Interactions between synaptic plasticity and switches in brain states for memory consolidation: a modeling study

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Interactions between synaptic plasticity and switches in brain states for memory consolidation: a modeling study.

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Abstract

Once a day, every individual lay down and becomes unconscious. Isn't sleep a strange thing to do? Despite the risks associated with it, our ancestors used to sleep too, suggesting that it should provide an evolutionary advantage. Thus, it raises a fundamental question: why do we sleep? Among all essential functions of sleep, research has proved its preponderant role in memory formation and consolidation. At the cellular level, memory is achieved through processes referred to as synaptic plasticity and translating the remarkable ability of the brain to constantly evolve due to various stimuli. Furthermore, differences in the neuronal firing patterns have been highlighted between wake and sleep: during sleep, neurons are bursting while during wake, neurons show a tonic firing pattern.

Memory is an abstract concept, it is not a simple task to understand the processes behind it. As experimental evidence provides insights about how plasticity is induced, modeling techniques reproducing experimental data can give insights about memory mechanisms. Literature is broad concerning plasticity modeling. In this work, a concise review of phenomenological models is conducted.

Then, some of them are implemented in a conductance-based model able to switch from waking to sleep i.e. from tonic to bursting activity. Compared to simplified spiking neuron model, this conductance-based model is a powerful tool to be able to faithfully replicate neuronal behavior in a waking and sleeping period. Reproduction of experimental protocols is carried in tonic mode as well as the impact of variability in the firing pattern to mimic more in vivo situations. As the ultimate goal of this thesis is to see the impact of existing models on memory consolidation during sleep, their robustness and behaviour during a bursting period are investigated. It led to unsatisfactory results regarding memory consolidation, highlighting the limitations of those phenomenological models. The behaviour of the models implemented highly depends on the method used to bound the synaptic weight in-between extreme values. Finally, insights about neuromodulation are suggested as improvements.

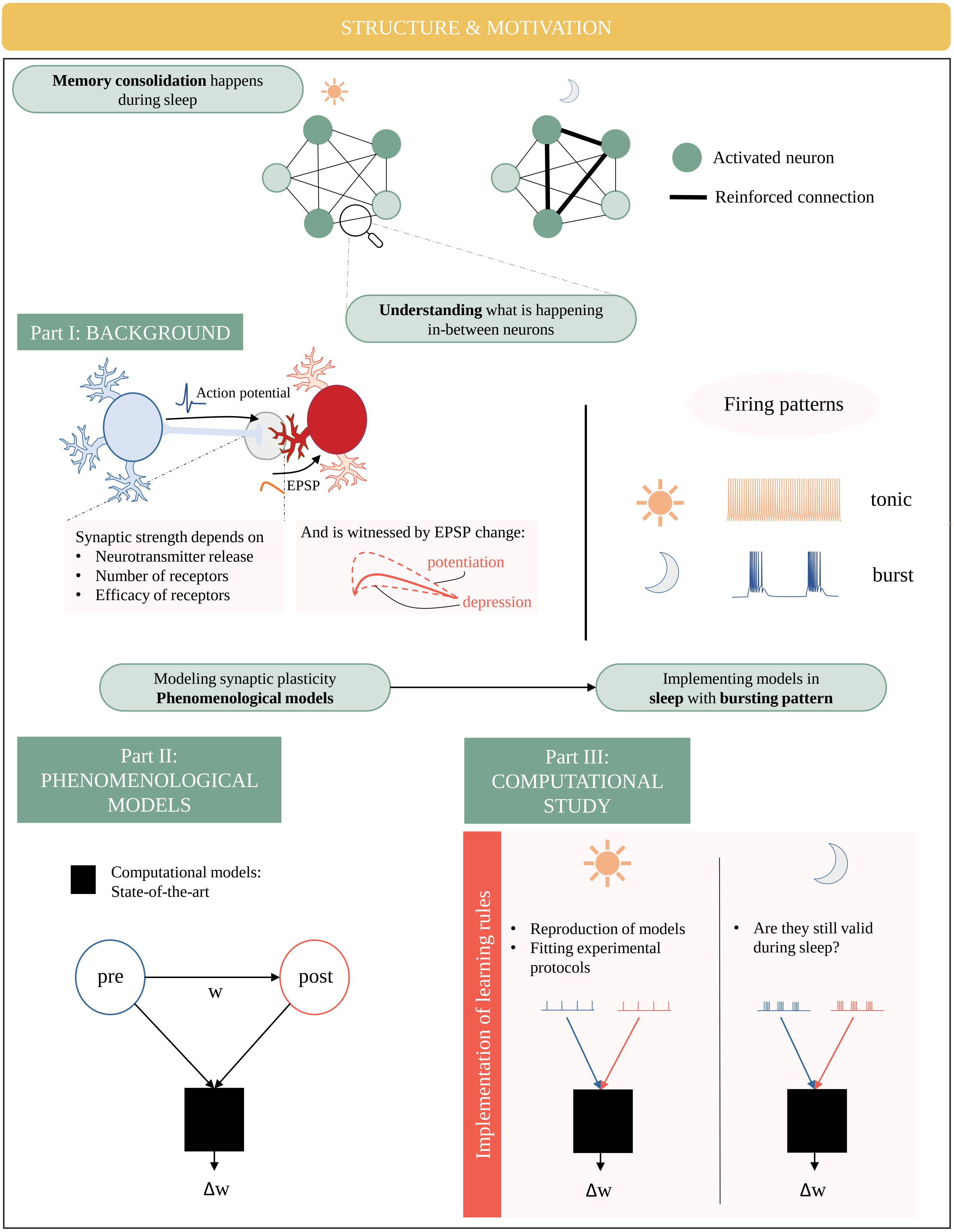

Figure 1 – *Summary of the thesis aiming at understanding memory consolidation during sleep.* **Part I** develops the necessary biological background, **Part II** is dedicated to a literature review on phenomenological models and **Part III** to computational experiments in both wake and sleep mode.

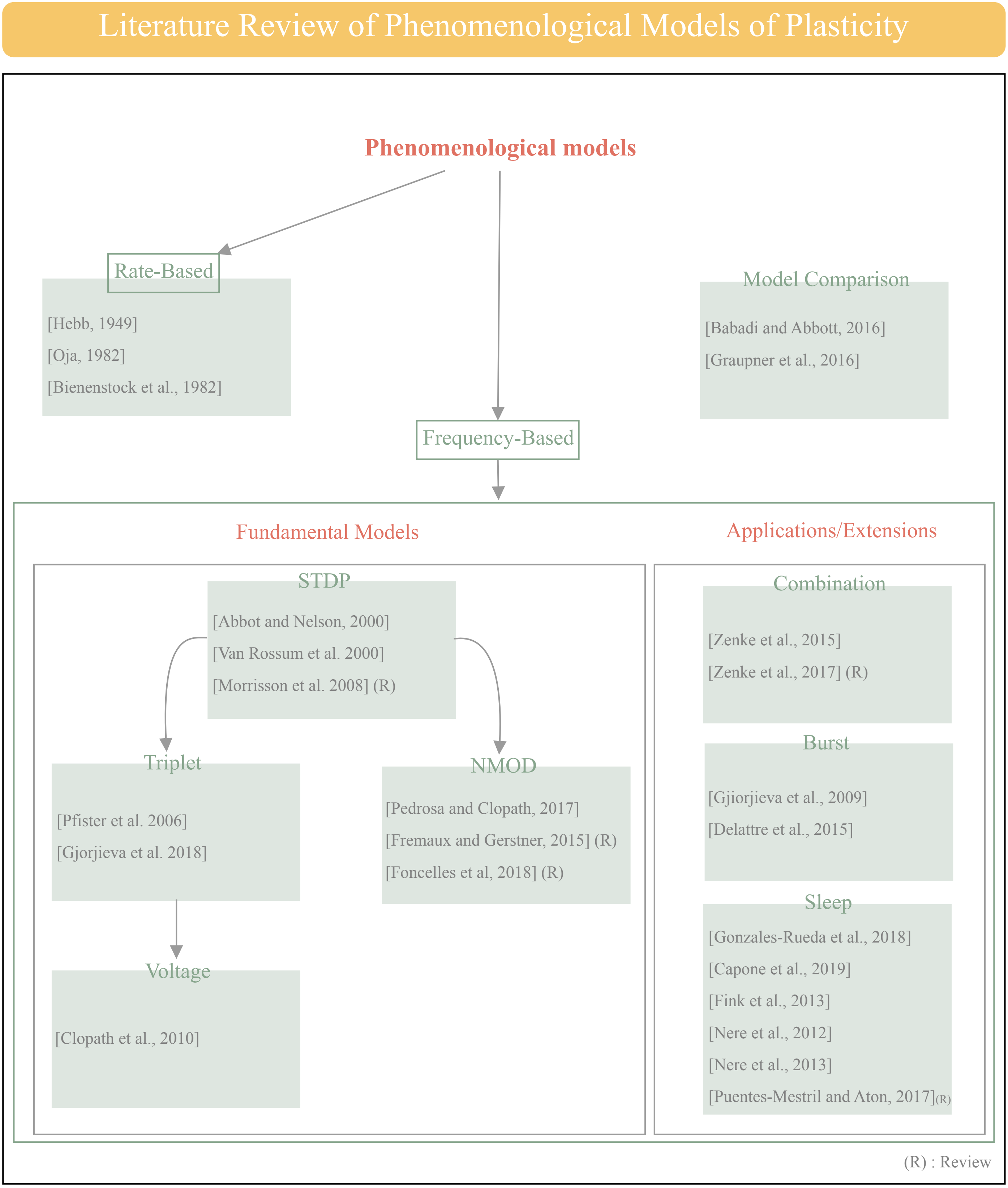

Figure 2 – *Litterature review of phenomenological models*

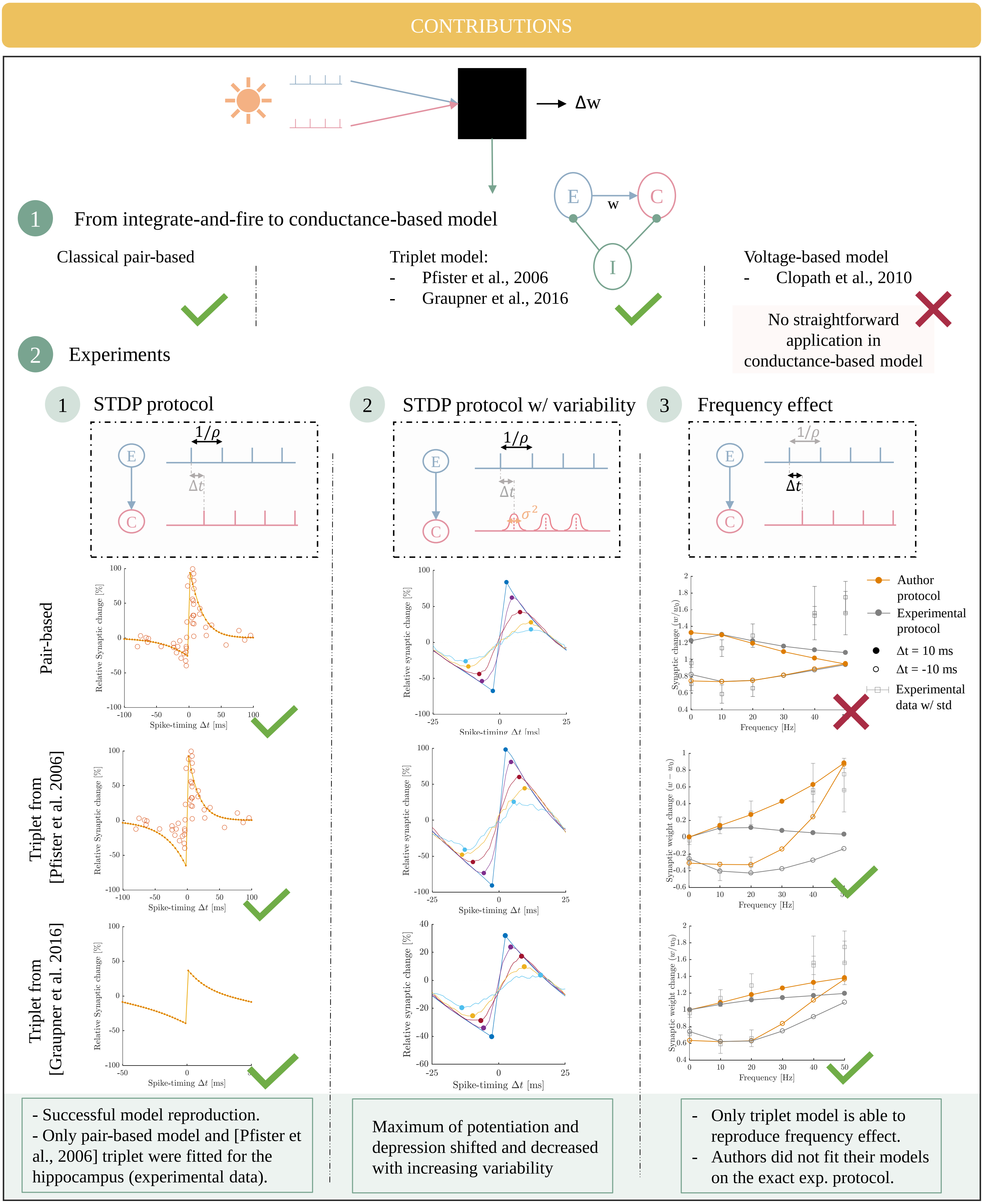

Figure 3 – *First computational contribution:* **1.** Implementation of phenomenological models in a conductance-based neuron model. **2.** Reproduction of experimental protocols and investigation of the impact of the variability in the firing pattern to mimic *in vivo*-like situation.

CONTRIBUTIONS

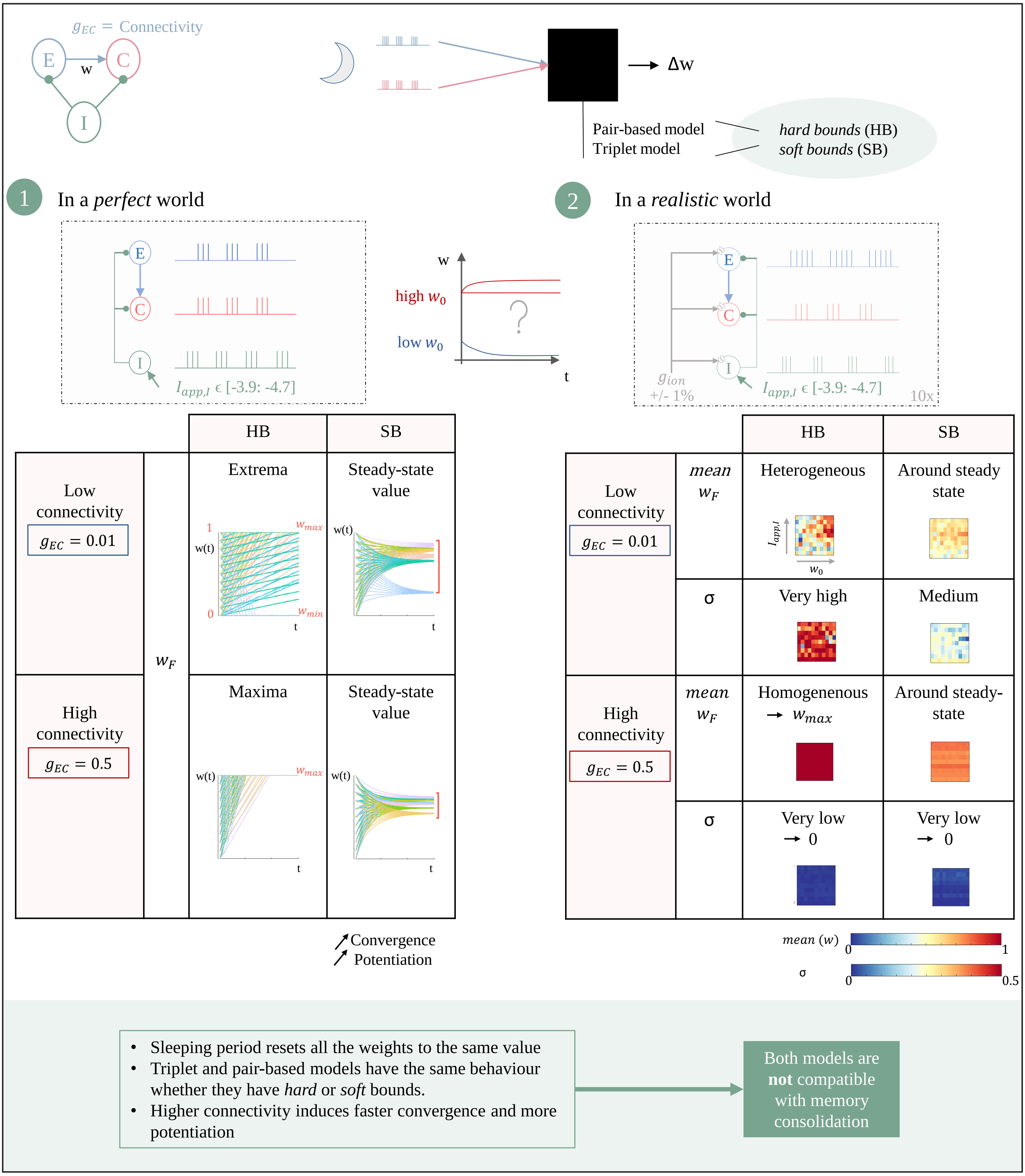

Figure 4 – *Second computational contribution* Evaluation of the impact of a sleeping (*i.e.* bursting) period on the implemented models. **1.** in a perfect world in which the pre- and postsynaptic cells are similar **2.** in a realistic world in which the cells show variability in their ionic conductances.