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POLARIZATION PROCESSES IN THE NERVOUS SYSTEM AND BEHAVIOR

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The effect of visual cortex polarization with direct current on differentiation of lighting has been studied in rats by the conventional reflex method. The cathode and anode were shown to produce an opposite effect on distinguishing visual stimuli. The anode polarization of the visual cortex improved differentiation of lighting and the cathode one, on the contrary, deteriorated it. The results obtained are considered in light of the role of polarization processes in organization of adaptive behavior. In particular, the idea is advanced that the membrane potential level is a measure of importance of information for the cells. It is a basis for the neurophysiological mechanism for motivational-emotional behavior considered in the paper.

Keywords: Emotions; motivation; excitability; neuron polarization

The mechanism of perceptive processes in the central nervous system is classically related to convergence and divergence of nerve impulses and formation of specific mosaic of neuron ensembles (Keidel, 1975; Szentagothai and Arbib, 1976; Kogan, 1979; Batuev, 1981). It can be a basis for building particular conceptual models of the activity of the nervous system involved in processing of information, like perceptrone, based on discrete, impulse code (Rozenblatt, 1965; Kratin, 1982; Sokolov and Vaitkavichus, 1989). However, such approach can not be used to build a model of the importance part of information, its semantics for the neuron and the organism as a whole (Kogan, 1979), and hence, it is impossible to understand the mechanism of purposeful behavior.

A number of researcher have long focused attention on the existence of slow electric processes in the nervous system and their possible role in information processes (Vvedensky, 1901; Ukhtomsky, 1966). In particular, dendrite potentials as well as slow changes in membrane potential of the neuron soma can be classified with these phenomena.

Such phenomenon as the Vvedensky parabiosis (Vvedensky, 1901) being a stationary excitement by its nature is well known. The Vvedensky parabiosis is considered to be a possible mechanism of inhibition in the central nerve system, the basis of which is persistent depolarization of the cell membrane.

Another phenomenon, the Ukhtomsky dominant (Ukhtomsky, 1966) is a zone (neuron system) of enhanced excitability. Sudakov (1987) considers that this very dominant is the basis of the mechanism of motivation. The Rusinov-polarization dominant (Rusinov, 1969) formed by low direct anode current is an experimental model of the Ukhtomsky dominant. Its neuron mechanism is presumably related to prolonged hyperpolarization of the membrane and exaltation of excitability of the nerve tissue located below the anode.

It is the study of the role of slow electric processes in the nerve cells during different psychic acts that can be crucial, in our opinion, for understanding the mechanisms of adaptive purposeful behavior. In particular, polarization processes in the nerve tissue are likely to play a fundamental role in the neurophysiological process of emotional states (Murik, 1995, 1997). According to the polarization theory advanced in the paper, emotions are a subjective reflection of a degree of polarization of neurons involved in processing of information generating emotions. Such approach makes it possible to abandon an unpromising search for a specific center of emotions and to relate them to polarization processes in mono and polymodal analyzers.

For instance, the emotion of fear arising during analysis of visual or auditory stimulus and associated with impossibility to recognize it may reflect the initial formation in the sensor systems mentioned of the depolarization zone followed by a decrease in excitability of the neurons composing it. This zone will further expand into associative systems.

A decrease in neuron excitability of this zone will be subjectively reflected as a negative emotion, on the one hand (Murik, 1997), and will apparently hamper further processing of information by these neurons, on the other hand, which should generally decrease adaptive functions of the organism, and which, in our opinion, can be an important part of information processing.

Concerning the first suggestion, it has been shown (Murik, 1994, 1995, 1997) that artificial depolarization of the auditory cortex by the direct current cathode increases, a negative emotion of "fear" in the "open field" test. Direct or indirect indications on particular relation between emotions and polarization processes can be also found in other papers (Sawyer and Kawakami, 1959; Clemente *et al.*, 1964; Buchwald *et al.*, 1967; Avramov and Smirnov, 1968; Smirnov and Speransky, 1972).

The second assumption, on the effect of polarization phenomena on information processes, has given an impetus to perform an experimental part of the present paper, the aim of which was to study the effect of artificial polarization of sensor neurons on their processing of information. Specifically, we examined the differentiation of lighting of visual stimuli by rats with simultaneous polarization of the visual cortex by direct current anode and cathode.

METHODS

The experiments were performed with nonpedigreed albino male rats ($n = 8$). The training for differentiation of lighting was performed in an experimental chamber (Fig. 1). The experimental device was a right-angled box separated by a moving barrier (3) into starting (1) and working sections (2). The working section had two doors (4), opening of which by the rats gave them an excess to feed boxes (5). The doors were made of frosted glass and served simultaneously as screens into which differentiated stimuli were projected. More brightly illuminated door-screen was a positive conditioned stimulus. Seven-fold less illuminated door was a differentiated negative

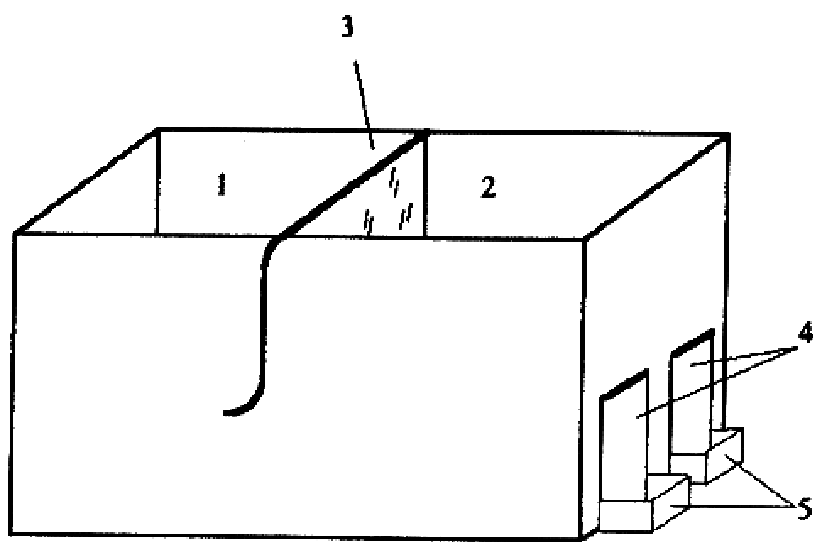

FIGURE 1 The scheme of the experimental device for formation of differentiation of lighting in rats. 1. a starting section; 2. a working section; 3. a moving barrier, 4. doors-screens, 5. feed boxes.

conditioned stimulus. Positive and negative conditioned stimuli were projected simultaneously and the sequence of their projection on right and left doors varied at random.

The scheme of experiments for training the rats to differentiate 7-fold difference in lighting of visual stimuli was the following. A hungry rat was placed in the starting section. Light stimuli were projected on the door-screens with a slide projector. The barrier separating the starting and working sections was removed. The rat should approach the more illuminated door, after which it can open it (by the head) and have some refreshment from the feed box. The runs to the less illuminated door and the attempts to open it failed to be refreshed. The stimuli were projected 40 – 50 times during a single experiment. The differentiation of lighting was considered to be accomplished if the rat made no less than 75% of correct runs during three successive experiments.

After formation of the criteria of differentiation and strengthening of the reflex the rats narcotized by nembutal were implanted by silver plate electrodes bilaterally under the skull bones above the visual cortex according to the Woolsey map (Woolsey, 1958, 1960). The total area of electrodes implanted above the cortex was 40 mm^2, which amounted to 82% of the visual cortex. The second electrode with a working surface of 40 mm^2 was implanted under the skin in the back. The tappings were fixed to the skull bones with self-hardened plastic.

In two days after the operation the rats were used in the experiments of differentiation of seven-fold difference in lighting of visual stimuli. The retention of the reflex was tested in the first experimental day. Next days the experiments on differentiation of lighting were performed in each rat with simultaneous polarization of the visual cortex by anode or cathode of direct current of 7 $\mu A/mm^2$. There were two day intervals between polarization of the visual cortex by current of different polarity. The sequence of polarization varied in different rats.

The results were statistically analyzed using the criteria of *t* and Wilcoxson.

RESULTS

The criteria of formation of the reflex was attained by the rats after 12 – 16 experimental days. When the reflex was strengthened, the percentage of correct responses averaged to 77.9-:-0.63.

Figure 2 shows the effect of polarization of the visual cortex with direct current on differentiation of the 7-fold difference in lighting of visual stimuli. It can be seen that the cathode polarization decreased the percentage of correct responses (Fig. 2A, $p < 0.001$) and moreover, the differentiation dropped below 75% level, a criteria of the reflex formation. The general moving activity of the rats remained in this case. It can indicate that with the cathode polarization the rats actually ceased to distinguish the lighting of the stimuli.

The polarization of the visual cortex with the direct current anode in the same rats resulted, on the contrary, in improving the differentiation of lighting as compared to the norm (Fig. 2B, $p < 0.01$). Correct responses amounted almost to 100%.

Thus, a distinct difference was observed in the effect of anode and cathode polarization of the visual cortex on the differentiation of lighting by the rats. During the cathode polarization of the visual cortex they could not distinguish a 7-fold difference in lighting of visual stimuli, while during the anode effect the differentiation of stimuli was found to improve.

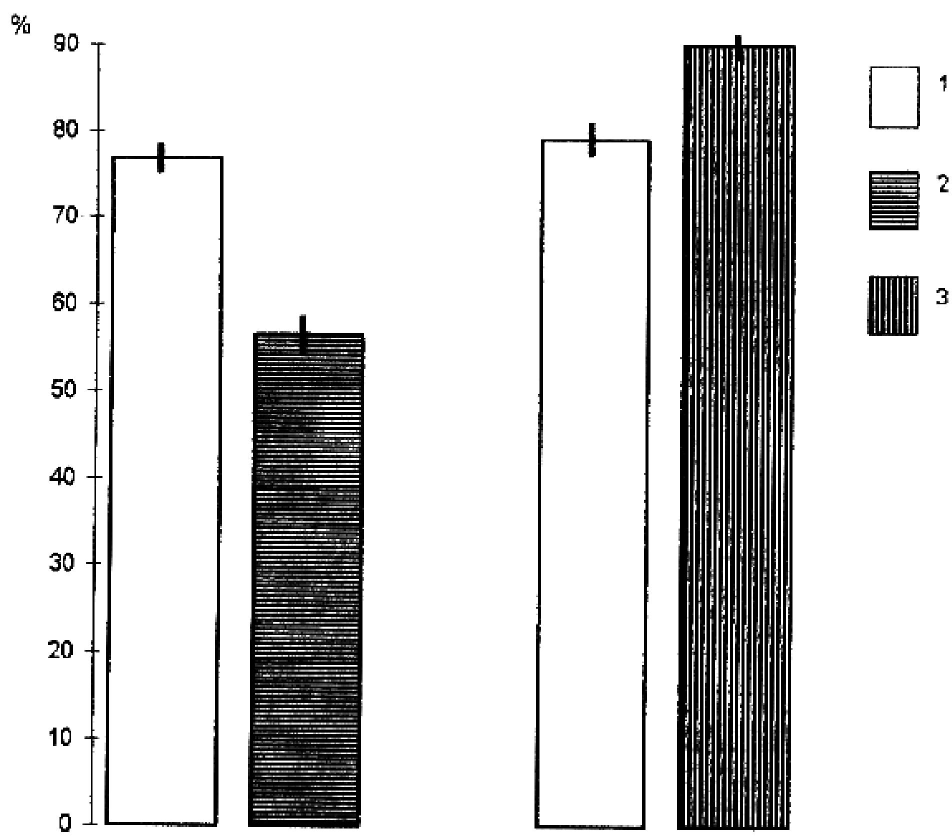

FIGURE 2 The effect of polarization of the visual cortex with direct current on differentiation of lighting in rats. 1. norm; 2. cathode effect; 3. anode effect.

A repeated testing of the same rats but with opposite sequence of anode and cathode polarization of the visual cortex provided similar results. In all rats the cathode polarization deteriorated visual differentiation, while the anode polarization, on the contrary, improved distinguishing the stimuli.

DISCUSSION

It is known (Khodorov, 1969) that prolonged (more than 10 mc) cathode depolarization of the membrane of the nerve cells decreases their excitability, while prolonged anode hyperpolarization increases it. In our experiment an artificial depolarization of neurons of the most part (82%) of the visual cortex and an apparent decrease in their excitability correlated with a decline in distinguishing lighting of the visual stimuli. However, prolonged hyperpolarization of visual neurons and a resulting increase of their excitability, on the contrary, improved visual analysis.

Thus, the results obtained indicate the importance of the membrane potential level in perceptive processes of information processing. Moreover, depolarization and hyperpolarization of the sensor neuron membrane produced an opposite effect on information processing: prolonged depolarization deteriorated analytic-synthetic processes and hyperpolarization improved them.

The appearance of the groups of depolarized neurons is thought to be possible in sensor systems under native conditions due to their "over-excitement" for instance, because of impossibility to recognize a stimulus or to make an adequate decision. Prolonged depolarization and a decrease in excitability of the neuron systems are presumably "undesirable" as they were shown to reduce efficiency of perceptive processes and to decrease finally adaptive abilities of an organism. Therefore, it is the change of excitability under the effect of sensor fluxes which can be considered to be a basis for the importance part of information for the nerve cell and the whole organism.

The effects resulting in rather long membrane depolarization are "undesirable" for any living cell, as it indicates disturbances in discriminating membrane permeability, which can finally result in its death. From this point of view, the nerve cells are those specializing during evolution in assessing quality of stimuli according to the change in the membrane potential level.

Different-directed changes in excitability depending on the biological sign of the refreshing stimulus has been reported by Davydova (1986). It was shown that in the same motor cortex point, the excitability increased under the effect of the positive support and decreased under the effect of the negative one.

The main mechanism of assessment of the quality of stimulus by the living cells is, in our opinion, the change in the membrane potential. The cells should avoid stimuli causing their rather long depolarization, since it can result in their death. With the appearance of multicellular organisms, a part of the cells is likely to specialize in determination of stimuli quality according to this principle and in organization depending on this quality of adaptive behavior eliminating the effect of the "nondesirable factor".

The depolarization of the sensor neurons followed by a decline in their excitability can be a neurophysiological basis of motivation and motivated behavior. The depolarization of the nerve cells and the reduction in their excitability are subjectively reflected as a negative emotion (Murik, 1995, 1997). In such case the neurophysiological mechanisms of motivation and negative emotions are closely related. Positive emotions appear to reflect the processes of elimination of the motivation zone (restoration of the resting potential of neurons and their excitability), as well as the processes associated with hyperpolarization of the membrane and the increase in its excitability. Kozhedub (1992, 1993) also believes that the mechanism of the change of cellular excitability is used in motivation-emotional processes.

Thus, motivation and emotionality are fundamental properties of all living systems begining from one-celled organisms and are built in particular structural-functional organization of the cellular membrane, i.e., to avoid stimuli disturbing its integrity.

We can state with certain assurance that any cell is emotional and especially the nerve cell. If the neuron being in the state of prolonged depolarization could express its feelings, it would be the sense of horror of approaching death.

The performed investigation of the artificial polarization of the cortex neurons not only supports an idea proposed on an important role of slow polarization processes in a number of psychic acts (Vvendensky, 1901; Ukhtomsky, 1966; Sudakov, 1987; Kozhedub, 1992, 1993) but provides an opportunity to take a new look at the problem. Thus, the processes similar to Vvedensky parabiosis associated with formation of the persistent depolarization zone are more appropriate as the neurophysiological mechanism of motivation than the Ukhtomsky dominant, which according to Rusinov (1969) is by its mechanism a system of hyperpolarizated neurons. The Ukhtomsky dominant most likely can correspond to the process of meeting the demand coloured in positive tones than the formation of motivation.

Further study of slow polarization processes in the nerve tissue during adaptive behavior is believed to be helpful in understanding the essence of the importance part of information both for the central nervous system of the organism as a whole and for a single cell in particular.

CONCLUSIONS

1) The polarization of the visual cortex of rats by direct current affects the differentiation of lighting by the rats, anode and cathode producing opposite actions.
2) Cathode polarization of the visual cortex deteriorates distinguishing lighting of visual stimuli, while the anode effect, on the contrary, improves it.
3) On the basis of our own and reported data an assumption is proposed that the level of the membrane potential can be a measure of the importance part of information of the stimulus for the cell. Living organism beginning from one-celled organisms should avoid stimuli causing rather long depolarization of the cellular membrane as it can eventually result in their death because of disturbances in membrane selecting permeability. This "striving" is thought to be the basis for formation of motivated behavior in multicellular organisms during evolution. The appearance in the central nerve system of the area of depolarized neurons is the neurophysiological bases of this behavior.

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