Anatomical Constraints on Lateral Competition in Columnar Cortical Architectures

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Author(s) Muir, Dylan R; Cook, Matthew
Author(s) at UniBasel Muir, Dylan ;
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Competition is a well-studied and powerful mechanism for information processing in neuronal networks, providing noise rejection, signal restoration, decision making and associative memory properties, with relatively simple requirements for network architecture. Models based on competitive interactions have been used to describe the shaping of functional properties in visual cortex, as well as the development of functional maps in columnar cortex. These models require competition within a cortical area to occur on a wider spatial scale than cooperation, usually implemented by lateral inhibitory connections having a longer range than local excitatory connections. However, measurements of cortical anatomy reveal that the spatial extent of inhibition is in fact more restricted than that of excitation. Relatively few models reflect this, and it is unknown whether lateral competition can occur in cortical-like networks that have a realistic spatial relationship between excitation and inhibition. Here we analyze simple models for cortical columns and perform simulations of larger models to show how the spatial scales of excitation and inhibition can interact to produce competition through disynaptic inhibition. Our findings give strong support to the direct coupling effect—that the presence of competition across the cortical surface is predicted well by the anatomy of direct excitatory and inhibitory coupling and that multisynaptic network effects are negligible. This implies that for networks with short-range inhibition and longer-range excitation, the spatial extent of competition is even narrower than the range of inhibitory connections. Our results suggest the presence of network mechanisms that focus on intra- rather than intercolumn competition in neocortex, highlighting the need for both new models and direct experimental characterizations of lateral inhibition and competition in columnar cortex.
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