NEURAL NETWORKS AND COGNITIVE PROCESSES IN HEALTH AND DISEASE

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Functional activity of neurons is determined by efficiency of synaptic formations functioning. Plenty of signal molecules (from neurotransmitters till growth factors, aminoacids and gas molecules) are involved into interneuronic communications. By the way, every human has its own complex (pattern) of signal molecules which significantly determine intellectual features and personality. Unfortunately, namely the targets of signal molecules – neural networks and synapses – are the most sensitive to inflammatory factors, toxins, endogenous and synthetic neutrophilic substances exposure. Acute or chronic disruption of interneuronic communications is always followed by failure in neural networks integrative work. Development of pathological processes in brain becomes the result of such failures. These processes may acquire functional character after initiation of plastic processes in nerve tissue. On the other side, disturbance of brain plasticity leads to development of destructive transformations in neurons, synapses and glial cells. The process becomes irreversible, and patients usually visit doctor only at this stage. The standard treatment scheme is usually applied in clinical practice: medicines with neurotropic effect. Additional "intervention" in neural networks activity transforms their regular work. Pathological process becomes chronic. Then the doctor decides to change treatment scheme. But where to shift focuses in correction of neural networks functions? Special methods are applied in preclinical studies in order to assess the effects of new substances on functional state of neurons and interneuronic communications. In particular, neurophysiological techniques allow quantitatively and dynamically establish the efficiency of signals transmission in nerve tissue and assess synaptic plasticity. Modern neurophysiological techniques of electrical events registration at the level of single synapse or part of neuron membrane (patch-clamp) increase opportunities in assessment of neural networks functions in health and disease. But there are difficulties in common analysis of revealed patterns at the levels of neuron membrane part and multicomponent neural network. Integrative analytic approach with computer modelling is needed. Otherwise the diversity of mechanisms of neurotropic substances action on central nervous system (from synapses and cells till integrative level of brain and spinal cord) cannot be ascertained.

Interneuronic communications modelling at the level of integral brain is one of the technologies to answer the raised questions. Formation of such models became available after development of numerical methods of analysis of biophysical processes of data processing in biological neural networks. Data processing at this level requires special hardware and software design. For example, the project "BlueBrain" uses supercomputer DeepBlue (IBM) for detailed modelling of one part on cerebral cortex [1, 2]. One can imagine the required level of computer to model not the one part of cerebral cortex, but the functions of whole brain. That is why methods of computer modelling attract special attention of researchers and doctors.

In many cases models of neural networks with certain configuration are used in the analysis of experimental data. There is popular model [1] consisting of several hundred input neurons forming synaptic contacts with output neuron, which is used in numerous studies of synaptic plasticity investigation. This model considers spike-timing dependent plasticity (STDP), revealed in many brain regions [1]. Change of synaptic conductivity in the model is determined only by time parameters of pre- and postsynaptic activation [1-3]. Such relatively simple model provides insight into essential features of neural network. It is all about stability of output activity after change of different parameters and formation of competitive input signals during interaction of synapse groups. In this case, the increase in conductivity in one group of synapses is accompanied with the decrease in conductivity of other synapses.

Ideas of competitive learning appeared in theoretical studies dedicated to pattern recognition and self-management in neural networks [1, 2], as well as in modelling of the processes of topological mapping formation (correlation between receptor and the area of brain cortex) [1]. Hebb's theory of competitive learning is used in modelling of patterns formation, maps of brain cortex and selectivity columns and is characterized as "flexible, simple and useful" [1]. For example, only part of information presented at eye retina can be processed at any specific time (namely the information which is in the focus of attention). That is why populations of neurons responsible for mapping of certain patterns compete for priority of their information processing [1, 2]. The effect of medicinal substance in these models is considered as factor influencing on certain features of used model. Conditions of spike potentials generation and electrical processes at the level of pre- and postsynaptic membrane, characterizing synaptic transmission are considered the most important processes [4]. Influence of substance or other disturbing factors is manifests as change of threshold of spike potentials generation that can be easily detected experimentally and realized in model neuron. Main experimental studies in assessment of disturbing factors influence on the processes of synaptic plasticity are considered classic protocols of long-term potentiation induction based on the use of high frequency of train stimulation.

The rate of neural network learning is one of the parameters which characterize efficiency and productivity of neural network functioning. The rate of learning in models is determined by time needed for primary single-mode histogram of synaptic conductivities to become bimodal one. Such computer models adequately display real situations in living, but not computerized brain. High frequency of neural network activity and maximal conductivity of all synapses lead to "epileptiform" state, when the rate of learning increases under controlled conditions. The rate of learning decreases in the presence of pathological processes in brain or during uncontrolled use of neurotropic drugs; epileptiform activity accompanied with such motor effects as frank and absence seizures begins to appear in brain.

Therefore, the modelling of processes of biological neural networks functioning under conditions of neuromodulatory factors action is promising technique for the development of new neuropharmacological substances action analysis. Above mentioned goes near development of adequate methods of correction of nerve system dysfunctions, because performing of unique calculations is one of brain features. Traditional conservative approaches cannot always afford tools suitable for analysis of biological neural networks functional activity. The time is ripe for integrative analytic approach with computer modelling use including topological approach to explain multisensory neurons functioning as nonlinear chaotic systems [5, 6].

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