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Title: Intrinsic dendritic plasticity maximally increases the computational power of CA1 pyramidal neurons.

Abstract: What additional computing power do dendrites add to a neuron? Previous work using artificial neural networks has suggested that active dendrites improve the computing power of CA1 pyramidal neurons by increasing the number of possible input/output relationships (Poirazi et al 2001). However, several key questions remain open: what characterizes these new input/output behaviors? Is there a dendritic morphology which maximally increases the computational power of such «dendritic» neurons? And which physiological parameters of the neuron should change to reach this maximal computational power? In order to address these issues we start out with the approach of Poirazi et al (2003) and consider the dendritic tree of the CA1 pyramidal neuron as a two layer neural network with excitatory connections.

We begin by showing that we can exhaustively characterize the entire space of possible two-layer networks. Extending results on single layer networks by Minsky and Papert (1988) we prove that any two layer neural network, with real, positive synaptic weights and thresholds, has a discrete, weightless equivalent with the same input/output mapping. Using this discretization, we are able to enumerate all possible input/output functions of a two layer neural network (for up to 6 distinct inputs).

Analytically we identify the input/output combinations that could only occur in two-layer but not in one-layer networks. Such input/output combinations, should they be identified in a CA1 pyramidal neuron, would indicate that the cell functionally implements a two-layer neural network. For instance, given four independent Schaeffer collaterals (A, B, C and D) impinging on a CA1 pyramidal neuron, our analysis predicts that if both A+B and C+D elicit a response, but A+C, A+D, B+C or B+D do not, then the dendritic tree is equivalent to a two-layer network, and cannot be reduced to a single layer.

Our analysis also shows that a surprisingly simple dendritic tree morphology is required to maximize the computational power of CA1 neurons: the number of dendrites should match and not exceed the dimensionality of space spanned by the inputs. Our model thus predicts that the ratio of oblique dendrites of the CA1 pyramidal cell to the Schaeffer collaterals should be around one in order to efficiently maximize the range of input/output functions.

Finally, we find that modification of the somato-dendritic coupling strengths does not change the input/output mapping of the neuron. Conversely, we show that modifying dendritic branch excitability is necessary to access the full range of input/output functions. Thus, our model suggests that intrinsic dendritic plasticity is key to maximizing the computational power of a CA1 pyramidal neuron, consistent with recent experimental demonstrations of dendritic plasticity in CA1 pyramidal cells (Losonczy et al. 2008).

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