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Neuronal Cells Spontaneous Activity is One of the Key Functional Aspects of Brain Information Processing: Neurosurgical Case Analysis

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ABSTRACT

The article examines the role of the spontaneous activity of neurons, and therefore, of brain neural networks, in information processing. Analysis of the spontaneous activity of neural networks is based on data obtained during neurosurgical operations conducted by W. Penfield. The case of frequentative electrode stimulation of the human brain temporal cortex and the patient simultaneous interview were analyzed. Such a survey revealed that the irritation of a specific localization caused the actualization in a person memory of an episode of her past according to this localization. The analysis of the spontaneous activity of neural networks of the brain is based on comparing the conditions of conducting this experiment, in which the actualization of long-term memory occurs artificially that is, with the help of electrode stimulation of the corresponding neural networks (and therefore guaranteed not spontaneously), with the conditions for actualizing long-term memory during the natural processing information in neural networks of the brain.

This analysis made it possible to form a hypothesis and draw conclusions that, first, the spontaneous activity of neurons and neural networks of the brain is an indispensable condition for the actualization of long-term memory so that it is involved in the regulation of expedient human behavior, and, second, the phenomenon of spontaneous activity of neurons proved the impossibility of processing information in the brain without the participation of mental phenomena, at least representations that actualize personal experience (information) for further use.

Keywords: Spontaneity of Neuronal Networks, Neurosurgical Operation, “Shift” of Information from the Past to the Present by Mean of Spontaneity, Memory Fragments Actualization, Mental Representations, General (Holistic) Brain Information Activity.

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INTRODUCTION

The collective bioelectrical activity of the brain recorded by the EEG is characterized by the fact that it is formed mainly based on the spontaneous activity of neuronal cells, that is, the activity that, in contrast to the induced bioelectrical activity, cannot be explained by external physical effects of the environment on the brain [1,2] in the "now" moment. In this regard, the study aim to answer how, due to the spontaneous activity of neuronal cells, and thereby due to the spontaneous activity of corresponding neural networks of the brain, information stored in them for a long time is actualized. (The ability of living beings to actualize long-term information and use it for regulating their behavior is fundamentally necessary for the general (holistic) information activity of the brain.) In addition, here we will formulate a hypothesis about how the phenomenon of spontaneity can, through the hierarchical management-controlled relations of neural networks of different brain structures among themselves, ensure the biological and/or social expediency of general information activity in it [3-6].

SEARCH METHODOLOGY

Solving this problem requires considering the critical importance of two facts, the first of which is one of the postulates of information science. It claims that any information has its own "carrier," that is, some structure in which relevant information can be fixed (encoded). Neural networks of the brain as well, along with any informational devices and biologically functioning systems, implement this principle [7]. In our case, the "carriers" of information in the functioning of the brain are the neural networks themselves, which, depending on their spatial structure, temporal parameters of their activity, and on belonging to specific brain structures, can record (encode) relevant information that can be remembered during life by a living being.

CASE DESCRIPTION

The second of the aforementioned two facts, from which we have to start in order to point out the fundamental role of the phenomenon of spontaneity in the informational activity of the brain, is a fact that, in the middle of the last century, became known from the clinical practice of the Canadian neurosurgeon W. Penfield [8,9][1]. During brain surgery for epileptic seizures, Penfield discovered the following. He irritated a group of neurons in the temporal cortex, which is responsible for recording the experience accumulated by a person. Then, to the question "what do you feel now", the person answers this question (such a dialogue is possible due to the absence of pain receptors in the nervous tissue). In the context of modern knowledge about the brain, the answer can explain how accumulated experience is actualized and can be applied. Here it should be taken into account that the operated person, focusing on what he feels ("sees"), forms his speech activity. The operated person, depending on the localization of the irritating electrode in cortical fields 20 and 21 (according to Brodman), "sees" (restores in memory) an episode of her (his) past life in the form of representations (dynamically changing mental images) and can describe it in detail.

For example, one of Penfield's patients described, down to minor details, the episode of her first meeting with her father after his return from the Second World War [8,9] , which took place several decades before the moment of this brain operation. Moreover, if the electrode was held in a given area of the cortex for a long enough time, irritating the same cells, then this dynamic of mental representations (mental images) was constantly interrupted at the same place of the episode and later repeated from the same place. This phenomenon indicated that the information about the past represented in this episode (sequences of mental images changing over time) was recorded precisely in the structure of neural networks of the brain, the elements of which were those nerve cells stimulated by the electrode. Here we can state that thanks to such "artificial" activity of these neural networks, there is a certain "shift" of information from the past to the present in order to use this information to regulate behavior (to answering the question). Another preliminary conclusion from this surgical practice should be that the bioelectric activity of neural networks of the brain, which fix in their structure the experience accumulated during life, is a direct physical factor that "reads" information from neural networks through mental representations.

DISCUSSION

Now we can conduct a more thorough analysis of this neuropsychological fact within a broader context that takes into account the "artificiality" and lack of biological (or social) expediency [3-6,10] of the actualization of the described episode in the conditions of the operation. Indeed, in natural conditions, a person usually restores in her memory primarily what is directly related to the solution of her immediate or long-term life problems, which have biological (or social) expediency within the framework of

[1]Due to the war in Ukraine and the impossibility of using his archives, the author in this reference cannot indicate the pages and provide the relevant quote from the books of W. Penfield and others, translated into Russian, with the patient's explicit statements. The author is unsure which of the two specified books contains the described fragment. However, this episode was most likely described in both sources indicated here.

her subjective values [3-5,10]. At the same time, "artificial" stimulation of the brain in this experiment actualizes a memory fragment, which is not significant for the patient to solve her immediate or long-term problems. In addition, we must also consider the indisputable fact that the information here is presented to the operated person in the dynamics of mental representations (images).

Further, our last closing conclusion from this experiment is as follows: it is unlikely that the patient could reasonably answer the psychologist's questions during the operation if a sequence of mental representations (images) had not been formed in her brain due to the "artificial" excitation of the corresponding neural network, which allowed her to restore in her memory ("see") an episode from her past. In this case, she would not have that informational context that did not unexpectedly and arbitrarily appear "before her" during the operation and which allowed her to answer the question "with knowledge of the matter." In other words, she would not be able to skillfully orchestrate the muscles of her tongue and larynx to answer the question if she did not "see" the contents of the dynamics of the representations in which information about her past was presented to her. Furthermore, here we must consider that such an informational process of behavior regulation based on experience obviously cannot occur without the mediation of mental phenomena, at least mental images.

Below, we will consider the role of spontaneous activity of neural networks implementing the function of long-term memory within the framework of the above-described experiment and its interpretation. For this, we will need to again compare the actualization of memory in the "artificial" conditions of the described experiment with how it normally occurs during informational activity in the brain. However, first, let us point out the crucial point of how the phenomenon of spontaneous activity of neural networks can occur in the brain's neuronal cells. Without going into details, let us recall that for a spontaneous activity to occur in neural networks of the brain, it is necessary that the relevant neurons in them accumulate energy through the mediation of known biochemical mechanisms [11] and then spontaneously discharge it during bioelectric activity. Further, suppose that neural networks functioning as "carriers" of information are spontaneously excited in the brain (either by themselves or due to the spontaneity of other neural networks). In that case, according to the Penfield experiment, this bioelectrical excitation should actualize the information fixed in them in the form of the dynamics of mental representations and thereby ensure its application for regulating the corresponding motor acts.

Thus, this spontaneous activity of the neural "carrier" of information forms a person's ability to "see" an episode from her past in the present. Moreover, it does not matter whether this spontaneity will be realized by the neural network that is the "carrier" of this experience or by other neural networks of the brain that were able to initiate spontaneous activity and thereby actualize the information fixed in another neural network that is its "carrier." (In Penfield's experiment, the "carrier" of information was excited by an object external to the brain, namely, an electrode).

Further on, we should be interested not only in the actualization of past experience in the present but also in the context of this actualization of information about the past, which should accompany any actualization of information in the conditions of the natural functioning of the brain. The need to actualize information is usually formed when a person needs to use a particular experience fixed in his brain (patient W. Penfield did not have such a need during her stay on the operating table). In this case, we can now assume that the actualization of information currently necessary for a person and fixed in a certain "neuron carrier" can be carried out through the mediation of other neural networks. These networks, for example, might belong to neural structures of the brain which can more effectively implement spontaneous activity and, at the same time, implement other informational functions related to the ability to evaluate the biological (or social) significance of information [3,5], including evaluation of fragments of personal experience.

Obviously, such neuronal structures of the brain should not only be more capable of spontaneous activity but also implement, in connection with this spontaneity, the function of memory management and, in general, the information process in the brain. Such spontaneous (intra-cerebral) triggers of actualization of expedient information in the brain during the information process can be neural networks of brain structures, which, one way or another, according to their functional potential, are related to the evaluation and selection of information necessary for solving problems. First of all, such brain cortical structures include the frontal cortex, the cingulated cortex, and the insula [12]. Among the subcortical structures, we can mention the hypothalamus, the amygdala, and some large nuclei, in particular, the adjacent nucleus, which are related to the realization of mental phenomena that have an evaluative function, such as feeling pain, experiencing pleasure or displeasure, fear, rage, etc. In our works [3,5,10], these brain structures received the status of management since, in our opinion, they are related to the realization of the ability of living beings (including humans) to subjectively evaluate the biological or the social significance of information and decision-making, which indicates their managerial function. The ability for subjective evaluation can be realized in the brain through the already listed emotional manifestations, such as fear, the experience of pleasure or displeasure, disgust, and even aesthetic or ethical evaluations.

Now, taking into account the analysis of the clinical case carried out here, we will form a hypothesis that could explain the phenomenon of the spontaneity of neurons and the neural networks formed by them within the general informational activity of the brain. When actualizing long-term memory in natural conditions, the brain's neural networks that record information in their structure, should be optimally excited to prepare the information fixed in them for use. In other words, the bioelectric impulse is, as in the above experiment by W. Penfield, a factor of "reading" of the information encoded in the neural network, which includes the information that is "read" (actualized) to the general informational context that occurs in the brain. However, if, as a part of the experiment, this actualization was caused by the "artificial" irritation of the electrode from the outside, not only of the brain but also of the entire body, then in the conditions of the natural informational activity of the brain, such a reason is probably the spontaneous activity of neural networks of other brain structures, which, producing their spontaneous activity, "force" neural networks, which are "carriers" of information, to also perform a spontaneous activity together with them. Such managing neural networks should spontaneously actualize expedient information within the framework of the general information process currently taking place in the whole brain.

This hypothesis about at least one of the manifestations of the phenomenon of the spontaneity of neural networks of the brain during information processing, which ensures the information process through the actualization of information, is also indirectly confirmed by the following idea about the functional properties of neural networks of the brain. If we resort to the analysis of the activity of the most primitive neural networks of the brain, namely, those that can be called stimulus-reactive (or unconditioned reflex) networks, then it should be "obvious" to us that their informational activity, based on their functional opportunities, does not need spontaneity. (Here we can note that certain biochemical processes can internally only strengthen the external stimulus-reactive response trigger). Furthermore, they skillfully implement their function of transmitting information (signal) from the sensory input to the corresponding motor output through a bioelectric potassium-sodium "standing wave."

The functional primitivism of such neural networks lies in the fact that they cannot accumulate new experiences during their lifetime, so they "use the services" of genetic experience only, being formed on its basis [3]. They are also unable to integrate (in the sense of G. Tononi's Integrated Information Theory [13] this experience, genetically fixed in their structure, with other information fixed in other stimulus-reactive neural networks, no matter how complex their neural network structure may be. So, their generalized evolutionary "disadvantage" is that these neural networks cannot form new and biologically expedient motor acts in response to new external stimuli at their "motor end." However, the main thing we must consider here is that they do not have to be spontaneous, as they function skillfully in response to routine "genetically programmed" stimuli, being activated exclusively from outside a local neuronal informational stimulus-reactive system.

At the same time, "mentally active neural networks" [3], with which we are dealing in the described above experiment by W. Penfield, in contrast to stimulus-reactive neural networks, are able, precisely due to spontaneity, to accumulate experience and use it in the orchestration of the muscular activity of a living being. This ability allows "mentally active" living beings (and most successfully humans) to form biologically or socially expedient behavior in response to external novelty in a probabilistic environment.

CONCLUSIONS

The hypothesis formed here, explaining the phenomenon of spontaneous activity of neurons and the neural networks formed from them within the framework of the general informational activity of the brain, implies if it is confirmed, the following conclusions:

1. Spontaneous activity of neural networks of the brain, as a physiological phenomenon, is functionally related to the purely informational phenomenon of access to information, long-term fixed in the corresponding cortical neural networks, to the possibility of its evaluation, processing, and application in regulating the behavior of living beings that have a mentally (psychically) functioning brain.
2. Another significant conclusion from the analysis of the experiment described here by W. Penfield is that, probably, during the processing of information in the neural networks of the brain, mental (psychic) phenomena play a much broader functional role than it could be predicted based on the analysis of the indicated the experiment of W. Penfield and what was pointed out here in point 1 of these conclusions (such a broader functionality of mental phenomena during information processing in the brain is described in detail in works [3,6,10].

DECLARATION OF CONFLICT OF INTERESTS

There is no conflict of interest due to the presence of only one author of the article.

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