NMDA-Rich Dendritic Subunits as a Substrate for Divisive Arithmetic

Monika Jadi¹, Bartlett Mel¹,²

¹Department of Biomedical Engineering, USC and ²Neuroscience Graduate Program, USC

Many models of neural processing include division (e.g. divisive normalization) as a common and important neuronal computation, presumably mediated by synaptic inhibition. Yet the details of its neuronal substrate: the "where" and "how", are far from answered. If the output function of a neuronal unit is an expansive nonlinearity approximating an exponential function, then, to divide its output by a factor D is simply a matter of subtracting \( \log(D) \) from its input. Dendritic sub-units of pyramidal neurons are known to generate NMDA spikes, which provide a nonlinear input/output function. To investigate the divisive competence of this nonlinearity, we used a model pyramidal cell populated with active conductances and AMPA/NMDA type excitatory synapses stimulated by 50 Hz poisson spike trains. We found that the nonlinear function relating peak membrane potential to stimulus intensity provided a relatively poor approximation of the divisive operation. This was due in part to the very short range of inputs over which the NMDA nonlinearity accelerates and then saturates. In contrast, we found that the nonlinear function relating the time-averaged membrane potential to stimulus intensity provided a reasonably high level of divisive competence. This was explained in part by our finding that this nonlinearity exhibited a two-tier acceleration: firstly, the NMDA spike mechanism itself and secondly the acceleration from individual spikes to a plateau potential. We conclude that time averaged currents sourced from NMDA-rich subunits may provide a viable substrate for neural division.

Acknowledgments

This work was supported by NIH grant MH065918-03.