საქართველოს მეცნიერებათა ეროვნული აკადემიის მოამბე, ტ. 18, №2, 2024
BULLETIN OF THE GEORGIAN NATIONAL ACADEMY OF SCIENCES, vol. 18, no. 2, 2024

Human and Animal Physiology

Effect of 5G Electromagnetic Field on the Neuron Informative Activity

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(Presented by Academy Member Teimuraz Naneishvili)

The paper presents the impact of the 2.4 GHz electromagnetic field on a single neuron. It is established that exposure to the electromagnetic field of this frequency on a single neuron leads to a reduction in the amount of information contained in action potential parameters about habituation. Thus, the neuron's informational activity capabilities deteriorate. An individual neuron responds with action potentials to repeated intracellular stimulation with current pulses. After a certain amount of stimulation, the neuron stops responding with action potentials. This phenomenon is known as habituation. As a result of repeated delivering a stimulus, the parameters of the action potential change. In particular, the width of the action potential expands, the rise and fall times of this potential increase, and the latency time of the emergence of the action potential increases. Steady rising trend in these values was observed. The question arises if these parameters contain information about habituation. If so, whether there is a difference in the behavior of these information quantities in the EMF-irradiated and control neurons. The research has demonstrated that action potential parameters, contain information about habituation. The amount of this information for each action potential was calculated (measured) and the corresponding graphs were processed for both the neurons irradiated with the electromagnetic field and the control neurons. The difference between the dynamics of these two information quantities is obvious. It is concluded that the impact of the 2.4 GHz electromagnetic field of the 5G on a single neuron leads to a rapid decrease in the ability of neuron to receive and process information. *© 2024 Bull. Georg. Natl. Acad. Sci.*

neuron, action potential parameters, information processing, electromagnetic field

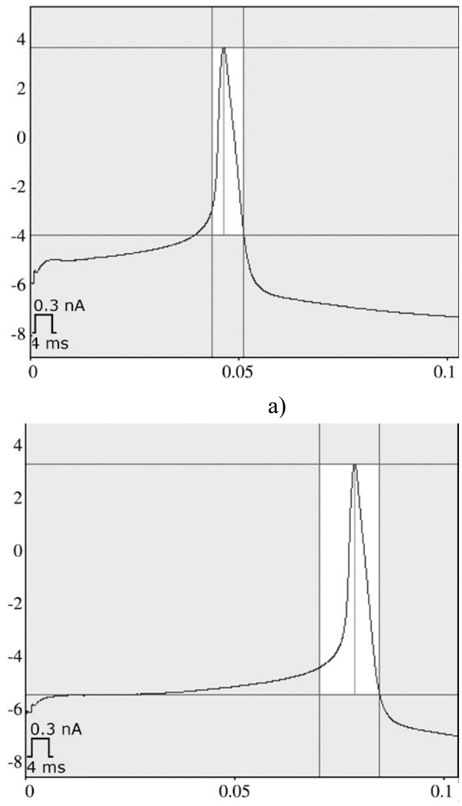
Neurons communicate and encode information through action potentials (AP). In [1], it is shown that various AP waveforms produced in a single cortical neuron under dynamical stimulation may carry information about synaptic input. A constant current step injection into neuron results in several APs with various forms. AP frequency and AP widening are correlated with intracellular current [2-4]. When the neuron habituates to the injected current, it finally stops firing AP. In our earlier research, we studied how AP parameters changed in response to repetitive intracellular stimulation and explored the possibility that AP parameters play a role in information processing [5]. In the current study, we answer the question if there is a difference in the behavior of the amount of information contained in AP parameters about habituation to stimulation to recurrent intracellular impulses for neurons exposed to an electromagnetic field and for control neurons.

Methods

The isolated nervous system of the mollusk Helix Pomatia was used in the experiments. The microelectrode method was employed. The method is described in detail in [6]. Isolated ganglion with neurons was exposed to 2.4 GHz electromagnetic field (EMF) in the TEM Cell in order to investigate the effects of EMF on neurons. Detailed exposure method and dosimetry are provided in [7]. At the beginning of every recording, the intracellular stimulant impulse threshold value was determined, and the neuron was stimulated with a slightly higher stimulus than the threshold. This caused firing of 1 AP on one stimulus. The width of these impulses was 4 ms each. Frequency of stimulation was 1 Hz. We measured the following parameters of AP: latent period, width of the AP at the level of 20% (W20) from the baseline (resting potential); time between two giving levels of the AP (10% and 90% from the baseline) on the leading edge of AP (Tr) and *area* under AP (*area*). For exposed and control neurons, all these variables were measured for each AP. As a result, for every experiment, packages of measured numbers were obtained. The package contained data of: latent periods, W20s, Tr and *areas*. Measurements were performed using software peak parameters extension of the software Chart 5.5 (AdInstrumenrs Australia).

Results

At the beginning of every recording, the intracellular stimulant impulse (ISI) threshold value was determined. Upon stimulation, the neuron generated a single AP on one stimulus. Neuron responded to ISI with APs for a while before being habituated. For EMF-exposed neurons, the average time of habituation was more than 3 minutes, while for control neurons, it was about 1.5 minutes. The habituation time is considered as the time interval between the first AP and the last AP, after which the neuron no longer generates APs on stimulation. We study 32 neurons in each series experiment (a total of 64). The results showed that the AP parameters were not constant. As the ordinal of stimuli grew, correspondingly increased the W20 and other AP parameters. Both exposed neurons and control neurons showed one and the same effect. Figure 1 provides an example of this, showing two APs for a single neuron, each with a different AP parameters.



b)

Fig. 1. Changes in AP parameters due to different stimulus ordinal: a) AP is a response on the 1st stimulus. Parameters are: latent period=17ms; W20=4.1ms, Tr=0.92 ms; *area*=0.106 V.s. b) AP is a response on the 15th stimulus. Parameters are: latent period=39,9 ms; W20=8,1 ms; Tr=1.56 ms; *are a*=0.135 V.s. Stimulant intracellular impulses are schematically shown in the left corner. The width of this impulse is 4 msc. AP are copied directly from the Chart 5 software. Thereby, the Y-axis corresponds to volts. The amplified amplitude of AP can be evaluated on the Y-axis.

Over the course of the repeated intracellular stimulation, the parameters of AP fluctuated irregularly, but they had increasing trend. This dependence was seen in both experimental series: the exposed and the control. Fig. 2a depicts the dependency of the AP width on the ordinal of stimuli for control neuron and Fig. 2b shows the same dependence for EMF-exposed neuron. In both instances, an increasing trend in AP width was seen. Other AP parameters showed a similar dependency on the ordinal of stimuli and similar kinds of trends on the corresponding graphics of dependences, thereby not shown here.

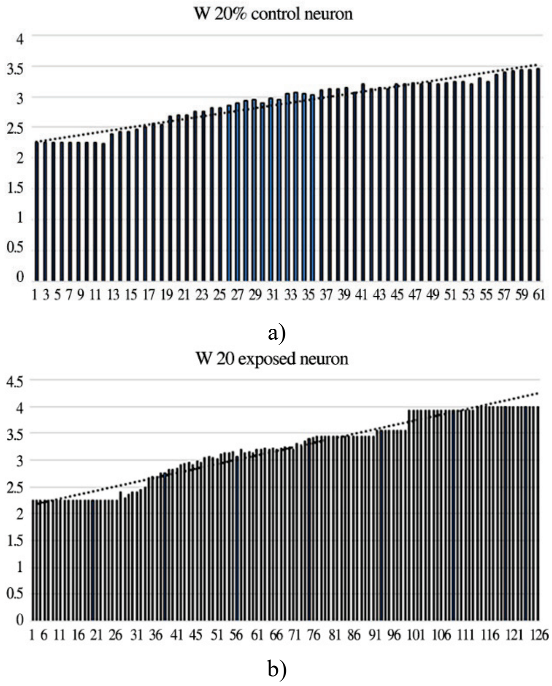


Fig. 2. AP width (W20) dependence on the stimulus ordinal for the control neuron (a) and the EMF exposed neuron (b). A trend of increasing is evident. The amplitude of the applied stimulus was 0.5 na, and the duration of each stimulus was 4 ms. On the X-axis is the plotted stimulus ordinal, and on the Y-axis is AP width in msec.

We calculated the amount of information about habituation contained in AP parameters (AIHCP). The meaning of AIHCP is given in [8]. It is established that AIHCP changes during the increase of the stimulus`s ordinal. Under the term “amount of information,” we imply the interpretation given in the information theory [9].

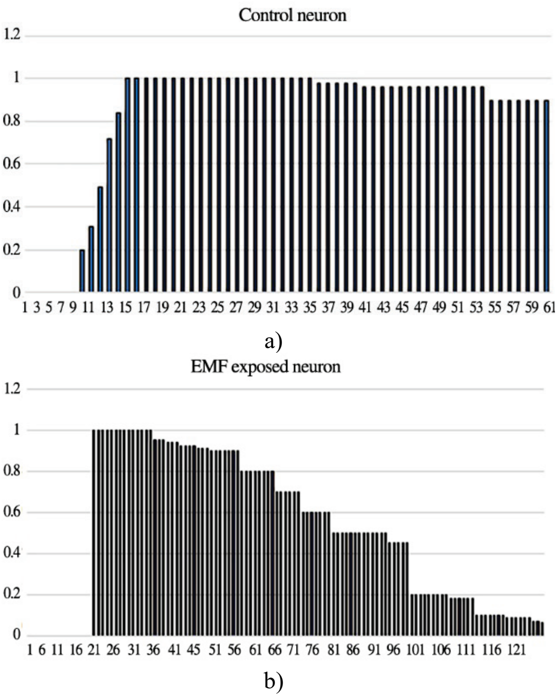


Fig. 3. Dependence of the amount of information about habituation contained in AP width (W20) on the stimulus ordinal of control (a) and exposed (b) neurons. We see that the information amount is equal to 0 up to the 14th stimulus for the control neuron, while value 0 continues up to the 22th stimulus for the EMF-exposed neuron. In the case of the control neuron, the maximum value of information (equal to 1) continues during the application of 21 stimuli, while for the EMF-exposed neuron, this amount was 14 stimuli. Besides, in the control case, the amount of information is above 0.8 for all the time until habituation. In contrast, the amount of information falls rapidly in the case of exposed neuron. On the X-axis are plotted the stimulus ordinals. Calculated values of the amount of information are plotted on the Y axis.

The stochastic mathematical model was selected. Consequently, sequences of AP parameters calculations (measurements) create a time series with a linear trend. The statistical time series with a linear trend represent a sufficiently good mathematical model for our purpose, as proved in [9]. The AIHCP was calculated on the basis of experiments both for exposed and control neurons for each AP separately. Calculation method is given in [8]. The dependence of the AIHCP on the ordinal of stimuli has a different form for control and exposed EMF neurons. Thereby, we obtained a series of numbers that correspond to the AIHCP that depends on the stimulus ordinal (for exposed and control neurons separately). The dependence of the amount of information about habituation contained in AP width (W20) on AP ordinal for control and exposed neurons is shown in Figs. 3a and 3b, respectively.

In order to get better understanding of the problem, let us first regard the example of AP width and thereafter apply it to all parameters. As is known [9], it is possible to calculate the amount of information contained in one random experiment relative to another random experiment. In our case, the first random experiment is the behavior of the AP width (as a random variable) with respect to its own trend. Let us use "α experiment" for determination of the variable location relatively to its own trend (above or below). Under the term "α experiment" we imply results of measurements of variables. Under term "variables," values of the W20 are implied. Let us use "β experiment" for process of establishing the habituation. Under term "β experiment" we imply determination whether habituation is established. $I(\alpha,\beta) = H(\beta) - H_\alpha(\beta)$ is the amount of information retained in the "α experiment" regarding "β experiment" [9].

Here $H(\beta)$ is entropy of the "β experiment" and $H_\alpha(\beta)$ is conditional entropy of the "β experiment" in relation with the "α experiment".

Now let us measure the ordinal of a stimulus on the X-axis. The amount of the information contained in the α experiment with respect to the β experiment (i.e. about habituation) is measured on the Y axis (see Figs. 3a and 3b). The time necessary for establishing the habituation was not constant and varied from neuron to neuron. For the times of habituation, we got a numerical sequence with 32 observed values both for control and exposed neurons separately. The time of habituation might be regarded as a random variable. The theoretical mean value (mathematical expectation) of this random variable is unknown. As we see in both cases (control and exposed), the amount of the information is a function with ascending, plateau, and descending parts. The results of the experiments showed that these functions are different for exposed and control neurons.

It is acknowledged that habituation is one type of learning [10,11]. The process of neuron habituation to a stimulus might be regarded as the processing of information at the single-neuron level. The type of stimulation that is described in this paper—namely, 1 Stimulus – 1 AP—could be thought of as the process of information transmitted to the neuron. Experiments revealed that the AP parameters are not constant and vary during stimulation. Based on the experiments, we calculated AIHCP, i.e. information amount in these variables both exposed neurons and for control neurons. Calculations were performed separately for all AP variables. Therefore, we obtained that from the start of stimulation to the seventh or tenth application of the stimulus, the amount of information about habituation contained in the AP parameters for control neurons is equal to zero. In contrast, the amount information about habituation in the AP parameters for exposed neurons is 0 from the beginning of stimulation until the twenty-third or twenty-sixth application of the stimulus. It means that in the control case, the neuron does not "recognize" the stimuli 7–10 as a signal that has to be "learned" (habituated), while the exposed neuron does not "recognize" the stimuli 23–26. The computed amount of information grows up to specific values quickly during recurrent stimulation following the 7–10 and 23–26 stimuli, respectively, to control and exposed neurons (see Figs. 3a and 3b). Then, as seen from these diagrams, some plateaus appear. This can be explained as follows: at this stage in the stimulation process, stimuli are not transferring "new" information to the neuron any more, hence we are not seeing any increase.

Experiments revealed that AP parameters are involved in the habituation process. The increasing trend of referred variables was confirmed with corresponding procedures of the hypotheses testing [5]. In general, the calculated amount of information is greater than zero for both control and exposed neurons. It is shown that certain amounts of information about habituation are contained in AP parameters (W20, Tr *area* and latent period). However, it is obvious that the behavior of these information quantities is different for control and EMF-exposed neurons. Particularly, the time for "learning" an exposed neuron is statistically greater than for control neurons. Thereby, it might be stated that exposure to 2.4 GHz EMF causes worsening neuronal ability to process information.

This work was supported by Shota Rustaveli National Science Foundation of Georgia (SRNSFG), grant number: FR-22-2771.

ადამიანისა და ცხოველთა ფიზიოლოგია

5G ელექტრომაგნიტური ველის ეფექტი ნეირონის ინფორმაციულ აქტივობაზე

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(წარმოდგენილია აკადემიის წევრის თ. ნანეიშვილის მიერ)

ნაშრომში წარმოდგენილია 2.4 გეგაჰერცი სიხშირის ელექტრომაგნიტური ველის ზემოქმედება ცალკეულ ნეირონზე. დადგენილია, რომ აღნიშნული ველის ზემოქმედება ცალკეულ ნეირონზე იწვევს იმ ინფორმაციის რაოდენობის შემცირებას, რომელსაც შეიცავს ქმედების პოტენციალის პარამეტრები ჰაბიტუაციის შესახებ. ამრიგად, უარესდება ნეირონის ინფორმაციული აქტივობის შესაძლებლობები. ცალკეული ნეირონი ქმედების პოტენციალებით რეაგირებს დენის იმპულსებით განმეორებად უჯრედშიგა სტიმულაციაზე. განსაზღვრული რაოდენობით სტიმულის მიწოდების შემდეგ ნეირონი წყვეტს რეაგირებას ქმედების პოტენციალებით. ეს მოვლენა ცნობილია როგორც მიჩვევა, ანუ, ჰაბიტუაცია. სტიმულის პერიოდულად მიწოდების შედეგად ადგილი აქვს ქმედების პოტენციალის პარამეტრების ცვლილებას. კერძოდ, ფართოვდება ქმედების პოტენციალის სიგანე, იზრდება ამ პოტენციალის აღმასვლისა და დაღმასვლის დროები, იზრდება ქმედების პოტენციალის აღმოცენების ლატენტური დრო. შემჩნეულია ამ მნიშვნელობების სტაბილური ზრდის ტენდენცია. წარმოიშობა კითხვა: შეიცავს თუ არა ეს პარამატრები ინფორმაციას ჰაბიტუაციის შესახებ? თუ კი, არის თუ არა განსხვავება ამ ინფორმაციის რაოდენობათა ქცევაში ელექტრომაგნიტური ველით დასხივებულ და საკონტოლო ნეირონში? კვლევამ აჩვენა, რომ ქმედების პოტენციალის პარამეტრები შეიცავს

ინფორმაციას ჰაბიტუაციის შესახებ. გაიზომა აღნიშნული ინფორმაციის რაოდენობა თითოეული ქმედების პოტენციალისათვის და დამუშავდა სათანადო გრაფიკები როგორც ელექტრომაგნიტური ველით დასხივებული ნეირონებისთვის, ასევე საკონტროლო ნეირონებისთვის. განსხვავება ამ ორი ინფორმაციის რაოდენობათა დინამიკებს შორის აშკარაა. დადგენილია, რომ 5G-ს 2.4 გჰც ელექტრომაგნიტური ველის გავლენა ცალკეულ ნეირონზე იწვევს ნეირონის ინფორმაციის მიღებისა და დამუშავების უნარის სწრაფ შემცირებას.

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Received February, 2024