

Abstract

Symposium IV: Quantitative EEG and neurofeedback

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Introduction: Efficacy of EEG Biofeedback, Eran Zaidel, University of California at Los Angeles, USA, and Anat Barnea, Bio-Keshev Clinic, Kibutz Givat-Chaim Ichud, Israel

The symposium is the third in a series organized to assess the methodology, the mechanism, and the prospects of modulating cognition by changing the EEG profile of the brain. (The first was at Bar Ilan University in Israel in March, 2004, the second at UCLA in April, 2005.) This symposium addresses three main themes: (1) selecting a control group/experiment, (2) the specificity of the training site, of the target frequency, of the affected cortical region, and of the affected function, and (3) the search for a physiological correlate of the effect of NF and its mechanism.

Use of double-blind sham control subjects who receive nonveridical feedback with the same reward contingency as the experimental group remains the gold standard. However, it requires careful control or removal of distorting artifacts in the EEG record in real time prior to NF. Alternatives include comparing “responders” and “nonresponders” to training, delayed feedback, and comparing training with left- and right-side electrodes. It is not known whether operant conditioning is the only effective method of feedback, or whether delayed feedback and summary performance statistics are also effective methods of training. New technology offers a rich range of target EEG training profiles, ranging from a linear combination of amplitudes of different bands in different electrodes, or the coherence of signals across sites, to a source dipole localization (e.g. using LORETA), to independent factors in the EEG signal that are associated with specific stages of processing (e.g., Independent Component Analysis), and even to an ERP or a regional activation in contemporaneous fMRI.

It is already clear that the electrode site \times frequency band characterization of NF is inadequate because it represents a many-to-one mapping from cognition to EEG profile. While it is clear that NF exhibits training-site specificity, it is also clear that the affected function is not necessarily the cortical region under the electrode. Further, EEG-Biofeedback can effectively modulate behavior without permanently affecting the EEG profile in the training electrodes. This suggests that training is mediated by meta circuits whose short term activation creates long term changes elsewhere in the brain. How permanent those changes are remains an open question.

This symposium will focus on methodological issues, including basic models of NF (Serman), a consideration of a control experiment (Achim), the problem of the physiological correlates (Beauregard), and the application to clinical populations (Kropotov). The presentations will conclude with an integrative discussion (Kaiser).

Foundations of neurofeedback, Barry Serman, Departments of Neurobiology and Psychiatry, University of California, Los Angeles, USA

The integration of a body of both animal and human EEG findings in my laboratory led to the conclusion that voluntary control of specific EEG states was possible, and that this learned control was associated with unique physiological alterations. When applied to the epileptic CNS these alterations were apparently anticonvulsant, a fact which launched clinical neurofeedback. Recent concepts associated with the basis of synaptic plasticity in relation to learning provide a bridge between cellular changes associated with the manipulation of EEG oscillatory mechanisms in neurofeedback and the clinical changes observed.

Surgically prepared cats were trained in several studies using operant conditioning to achieve food reward with either a bar press or through the production of a 12–15 Hz sensorimotor EEG rhythm (SMR), characteristic of central cortex EEG during motionlessness. Reward in both tasks was followed by a slower 8–10 Hz post-reward EEG synchronization (PRS) in posterior areas. Thus, the response-reward contingency related to this learning situation consisted of both pre- and post-reward EEG oscillatory events. Subcortical EEG and unit correlates of these cortical EEG responses were tracked to identify relevant pathways and underlying mechanisms. Subsequently, EEG data from human studies of both declarative memory and neurofeedback tasks were examined to see if similar response-reward EEG characteristics could be observed. Both SMR and PRS EEG rhythms were documented in human studies as well. Moreover, the PRS response was positively correlated with the desirability of reward, rate of response acquisition, and stability of learning.

It is proposed that the thalamocortically organized oscillations associated with this neurofeedback paradigm produce long-term potentiation in neural circuits associated with motor control and drive reduction, a consequence of which is the normalization of relevant circuits and the stabilization and consolidation of the newly-acquired functional organization.

Sham control and the validity of neurofeedback, Andre Achim, Caroline Picard, Aimée Benoit-Lajoie, Étienne Vachon-Présseau, Department of Psychology, University of Quebec at Montreal, Montreal, Que., Canada

Acceptance of neurofeedback (NF) in the scientific community is growing but resistance remains high, partly due to our limited understanding of how NF works. To date, few studies have tested or challenged many assumptions taken for granted within the NF community. For example, both the benefits of pairing NF with cognitive skill training and the scarcity of discussions on partial reinforcement schedules cast doubt that NF is mediated by operant conditioning of the brain and that it modulates attention.

One sham controlled study sought to ascertain the part of the NF effect attributable to the experience of mastering a difficult task through

perseverance and practice. It showed that such factors are not sufficient to explain the effects of NF on attention.

A second study examined the possibility that NF might not facilitate attention but rather facilitate interest in required daily activities. This experiment investigated the role of emotions (evoked by pictures or from autobiographic memory) in modulating the EEG towards the spectral profile targeted by the NF protocol. A third study investigated the relationship between the EEG profile and attention by comparing three tasks: one requiring external focus (tracking multiple objects), the other requiring internal focus (retention of visuo-spatial information in working memory), and the third consisting of simply waiting between trials, which imposed no attentional demand. These two experiments with normal young adults showed that remembering emotional experiences increases the amplitudes of SMR and beta, whereas focused external attention reduces them. This casts doubts on the notion that increased low beta or SMR is the hallmark of increased attention.

Effect of neurofeedback training on the neural substrates of executive deficits in children with attention-deficit/hyperactivity disorder: A functional magnetic resonance imaging study, Mario Beauregard, Departments of Psychology and Radiology, Neuroscience Research Center, Université de Montréal, Montreal, Que., Canada

Twenty unmedicated AD/HD children participated to the study. Fifteen children were randomly assigned to the Experimental (EXP) group whereas the other five children were randomly assigned to the Control (CON) group. Only subjects in the EXP group underwent neurofeedback training (NFT). EXP subjects were trained to enhance the amplitude of the SMR (12–15 Hz) and beta 1 activity (15–18 Hz), and decrease the amplitude of theta activity (4–7 Hz). Subjects from both groups were scanned one week before the beginning of the NFT (Time 1) and one week after the end of NFT (Time 2), while they performed a “Counting Stroop” task and a Go/NoGo task. At Time 1, in both groups, the Counting Stroop task was associated with significant activation in the left superior parietal lobule. No activation was noted in the anterior cingulate cortex (ACC). For the Go/NoGo task, in both groups, there was no significant activity in the prefrontal cortex and striatum. At Time 2, in both groups, the Counting Stroop task was still associated with significant activation of the left superior parietal lobule. This time, however, there was a significant activation of the right ACC in the EXP group. No such activation was seen in CON subjects. For the Go/NoGo task, significant loci of activation were noted, in the EXP group, in the lateral prefrontal cortex, bilaterally, and the left caudate nucleus. No significant activation of these brain regions was measured in CON subjects. These results suggest that NFT has the capacity to functionally normalize the brain systems mediating attention and response inhibition in AD/HD children.

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NF in treatment of ADHD, J.D. Kropotov, Institute of the Human Brain, Russian Academy of Sciences, St. Petersburg, Russia

Introduction. Knowledge about EEG organization in the patient’s brain is a necessary prerequisite for application of neurofeedback. This paper presents a methodological approach developed in my laboratory for (1) assessment of electrophysiological indices of executive functions in an

ADHD population, and for (2) constructing individually tailored neurofeedback protocols to correct executive dysfunctions.

Method. Two hundred and fifty normal children and 300 ADHD children (ages 7–16 years) participated in the study. EEG was recorded during task performance. Artifacts were corrected by means of an ICA (independent component analysis). Absolute and relative spectra, spectral ratios, spectral asymmetries, coherence, phase, as well as event-related potentials (ERPs) and event-related desynchronization (ERDs) in four different tasks were used as parameters for electrophysiological assessment. The tasks included: (1) GO/NOGO task for assessment of executive functions, (2) mathematical task for assessment of abstract reasoning, (3) reading task for assessment of reading and speech comprehension, and (4) acoustic task for assessment of auditory information processing. ICA was applied to separate ERP components, reflecting different stages of information processing. Power spectra and ERP components were mapped into Talairach space by LORETA.

Results. We compared spectral, ERP and ERD parameters between two groups (ADHD vs. normal). The data revealed several sub-types of EEG abnormalities in ADHD. Application of EEG spectrograms, ERPs and ERDs for constructing individual protocols of neurotherapy will be presented. In particular, the effect of beta training on EEG parameters in a subgroup of ADHD children characterized by increased theta/beta ratio in central areas will be presented.

Conclusion. This study is the first to show that three types of parameters (amplitude/coherence spectra, ERPs, and ERDs) can be effectively used for constructing individual protocols in ADHD subtypes.

The many possible futures of neurotherapy: What’s done can be undone, David A. Kaiser, Rochester Institute of Technology, Rochester, NY, USA

Neurotherapy is physical therapy for the brain. Using the tools and techniques of neurotherapy an individual establishes or re-establishes adaptive patterns of neurophysiological function: they learn their way to better mental health. In the upcoming decade we will witness the development of many new and exciting techniques that can revolutionize the way people attain and maintain a sound mind and body. Its tough to make predictions, especially about the future (Berra), but here are a few: the number of electrodes or channels used in training will increase, the complexity of analyses will increase, and the training techniques and rewards will become more tailored to client deficits. Coherence and comodulation training are realities already, as is LORETA training. Task-based neurofeedback will foster appropriate brain responses to math, reading, and other executive function challenges. This, too, is already a reality. Desensitization training will become in part neurotherapeutic and allow us to address the most intractable issues of childhood, such as nonverbal stage traumatization. Joint training sessions that involve dyadic coupling are now practical and can address affect synchrony and other parent-child and spousal neurobiological issues. Consciousness itself may be trainable using bispectral coherence and bi-comodulation techniques. As technology advances and sessions get cheaper, coregistration training with fMRI should emerge to correct dysrhythmia and discord between any two brain areas. The power for good and the potential for harm will increase exponentially in the next decade. To maximize the former and minimize the latter we must not only refine our assessment and training capabilities, as well as increase our general knowledge of how the brain works, but we will need to better understand and harness the most powerful force in nature, namely, learning.