RESEARCH ARTICLE

ACTA Vol. 14, No. 1, 2016, 17-33
NEUROPSYCHOLOGICA

Received: 11.12.2015
Accepted: 28.03.2016

A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

DOI:10.5604/17307503.1201711

STATE OF MIND AS A SUBJECTIVE MENTAL SENSATION RESULTS FROM OBJECTIVE BRAIN ACTIVITY FOLLOWING NEUROFEEDBACK-EEG AND RELAXATION TRAININGS

Mirosław Mikicin(A,B,C,D,E,F)
The Józef Piłsudski University of Physical Education, Warsaw, Poland

SUMMARY

Background: The paper attempts to examine the relationships of the states of mind with brain activity with regards to reports and empirical studies available in the subject literature. Questions were asked about the processes that occur in the brain and the cognition to produce basic states of mind, which were termed: state of readiness attention (conscious attention), state of attention engagement (automated attention, unconscious attention) and alpha state (no attention, relax).

Material/ Methods: 73 student athletes involved in swimming, fencing, track and field, taekwondo, and judo, took part in the experiment with five people representing each sport. They were 18 to 25 years of age and showed similar sports skill level (national level) and trained at the same club (5 to 7 years). Before and after 20 neurofeedback-EEG training sessions, all the subjects performed EEG recordings. Eighteen athletes were included in the experimental group, subjected for 7 months to relaxation training sessions.

Results: A twenty-week neurofeedback-EEG training course aimed at the reinforcement of the amplitude of the SMR and beta 1 bands while reducing the amplitude of the theta and beta 2 bands in athletes causes changes in brain activity at rest and, consequently, in the states of mind. The amplitude of the alpha band changed after relaxation training sessions.

Conclusions: In the empirical studies described ones based on scientific achievements and focused on the problem of human mind, attempts were made to find correlations between subjective states of mind and objective brain activity.

Key words: brain activity, alpha state, attention

INTRODUCTION

From the standpoint of this study, the states of mind that occur in the human brain are subjective mental sensations during concrete activities, the cognition of which is reflected by brain activity and the whole nervous system. The investigations should be commenced with a comprehensive neuropsychological analysis (Sarle, 2004; Damasio, 2010; Hamilton, 2007; Fields, 2012; Cavdar et al., 2008; Leon-Domínguez et al., 2013; Leon-Carrion et al., 2012; Zhou et al., 2011) of the mind as a brain function and adopt it as a theoretical basis for investigations of the subjective states of mind resulting from objective brain activity and cognition. The concepts of naturalism (Sarle, 2004) and functionalism (Libet, 1992) adopt that in the future, science should reveal deep brain structures and, with these structures, conscious, intentional and subjective mental states. Basically, the naturalistic solution to this problem is consistent with most of the experimental data. These data have often demonstrated that the brain and cognition are a source of mind, whereas states of mind represent the „brain product.„ Based on empirical data (Leon-Domínguez et al., 2013; Langsjo et al., 2012; Hamilton 2007) which are close to the viewpoint presented in this study, the mind is considered as a function that organizes the neural networks in all brain areas. Leon-Dominguez and his colleagues (2013) found functional chronometric subnetworks in the thalamocortical system that regulate and control states of wakefulness through synchronization of the spatiotemporal brain structure. Furthermore, this thalamocortical subnetwork (Langsjo et al., 2012) supports state of readiness attention through regulation and controlling excitation, cognitive processing and behavioural manifestations. Therefore, a loop that is connected with thalamic nuclei and cerebral cortex can be emphasized, modulated through network activity and playing a key role in the conscious attention state. Several questions were asked in this study, with the answers requiring attempts to explain which neural processes are responsible for the basic states of mind which are termed the state of readiness attention (conscious attention), the state of attention engagement (automated attention, unconscious attention) and the alpha state (no attention, relax): Can the problem of the human mind be reduced to the basic assumptions that all that exists in the world is either physical or mental and that cause-and-effect relations can be observed between each other, and, that the wholeness of what is physical is in nature a closed-ended chain of causation?

Firstly, mental properties are characterized by specific features, such as intentionality and awareness. They remain in relation to basic items and physical properties. These include: supervenience and emergence relations (Searle, 2004). The supervenience relation is especially important. While referring to this relation, Searle wrote that mental phenomena such as intentionality should be approached as neurophysiological processes in the human brain as part of nature, such as photosynthesis or digestion. Therefore, the field of the mind is determined by neural activity, but it differs from this activity. According to the views of Leon-Carrion (2012), it should be adopted that the mind represents a processing of brain signals and the conversion of these signals into cognitive representations, a product of a number of various cortical structures and their dynamic states that form a uniform experience (Leon-Carrion et al., 2012).

Secondly, in emergence naturalism, Searle (2010) adopts that, at a specific level of structural complexity of elementary physical properties (of the brain), some new properties „emerge„ which cannot be explained based on knowledge about elementary properties. Although knowledge about elementary brain structure is now readily available, it remains unknown how it happens that the mind appears in the brain and, consequently, any change in the area of mental properties is connected with the supervenience relation i.e., the relation of „dependent changes" with respect to the level of elementary components. Therefore, the pattern of activity that results from the effect of physical cells is as physical as the activity which is mapped in the human brain and cognition. It is obvious that in the case of emergence, even the deepest examination of the components of the mind cannot contribute to an understanding of the structure and importance of the wholeness. Thus, most of the methodologies of brain examinations assume its division into parts.

Thirdly, and finally, neural networks in the anterior and posterior regions of the cerebral cortex facilitate synchronization and coherence of large populations of remote cortical neurons on a precise temporal scale. Consciousness has been demonstrated to be either modified or lost after losing the synchronization and coherence of these networks (Leon-Carrion et al., 2012). However, it remains unclear which of these electrophysiological phenomena play causal-functional roles in the overall organization of the nervous system and which of them are manifestations of the brain function that generates cognitive processes and states of mind.

The mind is a brain function

The system of the senses should be adopted as a starting point: they reflect the properties of the stimuli present in the external environment as a result of transduction with the activity of glial cells, thus modifying neural activity. Internal cell activity represents the basis for the participation of neurons in the neural network, and, consequently, in complex activities of the nervous system. The assumption was also made that the function of senses, apart from the modification of neural excitation, is to provoke sensory impressions. Sensory impressions such as cognitive processes perform two roles: on the one hand, they reflect the elementary properties of stimuli and, on the other hand, they produce neural representations in specific brain regions. After the selection of stimuli in the attention process and the appearance of the holistic meaning of the sensation, the brain generates either a conducive or unfavourable state of mind in temporary connection of information (experience). Therefore, it is worthwhile to look closer at the whole process of these phenomena. The mind as a brain function that generates mental processes begins with perception mechanisms. Sensory analysers, which form the system that transfers neural activity to the brain using afferent pathways, represent the beginning of the process of information transmission. In order to send consecutive messages, it is important for this process to clear the synaptic space of the neurotransmitter which has already performed its role. It has been demonstrated (Fields, 2009) that the clearing function in the synaptic space is performed by astrocytes, which are one of the four types of glial cells. By surrounding the synaptic gap, they „filter" the neurotransmitter, which consequently becomes inactive, and then transfer it back to the pre-synaptic region. It can be expected that this dependency of the synapse on the astrocytes' clearing function offers opportunities to take control over the synapse, especially due to the fact that, if the neurotransmitter used cannot be effectively removed, communication in the synapse might fail since the synaptic space will be filled with „obsolete messages.„ It should be noted that, if a neurotransmitter will be detected too fast, the message will be available for too short a period for the post-synaptic cell to fully utilize the message. Furthermore, if the energetic demand of the neuron cannot be satisfied with the nutrients supplied by astrocytes, the neuron will run out of „fuel.„ Therefore, astrocytes, although present outside neurons and not communicating by means of electrical pulses, perform a strategic role and are likely to generate mental processes. This would suggest that glial cells perform functions of not only servicing neurons but are also likely to modify the unconscious or even conscious mind. The most recent discoveries (Fields, 2009) concern the circuits controlled by glial cells that regulate motor coordination or „muscle memory.„ It has also been found that glial cells, through modification of the shape and position, are likely to restructure the brain, affect its structure and, consequently, its functions connected with unconscious mental processes. These discoveries make it easy to imagine their role within conscious processes. Sensory impressions are likely to be a product of relations between neurons. Their formation is understood to mean structures comprising sensory and motor components. However, under conditions of neuropsychophysological experience, explorations might concern only those afferent pathways that start in the receptors and end in the highest, cortical level of the analyzer (Wróbel, 2014). Using the method of sensory mean responses caused in the perception field of the cerebral cortex, connected anatomically and physiologically with the irritated receptor, a neurophysiological correlate of the conscious sensory impression was obtained. Sensory impressions reflect properties of stimuli that represent elementary information and they produce neural representations in specific brain regions. Integration and sensory processing of incoming information (Damasio, 2010) are performed by the area of the cerebral cortex which is located behind the central sulcus in the parietal, temporal and occipital lobes depending on the type of information.

The brain is a neuropsychological determinant of a state of mind

Despite the number of experiments and findings concerning states of mind (Alkire et al., 2008; Tononi and Laureys, 2008), it remains difficult to determine the minimal number of the areas in the brain which are necessary and sufficient to support these states. Reticular formation in the brainstem and its numerous cortical connections through the thalamus form a webbed system which probably intervenes with the consciousness through a regulation of the states of mind (Langsjo et al., 2012). Consequently, the state of mind is a broad continuity of brain activity. It spans from zero to maximum neural excitation; a decline in neural inhibition occurs simultaneously with the increase in the state of excitation (the inhibition might also increase). The presence of such a continuum has been objectivized and demonstrated by means of electroencephalography (Gwin et al., 2011), which gives a key insight into bioelectrical brain activity. Therefore, neural activity i.e., the generation of high or low frequencies and voltages in individual regions of the cerebral cortex might represent an objective (although not the only) manifestation of the states of mind. A study by Cavdar et al. (2008) demonstrated that, since connections in the central thalamic nuclei exist in the prefrontal cortex, medial cortex and the hippocampus, the state of mind might be modified by these three structures. They form a one-direction pathway, with projection of the hippocampus to thalamic nuclei and then back to the hippocampus (Vertes, 2002; Vertes et al., 2007). The authors suggested that connections of the hippocampus in the thalamus connect the cerebral cortex and sensory thalamus. In this sense, thalamic circuits and the hippocampus are likely to be engaged in the attention processes due to its effect on brain activity. Furthermore, Leon-Domínguez et al. (2013) demonstrated that chronometric functional subnetworks of the thalamocortical system regulate the flow of neural information necessary for cognitive processes. These authors believe that the thalamocortical system, defined as a neural network connected with consciousness (although this view remains as yet unsupported), affects wakefulness and excitation. The researchers also suggested that thalamic nuclei formed in the medial prefrontal thalamic cortex of the network represent the main axis for the states of mind. This axis regulates different structures of the brain which allow for the appearance of the basic cognitive processes, such as attention. Therefore, a network of neurons in the thalamocortical system maintains humans in an optimal and continuous functional state, which means that cognitive processes, necessary for the perceived state of mind, are able to occur. Leon-Dominguez et al. (2013), considered synchronously excited circuits (networks) in the thalamus and cerebral cortex to represent such a „neural correlate.„ A recent study (Langsjo et al., 2012) demonstrated that during the occurrence of consciousness, there are active connections between the lower occipital cortex (Brodmann area 39/40) and the temporal cortex of the cingulate cortex (Brodmann area 32) and other frontal regions. These results and the results obtained in other studies (Leon-Carrion et al., 2012) would suggest that cortical networks are capable of perceiving various dimensions of stimuli as a whole, and, concerning previous experiences and meanings, they are necessary for human cognition. For this reason, the role of this network in consciousness should be viewed as an internal part of conscious processes, which ends with the adequate reaction of a person at a specific moment. Contrary to them, the functional states of the thalamocortical system will modulate the individual state of mind and, consequently, the functional ability to effectively process information and generate subjective awareness (Tononi and Laureys, 2008). Therefore, in the present study, two questions arise: How can objective brain activity stimulate subjective states of mind and how can the subjective states of mind affect neural activity? The assumption was made that the state of mind results from brain activity i.e., they represent two aspects of the same process i.e., the mind, as a brain function, and the stimuli reaching the mind through perception, determine the produced states of mind. Brain activity can be attempted to be determined through the activity of groups of neurons. However, it is essential not only to analyse this activity (since it can be defined from the standpoint of a multifaceted research space) but also the relations between neurons. It is impossible to investigate this relation due to both insufficient biotechnological advances and the state of knowledge concerning the activity of glial cells (Fields, 2009), chiefly astrocytes. Therefore, the state of mind can be examined only through the analysis of neural activity. With the neural aspect, the state of mind can be considered as a correlate of brain activity since any analysis of this activity is likely to provide the answer to a number of specific questions. The experiments in this field have verified the hypothesis concerning brain activity and cognition engaged in producing states of mind: the state of readiness attention, the state of attention engagement and the alpha state.

State of readiness attention (conscious attention)

The subject literature offers two distinct functional, neuroanatomic correlates for the state of mind: thalamocortical and cortical-subcortical systems (Dehaene et al., 2006; Leon-Carrion et al., 2012). The thalamocortical system is connected with modulation of the states of wakefulness of a particular person i.e., cognitive and physiological states during processing information. The cortical-subcortical system is connected with the content of conscious experience and expression. However, both networks are interconnected, while their interaction depends on the state of mind of a person (García-Panach et al., 2011; Langsjo et al., 2012; Leon - Carrion et al., 2012; Zhou et al., 2011). A study by Leon-Dominguez et al. (2013) found that thalamic nuclei share physiological and morphological properties. They help participate in certain functions, including the focusing of attention and the state of brain readiness (Zhou et al., 2011) and intervene in the regulation of excitation through the control of thalamocortical activity. They also supervise those changes of attention which are organized by the cortex and adjust the level of wakefulness over the frontal system of attention (Schiff, 2008). Therefore, attention processes are closely related with consciousness since, in the state of attention focus, they help differentiate between stimuli within a specific cognitive context. It should be emphasized that both conscious and unconscious attention as a mechanism of reducing the reception of stimuli represent a non-content determinant of mental processes and states of mind (from subjective states with conscious attention towards objective neural activity with unconscious attention). Attention performs four basic functions: 1. The function of stimuli selection (it reduces information noise): it filters the irrelevant sensory stimulation; 2. The function of wakefulness, which means expectation of a specific signal and restrain from reaction to disturbing stimuli; 3. The function of searching that consists in active verification as to whether there is a specific stimuli in the perception field, usually hidden among the distracting stimuli; 4. The function of the supervision of simultaneous activities, which means controlling those cognitive processes connected with performing various activities. Attention is characterized by certain characteristics. One of them is the degree of attention focus (concentration). Attention, examined empirically using tests of attention tasks and EEG, is probably the most important factor (neuropsychological determinant) in the achievement of success in human activity. It is manifested in the limited-scope separation of the objects on which it is oriented. It causes that higher oscillation frequency (coherent 40 Hz), i.e., functional state of the brain, is involved in the temporary binding of experience (information), thus the formation of the holistic meaning and functional state of mind (Schroeder end Lakatos, 2009). The processes of attention, visual-motor coordination and the processing of visual and auditory information are typically connected with brain activity in parieto-occipital leads. Therefore, plastic changes during the attention task are connected with planned rather than actual motor control (Desmurget et al., 2009). A study by Wróbel (2014) demonstrated that the power of the beta band is specifically increased during the performance of the tasks that necessitate visual attention in many structures of the visual system (including visual cortex). According to the hypothesis proposed, the increased power in the beta band accompanies the visual tasks which engage the ventral pathway connected with shape perception.

State of attention engagement (automated attention, unconscious attention)

The factors which are conducive or unfavourable to experiencing the state of attention engagement (Vecina et al., 2012, Vecina end Chacón, 2013) during active human cognitive activities have a neuropsychological background, connected with the opportunities to stimulate particular brain activity. Attention engagement can be also approached as an emotional dimension of the person's attitude towards their own actions. It represents a manifestation of identification with activity and a feeling of „emotional attachment.„ Furthermore, it reflects the degree of „participation" expressed with a positive valuation of this activity. The essence of the state of attention engagement is the flow of the attention (automated attention, unconscious attention) necessary to be involved in the action performed just for itself. Identification of those factors connected with an autotelic personality (Mikicin, 2015) appears to be particularly important. For example, people who are able to control mental energy might experience engagement in action while those who are incessantly worried about how they are perceived by others are doomed to feel a constant lack of satisfaction (Wefald, 2009) since they are excessively focused on their deficits (Hamilton, 2007). Engagement is therefore a predictor of satisfaction and an index of perceived physical health (Vecina et al., 2012; Vecina and Chacón, 2013). The data demonstrate a greater engagement of the cortex when there is a greater engagement in physical exercise, which is reflected by increased amplitude in all EEG bands as the locomotion velocity increases. During a motor task, amplitude increases near the somatosensory (parietal lobe) and motor (frontal lobe) cortex. This change is connected with the engagement of attention (Leff, 2008). The modifications in the regions of the premotor and visual cortex reinforce the presumptions that the observed brain plasticity during movement determines a conscious control over locomotion (Strupp, 2009). This is likely to be connected with actual motor control. The observed change in bioelectrical brain activity in the occipital leads is generally connected with visual-motor coordination and processes of attention. This is consistent with other findings (Lau et al., 2012; Gwin et al., 2011), which have provided indirect evidence for the cortical contribution to human locomotion. Positron emission tomography (PET) and functional magnetic resonance imaging revealed that the motor cortex is active during preparation and expectation of movement, especially in the frontal areas of the brain. Other authors (Gramann et al., 2010; Gwin et al., 2011; Gorassini et al., 2009; Bazanova et al.. 2009) have suggested that a direct cortical pathway determines locomotion since it is there where locomotion is planned and modulated. It has also been demonstrated (Ray, 2010) that the motor cortex is active when sensory modulations of rhythmic motor tasks occur and, even when the tasks performed are passive, the cortex modulates the signal of the cord through mesencephalon to the motor region. Most variables of maintaining motor performance might substantially affect learning and neural plasticity. It was also observed that, during dynamic work towards modifications in the motor cortex, the gamma EEG frequency integrates a number of senses which are responsible for preparation of the relevant motor order (Omlor et al., 2007). Consistently with previous studies on submaximal exercise, an increase in motor cortex activity was found and, in several registers (also in the cingulate cortex and the dorsolateral prefrontal cortex and premotor cortex). Posterior parietal and occipital cortices are connected with visual-motor integration and motor coordination.

Alpha state (no attention, relaxation)

Experiencing the alpha state manifests itself in passive attention, release from stress, internal quiet and reduced brain activity. Therefore, it characterizes the internal levels of mental activity which are responsible for quiet and relaxation. Previous studies have demonstrated the advantage of the alpha band (7 - 12 Hz), which is recorded mainly in the parieto-occipital region and is characterized by a variable amplitude. It reflects the synchronization of activity in many dendritic cells that occur in the state of wakefulness with relaxation and with closed eyes (Singer, 2002). They disappear during exercise or with eyes open and the effect of light. There have been reports which have demonstrated that the state of relaxation improves emotional stability (Cherapkina, 2012). Del Percio has emphasized that alpha rhythm is connected with the effectiveness of the cortical motor systems. His examinations of the activation of the range of the alpha band with eyes open demonstrated that the alpha band is characterized by a reduced activation of the cortex (Del Percio et al., 2011). Reduced activation of the cortex in the left temporal region was observed, which allows for the predominance of visual and spatial processes in the right hemisphere. However, a study by Shelley-Trembley (2006) has shown that the increase in alpha band range activity , usually perceived as an increase in the level of skills, does not point directly to cortical disactivation but to simultaneous neural reorganization, with the development of a greater performance for specific cognitive tasks and mechanical processes. J. C. Shaw (2012), who has carried out studies on athletes using electroencephalography, found a reinforced EEG alpha band just before the activity. This researcher has ascribed increased activity in this band to planned processes, contrary to those that need attention, accompanied by decreases in bioelectrical activity within the alpha band (Gwin, 2010, Mikicin et al., 2015). More specifically, an optimized state of the human body exists when a decline in the activity of the alpha band is recorded, which is correlated with increased mind performance. Another researcher who has examined this problem, O. Strizkhova, drew a conclusion that relaxation supports increased activity of the alpha range in the left hemisphere (Strizhkova, 2012). In the study by Mikicin and Kowalczyk (2015), everyday audiovisual and autogenic relaxation training cause the mean amplitude of the alpha band to increase throughout the experiment. Further, using a similar autogenic relaxation training on a daily basis (Marshal end Bentler, 1976; Hashim, 2011), showed that the reduction of fatigue and tension and improvement in the mood of healthy people causes an increase in the mean amplitude of the alpha band in the parieto-occipital and temporal cortical regions. Similar training was also used in order to obtain an internal quietude in investigations into well-being improvement in clinical patients (Teplan et al., 2006). Hatwield (2001), who has examined alpha frequency in professional snipers, found that alpha training improves the performance of their mind during activities that require elevated amplitude of the alpha band for the improvement of the „quiet mind" (Bradley, et al., 2010) or an improvement in physical balance (Horlings et al., 2008). The effect of alpha training has been regularly analysed with respect to rehabilitation (Kirtley et al., 2009). In particular, it is used in the rehabilitation of psychomotor disorders for muscular relaxation, after which the feedback signal supports motor activity. Also been explored has been whether alpha training is effective in the area of motor performance improvement following surgical interventions (Zijlstra et al., 2010). Due to the coexistence of other health problems, such as musculoskeletal system disorders, cardiovascular problems, deteriorated sensory function or deteriorated cognitive abilities (De Bruin et al., 2009, Heiden and Lajoie, 2009), there exists the necessity for evaluation of the effectiveness of this training with respect to its use for balance and mobility improvement in older people. However, various criteria used by other authors based on programmes for practising balance (Horlings et al., 2008) and mobility

(Eser et al., 2008) have supported its effectiveness. Experiencing the alpha state represents an irreplaceable means of recovery and a method to reduce the level of muscular tension. People performing alpha training demonstrate a progression in the level of relaxation and in activity after the completion of „alpha training" (relaxation training). This suggests the positive effect of regular relaxation on behaviour (Mikicin and Kowalczyk 2015). However, learning about the specific mechanisms and brain structures connected with the observed changes in amplitude within individual EEG bands (Ros et al., 2011) and their role in the improvement of behavioural and cognitive indices necessitates further research.

MATERIAL AND METHODS

73 student athletes involved in swimming, fencing, track and field, taekwondo, judo: five people per sport, took part in the experiment. They were 18 to 25 years of age and showed a similar sports skill level (national level) and trained at the same club (5 to 7 years). The subjects from the experimental group (34 people) were for five months (on average every 7 days) subjected to 20 neurofeedback-EEG training sessions. For five months between EEG examinations, the subjects from the control group (16 people) were involved in a physical activity similar to the study group. Before and after 20 neurofeedback-EEG training sessions, all the subjects performed the EEG recordings. Eighteen athletes were included in the experimental group, subjected for 7 months to relaxation trainings. Every day, after each athletic training session, a 45-min period of audio-visual relaxation was carried out, involving stimulation of the subject with light stimuli (lying position, eyes closed, green light, light intensity adjusted individually to the visual sensitivity of the subjects) and auditory stimuli (high-pitched tone; 7–13 Hz, sound intensity adjusted individually to the auditory sensitivity of the subjects) with the alpha frequency (7–13 Hz) and autogenic relaxation (Schultz's autogenic training). The control group (ten men and eight women) followed the same training/competition programme as the experimental group, but they were not involved in relaxation techniques between EEG examinations. Two observations, before and after the 7-month period of the study involved EEG records and the work curve test performed by all study participants. Flex 30 electrode systems based on a system of leads (10-20) with TruScan software and a non-invasive method for the examination of brain activity in motion were used. Before each examination, the caps and electrodes were washed and disinfected. The skin on the head was degreased in order to reduce the impedance of electrodes to a level below 5kOhm. The amplification was set at 100uV/10 mm and barrier filters (time constant) were used: 0.5 Hz (low-pass) and 40 Hz (high-pass). The same settings were used for each examination. Before the beginning of the study, all those from the experimental and control groups used similar computer software, and to the same degree every day. The examination of all the athletes in one group was aimed to determine ther general state of "readiness and attention engagement for exercise" which, as demonstrated, can be compared across different

sports. All the subjects gave written consent to participate in the experiments. The procedure was approved by the Ministry of Science and Higher Education, according to the standards used by the Research Bioethics Commission of the Józef Piłsudski University of Physical Education in Warsaw, Poland and all the procedures were approved by the Bioethical Committee and were consistent with the standards of the Declaration of Helsinki.

RESULTS

Changes in brain activity to a state of attention readiness

During brain bioelectrical activity after neurofeedback-EEG training (Mikicin et al. 2015) in the procedure of amplification of the SMR and beta 1 bands and a weakening of the theta and beta 2, the EEG power spectra changed in the beta 2 band. The results of the examinations suggest that although effectively increasing the power of beta 2 bands in trained athletes, the Neurofeedback-EEG method in the classical laboratory sitting position from C3 and C4 leads is not optimal for athletic training because the muscle tension syndromes which are not connected with the specific nature of the particular sport are consolidated. Differences in the EEG bands were supported by the statistical analyses that compare the power spectra recorded in 25 study participants in the cortical leads T3, T4, T5, T6, O1, O2 before and after 20 neurofeedback-EEG training sessions in paradigms of a weakening of the beta 2 band in the visual task (see Fig. 1).

Neurofeedback-EEG training modifies bioelectrical brain activity maps (Mikicin et al. 2015). These changes were significant depending on the place and situation of recording using the experimental electrode (lying with one's eyes open and during the attention position, see Fig. 1). The power of the beta 1 band which was modulated over the training (Mikicin et al. 2015) was increased. The beta 2 band was reduced for eyes open in the occipital regions. The areas for

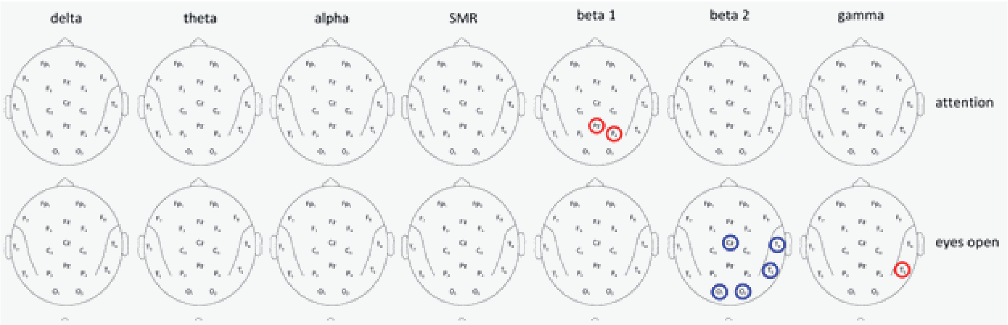

Figure 1. Changes in the mean frequency amplitude in selected scopes of EEG bandwidth before and after 20 neurofeedback-EEG training sessions measured in a lying position with eyes open and attention position. N=25.
Notes: a dark colour denotes increased power, blue means power reduction

which the analysis revealed significant differences in the results of the examination within the experimental group before and after twenty neurofeedback-EEG training sessions in a sitting position are shown in the heads of the marked channels. Changes in the mean beta 1 and beta 2 amplitude are important, with the level of significance being p <0.05 and p <0.01.

Changes in brain activity to the state of attention engagement

An analysis of studies demonstrated (Mikicin 2015) that neurofeedback-EEG training in motion is conducive to experiencing autotelic engagement during an athletic competition. After 20 neurofeedback-EEG training sessions in motion using the procedure of weakening the beta 2 band, an increase in the dimensions of the autotelic attention engagement was observed. It turned out that the level of the beta 2 band was significantly reduced (p<0.01) during submaximal exercise. The results obtained in the control group recorded after four months without neurofeedback-EEG trainings were not significantly changed, demonstrating that changes in the amplitude observed in the study group result from this training (Figure 2).

During submaximal exercise (running and crawl movement at 2m/s), the beta 2 was reduced in the motor cortex and premotor cortex, whereas in the visual cortex, attention-related brain activity caused all the bands analysed to have the highest amplitude. The activity observed in the O1 and O2 leads is commonly linked to the processing of visual information, visual-motor coordination and attention processes. Significant differences (p<.001) can be found between visual (occipital) and motor (parietal) or auditory (temporal) cortex activity or that of the premotor (frontal) cortex. Near the left and right motor cortex, the significant reduction in the beta 2 band (Mikicin and Kowalczyk 2015a) was also accompanied

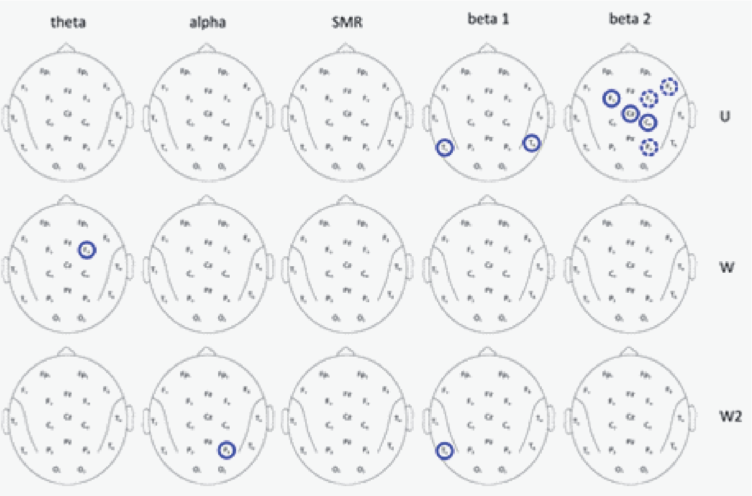

Figure 2. Changes in the mean frequency amplitude in selected EEG bandwidths before and after twenty neurofeedback-EEG training sessions measured in a standing position with eyes open with attention (U), exercise (W), submaximal exercise (W2) means power reduction. N=14

by a reduction in the amplitude of the beta 1 bands ($p<0.01$), which occurred for all leads during attention engagement.

Changes in brain activity to the alpha state

A significant increase was observed in the amplitude of the alpha band which was stimulated during relaxation training after each day's athletic training sessions. A 45-minute audio-visual and autogenic relaxation training after each athletic training session caused an increase in the amplitude of the alpha band over the whole experiment with eyes closed while the amplitude was reduced during the test (Mikicin and Kowalczyk 2015b). Changes in bioelectrical activity within the EEG alpha band after relaxation training, observed mainly in the parieto-occipital region, are characterized by a variable amplitude (Mikicin and Kowalczyk 2015b).

Better synchronization of dendritic units is obtained for closed eyes. This is not observed during the exercise or after the eyes are open and a person is exposed to the effect of light. The everyday training of audiovisual and autogenic relaxation over the course of the whole experiment meant that the mean amplitude of the alpha band recorded from all the leads was considerably increased ($p< 0.01$) in the control lying position with eyes closed (before - 7.75 μV, SD +/-1.58, after -9.31 μV, SD +/-1.57).

DISCUSSION

Changes in brain activity to the state of attention readiness following neurofeedback-EEG training

The biggest changes in the EEG amplitude in all the bands trained were observed in the signals from parieto-occipital and temporal electrodes. Activity in these leads is commonly associated with processing visual and auditory information, visual-motor coordination and attention. Therefore, the results obtained in the study are consistent with the training paradigm used in our experiment, which required attention concentration in visual and auditory modalities. It also seems possible that, apart from the perception processes, the study participants might have automatically processed the expected changes in the images of moving balls into movement programmes which should cause the expected movements of the balls. Increased SMR amplitude in parieto-occipital and temporal regions following Neurofeedback-EEG training has been found to be correlated with improved visual and auditory attention (Vernon et al. 2003). Similarly, the increase in the power of the SMR and beta 1 bands was accompanied by the increase in visual attention in the experiment that evaluated the perceptional variability of reaction time following the neurofeedback EEG training (Egner and Gruzelier 2004).

Since the amplitudes of activity in selected EEG bands changed towards those effects expected from the training, it can be presumed that the neuronal processes have been well established. Learning about the specific mechanisms and brain structures connected with the observed changes in the amplitude in individual EEG bands (Hinds et al. 2011, Kowalczyk 2009, Ros et al. 2001) and their role in an improvement in behavioural indices, which is the aim of the training, necessitates, however, further research.

Changes in the amplitude in the beta 2 band to the state of attention engagement following the EEG neurofeedback training in motion

The amplitude in the beta 2 band, which was inhibited during 20 neurofeedback-EEG training sessions in motion in the situation of elevated visual attention and the exercise of the first and second degree was, as expected, significantly reduced in all the involved brain regions. This is likely to be attributable to attention engagement (Mikicin 2015) and is also linked to work performance. Reduction in the amplitude in the beta 2 band turned out to be also efficient in improving the results of attention tasks, which is consistent with previous reports (Mikicin and Kowalczyk 2015a).

A change in the activity was also observed in the O1 and O2 leads, commonly linked to the processing of visual information, visual-motor coordination and attention processes. The results obtained in the above mentioned study are consistent with the training paradigm used in our experiment, which required concentration of attention in visual modality.

Changes in the amplitude in the alpha band to the alpha state following the relaxation training (Pąchalska et al. 2014). In our study, the improvement in relaxation abilities is reflected by changes observed in the alpha band. The results show that regular audio-visual relaxation training sessions connected with autogenic training stimulate the modifications in the cortex which are considered as typical of relaxation or other states of consciousness (Mikicin and Kowalczyk 2015a). Therefore, it seems that audio-visual relaxation with autogenic training can be effective in inducing changes in EEG. However, it cannot be excluded that certain improvements in relaxation effects might be attributable to other causes.

This study was aimed at deepening the knowledge of brain function during prolonged relaxation training sessions. The study demonstrated that, from the standpoint of effectiveness, the method of audiovisual relaxation and autogenic training is a very effective method of psychosomatic recovery in sport. Daily training in audiovisual and autogenic relaxation after each athletic training session caused that the mean alpha band amplitude over the whole experiment was increased for closed eyes , whereas it was reduced during the performance of the attention task, which means that faster desynchronization occurs during activity.

CONCLUSIONS

In conclusion, the practical aspect of the present analysis can be justified through the application of gradual simplification, starting from the effect of neural groups and anatomically indistinguishable brain regions through to the global dynamics of brain bioelectric phenomena and cognition, which seems to be correlated with states of mind. Considering the brain as the biological location of the mind, the thesis was adopted for empirical examination. Brain activity and cognition should be reviewed comprehensively since it can be a manifestation of the experiencing of expected or unexpected states of mind. The visual EEG-neurofeedback training and audiovisual alpha relaxation training constitute holistic assistance within the athletic training. It produces changes manifested in functionally different, eyes-open and eyes-closed states of the brain.

ACKNOWLEDGEMENTS

The study was financed from budgetary means for scientific research in 2011-2014 as the research project No. NRSA1 000751.

REFERENCES

Alkire, M.T,, Hudetz, A. G., Tononi, G. (2008). Consciousness and anesthesia. Science, 322, 876-880.

Bazanova, O.M., Mernaya, E.M, Shtark, M.B. (2009). Biofeedback in Psychomotor Training. Electrophysiological Basis Neuroscience and Behavioral Physiology, 39, 437- 448.

Bradley, R., McCraty, R., Atkinson, M., Tomasino, D., Daugherty, A., Arguelles, L. (2010). Emotion self-regulation, psychophysiological coherence and test anxiety results from an experiment using electrophysiological measures. Apl. Psychophysiol. Biofeedback, 35(4), 261-283.

Cavdar, S., Onat, F. Y., Cakmak, Y. O., Yananli, H. R., Gülçebi, M., Aker, R. (2008). The path ways connecting the hippocamp alformation, the thalamic reuniens nucleus and the thalamic reticular nucleus in the rat. Journal of Anatomy, 212, 249-256.

Cherapkina, L. (2012). The neurofeedback successfullness of sportsmen, *Journal of Human Sport and Exercise*, *7*(1)

Damasio, A. (2010). Self Comes to mind: Constructing the Conscious Brain, Pantheon books, New York.

De Bruin, E.D., Swanenburg, J., Betschon, E., Murer, K. (2009). A randomised controlled trial investigating motor skill training as a function of attentional focus in old age. BMC Geriatrics, 9-15.

Dehaene, S., Changeux, J.P., Naccache, L., Sackur. J., Sergent, C. (2006). Conscious, preconscious, and subliminal processing: at estable taxonomy. Trend sin Cognitive Sciences, 10, 204-211.

Del Percio, C., Infarinato, F., Marzano, N., Iacoboni, M., Aschieri, P., Lizio, R., Soricelli, A., Limatola, C., Rossini, P. M., Babiloni, C. (2011). Reactivity of alpha rhytms to eyes opening is lower in athletes than non-athletes: A high resolution EEG study. *International Journal of Psychophysiology*, *82*(3), 240–247.

Desmurget, M., Reilly, K. T., Richard, N., Szathmari, A., Mottolese, C., Sirigu, A. (2009). Movement intention after parietal cortex stimulation in humans. Science, 324, 811-813.

Eser, F., Yavuzer, G., Karakus, D., Karaoglan, B. (2008). The effect of balance training on motor recovery and ambulation after stroke: a randomized controlled trial. Eur J Phys Rehabil. Med. 44, 19-25.

Fields, R.D. (2009). The Other Brain: The Scientific and Medical Breakthroughs That Will Heal Our Brains and Revolutionize Our Health. Simon & Schuster, 28-64.

García-Panach, J., Lull, N., Lull, J.J., Ferri, J., Martínez, C., Sopena, P., et al. (2011) Voxel-based analysis of FDG-PET in traumatic brain injury: regional metabolism and relationship between the thalamus and cortical are as. Journal of Neurotrauma, 28, 1707-1717.

Gorassini, M.A., Norton, J.A., Nevett-Duchcherer, J., Roy, F.D., Yang, J.F. (2009). Changes in locomotor muscle activity after treadmill training in subjects with incomplete spinal cord injury. J. Neurophysiol., 101, 969-979.

Gramann, K., Gwin, J.T., Bigdeli-Shamlo, N., Ferris, D.P., Makeig, S. (2010). Visual evoked responses during standing and walking. Frontiers in Human Neuroscience, 4, 201-202.

Gwin, J.T., Gramann, K., Makeig, S., Ferris, D.P. (2010). Removal of Movement Artifact From High-Density EEG Recorded During Walking and Running. *Journal of Neurophysiology*, *103*(6), 3526–3534.

Gwin, J.T., Gramann, K., Makeig, S., Ferris, D.P. (2011). Electrocortical activity is coupled to gait cycle phase during treadmill walking. NeuroImage, 54, 1289-1296.

Hamilton, A.F., Brindley, R.M., Frith, U. (2007). Imitation and action understanding in autistic spectrum disorders: Howvalid is the hypothesis of a deficit in the mirror neuron system? Neuropsychol., 45, 1859-1868.

Hashim, H.A. (2011). The Effects of Progressive Muscle Relaxation and Autogenic Relaxation on Young Soccer Players' Mood States. Asian Journal of Sports Medicine., 2, 99-105.

Hatfield, B.D. (2001). The role of the left temporal region during the cognitive motor demands of shooting in skilled marksmen. Biological Psychology., 58(3), 263-277.

Heiden, E., Lajoie, Y. (2009). Games-based biofeedback training and the attentional demands of balance in older adults. Aging Clin Exp Res.

Horlings, C., Engelen, B., Allum, J., Bloem, B. A. (2008). Weak balance: thecontribution of muscle weakness to postural instability and falls. Nat Clin Pract Neurol., 4, 504-515.

Kirtley, E., Thornton, Ć., Dennis, P. (2009). Traumatic Brain Injury Rehabilitation: QEEG Biofeedback. Treatment Protocols. Springer Science Media. LLC.

Långsjö, J.W., Alkire, M.T., Kaskinoro, K., Hayama, H., Maksimow, A., Kaisti, K. K., et al. (2012). Returning from Oblivion: Imaging the neural core of conscious- ness. Journal of Neuroscience. 32, 4935-4943.

Lau, T.M., Gwin. J.T., Ferris, D.P. (2012). How many electrodes are really needed for EEG-based mobile brain imaging? *Journal of Behavioral and Brain Sciences,* 2, 387-393.

Leff, D., Aggarwal, R., Rana, M., Nakhjavani, B., Purkayastha, S., Khullar, V., Darzi, A.W. (2008). Laparoscopic skills suffer on the first shift of sequential night shifts: program directors beware and residents prepare. Ann Surg., 247, 530-539.

Leon-Carrion, J., Leon-Dominguez, U., Pollonini, L., Wu, M.H., Frye, R.E., Dominguez-Morales, M.R., et al. (2012). Synchronizing the anterior and posterior cortex to produce conscious nessin patients with traumatic brain injury (TBI). Brain Research, 1476, 22-30.

León-Domínguez, U., Vela-Bueno, A., Froufé-Torres, M., León-Carrión, J.A (2013). Chronometric functional sub-network in the thalamo-cortical system regulates the flow of neural information necessary for conscious cognitive processes. Neuropsychology, 51(7), 1336-1349.

Libet, B. (1992). The neural time-factor in perception, volition and fire will. Revue de Metaphisique et de Morale, 2, 255-272.

Marshall, M.S., Bentler P.M. (1976). The Effects of Deep Physical Relaxation and Low-Frequency-Alpha Brainwaves on Alpha Subjective Reports. Psychophysiology. 13(6), 505-516. Article first published online: 2007, DOI: 10.1111/j.1469-8986; tb00870.x.

Mikicin M. (2015). The autotelic involvement of attention induced EEG neurofeedback training improves the performance of an athlete's mind. Biomedical Human Kinetics, 7, 58–65, DOI: 10.1515/bhk-2015-0010.

Mikicin M., Orzechowski G., Jurewicz K., Paluch K., Kowalczyk M., Wróbel A. (2015). Brain-training for physical performance: a study of EEG-neurofeedback and alpha relaxation training in athletes. Acta Neurobiologiae Experimentalis 75, 4, 434-445.

Mikicin M., Kowalczyk M. (2015a). Improvement in peak performance as a result of the inhibition of beta 2 bands (EEG) in neurofeedback-EEG training in motion. Acta Neuropsychologica, 13, 4, 365-375

Mikicin M. Kowalczyk M. (2015b). Audio-visual and autogenic relaxation alter amplitude of alpha EEG band, causing improvements in work performance in athletes. Applied Psychophysiol and Biofeedback, 40:219–227. DOI: 10.1007/s10484-015-9290-0).

Omlor, W., Patino, L., Hepp-Reymond, M.C., Kristeva, R. (2007). Gamma-range corticomuscular coherence during dynamic force output. Neuroimage, 34, 1191-1198.

Pąchalska M., Kaczmarek M., Kropotov J.D. (2014) *Neuropsychologia kliniczna: od teorii do praktyki.* Warszawa: Wydawnictwo Naukowe PWN.

Ray, S., Niebur, E., Hsiao, S. S., Sinai, A., Crone, N. E. (2008). High-frequency gamma activity (80–150 Hz) is increased in human cortex during selective attention. Clin. Neurophysiol., 119, 116–133.

Ros, T., Théberge, J., Frewen, P.A., Kluetsch, R., Densmore, M., Calhoun, V.D., Lanius, R.A. (2013) Mind over chatter: Plastic up-regulation of the fMRI salience network directly after EEG neurofeedback. NeuroImage, 65, 324–335.

Schiff, N.D. (2008). Central thalamic contributions to arousal regulation and neurological disorders of consciousness. Annals of the New York Academy of Sciences USA, 1129, 105-118.

Schroeder, C.E., Lakatos, P. (2009). Low-frequency neuronal oscillations as instruments of sensory selection. Trends Neurosci., 32, 9-18.

Searle, J.R. (2004). Mind: A brief Introduction. Oxford University Press, 1-168.

Shaw*,* L.*,* Zaichkowsky*,* L*.* *(*2012*).* Setting *the* Balance *:* Using Biofeedback *and.* Neurofeedback *With* Gymnasts*. Journal of Clinical Sport Psychology, 6, 47-66.*

Shelley-Tremblay, J.F., Shugrue, J.D., Kline, J.P. (2006). Changes in EEG laterality index effects of social inhibition in novice golfers. Journal of Sport Behavior, 29(4), 353-373.

Singer, W. (2002). Synchronization neuronale et représentationsmentales. *Pour la science*, *302*, 74–79.

Strizhkova, T. Strizhkova, O., Cherapkina, L., (2012). Neurofeedback course applying of high skilled gymnastics in competitive period. *Journal of Human Sport and Exercise*, *7*(1), 185-193.

Strupp, M., Bartenstein, P., Jahn, K. (2010). Real versus imagined locomotion: a [18F]-FDG PET-fMRI comparison. Neuroimage, 50, 1589-1598.

Teplan, M., Krakovska, A., Stolc, S. (2006). EEG responses to long-term audio-visual stimulation. International Journal of Psychophysiology, 59(2), 81-90.

Tononi, G., Laureys, S. (2008). The neurology of consciousness: Another view. In: S. Laureys, G. Tononi (Eds.), The Neurology of Consciousness: Cognitive Neuroscience and Neuropathology. Elsevier Ltd.

Vecina, M.L., Chacón, F., Sueiro, M., Barrón, A. (2012). Volunteer Engagement: Does Engagement Predict the Degree of Satisfaction among New Volunteers and the Commitment of Those who have been Active Longer? Applied Psychology, 61(1), 130-148*.*

Vecina, M.L., Chacón, F. (2013). Is engagement different from satisfaction and organizational commitment? Relations with intention to remain, psychological well-being and perceived physical health in volunteers. Anales de Psychology, 29(1), 225-232.

Vertes, R.P., Hoove, W.B., Szigeti-Buck, K., Leranth, C. (2007). Nucleus reuniens of the midline thalamus: link between the medial prefrontal cortex and the hippocampus. Brain Research Bulletin, 71, 601-609.

Vertes, R.P. (2002). Analysis of projections from the medial prefrontal cortex to the thalamus in the rat, wit hemp hasison nucleus reuniens. Journal of Comparative Neurology, 442, 163-187.

Wefald, A.J., Downey, R.G. (2009). Construct Dimensionality of Engagement and its Relation with Satisfaction, The Journal of Psychology, 143(1), 91-111.

Wróbel, A. (2014). Attentional activation in corticothalamic loops of the visual system. In: The New Visual Neurosciences, Eds John S. Werner and Leo M. Chalupa, 339-349.

Zhou, J., Liu, X., Song, W., Yang, Y., Zhao, Z., Ling, F. et al. (2011). Specific and nonspecific thalamocortical functional connectivity in normal and vegetative states. Consciousness and Cognition, 20, 257-268.

Zijlstra, A., Mancini, M., Chiari, L., Zijlstra, W. (2010). Biofeedback for training balance and mobility tasks in older populations: a systematic review. Journal of NeuroEngineering and Rehabilitation, 7, 1, 58.

Address for correspondence:
Mirosław Mikicin, PhD
The Józef Piłsudski University of Physical Education
34 Marymoncka Street
00-968 Warsaw, Poland
E-mail: miroslaw.mikicin@awf.edu.pl
tel.: +48 22 8340431