Layer 2/3 Is A Neural Multigrid: Information Maximization In A Local Network Explains V1 Hypercolumn Formation

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One of the most striking feature of primate V1 is a topographic ordering of receptive fields. Previous models of topographic map formation (e.g., [1]) pose topography as a constraint on receptive-field formation. Optimization techniques maximize information between visual inputs and outputs [2], and produce receptive fields strikingly similar to those in V1, but not topography. Neural network implementations of infomax [3] require fully connected lateral networks, which the cortex does not possess. While the density of lateral connections in layer 2/3 surpasses all other connection classes [4], a local, patchy connectivity pattern is still observed [5]. A model of infomax in 2/3 must therefore explain how this optimization can be implemented in a local network. We hypothesized that topography might emerge naturally from such a model.

Here we present a neural multigrid that approximates infomax in a locally connected network, and embeds optimal receptive fields in a phase-independent topographic map. Our approach allows for a 66% reduction in the density of lateral connections, and yields a network topology similar to that observed in layer 2/3. We conclude that two key features of layer 2/3, 1) local, patchy synaptic connectivity and 2) topography, together serve the same goal: information maximization in a biologically constrained network.

Figure 1: A. Neural multigrid maps optimal filters. B. Local network yields hypercolumns.

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References