Thalamo-cortical spiking model of incremental learning combining perception, context and NREM-sleep-mediated noise-resilience

Chiara De Luca3,4, Bruno Golosio1,2, Cristiano Capone4, Elena Pastorelli3,4, Giovanni Stegel5, Gianmarco Tiddia1, Giulia De Bonis4, Pier Stanislao Paolucci4

1 Dipartimento di Fisica, Università di Cagliari, Italy
2 Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Cagliari, Italy
3 Ph.D. Program in Behavioural Neuroscience, “Sapienza” University of Rome
4 Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Roma, Italy
5 Dipartimento di Chimica e Farmacia, Università di Sassari, Italy

Email: Chiara.DeLuca@roma1.infn.it

The brain exhibits capabilities of fast incremental learning from 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. In particular, increasing experimental evidence is mounting for the role played by the combination of bottom-up (perceptual) and top-down/lateral (contextual) signals, and for the beneficial effects of sleep that appear to have impact on several aspects, such as pattern recognition, classification and decision making.

In this work [1], we exploited 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, starting from the description proposed by [2]. First, the new 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 cognitive role played by such adaptions. Second, it exploits the combination of context and perception during incremental learning, following the experimental cortical architectural principles and the evidence about the role of the combination of apical and basal inputs proposed by [4]; the two principles cooperate to support the incremental creation of a soft winner-take-all mechanism. Third, the model is capable of fast incremental learning from few examples and it is resilient when proposed with noisy perceptions and noisy contextual signals. Last, hundreds of memories during incremental learning are learnt by this model, also demonstrating comparable performances to artificial learning algorithms. Finally, the predictions of our model constitute a relevant contribution towards the reconciliation of recent experimental observations about both an average synaptic down-scaling effect and a differential modulation of firing rates.

Acknowledgements
This work has been supported by the European Union Horizon 2020 Research and Innovation program under the FET Flagship Human Brain Project (grant agreement SGA3 n. 945539 and grant agreement SGA2 n. 785907) and by the INFN APE Parallel/Distributed Computing laboratory.

References
1. Golosio et al., arXiv:2003.11859.
2. Capone et al, Scientific Reports (2019) 9:8990.
3. Watson et al., Neuron (2016).
4. Larkum M., Trends in Neurosciences (2013).

Copyright 2020 C. De Luca, B. Golosio, C. Capone, E. Pastorelli, G. Stegel, G. Tiddia, G. De Bonis, P.S. Paolucci under Creative Commons Attribution License (CC BY-NC 4.0).