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Reflex inhibition. Global manifestation of the local mechanism

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Abstract. The paper considers the issues of training and retraining in self-organizing natural information processing systems and shows the reasons for the rule “The one who comes first gets all” and the possibility of creating a technical device, which is an artificial intelligence carrier. Such a device is not filled with the necessary information at the stage of creation, but receives all the necessary information in the process of functioning, especially at the beginning of its activity and in the process of education, just as the intellect of a person is being raised since childhood.

1 Introduction

Until now, physicians and biologists speak of “the doctrine of the higher nervous activity” when describing the functioning of the nervous system (NS) and the brain [1–4] (I.Setchenov, I.Pavlov). At the same time, specialists in other fields speak about their disciplines as theories. It is generally accepted that a theory differs from teaching (doctrine) by its logical validity and practical confirmation. Whereas a doctrine is based mainly on believe in the truth of a doctrine based on the authority of a doctrine’s creator without special concern about practical confirmation of a doctrine and based on the absence of alternative evidentiary logical constructions that resolutely reject the doctrine. Why does this situation continue to be true? When applied to the discipline concerning such an important subject as conditioned reflexes and, ultimately, our thinking, the use of the term “doctrine” indicates the absence of a firm theoretical and practical foundation for this discipline despite achievements in the field of cognition and successes in correction of the nervous activity when necessary. Indeed, there are still no theoretically substantiated and practically confirmed representations about the mechanisms of functioning of memory, thinking, and about the details of these mechanisms and processes. The aims of the work presented by us include change of the situation in the study of higher nervous activity; we mean the change of the term “doctrine” to the term “theory”. We will try to do this based on the principles of brain functioning, which are theoretically grounded [5], supported, and patented [6-9]. The principles proposed were confirmed practically during implementation of the research project RW 9006 [9], but so far only by the example of a small electronic scheme. The model of the simplest nervous system consisting of three electronic neural-like elements demonstrated the ability to completely independent “learning” by self-formation of connections between neurons, in which traces of events are reflected. In addition, this simple model demonstrated the ability to re-learn when circumstances change. It is expected to confirm the principles proclaimed by conducting experiments on simple organisms (by the example of nervous systems of simple biological objects such as mollusks and insects).



2 The mechanism of training (formation of communication between neurons)

The main features of brain functioning described in [5] include a purely local mechanism for formatting connections between pairs of excited neurons and a continuous decrease in the weights of all connections (new and long-existing). Only the state of neurons and their spatial proximity (mechanical contact) have the meaning for formation of connections between neurons. The mechanism of formation of connections should not only be purely local but also extremely simple because it originated itself, it was not designed by engineers. Confidence in the simplicity of the mechanism for formation of inter-neural connections follows already from the fact that when the organism is born, there are no connections between neurons, no mechanism for establishing connections, and even no neurons themselves. There is no place for storage of information about the mechanism for control over formation of links and about rules, according to which communication should be established. Where is the information about this local mechanism arrangement stored? This information is contained in the parent (mother) cell itself; it includes the information about how a cell can reproduce its copy next to itself, how it reacts to the nearest environment, which, in turn, can influence it. This mechanism ensures formation of connections between mechanically contiguous components of neuron pairs throughout the human brain with an average speed of about 30 thousand new connections per second. The rate of formation of connections is easily estimated by the time of life of the brain and the number of connections between neurons in the mature brain. The number of 30 thousand comes from the fact that the number of connections in the human brain during its lifetime (about 100 years) grows from zero at conception to the value of about 150×10^{12} connections (15 billion neurons, up to 10 000 connections for each neuron). The proposed mechanism for local formation of connections is realization of the logic of formation of connections between excited neurons at the intersection of half-selected sets of outputs of *exciters* and inputs of *excited neurons*. This can be represented visually as appearance of a standard value positive potential at the outputs and a negative potential of approximately the same value at the inputs of the excited neurons and further appearance of the possibility of forming connections between points if the potential difference of these points exceeds the potential for forming connection U (FP). The scheme of formation of the connection is shown in Figure 1.

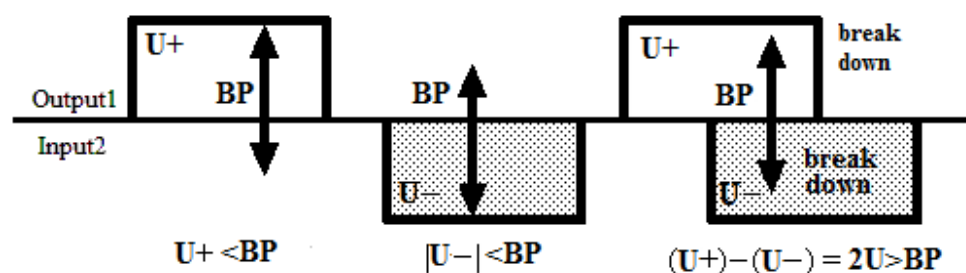


Figure 1. Formation of the connection between two excited neurons.

This Figure illustrates the logic for formation of a connection between excited active elements (neurons in a biological organism or neuron-like elements (NE) in artificial devices). Excitation of active elements occurs in a usual way. It occurs when the total signal at the input of the active element exceeds a certain threshold U_{th} .

Formation of the depicted potentials at the outputs and inputs of the excited elements can be easily realized for electronic devices. Such formation of potentials contradicts the usual practice of creating various electronic devices. However, it provides formation of connections between the NE of the electronic device. Is existence of such mechanism possible in natural organisms?

the “forecast”, NE2 will excite at NE1 excitation. Therefore, an organism can pre-evade the approaching factor2 because of the “forecast” based on the formed connection.

3 How excited neurons get tired

Neurons are not exceptional cells dealing with electricity. The receptors transform optical, chemical, mechanical, and thermal stimuli into electrical signals. Muscles turn potentials into mechanical actions. Electric generating cells (tissues) of some animals form electrical impulses of high voltage; this fact additionally indicates the general nature of all cells of the body. We should note that the cells of electric fish generating electricity rapidly weaken when generating several pulses in a row, that is, they generate a discharge of lower voltage and a lower current.

The neuron behaves the same way. Under the conditions of frequent excitement, it does not have time to recover completely and fatigue occurs. The energy for the signal is stored in the body of a neuron (in the form of nutrients). Because of excitation, the neuron each time consumes a portion of energy from its stock, which is restored at a certain rate. Therefore, the ability of the neuron to excitation decreases after each excitation. That is, the threshold voltage (UT) increases slightly. We can say that the neuron “gets tired”. If a neuron is excited quite often, then its energy reserves will not have time to recover. It can even stops being excited.

4 Choice of direction of signal propagation

Because of an electrical breakdown or an equivalent phenomenon, the output of one excited neuron and the input of another excited neuron form a permanent connection for the rest of life. Communication cannot be formed with other neurons, which are not excited at the moment, because the potential differences between them are insufficient for breakdown. If the connection is formed, then, most likely, the resistance of the formed connection, as well as of the previously existing connections will slowly increase over time $r_{cf} \rightarrow R_{cf}$ because of the resorption of the conducting channel. Conductivity decreases, communication weakens, and the event is forgotten. Because of the weakening of ties over time, old events are recalled with greater difficulty than recent events. Recalling of old events require more associations for neuron excitation because neuron excitation occurs when the total signal, which is the sum of contributions of the signals to individual inputs, exceeds a certain threshold (UT). That is, the sum of the products of the potentials by the weights of the individual connections is greater than the threshold: $S(U_i * W_i) > UT$

We should note that when a new connection is formed, or when an element of the next stage is excited, simple rectangular potentials cease to be regular rectangular because of partial compensation of the potentials of the associated outputs and inputs. This process is shown in Figure 3.

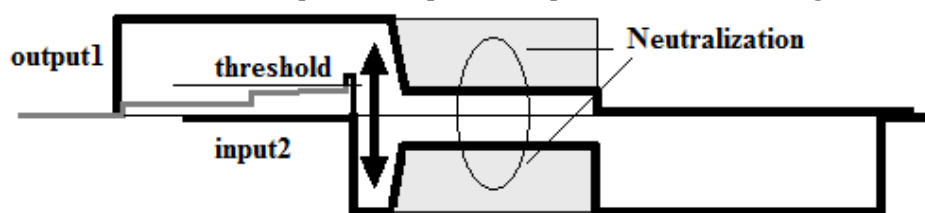


Figure 3. Compensation of potentials at the inputs and outputs of excited neurons.

Formation of bi-polar potentials at the output and input of excited neurons not only ensures formation of new connections. The opposite polar potentials mutually compensate themselves and, thus, provide a solution of other problems associated with the signal propagation through the labyrinths of brain structures. Because of the spread of the neuron parameters and weights of their input connections, the moments of exceeding the excitation thresholds will differ for different neurons and one of the neurons will be excited first. It will immediately give a negative potential to its total input. This potential partially compensates the potential that has excited this neuron. The same

exciting potential, which had excited the first of the neurons, also enters inputs of other neurons. Partial compensation of the exciting potential will prevent excitation of other neurons that did not have time to be excited. Therefore, only the neuron excited first will be excited because of the optimal configuration of the weights of its input connections and the values of the input signals. Because of compensation of multi-polar signals, the rule "The one who comes first gets all" is automatically generated; in the artificial neural networks, this rule is introduced by directive.

We have considered the local mechanism for formation of a trace of an event, that is, formation of a neuronal connection that does not require external control. We can say that we have examined the procedure of "training" of the nervous system. However, in real life, the conditions of existence of the organism with the NS are constantly changing. Therefore, survival and evasion of the organism from the stimulus can be ensured only when the reaction of the organism to almost identical stimuli will change in accordance with new circumstances. It means that it is necessary that the organism can change its reaction (retrain).

5 A mechanism of retraining (inhibition of obsolete reflexes)

It turns out that the mechanism of organization of functioning of the organism's memory (including formation of new connections (remembering), forgetting (fading of connections, reduction of their weights), and neuron tiredness because of rapid energy expenditure and slow restoration of its reserves) automatically provides "retraining" of the nervous system in conditions of circumstances change. Let us show how the reaction of the organism and the conditioned reflexes change in such cases.

When circumstances change, the old reaction of the organism no longer leads to success, to evasion from the stimulus, and to the cessation of its action. Because of unsuccessful excitations of neurons forming a chain of the old reaction, which does not lead to cessation of irritation, these neurons "get tired", their individual thresholds of excitation grow. There appears a possibility of excitation of neurons that are not part of the chain of the old reaction. Some of them are excited, new connections and a new reaction are formed. New connections have the greatest weight, which decreases over time as well as the weight of all other connections. However, the new connections continue to have greater weight than the old ones. Therefore, subsequently, in similar situations, neurons that form a chain of a new reaction are excited first because of the greater weight of connections. This is because everything in our world is inertial. Therefore, the change in potentials at the total neuron input changes at a certain rate determined by the electrical capacitance, the weight of the individual connections (inputs), and the potentials at the outputs of the neurons of the preceding cascade participating in the excitation of the neurons of the cascade under consideration. When getting excited, neurons that form the beginning of a new reaction chain (a new reflex) partially compensate the positive potentials of the neuron outputs of the previous cascade (that excite them) by negative potentials at their inputs. It means that neurons from the old reaction chain that have not yet had time to be excited can no longer be excited. As physiologists say, the "inhibition" of the old reflex occurs.

However, according to widespread contemporary ideas, the inhibition of old reflexes that do not lead to success is ensured by the existence of a special mechanism of inhibition. The essence of this mechanism is in the fact that along with the signals involved in the excitation of neurons by summing the individual signals of the same polarity at the summing input, there are also signals of the opposite polarity, which come at the same summing inputs and prevent excitation of neurons. However, none of the researchers observed these inhibitory inputs (signals) in practice.

There must be some mechanism for suppressing the old reflex. How else can the observed suppression of the old reaction be explained? We put forward the explanation of the observed phenomenon. However, if we admit the existence of inhibitory signals, then it becomes necessary to explain a mechanism of formation of such inhibitory connections (signals). What is the logic of formation of such connections and supply of inhibitory signals to them? Who or what decides when to give such signals? Obviously, such a difficult task of determination of the necessity of inhibition requires analyzing several "global" parameters that are inaccessible to an individual neuron dependent

only on the potential at its summing input. That is, the local neuron mechanism cannot ensure formation of inhibitory signals according to the adopted scheme.

The local mechanism of formation of new connections and formation of signal paths with the participation of global "inhibition" proposed by us is realized by a purely local mechanism because of the tiredness of often-excited neurons and the subsequent "competition" of neurons for a limited resource (energy of the exciting signal).

Neurons become tired because of the ineffectiveness of the old reaction; it does not lead to elimination of irritation, cessation, and consequently, excitation of the neurons of the old chain. Because of the neurons tiredness (multiple excitation), they cease to be excited and to prevent excitation of other neurons. These neighboring neurons are excited and new strong connections with the greatest weights are formed. A chain of new reaction to the environment changed is being formed.

Subsequently, the neurons that had formed the chain of a new reaction would be excited first because of the great weights of their connections. In conditions of their excitation, they will prevent excitation of the neurons of the chain of the old reflex. This is how the old reflex will be suppressed because of a purely local mechanism of comparing possible ways of signal propagation along brain structures.

6 The mechanism of thinking

Nature is economical. It does not have resources to create complex mechanisms. All objects and structures are formed by themselves in accordance with initial mechanisms and the influence of their environment. We offer a purely local, extremely simple mechanism for the neuron excitation and formation of connections, which provides training, retraining of nervous systems, and the choice of signal paths through the brain structures. This local mechanism ensures functioning not only of nervous systems of the simplest organisms, but also of the brain of higher animals, which consists of tens of billions of neurons, each of which can have up to 10 000 separate inputs (connections with topological neighbors). We have examined the most important logical principles that ensure functioning artificial devices and natural biological objects, which are capable for self-training under the influence of the environment.

Omitting consideration of less significant details of functioning of such objects, we will present a scheme of the electric brain of a developed animal shown in Figure 4. Contemporary level of microelectronics allows implementing such a scheme. In the initial state, prior to the operation of the device with such a scheme, a number of connections must be established in the device; these connections must be analogous to the connections in the brain of animals, which represents unconditioned reflexes. These unconditioned reflexes are genetically conditioned; they are formed because of the evolutionary experience of this population. Based on these genetically conditioned reflexes (initial reactions) further accumulation of individual experience occurs (formation of a set of individual conditioned reflexes of the given organism).

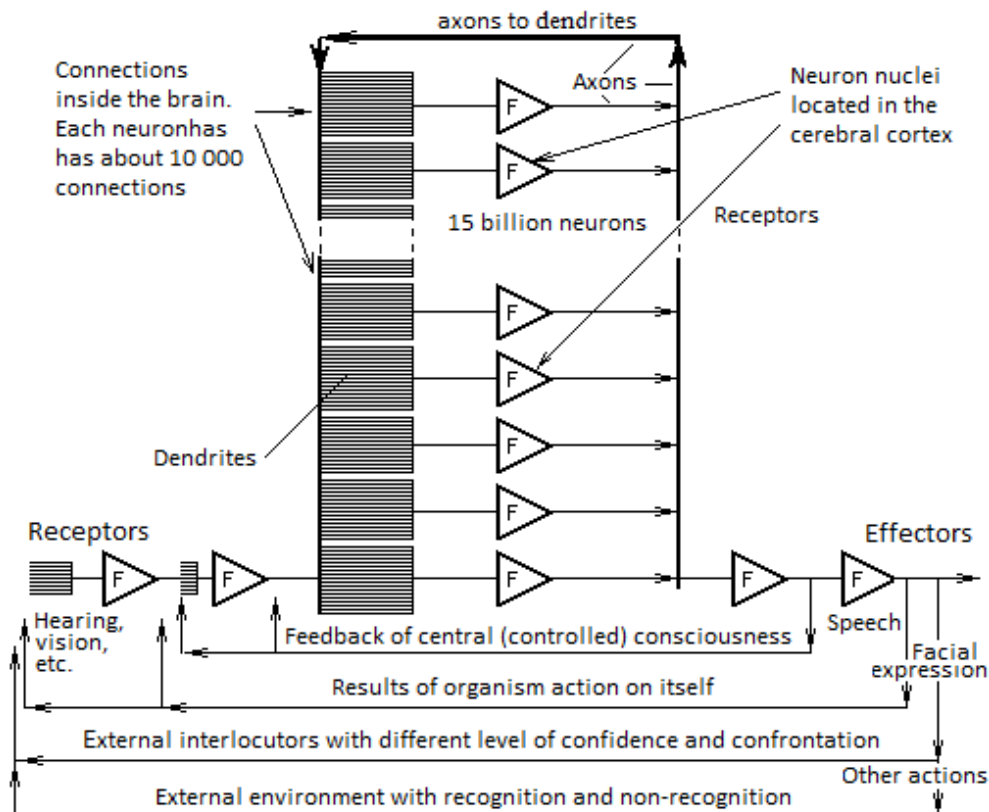


Figure 4. Electric scheme of the brain.

Accumulation of reflexes is a process of constant training and retraining with participation of a mechanism of global “inhibition”. The process of constant training and retraining is formed based on the properties of the local mechanism of remembering, forgetting (formation and properties of bonds), and tiredness of neurons (active elements of retransmission of receptor responses to stimuli). Formation of conditioned reflexes in the device as well as in biological objects will occur more effectively because of training the same way as it occurs with children of various animals from the simplest to the highest ones. Therefore, in a full-scale device with the presented scheme of connections (existing and potential ones), an educated intellect can be brought up.

From the point of view of creation of devices with the presented scheme of connections between active elements - formers F, formation of reflexes is formation of chains of connections between formers (neurons, NE). Reflexes provide passage of signals from receptors to actuators (effectors) when receptors are influenced by stimuli (environmental influences) through connecting (intercalary) structures of the brain. Locality of mechanisms of brain functioning and their distribution throughout the brain volume provides parallel asynchronous modification of brain structures with a huge speed, which cannot yet be provided in sequential software and hardware complexes.

In our work, we give logical arguments. In addition to arguments about the principles of the nervous systems functioning, these principles were tested by highly qualified specialists, were protected by the patent of the Russian Federation [6], and were published and presented at various conferences [10–13]. However, most important is that these principles are confirmed in practice: we created a device - an electronic model of the simplest nervous system consisting of three neural-like elements, which has demonstrated the ability to be trained and retrained in accordance with the above-described arguments [9]. Currently, in partnership with biologists from Tomsk State University, we are trying to confirm the efficiency of the proposed principles of the NS functioning for the living biological objects.

7 Conclusion

The arguments presented in this paper demonstrate the wide possibilities of the purely local mechanism for functioning of the nervous system structures both of the simplest animals and the human brain. We can see their evolutionary connection. Realization of these principles, which formed the basis for self-organization of mechanisms of training, retraining, and thinking in natural organisms, can provide creation of artificial intellect carriers with a large number of active elements, in which an intellect equal to the human one (or even superior) can be brought up. In this situation, there is a potential danger of antagonistic competition for resources between man-made artificial devices and humans. Therefore, in order to avoid antagonism, it is necessary to create devices that will not antagonistically compete with humans, but will coexist in symbiosis and with mutual benefit.

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