

POSTER PRESENTATION

Open Access

A minimal model for a slow pacemaking neuron

Alexey Kuznetsov^{1*}, Denis Zakharov²

From Twenty First Annual Computational Neuroscience Meeting: CNS*2012
Decatur, GA, USA. 21-26 July 2012

We have constructed a phenomenological model for slow pacemaking neurons. These are neurons that generate very regular periodic oscillations of the membrane potential. The examples of these neurons are serotonin-containing neurons from the raphe nuclei, noradrenergic neurons located in the pontine nucleus locus coeruleus (LC) and dopaminergic neurons from the substantia nigra pars compacta. Many of these neurons also differentially respond to various types of stimulation. In particular, stimulation by injecting a current into the cell body (applied somatic depolarization) is expected to elicit bursting similar to stimulation by inputs from other neurons (synaptic currents), but it does not.

We have separated the most important property of the neuron that allows for the differential responses (see Fig. 1). Our model is based on FitzHugh-Nagumo (FHN) oscillator and implements a nonlinearity introduced by a current that depends on an ion concentration. The nonlinearity is crucial for such differentiation. We have explicitly shown that when the nonlinear activation function is replaced by a

linear dependence, the model responds similarly to all stimuli and shows very little frequency variation. These are the properties of the classical FHN oscillator. Thus, the new nonlinear dependence allows for differentiating responses to various stimuli.

In the DA neuron, an SK-type Ca^{2+} -dependent K^{+} current provides the necessary nonlinearity. Presumably, the same current works in serotonergic neurons. No data is available for other neurons, and the SK current may not be the only current that differentiates the responses. The mechanism works for other currents with a sigmoidal activation function. In fact, any function that starts flat and then sharply increases its slope works. The saturation part of the sigmoidal dependence is not necessary for the frequency responses. The current may depend on ion concentration, on the voltage, or on both variables. This further expands the applicability of our results to neurons expressing various currents. Therefore, in a wide class of neurons, the nonlinearity of a conductance will cause distinct responses to stimuli.

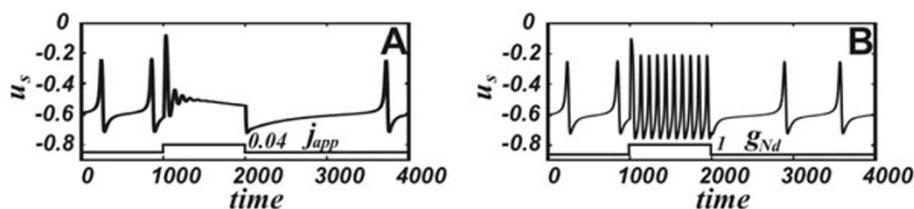


Figure 1 The NMDAR activation elevates the frequency, while the applied depolarization blocks oscillations. The voltage time-series are shown in response to square pulses of the applied depolarization (A) and NMDAR activation (B).

* Correspondence: askuznet@iupui.edu

¹Department of Mathematical Sciences and Center for Mathematical Biosciences, Indiana University Purdue University Indianapolis, Indianapolis, IN 46202, USA

Full list of author information is available at the end of the article

Acknowledgements

The work was supported by the National Science Foundation grant DMS-0817717.

Author details

¹Department of Mathematical Sciences and Center for Mathematical Biosciences, Indiana University Purdue University Indianapolis, Indianapolis, IN 46202, USA. ²Nonlinear dynamics department, Institute of Applied Physics, RAS, Nizhny Novgorod 603950, Russia.

Published: 16 July 2012

doi:10.1186/1471-2202-13-S1-P101

Cite this article as: Kuznetsov and Zakharov: A minimal model for a slow pacemaking neuron. *BMC Neuroscience* 2012 13(Suppl 1):P101.

**Submit your next manuscript to BioMed Central
and take full advantage of:**

- Convenient online submission
- Thorough peer review
- No space constraints or color figure charges
- Immediate publication on acceptance
- Inclusion in PubMed, CAS, Scopus and Google Scholar
- Research which is freely available for redistribution

Submit your manuscript at
www.biomedcentral.com/submit

