

# Mechanical Microvibrations as a Basis Organization of Functional Cells Groups

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## Abstract

The paper proposes a conceptual model in which for each function—from cellular to organism, a frequency cluster (group) consisting of nerve, glial or any other cells is built based on needs. The organizing factor of these cells is one frequency of mechanical microvibrations, and the functional state of such groups is determined by their total amplitude. To record the spectrum of acoustic signals from the head, a prototype of the medical device “Recorder of the spectrum of the brain acoustic field RS AEG-01” was developed. The device, using piezoceramic vibration sensors, recorded the total rhythmic activity separately for the right and left hemispheres and performed its high-resolution spectral analysis in the frequency range from 0.13 to 27 Hz. The 8400 central frequencies obtained from the left and right hemispheres with the corresponding spectral evaluation amplitudes were folded into two spectral matrices measuring  $24 \times 175$  frequency cells. The signal summation time for each spectral cell was chosen to be 160 sec—the duration of the information frame. The paper presents examples of recording and analyzing cell groups of the skin, taste, visceral, and cognitive analyzers. In conclusion, the main principles of constructing a model for organizing a cell functional group are highlighted—mechanical vibrations at low frequencies propagate in the body’s environments with virtually no attenuation; gene expression and synthesis of protein components are sources of mechanical microvibrations. Cells respond to mechanical microvibrations selectively only at their own frequency.

## Keywords

Cellular Functional Group, Mechanical Microvibrations

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## 1. Introduction

Bekhterev and Livanov [1] [2] demonstrated that cells of a living organism, wherever they are, work synchronously if they perform one task. Numerous physiological studies were based on this statement, which confirmed the principle. Such cell associations—functional groups—form the basis for regulating physiological functions in the visceral and somatic spheres, forming cognitive groups of neurons during mental activity and maintaining various systemic functions of internal organs and the body as a whole. However, a number of authors, using microelectrode leads, showed that the existence of such group where the cells can be scattered in a wide variety of parts of the central nervous system is not directly related to the impulse activity of nerve cells, while the coherence of the group is preserved even when they are completely silent [3]-[5]. In dynamics, such groups can instantly switch and “light up” like Christmas lights. Until now, the problem of forming such functional cell groups has been the “dark matter” of neurophysiology [6]-[8].

The presence in the body of a constant source of “dynamic tone” or “background adaptation potential” for each of its functions, vegetative and somatic, seems to be extremely important. The body must always predict its state for the future in a certain time interval based on past experience. This is necessary for the effective response of the body’s functions to changes in the external environment, behavior in general, and survival. In this regard, the oscillating principle of the structure of the brain activating system, capable of maintaining the state of functions for a long time without external influences, seems important and evolutionarily justified. The principle of the active brain complements and improves the generally recognized reflex paradigm of the functioning of the nervous system—the reactive brain [9]-[12].

Anokhin formulated the concept of specificity of non-specific activation. He claimed that each type of motivation is provided by the excitation of its own non-specific activating system, which has a special chemical specificity [13].

Starting with the general monograph by Magoon [14], the idea was formed that the physiological approach to assessing the state and regulation of functions requires studying the regulatory or modulating influences from spontaneously active interactive structures of the brain, and their functional heterogeneity can be considered as an independent complex neurophysiological mechanism.

Kratin and Stabbs (1965-1976), without denying all previous views on reflex principles in the allocation of biologically significant signals, bring in the importance of frequency tuning of resonant circuits formed by specific and non-specific systems of the brain. Such frequency-resonance approach asserts the presence and information interaction of oscillating elements of the brain and the possibility of coherent relationships in groups of cells [15]-[17].

Our studies concluded that the energy of oscillations, as the simplest form of energy accumulation, is used by nature to form the background adaptation potential of non-specific reticular structures of the brain—a multi-frequency matrix

of various functional states. The most important activity sign of such system should be sufficiently long periodic modes in it, forming the spatial organization and functional state—the dynamic tone of the overlying brain structures, of the underlying peripheral effectors and of the organism as a whole [18].

Billions of small cells of the interactive activating system represent a kind of combination in which all types of information transfer are present and important—mechanical microvibrations, chemical, electrical, synaptic nervous, and not just isolated cells and networks enveloped only by nerve conductors and synaptic connections. Any body cell, glial and nerve cells, in particular, have significantly greater functions, which allows us to look at the brain from a variety of positions, often unexpected.

We now carefully subsume any newly studied control system in the body under synaptic transmission in the nervous system. We are “enslaved” by the paradigm of the most perfect neural transmission of information. Nevertheless, one of the founders of comparative physiology of the evolutionary approach to information transmission, Koshtoyants (1950), claimed that in a living organism, absolutely everything takes place and functions together, both new and simpler, old mechanisms of information transmission. New mechanisms not only replace but also integrate into old ones, which continue to function together, each in its place [19].

In previous studies, we noted that the most ancient mechanism of information transfer still exists in the human body—mechanical microvibrations of cells. Using the example of multi-frequency photostimulation of the visual analyzer, we proved that in addition to the recorded EEG reactions, it is possible to identify a mechanism of microvibrations that participates in the reflex activity of the brain [20] and in the control of physiological functions [21]. The number of studies on the effect of transcranial-focused ultrasound on various functions of the brain is growing in laboratories around the world [22]-[25].

The work aims to reveal and explore the basic principles for modeling the organization of functional cellular groups. Such groups are based on mechanical microvibrations of cells, as the simplest and most ancient form of “pre-nervous” information transfer and energy accumulation. The latter is used by nature to form the background adaptive potential of the “active brain”—continuous activity and regulation, maintenance and prediction of a wide variety of physiological functions.

## 2. Materials and Methods

The design of the present study was educational. It was envisaged to obtain preliminary results and test the hypotheses put forward for the purpose of planning and conducting subsequent large-scale studies. To solve various problems, 97 practically healthy people aged 35 - 70 were examined. The inclusion criterion was a conclusion on the patient’s condition. The exclusion criterion was any somatic or mental diseases in the anamnesis.

A prototype of a medical device called the “Recorder of the spectrum of the

brain acoustic field RS AEG-01” was developed to record the spectrum of acoustic signals of the head. The device recorded the total rhythmic activity separately for the right and left hemispheres using vibration sensors and performed its high-resolution spectral analysis [26] [27]. Piezoceramic plates poured into a silicone shell were used as mechanical microvibration sensors. The diameter of each sensor was 60 mm, the height was 30 mm, and the weight was 95 g. The sensor was pressed against the head with the standard pressure of its own weight (the industrial metal analogue of such sensor is the piezoelectric accelerometer CA-YD-109 for the frequency band of 0.1 - 1000 Hz).

The right and left sensors were located in the temporoparietal regions of the left and right hemispheres, allowing reliable recording of the total rhythmic activity of both hemispheres in the frequency range 0.13 - 27.0 Hz. The arrangement is shown in **Figure 1**. The sensors contacted the head through a standard disposable sterile medical cap. The average amplitude of the signal at the output was 20  $\mu$ V. Electrical signals from the acoustic sensors were fed to the inputs of a two-channel amplifier (any standard DC amplifier, EEG amplifiers). Digital filtering and spectral analysis with fast Fourier transform had their own characteristics. The entire range of the studied signal was divided into 4200 bands, the central frequencies of which form a geometric progression with  $q = 2^{1/24}$  with the reference frequency of 27.005 Hz, while the spectral harmonics that fell into one of the 4200 bands were integrated by amplitude. The 8400 central frequencies obtained from the left and right hemispheres with the corresponding spectral estimate amplitudes were folded into two spectral matrices measuring  $24 \times 175$  frequency cells. The signal summation time for each spectral cell was chosen to be 160 sec—the duration of the information frame [18]. This summation determines the focus on identifying only the processes of long-term activity of the brain and studying the functions of the visceral system.



**Figure 1.** Location of piezoceramic sensors of mechanical microvibrations on the human head.

Statistical processing of the research results was carried out on a personal computer using the Microsoft Excel application; Statistics 6.0 application package was used to perform the calculations. From the main characteristics of relative statistics for each variation series of the obtained results, the following were calculated: arithmetic mean values ( $M$ ), standard deviations ( $\sigma$ ), relative values and confidence interval ( $P$ ), and correlation between a pair of functions ( $r$ ). When performing a comparative analysis of groups, Student's  $t$ -test, Spearman's paired rank correlation coefficient ( $R$ ), and reliability of the correlation coefficient were used. The null hypothesis about the differences between the features of the analyzed samples was accepted at  $p \leq 0.05$ .

Software for collecting and processing information with the output of two matrices of a set of functional states with a total of 8400 spectral cells was registered in the Register of Computer Programs on July 26, 2016, Certificate of State Registration of Computer Program No. 2016618291 (RU) [28].

Blood glucose was measured using a OneTouch Select Plus Flex glucometer. For quantitative assessment of genetic material and gene expression, a high-speed PCR device with the ability to register products in real time was used—C1000 Touch (CFX), Bio-RAD (USA).

### 3. Results and Discussion

Mechanical vibrations of cells, as the simplest and most ancient form of “pre-nervous” transmission and accumulation of energy, are used by nature to form the background adaptive potential of the active brain by brain structures—a multi-frequency matrix of numerous functional states. Mechanical microvibrations are the most energy-efficient form of energy transmission; they propagate at ultra-low frequencies without attenuation, and the frequency code gives it functional specificity. A conceptual model was proposed in which for each function, from cellular to organism, a frequency cluster (group) consisting of nerve, glial or any other cells is built based on needs; the organizing factor is one frequency, and the functional state of such group is determined by the amplitude of mechanical microvibrations of cells [20] [21].

This experimental model assumes that a single oscillator-vibrator in such system is a cell that creates mechanical microvibrations into the surrounding space with the frequency specific to a particular gene during the synthesis of protein components, or capable of being excited when the cell is exposed to external vibrations of the same frequency [6] [7] [29]-[32]. Ultra-low frequency microvibrations (up to 30 Hz) are capable of spreading throughout the body with virtually no attenuation. Any cell “sees” and can “react” to the state of other cells of the entire organism in the language of frequencies. At the same time, a nerve cell is capable of being excited at several frequencies and, if necessary, instantly remembering them, while a somatic cell operates only at one specific frequency [33] [34].

Once again, for each function, from cellular to organism, a frequency cluster (group) consisting of nerve, glial or any other cells is built based on needs; the organ-

izing factor is one frequency, and the functional state of such group is determined by the total oscillatory energy of the frequency cluster—the amplitude of its activity. Thus, the model demonstrates that behind each frequency generated and recorded in the central nervous system is a functional group of numerous tuned cells and its inherent function, cognitive image or behavior vector.

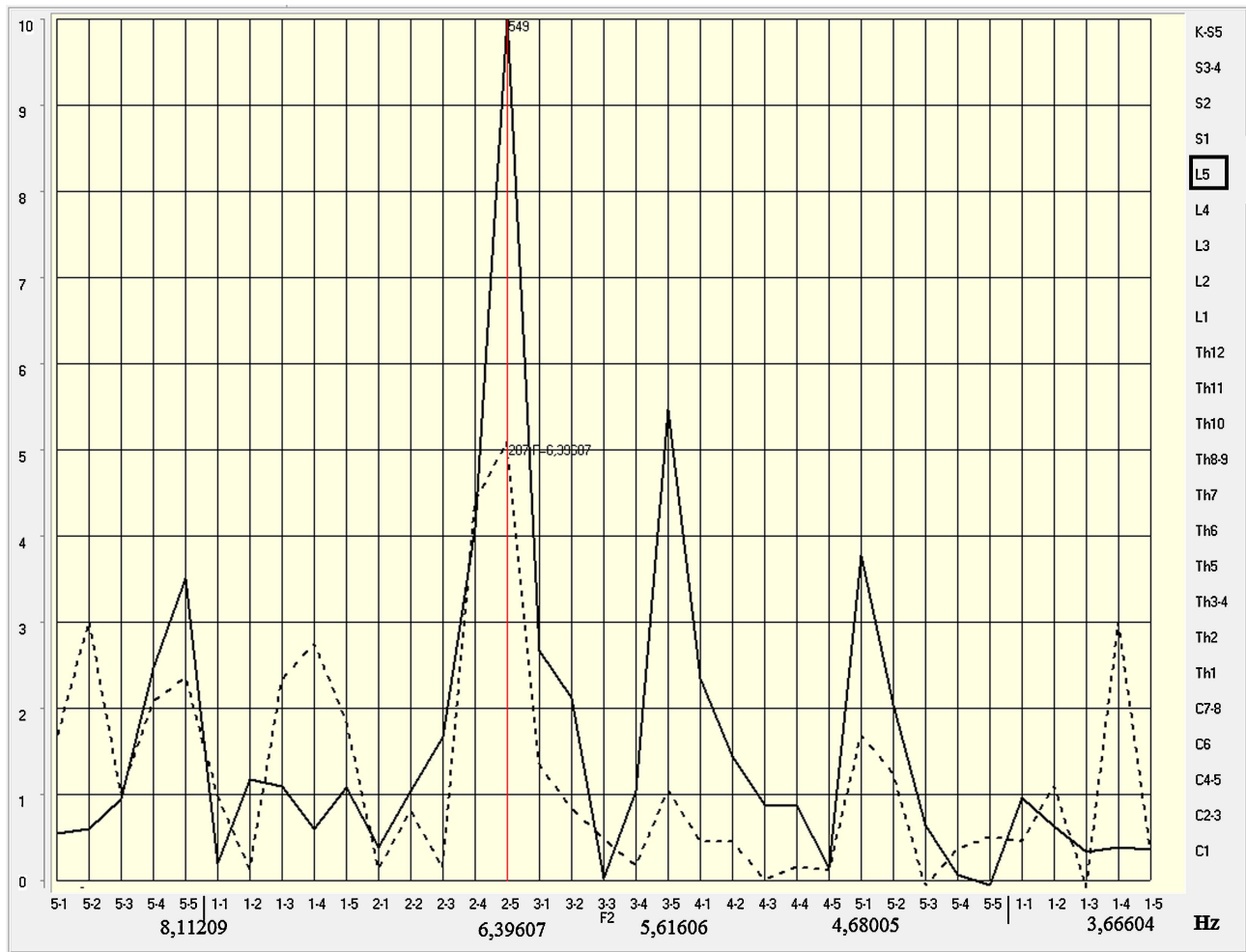
Such model correctly solves the problems of “global access” and synchronization of the work of nerve and somatic cells in one functional-frequency group, regardless of its location in space, the presence and trajectory of nerve conductors. Single-frequency cell groups (SFGs) are closely interconnected into functional modules, provide hierarchy in their organization and integrity of the organism, represent a potentially huge set of cognitive images, somatic and visceral functional groups, competing needs and behavior vectors [14] [15].

The model predicts the sequential occurrence in a functional cell group of heterogeneous and weakly dependent mechanisms of information transfer emerge—from mechanical microvibrations of cells, chemical transmission to neural synaptic. Nervous impulse activity occurs within the already formed frequency cell cluster only with its biological significance—an increase in sufficient vibrational energy of mechanical microvibrations. At the same time, neural synaptic networks built on this “pre-nervous” basis inside and between different frequency clusters, isolate and morphologically fix the most significant target connections that provide a hierarchy of functions, memory and integrity of the organism.

A single cell can generate microvibrations at several frequencies, switching gene expression into a programmed sequence. This behavior creates preconditions for more complex interactions between cellular functional groups, creating their subgroups, associations with sequential or parallel coordination. Intracellular gene networks in unicellular organisms and neural networks in animals perform, in essence, the same function: to integrate all sensory signals from the external and internal environment and generate a response in light of past and present states. Evidence of learning in unicellular organisms suggests that this feature of cognition may have preceded the evolution of the nervous system [35]-[37].

Let us give examples of studies of functional cellular groups frequencies and some methods for obtaining them.

1) We have found that any (mechanical, chemical, temperature) irritation of skin areas (from weak to strong) leads to a new spectral harmonic of altered amplitude in the frequency spectrum [38]. Mapping of different skin areas showed their high frequency specificity and population stability. To form the coordinate system of the frequency matrix of cutaneous sensitivity of the body, 32 dermatomes from C1 to K were plotted along the ordinate axis, and seven areas of cutaneous nerve exit—modes (three on the anterior surface of the body, three on the back and one on the side) were plotted along the abscissa axis within each dermatome. Thus, for the activating system of the brain, the somatic coordinate system “Body Scheme” (8400 functional groups of the skin analyzer) was inscribed in the multi-frequency matrix of various functional states [18]. **Figure 2** shows an

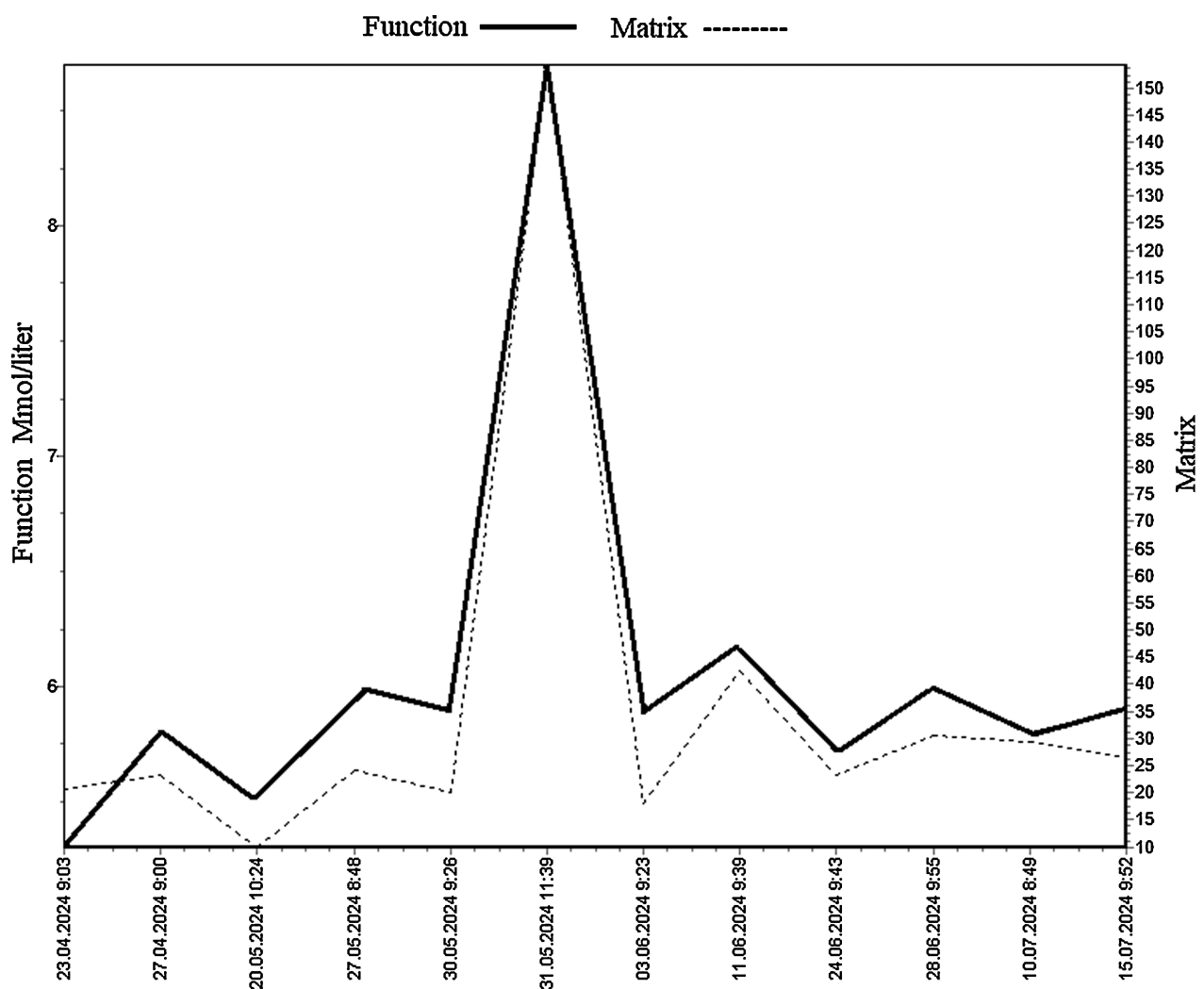


**Figure 2.** As a result of irritation of the L5 dermatome area with Finalgon, a surge in the amplitude of the 6.396 Hz spectral harmonic was recorded in the right hemisphere. The abscissa axis shows the frequency in Hz, the ordinate axis on the left shows the amplitude in relative units, and the dermatome numbers on the right. The solid line of the spectrum envelope graph shows the right hemisphere, and the dotted line shows the left hemisphere.

example of an abnormally high spectral harmonic at the frequency of 6.396 Hz during local irritation of skin area on the L5 dermatome (anterior region of the shin, distal to the apex of the patella). The chemical irritant ointment Finalgon was used. By analogy, it is possible to obtain the spectrum of any of the 8400 matrix cells of various functional states of the skin analyzer. This approach opens up opportunities for creating a technological platform for conducting physiological and medical studies on functional topical diagnostics of diseases of internal organs and body systems, mapping any functions, foci of pathology, stages of the inflammatory process, tumors, etc. [39]-[41]. The body scheme in the spectrum of continuous rhythmic activity of the brain is a striking example of the concept of the active brain, awareness of own I and orientation in space, and development of elements of consciousness [41] [42].

2) Any function can be represented as a graph of the functional state over time. A volunteer had their blood glucose measured over three months (12 measure-

ments in total). The graph in the form of a solid line is shown in **Figure 3**. Some of the measurements were taken on an empty stomach, some after eating something sweet. Synchronously with the glucometer measurements, an acoustic encephalogram was recorded—three frames of 160 seconds, which were averaged during processing. As a result of spectral analysis, 12 matrices of multiple functional states were obtained, each containing 8400 spectral cells. Cross-correlation analysis was performed, where each such graph was compared with the real blood glucose graph with pairwise measurement of the correlation coefficient. One single graph out of 8400 was selected, which was maximally similar to the blood glucose graph and had the maximum correlation coefficient. This turned out to be a spectral cell of 0.295 Hz in the left hemisphere with a correlation coefficient of  $r = 0.96$ . In **Figure 3**, such graph is shown as a dotted line, the amplitude values



**Figure 3.** Result of cross-correlation analysis of the blood glucose (mmol/l) function for 12 measurements on different days and at different times in one volunteer (solid line, glucometer readings) and the function selected for the maximum correlation, one of 8400 in the matrix of various functional states (dotted line). The maximum correlation coefficient between two functions is 0.96. The abscissa axis shows the date and time of measurements. The ordinate axis on the left shows blood glucose readings, on the right—the amplitude of the selected spectral function in rel. units.

displayed on the right along the abscissa axis. In this way, it is possible to measure the blood glucose content (as well as any other function) non-invasively, by analyzing the rhythmic activity of the brain. Thus, the amplitude of the spectral harmonic with the frequency of 0.295 Hz reflects the state of the functional group of cells responsible for the function of maintaining glucose in the blood. The results are reproducible for other patients ( $p = 0.85$ ).

3) The volunteer was shown the letter A, 20 cm in size, printed on white cardboard. The subject had to pronounce the name of the letter to themselves and trace its contour with their eyes as if they wrote it. The eyes were closed for about 10 seconds, followed by relaxation, and then everything was repeated for the duration of the information recording frame, 160 seconds. Thus, the subject received multiple presentations of the visual image of the letter A; before each, the subject was recorded a “Background” frame lasting 160 seconds, with closed eyes in a relaxed state. The study was repeated at least 10 times on different days and at different times. The frames obtained for 160 seconds were summed up, and a multi-periodic pattern characteristic of the letter A (dominant frequencies 0.15495 Hz; 3.61129 Hz) was identified based on the difference with the “Background” indicators. The spectrum amplitude analysis software block was “trained” for the selected pattern, and a rule was formed—“Letter A”. Then, the “Background” was recorded again for the subject on different days and at different times, and then the letter A was presented 20 times. The spectrum analysis block in a sample of 20 frames successfully identified the spectrum of the letter A 18 times ( $p = 0.9$ ). In the background state, there were no false positives for the spectrum of the letter A. The developed rule for recognizing the image of the letter A worked successfully only on one volunteer. Application to other volunteers sharply reduced the recognition probability to  $p = 0.5$  [18].

4) The volunteer showed 5 images on different days and at different times—photographs of familiar and unfamiliar faces. Before each study, the background was recorded for 160 sec, and then one of the images was immediately recorded. As a result, the leading spectral harmonic with the maximum amplitude was identified for each image: Photo 1—6.008 Hz, Photo 2—6.977 Hz, Photo 3—7.065 Hz, Photo 4—6.92 Hz, Photo 5—7.01 Hz. Showing these photographs to the volunteer over the next three months showed the same results. The images were remembered. Automatic recognition of images presented out of sequence gave the probability of the correct result  $p = 0.85$ . Replacing the photograph with a mental memory of the image also gave a positive result of the study. Presenting the same photographs to another volunteer gave completely different frequencies, which were subsequently retained only by them. Probably, the current experience obtained is recorded instantly and stored by molecular mechanisms strictly individually.

5) The subject was given a pill with a pronounced mint flavor, sucked under the tongue for 160 sec. The study was repeated at least 10 times on different days and times. Before stimulating the taste analyzer, the “Background” was removed from the subject. When stimulating the taste analyzer with the mint pill, a diffuse multi-

periodic pattern was formed. The spectrum analysis unit in a sample of 20 frames of presentation of the mint taste successfully identified its spectrum 17 times ( $p = 0.85$ ). There were no false alarms during the background study. The leading spectral harmonics for the mint taste, 0.1303 Hz and 3.7890 Hz, were preserved in all subjects [18].

#### 4. Conclusions

*Biological microvibrations are the most important transport resource of living organisms and a catalyst for metabolism, the most important component of integrity and a condition for the vital activity of the organism* [43] [44]. Therefore, the functional state of the cell is directly related to the amplitude of its microvibrations. The absence of vibrations means cell death and the maximum amplitude of vibrations means high functional activity.

The paper proposes a conceptual model of the organization of a cellular functional group, which is based on (and will be improved by taking into account) the following main provisions:

- Mechanical microvibrations in the ultra-low frequency range propagate in various environments practically without attenuation and over relatively large distances.
- A point source of microvibrations located anywhere in the body can be heard by absolutely all cells, and the energy costs of such information transmission systems, unlike biochemical ones, are minimal [44].
- It has been proven that a cell can respond to mechanical microvibrations without having specialized receptors [45].
- External energy of mechanical vibrations can resonate at a certain frequency with a number of biochemical processes in the cell, including causing the expression of the gene-specific only for this frequency, and when a gene is expressed, this energy can emit vibrations at this specific frequency, forming a coherent system with other cells of the group [29]-[32].
- Nerve and glial cells can respond to several vibration frequencies and enter into different functional groups accordingly, creating more complex mechanisms of interaction between cell groups. A somatic cell can operate only at one frequency, which is determined by the gene and protein production.
- The polarization potential and the discharge frequency of a nerve cell are an independent information mechanism that requires additional study in terms of interaction with mechanical vibrations of the cell. The electric field and mechanical microvibrations are physically different in nature. The nerve and synaptic information channel depends on, but is not directly related to, the frequency and amplitude of mechanical microvibrations of the nerve cell. The frequency and amplitude of mechanical microvibrations of a cell are a product of the genome, an ancient epigenetic mechanism of interaction between a cell and the environment.
- For each function, vegetative and somatic, evolution has assigned one and only

one frequency of functional group activation, which is characteristic of the entire species (body scheme, visceral analyzer, emotions, smell, and taste). The only exceptions are cognitive functional groups, groups associated with visual and auditory images, each of which is obtained from individual experience and has a stable frequency of binding to an image for only one organism. The more “corticalized a functional group is”, the more individual its spectral vibration characteristics are.

- The cellular elements of a functional group or their associations that support one function of the organism are scattered throughout the brain and body, so it is pointless to look for their topographic clusters. The unifying principle or system-forming factor is the synchronization of the elements of the group at one frequency. The executive mechanism of this association is the phenomenon of microvibrations, chosen by evolution as the simplest beginning of all living things. At ultra-low frequencies, microvibrations have an all-pervasive ability and spread practically without attenuation, with a relatively high speed and minimal energy costs. In addition, the total mechanical energy received from the functional group in the form of microvibration is a supporting contribution to the energy of the cell itself, its functional state. All oscillating elements of one functional group—cells—strive to equalize the total oscillatory energy of the group to the same level.
- The central frequency of the functional group has a very high stability, which we define as accuracy with “five decimal places”. This is due to the very large number of oscillating elements that are weakly coupled and each of which is approximately tuned to one frequency. In such “imprecise” systems, the overall generation frequency is averaged, and its accuracy directly depends on the number of elements. With a number of elements in the tens and hundreds of thousands, the central frequency turns out to be comparable with the accuracy of a quartz generator. This allows for up to a hundred thousand spectral harmonics to be placed on a small frequency range, for example, from 0.1 to 30 Hz [46].
- Mechanical microvibrations of a living cell and the organization of cellular functional groups on this basis are the most ancient mechanisms of pre-nervous transmission of information and accumulation of vibrational energy, the basis for the “continuous activity” of the brain and for its adaptive regulation.
- *A functional group of cells based on mechanical microvibrations*—universal mechanism of the “active brain”—is an evolutionary acquisition that exists for any physiological functions of the body at all its levels and covers all analyzer systems, including cognitive functions.

### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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