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Ocular Influence of Nano-Modified Fullerene Light, 2: Time Correlation of the Choice and Simple Sensorimotor Reactions That Determine Blinding Compensation of the Driver

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Abstract: We studied the ocular effect of light converted by fullerene on the dynamics of a simple sensorimotor reaction, a reaction of choice (CR) and their correlation at the background of recording the electrical activity of the human brain under extreme lighting conditions and inadequate visibility of the object. We examined 17 people (170 surveys of 8 men and 9 women) aged from 18 to 22 years without health complaints, according to the requirements of ethics when working with people. The ocular pathway of light exposure was provided by the use of glasses with fullerene (C_{60}) filters (Tesla Hyperlight Eyewear®) with 0.33 ‰ concentration of fullerene in polymethyl methacrylate organic glass, 2 mm thick. For a placebo, we used glasses in a similar frame with a filter similar in light range, but not containing fullerene. The experimental model reflected the standard situation in which the driver of a vehicle falls in blindingly bright light. We determined the latent periods of a simple sensorimotor reaction and a CR. Electroencephalography (EEG) was recorded with eyes closed and open, with glasses with a fullerene nano-filter and a placebo filter. The Neuron-Spectrum-4/VP (NeuroSoft) complex was used. The recording was carried out mono-polarly, with a quantization frequency of 500 Hz, the electrodes were arranged according to the international system 10-20 in 19 leads. 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, power spectral density (PSD) was calculated. We revealed a decrease in correlation of the latent periods of a simple sensorimotor reaction and the CR when using light modified by fullerene. This indicates an improvement in the rate of inter-hemispheric information processes and improvement in the quality and effectiveness of decisions made. It was found a significant (significant) decrease in the activity of frontal and central zones of the right hemisphere in the delta and beta2 ranges. This indicates a decrease in tension during identification of the stimulus and weakening of the activity of image processing operations, i.e. developing a less stressful state and facilitating the decision-making process. It was evidenced a significant increase in the activity of Posterior cingulate cortex in the theta and alpha ranges. This indicates improved coordination of visual information, attention, assessment of the position of the body, inhibition of irrelevant information and optimization of decision-making processes. The result of these changes was an increase in the speed of central information processing and a shift in focus from image processing to decision-making processes.

Key words: Tesla Hyperlight Eyewear®, THE®-glasses, fullerene, fullerene-converted light, sensorimotor reaction, CR, EEG, “blinding” of the driver.

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1. Introduction

Performing actions where high accuracy, adequacy and coordination of the human movements are necessary, puts forward high demands to his psychomotor capabilities. For example, the time of signal perception and reaction to it are crucial for efficient and safe road traffic [1]. In a sensorimotor reaction, there are distinguished phases of reception, processing of received information and response motor realization, determining the beginning of the movement. A simple sensorimotor response is perhaps, a faster response of the previously agreed simple single motion to a suddenly appearing but previously known signal. An example of such a reaction is pressing a button at a light or sound signal or pressing the brake pedal if the driver, waiting for a red light, prepared in advance for this action. In dangerous driving situations, often only quick actions of the driver can prevent a tragic outcome [2]. It was found that in the most cases of knocking down a pedestrian, the car would have lacked 1-2 meters for a full stop. If the reaction time of the drivers was shorter for a tenth of a second, a catastrophe would have been prevented. Therefore, the reaction time of the driver is directly related to the risk of an accident [3]. A simple sensorimotor reaction is evaluated by the latent period of the reaction (LP), i.e. time from the moment of the appearance of the stimulus, to which attention is drawn, until the onset of the response movement.

Studying the characteristics of the work of the persons performing complex operator activities, for example, transport drivers, it was found that when deciding, a decisive role plays the speed characteristics of processing information by man. However, the result of the reaction is characterized not only by speed, but also by correctness. For example, the reaction is considered unsatisfactory if the direction of a movement or a control algorithm is confused. It should be noted that in the activities of the driver dominate complex reactions. He constantly has to evaluate the rapidly changing traffic situation and choose the appropriate action from a number of possible responses. In this case, it is the speed of information processing that is one of the main components of the choice out of a large number of alternative incentives. It is also established that after a long training the time of such a reaction is approximately equal to the reaction time to only two alternative stimuli (the disjunctive reaction, which is the basic characteristic of the choice reaction).

Studying the functional state of the nervous system, PL is the basic element of the simple sensorimotor reactions, as it is considered to be an indicator of the excitability of the central nervous system (CNS) [4]. In addition, it is found that automobile incidents are directly associated with delayed reactions of drivers [5]. Comparing the choice reaction time and the simple sensorimotor reaction, one should pay attention to their fundamental differences. The choice reaction, in contrast to a simple sensorimotor reaction, requires not only the perception of the signal and the stereotypical reaction to it, but also complex processes of the signal identification, which culminate in the choice of the appropriate action. The duration of the driver's choice reaction is directly related to safe driving [6]. The greatest expenditure of time occurs precisely in the central link, where the operations of information processing and the choice of optimum actually take place. The time of the central switching is related to the speed of the nervous processes mobility in the CNS [7]. This pattern was previously noted in persons under extreme conditions (hyperbaric) and performing responsible operator work [8, 9].

There is a constant search to create conditions that improve regulatory capabilities of the psycho-physiological processes to create optimal reactions of choice. There are directions related to the effect on the CNS by pharmacological neurostimulators, adaptogens, extracts of psycho-activating plants, etc. The effectiveness of these agents are different, most of them cause a total chemical overload up to drug dependence. Therefore, the non-pharmacological way of optimizing operator activity can create conditions for the environmentally beneficial functioning of the structures that underlie complex decision-making mechanisms.

Our pilot study of the use of ocular correction of the visual analyzer by a luminous flux of nano-modified fullerene molecules revealed a number of positive effects [10]. In particular, the features of the activity of default networks were studied with the help of electroencephalography. Analysis of the EEG spectral characteristics showed that a more contemplative attitude to the introspective emotional experiences of past events developed with their active involvement in figurative modeling of a hypothetical future. We made a general conclusion about the possibility of specific changes in the electrical activity of the human brain in response to application of light, modified with fullerene, through a visual analyzer.

In this article, we draw attention to the fact that a person's normal vital activity is accompanied by being in different lighting conditions. They can often have a negative effect in cases of increased demands to the adequacy and speed of the human response in the face of time pressure. We chose a model that describes the standard situation in which the driver of a vehicle falls. In this case, the person finds himself in the most difficult situation, when he has to make decisions in blindingly bright sunlight or "blinding" at night with oncoming headlights. In this paper, we modeled a similar situation to study the effectiveness of a simple sensorimotor reaction and reaction of choice (CR), as well as the electrical activity of the brain and the corresponding reactions of the cortical structures of the brain using two options of light protection. Imitation of the road situation was created by the appearance of a bright stimulus against a dark background (control) and a bright stimulus against the blinding background (experiment).

As a means of correcting emerging CNS disorders and their prevention, we considered the possibilities of fullerene filter glasses (Tesla Hyperlight Eyewear®; THE®-glasses). The credibility of their effectiveness was based on a randomized controlled trial in which an experimental study was conducted using a fullerene filter and a placebo—a darkened filter, with a similar spectrum. The impurity of fullerene weakens the high-energy part of the solar spectrum: it reduces the power density in the UV, violet, indigo, green and yellow ranges [10]. The main difference of this filter is the intended benefit of modifying the light with fullerene at the nano-level. Light photons that fall inside a rotating (speed of rotation 1.8×10^{10} s^{-1}) fullerene ball (C_{60}) interact with areas (hexagons and pentagons) located on its surface that has paramagnetic and diamagnetic properties. As a result, photons receive a spiral correction of their trajectory and their flux acquires additional rotation properties. A hypothetical 2D-energy membrane [$\Phi^2 + \varphi^2 = 3$] participates in the distribution of photons in the beam, which "filters" the resulting photons according to the Fibonacci law. As a result, Tesla's rotational-spiral toroids [11] are formed from the three energy forms of the photon flux, which are applied to biological substrates. The result is a more concentrated and uniform distribution of photons in the light flux (in accordance with the Fibonacci law). As a result, the receptor zone of the fundus, as well as any other object, receives additional stimulation and more complete coverage of each anatomical structure with light radiation [12]. Therefore, additional nervous impulses of the central link of the visual analyzer can improve its energy balance, as well as ensure the irradiation of signals to functionally connected brain areas and their activation.

Purpose: the study of the ocular effect of light, nano-modified by fullerene, on the dynamics of a simple sensorimotor reaction, CR and their relationship against the background of recording the electrical activity of the human brain under extreme lighting conditions and inadequate visibility of the object.

2. Materials and Methods

2.1 Contingent Surveyed

The survey involved 17 people (8 men and 9 women) aged from 18 to 22 years without health complaints, right-handers, students. Testing was conducted voluntarily and anonymously according to the ethical requirements for working with people, 170 surveys were conducted.

2.2 Registration Methods

For EEG registration and analysis, we used the Neuron-Spectrum-4/VP complex (NeuroSoft). The surveys were conducted in a soundproof room. The recording was carried out monopolar, with a quantization frequency of 500 Hz, the reference electrodes were located 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 EEG frequency ranges: 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) we calculated the total power spectrum (power spectral density (PSD), mkV^2/s^2) in the Neuron-Spectrum program. The CNS indicators were tested using a computer program for determining a simple sensorimotor reaction and a CR [13].

2.3 Survey Scheme

EEG was recorded for 3 minutes, in the sample with eyes closed, and 5 minutes—with eyes open in variant 1, in glasses with a placebo filter (of the same spectrum) without fullerene (variant 2) and in glasses with a fullerene filter (Tesla Hyperlight Eyewear®; THE®-glasses), with concentration of fullerene 0.33 ‰ in polymethylmetacrylate organic glass C_{60} @ PMMA, 2 mm thick [11] (3rd variant). Eyeglass frames were lightweight and identical.

In the first test (simple sensorimotor reaction), the subject was given an instruction on the computer screen, following which he would respond to the appearance of the image (square) as quickly as possible by pressing any key. After that, the word “Start” appeared on the screen, 2 s was provided for focusing, after which the first 15 images (squares) were given for adaptation and were excluded from further analysis. Then another 100 images of the main group followed in succession. The pause between them was chosen randomly from the interval of 500-600 ms so that the next signal was expected, but there was no adjustment to the rhythm of presentation of images. The image disappeared after pressing any key, otherwise it was displayed 1,500 ms. The latent period (LP) of a simple sensorimotor reaction with an accuracy of 10 ms was recorded. The speed of the simple sensorimotor reaction (Simple Response Time, SRT, ms) was calculated as the average of 100 reactions of the main group.

We carried out 4 series of surveys (series 1-4): presentation of a bright blue square against the dark background (control); demonstration of a white square on the bright blue background, which simulated a bright sunny day, when a person in light-colored clothes or a poorly visible object (light) may appear on the road in front of the driver; performing a test for determining a simple sensorimotor reaction with a second type of stimulus (white square) in placebo glasses, and in glasses with a fullerene filter.

In the second test (determination of the choice reaction time), we used a computer modification of the classical method of presentation a series of 200 stimuli to the subject. At the same time, in a random order, a square or a triangle appeared on the computer screen, to which it was necessary to react, respectively, with the right or left hand. The computer did not register the erroneous reaction, but expected the correct reaction, that is, the test registered the time required for correct identification of the image (in ms with an accuracy of 10 ms). Similarly, as in the first test, the word “Start” appeared on the computer screen after the instruction to perform the test, 2 s was provided for concentration, after which 5 images were presented, which were considered mainly adaptive, and then 200 images of the main series.

Like in the previous test, the pause between images was randomly selected within the interval of 500-600 ms. We determined the average response rate of the choice (Choice Response Time, CRT, ms). This test was also done in 4 series of surveys (series 5-8) with similar stimuli as for SRT.

Accordingly, during fulfillment of all the tests we recorded EEG.

2.4 Statistical Analysis

Statistical analysis was performed using the Statistica 8.0 software package (StatSoft, USA). The critical level of significance when testing statistical hypotheses were assumed to be 0.05. The distribution of variables was checked for normality by Shapiro-Wilk criterion. Comparison of two dependent samples was performed by the Student's criterion for normally distributed indicators and by the Wilcoxon criterion for abnormally distributed indicators. The data are presented in the form of M ± SD for normally distributed variables and in the form of Me [25%; 75%]—for abnormally distributed.

3. Results

3.1 Correlation of Latent Periods of Simple Sensorimotor Reaction and Selection CR

Since the PL of the simple sensorimotor reaction and the CR were normally distributed (p > 0.05), the Student's criterion was used to compare the two samples. As a result of the study, there were no significant differences in the LP of a simple sensorimotor reaction in the 1-4 series of the test surveys (p > 0.05). Similar results were obtained when comparing the CR when presenting control and blinding stimuli, when there were also no significant differences revealed (p > 0.05) (Table 1).

Let us note that in the situation of choice in glasses with both a fullerene filter and a placebo filter, the subjects reacted significantly faster ($p \leq 0.05$) (Fig. 1).

As noted above, the most accurate regular capabilities of the CNS reflect correlation of the simple sensorimotor reaction and CR, which characterizes the rate of central switching. CRT/SRT distribution was normal (p > 0.05), so pair-wise comparisons were performed using Student's test. As the statistical analysis has shown, the CRT/SRT was the lowest among the subjects, who used glasses with a fullerene filter (Fig. 2). We note that this study did not reveal significant differences either in a simple sensorimotor reaction or in the choice reaction for Types I and II stimuli (Table 1). However, the use of glasses with a fullerene filter (IV) led to the most noticeable improvement in the rate of interhemispheric information processes, although placebo (III) also produced a like effect. This may indicate an improvement in the quality and effectiveness of decisions made. The most dangerous (for the driver) is the significant difference in the rates of a simple sensorimotor reaction and the CR. If the decision-making LPs significantly prevail over the PL of the simple sensorimotor reaction, this indicates that the person can react to the stimulus, although he has not correctly identified it yet. In this case, a person may react, taking a still unformed and unconscious decision, which may provoke emergency situations and

Table 1 The latent period of the simple sensorimotor reaction and the CR.

Options conditions		Valid, No.	Series	SRT: M ± SD, ms	Series	CRT: M ± SD, ms
I	Control	17	1	289 ± 54	5	481 ± 50
II	Day light	17	2	280 ± 55	6	463 ± 48
III	Placebo filter	17	3	290 ± 47	7	436 ± 59
IV	Fullerene filter	17	4	294 ± 40	8	423 ± 65

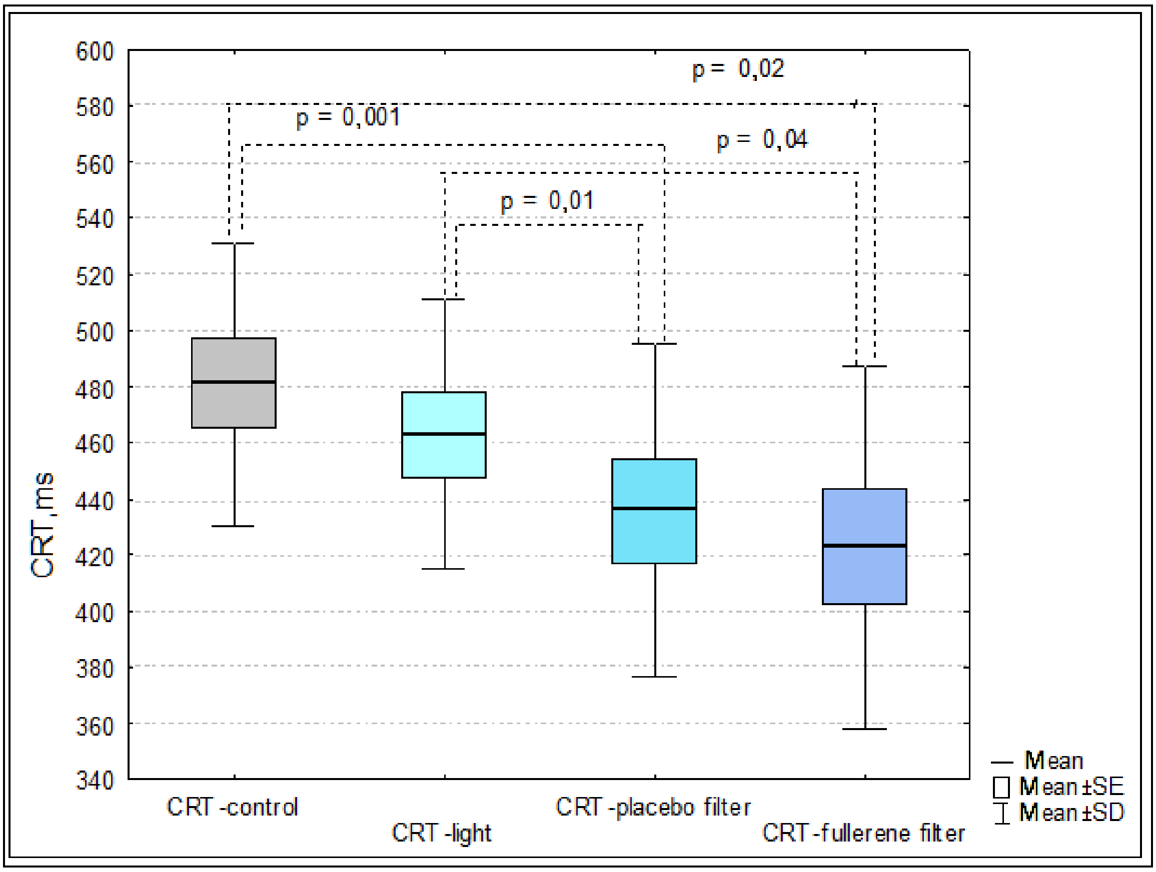

Fig. 1 Latent period of the choice reaction (CRT) depending on external conditions.

inadequate behavior in difficult situations on the road. From the above data it follows that the use of glasses with a fullerene filter significantly reduced the difference in these two reactions (Fig. 2).

3.2 Electrical Activity of the Brain

Distribution of the total power of the electrical activity spectrum of the brain in almost all leads and, in all ranges, differed from the normal ($p \leq 0.05$), therefore pairwise comparisons were made with the help of Wilcoxon criterion. EEG analysis revealed a significant decrease of the activity in the frontal and central zones of the right hemisphere in the delta and beta2 ranges (Figs. 3 and 4). Since activity in the delta range is associated with signal recognition, attention control, and processing of incoming sensory streams [14], a decrease of the activity in this range in the right central zone indicated a decrease of tension during stimulus identification (Fig. 3). Activity in the beta2-range reflects synchronization of the different strategies of multimodal informational choice during the thinking processes, it is also associated with higher cognitive functions and with the knowledge of "per-se" [15]. A decrease in the activity of beta2 range in the right frontal zone (Fig. 4) may indicate weakening of the activity of image processing. Thus, in glasses with a fullerene filter, the activity of the operation of image processing decreased. Probably, such a sedative effect could have contributed to decision making on a less stressful background for the CNS. This is confirmed by previously obtained data about the increase in sleep episodes in animals with tonic pain, under the influence of fullerene light on the acupuncture point E-36 [16].

At the same time, in the Pz lead zone, which is associated with Posterior cingulate cortex [17], it was found a significant higher activity in the theta and alpha ranges (Figs. 5 and 6).

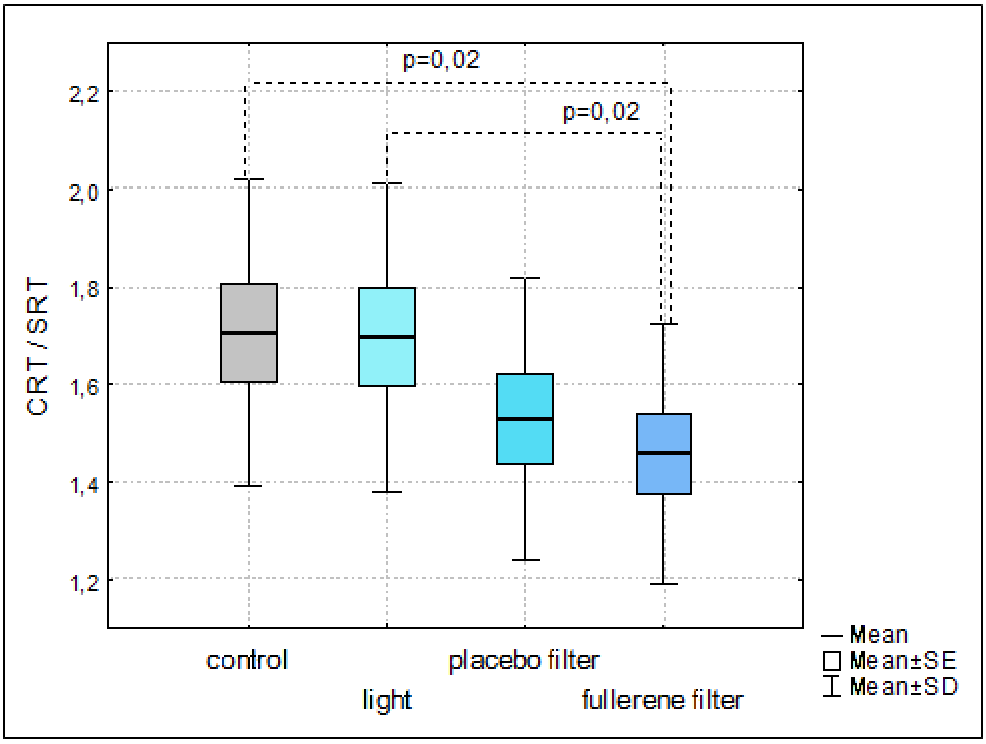

Fig. 2 Correlation ratio of the CR and simple sensorimotor reaction: CRT—latent period of choice response time, ms; SRT—latency of simple response time, ms.

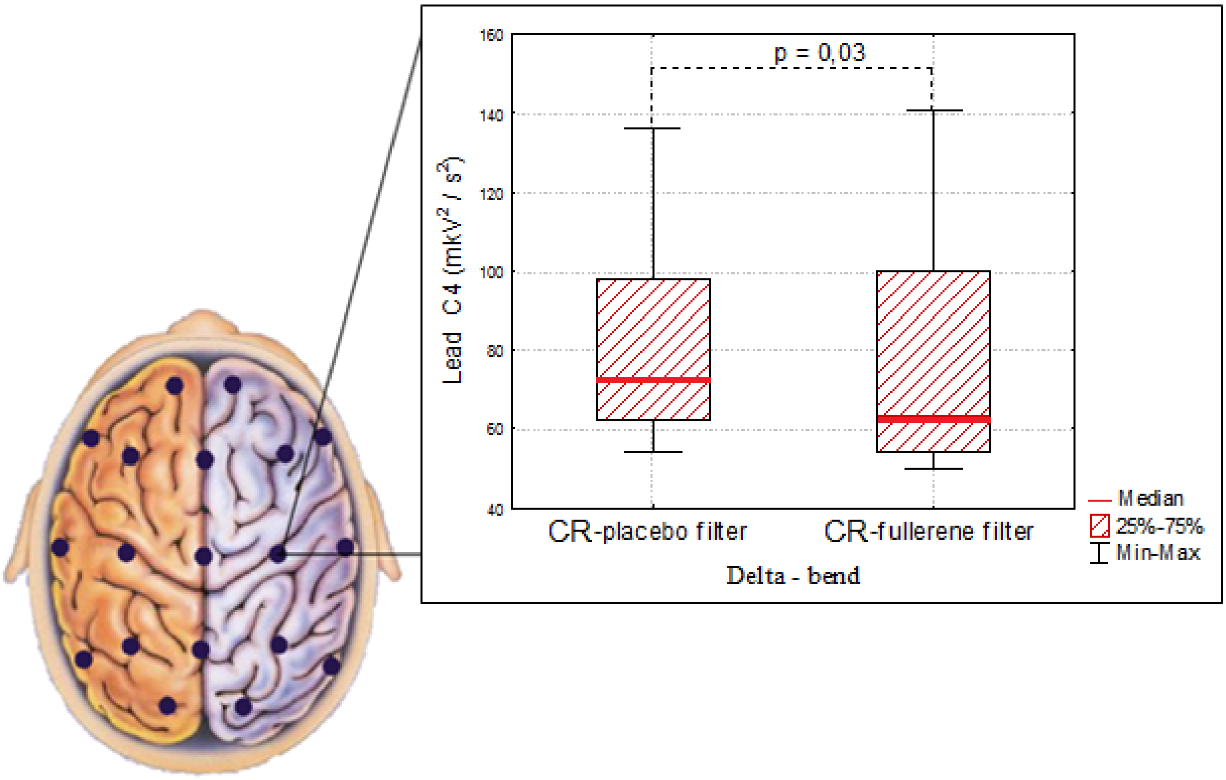

Fig. 3 EEG spectral power in the delta range during testing the CR when using glasses with placebo filter and fullerene filter.

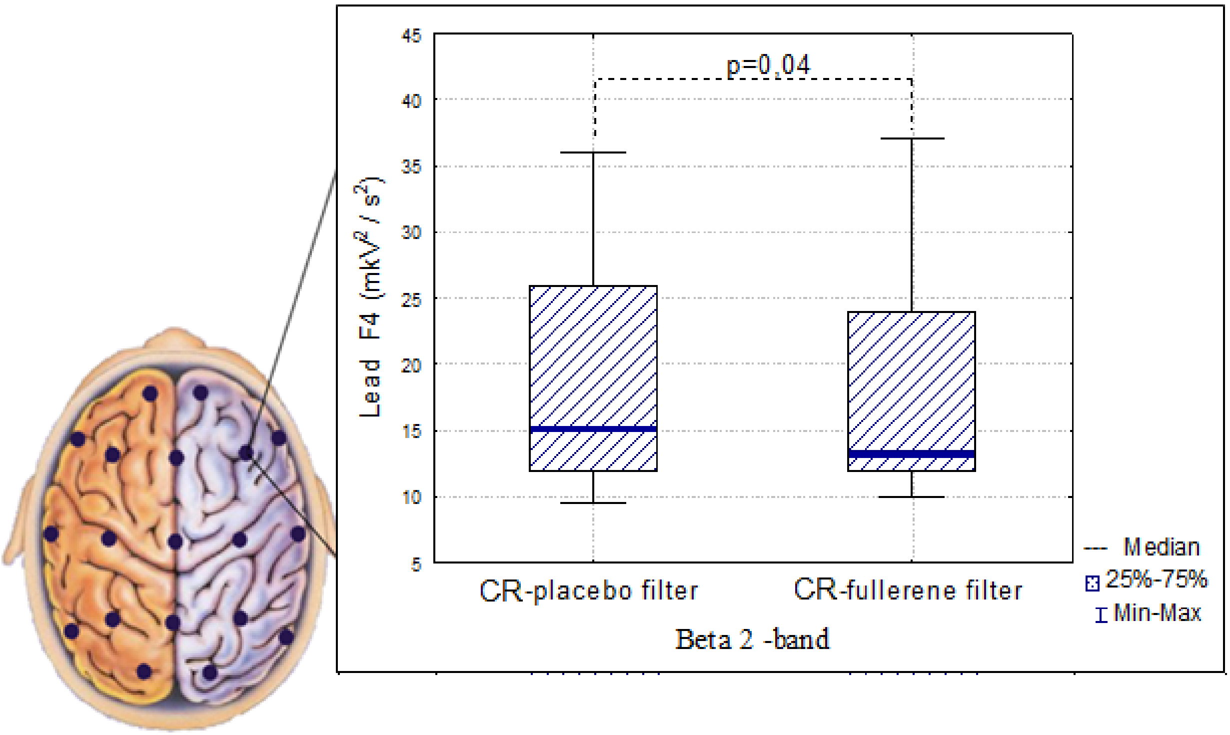

Fig. 4 **EEG spectral power in the beta2-range during testing the CR using glasses with a placebo filter and a fullerene filter.**

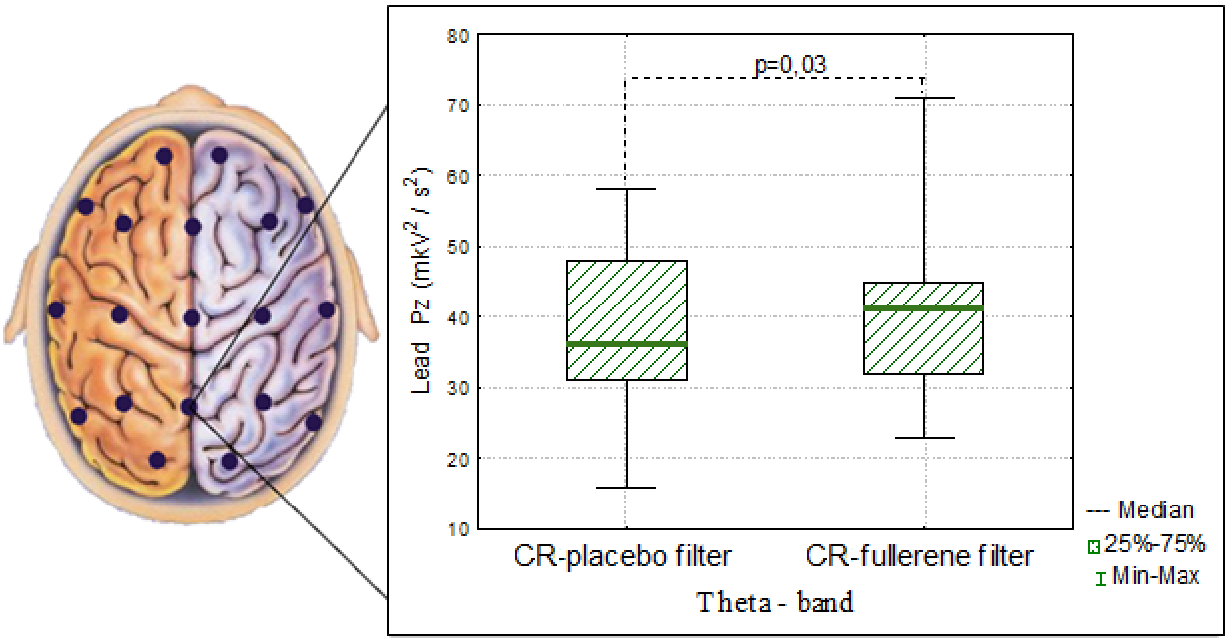

Fig. 5 **EEG spectral power in the theta range during testing the CR using glasses with a placebo filter and fullerene filter.**

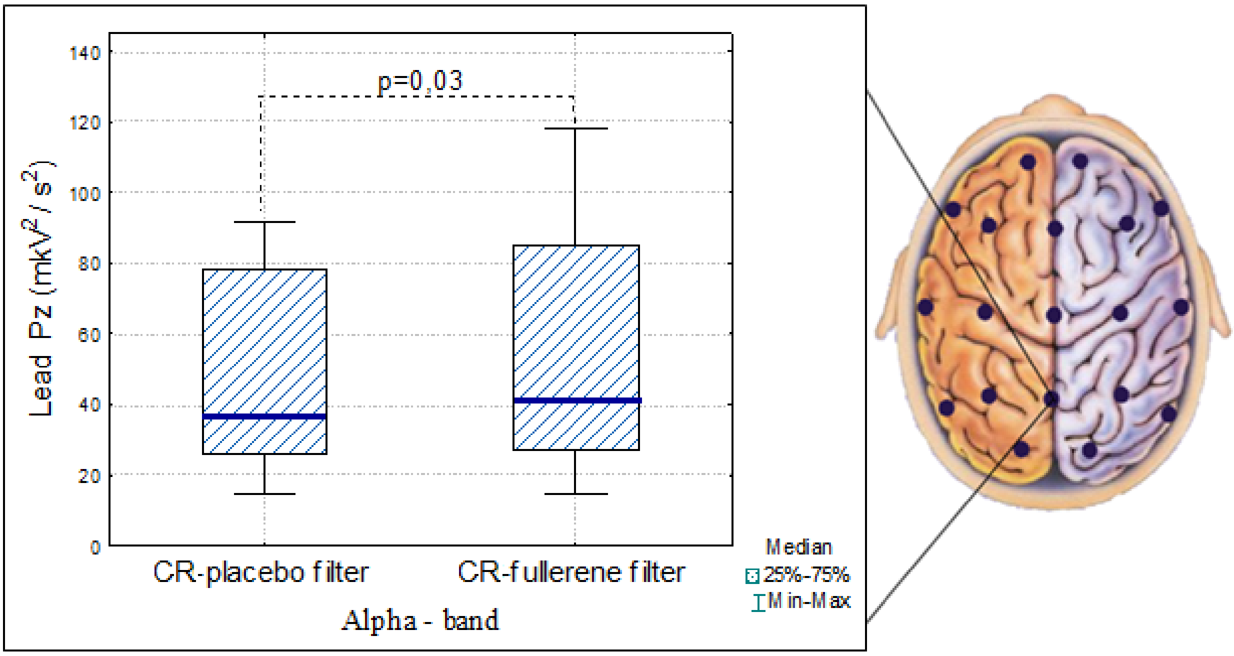

Fig. 6 EEG spectral power in the alpha range during testing the CR using glasses with a placebo filter and fullerene filter.

4. Discussion

According to data [18], neural networks that are activated in the theta range are involved in information coding, as well as in decision-making processes, namely, search for relevant information, including the memory processes. Desynchronization of the activity in the alpha range responds to activation of the top-down control—a mechanism that performs the function of an attention controller over selective, and later on relevant information, by inhibiting other areas of the brain for high-quality processing of this information [18].

Posterior cingulate cortex (PCC) plays a central role in supporting internally-directed thinking [19]. In addition, the PCC is a key part of the control networks of the task fulfilment—the interface between top-down control of visual attention and brain areas connected with motivation [20]. We revealed the PCC role in the processes of learning, memory, assessment of the relationship between requirements and rewards for performing tasks, in assessing the environment and making subsequent changes in the behavior [21]. There were obtained first data on the mechanisms of oneself and one's body correlation in space, which underlie the dynamic interaction of a person with the external world [22]. In this case, PCC plays a major role in the interaction of such areas of the brain as the hippocampus, retrosplenial and intraparietal cortex.

Thus, it can be assumed that the ocular influence of nano-modified fullerene light manifested itself in the activation of neurons located in the Posterior cingulate cortex zone. This testified to the improvement of inter-regional interaction related to the coordination of visual information, attention, assessment of the position of the body in the environment, inhibition of irrelevant information and optimization of decision-making processes. The consequence of these changes was an increase in the rate of information central processing. Thus, compared with the reactions obtained while application of the placebo light, the emphasis shifted from image processing to decision-making processes.

5. Conclusions

The latent periods of a simple sensorimotor reaction and CR in a person under the action of darkness, natural light, converted by fullerene (Tesla Hyperlight

Eyewear®; THE®-glasses) and placebo light have a normal distribution and do not significantly change upon presentation of control and blinding stimuli.

Regulatory capabilities of the CNS (central switching rate) are most accurately characterized by the ratio of simple sensorimotor reaction and CR. The lowest CRT/SRT was when using light modified by fullerene (THE®-glasses). This indicates an improvement in the rate of inter-hemispheric information processes and an improvement in the quality and effectiveness of decisions made.

EEG analysis revealed a significant decrease of the activity in the frontal and central zones of the right hemisphere in the delta and beta2 ranges. This indicates a decrease of stress when identifying the stimulus. EEG activity in the beta2-range reflects synchronization of various strategies of multimodal informational choice throughout the thinking process, it is also associated with higher cognitive functions. Its decrease may indicate weakening of the image processing activity. Probably, such a sedative-like effect could contribute to decision-making on a less stressful background for the CNS.

It was revealed a significant increase in the neuron’s activity located in the Posterior Cingulate Cortex, in the theta and alpha ranges. Neural networks that activate in the theta range are involved in coding information and decision-making processes. Desynchronization of the alpha range activity testifies to activation of the top-down control attention over CR and relevant information by inhibiting other areas of the brain for high-quality processing of this information.

It can be assumed that the ocular influence of light modified by a nanophotonic fullerene filter manifested itself in the activation of Posterior Cingulate Cortex. This testified to the improvement of inter-regional interaction related to the coordination of visual information, attention, and assessment of the position of the body in the environment, inhibition of irrelevant information and optimization of decision-making processes. The consequence of these changes was an increase in the rate of central processing of information and a shift in the focus from the image processing to decision-making processes.

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