Medical Xpress

Interaction with neighbors: Neuronal field simulates brain activity

September 27 2010

The appearance of a spot of light on the retina causes sudden activation of millions of neurons in the brain within tenths of milliseconds. At the first cortical processing stage, the primary visual cortex, each neuron thereby receives thousands of inputs from both close neighbors and further distant neurons, and also sends-out an equal amount of output to others.

During the recent decades, individual characteristics of these widespread network connections and the specific transfer characteristics of single neurons have been widely derived. However, a coherent population model approach that provides an overall picture of the functional dynamics, subsuming interactions across all these individual channels, is still lacking. German scientists of the RUB's Bernstein Group for Computational Neuroscience developed a computational model which allows a mathematical description of far reaching interactions between cortical neurons. The results are published in the prestigious open-access *Journal* PLoS Computational Biology.

Cortical activity waves and their possible consequences for visual perception

By means of fluorescent dye that reports voltage changes across neuronal membranes it has been shown how a small spot of light, presented in the visual field, leads to initially local brain activation followed by far distant traveling waves of activity. At first, these waves remain subthreshold and hence, cannot be perceived consciously. However, a briefly following elongated bar stimulus leads to facilitation of the initiated activity wave. Instead perceiving the bar at once in its full length, it appears to be drawn-out from the location of the previously flashed spot. In psychology this phenomenon has been named 'line-motion illusion' since motion is perceived even though both stimuli are displayed stationary. Thus, brain processes that initiate widespread activity propagation may be partly responsible for this motion illusion.

Neural Fields

RUB Scientists around Dr. Dirk Jancke, Institut für Neuroinformatik, have now successfully implemented these complex interaction dynamics within a computational model. A so-called neural field was used in which the impact of each model neuron is defined by its distant-dependent interaction radius: close neighbors are strongly coupled and further distant neurons are gradually less interacting. Two layers one excitatory, one inhibitory, are recurrently connected such that a local input leads to transient activity that emerges focally followed by propagating activity. Therefore, the entire field dynamics are no longer determined by the sensory input alone but governed to a wide extent by the interaction profile across the neural field. Consequently, within such a model, the overall activity pattern is characterized by interactions that facilitate distant pre-activation far away from any local input.

Such pre-activation may play an important role during processing of moving objects. Given that processing takes time starting from the retina, the brain receives information about the external world with a permanent delay. In order to counterbalance such delays, pre-activation may serve a "forewarning" of neurons that represent locations ahead of an object trajectory and thus, may enable a more rapid crossing of firing thresholds to save important processing times.

What can we generally learn from such a field model regarding brain function? Neural fields allow for a mathematical framework of how the brain operates beyond a simple passive mapping of external events but conducts inter-"active" information processing leading, in limit cases, to what we call illusions. The future challenge will be to implement neural fields for more complex visual stimulus scenarios. Here, it may be an important advantage that this model class allows abstraction from single neuron activity and provides a mathematically handable description in terms of interactive cortical network functioning.

More information: Markounikau V, Igel C, Grinvald A, Jancke D (2010). A Dynamic neural field model of mesoscopic cortical activity captured with voltage-sensitive dye Imaging. PLoS Comput Biol 6, e1000919. doi:10.1371/journal.pcbi.1000919

Provided by Ruhr-University Bochum

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