

Dendritic Computation

In recent decades, thanks to new patch clamp recording and optical imaging techniques, it has been well established that most dendrites (from the greek dendron - tree) are not simple passive neuronal compartments, but that they are endowed with a rich repertoire of voltage-gated ion channels that confers upon them the ability to finely tune incoming synaptic potentials, allow backpropagation of action potentials and generate dendritic calcium spikes. These so-called 'active' properties have been demonstrated to have profound implications for synaptic integration and plasticity (e.g. spike timing dependent plasticity) in several neuronal types including hippocampal and neocortical pyramidal neurons, cerebellar Purkinje neurons and olfactory bulb neurons. To date however, very little is known in regard to the dendritic physiology of sensory thalamocortical (TC) neurons, in particular higher order dendrites that are more distal from the soma.

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Descending corticofugal afferents to TC neurons of the thalamic sensory nuclei preferentially form synapses onto thin intermediate/distal dendrites, whereas the other major glutamatergic input, i.e. the sensory afferents, most commonly makes synapses on proximal TC dendrites, in particular upon specialized dendritic 'grape-like' appendages. Both the response to sensory stimuli and sleep oscillations expressed by TC neurons are crucially determined, to a large extent, by the corticothalamic input, and thus the ability of TC neurons to couple distal synaptic signals to axo-somatic output is of vital importance. Nevertheless, very few studies have directly addressed the mechanisms that control integration of intrinsic activity and excitatory dendritic synaptic inputs in TC neurons, and how these properties ultimately determine the thalamic output to the CX. For example, whilst somatic voltage steps have been shown to produce larger $[Ca^{2+}]_i$ in TC neuron dendrites than in the soma, these experiments were limited, for technical reasons, to only proximal ($<30\mu\text{m}$) dendrites. Moreover, although dual somatic and dendritic patch clamp recordings demonstrated active action potential backpropagation in TC neuron dendrites these too were limited to only $\sim 60\mu\text{m}$ from the soma in neurons that have mean dendritic path lengths of $\sim 180\mu\text{m}$.

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OUR RESEARCH

Using in vitro patch clamp recording coupled with 2 photon laser scanning microscopy and targeted synaptic stimulation, we have recently started to investigate intrinsic and synaptic $[Ca^{2+}]_i$ dynamics in proximal and distal dendrites of TC neurons, and their impact on different firing outputs (Fig. 1) and physiologically relevant oscillations (e.g. alpha rhythm, slow sleep oscillations) (Fig. 2) (Movie 1).

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Our preliminary results can be found in the following meeting abstracts:

1. Errington, A.C., Crunelli, V. (2009). State-dependent spatio-temporal calcium dynamics in dendrites of thalamocortical neurons. Physiological Society meeting, Cardiff, December 2009, PC44.
2. Watson, J., Errington, A.C., Crunelli, V. (2008). Firing mode-dependent calcium dynamics in proximal and distal dendrites of thalamocortical neurons. Soc. Neurosci. Abstr. 34, 44.2.
3. Errington, A.C., Crunelli, V. (2008). Dynamic calcium changes in dendrites of cat thalamocortical neurons during the slow (<1 Hz) sleep oscillation. Soc. Neurosci. Abstr. 34, 44.1.