Ocular Influence of Nano-Modified Fulleren Light: 1. Activity of Default Networks of the Human Brain

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Abstract: We studied dynamics of the activity of the default networks as the human large scale brain networks in response to the ocular influence of light, which was nano-modified with a fullerene filter. We examined 7 volunteers (4 males and 3 females) aged from 18 to 22 years without health complaints, right-handers, students. The ocular pathway of the light influence was provided by the use of glasses with fullerene (C_{60}) filters (Zepter Tesla LightWear, 0.3‰ in polymethylmethacrylate organic glass, 2 mm thick), for placebo we used glasses in a similar frame with a filter similar in the light range but not containing fullerene. For EEG recording and analysis, we used the Neuron-Spectrum-4/VP complex (NeuroSoft). The recording was carried out in monopolar way, with a quantization frequency of 500 Hz, the electrodes were arranged according to the international system 10-20 in 19 leads. In each lead, the power spectral density was calculated for all EEG frequency ranges according to the Neuron-Spectrum program. Statistical analysis was performed by using Statistica 8.0 (StatSoft, USA). As a result of the study, we obtained significant differences (as compared with placebo) of the electrical activity of the human brain (EEG) under the influence of light transmitted through a fullerene filter. Changes in the delta and theta ranges indicated changes in the state of the default networks, since they are characterized by low-frequency of EEG oscillations. Reduced EEG activity in the alpha range in the right frontal zone indicated an increase in interregional synchronization involving figurative information in the processes of internal thinking. Increased EEG activity in the delta range in the temporal zone indicated activation of the imaging modeling processes of the future, and reduced EEG activity in the in the posterior temporal area indicated a decrease of attention to internal processes, i.e. relaxing. Increased EEG activity in the theta range in the posterior singular cortex testified to the intensification the processes of introspective emotional experience of the past events. These data suggest that under the influence of light, modified at the nano-scale level by fullerene, there developed a more contemplative attitude toward the introspective emotional experiences of the past events developed while they were actively involved in figurative modeling of a hypothetical future.

Key words: EEG, default networks, fullerene, light nano-modification, Tesla LightWear.

1. Introduction

Brain activity at rest is not less than when performing cognitive activity. It is revealed a higher activity of certain areas of the human brain in the absence of purposeful activity. To describe these neural ensembles in 2001, M. Raichle [1] proposed to introduce the concept of default networks. Electric oscillations in such zones are characterized by higher activity in the periods before and after doing the task, rather than during the process itself [2–4]. Later, the default networks began to be associated with the processes of internal speech, self-awareness, self-projection, self-contemplation, and independent thinking [2]. One of the important tasks of the default networks is also called autonomous information conversion and transition of objects from short-term memory to long-term one [3]. Another important function of default networks is to ensure that memories

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from the past are used when planning the future and comparing them with the present [5].

Clinical observations revealed changes in the default networks for various cognitive disorders [6-10]. In patients with depression, impairments in the default networks were manifested in the distortion of self-esteem and depression after viewing negative images [10]. Patients with schizophrenia showed higher activity of default networks, more connections between their various types, which were not suppressed during the subsequent performance of a certain task. This may be due to the presence of hallucinations and delusional states [6].

Using the functional magnetic resonance imaging method, it was found that the default networks include structures of the medial and lateral parts of the temporal lobes, the medial prefrontal and dorsolateral prefrontal cortex, the singular cortex, the lower parietal zone and some other areas associated with them [11, 12]. Most researchers believe that default networks are a heterogeneous array. Since they are activated when a person's thoughts are not oriented towards the outside world, a question arises as to the various structures that should be activated according to the nature of the mental activity observed at the moment [5].

It has been revealed that the areas of default networks are responsible for introspective considerations, including thoughts about personal preferences. At the same time, when the examined were busy thinking about other people, the same neural networks were activated as when thinking about their own feelings and desires, i.e. they felt themselves in the place of another person [13].

It has been shown that some subsystems exhibit different activities when the subject thinks about himself in the past, present, or future. These include: I—posterior singular cortex-frontal cortex, II—temporal lobe, including the hippocampus and other structures involved in memory processes and III—subsystem associated with autobiographical reflections [14]. A number of papers confirmed participation of the default networks in the processes of autobiographical memory, modeling future events and affective decisions [5, 14, 15].

Default networks also take part in the so-called autonomous transformation of information and its transition to long-term memory, which, according to many researchers, occurs mainly in sleep [3, 16, 17]. It is an autonomous transformation that consolidates traces of memory, while activating the zone of the precuneus, as well as ventrolateral and dorsolateral prefrontal areas [3].

Summing up these data [1-18], we can distinguish 4 subsystems involved in the default brain activity. The first of them is responsible for planning processes, comparing the present with the past and includes the dorsal part of the medial prefrontal cortex, the lateral temporal region and the lateral parietal cortex (Fig. 1A). The second subsystem plays the role of supporting readiness for future actions, "scanning" the external environment. It includes the dorsolateral prefrontal cortex, the motor region, the lower and upper portions of the singular cortex, and the middle temporal cortex (Fig. 1B). The third subsystem is involved in the processes of using past experience. It includes the medial temporal lobe, the retrosplenial area, the ventral part of the medial prefrontal cortex, the lateral parietal region and the hippocampus (Figs. 1, C-1 and C-2). The fourth subsystem is associated with memories about yourself (autobiographical) directly and combines the following structures: the lower part of singular cortex, the medial prefrontal cortex in the left hemisphere, the dorsolateral prefrontal cortex, the lower and middle temporal cortex and lateral parietal regions (Figs. D-1 and D-2).

Thus, the human brain is never really "at rest", and its functioning is rather "an orchestra of various functional networks at a dynamic concert" [6]. Asymptomatic or working "idle" brain activity contributes to the internal thinking processes that occur when people are not involved in external interactions [18].
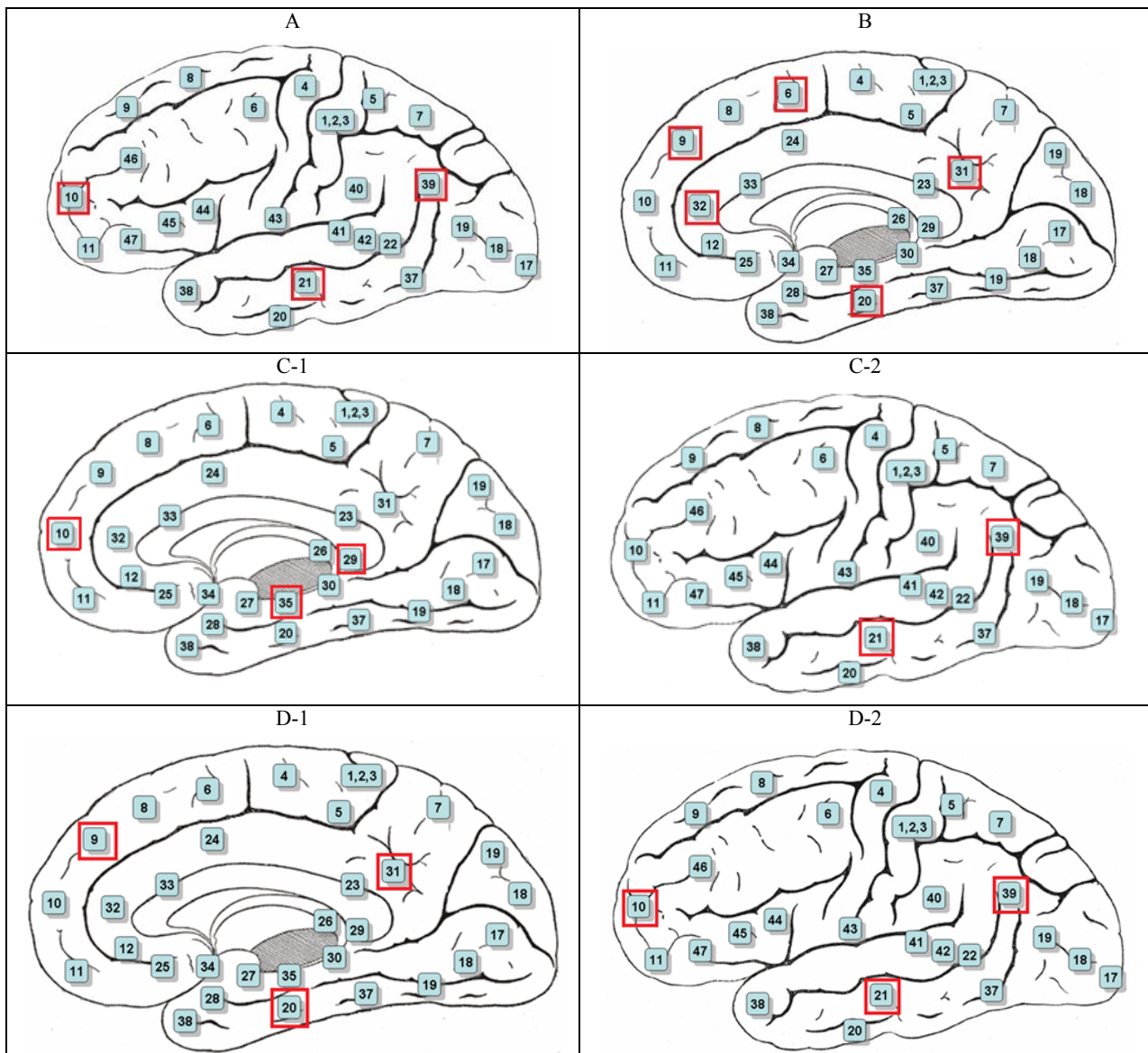
Fig. 1 Default brain networks and Brodman's areas (highlighted in red):
A—the subsystem responsible for planning; B - the subsystem responsible for attention; C-1 and C-2—subsystems responsible for using past experience; D-1 and D-2—the subsystem responsible for autobiographical memory.

Higher activity of some areas of the human brain in the absence of purposeful activity may be associated with manifestations of the action of the electromagnetic background of the environment. Changes in the physical parameters of the environment against the background of the default state of the brain can probably make its own corrective contribution. The ocular pathway of energy transport in the visible spectrum for humans and animals is considered to be the leading one for the activation of many cortical systems. Accordingly, modification of the characteristics of the luminous flux is likely to be important for changing functioning of the default subsystems. Use of polychromatic and monochromatic filters (glasses) has a prophylactic protective value, and some of their types, such as green, red and others, can be used for therapeutic purposes. In recent years, the possibility has arisen of the direct application of polychromatic polarized light (Bioptron devices) for correction of disorders in the structures of the eye

(therapeutic solar prophylaxis) [19].

Modification of the luminous flux at the nanoscale level can be achieved using materials containing fullerene molecules (C_{60}: 60 carbon atoms under the influence of atomic forces create a stable structure of spherical shape, on the surface of which carbon atoms are located in the form of 5 and 6 angles). The light modification consists in the fact that a photon falling inside a rotating (speed of rotation 1.8 10^{10} s^{-1}) fullerene ball interacts with paramagnetic and diamagnetic portions (pentagons and hexagons) and receives spiral stimulation for its trajectory. In this case, the photon flux acquires additional rotational properties. Next, it generates the photon distribution in such a way that it creates a 2D energy membrane [$\Phi^2 + \varphi^2 = 3$], which "filters" the resulting photons according to the Fibonacci law. In this way Tesla energy toroids are formed [20], which are applied to biological substrates. The result is a more concentrated and uniform distribution of photons (in accordance with the Fibonacci law). As a result, the receptor zone of the ocular fundus receives additional stimulation and more complete coverage of each anatomical structure with light radiation [21]. Therefore, additional nervous impulses of the central link of the visual analyzer can improve its energy balance, as well as provide irradiation to the silent zones.

Our previous studies have shown that both the short- and long-term effects of light passing through a fullerene filter cause a number of changes that can be interpreted as beneficial [21, 22]. In particular, it was found that a 10-minute transdermal light exposure to the pain center or acupuncture point created noticeable analgesia and improved sleep. The many-month stay under the fullerene lighting (transdermal and ocular) improved the quality of life of older animals (appetite, body weight, activity, performance). These data indicate the possibility of biological reactions to the action of light modified with fullerene. However, realization of these effects was achieved in two ways—transdermal and ocular, which makes it difficult to understand the role of the initial point of application of the considered variant of electromagnetic light radiation. Such studies have not been made before. Therefore, in order to explain the mechanisms of physiological reactions, it is of interest to highlight the role of ocular light application.

The purpose of this study was to examine the dynamics of the activity of the default networks of the human central nervous system in response to the ocular influence of light nano-modified with a fullerene filter.

2. Materials and Methods

2.1 Contingent of the Examined

Examination involved 7 volunteers (4 men and 3 women) aged from 18 to 22 years without complaints about health, right-handers, students. Testing was conducted voluntarily and anonymously according to ethical requirements for working with people. Fourteen (14) examinations were conducted, in which all the subjects were tested 2 times on different days.

2.2 Modification of Light

The ocular pathway of light exposure was provided by the use of glasses with fullerene filters (Zepter Tesla LightWear, polymethylmethacrylate organic glass C_{60} @ PMMA, 2 mm thick [23]), for the placebo studies, glasses were used in a similar frame with a filter, similar in the light range, but not containing fullerene. A modification of the fullerene spectrum of visible light is shown in Fig. 2. Weakening of the high-energy part of the solar spectrum is noticeable: the power density decreases in the UV, violet, blue, green and yellow ranges. Modification of the fullerene flux of light photons was described by us earlier [21].

2.3 Registration Methods

The subjects were illuminated with daylight of moderate intensity. EEG was recorded in the soundproofed chamber in a state of calm wakefulness with open eyes for 5 minutes. During the examination, on the first day, glasses with a fullerene filter were used, and on another day—glasses of a similar spectrum
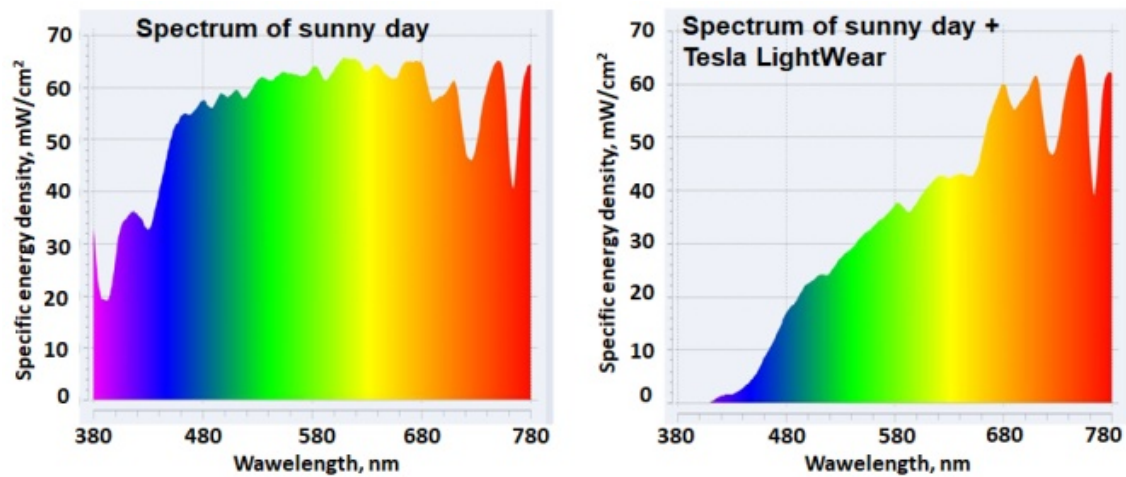
Fig. 2   Natural spectra of the sunlight and modified by a fullerene filter.

without fullerene (placebo).

For recording and analysis of EEG, we used the Neuron-Spectrum-4/VP complex (NeuroSoft). The recording was monopolar, with a quantization frequency of 500 Hz, a notch filter of 50 Hz, upper and lower frequency filters, respectively, 0.5 and 200 Hz, and reference electrodes were placed on the earlobes. We used bridged silver-plated electrodes, which were superimposed according to the international system 10-20 in 19 leads Fp1, Fp2, F3, F4, F7, F8, Fz, C3, C4, Cz, T3, T4, T5, T6, P3, P4, Pz, O1, O2. In each lead for the frequency ranges of EEG-Delta (0.5-3.9 Hz), Theta (4.0-7.9 Hz), Alpha (8.0-12.9 Hz), Beta1 (13.0- 19.9 Hz) and Beta2 (20.0-35.0 Hz) in the Neuron-Spectrum program, the total spectrum power was calculated.

2.4 Statistical Analysis

Statistical analysis was performed using Statistica software (StatSoft, USA). The critical level of significance when testing statistical hypotheses was assumed to be 0.05. The distribution of variables was checked for normality by the Shapiro-Wilk criterion. Since the distribution of the most variables differed from the normal ($p \leq 0.5$), the comparison of two dependent samples was performed using the Wilcoxon test, and the data in the graphs are presented as Me (25%; 75%) [24].

3. Results

In the process of the study, we obtained statistically significant differences in the activity of the human brain under the influence of light passing through a fullerene filter (glasses). The results of the comparison of the power spectra in the respective leads are presented in Figs. 3-5. The differences appeared in the areas of the brain associated with the functioning of the default networks: the lower part of the singular cortex, the right frontal zone, the middle and lower temporal region.

4. Discussion

Since oscillations with low frequencies are characteristic of default networks [8], the data obtained in the delta and theta ranges indicated changes in the activity of exactly the default networks under the influence of fullerene light (Figs. 3-5). The properties of neural networks indicate that low-frequency oscillations are likely to be associated with the possibility of the formation of a neural network of a larger scale. At the same time, higher frequencies are limited by smaller neural networks and can be modulated by the activity of slow oscillations of large neural networks [8].

A fundamental question is understanding of how the
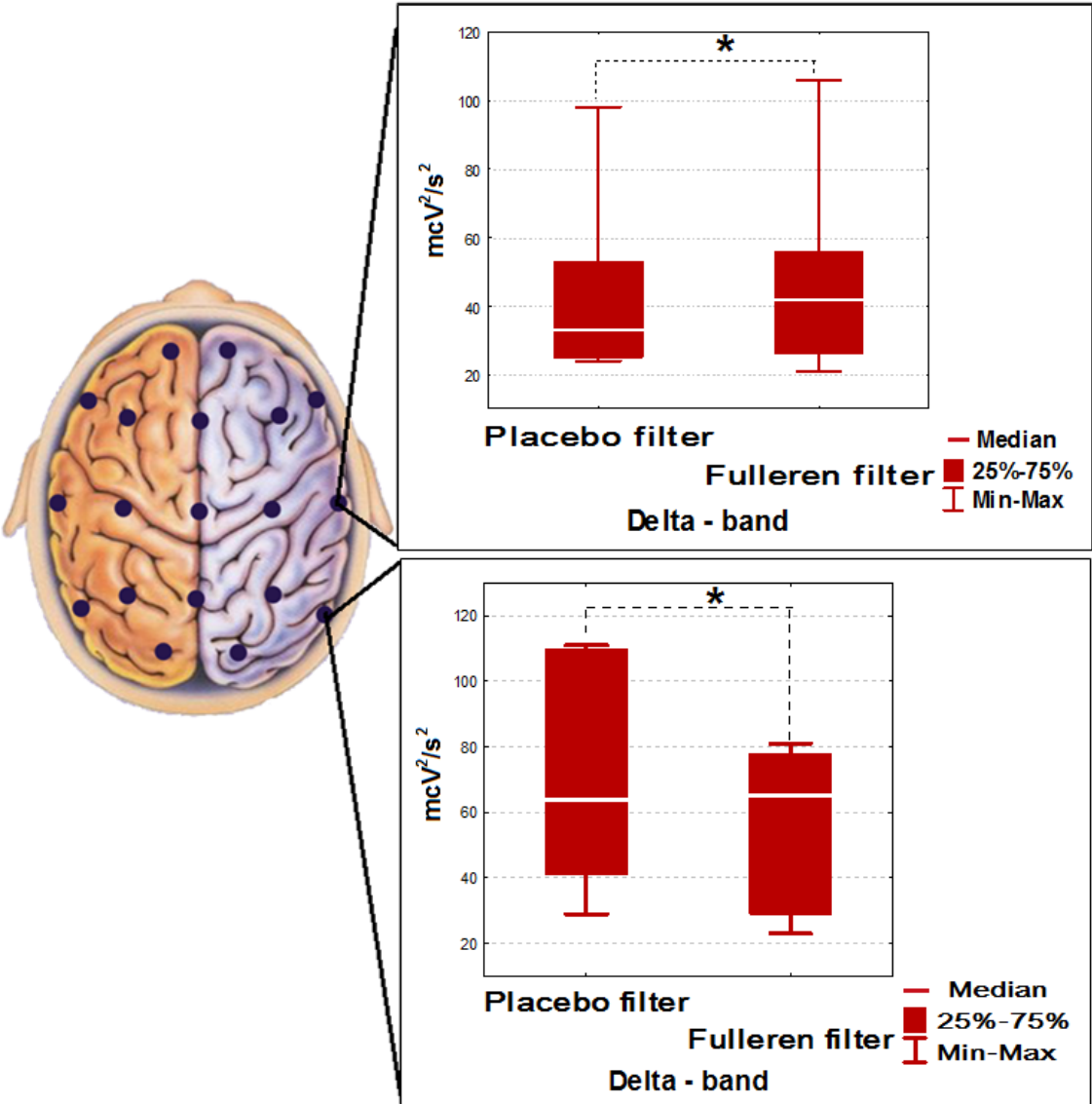
Fig. 3   Statistically significant changes in the brain activity in the middle and lower temporal cortex in humans under the influence of fullerene light (Tesla LightWear) at rest:

White line—median; rectangles—data spread (upper and lower quartiles, 25%-75%); vertical lines with delimiters—maximum and minimum values of indicators.
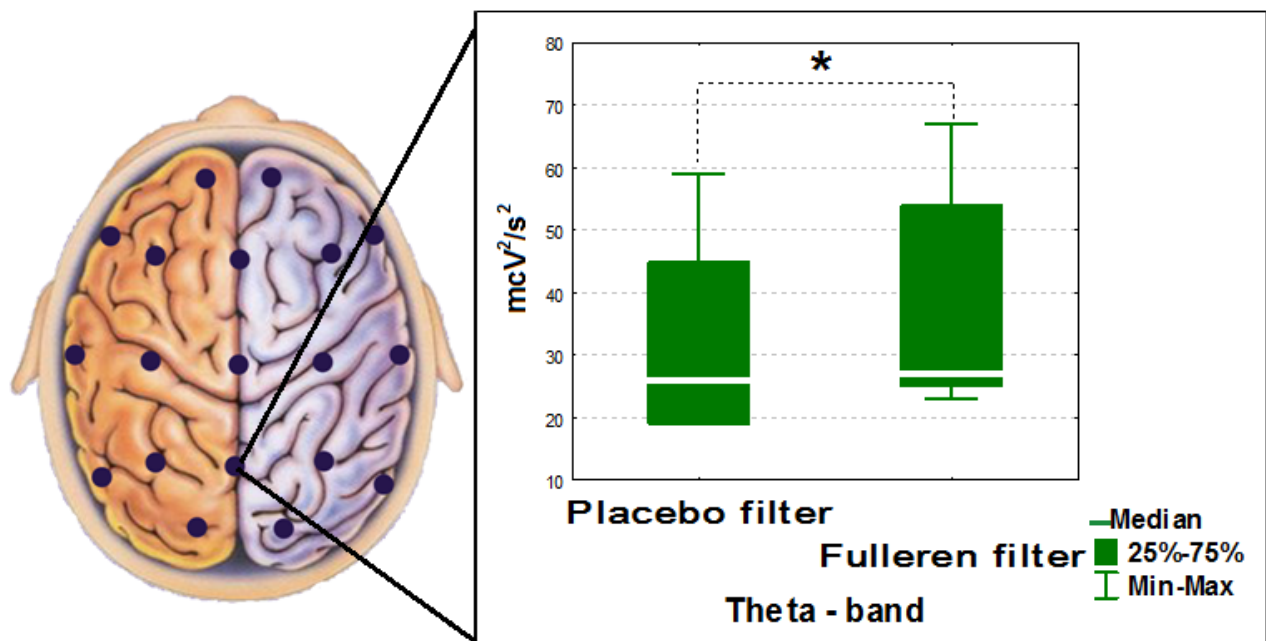
Fig. 4   Statistically significant changes in brain activity in the lower singular region of the human cortex under the influence of fullerene light (Tesla LightWear) at rest.
White line—median; rectangles—data spread (upper and lower quartiles, 25%-75%); vertical lines with delimiters—maximum and minimum values of indicators.
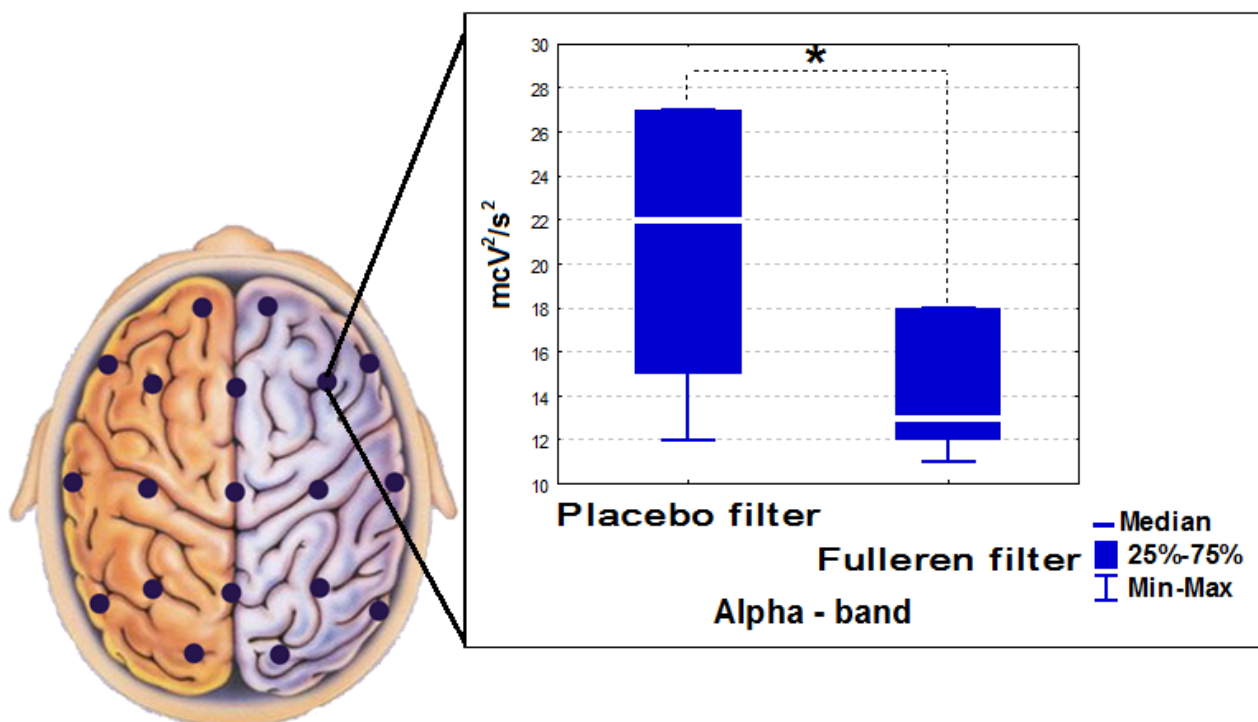
Fig. 5   Statistically significant changes in the brain activity in the right frontal area of the human cortex under the influence of fullerene light (Tesla LightWear) at rest:
White line—median; rectangles—data spread (upper and lower quartiles, 25%-75%); vertical lines with delimiters—maximum and minimum values of indicators.

individual neural blocks of the brain cooperate in solving certain tasks, and what mechanisms underlie this cooperation, which is the basis for all sensory and cognitive processes, as well as motor activity. There is evidence in favor of the hypothesis that low-frequency oscillations synchronize the activity of spatially distributed local neural networks that operate in higher-frequency ranges [8].

An MRI scan showed that the medial prefrontal cortex, the middle temporal lobes, the posterior singular cortex, and, in particular, its retrosplenial region are included in episodic memory processes [25]. Moreover, anatomical connections between the middle temporal lobe and the retrosplenial cortex and between the medial prefrontal cortex and the posterior singular cortex were revealed [26]. Based on the correlation between the localization of EEG leads and Brodman's areas [27] with the differences found in the low-frequency activity of the brain, it can be assumed that the light passing through the fullerene filter into the visual analyzer activated episodic memory processes.

The detected decrease in electrical activity in the alpha range (synchronization) in the right frontal zone indicated the inclusion of this zone in interaction with other areas of the brain. It is known that alpha activity provides local specialized information transformation [28-30]. With the desynchronization reaction, the rhythm amplitude increases, and during synchronization, on the contrary, it decreases. Local synchronization of activity in the alpha range is associated with an active inhibition of information processing and an increase in the interregional functional interrelation of separate areas of the brain.

The frontal zone of the right hemisphere is associated with the processes of operational memory, namely, its component—the visual-spatial notebook [31], in which, according to Baddeley's model of working memory, the figurative and spatial information is stored. This area is also involved in the planning of spatial movements, as well as in spatial orientation [31]. In addition, an increase in activity in

this area for introspectively oriented stimuli was noted [11]. Thus, under the influence of fullerene light, inter-regional synchronization with the involvement of figurative information in the processes of internal thinking has increased.

Activity in the delta range is associated with signal recognition, attention control, processing of incoming sensory streams [32], and it was also shown that the temporal lobe is occupied in the imagination of a hypothetical future [5]. Thus, under the influence of fullerene light, an increase in the activity in the delta range in the temporal zone indicated activation of the figurative modeling of the future, and a decrease in the activity in the posterior temporal zone—a decrease in attention to internal processes, i.e. relaxing.

The posterior singular cortex performs an important adaptive function of the continuous comparison of internal and external information; it is involved in the processes of operational memory and is also associated with the processing of emotionally significant stimuli [26]. This zone of the brain is the most specific zone associated with default networks and can play an important role associated with emotional experiences and episodic memory. Activity in this zone drops when the brain switches to performing an external task [26]. The concept of episodic memory is used to determine the form of memory, which allows you to link numerous types of information in a space-time context. Association or context are two central ideas in the history of the study of episodic memory. The mechanism of association is to establish the relationship between the impressions that simultaneously arise in the mind. One of the main functions of the middle temporal cortex and hippocampus is to combine various features of the episodes into a holistic view and consolidate this view in coordination with the sensory cortex and with the associative areas of the posterior parietal cortex.

Activation of the brain in theta range occurs when coding (remembering) information and its decoding (memories) [28]. Activity in this range is associated

with the organization of a neural network for the task and the subsequent control of erroneous reactions [33].

Thus, the influence of light passing through the fullerene filter was manifested in the intensification of the processes of the introspective emotional experience of past events. In addition, it was shown that in the default networks, low-frequency oscillations in the delta and theta ranges determine the activity of the sensory cortex [34], namely, somatomotor, auditory, and visual. Higher frequencies are associated with higher cognitive functions, such as self-reflection, attention, and operational memory. Therefore, it can be assumed that the ocular influence of the fullerene light manifested itself in the implementation of default networks in a more relaxed, contemplative form. The data obtained also make it necessary to pay attention to the need for a deeper consideration of the role of the two basic components of the light factor under the study. What is crucial—weakening the intensity of the blue part of the spectrum or nano modification of the light flux? Comparison with the data obtained in the placebo glasses indicates that the fullerene-modified light prevails. Since this is a new data, it will be appropriate to reinforce this hypothesis by additional studies of the influence of this factor on other functions of the central nervous system.

5. Conclusions

As a result of the study, the ocular effect of light, nano modified with fullerene, on the state of default networks was identified and statistically confirmed. The examined persons had a more contemplative attitude to the introspective emotional experiences of past events with their active involvement in the figurative modeling of a hypothetical future with elements of reverie.

Acknowledgments

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