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Active dendrites: adaptation to spike-based communication

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Dendritic trees possess a plethora of voltage-dependent conductances that render them sophisticated computational devices well beyond the realm of traditional cable theory. Branch specific regulation of dendritic excitability and synaptic plasticity suggests that local nonlinear processes play an essential role in single-cell and network computations. Indeed, much of classical theoretical work focussed on how units that perform complex, nonlinear mappings from their inputs to their outputs contribute to cognitively relevant computations. However, the variables relevant for such computations have often been assumed to be represented by analogue quantities (e.g., somatic membrane potential), ignoring that neurons communicate by spikes, and spike generation loses information about subthreshold membrane potential dynamics. Here we studied how the nonlinear properties of dendrites may be adapted to the computational demands of spike-based communication. We found that the optimal implementation of even purely linear dendritic computations requires the interplay of many independent nonlinear subunits within the postsynaptic dendritic tree. We demonstrate that nonlinear dendritic trees bring significant benefits to single-neuron computation across a wide range of input correlations, even if the individual synapses are optimal estimators of the corresponding presynaptic membrane potentials.