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Original Contribution

HEMOENCEPHALOGRAPHY NEUROFEEDBACK – MECHANISM OF ACTION

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ABSTRACT

This article explains how the hemoencephalography neurofeedback works, as well as its effect in children with autism spectrum disorders (ASD). The technologies for biofeedback or also biological feedback are becoming more and more popular these days and are used as an alternative treatment technique for a number of diseases, mostly neurological, psychiatric and psychosomatic disorders. Hemoencephalography neurofeedback is a modern alternative aiming to achieve physiological influence on the condition of children with ASD. Hemoencephalography neurofeedback can be used also as an alternative supporting treatment for other pathological states of the frontal lobes, independently or in combination with the conventional drug therapy.

Key words: biofeedback, ATEC, pIR HEG, nIR HEG, feature integration theory, autism spectrum disorder

INTRODUCTION

The development of the theory of Iv. P. Pavlov of the conditioned reflexes and the regulatory role of the cerebral cortex, allowed the term "biological feedback" (also "biofeedback") to emerge. It should be highlighted that this scientific area being part of the applied Neurophysiology and Psychophysiology originated at the Institute of Experimental Medicine in Saint Petersburg in the 1920s.

P. K. Anokhin, follower of the theory and ideas of Iv. P. Pavlov, has proven that the mechanism of the natural biofeedback plays a decisive role in the regulation of both the human adaptive reactions and also in the regulation of the human internal environment.

In the 1950s, in the two leading countries, Russia and USA, a new area of Physiology was developed, i.e. the instrumental conditioning theory.

A fundamental role in the historical development of the biofeedback theory played the Conference on the biofeedback problems which took place in Santa Monica in 1969. Major organizers of this Conference were Kenneth Gaarder, Gardner Murphy and Barbara Brown. The Conference agenda covered different areas such as: state and control of the autonomic nervous system functions, muscle feedback, EEG feedback, states of mind, feedback methodology, etc.

The Neurofeedback is based on the changes in the cortical bioelectrical activity. Supported by the property of neuroplasticity, the trainee tries to manage the changes in his/her bioelectrical activity, monitoring or listening to the changes in the neurofeedback device. This is how the trainee achieves conscious control of a function which at first was subconsciously controlled.

The technologies for biofeedback or also biological feedback are becoming more and more popular these days and are used as an alternative treatment technique for a number of diseases, mostly neurological, psychiatric and psychosomatic disorders

Concept and principles of the biofeedback

Elmer Green and Alyce Green in their article "Biofeedback and Volition" (1) provide a definition of the **basic principle and first concept**, onto which the biofeedback training rests, i.e. "...Every change in the physiological state is accompanied by an appropriate change in the mental-emotional state, conscious or unconscious; and conversely, every change in

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the mental-emotional state, conscious or unconscious, is accompanied by an appropriate change in the physiological state" (2). This, so-called "closed principle" creates a possibility for putting into practice the idea of psychosomatic self-regulation, however this time also by a change in human volition or achieving conscious self-regulation.

The second concept which has found place in the main principles of the biofeedback training, is the concept of **brain plasticity**. Brain plasticity is a term which describes the ability of the brain, without any structural changes in its tissues, to go into a state which is relatively susceptible and adaptable to external factors. This refers especially to its bioelectrical activity. This concept plays an intermediate role and is directly linked to the **third**, general concept, which refers not only to the biofeedback training, i.e. **quantitative accumulations lead to qualitative amendments**. Relying on the principle of conditioned reflex activity introduced by Iv. P. Pavlov, the applying of systematic biofeedback sessions aims at **transition from unconscious regulation of an action or function, to conscious or volitional regulation of these functions**. This is the **fourth principle** of the biofeedback.

As it is already known, the biofeedback technique has three main stages:

1. Measuring a particular physiological function and converting the measurement into an electrical signal;
2. Signal conversion to allow electronic device operation;
3. Getting a feedback signal (visible or audible) in accordance with the changes registered by this device;

Considering the fact that the human brain is amazingly adaptive in a very specific manner, by changes in its functions, using environmental stimuli varying in nature and the type of targeted changes, this specific feature of the brain can be benefitted from by using brain computer interface, changing the stimuli and sensory modalities directed to the brain, the functions of the brain itself and its ability to switch over, block or unblock neuronal activity and hence, change its functional and regulatory abilities, respectively modify human behavior. These abilities give grounds and possibilities for the development of new training methods, brain training and rehabilitation.

HEG neurofeedback

The modern elaboration with regard to monitoring the brain activity is called "Hemoencephalography" (HEG). HEG displays the quantitative changes in the brain activity in a slightly different manner.

When the brain performs a particular mental task, it is assumed that certain areas of the cortex are involved directly and very actively in completion of this task. This also suggests that these areas have a faster metabolism and respectively a higher metabolic rate in comparison with the other areas of the cerebral cortex, not involved in the completion of this task.

The human brain and respectively the cerebral cortex are metabolically very active. Regardless of the fact that the weight of the human brain is only about 2% of the body weight, the brain itself accounts for approximately 20% of the body's total oxygen consumption and approximately 25% of the body's total glucose consumption. Because of this, the human brain as a whole and the cerebral cortex, have a very well-developed network of blood vessels and capillaries.

The metabolic rate can be measured by the phenomenon known as "neurovascular coupling". This is a mechanism for matching the metabolic demands in the brain to the blood flow. This means an increasing of the cerebral blood flow in the area of the brain and the cerebral cortex where there is an intense neuronal activity, e.g. when the brain is engaged with completion of particular tasks. The consequence of this response is that the blood transported to this area is more oxygenated, i.e. it shows higher oxygen content. This entire process is managed by astrocytes. It is known that the neurovascular coupling is a process highly dependant on the factors determining its components and regulation, i.e. condition of the brain tissue, respectively neurons, neuronal metabolism, blood vessels of the brain, the excess or the absence of neuromediators, state of the interneuron connections, etc.

At present, there are two forms of HEG. Each form uses its own sensor. The two forms measure different aspects of the same process (the process of metabolic activation) and hence have a similar scope of application and achieve similar results.

Historically, the first form is nIR HEG (Near Infra Red). This form was invented by Dr. Hershel Toomin who adapted the InfraRed Spectroscopy method. The unique idea of this form is that the signal measures can be consciously influenced, meaning that this is

how it can be used for the purposes of the biofeedback training.

The nIR HEG device emits a sheaf of light beams into the head, mainly the forehead, which is quite convenient as there is no hair growth there. The sheaf of light beams is a mixture of red and infrared wavelengths.

The sheaf of light beams penetrates through the skin of the head, the cranial bones and reaches the brain.

A part of this sheaf is reflected back to the emitter-sensor device by the physical processes of light scattering and light reflection.

The device measures the light which is reflected back.

This process becomes possible because of the fact that the skin of the head (the scalp), the cranial bones and the brain tissue have the ability to allow light within this wavelength range pass through.

Blood, however, because of its natural red color, has the ability to absorb such a sheaf of light beams.

This is how the proportion of the light absorbed and reflected by blood depends on the oxygen saturation level, i.e. blood oxygen content (oxygenation).

This means that when the oxygen level of the localized cerebral blood flow increases as a result of the neuron activation, there is a change in the signal received by the device. This means that the device can track the changes in the brain activity level.

Passive IR HEG (pIR HEG). This method is conceptually much simpler. It has been invented by Dr. Jeffrey Carmen who adapted the infrared thermoscopy technique.

The pIR HEG sensor detects heat radiation (or electromagnetic radiations of a particular wave length) in a much narrower band of the infrared light spectrum. In practice, the infrared radiation is the heat emitted by the brain as a result of its activity. Sources of this heat are in the first place the local metabolic activity of the neurons, expressed by the energy burnt in the form of heat, and in the second place - indirectly, the local cerebral blood flow. This method is a smaller and simpler version of another form of thermal imaging, i.e. thermography. Cranial thermography can be used for comparison and determining the efficiency of the two forms of HEG biofeedback.

pIR measures the temperature or the infrared radiation from the brain tissue, this radiation depending on the local cerebral perfusion and metabolic activity in the specified area.

nIR measures the changes in the relative absorption of the red light of a particular wavelength and the infrared emission which penetrates through the tissues and reaches the nIR sensor.

The red light emitted by the emitting device penetrates through the tissues of the scalp and skull and reaches the brain matter. The sensor reads the proportion between the reflected red light and the infrared light, which also depends on the local perfusion of the cerebral cortex and the oxygenation level of the blood reaching this area.

With both techniques, no electrodes are placed on the skull and no conducting substances are used, i.e. there is no measurement of the brain activity.

Considering the fact that HEG does not measure the brain activity, the risk of artefact contamination of the signal in connection with muscle or another form of bioelectrical activity of the human body, is reduced to a minimum.

The prefrontal cortex produces signals which “set up” most of the other lobes of the cerebral cortex, influencing not only the processing of the visual and audio signals, but are also responsible for the execution of voluntary movements, memory processing and extraction, evaluation of emotions, etc. The result of these “setting” signals is directing the neural activity flow along neuron routes, achieving their coordination between the incoming impulses, the internal state and the output signal, needed for the performance of a particular task.

Creating a cognitive map with the HEG neurofeedback training is possible by the utilization of a large number of incoming signals, including visual and audio signals. The HEG neurofeedback training allows such a cognitive map to be developed and respectively the brain processes to be regulated according to the changes happening in the monitored environmental changes (watching a cartoon or other moving pictures and sound.

In order to fully understand how HEG neurofeedback works, it is necessary to know in details the theoretical foundations of the visual perception. These foundations have found place in the Integration Theory proposed by Anne Treisman и Gary Gelade (3). This

theory deals with visual attention and suggests that when perceiving a stimulus, its features are registered early, automatically, and in parallel, while objects are identified separately and at a later stage in processing of the information. **This is one of the most influential theories and psychological models of human visual attention**.

With the help of the Feature Integration Theory, the main principle of the HEG neurofeedback training mechanism can be explained. The following example can be used: A child with a disorder from the autistic spectrum is watching on the monitor a favorite film.

When the child gets distracted away from the monitor, the sensor placed on the child's forehead registers a change in the biological signal monitoring parameters, i.e. lower temperature of the radiation emitted or a decrease in the blood oxygen content.

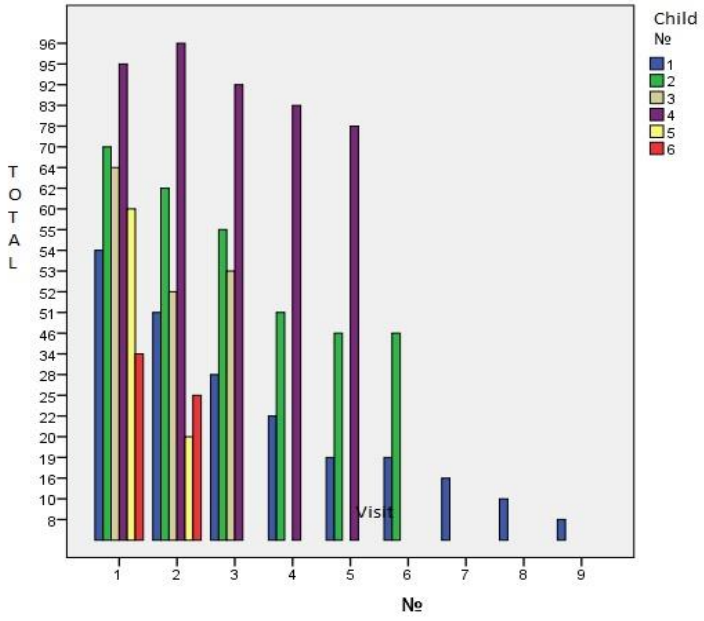
The HEG neurofeedback program is set up in a way that after a change in these biological parameters, the brightness of the film changes, accompanied by a change in the speed at which the film is displayed. With some programs the film is displayed in reverse chronology.
Thanks to the mechanisms described in the Feature Integration Theory, visual attention and visual seeking, the brain becomes aware of the changes happening in the visual perception and the awareness with regard to the changes happening, the cerebral cortex is "striving" to restore the images seen to such which already known and memorized.

This process takes place mainly in the prefrontal cortex; it requires efforts and respectively energy. Further, by the neurovascular coupling, more oxygenated blood and glucose are supplied to the target areas of the cerebral cortex. These changes lead to the relevant change in the level of the output signal, needed for the operation of the brain - computer interface, which, in turn, triggers the normal display of the film.

DISCUSSION

Over a period of 1 year, HEG neurofeedback training sessions were applied to 6 children diagnosed with General Developmental Disorder. The total number of the sessions applied was 174, each of them with an average duration of 30min. After the tests and reading of the results from the applied training sessions using the Autism Treatment Evaluation Checklist (ATEC) on children with ASD, there is evidence for an improvement in the general condition of each child, as shown on **Diagram 1.**

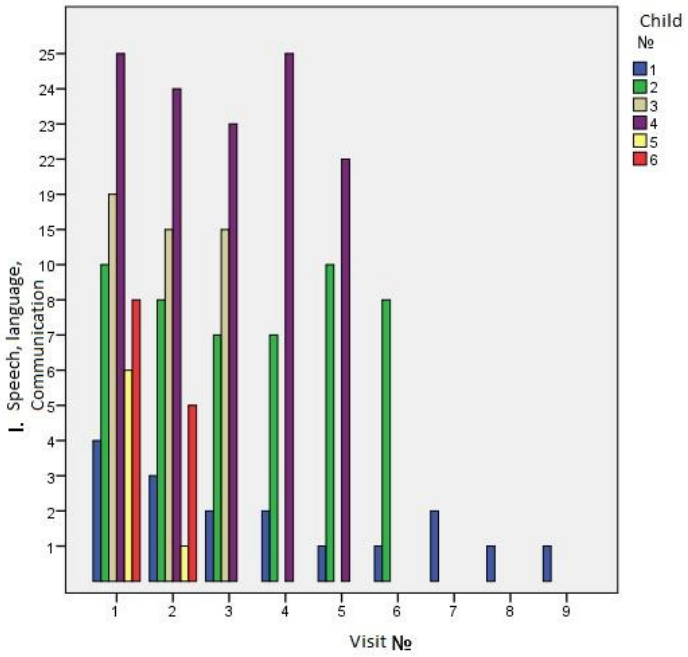
Diagram 1. *Dynamics of the total score according to the ATEC rating scale for the children included in the study*



The analysis of this diagram shows that regardless of the disorder severity level of a child diagnosed with ASD, evaluated using the ATEC rating scale upon the first visit, after applying the HEG neurofeedback training, there is an improvement in the child's overall condition, expressed by a lower total ATEC score.

The analysis of the communication skills also shows an improvement as seen from **Diagram 2:**

Diagram 2. *Dynamics of the values based on "Speech, Language, Communication" criterion for the children included in the study*



Of course, there are variations depending on the disorder severity level and the nature of the autistic disorder.

Similar improvement was registered also upon the analysis of the two other criteria: "Sensory/Cognitive Awareness" and "Health/ Physical Behavior".

RESULTS AND DISCUSSION

Hemoencephalography neurofeedback is a modern alternative aiming to achieve physiological influence on the condition of children with ASD. Considering the possibility for affecting brain processes dependant on the hemodynamics by inclusion of the phenomenon neurovascular coupling, without the use of a drug therapy, the hemoencephalography neurofeedback can be used also as an alternative supporting treatment for other pathological changes in the frontal lobes, independently or in combination with a conventional drug therapy.

REFERENCES

1. Elmer E. Green, Alyce M. Green, Biofeedback and volition, *Subtle energies medicine*, Vol. 10, sec. 2, p. 89
2. Green, E., A. Green, Biofeedback and Volition, *Subtle energies & Energy medicine*, Vol. 10, Sect. 10, page. 93
3. Anne M Treisman, Nancy G Kanwisher, Perceiving visually presented objects: recognition, awareness and modularity, *Current Opinion in Neurobiology* 1998, 8:218-226