Title: Feedback processes in neuronal systems: some examples and functional implications in cognitive tasks

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In the talk, I presented the study of two examples of biological feedback processes present in the nervous system, one at the single cell level and the other one at the network level. I study these phenomena using tools from dynamical systems theory (Ermentrout and Terman, 20).

At the single cell level, I showed the example of phasic neurons, which typically fire only for a fast-rising input, say at the onset of a step current, but not for steady or slow inputs, a property associated with type III excitability. Exemplars are found in the auditory brain stem where precise timing is used in sound localization. Phasicness at the cellular level arises from a dynamic, voltage-gated, negative feedback that can be recruited subthreshold, preventing the neuron from reaching spike threshold if the voltage does not rise fast enough. We consider two mechanisms for phasicness: a low threshold potassium current (subtractive mechanism) and a sodium current with subthreshold inactivation (divisive mechanism). We analyse reduced models using tools from dynamical systems theory. We find that each mechanism contributes features but best performance is attained if both are present. The subtractive mechanism confers extraordinary precision for phase locking and coincidence detection but only within a restricted parameter range when the divisive mechanism of sodium inactivation is inoperative. The divisive mechanism guarantees robustness of phasic properties, without compromising excitability, although with somewhat less precision.

At the network level, I discussed the role of oscillations in neural communication. The Communication Through Coherence (CTC) theory (Fries, 05,15) proposes that neural oscillations regulate the information flow without changing the anatomical connections. Thus, neural communication is established if the underlying oscillatory activity of the emitting and receiving populations is properly phase locked, so that inputs arrive at the peaks of excitability of the receiving population. The oscillators must be therefore phase-locked to accomplish strong communication. In the talk, I discussed how phase-locking properties may be studied in an Excitatory - Inhibitory (E-I) network subject to external periodic forcing, simulating the input from other oscillating neural groups. Finally, I discussed the implications of the computed phase-locked states on neuronal communication.

Book

[1] B.G. Ermentrout and D.H. Terman. Mathematical foundations of neuroscience. New York : Springer, 2010.

Reviews

[2] J. Rinzel and G. Huguet. Nonlinear Dynamics of Neuronal Excitability, Oscillations, and Coincidence Detection. Communications on Pure and Applied Mathematics, 66(9):1464-1494, 2013.

[3] Peter Ashwin, Stephen Coombes, and Rachel Nicks. Mathematical frameworks for oscillatory network dynamics in neuroscience. The Journal of Mathematical Neuroscience, 6(1):2, 2016.