Possible Distance-Dependence of Nonlinear Spatial Summation in Basal Dendrites of Neocortical Pyramidal Cells

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The thin basal and apical oblique dendrites of pyramidal neurons receive a large fraction of the cells' excitatory inputs. Yet how these inputs are integrated remains an important open question. A recent in vitro study (Polsky, Mel & Schiller 2004) found that NMDA spikes contribute to a highly nonlinear (i.e. sigmoidal) summation rule when two closely spaced synaptic inputs activate the same thin branch. In contrast, when two stimuli were increasingly spatially separated within a branch, summation grew increasingly linear, just as for inputs delivered to two different branches. We have now used biophysically detailed compartmental models of pyramidal neurons to study this separation dependence, leading to two different outcomes depending on whether we assume locally balanced or imbalanced stimuli. If we assume locally balanced inputs, that is, the two inputs cause local depolarizations that are approximately matched, our findings clearly indicate that cable attenuation is unlikely to account for the trend to linear summation with increasing separation of the two stimuli. Rather, our results suggest that the branch excitability in distal thin dendrites, and in particular the NMDA/AMPA ratio, may be severalfold greater than in proximal thin dendrites. In contrast, if we model inputs that are balanced at the soma—corresponding to smaller depolarizations at more proximal stimulus sites and larger local depolarizations at more distal sites—we find that two-input summation experiments are not definitive: the separation-dependent trend to linear summation could result EITHER from a branch excitability gradient (see above), or from a simple failure to exercise the nonlinear membrane response at the more proximal stimulus site (given the much smaller local depolarizations). Preliminary data analyzing local spike properties as a function of branch location weighs in favor of the location-dependent gradient of branch excitability.