

POSTER PRESENTATION

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Why are all phase resetting curves bimodal?

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From Twenty Second Annual Computational Neuroscience Meeting: CNS*2013
Paris, France. 13-18 July 2013

Neurons are excitable cells, which means that they operate close to a bifurcation points that allows them to switch back and forth between stable steady states and periodic attractors [1]. Repetitive firing neurons belong to either Class 1, i.e., characterized by a continuous frequency versus bias current ($f-I$) curve and arbitrarily low frequency of oscillation, or Class 2, i.e., discontinuous $f-I$ curve and firing starts with a relatively high frequency at threshold stimulation [2]. The bifurcation mechanism leading to repetitive firing is related to excitability classes, i.e., saddle node on invariant circle (SNIC) bifurcation is associated to Class 1 and Andronov-Hopf (HB) bifurcation to Class 2 excitability [3]. The complexity of model neurons can be significantly reduced near bifurcation points, e.g., by using normal forms. Although such dramatic reductions oversimplify biophysical mechanisms they allow a better understanding of the phenomenology of phase locked modes and synchrony in neural networks. A phase resetting curve (PRC) is not concerned with the biophysical details of neurons, but rather tabulates the transient changes in the firing period due to an external perturbation, usually a brief current or synaptic conductance pulse. Despite its limitations, PRC-based approaches to treating Parkinson's and epilepsy are at the forefront of practical applications [4], or predicting the shape and timing of necessary stimuli that destabilize a synchronous state of a large population of neurons [5].

It was long advocated that the PRCs are either of Type I when the bifurcation mechanism leading to oscillatory behavior is a SNIC, or of Type II when the bifurcation is of HB type [3,6]. Type II PRC has an almost sinusoidal shape and comparable sizes of the positive and negative lobes, and synchronize more readily due to

their ability to both slow down and speed up [3,6]. Type I PRC has a disproportionate ratio of the two PRC lobes, can predominantly speed up (or only slow down) their rhythm when coupled with other neurons.

We showed that any stable limit cycle oscillator has two remarkable points, which we called neutral points, at which brief perturbations do not induce any phase resetting. Furthermore, for a planar system there are only two such neutral points and we derived an analytical method of localizing them based on the Floquet multipliers. The PRC changes its sign at neutral points. Since there are two neutral points for any planar system it results that the corresponding PRCs must be all bimodal. Additionally, we derived analytical criteria for the degree of bimodality and were able to smoothly control the transition of the PRC from a Type I to a Type II. The ability to smoothly change the PRC type through experimentally available control parameters, such as bias currents or pharmacologically controlled ionic channels, has potential application in shaping the activity of neural cells and networks.

Acknowledgements

This research was supported by the National Science Foundation CAREER award IOS 1054914 to SAO.

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Published: 8 July 2013

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doi:10.1186/1471-2202-14-S1-P398

Cite this article as: Oprisan et al.: Why are all phase resetting curves bimodal? *BMC Neuroscience* 2013 **14**(Suppl 1):P398.

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