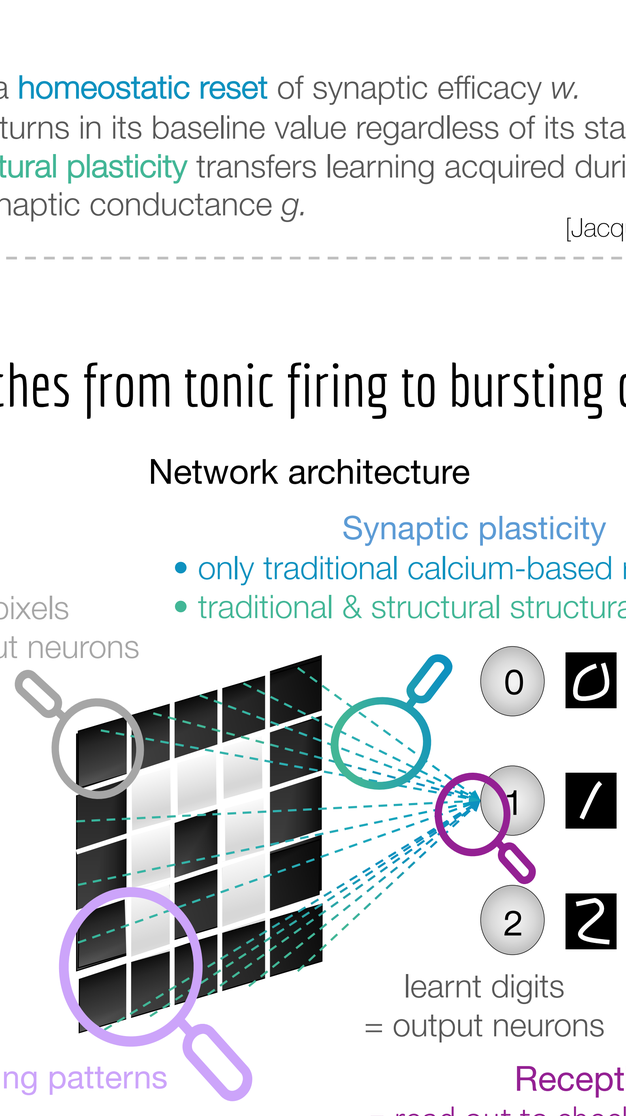
Learn MNIST

pixels
= input neurons

Network architecture

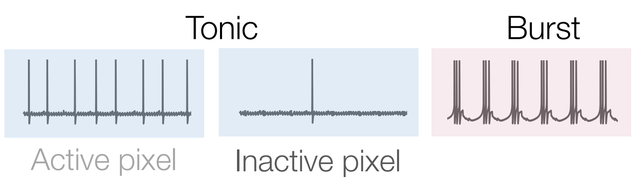
Synaptic plasticity

- only traditional calcium-based rule
- traditional & structural structural plasticity



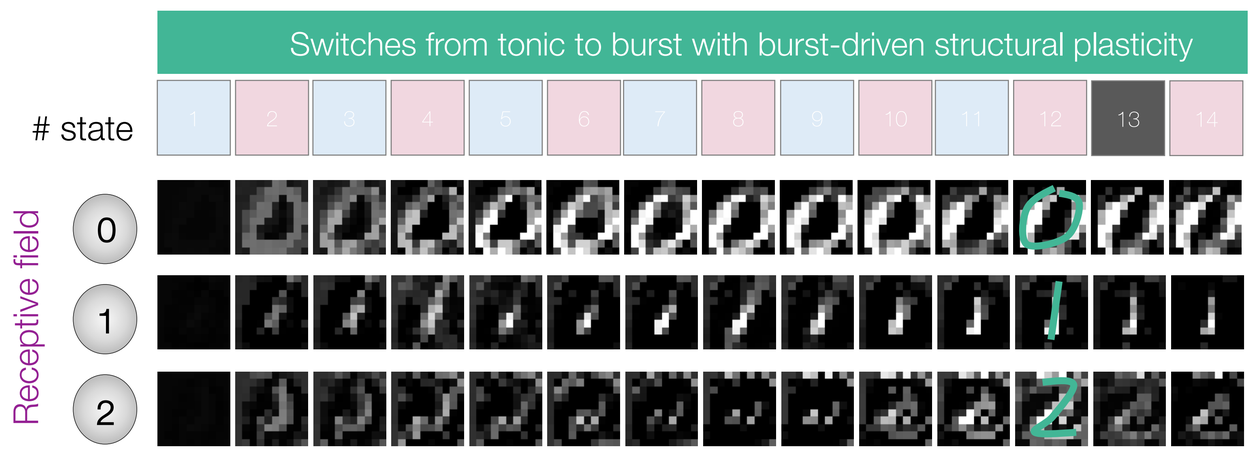
learnt digits
= output neurons

Receptive field
= read out to check how each output neuron gets associated to a digit using the weight matrix



Results

- During tonic firing, digits are learnt.
- After each bursting state, all the weights are reset that leads to forgetting.
- The network is fragile to noise.



- Digits are learnt during tonic firing and further consolidate during bursting.
- The network is robust to noise.

Summary

This study highlights the importance of firing patterns in synaptic plasticity and proposes a solution to bridge the gap between the switches from tonic firing to bursting, learning and memory consolidation. This solution is a structural plasticity mechanism that exploits the homeostatic reset during burst. Successive switches between active and quiet waking enhances memory consolidation.