International Journal of Humanities and Social Science Invention
ISSN (Online): 2319 – 7722, ISSN (Print): 2319 – 7714
www.ijhssi.org ||Volume 5 Issue 9||September. 2016 || PP.50-56

Current Approaches to Neurofeedback

Pawel Bodera[1] , Wanda Stankiewicz[1]
[1]*Department of Microwave Safety, Military Institute of Hygiene and Epidemiology,*
4 Kozielska Str., Warszawa, Poland

ABSTRACT: *This article is a review of neurofeedback techniques in the broad context of various clinical implications. Authors presented the neurophysiological background of these developing methods in relation to the state-of-the-art techniques. The broad range of methods of neurofeedback were reviewed, comprising the transfer of information, automation, brain-computer interface, multichannel Z-Score neurofeedback and slow cortical potentials. Neurofeedback may be an effective tool for self-regulation, useful for achieving better self-knowledge and enhanced cognitive skills. A tailored, dedicated program, based on quantitative electroencephalographic (QEEG) assessment and/or Z-Score should be implemented for a given patient in order to gain trust and fulfill the compliance.*
The proven clinical benefits of multi-channel neurofeedback, targeting regulation of particular brain regions, or inducing specific neural patterns, may be an alternative method for treating diseases in a non-invasive, introspective way. Effective modulation of the physiological functions which may affect various neural mechanisms of cognition and behavior seems to be the future perspective of neurofeedback.
Keywords: *biofeedback, neurofeedback, brain-computer interface, Z-Score neurofeedback, slow cortical potentials (SCP), quantitative electroencephalography (QEEG).*

I. INTRODUCTION

Biofeedback is a technique which makes information available to the mind in order to understand and manipulate physiological activity, based on the selected sensors which are attached to the body. Neurofeedback is aimed at self-regulation of brain activity as a form of behavioral training where desirable brain activity is rewarded and undesirable brain activity is inhibited. Neurofeedback (NFB) is currently perceived, among the different neuromodulation techniques, as the efficient tool in the treatment of children with attention-deficit/hyperactivity disorder (ADHD). The dynamic development of neurofeedback uses the modulation capabilities of the human brain, where billions of interconnected neurons in our brain are processing information and control our body and internal organs. The brain activity correlated with a conscious perception, which is measurable, occurs several hundred milliseconds after stimulus correlated with a conscious perception.

In activities such as rapid conversation or competitive athletics, the answers on stimuli (seemingly consciously) may occur before the above-described, activity leading to the correlation in the brain. Improvement of body awareness and control may be obtained by a fully operational biofeedback system which can be used as extendable platform for novel physiological sensors and research projects. Multiple physiological sensors allow simultaneous acquisition of data which may be interpreted in an efficient way.

This technique enables the mind to learn to be more aware of what is happening inside the subliminal brain. The conversion of a conscious choice into an automatic reaction is possible when training a given response to a signal over a given time.It is often not possible to get an objective snapshot of the body status without help from technical devices, gaining access to information that normally is not available.

Brain Activity Patterns

Bearing in mind that amplitudes of most of the waves range from 10μV to 100μV, and lie within 1 and 60 cycles per second, and that distribution of brain activity patterns are very different between subjects and also change with age, the interpretation of brain waves is not an easy task. In most cases, brain waves with a frequency between 38Hz and 60Hz are not taken for further diagnosis. Nowadays, even an expert may have trouble detecting and understand brain activity patterns, therefore nowadays the brain waves are not only viewed and interpreted in the time domain, but also in the frequency domain after spectrum analyses. The six common brain wave types are varied on: delta, theta, alpha, beta, gamma and mu waves.

Delta Waves

These very slow waves are broadly localized, and are diffused, bilateral, widespread and range from 0.5Hz to 3.5Hz. They are often found frontally in the brain and are very slow and present during deep sleep, but have also been found in subjects who are awake, being then called delta waves. They are visible in such pathologies as trauma, toxicity, neuropathy and subjective states as deep, dreamless sleep, trance, unconsciousness.

Theta Waves

The rhythm of theta is mediated by subthalamic mechanisms, and like delta waves, may have a distinctive non-sinusoidal appearance. Such waves are visible in arousal state or the transition process from a conscious mental state to sleep and have a frequency of between 3.5Hz and 7.5Hz.

Volition and movement is often connected with the theta formation, especially in the frontal areas of brain. Theta waves, particularly high in such deviations as inattention and internalized thought, are associated with attention deficit disorder in children, and connected with creative thoughts and memory retrieval.

The higher theta wave ratios, usually accompanied by other wave frequencies in the mid brain, are more present in children than in adults due to stress, frustration or disappointment. Thus, theta it is not intrinsically bad rhythm that needs to be minimized, but rather important is flexibility and appropriateness.

Alpha Waves

The waves range from 7.5Hz to 12.0Hz which can be detected in both hemispheres in the back of the brain are named alpha waves. They occur when one is thinking about something peaceful and calm with closed eyes. Alpha waves decrease or fully disappear when we open the eyes again.

Alpha waves that have a form of a round, sinus-shaped signals can also be sharp and diffuse in the state of coma. The weakness, or lack of, alpha waves is often associated with deep concentration or feelings of anxiety.

Beta Waves

Beta waves range from 12.0Hz to 30.0Hz are divided into three sub-ranges, namely low beta, medium beta and high beta waves. Moderate mental activity, active, busy or anxious thinking or concentration are indicated by low beta waves.

A state of high alertness, and also intensive thinking, is often associated with medium beta waves, which can be interfered with by mu waves, as they share a part of the frequency band.

Band	Frequency (Hz)	Description
Delta	0.5Hz to 3.5Hz	Deep sleep or meditation.
Theta	3.5Hz to 7.5Hz	Sleep, daydreaming, relaxed or conscious.
Alpha	7.5Hz to 12.0Hz	Concentrated state, peaceful thoughts.
Beta	12.0Hz to 30.0Hz	Thinking or concentration, activity, busy or anxious.
Gamma	30.0Hz to 50.0Hz	Perception, cognition, attention.
Mu	8.0Hz to 13.0Hz	Present when body is idle and not moving, overlapping with alpha and low beta.

Such mental states as stress, panic, anxiety or hyper-awareness are often accompanied by high beta waves, which generally means that information is being processed and that the mind is awake.

Beta waves (mostly occurring in central or frontal regions of the brain and being equally distributed between the left and the right hemisphere with the amplitude approx. 30 μV) are present when solving complex mathematical problems.

Gamma Waves

Gamma waves, range from 30.0Hz to around 50.0Hz, together with beta are associated with attention, perception and cognition and are related to consciousness. Gamma waves, which have very small amplitudes, are also related to motor functions when several brain regions are working together.

Rarely-found frequencies higher than 50Hz are indicators for brain diseases.

Mu Waves

Mu waves range from 8.0Hz to 13.0Hz overlap alpha and low beta wave frequency ranges and they have the same kind of behavior as alpha waves when the eyes are closed. Therefore, they have to be filtered and assigned correctly for interpretation because they can be easily mixed up. Mu waves may be observed when our hands are at rest, being dominant when the motor neurons recover.

II. QUALITATIVE ENCEPHALOGRAPHY (QEEG) IN NEUROFEEDBACK

Neurofeedback should be distinguish from conventional EEG, and also from quantitative EEG (QEEG). Despite the apparent similarities, they are by no means the same.

Electroencephalography (EEG) which is a technique by which the electrical activity of brain is recorded by the use of sensors placed on the scalp, coupled with highly sensitive amplifiers, was first recorded by the German psychiatrist Hans Berger in 1932.

EEG is a widely accepted clinical tool for psychiatrists and neurologists. Visual inspection of EEG based on the waveforms analysis may help in the identification of abnormalities such as epilepsy, head injuries, stroke and other disease conditions.

Quantitative EEG (QEEG) is a procedure in which EEG recordings are computer-analyzed to generate numbers referred to e.g. amplitude or power, ratios, coherence, phase etc. QEEG is used to guide decision making and therapeutic planning, and can also be used to monitor and assess treatment progress.

The expert in quantitative EEG (QEEG) must be capable of answering standard questions and providing counsel with the relevant discovery issues such as EEG recording procedures, a retest reliability, elimination of artifact, measures of focal sharp waves and brain deregulation, etc. Such persons should explain to the patient that the qEEG is not to be used as a stand-alone diagnostic test for any clinical condition including for traumatic brain injury or schizophrenia, etc.

The standard 10-20 system for EEG electrode placement using 19 or 21 locations on the scalp was developed by Klem et al. [1]. All electrodes, which are connected to the medical-grade EEG amplifiers, are checked for proper impedance, typically at 5 kΩ or below.

The amplified EEG signals, which are digitalized, are filtered through a band-pass filter to eliminate noise and other frequencies (usually >40 Hz). The sampling rate should be is 2.5 times greater than the highest frequency of interest in order to fulfill the minimum requirements. The signal is then subjected to fast Fourier analysis for further processing to derive the amplitude and power in each of five frequency bands. 120 and 256 samples per second are the most acceptable for the majority of neurofeedback applications.

Discussions on the measure of electrical resistance between the scalp and the electrode, led to the medical standards for obtaining correct input impedance.

Fast Fourier Transform

Fast Fourier Transform analysis is the usual method for brain map analysis for deriving the power in each frequency band, where the unwanted frequencies are eliminated during passage through a band-pass filter. The differences at each stage of this process are caused even by small coding errors.

Blind source separation

Neuroplasticity, having an activity-dependent nature, provides us the potential for enhancing our understanding of brain processes and using neurofeedback manipulations for treating clinical conditions. A number of methods may be applied to alter brain activity, such as electrical stimulation e.g., deep brain stimulation, transcranial direct current and alternating current stimulation, Transcranial Magnetic Stimulation (TMS) as well as pharmacological interventions.

Contrary to these methods, neurofeedback offers a non-invasive technique which is capable of manipulating endogenous brain activity. A range of clinical conditions, particularly ADHD and epilepsy may be treated using neurofeedback. The functional significance of endogenous brain activity may be studied in addition as the independent variable using experimental neuro feedback.

A spatial smearing effect, is derived of a linear mixture of activity of multiple brain sources and artifacts, because traditional EEG neurofeedback utilizes a small number of active electrodes on the scalp. Therefore, training based on single electrode sites is likely influencing multiple brain regions and processes. Blind Source Separation (BSS) is a group of processing techniques, capable of processing signals which provide the source activity identification from a mixed signal.

The widespread applicability of such methods was possible due to their blind nature, where no knowledge of the source activity or mixing process is required. BSS was identified as a method suited to EEG signal processing, and is widespread use in EEG research both in the exploration of functionally and spatially distinct brain sources and the identification and removal of artifacts.

BSS methods were recently proposed because they have important advantages in multi-channel neurofeedback, outweighing those methods based on source localization.

The sources derived from signal processing methods such as BSS may be a groundwork for neurofeedback, which may be less susceptible to common artifacts, having significant advantages over traditional methods. Such signal processing methods open new fields of the studies of functional significance of identified sources via trained procedures.

Threshold regulation

Lansbergen et al. [2] demonstrated when a patient is rewarded at least in 60% or 70% of trials the automatic threshold regulation may be introduced. A performance that is worse than the performance the day before may be rewarded. Therefore, the patient gets positive reinforcement in 60% -70% of the time or trials even if he is doing nothing.

Nevertheless, the argument against automatic threshold regulation reveals the need for manual and/or individualized regulation of thresholds which may guarantee a certain amount of reward to keep the participant motivated. Therefore, when the participant “earns” too much or not enough reward, the threshold has to be manually adjusted, i.e. is set higher or lower.

Finally, during the establishment of the final goals, one ought to generalize similar though different situations in life. The specificity of neurofeedback is such that neither breakpoints nor final goals, nor a prognosis are known.

The amount of activity in a certain frequency band such as norms of theta/beta ratio, which were registered and assessed during spontaneous EEG measurements, cannot be simply transferred to brain activity in a neurofeedback session.

Transfer

An important issue of neurofeedback is the transfer of a skill from the training setting in which it was acquired to any situation in life. Cartoni et al.[3] conclude that an associated to a reward, conditioned stimulus affect the operant conditioned behavior in different ways.

In order to discriminate between situations in which a certain behavior would be useful or not some cues are necessary. For example, an decrease of theta might be useful to be concentrated and awake while an increase may help in order to fall asleep.

As long as the cues are not transferred to everyday life situations, cue-dependent learning constricts learning to the ‘artificial’ learning environment. The same holds for the old, dysfunctional behaviors, and not only for newly acquired behavior.

A systematic and thorough behavior analysis will help in the assessment of the efficiency of training and help the therapist to become aware of proper adjustment to the eliciting environmental, emotional, cognitive, behavioral or physiological variables. An additional problem transferring newly acquired behavior to everyday life may occur among children with Attention Deficit-/Hyperactivity Disorder (ADHD), which may be caused by the inability to anticipate consequences, and in turn affect the perception of cues.

Automation

The final aim of therapeutic session is skill-automating of the self-regulation of brain activity. Biofeedback training leads to autonomic control through a process consisting of the identification of efferent programs. The learner will identify by trial and error the correct behavior during the “cognitive phase” at the beginning of the process. It demands a high amount of attentiveness while learning the basis sequences. The new behavior is practiced during the subsequent “associative” phase, when the wrong reactions should be inhibited. Less attentiveness is needed in reliable execution of the “autonomous, automatic phase” at the end of the performance.

The repeated matching of a reaction and feedback that signals from an image of a correct reaction, occurs during the cognitive phase when the participant tries to identify strategies that lead to successful behavior.

Slow Cortical Potentials Training

The patient focuses on changing a visual display on the computer with one electrode placed in the center of the top of the head and another electrode behind each ear during SCP training. The positive or negative polarizations of the EEG in the very slow frequency range from 0.3 Hz to usually about 1.5 Hz are called slow cortical potentials (SCPs). A negative shift in DC potentials, which create excitatory effects, may occur during cognitive processing. In turn, when cortical networks are being inhibited, positive SCPs are observed.

For example, the cortex is electronegative during and prior to an epileptic seizure and similar hyper-excitability is observable before many migraines. A seizure tends to be electropositive in a cortex which is fatigued. SCP neurofeedback training, which is most popular in Europe, has been done particularly with epilepsy, ADHD and migraine. It was proved by Kotchoubey et al. [4], who studied self-perception of self-regulation in patients with epilepsy, who were first trained with neurofeedback and then improved after additional SCP training.

They also observed that the extension of receptors in the arterial walls during cortical activation and deactivation may be responsible for the cerebral blood flow changes. The task, which produced both electrically negative and positive slow potential shifts, caused an increase of blood flow in different areas of the cortex. Patients with ADHD may self-regulate the brain activity after 6 months and 2 years after the final session of the SCP-neuro feedback treatment.

The slow negative potential shift of cortical excitation among SCP feedback participants who were asked to self-regulate thresholds is similar to the dependent negative variation (CNV) which was observed in, as an example, Go/No-Go experiment.

Practice schedules

The number of sessions necessary for the skill to be properly acquired is still an open question, which comprises several aspects. This question, regarding the training schedule, was studied by Wang et al. [5] who reported significant improvement after 20 sessions in healthy children compared to cumulative training (20 sessions in 2, 5 or 10 days). Designing of cognitive training research and neurofeedback training protocols is not easy in the absence of any systematic research.

More than one session per day does not seem to be possible simply for practical reasons, bearing in mind that neurofeedback sessions normally last 20 to 60 min. Although parents of the trained children preferred the schedule with three sessions a week, Arnold et al. [6] observed no difference in outcome after two vs. three weekly sessions.

There are three different effects of neurofeedback: self-regulation which may be improved without clinically important effects, clinical improvement without ability to self-regulate, and also self-regulation and clinical outcome. These are similar, or equal, in effect.

Drechsler et al. [7] and Strehl et al. [8] used a significant differentiation between tasks (cortical negativation and cortical positivation) as a marker for learning progress. A meta-analysis by Arns et al. [9] reported a significant correlation between the number of sessions and decrease of symptoms of inattention. The authors also stated that the relation between the number and frequency of sessions was not investigated so far. Age, maturation of brain, stress vulnerability and/or cortical functioning may influence the speed of learning, therefore when a participant is a ‘quick learner’ fewer sessions are necessary.

III. BRAIN COMPUTER INTERFACE (BCI) AND NEUROFEEDBACK

Neurofeedback supports brain functioning and behavioral cognitive performance through growth and changes at cellular levels of the brain.

However, Liu et al.[10] suggested two important limitations of the current neuro feedback systems. The monotonous feedback methods which cannot attract subjects to focus on them is one such limitation, and the other is the EGG collection limited in central area of the head.

The authors presented a system based on neurofeedback and virtual reality technology for ADHD treatment in response to these problems. The impact of achievement of the intrinsic and extrinsic motivation, which are influenced by hope for success or fear of failure was not studied in neuro feedback, nor in BCI-research.

Belief in the positive aspect of technology may influence the ability to self-regulate SMR. Emotional or cognitive overload negatively influenced the performance as they observed

It has been widely accepted for years that performance might be influenced by the factors being correlated with a disease. Such symptoms as moods and bodily complaints influence the performance in locked-in patients with Amyotrophic Lateral Sclerosis (ALS). An impairment of executive functions is a factor which may hinder self-regulation.

Gaining of relevant information, inhibition of irrelevant impulses and shifting the mental set are the working memory features which are necessary for self-regulation. Some authors, such as Strehl et al. [11] and Mayer et al. [12] observed this effect among patients with ADHD who successfully completed training, although they were impaired.

In some diseases, the typical symptoms may preclude participation in neurofeedback training. For example, autistic children are not allowed to be touched or to have electrodes fixed on head. A tailored program should be implemented by the experienced therapist in order to gain trust and fulfill the compliance.

Neuronal Basis of Neuro feedback Learning

The latest animal studies, utilizing intracranial electrodes, provide insight into the neuronal basis of neurofeedback learning. Koralek et al. [13] observed striatal neurons, changing their firing rates, which lead to the building of strong connections with motor cortex neurons.

The animal is not able to learn the skill if these connections cannot develop, due to experimental manipulations. Schafer and Moore [14] proved the specificity of neurofeedback on the Rhesus monkeys which learned to voluntarily reduce or enhance the activity of neurons within the frontal eye field. They used the pitch of a tone as feedback and juice as reinforcement.

The specific association of self-regulated neural activity with top-down attention may determine a basis for neurofeedback training improvements in patients with ADHD.

Neurofeedback is mostly directed to the motor cortex, which is probably the most obvious place to search for a cortical signal directly associated with volitional movement. A substantial part of the available data of neurofeedback research was gathered from people with disabilities, aiming to restore their communicative or motor functions.

Several studies use Brain-Computer Interfaces (BCI), studying such diseases as brain stem stroke, amyotrophic lateral sclerosis, or spinal cord lesions using signals including slow cortical potentials, P300 potentials. The brain oscillations play a key role in mediating multi-scale communications, for example lower-frequency oscillations allow an integration of long-term neuronal effects of the broad brain areas. Contrary to this, high-frequency oscillations facilitate a temporally more precise and spatially limited representation of information, being confined to small ensembles of neurons.

Delta activity phase (1–4 Hz), which is modulated by attention in the visual cortex, in turn modulates the power of higher frequencies and the firing of neurons. Changes in large-scale neural activity allow effective communication between distributed networks and regulate the flow of information processing. The recently presented model attempts to integrate the evidence for neurofeedback control with the view of multi-scale coordination in neuronal dynamics. The large-scale brain activities which may reveal regional diversity in the properties of local brain activity (such as their spatial topography, spectral characteristics, propagation, and phase coherence) was presented originally by Lachaux et al. [15]

Power, amplitude, synchronization, or phase locking are the key parameters which reveal changes across neurofeedback sessions. Therefore, the progressive difference in observed parameters is rather expected. One important question concerns the determination of which spatial and temporal scale the neural dynamics can be influenced, and in the most efficient manner. Future studies may provide an answer to whether or not control can be achieved in such areas that are known to be hierarchically structured, as the motor, visual, or other primary sensory cortices, in order to be appropriately wired for top-down coordination.

Assuming the anatomical and organizational differences of the brain, the modulations will not be homogeneously efficient across cortical regions. Scharnowski et al. [16] presented that neurofeedback based on real-time fMRI offers control in spatially localized brain activity in the range of millimeters across the entire brain. The benefits from a very high temporal resolution of EEG-based biofeedback, are limited with respect to spatial specificity.

The reaching of certain brain regions (such as hippocampus, amygdale, and prefrontal cortex) that can be efficiently treated with neurofeedback, to acquire sufficient regulation, is very limited. The alternative choice is Z-Score neurofeedback, which the option to use from 1 to 19 electrodes in a *Z*-score neurofeedback protocol (19ZNF). The positive clinical outcomes of 19ZNF may occur in fewer sessions than traditional NF, approximately three times fewer. Another important issue is neuronal plasticity, which may lead to regeneration of motor function or boost memory processes, and can modulated during neuro feedback .

Schizophrenia is another possible intriguing application of neuro feedback. Uhlhaas and Singer [17] showed impaired neural synchronization in gamma and beta ranges, but not in lower frequencies, thus the synchronization in these frequency bands may be achieved directly or indirectly through the theta band via cross-frequency coupling.

The hyperactive stress-response of the hypothalamic-pituitary-adrenal (HPA) axis underlies depression research. HPA activity, controlled by functional axes including the hippocampus and the amygdale, is reduced and enhanced in depression, respectively, and could be treated with neuro feedback. To sum up, neurofeedback may be an effective tool for self-regulation, which can help achieve a better self-knowledge and enhanced cognitive skills in certain clinical conditions. Effective modulation of physiological functions, which may take control over various neural mechanisms of cognition and behavior, seems to be the future perspective of neurofeedback.

The proven clinical benefits of multi-channel neurofeedback, targeted to regulate particular brain regions or induce specific neural patterns, may be an alternative method to treat diseases in a non-invasive, introspective way.

REFERENCES

[1]. Klem GH, Lüders HO, Jasper HH, Elger C. The ten-twenty electrode system of the International Federation. The International Federation of Clinical Neurophysiology. Electroencephalography and Clinical Neurophysiology Suppl 1999, 52:3-6.

[2]. Lansbergen MM, van Dongen-Boomsma M, Buitelaar JK, Slaats-Willemse D. ADHD and EEG-neurofeedback: a double-blind randomized placebo-controlled feasibility study. J. Neural Transm. 2011, 118: 275–284.

[3]. Cartoni E, Puglisi-Allegra S, Baldassarre G. The three principles of action: a Pavlovian-instrumental transfer hypothesis. Front. Behav. Neurosci. 2013, 7:153.

[4]. Kotchoubey B, Schleichert H, Lutzenberger W, Birbaumer N. A new method for self-regulation of slow cortical potentials in a timed paradigm. Appl Psychophysiol Biofeedback. 1997, 22:77-93.

[5]. Wang Z, Zhou R, Shah P. Spaced cognitive training promotes transfer. Front. Hum. Neurosci. 2014, 8:217.

[6]. Arnold LE, Lofthouse N, Hersch S, Pan X, Hurt E, Bates B, et al. EEG neurofeedback for ADHD: double-blind sham-controlled randomized pilot feasibility trial. J. Atten. Disord. 2013, 17: 410–419.

[7]. Drechsler R, Straub M, Doehnert M, Heinrich H, Steinhausen HC, Brandeis D. Controlled evaluation of a neurofeedback training of slow cortical potentials in children with Attention Deficit/Hyperactivity Disorder (ADHD). Behav. Brain Funct. 2007, 3:35.

[8]. Strehl U, Kotchoubey B, Trevorrow T, Birbaumer N. Predictors of seizure reduction after self-regulation of slow cortical potentials as a treatment of drug-resistant epilepsy. Epilepsy Behav. 2005, 6, 156–166.

[9]. Arns M, de Ridder S, Strehl U, Breteler M, Coenen A. Efficacy of neurofeedback treatment in ADHD: the effects on inattention, impulsivity and hyperactivity: a meta-analysis. Clin. EEG Neurosci. 2009, 40: 180–189.

[10]. Liu T, Wang J, Chen Y, Wang R, Song M. Neurofeedback Treatment Experimental Study for ADHD by Using the Brain-Computer Interface neurofeedback system, World Congress on Medical Physics and Biomedical Engineering May 26-31, 2012, Beijing, China IFMBE Proceedings Volume 39, 2013, 1537-1540.

[11]. Strehl U, Leins U, Goth G, Klinger C, Hinterberger T, Birbaumer N. Self-regulation of slow cortical potentials - a new treatment for children with attention-deficit/hyperactivity disorder. Pediatrics 2006, 118: 1530–1540.

[12]. Mayer K, Wyckoff SN, Schulz U, Strehl U. Neurofeedback for Adult Attention-Deficit/Hyperactivity Disorder: Investigation of Slow Cortical Potential Neurofeedback - Preliminary Results. J. Neurother. 2012, 16: 37–45.

[13]. Koralek AC, Jin X, Long JD, Costa RM, Carmena JM. Corticostriatal plasticity is necessary for learning intentional neuroprosthetic skills. Nature 2012, 483: 331–335.

[14]. Schafer RJ, Moore T. Selective attention from voluntary control of neurons in prefrontal cortex. Science 2011, 332: 1568–1571.

[15]. Lachaux JP, Rudrauf D, Kahane P. Intracranial EEG and human brain mapping. J. Physiol. Paris 2003, 97: 613–628.

[16]. Scharnowski F, Hutton C, Josephs O, Weiskopf N, Rees G. Improving visual perception through neurofeedback. J. Neurosci. 2012, 32: 17830–17841.

[17]. Uhlhaas PJ, Singer W. Neural synchrony in brain disorders: relevance for cognitive dysfunctions and pathophysiology. Neuron 2006, 52:155–168.