

POSTER PRESENTATION

Open Access

Compromise revisited: inhibitory synapse and electrical coupling effects on bilateral phasing in the leech heartbeat system

Adam L Weaver*, Kristen B Cowens

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

The leech heartbeat central pattern generator (CPG) consists of a network of heart interneurons (HN) that coordinate heart excitor (HE) motor neuron activity via inhibitory chemical synapses. Each segmental pair of HE's is connected to one another via electrical coupling. Depending on the segment, the pair of motor neurons in the living system is active across a wide range of phase differences from nearly in-phase to anti-phase [1]. Prior efforts to model this complete network have not quantitatively matched the intersegmental phase differences observed [2]. We have created a reduced network model in Simulink to explore parameters that contribute to these phase differences.

In our network model, we implemented known neuronal properties and synaptic connections from a single segmental ganglion as shown in Figure 1. In our initial model run, the HN's were modeled as endogenous bursters as previously described [3]; the HE's were modeled as tonic firers. We varied three parameters in this study: phased delay of the right HN synaptic input (Φ_{Syn}) and the maximum conductances of the inhibitory synapse (g_{Syn}) and electrical coupling (g_{coup}).

We found that in this network g_{Syn} must be at least 150 times greater than g_{coup} in order to obtain 1:1 entrainment of the HE's with the HN's. Under conditions with zero Φ_{Syn} , increased g_{coup} led to increased instantaneous spike frequencies (ISF) and reduced duty cycle, primarily due to a delayed burst beginning. Increasing g_{Syn} alone with zero Φ_{Syn} led to little change in HE phase or duty cycle, but saw increased ISF. With relatively high levels of g_{Syn} (300-600 nS), increasing Φ_{Syn} (0.2-0.5) caused one HE to decrease its duty cycle

Figure 1 Leech heartbeat circuit diagram showing identified heart interneurons (HN) of the CPG and their pattern of inhibitory synaptic connections (lines with circles) onto each other and the heart excitor motor neurons (HE). The resistor symbol indicates rectifying electrical coupling connecting two HE neurons in the same segment. Three parameters were varied in this study: the phase of the right HN synaptic input (Φ_{Syn}) and the maximum conductances of the inhibitory synapse (g_{Syn}) and electrical coupling (g_{coup}).

while the other increased. Higher levels of Φ_{Syn} (0.5-0.8) caused the HE's to switch their relative duty cycle patterns. With weak g_{coup} (0.25-0.50 nS) and moderate Φ_{Syn} (0.4-0.6), increasing g_{Syn} led to a reduced HE duty cycle and side-to-side phase difference. The largest phase

^{*} Correspondence: aweaver2@smcvt.edu Department of Biology, Saint Michael's College, Colchester, VT 05439, USA



HE g_{coup} HE

differences were found when both g_{Syn} and g_{coup} were relatively strong. In summary, increases in g_{coup} tended to lead to increased phase differences, while increases in g_{Syn} led to decreased phase differences.

Our search of parameter space has provided a foundation for understanding the mechanisms underlying variable phase differences in neuronal networks and reinforced the importance of compromise between synaptic and neuronal properties for producing functional motor patterns.

Acknowledgements

We would like to thank Gennady Cymbalyuk, Ronald Calabrese, and Paul S. García for model input and support. The project described was supported by the Vermont Genetics Network through Grant P20 RR16462 from the INBRE Program of the NCRR (NIH).

Published: 16 July 2012

References

- Norris BJ, Weaver AL, Wenning A, Garcia PS, Calabrese RL: A central pattern generator producing alternative outputs: phase relations of leech heart motor neurons with respect to premotor synaptic input. J Neurophysiol 2007, 98(5):2983-2991.
- García PS, Wright TM, Cunningham IR, Calabrese RL: Using a model to assess the role of the spatiotemporal pattern of inhibitory input and intrasegmental electrical coupling in the intersegmental and side-to-side coordination of motor neurons by the leech heartbeat central pattern generator. J Neurophysiol 2008, 100(3):1354-1371.
- Weaver AL, Roffman RC, Norris BJ, Calabrese RL: A role for compromise: synaptic inhibition & electrical coupling interact to control phasing in the leech heartbeat CPG. Front Behav Neurosci 2010, 4:1-17.

doi:10.1186/1471-2202-13-S1-P161

Cite this article as: Weaver and Cowens: Compromise revisited: inhibitory synapse and electrical coupling effects on bilateral phasing in the leech heartbeat system. *BMC Neuroscience* 2012 13(Suppl 1):P161.

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

