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To cite this version:

HAL Id: hal-01402515
https://inria.hal.science/hal-01402515
Submitted on 24 Nov 2016

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Firing patterns in model networks of hippocampal persistent firing neurons

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Motivation

- Persistent firing has long been thought to be the neural mechanism underlying short-term memory encoding and storage [1].
- We analyse the dynamics of networks of persistent firing hippocampal neurons.
- We hypothesise that these circuits could contribute to the emergence of theta oscillations in the hippocampus.

Neuron Model

- Neuron Model [4]:
  \[ I_{\text{Neuron}} = I_{\text{Na}} - I_{\text{K}} - I_{\text{L}} - I_{\text{CAN}} - I_{\text{Syn}} + I_{\text{stim}} \]
- Hodgkin-Huxley and M Currents:
  \[ I_{\text{Na}} = g_{\text{Na}} (V - E_{\text{Na}}) \]
  \[ I_{\text{K}} = g_{\text{K}} (V - E_{\text{K}}) \]
  \[ I_{\text{L}} = g_{\text{L}} (V - E_{\text{L}}) \]
- Excitatory Postsynaptic Current:
  \[ I_{\text{Syn}} = g_{\text{Syn}} (V - E_{\text{Syn}}) \]
- Calcium Dynamics:
  \[ \frac{d[Ca^{2+}]_c}{dt} = \gamma_{\text{Ca}} - \delta_{\text{Ca}} [Ca^{2+}]_c + \beta_{\text{CAN}} [Ca^{2+}]_{CAN} \]

Calcium Dynamics

- The Calcium Dynamics:
  \[ \frac{d[Ca^{2+}]_c}{dt} = \gamma_{\text{Ca}} - \delta_{\text{Ca}} [Ca^{2+}]_c + \beta_{\text{CAN}} [Ca^{2+}]_{CAN} \]
  \[ \gamma_{\text{Ca}} = \frac{[-10^3 I_{\text{CAN}}]_{\text{area}} \cdot F}{\lambda \cdot \text{depth}} \]
  \[ \delta_{\text{Ca}} = \frac{24 \mu M}{200 \text{msec}} \]

Fitting Model to In-Vitro Data

Results – CAN-Mediated Theta Oscillations

The interaction between CAN-mediated persistent firing and synaptic activity allow for the emergence of self-sustained synchronous theta oscillations in the CA3 pyramidal network.

Conclusion

- Networks of CAN-equipped neurons display a rich array of firing regimes.
- Self-sustained theta oscillations emerge from the interaction between CAN-mediated persistent firing and synaptic activity.

References