Local order within global disorder: synaptic architecture of visual space

Benjamin Scholl
Daniel E. Wilson
David Fitzpatrick

Video Abstract

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Abstract

Behind the brain's remarkable abilities is a thick network of neurons, each receiving many inputs. To do anything – think, touch, or see – neurons have to integrate the many signals they receive. But how do they do this? One proposed mechanism is spatial clustering of synaptic inputs. Now, researchers from the Max Planck Florida Institute for Neuroscience report that synaptic inputs carrying visual information are clustered at a scale of 5 to 10 microns, sharing functional properties and activity. To evaluate the degree of synaptic clustering in the circuits responsible for vision, the team mapped the spatial receptive fields of about a hundred spines – the structures that receive synaptic inputs – on the dendrites of individual neurons in the visual cortex of ferrets. They used two-photon imaging to record activity while the animals looked at a variety of white and black bars. The spines responded to different features and areas of the images. Strangely, the responses to even a single stimulus were scattered across the dendrites. Inputs close to the neuron's cell body weren't substantially different from those far away, and there was no detectable overarching order. Zooming-in, though, the neuroscientists noticed a pattern. Within individual dendrites, spines with similar responses were often neighbors. Sometimes they were on the same side of the dendrite shaft; sometimes they were across from one another. Either way, they were consistently less than 5 microns apart. The researchers then checked whether neighboring spines carrying similar signals would actually be co-activated by individual visual stimuli. They repeatedly showed ferrets the same stimulus, and confirmed that neighboring spines within 5 microns were more likely to be co-activated. The team also observed local clustering when they showed other types of visual stimuli or when neurons responded spontaneously in the absence of visual stimulation, suggesting that this phenomenon is a common property of how neurons connect with one another and process a variety of sensory information. These findings demonstrate that synaptic inputs in the visual cortex are locally – but not globally – organized. This local functional synaptic clustering applies to a diverse set of inputs and appears to be a fundamental principle of dendritic organization. Future work should reveal more about the source of these clustered inputs and how these clusters arise during the development of neural circuits.