# Electroencephalography Registration of Laser Acupuncture Action on Children with Autism Disorder

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Abstract: Laser action on acupuncture points is an alternative to traditional acupuncture. We used red semiconductor laser diodes with a wavelength of 650 nm. Three acupuncture points (GV20, LI4, P6) were selected to relieve headaches and reduce anxiety in the study. EEG data had been obtained from two siblings, one of whom is without pathologies of the nervous system (8 years), and the second has a diagnosis of autism (10 years). A significant increase in the total activity of the brain for ASD patients up to a value close to the brain activity of healthy patients was registered.

## 1 INTRODUCTION

Electroencephalography (EEG) is one of the most informative methods of studying the human brain from the standpoint of its holistic systemic activity. This method is based on recording the total electrical activity of brain neurons from the surface of the scalp. EEG makes it possible to analyze qualitatively and quantitatively the functional state of the brain and its reactions under the influence of stimuli. EEG recording is used widely in medical diagnostics and treatment, in anesthesiology, as well as in the study of brain activity related to the implementation of functions such as perception, memory, and adaptation (Louis et al. 2016).

Functional tests are of great importance in the diagnosis of brain lesions: intermittent light irritation (photostimulation), enhanced deep breathing for 2-3 minutes (hyperventilation), sound irritation, research after a sleepless night (sleep deprivation), and others.

It is possible to identify changes in the EEG in 90% of patients with epilepsy using functional tests (Dziadkowiak and Podemski 2019). The EEG allows registering neoplasm transformation when the tumor is located close to the surface of the brain and affects mainly the cortex and subcortical structures. Local pathological changes in the area of the projection of the tumor are noted, such as inhibition of the alpha rhythm, an increase in the amplitude of delta waves (Roohi-Azizi et al. 2017). Intracerebral tumors cause significant general changes in the EEG, masking focal disorders of biopotentials.

Autism spectrum disorders (ASD) are a group of lifelong disorders of the nervous system, and it is believed to be the result of atypical neural connections in the brain (Belmonte et al. 2004), (Wang et al. 2013), (Assaf et al. 2010). Studies show that ASD can be described as a dynamic disorder and analyzed in terms of complex dynamic systems (Bosl et al. 2011), (Megremi 2014). Changes in cortical excitability may contribute to or be a manifestation of disorders of connectivity (Boutros et al. 2015).

In (Duffy and Als 2019) showed that in patients (N = 430 children) with a diagnosis of autism aged 2 to 12 years, the connections between different parts of the brain are disrupted partially, which is reflected in the EEG shape. To estimate the level of these interactions, the authors have used the degree of coordination (coherence) of the waves of electrical activity in various areas of the brain. As a result of a

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computer analysis of EEG signals, the authors managed to identify 33 areas of wave combinations characteristic only for autists, statistically different from the EEG signals of children from the control group, and this applies to all age categories.

Studies show that individual rehabilitation of a person with autism has the most positive effect on his abilities. There are various ways of influencing the brain to rehabilitate the patient, including transcranial magnetic stimulation (TMS), transcranial micro polarisation (TCMP) and reflexotherapy.

The TMS, as a method for treating ASD, is based on the stimulation of brain neurons with an alternating magnetic field and recording responses to stimulation using electromyography (Eldaief et al. 2013). The essence of this approach is the occurrence of depolarization of the membranes of nerve cells under the influence of a strong magnetic field. TMS helps to regenerate neural connections in the cerebral cortex, allowing purposeful stimulation non-invasively individual structures of the cerebral cortex. Depending on the regimen chosen by the specialist, the effect on the central nervous system can be either exciting or inhibitory. Regardless of the type of influence, in the tissues of the cerebral cortex, there is an improvement in the intercellular interaction and all types of metabolism, and the blood microcirculation is normalized. Some of the clinical trials of the effectiveness of the TMS method suggested that its use can help alleviate symptoms such as irritability and stereotyped behavior, as well as reduce the manifestation of autism symptoms associated with deficiencies in areas of functioning and connections such as coordination of vision and arm movement, development of social skills (Oberman et al. 2016).

The TCMP of the brain consists of exposure to certain parts of the brain with an electric current of low intensity and is used in the comprehensive rehabilitation of children with various forms of cerebral palsy and other central nervous system disorders, speech disorders, hearing loss, stuttering, and so on. With the appointment of TCMP, the EEG is recorded, based on the data of which the areas for applying electrodes of the micro polarisation circuit are determined. Thus, selective stimulation by microcurrents of the weakened areas of the brain responsible for the formation of speech, motor activity, and mental development, allows achieving a significant restoration of their functionality.

Reflexotherapy, as a method of rehabilitation in autism, is based on exposure on biologically active points located on the skin. As a result of exposure, a local, regional or general reaction of the body is caused, which leads to a restoration of balance in the nervous, immune, endocrine systems, the production of biologically active substances that block nerve impulses and lead to pain relief, muscle relaxation, stress relief, normalization of motor, autonomic and emotional reactions in the body, regulation of blood pressure.

One of the classic methods of reflexotherapy is acupuncture, and one of the most innovative methods is laser exposure to bioactive points. The main objective of reflexotherapy in children with autism is to strengthen the neuroendocrine links in the regulation of autonomic tone and activation of the subcortical formations of the brain. As a result of the treatment, a decrease in stereotyped hyperkinesis and phobias is observed, which helps to compensate for the condition of children and their adaptation in the family and children's team (Cheuk et al. 2011).

Laser action on acupuncture points is an alternative to traditional acupuncture. Low-level laser stimulation causes biological and physiological changes. Using various frequencies of laser stimulation was showed to cause activation of different areas of the brain (Hsieh et al. 2011).

In the previous study (Knyazkova *et al.* 2019), we showed that laser stimulation at the Hegu (LI4) acupuncture point with low-level laser exposure ($\lambda$ = 532 nm) entails a redistribution of brain activity between its regions, without changing the average total brain activity.

The aim of this work is to test the laser reflexotherapy as a way of individual rehabilitation of a patient with autism.

## 2 MATERIALS AND METHODS

### Acupoint Selection and Application Protocol in Our Study

Three acupuncture points were selected to relieve headaches and reduce anxiety in the study.

BaiHui (GV20) is one of the most important points of the Du (the government vessel) meridian and is commonly used in neurology and psychiatry. It is located on the crown, at the intersection of the line connecting the tops of the two auricles and the midline of the head, behind the front line of hair growth (see Figure 1a). The main therapeutic effects of the GV20 are usually relief from headache, stroke, dizziness, tinnitus, and anxiety (Satoh et al. 2009), (Zhao et al. 2007). In addition, this point is used to activate the area of association (associated with emotions, memory, and behavior).

The Hegu point (LI4), also known as large intestine 4, is located in the meridian of the colon in the middle of the 2nd metacarpal bone on the radial side (see Figure 1b). LI4 is considered one of the most effective acupuncture points for general pain control, especially headaches (Luong et al. 2018).

Nei Guan (P6) is commonly used to relieve nausea, motion sickness, and headaches (Ezzo et al. 2006), (Lee and Fan 2009). P6 is located three fingers below the wrist on the inner forearm between the two tendons (see Figure 1c).

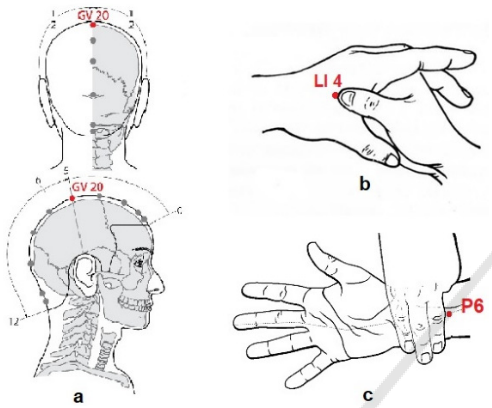


Figure 1: a - BaiHui (GV20), b - Hegu (LI4), and c - Nei Guan (P6) acupoint.

EEG data had been obtained from two siblings, one of whom is without pathologies of the nervous system (8 years), and the second one has a diagnosis of autism (10 years). Participation in the study of one child with autism and the selection of the necessary individual parameters is explained as an approach to personalized medicine and individual rehabilitation. The study protocol was approved by the local ethics committee of TSU. Adult participants and official representatives of the minors signed "the informed consent" to the manipulation.

The subject was supposed to take a comfortable position in the chair, which allowed him to relax the muscles of the head, neck, and belt of the upper extremities as much as possible, the left hand and forearm of the right hand were released to attach the lasers. It was forbidden to talk, chew anything, completely close my eyes, remove the mounts for lasers. In the case of a child with autism, hand movements and slight head movements were allowed.

A helmet was put on a participant's head with electrodes located according to the standard international scheme 10-20 (Figure 2). The electrodes were pre-lubricated with a special conductive gel for EEG studies.

| | |
|---|---|
| 1 | Fp1-A1 |
| 2 | Fp2-A2 |
| 3 | F3-A1 |
| 4 | F4-A2 |
| 5 | C3-A1 |
| 6 | C4-A2 |
| 7 | P3-A1 |
| 8 | P4-A2 |
| 9 | O1-A1 |
| 10 | O2-A2 |
| 11 | F7-A1 |
| 12 | F8-A2 |
| 13 | T3-A1 |
| 14 | T4-A2 |
| 15 | T5-A1 |
| 16 | T6-A2 |

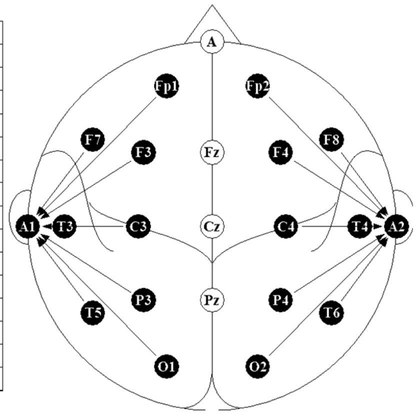


Figure 2: Scheme electrode overlay 10-20.

Data were recorded in a state of calm wakefulness with open eyes when watching a video clip (cartoon). Note that to avoid the occurrence of random artifacts during EEG recording, all objects that could distract children from the cartoon were out of sight.

We used a CONTEC KT88-1016 digital 16-channel EEG analyzer (China) with the EEG18V5.0.3 software. The recording time was reduced to 5 minutes because there was no purpose to track the temporal dynamics of any pathology, it was only necessary to capture the moment when the laser was turned on and to determine whether there was a laser effect on the functioning of the brain in a state of calm wakefulness with open eyes.

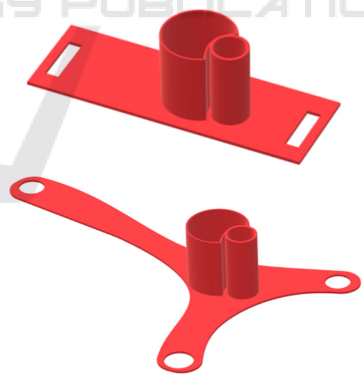

Figure 3: Holders for points GV20, P6 (top), and for point LI4 (bottom).

We used red semiconductor laser diodes with a wavelength of 650 nm. Special holders have been developed to fix the lasers at selected acupuncture points (see Figure 3). Holders printed on a 3D printer made of PLA plastic.

Laser diodes were fixed in the holders and connected to a YIHUA 305D power supply with an adjustable output voltage in the range from 0 to 30V, an output power of 150W and an adjustable output current from 0 to 5A. The measurements were carried out at the following power values: 3 mW, 4 mW, and 5 mW. Table 1 shows the output voltage values and the corresponding current power value.

Table 1: The output voltage values for the corresponding current power value.

| Power | Voltage |
|---|---|
| 3mW | 2V |
| 4mW | 2.5V |
| 5mW | 3V |

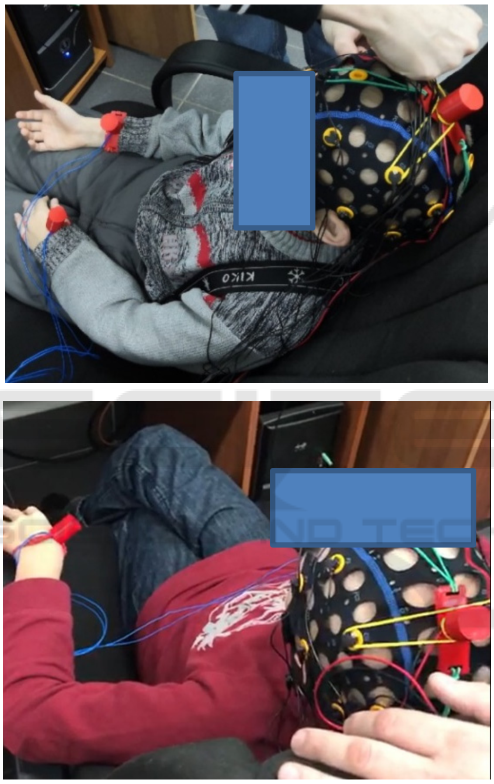

Figure 4: Disposition of lasers in selected acupuncture points for a healthy child (top) and a child with autism (bottom).

Lasers were placed on the hands and head of a subject at the selected acupuncture points and were fixed (see Figure 4). The diodes were mounted at a distance of approximately 30 mm from the skin (spot area 0.31 cm$^2$) and perpendicular to the selected point. Each of the selected points was stimulated by the laser for 2.5 minutes.

We used power spectral density (PSD) to describe the EEG signal. The PSD describes a signal spectral power distribution as a function of frequency. To calculate PSD, the truncated Fourier transform $\widehat{U}(\omega)$ in a finite interval $[t_1, t_2]$ of a raw signal $U(t)$ was calculated:

$$\widehat{U}(\omega) = \frac{1}{\sqrt{T}} \int_{t_1}^{t_2} U(t) e^{-i\omega t} dt.$$

We used $T = t_2 - t_1 = 20$s.

Then the power spectral density (Rieke and Warland 1999), (Millers and Childers 2012) can be calculated

$$S_{UU}(\omega) = \lim_{T \to \infty} \mathbf{E}\left[\left|\widehat{U}(\omega)\right|^2\right],$$

where **E** denotes an expected value.

The PSD used to compute a variance of a process (net power) by integrating over frequency (Storch and Zwiers 2001)

$$\mathrm{Var} = \frac{1}{\pi} \int_0^{\infty} S_{UU}(\omega) d\omega.$$

## 3 RESULTS

A preliminary study had been conducted with a group of healthy adults. Low-level laser stimulation was shown to be able to change the power of rhythms in the head region, which corresponds to the stimulation of various brain regions (Knyazkova et al. 2019).

Similarly (Knyazkova et al. 2019), an EEG signal in a 300 s interval was divided into two parts, where the first 150 seconds are the signal without any laser action, and the second 150 seconds are the signal when exposed to lasers. To minimize the factors associated with the beginning and end of signal acquisition and the inclusion of lasers, a time interval of 90 s was cut from each part of the interval center. Significant noise in the form of emissions was observed in this area (Figure 5) associated with patient movements.

Note that patients diagnosed with ASD have much more such noise. Noise removal (filtering) in the form of emissions was carried out by means of a combination of gradient methods (Kistenev et al. 2019), taking into account the threshold value of the absolute value of 80 µV. The limitation of 80 µV obtained by us in preliminary studies characterizes the maximum value of the signal generated on the surface of the head during negligible movements of patients. Figure 5 bottom shows the result of the filtering of the signal depicted in Figure 5 top.

The minimum time interval of the signal after filtering during the study in all cases was more than 50 s, therefore, when analyzing the data, intervals of 50 s were used (the rest of the signal was discarded).

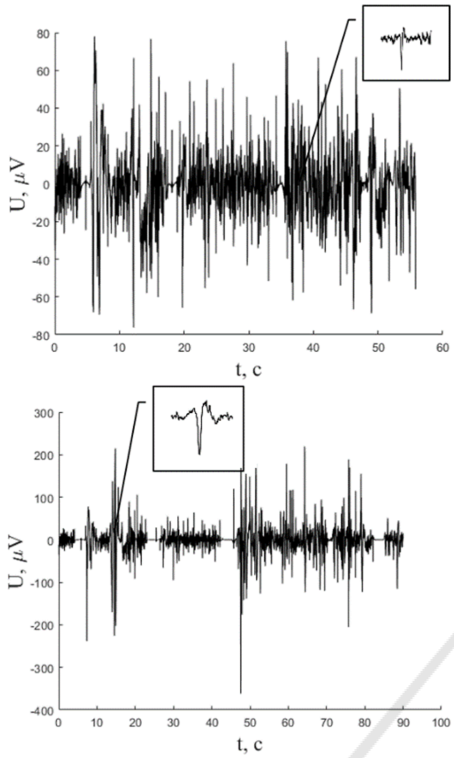


Figure 5: Example of an EEG signal from a healthy child (top image) and a patient with ASD (bottom image) in which there are noise components in the form of ejections.

A discrete window Fourier transform (Sherlock 1999) was applied to the filtered signal (Figure 5, bottom), and many different spectrograms were constructed with the Hamming weight function (Harris 1978), the length of which was varied so that it was possible to analyze time intervals from 0.1 s to 50 s in duration. When constructing spectrograms, the overlap of adjacent signal segments varied from 0 to 50%.

Figure 6 shows an example of the dependence of the PSD (Maral 2003)of the EEG signals averaged over the window of the spectrograms for a healthy child and a patient with ASD. It can be concluded that the energy density signal from all electrodes for the patient with ASD is significantly lower than for the healthy child.

Figure 7 shows an example of a dependence of PSD averaged over the spectrogram window of EEG signal signals for a healthy child and a patient with ASD when exposed to laser radiation with a wavelength of 650 nm at various power levels.

It is obvious that when exposed to lasers, the energy density in a patient with ASD significantly increases at all leads with increasing radiation power.

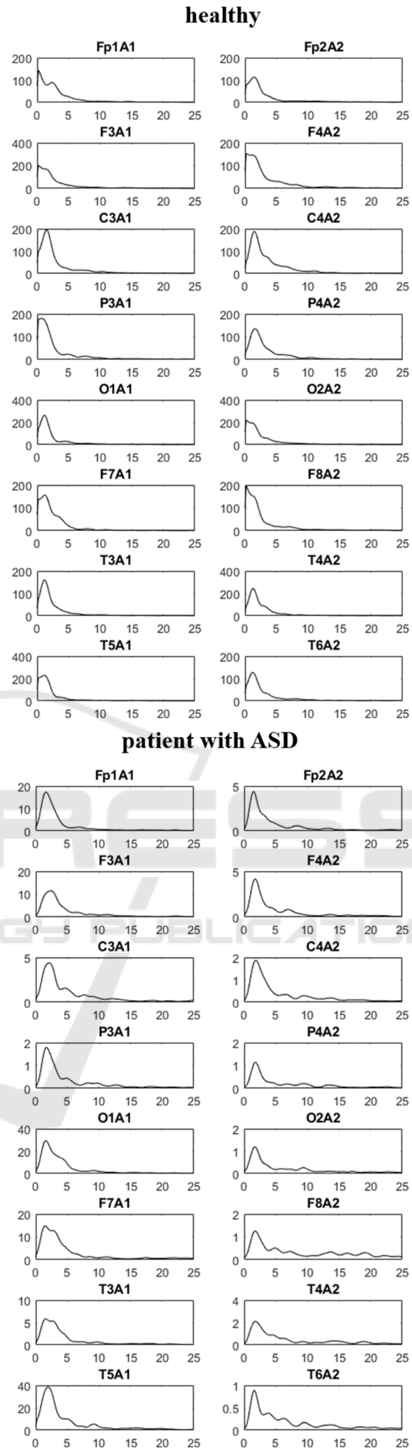


Figure 6: The dependence of the PSD on the frequency (Hz) averaged over the windows of the spectrograms for a healthy child (top) and a patient with ASD (bottom).

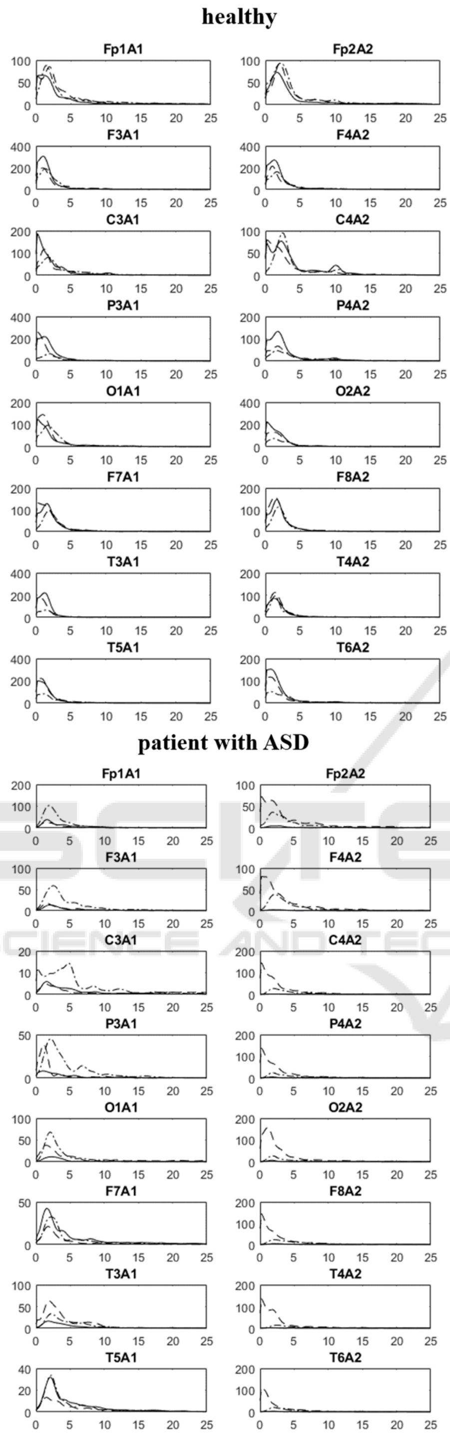


Figure 7: Dependence of the PSD on the frequency (Hz) averaged over the window of the spectrograms for a healthy child (top) and a patient with ASD (bottom) when exposed to laser radiation with a wavelength of 650 nm at a power: 3mW - solid line, 4mW - dash - point line, 5mW - dotted line.

The energy density in a healthy child does not change significantly.

It was shown, that when exposed to Hego's point, the total brain activity does not change on average for healthy participants, but a redistribution of brain activity between its spatial regions takes place (Knyazkova et al. 2019). A significant increase in the total activity of the brain for ASD patients up to a value close to the brain activity of healthy child was registered.

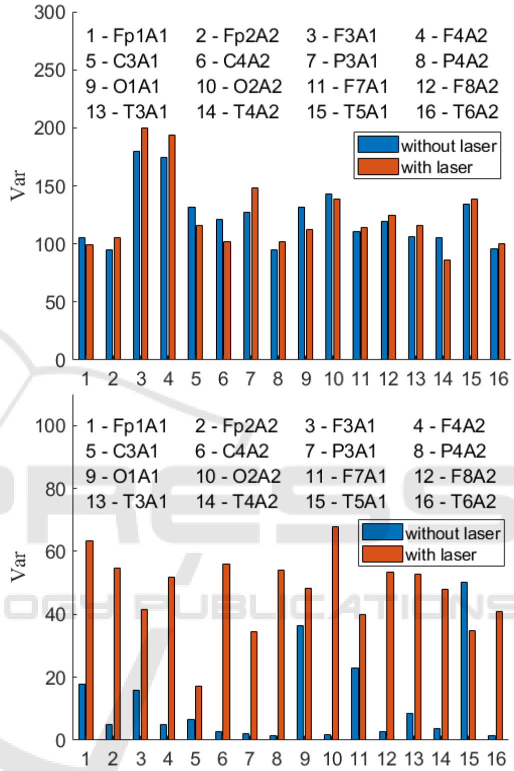


Figure 8: The total value of PSD for all temporal windows inside 90s interval for the healthy child (top) and the patient with ASD (bottom) before and after laser action.

Note that visual observation of the behavior of patients with ASD showed that when exposed to laser radiation, there were changes in the patient's behavior, expressed in a decrease in anxiety. For example, the patient with ASD was obsessively played with a laser mount mounted on his arm without laser exposure. When the laser was turned on at a power of 5 mW, the patient with ASD practically stopped paying attention to this mount.

Figure 8 shows the total value of PSD for all temporal windows inside 90s interval for the healthy child (top) and the child with ASD (bottom) before and after laser action. The latter presented averaged results for three levels of laser power: 3, 4, and 5 mW.

## 4 CONCLUSIONS

Reflexotherapy, as a method of rehabilitation in autism, is based on the exposure of biologically active points located on the skin. Laser action on acupuncture points is an alternative to traditional acupuncture. We used red semiconductor laser diodes with a wavelength of 650 nm. Three acupuncture points (GV20, LI4, P6) were selected to relieve headaches and reduce anxiety in the study. The measurements were carried out at the following power values: 3, 4, and 5 mW. EEG data had been obtained from two siblings, one of whom is without pathologies of the nervous system (8 years), and the second one has a diagnosis of autism (10 years). In the previous study (Knyazkova et al. 2019), we investigate a group of healthy volunteers (N = 10), adult men (the average age was 25 years old). It was shown, that when exposed to Hego's point, the total brain activity does not change on average for healthy participants, but a redistribution of brain activity between its regions takes place. In this study, it was confirmed for a healthy child of 8 years old, and the ASD child. A significant increase in the total activity of the brain of the ASD child up to a value close to the brain activity of healthy participants was registered after the laser action.

Note that visual observation of the behavior of patients with ASD showed that when exposed to laser radiation, there were changes in the patient's behavior, expressed in a decrease in anxiety.

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