NEURAL COMPUTATION IN NETWORKS

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Neural computation, i.e. the way in which the nervous system processes information and solves computational problems, depends on basic properties of axons, dendrites and synapses. These biological elements in many cases appear to behave as reliable computing elements, but often and in particular synapses, they are seen as a major source of variability. The reliability of these biological elements, however, has been addressed primarily in single cells and only rarely in a neuronal network.

We have studied neural computation in two different networks: an isolated ganglion of the leech and a neuronal culture of dissociated cortical neurons of neonatal rats. The input output relations in a leech ganglion were studied by simultaneously using six suction pipettes and two intracellular electrodes. The analysis of extracellular and intracellular voltage signals allowed a precise description of the spread of excitation from a single mechanosensory neuron to identified motorneurons and interneurons. A single action potential evoked in a mechanosensory neuron activated a clear electrical activity in at least 10 different motorneurons and/or interneurons. The evoked spatio-temporal electrical activity was characterized by a high degree of variability, much larger than that observed in a single neuron. This significant variability is set by basic properties of synaptic transmission and is not a peculiarity of a leech ganglion, but instead is likely a typical feature of neuronal assemblies.

The neuronal network of dissociated cortical neurons from neonatal rats was cultivated over a multielectrode dish with 64 active sites, which were used for recording the electrical activity or for stimulation. After about 4 weeks of culture a dense network of neurons was observed and their electrical activity was studied. When a brief voltage pulse was applied to one extracellular electrode a clear electrical response was evoked. When a strong voltage pulse was used the response was composed by an early phase, terminating within 25 msec and a late phase which could last several hundreds of milliseconds. During the early phase of the response was rather reproducible and the network was able to efficiently process information.

On the contrary the late phase was characterized by significant spatio-temporal fluctuations.

These results, obtained from two different neuronal networks show that neural computation is characterized by a high degree of spatio- temporal variability, i.e. noise, most likely originating from the stochastic nature of synaptic transmission. However this noise does not limit performances of neural computation and can often be used to increase reliability of information processing and possibly as a sophisticated computing tool.