Towards a systematic understanding of deep-sleep-like activity effects on the network working points during learning cycles

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Abstract

The brain exhibits capabilities of fast incremental learning from a few noisy examples, as well as the ability to associate similar memories in autonomously-created categories, and to combine contextual hints with sensory perceptions. Together with sleep, these mechanisms are thought to be key components of many high-level cognitive functions. Sleep is known to be essential for awake performance, but the mechanisms underlying its cognitive functions are still to be clarified: here we aim to investigate the effect of deep-sleep-like activity over internal memory representation and its energetic and entropic effects.

At last year NEST 2020 Conference, we demonstrated how to exploit the combination of context and perception in a new thalamo-cortical model (ThaCo) based on a soft winner-take-all circuit of excitatory and inhibitory spiking neurons [1][2]: this model is capable of undergoing multiple wake-sleep cycles during incremental learning, it adapts its pre-sleep, deep-sleep and post- sleep firing rates in a manner that is similar to the experimental measures of [3], and it demonstrates the beneficial cognitive role played by such adaptations. During the last year, we investigated the effect of a deep-sleep like activity on the network working point exploring the transition from awake classification phases towards deep-sleep like phases, and vice versa. We show that during sleeping, the total input current to the cortical neurons decreases due to the sleep-induced homeostatic effect. Sleep-like activity, on the other hand, affects the network status during the following awake classification phase: the effect of STDP during sleep is a general reduction and homogenization of input current distribution. We also show an association effect between the internal representation of similar memories. Finally, aiming at a more systematic description of the effects of deep-sleep-like activity, some of us defined a simplified rate-based thalamo-cortical model relying on minimal In this model, sleep formally implements a "density based clustering" in the assumptions. thalamo-cortical connections. Also, a set of entropic and energetic measures are introduced to quantify the effects of sleep. These measures are applicable to experimental data. These results are also reproducible in a more biological spiking network model.

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References

- [1] Golosio et al., arXiv:2003.11859. Accepted in PLOS Computational Biology
- [2] Capone et al, Scientific Reports (2019) 9:8990.
- [3] Watson et al., Neuron (2016).

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