Temperature dependence of spike jitter and neuronal synchronisation

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Even in thermo-regulating animals, such as mammals and birds, the brain is exposed to changes in temperature that can affect neuronal processing [1]. For example, certain forms of epilepsy can be induced by elevated brain temperature [2]. Here, we analyse how temperature influences the spiking regularity of single neurons and network synchronisation. This question is motivated by two observations: (1) Temperature influences the rates and conductivity of ion channels and (2) individual ion channel types, in turn, have been shown to influence single neuron spike regularity and network synchronisation (see, for example, [3]). The relation between temperature and a system's dynamics is complicated by the fact that neuronal voltage dynamics depend on multiple conductances, each of which is modified by the temperature in an idiosyncratic way. We approach this problem by analytical simplification and numerical continuation. For the analysis of spike jitter, conductance-based models with ion channel stochasticty, subject to variable temperature dependencies, are analysed either below or above threshold. Below threshold, the dynamics of these models is described by a coloured noise escape problem [4], and above threshold, a phase-oscillator description is utilised. Common parameter combinations show that an increase in temperature reduces spike jitter. In the subthreshold regime, this can be explained by a temperature-induced redistribution of current noise power to higher frequencies. These are then filtered out by the membrane impedance. In the suprathreshold regime, the faster dynamics at elevated temperatures alter the phase susceptibility, as measured by the ion channels' phase response curves. We interpret these results in the context of network synchronisation and show how the entrainment region of deterministic models is affected by temperature.

References

[1] Reig, R., Mattia, M., Compte, A., Belmonte, C., and Sanchez-Vives, M.V. (2010). Journal of Neurophysiology *103*, 1253–1261.
[2] Sun, L., Gilligan, J., Staber, C., Schutte, R.J., Nguyen, V., O'Dowd, D.K., and Reenan, R. (2012). J Neurosci *32*, 14145–14155.
[3] R.H. Cudmore, L. Fronzaroli-Molinieres, P. Giraud, D. Debanne (2010). The Journal of Neuroscience 30(38), 12885
[4] Fox, R. (1986). Physical Review A *33*, 467–476.

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