Dominique Martinez, DR CNRS

LORIA, Campus Scientifique, 54506 Vandoeuvre-lès-Nancy, France

Mél : dominique.martinez@loria.fr

May 6, 2023

Report on the PhD thesis of Tomas Barta

Tomas Barta presents a thesis dissertation entitled “Neuronal coding and metabolic cost of information” under the supervision of Lubomir Kostal (Institute of Physiology, Prague) and Philippe Lucas (INRAE, Paris), to obtain a joint PhD degree from the Charles University first faculty of medicine of Prague and the Sorbonne University of Paris.

The thesis manuscript is 200 pages long including 50 pages of main text and 150 pages of attached materials. The main text consists of four chapters (introduction, methods, results and conclusion) that provides the state of the art as well as an extended summary of the methods and results further detailed in the attached materials. The attached materials consist of two articles published in journals with high impact factor (IF 2.7 & 4.8), two manuscripts available on bioRxiv and presumably under journal submission, and two unpublished reports. It is worth noting that the attached materials are all written with T. Barta as first author. At first sight, the format of the document may appear unusual but it turns out that the manuscript is pleasant to read, as too heavy technical details are left in the attachments. Moreover, the document has a structured and logical approach that describes well the work done and, consequently, the areas of uncertainty and fuzziness are quite narrow.

In his thesis, Tomas Barta considers that information is encoded in the firing rate (number of spikes in a time window) of single neurons or populations of neurons. Under the rate coding hypothesis, maximizing the output entropy ensures that all possible firing rates are equally used (efficient coding). Yet, in vivo recordings of cortical neurons and olfactory receptor neurons (ORNs) indicate that neurons do not always make use of the entire range of firing rates. Rather, they tend to fire at a relatively low rate thereby minimizing their energy consumption. This observation led Tomas Barta to consider efficient coding as a balance between maximizing information transmission and minimizing metabolic cost. His main contributions concern the role of inhibition and spike frequency adaptation in metabolically efficient information transmission and in decreasing the trial-to-trial variability. Indeed, in addition of being efficient, the neural code has to be robust, *i.e.* it should be similar over repeated trials. These theoretical results are published in Physical Review E and PLoS Computational Biology, and as a manuscript available on bioRxiv.

In the second part of his thesis, Tomas Barta considered information coding in insect ORNs. Although he did not perform himself the extracellular neural recordings, he contributed to the development of a new experimental setup that allows to stimulate ORNs with temporally precise odor puffs. This device is of a crucial importance in olfaction because the odor stimulus is not as well controlled and digitally available as it is in vision or hearing. Using this new stimulator, the ORNs were characterized in a way that has never done before. By combining experimental data analysis and computational modelling, Tomas Barta demonstrated that, unlike prevailing belief, moth ORNs are capable of encoding both odor onset and offset. These findings are reported in a manuscript available on bioRxiv.

All together the results presented in this thesis are novel and contribute significantly to the understanding of information coding by single neurons and populations of neurons. I have been impressed with the work presented in the manuscript. It ranges from experiments, with the design of a new olfactory stimulator, to data analysis, with a new identification method for linear-nonlinear models, and to modeling, with a new ORN model accounting for stimulus onset and offset. Such a large diversity and high quality in the results produced are rarely encountered in a PhD thesis. The thesis exhibits all the expectations for an independent scientific work.

For these reasons, I recommend without any doubt awarding the academic doctor degree (PhD) to Mgr. Tomas Barta.

Below are some questions for the defense:

- LN model: Is the static nonlinearity in the LN model identified from the data or is it fixed by hand? How to identify jointly the static nonlinearity and the linear filter in LN models?
- Simulation: I did not find much information about the simulation of neural models. Is a simulation software used? And if so which one? What is the numerical integration method and the time step?
- ORNs: Moths flying in turbulent plumes encounter a large variety of odor puffs ranging from a few ms to several second (Celani et al. Phys Rev X. 2014). In this context, what is the advantage for ORNs to encode odor offset only for short stimuli (<200 ms)?
- Do the results on neural variability generalize beyond rate coding, e.g. precise spike timing or synchronization between neurons receiving the same stimulus? How do your results obtained with M-type or AHP currents compare with those of Prescott & Sejnowski (Spike-Rate Coding and Spike-Time Coding Are Affected Oppositely by Different Adaptation Mechanisms, J. Neuroscience, 2008)?

I am looking forward to attending the defense.

Sincerely yours,

[redacted]

Dominique Martinez