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Temporal tuning of the nonlinear input/output properties of biological neurons

We applied a systems-identification approach to quantitatively describe the nonlinear behavior of biological neurons. Dendritic membrane potentials were recorded from pyramidal neurons in mouse prefrontal cortex in response to either small (subthreshold) or large (suprathreshold) white-noise current injections. Convolving the small current injection with a linear filter fully accounted for the dendritic membrane potential. The filters were relatively fast, with an initial exponential-like decay followed by an undershoot that produced a resonance. The large suprathreshold injections produced both somatic action potentials (spikes) and dendritic spike-like nonlinearities. Deconvolution was used to isolate the nonlinear components from the linear response. The results of the deconvolution revealed nonlinear inward current spikes, that when added to the white-noise current injection, accounted for all of the dendritic membrane potential. We modeled the isolated dendritic spikes using a second linear spike-filter followed by a static nonlinearity. When convolved with the large stimulus, the spike-filter/nonlinear cascade described both the dendritic spike amplitude and the time that each dendritic spike occurred. In comparison to the filters that described the linear membrane potential, the dendritic spike-filters were much faster. The shape of the spike-filter suggests that dendritic nonlinearities are tuned to the temporal properties of fast inward current events such as synaptic inputs.