Neurofeedback – How Attention Takes Flight

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Attention Deficit Disorder (ADD) alone or in combination with Hyperactivity (ADHD) is one of the most common disorders in childhood and adolescence and even persists into adulthood. Children with ADHD show a higher amount of slow brain waves and a decreased amount of faster brain waves compared to children without ADHD (Barry et al., 2003). The basic idea of neurofeedback is to transfer the unconscious process of brain wave function into a conscious process by reporting it to the patient. The Brainfeeders project aims to evaluate the possibilities for integrating neurofeedback in a school setting. The primary goal of the study is to replicate results found in clinical trials without any additional human resources. We would like to evaluate how well a training programme like this fits in school settings and if results are comparable to clinical studies. We are interested in forming a transnational working group, integrating researchers who are working on similar projects or who are interested in working on Brainfeeders in their countries.

ADD, ADHD, attention deficits, Neurofeedback, Biofeedback, Training

ATTENTION: DEFINITION AND CLASSIFICATION

Attention can be described as a condition of increased alertness but – in contrast to concentration – is less aimed or not exclusively aimed at a single object. Within this state of perception, concentration is distinguished by targeted focusing on an object of attention.

Concentration (for example on an object to be observed) thus represents the deliberate limitation of attention by ignoring (select) external stimuli. The more developed the ability to concentrate and to pay attention, the more it is possible to consciously experience relaxed phases which are controlled deliberately.

Keller & Grömminer (1993) differentiate three essential kinds of attention:

a) Selective attention describes a state that we subsumed under the definition of "concentration" earlier on,

b) we talk of divided attention if many procedures can be pursued attentively at the same time (e.g. write a funny essay and pay attention to orthography) and finally we understand

c) permanent attention as the maintenance of attention (possibly also of selective attention) during a long lasting activity (e. g. a school test, solving maths quizzes, etc.)

For a pupil it is important to command sufficient abilities in all three kinds of attention. While divided attention and permanent attention are developed increasingly within the first four years of life, the ability for selective attention is developed at the beginning of school maturity (Resch et al. 1999, 332). Although many support programmes throughout the German-speaking world have been dedicated to enhancing attention in childhood, until now there has not been an

integration of evidence-based attention enhancement methods in schools. Within therapy for Attention Deficit Disorder (ADD) child-centred concepts play a superior role. Most approaches are designed in a multimodal way; that is, in addition to the child-centred approach, training for parents is also conducted, for example. The main focus of intervention lies in the usage of psychotropic drugs, usually methylphenidate (MPH - better known by its trade names Ritalin, Medikinet or Concerta) and atomoxetine (Strattera). MPH affects the central nervous system as a psychostimulant by inhibiting the reuptake of dopamine in the synaptic gap, whereas atomoxetine operates as a noradrenaline reuptake inhibitor. The effectiveness of MPH and atomoxetine on the enhancement of attention in the case of ADD is verified through numerous randomised and placebo-controlled double blind studies. The second focus of ADD intervention lies in behaviour therapy programmes. Here, it is mostly treated with operant methods and complex reinforcement schedules that can also be well implemented in school settings. Specific enhancement approaches in the German-speaking world are, for example, the training for children with attention deficit disorder (Lauth & Schlottke 2002), Attentioner (Jacobs et al. 2005) and the Marburger concentration training (Krowatschek et al. 2004), whose positive results are proven by a majority of researchers (Walther & Ellinger, 2008). The conditional variable for the success of supporting ADD inside schools is not just the training programme itself but, to the same extent, the user. That is the reason why the successful integration of attention-enhancing programmes into everyday school life depends on both the proof of its effectiveness and its practicability.

Great importance has to be given to the questions of a) the intensity of the need for supervision according to the teacher, b) the amount of fun, and thus motivation, the children have throughout the training and finally c) the degree of standardisation in order to have the least variance possible.

Here the Brainfeeders project sets in, determining the possibilities for computer-based neurofeedback therapy in school settings.

WHAT IS NEUROFEEDBACK?

Biofeedback as the Basis of Neurofeedback

The aim of the therapeutic method of biofeedback is to measure physical processes that are passing unconsciously and to make them accessible to apperception through acoustic or visual feedback.

Physiological variables such as muscle tone, heart rate, blood pressure, electrodermal and neuronal activity are measured and converted into primarily visual or auditive signals giving the patient regular and continuous feedback. Thus, the patient is able to realize the slightest change in the physiologic process to be controlled and to regulate it deliberately. The gradual acquisition of this regulation takes place by encouraging the person concerned to identify, through trial and error, those self-regulative strategies that influence the bio-signal in a desirable way.

With regards to the psychology of learning, biofeedback is based on the principle of operant conditioning. That is why direct positive reinforcement – for example, pleasant photos or sounds – is often used at the beginning of the desired physiological change. Apart from an acquired influence on physiological processes, therapeutic success is dependent on an increasing expectation of self-efficacy, a better interoception because of the treatment and a positive attitude on the patient's part (Rief & Birbaumer, 2006).

Biofeedback is a certain form of learning, which is used for better body perception, for acquiring self-control and for self-healing. The method is applied to numerous psychic, psychosomatic and physiologic clinical disorders and diseases (Rief & Birbaumer, 2006; Martin & Rief, 2009).

The present study illustrates the design of a neurofeedback treatment that is a certain form of biofeedback and aims at influencing the cerebral activity. Essentially, neurofeedback is understood as the reporting of certain parameters of the EEG to the patient and, thereby, facilitating the deliberate influence on brain waves. The reporting, like in biofeedback, can take place both visually and acoustically in neurofeedback trainings and is mostly implemented in the form of a computer game. The deliberate exertion of influence on processes running unconsciously, like activating and deactivating of the cortex or particular areas, shall thus be learned through play (Vernon, 2005).

The great impact of neurofeedback on ADD treatment is based on the fact that persons affected by ADD show an increased rate of low frequency bands and less high frequency patterns (Gamma and Beta waves) (Fuchs et al., 2003). By means of neurofeedback methods, this imbalance is reduced by targeted trainings of single frequencies in order to increase attention and concentration span.

Neurobiological Basis of Neurofeedback Training

Spontaneous EEG and Event-related Potentials (ERP)

The EEG measures spontaneous potential fluctuations of the brain (Birbaumer & Schmidt, 2000). The cortical activity, which is measured via the EEG, includes, on the one hand, the range of the spontaneous EEG and, on the other hand, event-related potentials.

The spontaneous EEG can be divided into different frequency bands: Delta-frequency (1-4 Hz), which can be found predominantly during sleep, is characterized by low frequency or slow brain waves. Slightly faster Theta-waves (4-7 Hz) occur with drowsiness and in the phase of falling asleep. Alpha-frequencies (8-13 Hz) are typical of the general wake state.

Higher frequency bands like beta (14-30 Hz) and gamma (over 30 Hz) are associated with an active and stimulated state of brain, hence increased attention (Gruzelier & Egner, 2005).

In case of inhibited behavior, the so-called sensomotoric rhythm (SMR) can be drawn out of the premotoric regions of the cortex in a frequency span of 12 to 15 Hz (Birbauer & Schmidt, 1996). The different EEG frequencies come along with different degrees of attention.

Referring to the close correlation between beta activities and states of high alertness, concentration and focussed attention (cf. Keller & Grömmiger, 1993), it can be deducted that low levels of beta waves have a negative effect on the ability to concentrate for children with attention deficits.

Optionally, when using neurofeedback, aside from the different frequency bands, the event-related potentials (ERP) are analyzed via EEG and reported to the patient.

Event-related potentials are electrocortical shiftings of potentials that come about from the handling of motoric, sensoric or psychological stimuli. Slow Cortical Potentials, or SCP, are shifts in the direct current voltage of EEG into electric negative or positive direction. SCPs arise while preparing for movement as so-called readiness potentials. Moreover, the Contingent Negative Variation (CNV) is counted with the slow potentials. This variation always appears when a stimulus is expected. That is why CNV is also referred to as expectation wave (Leins, 2004). Rockstroh et al. (1990) found that children with attention deficits had difficulties with self-control of SCP and a smaller negativation of slow potentials when expecting a task. Hence, SCPs can be understood as a correlate for the regulation of attention.

Effectiveness of neurofeedback in the treatment of attention deficits

In the past, many studies dealt with effectiveness surveys of neurofeedbacks. Especially over the last 6 to 7 years, the studies have improved methodologically. Their results prove that neurofeedback can be an effective treatment.

In a study of Monastra et al. (2002) the effects of a neurofeedback therapy were compared to that of a stimulants therapy. 100 children with ADD at the age of 9-16 participated in a multimodal therapy program (Clinical Comprehensive Care) for one year. The elements of the programme were: medication, parental training and individual academic support. 51 patients were additionally treated with neurofeedback treatment in 43 sessions on average. An evaluation of the effects of the therapy was made after one year by two examinations, once with and once without medication. Evaluations of those tests with medication in the experimental group showed a tremendous improvement in the parents and teacher rating, a clear improvement of T.O.V.A. („Test of Variables of Attention"; Greenberg, 1996) and a normalization of EEG parameters. In the control group, a clear improvement in T.O.V.A could be observed as well, only a slight improvement in parents and teacher rating and no changes in the relevant EEG parameters. A follow-up examination was conducted after one week of washout, during which all children formerly treated with medication were withheld from drugs. Evaluations showed that the effects in the neurofeedback group that were analyzed in the first follow-up examination remained stable. In the control group without neurofeedback no effects could be proven anymore.

In the first imaging study relating to neurofeedback by Lévesque, Beauregards & Mensour (2006), in the controlled and randomized functional nuclear magnetic resonance imaging study with 20 children with ADD, it could be demonstrably proven that neurofeedback can change the cognitive capabilities.

15 children received neurofeedback training in over 40 sessions. The training aimed at increasing SMR and beta activity as well as reducing theta activity. The evaluation showed a normalization of the anterior cingulate cortex activity, to which high importance is attached with regards to selective attention and inhibiting behaviour. No increased degree of alertness and excitement could be proven among the five children of the waiting control group in this area.

Bakhshayesh (2007) developed and implemented a new study design in neurofeedback research by examining the efficiency of neurofeedback on ADHD by means of a theta/beta training and by comparing it to an electromyogram biofeedback (EMG) as the placebo condition. The EMG biofeedback measures the level of muscle tension instead of the brain activity and reports it back to the test persons so that they learn to relax with the aid of self-regulative reduction of the EMG amplitude. 35 children with ADD at the age of 6-14 years participated in that study. Randomly, 18 children were distributed to the neurofeedback group and 17 children to the EMG group respectively. Values of attention and intelligence performance as well as data about the estimated behaviour from parents and teachers were ascertained before and after the therapy. The results show a significant improvement in terms of attention, intelligence and behaviour in the neurofeedback group. In the EMG group no significant improvements could be detected, apart from the working speed in paper-pencil-attention tests. After examination by an independent psychotherapist after the training, 55.6% of the 18 children with ADD from the neurofeedback group and 23.5% of the 17 children from the EMG biofeedback group were not diagnosed with ADHD according to ICD-10-criteria.

There are two studies that took place in school settings that are particularly important for our project. In the study of Boyd and Campbell (1998) six children with ADD at the age of 13 to 15 years underwent neurofeedback training in which the sensomotoric rhythm was addressed within

an everyday school situation. During the preliminary stages, attention and intelligence tests were conducted, whereas those children who were treated with drugs at that time, only were examined 72 hours after discontinuing medications. After 20 sessions, the post-tests showed significant improvements in performance for attention as well as impulsiveness. Boyd & Campbell came to the conclusion that this study confirmed the efficiency of neurofeedback within the treatment of patients with ADD. Besides, they were convinced that the use of neurofeedback would be possible in a real school situation without obstructing other school activities and could thus be seen as an effective alternative to medication in school contexts.

Equally positive are the results of Carmody et al. (2001) who examined the efficiency of neurofeedback in a primary school. Eight children between the ages of eight and ten, four with and four without an ADD diagnosis, were treated in 35 to 47 neurofeedback sessions over six months and were then compared to a control group. None of the children in the two groups received medication. The evaluation showed an increase in the attention performance of the neurofeedback group; however, no improvement in terms of hyperactivity and impulsiveness could be observed. The effects of neurofeedback are, according to the findings, not limited to the improvement of attention but also have positive effects on general cognitive performance.

As an intermediate result, it can be stated that neurofeedback can reduce neurological dysfunctions which in turn contributes to an improvement of academic performance as well as social interaction, and thus to an improvement of the general adaptation to life (Lubar, 2003).

THE BRAINFEEDERS PROJECT

Research Question and Hypotheses

The central question is whether clinically tested neurofeedback training can be integrated successfully into the school setting. The results of clinical studies on the effects of neurofeedback trainings and on the development of attention prove a positive effect on attention performance when the training intervals are adequate (e. g. 20 sessions, 15 minutes each). Successful integration of neurofeedback trainings into schools could result in access to this resource by those large groups of pupils who neither belong to the privileged children of wealthy parents nor are diagnosed as patients with ADD.

Because an immediate integration of the training into the learning process and associations with the content of the lessons are possible, the enhancement of attention during everyday life in class could be more effective than accentuated clinical training. In addition, prevention and intervention programmes within the school help prevent stigmatisation. However, a process the children can do almost autonomously during the training session and a smooth transition in the training room between pupils are preconditions for a successful integration of the training into school life because additional adult personnel cannot be expected.

Furthermore, it needs to be examined if other influential factors in schools, such as peer pressure or habitual rebellious attitudes, will hamper the success of neurofeeback trainings and how they can be overcome.

One training session in this project is divided into six steps:

- The pupil is picked up by a classmate and proceeds into the training room. They ticks their name off the list and sit down on a chair.
- The pupil is linked via an electrode to the computer, one on top of the head and behind the ears. Then, the computer checks if the electrodes are put on correctly and suggests necessary

adjustments. Another pupil assists with the electrodes and the controls that measure certain muscle contrations (like eye movements).

- The computer is set up for the pupil. This includes clicking on and opening the child's name file with the present data in order to enable continuous documentation.
- The training starts and the pupil plays the computer game. During the training, an EEG is recorded via the electrodes whose enhanced frequencies provide the signal for regulating the game. For example, concentration and attention control a plane for take-off and ascent via the high frequency waves like alpha and beta. Whereas inattentiveness and impaired alertness produce delta and theta waves that cause the plane to descend and land, respectively. The events on screen are directly reported back to the child and thus give feedback about the degree of concentration achieved. Concentration and relaxation are trained consciously by the beta/theta awareness (14-30 Hz / 4-7 Hz) that serves for take-off and landing.
- When the time has expired, the game is finished; the computer saves all data automatically and closes the file of the pupil. Now the ports have to be removed and the electrodes are loosened from the skin.
- The pupil exits the room and returns into the classroom in order to give word to the pupil whose name is written next on the list in the training room.

Pre-conditions for the smooth running of integrated trainings in schools are:

- Pupils receive an in-depth introduction, practice the use of the electrodes and are familiarised with the function of the appropriate computer games.
- Pupils want to participate in the training.
- There are only two pupils per lesson whose proper training can be verified by the teacher’s brief control check during the five-minute break.
- A training room is available which is located centrally and can be reached easily by all pupils as well as by the personnel in charge.
- Software is programmed according to the interests and needs of the pupils.

The pre-test for Brainfeeders took place at two schools for children with learning difficulties in 2010. The hypotheses were formulated as follows:

H1 Neurofeedback training for improving the performance of attention can be integrated into everyday school life without requiring extra human resources.

> H1.1 Pupils are able to cope with the preparations necessary for the training without the teacher's help.
>
> H1.2 Necessary mentoring and evaluation tasks can be performed without extra personnel within the set time limits in school.

H2 Neurofeedback training leads to performance improvements even in school settings where there is minimal contact.

> H2.1 The increase in intelligence values is higher in the test group than in the control group.

H2.2 The increase in the performance of attention is higher in the test group than in the control group.

H2.3 At the follow-up evaluation the test group's performance of attention is higher than that of the control group.

H2.4 Performances mentioned under H2.1 and H2.2 exceed the effects that are known from clinical samples that use conventional neurofeedback therapies.

Sample

For a pre-test and first evaluations, 90 pupils from two schools for children with learning difficulties were randomly divided into a test group (N=60) and a control group (N=30). The sample is a complete survey of pupils, with parental consent, out of six classes.

In order to prevent the concentration tests from being misunderstood and from the occurrence of anticipated ceiling effects, only pupils who were at least ten years old were selected. The pre-test serves for pre-evaluation and for justification of an extensive main test with a larger sample (N > 250) and in which the age span will be widened.

Diagnostics

Attention deficits cannot only be found in children with ADD. That is why a categorical classification in ICD-10 or DSM-IV-TR would leave a large number of children with milder forms of attention deficits unidentified.

The methodical orientation of a complete survey makes clear that the project is not primarily dedicated to a diminution of symptoms in AD(H)D but is rather considered to be a preventive and supportive programme for all children and adolescents.

That is why the project aims at evaluating the effect of neurofeedback training on attention and concentration as well as cognitive abilities, independent from ADHD diagnosis. Because of this goal and the age span of the sample the following methods were applied:

- In order to measure cognitive abilities, CFT-20R (Weiß, 2006) is used because this method is language neutral (culture fair) and covers a large age span.
- For attention, impulsiveness and hyperactivity, D2 (Brickenkamp, 2002) and DISYPS-II in self- and other evaluation versions are applied (Döpfner et al., 2006).
- Additionally, a general behavioural screening, SDQ, (www.sdqinfo.com), which is also available in self-, teacher- and parents versions, is applied.
- Besides the dimensional methods, the diagnosis criteria according to DSM-IV-TR are given to the teachers for processing.
- The course of the beta/theta quotient of the pupils is saved over the test span in order to relate possible potential effects to changes in EEG.

The time span for the pre-test is 34 weeks, with 20 weeks of training with two training units per week scheduled. Before the beginning of the training (week 0), cognitive abilities and the main symptoms are measured via the described methods.

For controlling the processes, the performance of attention is checked after 10 weeks of training, which ideally corresponds to 20 sessions, and behavioural evaluations are sought. Because of the

rather short time span, a further test of cognitive abilities within the first retest is not being conducted.

The second retest after 22 weeks (between both 10-week training blocks there are two weeks of school holidays) again contains the methods of the pre-test, including the diagnostics of cognitive abilities. After three months (week 34), without further intervention, a follow-up-evaluation takes place in order to check the sustainability of positive effects that are, on the basis of existing examinations, considered to be rather stable.

Within the first retest the test group is randomly divided into two groups (TG1, TG2) with 30 pupils each. While doing D2, TG1 receives a screenshot of the active phase of the neurofeedback training for facilitating everyday transfers between phases (the training is split into activating and relaxing exercises); TG2 proceeds without further stimuli.

TG1 is expected to achieve better concentration results than TG2 from the first retest onwards because the activation of faster brain activity or higher brain wave frequencies should be achieved more easily.

DISCUSSION

Undoubtedly, the adaption of a clinical/therapeutic method to the school setting hides a series of problems. First, the environmental variables in school differ from those in a therapeutic office. Second, it could be supposed that pupils were left by themselves to give therapy to one another.

Finally, the test could be accused of marginalizing severe disorders. In other words, for treating psychic disturbances, school does not seem to be an appropriate setting.

Ad1: Not only is the proof of the effectiveness of neurofeedback methods for treating AD(H)D to be supported, but to the same extent it is shown that this method can also be effective outside a therapeutic setting. Furthermore, it is possible that the effects can be compared to and even exceed the results in therapeutic settings because of other motivational factors (e. g. peer group, competition, etc.).

Thus, it is possible to establish a prevention and intervention programme that can be used by all pupils, independent of their social background, in order to increase attention and concentration. It is also necessary to put the question of possible adaptations of neurofeedback training in schools on the agenda.

Ad2: Due to educational policies, no therapists are implemented into schools. Our goal, to enhance attention and concentration via neurofeedback in school settings, is rooted in the conviction that teachers are fully stretched by school requirements. The project shall prove that pupils are able to create the necessary formal framework on their own. To the possible criticism of peer therapy, it must be suggested that the computer – and not the peers – adopts the role of the therapist.

The task of the pupils amongst themselves is limited to putting on the electrodes (whose correct position is then checked by the software). Nearly all pupils should be able to meet these requirements after an introduction and can be supported by pictograms, if needed.

Ad3: It could be suspected this attempts to marginalize AD(H)D because the training is removed from a therapeutic setting. The contrary is true because the extent of a severe disorder can be limited through early prevention. The particularly inattentive subtype of ADHD, which does not give any hints to possible problems through suspicious behaviour (impulsive interruptions or hyperactivity), receives early support at this stage.

It also should be mentioned that conspicuous beta/theta quotients (which are made visible via the training) provides the opportunity for children with ADD to be supported by the programme as well as referred over to professional care at an early stage.

Although there are legitimate doubts as to whether school is the ideal location for the prevention and intervention of psychic disorders, in case the first signs of deficits arise in this institution, it should not wait until a classifiable clinical picture has emerged. Enhancing attention can be thought of as a genuine task of schools. Here, several German programmes are available which can, in our opinion, be adapted well to school needs.

There are many manuals about those programmes in the German-speaking world, however, in our opinion, an effective enhancement of attention and concentration in school settings can only take place on the basis of intensive training of the teachers. The advantage of the Brainfeeders project can be attributed to the fact that sources for error are minimised when implementing manuals (cf. Lauth & Schlottke 2007) as the teacher is not in charge of the enhancement of attention itself anymore, but only for the integration of computer-based methods into class.

It can thus be concluded that prevention of and intervention for psychic disorders must be located in school. However, this does not imply that teachers should become therapists or that the eligibility of this profession was denied.

AIMS

We are convinced that integrating neurofeedback in schools can be a great step in preventing ADD/ADHD in children. We do hope that the results of the pre-test justify expanding this project into bigger samples, even all across Europe. That is why we are very interested in forming a transnational working group, integrating researchers who are working on similar projects or who are interested in working on Brainfeeders in their countries. Feel free to contact us.

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