Thinking Outside the Column: New Insights Into Brain Structure Reveal New Facets of Information Processing in Nervous System

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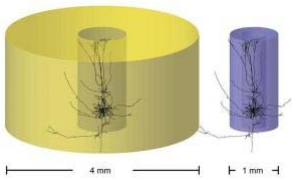

For more than 50 years, a dominating assumption in brain research was that nerve cells in the cortex of the brain are organised in the form of microscopically small columns. Subsequently, it became a textbook standard that connections are created predominantly between nerve cells within these columns. In a review article for the journal *Frontiers in Neuroscience*, Clemens Boucsein and colleagues from the Bernstein Centers in Freiburg and Berlin show that this view has to be revised: input from cells that lie outside this column plays a much more important role than hitherto assumed.

It was one of the great discoveries of the 20th century in the neurosciences that nerve cells lying on top of each other in the cortex react to the same stimulus -- for example edges of different orientation that are presented to the eye. Investigations of the connectivity between nerve cells further supported the assumption that these column-like units might constitute the basic building blocks of the cortex. In the following decades, much research was conducted on cortical columns, not least because the investigation of long-range connections within the brain is a very complicated affair.

But now, these assumptions about a columnar cortex structure come under scrutiny. New experimental techniques allow the tracing of connections over long distances. Boucsein and his colleagues at the University of Freiburg refined a technique to use laser flashes to specifically activate single nerve cells and to analyse their connections. These experiments led to surprising results: less than half of the input that a cortical nerve cell receives originates from peers within the same column. Many more connections reached the cells from more distant, surrounding regions.

The experiments also revealed that these horizontal connections operate very accurately in terms of timing. To the scientists, this is an indication that the brain may use the exact point in time of an electrical impulse to code information, a hypothesis that is gaining more and more experimental support. These new insights into structure and function of the brain suggest that the idea of a column-based structure of the cortex has to be replaced with that of a densely woven tapestry, in which nerve cells are connected over long distances.

Story Source:

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Journal Reference:

1. Boucsein C, Nawrot MP, Schnepel P and Aertsen A. **Beyond the cortical column: abundance and physiology of horizontal connections imply a strong role for inputs from the surround**. *Front. Neurosci.*, 5:32 DOI: 10.3389/fnins.2011.00032

Abstract

Current concepts of cortical information processing and most cortical network models largely rest on the assumption that well-studied properties of local synaptic connectivity are sufficient to understand the generic properties of cortical networks. This view seems to be justified by the observation that the vertical connectivity within local volumes is strong, whereas horizontally, the connection probability between pairs of neurons drops sharply with distance. Recent neuroanatomical studies, however, have emphasized that a substantial fraction of synapses onto neocortical pyramidal neurons stems from cells outside the local volume. Here, we discuss recent findings on the signal integration from horizontal inputs, showing that they could serve as a substrate for reliable and temporally precise signal propagation. Quantification of connection probabilities and parameters of synaptic physiology as a function of lateral distance indicates that horizontal projections constitute a considerable fraction, if not the majority, of inputs from within the cortical network. Taking these non-local horizontal inputs into account may dramatically change our current view on cortical information processing.

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