BMC Neuroscience

BioMed Central

Oral presentation

Open Access

Characterizing the transient K^+ current contribution to subthreshold membrane potential oscillations in a hippocampal interneuron model

Darrell Haufler*[1,2], France Morin[3], Jean-Claude Lacaille[3] and Frances Skinner[1,2,4]

Address: [1]Toronto Western Research Institute, University Health Network, Toronto, ON, Canada, [2]Physiology, University of Toronto, Toronto, ON, Canada, [3]Physiology, GRSNC, Université de Montréal, Montreal, PQ, Canada and [4]Medicine (Neurology), IBBME, University of Toronto, Toronto, ON, Canada

Email: Darrell Haufler* - darrell.haufler@utoronto.ca

* Corresponding author

from Seventeenth Annual Computational Neuroscience Meeting: CNS*2008
Portland, OR, USA. 19–24 July 2008

Published: 11 July 2008

BMC Neuroscience 2008, **9**(Suppl 1):O7 doi:10.1186/1471-2202-9-S1-O7

This abstract is available from: http://www.biomedcentral.com/1471-2202/9/S1/O7

A class of hippocampal interneurons in the CA1 region, bordering the lacunosum moleculare and radiatum hippocampal layers (the LM/R cell), has been shown to exhibit membrane potential oscillations (MPOs) subthreshold to action potential generation [1,2]. These oscillations occur at theta frequency (4–12 Hz) and are of interest because of their putative role in promoting theta activity at the network level. MPOs can be generated in the absence of synaptic input suggesting that they originate through interactions in the cell's repertoire of currents. In particular, the transient A-type K^+ current (I_A) has been shown to contribute [2]. In this study we present a model of the LM/R cell and show that I_A can enhance MPOs through modulation of the action potential threshold.

A single compartment model of the LM/R cell is developed using experimental data. I_A is based on the Kv4.3 model given in [3], and the remaining currents, which consist of fast and slow delayed rectifiers, transient and persistent sodium currents, and a leak current, are modeled as Hodgkin and Huxley type currents. We also include applied current and white noise terms. The noise is modeled as either voltage independent or proportional to current magnitudes.

We consider the behaviour of the model system at voltages hyperpolarized relative to action potential threshold. We define the subthreshold response function of the system for a given voltage and frequency as the complex ratio of voltage to total current for the currents driven by a small amplitude sinusoidal voltage around the fixed point. Here the voltage is a fixed function of time (as in idealized voltage clamp) and the currents follow passively. This ratio is preserved in the non-driven case in the vicinity of the fixed point and we can use it to predict the voltage response of the system to a given input signal. Simulations agree well with the theory and indicate that the assumed linearity is valid for physiological parameter ranges.

We assess the role of I_A by computing the difference between subthreshold response functions obtained with and without I_A. Blocking I_A can result in a hyperpolarizing shift in threshold depending on the $V_{1/2}$ value of I_A inactivation. For noise independent of voltage, I_A promotes subthreshold power at theta for larger values of the shift while for noise dependent on current activation, the presence of I_A results in a more consistent enhancement of subthreshold theta power.

Acknowledgements

This work was supported by the Natural Sciences and Engineering Research Council of Canada (NSERC) (FKS). JCL was supported by a Grant from the Canadian Institutes of Health Research (CIHR), the Fonds de la recherche en santé du Québec (Groupe de recherche sur le système

nerveux central), and is the recipient of the Canada Research Chair in Cellular and Molecular Neurophysiology.

References

1. Chapman CA, Lacaille JC: **Intrinsic theta-frequency membrane potential oscillations in hippocampal CA1 interneurons of stratum lacunosum-moleculare.** *J Neurophysiol* 1999, **81:**1296-1307.
2. Bourdeau ML, Morin F, Laurent CE, Azzi M, Lacaille JC: **Kv4.3-mediated A-type K+ currents underlie rhythmic activity in hippocampal interneurons.** *J Neurosci* 2007, **27(8):**1942-1953.
3. Wang S, Bondarenko VE, Qu YJ, Bett GC, Morales MJ, Rasmusson RL, Strauss HC: **Time- and voltage-dependent components of Kv4.3 inactivation.** *Biophys J* 2005, **89(5):**3026-3041.