Modulation of α-Rhythm and Autonomic Status of Human by Color Photostimulation

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Translated from *Byulleten' Eksperimental'noi Biologii i Meditsiny,* Vol. 149, No. 6, pp. 699-703, June, 2010
Original article submitted March 26, 2010

The effects of photostimulation with different colors on α-rhythm amplitude and parameters of variation pulsometry were studied. Green color stimulation modulates human functions: α-rhythm amplitude increases by 1.06 μV/√Hz ($p<0.05$) and the index of regulatory systems strain decreases significantly ($p<0.05$).

Key Words: *photostimulation; α-rhythm; variation pulsometry*

Control and correction of body functions is now one of the most important trends of biomedical research.

Sensory stimulation with frequency parameters coinciding with some EEG rhythm bands is now often used for non-drug correction of functional disorders in CNS.

The method is based on the effect of stimulation on the level of cortex activation through modulatory systems of the brain, in fact determining the mental and physical status of an individual. The methods of rhythmic stimulation of the visual analyzer are more and more often used for modulation of psychophysiological status [3,4,7], including that in athletes [6].

We studied the effects of color (green, red, and blue) rhythmic stimuli on human functions.

MATERIALS AND METHODS

The study was carried out in young men (students) who gave written informed consent to participation in the experiments, approved by the Ethic Committee of the Institute. The protocol of the study conformed to the philosophy of the Helsinki agreement on human rights. A total of 20 sessions were carried out in 12 volunteers (the majority of them participated in the experiment repeatedly) aged 22-28 years. The volunteers were mentally healthy and had no epilepsy or neurological diseases.

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The study consisted of two stages:

- stage I: rhythmic stimulation with three colors (10 volunteers);
- stage II: rhythmic stimulation with green color with parallel recording of the ECG (8 volunteers).

The studies were carried out in a noise-proof room at reduced light. The main instruction for the volunteer was to sit calmly and relaxed with closed (during background recording) or open eyes and use no strategies of any kind for perception of the stimuli.

EEG was recorded using Neocortex software (Neurobotics) through a Neurovisor BMM digital EEG amplifier in 17 standard leads (O1, O2, T5, T6, T3, T4, P3, P4, Pz, C3, C4, Cz, F3, F4, F7, F8, Fz) according to the International system of electrode positioning 10-20 with indifferent auricular electrodes.

Digitization frequency was set at 1000 Hz. Before digitization, the EEG signal was filtered at 0.5-45 Hz in order to eliminate high- and low-frequency spectral components containing no useful information for the experiment. Interelectrode resistance was did not exceed 5 kΩ. Spectral data were presented as the amplitude spectrum with μV/√Hz shown on axis Y.

Photostimulation was carried out using an APPZA device for photostimulation and photodiagnosis of the visual analyzer (created at our Institute) with three colors (green, red, blue) against the background of slight white fluorescence creating the effect of uniform Ganzfeld field. The photodiode brightness was leveled

0007-4888/10/1496-0759

by the subjective estimations of the volunteers at the level of comfortable sensations. The preset level of photostimuli filling was 60%. The frequency of stimuli release varied from 8 to 14 Hz.

At stage I, the effect of three-color (green, red, and blue) photostimulation on EEG spectral characteristics was studied using eyeglasses realizing the Ganzfeld nonstructurized field principle. First, the basal EEG was recorded for 3 min in volunteers in a calm conscious state with open eyes, calm consciousness with closed eyes, and calm consciousness with open eyes with the "Ganzfeld glasses" in order to detect individual α-rhythm peak for the volunteer. Then photostimulation with red, green, and blue colors was carried out for 3 min with subsequent recording of the recovery period (2 min after each color). This stage of experiment was aimed at detection of the color maximally modulating the spectral characteristics of volunteer's EEG.

At stage II of experiment, the effects of monochromatic photostimulation on variation pulsometry values were studied. Based on the results of stage I, the color most effectively modulating the α-rhythm amplitude was selected. Stimulation with the chosen color was carried out for 10 min using Ganzfeld eyeglasses with registration of ECG before (basal values) and during stimulation and over the 10-min recovery period.

Heart rhythm variability (HRV) was evaluated using commercial Varicard complex with ISKIM 6 software. The time and frequency methods of HRV analysis conformed to requirements of the international standards published in 1996 [5].

The following characteristics of cardiointervals were analyzed: SDNN, RMSSD, pNN50, SI, HF, LF, VLF, and IC.

The effects of photostimulation on HRV values were evaluated by comparing the basal and control values with the values during and after stimulation. Monochromatic stimulation with recording of the electrocardiosignal was carried out in the experimental group. The signal was continuously recorded in lead II for 25 min, after which 5-min fragments of cardiointervalograms were distinguished and processed: the first 5 min (T1) corresponding to basal values; the next 10 min (T2 and T3) corresponding to monochromatic stimulation at the individual α-rhythm frequency; the final 10 min (T4 and T5) corresponding to recovery phase. Similar data were recorded for the control group (without 10-min photostimulation).

Five 5-min cardiointervalograms were statistically processed.

Statistical analysis was carried out using standard methods (*M*: mean value, *m*: standard error). The means for two related samples were compared by the Student *t* test. Variation pulsometry data were processed by the Mann–Whitney *U* test. The statistical hypotheses were verified at the critical level of significance $p=0.05$.

RESULTS

During stage I, a shift of α-peak frequency towards acceleration of α-rhythm in O2 lead during stimulation in the presence of Ganzfeld eyeglasses was found in 100% volunteers. The mean acceleration of α-rhythm was 0.22 Hz ($p<0.05$) in comparison with stimulation under conditions of closed eyes. These data are in line with previous findings indicating the coincidence of EEG spectrum with the relaxed consciousness spectrum [8].

Importantly, the α-rhythm amplitude increased significantly ($p=0.003$) in the presence of Ganzfeld eyeglasses in comparison with calm consciousness with open eyes, but did not reach the maximum in volunteers stimulated with closed eyes (Table 1). The open eyes status with the Ganzfeld eyeglasses can be regarded as the intermediate status between the open and closed eyes.

Hence, two important physiological signs of the effects of nonstructurized uniform visual field on the volunteers in a state of relaxed consciousness with open eyes with the Ganzfeld eyeglasses were revealed: increase of the amplitude in comparison with that under conditions of open eyes and acceleration of α-rhythm in comparison with that with the eyes closed.

The eyes are open and the brain is "tuned" to perception of visual information. Hence, the Ganzfeld nonstructurized field amplifies the photostimulation effect, excluding other sources of illumination (1), providing even exposure of the entire visual field (2), and causing an appreciable increase of α-rhythm amplitude in a volunteer with the eyes open, which is characteristic of conscious, but relaxed status, promoting the perception of new information (3). In ad-

TABLE 1. Effects of Nonstructurized Field (Ganzfeld Eyeglasses) on α-Rhythm Amplitude ($M\pm m$)

Basal records	Mean amplitude of α-rhythm± standard deviation, μV/√Hz
Closed eyes	1.17±0.58
Open eyes	0.50±0.24
Open eyes (Ganzfeld eyeglasses)	1.02±0.39

Note. $p=0.003$ for values recorded with open eyes and open eyes with Ganzfeld eyeglasses.

dition, this effect provides a less contrast exposure in comparison with photostimulation against the dark background.

Photostimulation with three colors (red, green, and blue) showed significant changes in the amplitude under the effect of photostimulation (Fig. 1).

The results indicate a significant increase in α-rhythm amplitude under the effect of green and blue photostimulation, the greatest increment being observed in response to green (2.08 μV/√Hz) *vs.* blue (1.54 μV/√Hz) stimulation.

Manifest α-rhythm is traditionally regarded as an indicator of rest, relaxation, while the increase of EEG α-rhythm spectral amplitude in the occipital leads can be regarded as an indicator of relaxation after stimulation with the green color. The experimental findings confirm the previous conclusions [2] on the increase of spectral power after green stimulation and a significant decrease in the time of the common sensorimotor reaction after green photostimulation in the majority of volunteers, indicating the optimizing effect of the exposure on the functional status.

These data indicate that for the majority of volunteers photostimulation is an effective modulator of EEG α-rhythm activity. The increase of α-rhythm amplitude during photostimulation is obviously a positive sign of the functional status optimization in humans. In addition, the increase of α-rhythm amplitude positively correlates with the efficiency of memory processes in general.

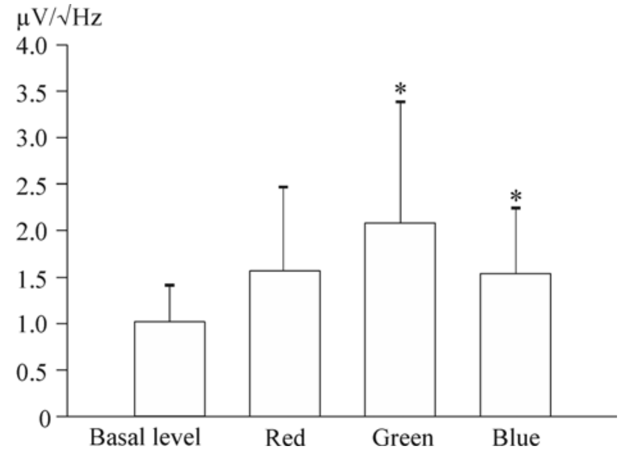

Fig. 1. Amplitudes of individual α-peak under the effects of photostimulation with three colors. *$p<0.05$ compared to basal values.

Results of stage II experiments (the effects of 10-min green photostimulation on HRV values) are summed up in Table 2.

A significant reduction of heart rate and increase of the time parameters (significantly higher SDNN and pNN50) in comparison with the basal values were recorded during photostimulation, indicating stimulation of the parasympathetic nervous system.

Analysis of low-frequency (LF) component of the spectrum showed a trend to reduction of the absolute value at the beginning of exposure in comparison with the initial measurements. This parameter increased

TABLE 2. Mean HRV Values in Volunteers at Different Stages of Experiment (*M*±*m*)

Stages	T1	T2	T3	T4	T5
	basal values	photostimulation		recovery	
Heart rate	75.8±8.9	72.6±8.7	71.9±10.4*	73.1±8.3	73.1±8.8
RMSSD, msec	42.0±15.2	45.5±17.4	52.6±25.9	49.4±22.0	53.9±17.3
pNN50, %	15.7±15.0	19.2±17.7	24.8±22.6*	19.6±18.1	21.7±17.5
SDNN, msec	43.4±16.4	45.9±11.4	58.4±22.5*	50.3±16.5	54.6±22.3
SI	192.6±131.3	138.8±71.2	101.0±70.4*	123.4±80.5	168.6±172.8
HF, $msec^2\times1000$	0.69±0.36	0.86±0.64	1.17±0.88	1.07±1.08	1.18±0.60
LF, $msec^2\times1000$	1.24±1.39	0.86±0.55	1.40±0.99	1.34±0.81	1.78±1.47
VLF, $msec^2\times1000$	0.33±0.19	0.48±0.72	0.72±0.85	0.50±0.33	0.71±0.44*
IC	2.4±1.3	2.4±1.8	1.9±0.7	3.1±2.7	2.2±1

Note. $p<0.05$* compared to basal value (T1). RMSSD: square root of the mean of the sum of squares of differences between adjacent intervals; pNN50: percentage of total number of successive pairs of intervals differing by more than 50 msec throughout the entire period of recording; SI: regulatory systems strain index, calculated by analysis of cardiointerval distribution curve; HF: power of high frequency component of the spectrum (respiratory wave); LF: power of low frequency component of spectrum (first-order slow waves or vasomotor waves); VLF: power of very low frequency component of spectrum (second-order slow waves); IC: index of centralization reflects the proportion between central and peripheral mechanisms of heart rhythm regulation (VLF+LF)/HF.

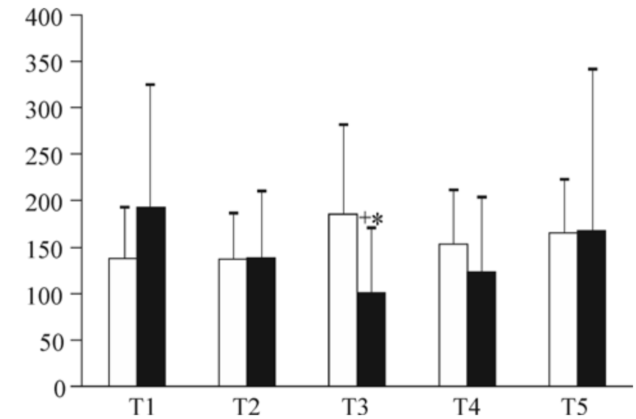

Fig. 2. Time course of SI in the control group (light bars) and in the group exposed to green photostimulation (dark bars). Here and in Fig. 3: p<0.5 compared to: *basal level (T1) and +control.

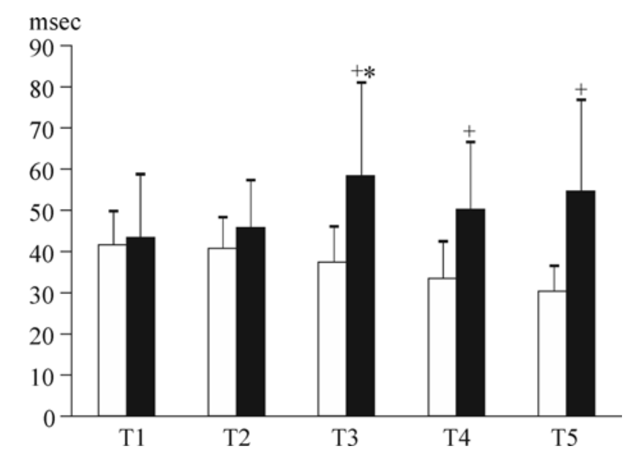

Fig. 3. Time course of SDNN in controls (light bars) and in volunteers exposed to green photostimulation (dark bars).

significantly (p<0.05) during photostimulation, this indicating stimulation of the vasomotor center.

The increment in the absolute value of the variability spectrum power high frequency (HF) component (69.6%) indicates an increase in the activity of parasympathetic regulation, retained after photostimulation. The increment of VLF power absolute value (121%), reaching the level of significance (p<0.05) during the recovery period, presumably indicates the mobilization of energy and metabolic reserve.

Reduction of index of centralization (IC) during photostimulation, characterizing the proportion of the central to peripheral mechanisms of cardiac rhythm regulation, can indicate normalization of the regulatory processes realized by the autonomic nervous system [2].

The significant (p<0.01) reduction of the strain index during photostimulation (T3) in comparison with the basal value indicates an increase of the total HRV, stimulation of the parasympathetic nervous system, and reduced activities of the sympathetic regulation mechanisms (Fig. 2). In addition, it is noteworthy that the regulatory systems strain index decreases significantly (p<0.05) during the second half of the photostimulation session (T3) in comparison with the control group. Experimental data indicate reduced strain of the regulatory systems under the effect of 10-min green photostimulation.

The summary index of *RR* intervals variability throughout the entire period analyzed (SDNN) indicates activity of the parasympathetic component of autonomic regulation. The time course of SDNN changes in the group exposed to photostimulation and in the control group indicates a significant (p<0.05) increase in this parameter starting from the second half of the photostimulation period and persistence of this effect until the end of the 10-min recovery period (Fig. 3). These data indicate more intense work of the parasympathetic compartment of the autonomic nervous system.

Hence, green photostimulation shifts the balance between the autonomic nervous system sympathetic and parasympathetic compartments: reduction of the sympathetic effects on heart rhythm and stimulation of the parasympathetic component. Virtually all these autonomic shifts approach the basal values by the end of the 10-min recovery period.

On the whole, these results suggest regarding the color photostimulation with the APPZA device as an effective method for total systems rehabilitation under conditions of professional activity.

The study was supported by the Ministry of Education and Science of the Russian Federation (State Contracts Nos. 02.522.11.2015 and 02.740.11.0300).

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