Patient Adaptive Neurofeedback for ADHD Therapy

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Abstract

An EEG-Based audiovisual stimulation system was tested on a group of 32 ADHD patients. The efficacy was compared in a pre- and post analysis over a treatment period of 3 month with a control group and a group of patients with an EEG-based neurofeedback therapy. The number of impulsivity errors in a stop-signal paradigm at several distinct times during and after the therapy was used as a quality marker. The main feature of this method uses real-time-EEG data derived parameters for a controlled manipulation of EEG patterns with persistently strong audio-visual stimuli. It is based upon a direct feedback of changes in short-term coherences in the context of central nervous stimulus processing to control the stimulating frequency. The real-time EEG processing is done on the basis of time-dependent coherence analysis of the theta and beta band.

1 Introduction

1.1 ADHD

ADHD is with 10% the most prevalent psychic disorder in children and adolescents [1,2]. The affected persons don’t possess the cognitive ability to follow short conversations and act permanently goal-oriented. Therefor is their school and work performance under par even with an IQ above average. The permanent experience of failure results in most of the affected people in further psychic problems – typically anxiety disorders, depression and drug abuse [3]. They are difficult to treat at the same time, because they cannot follow in an appropriate way to the therapeutic sessions due to their lack of attention. Therefor first their attention deficit needs to be treated before secondary diseases can be cured.

ADHD manifests itself on a neurophysiological scale as a striatofrontal dysfunction [4,5]. A reduced metabolic rate is proven in the frontal cortex [6] and on the right side of the frontal-striatal system [7]. The affected areas show a dysfunction of the dopaminergic and noradrenergic transmitters, who are responsible for a precise regulation of the behavioral reactions [8].

At the moment ADHD must be considered as almost not treatable. Only the symptoms can be pharmaceutically treated (mostly via Methylphenidat, more seldom via Antidepressiva) by temporally reducing the dopaminergic resp. noradrenergic transmitter balances. Therefore the medical treatment of the symptoms works only as long as medicine is active. After which the previously achieved improvements vanish [9,10].

After the effect of the medication declines which is already a couple of hours later the ADHD symptoms return back and occasionally even enhanced [11,12] (Esser, 2002; Lubar, 2003). This implies that the administration of drugs doesn’t lead to a learning process in the children or an behavioral change. Pelham & Gnagy [13] came to the conclusion that so far in none of the studies with a medical treatment, ADHD adolescents have had any persistent long-term benefit of a social appropriate behavior.

Other psychotherapeutic measures like behavioral or cognitive therapy show a high drop out rate and/or only short-term improvements [14] Regarding the efficiency of neurofeedback contradicting results are shown [15,16,17]. Only the individually tuned combined treatment of several methods led to sustained improvement of the symptoms [18,13,19]. Due economical unfavorable factors these methods didn’t succeed in practice [20].

1.2 Neurofeedback versus Stimulation

The theoretical background of the application of neurofeedback methods is derived from numerous studies implying that ADHD patients show a deviating EEG pattern in multiple ways compared to normal people who are able to concentrate. Often it is assumed that ADHD patients show an increased theta-band EEG pattern (4-8 HZ) whereas the beta-band in the EEG (12-30 Hz) is reduced, although not all treatments rely on this assumption. [21,22,23]. With neurofeedback the patients learn to control EEG pattern via the feedback information of some physiologic data, which normally is not voluntarily controlled. This requires however a strong inner sensibility and concentration [24]. Exactly here lies the main reason for the high drop out rates and lacking of efficiency of non-medical treatments, because as well the therapeutic sessions as the neurofeedback training requires a minimal set of concentration ability, but this is what is actually missing. At this point several stimulation methods start operating to externally influence the EEG-patterns. The general effect of persistent audio-visual stimuli on the EEG is well known since the early days of EEG, when the alpha-band could be influenced via well targeted visual stimuli [25,26]. In principal the procedure is to expose the patient with a series of light and/or acoustical impulses and to observe the subjective-physiological or EEG-pattern changes. The stimulation is performed within a fixed time...
period with a predetermined frequency [27], where the stimuli should be intense enough to pass the thalamus [28]. Although the positive effect of persistent audio-visual stimuli e.g. for the treatment of migraine [29], chronic pain [30] or depression [31] could be shown, the mechanism could not be target controlled satisfactorily. Partly it is possible to affect certain frequency bands, but not for all frequency bands as well [32]. Furthermore it is unclear how relevant the affected frequency band is for the goal in mind. Stimulation methods are not patient adaptive – here is their main disadvantage.

At a first glance neurofeedback and brainwave-entrainment methods seem to be based on the same principle to transform a dysfunctional EEG pattern into a normal one. The impression is that with neurofeedback the patient actively influence this transformation and with stimuli methods this is achieved passively via external stimuli. The underlying neural mechanism remains unclear, it seems to be sure that a bigger entity of the global neural system must be altered in order for the brain to accomplish such a transformation out of itself, even if is merely an external conditioning [33]. This disadvantage of not being patient adaptive explains why brainwave entrainment methods are less efficient compared to feedback methods as would be expected, because they don’t rely on a concentration and learning ability. Some studies indeed confirm the effectiveness of entrainment for ADHD [34,35], but not in all cognitive areas [30,36].

2  Methods

2.1.  Hardware in the loop - Therapy

Simplified the core of our proposed therapeutic method consists of a patient-adaptive stimulation process wrapped around a neurofeedback method. Since ADHD patients show more theta-band (4-8 Hz) and less beta-band (12-30 Hz) brain activity it would be obvious to stimulate the beta-band. Astonishingly this hardly leads to an improvement of the symptoms. It is to be assumed that this theta over beta ratio mismatch is by itself rather a symptom of more fundamental underlying neuronal processes.

It was shown that this ratio mismatch of the two frequency components is due to a lack in synchronization of cognitive feedback loops [37,38] (Barry et al., 2002; Chabot & Serfontein, 1996) Therefore ADHD patients suffer from the ability to adapt action pursuing and action controlling resp. correcting process to each other. An Effective entrainment method should therefore influence the synchrony of the relevant feedback loops and the resulting frequency components.

A special entrainment method was developed that addresses the synchrony of the disturbing feedback loops. It is based upon a time-variant coherence analysis developed in our group, which allows to localize the sources and the frequency components involved in ADHD [39]. Based on this procedure it is possible via the changes of the evoked potentials to detect “online” the disturbing frequency components while performing an audiovisual stimuli with real-time patient adaptive neuronal feedback [40] which otherwise would be only possible within the brain itself during neurofeedback. This method is therefore called „hardware-in-the-loop“-like.

A 32 channel EEG system (10/20-system) delivers signals being first amplified (EEG 8, Contact Precision Instruments) filtered (high-pass: 0.01 Hz, low-pass: 40 Hz, time constant: 16 s) digitized and transferred to a PC, where the incoming data are real-time processed to detect short term coherences. If such a coherence is detected for at least 60ms at two electrode positions in different brain hemispheres then a stimulation frequency is applied in the same direction as the previously detected coherence.

2.2.  Proof of Efficiency

To test the process 32 patients were randomly selected for the therapy sessions when they fulfilled to following criteria:
• DSM-IV Criteria for ADHD, ADS or HD [41]
• age: 9 – 15 years
• IQ > 80, using the Hamburg-Wechsler-IQ-test for children (HAWIK-III) [42]
• no other neurological or psychological disorder

The sample comprised 3 girls and 29 boys (age average=11.2; SD=1.53). The control group consisted of 26 patients waiting for a therapy during the 3 month testing period. (23 boys, age average=10.6; SD=1.73). As a further control group we used 18 patients (16 boys; age average=11.7; SD=1.32), which underwent neurofeedback training where the theta/beta ratio was an input parameter. The progress was controlled using two subsets of tests from the TAP (Testbattery for Attentioncontrol, Version 1.7, [43]: the test subsets Go/NoGo and reaction change. In both subsets the ADHD children made more errors compared to the control group and showed a higher variability in reaction times, so that 90% of the children could be classified correctly having ADHD (positive predictive validity=0.86 / negative predictive validity=0.93) [44].

3  Results

The progress was controlled using two subsets of tests from the TAP (Testbattery for Attentioncontrol, Version 1.7, [43]: the test subsets Go/NoGo and reaction change. In both subsets the ADHD children made more errors compared to the control group and showed a higher variability in reaction times, so that 90% of the children could be classified correctly having ADHD (positive predictive validity=0.86 / negative predictive validity=0.93)[44]. Images 1 and 2 show the under and above average results of the subsets before the actual training sessions, 3 measurements during the sessions period of 3 month and 1 post-training measurements after 1 month resp for all three groups. The evaluation of the complete test was done all common parameters as well as for the change rates (average, standard deviation).
Number of under-averaged (PR<25) test parameter of the Go/NoGo subset-test

ANOVA analysis with measurement repetition, measurement time and experimental group resulted only in the "hardware-in-the-loop" group a significant reduction in the rate change of the subset group "reaction change" of the under average test parameter (pre versus post =0.000) and a significant increase of the above average test parameter (p=0.000).

The number of under 25% and above 75% test criteria in the Go/NoGo subtest also changed only in the same group significantly (p = .048 resp. .34). A comparison of the 3 groups regarding the interaction of the parameters didn’t show any significant effects (p=.472 resp. p =0.276).

4 Conclusions

The lacking efficiency of the neurofeedback method could be due to the fact that 6 out of 11 patients prematurely stopped the treatment. Therefore the significance is beforehand hampered. Exactly the opposite was true in the case of the “hardware-in-the-loop” group. It could be concluded that a method based upon external EEG feedback with adaptive stimulation exactly that neuronal feedback systems could be excited which are relevant for the concentration process, which could otherwise only by addressed by training intense neurofeedback techniques.

5 References

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