

SPECIAL SECTION



Peak Performance Training Using Prefrontal EEG Biofeedback

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The use of biofeedback training to self-regulate EEG patterns with the aim of recovering or optimizing function and behavioral performance is becoming increasingly established. The most reasonable approach is to learn to generate and maintain optimal brain wave patterns and produce associated peak performance states on demand. We report two studies where 12 sessions of prefrontal EEG feedback were used to improve performance in both clinical and nonclinical populations. Neurofeedback using Focus, Alertness, and 40 Hz (Neureka!) measures resulted in improved selective attention and other cognitive functions. We discuss other potential applications of neurofeedback in the areas of “under-pressure” activity, where peak performance state is an essential part of the job, such as in sports or the performing arts, as well as for human operators, such as air traffic dispatchers and military personnel on duty.

Introduction

Mental peak performance training should be based on a clear, simple understanding of what types of shifts in mental states are necessary in order to optimally accomplish the task at hand. The activities of an athlete or musician—be they a golfer taking a tee shot, a football safety defending a play, or an opera singer’s aria—are all associated with a sequence of mental states that can be analyzed and refined by using EEG data. In applied psychophysiology, EEG biofeedback (neurofeedback) training operates with EEG rhythms, usually targeting suppression of one and enhancement of the other band (e.g., theta, alpha, beta, etc.) or their combination.

The understanding of the neurofeedback task is really facilitated by having a psychophysiological vocabulary that

accurately matches the everyday experience of the athlete or musician. The same is true for a clinical population. It is very difficult for a lay person to understand the meaning of beta–theta ratios or even beta waves. If, however, the vocabulary uses words like “Focus” and “Alertness” that are defined in a clear way and understood through some simple lessons, much more progress can be made. The Peak BrainHappiness Trainer™ (PBHT; Cowan, 2009) employed in these studies uses terminology that is very clear, related to everyday experience, and can be easily understood within the first few minutes of neurofeedback training.

All major neurofeedback training parameters of the PBHT are measured from the same sensors, one very near the frontal pole of the cortex and a reference on the left ear. The first location overlies the midline prefrontal center, an area densely packed with dopaminergic terminals from the nucleus accumbens. It is very strongly associated with the processing of new learning and its rewards. In the PBHT system there is a neurofeedback training protocol that uses so called “Neureka!” rhythm (a 40 Hz centered EEG gamma rhythm), which is associated with positive emotional experiences, awareness, mindfulness, and improved memory.

Another training measure, Focus, is related to the experience of the single-pointed focus of attention. Focus is actually derived from desynchronization, a measure of activation of the underlying cortex. We also refer to this protocol as “InAll,” short for “InhibitAll,” or wide band suppression. Our experience indicates that sampling from this one midline location is sensitive to the single-pointedness of focus on a wide variety of subject matter, including sights, sounds, kinesthetic sensations, thoughts, etc. Furthermore, the higher the quality of visualization of

an activity, the larger is the resulting Focus measure. This is extremely valuable for training via visualization.

There is a difference between Focus and the measure that is called Alertness. Alertness is really a euphemism for arousal of the central nervous system, which creates the underlying pattern of psychophysiological changes associated with excitement and “fight or flight” response. This measure of the underlying common pattern of emotional engagement can potentiate a variety of emotions, including anxiety, anger, interest, and excited happiness. If these experiences are absent, then the lower values of Alertness may reflect calm or relaxation. Alertness seems to be a good measure of the continuum underneath the inverted U-shaped curve relating the quality of performance to arousal. Finding the ideal level of Alertness for every point in the sequence of an activity by recording the EEG during visualization or video replay can be very valuable. It is far better training than just trying to adjust the level of Alertness at the beginning of the sequence. The demands of intense control of attention when learning something new will increase both Focus and Alertness simultaneously. This parallel increase will soon break down as fatigue decreases Alertness. In fact, training the brain to enhance its capacity to sustain Alertness with neurofeedback is quite valuable for peak performance, because it creates the energetic reserves necessary to continue to stay at the optimum level to make and carry out the best decisions.

Decision making is the role of the prefrontal cortex, particularly during initial learning. This role diminishes as many responses are learned well and become habitual, relocating to a combination of other sites. However, the prefrontal cortex still steps in to aid in difficult moments in the sequence and to add conscious nuances to create an excellent performance, so it is worth monitoring at all levels of mastery. Inappropriate focus on distractions will also be apparent as disruptions in the pattern occur and can then be corrected. Prefrontal neurofeedback is therefore very well suited for peak performance training purposes.

Despite significant progress in demonstration of clinical efficacy of specific neurofeedback protocols in treatment of some clinical conditions (e.g., ADHD: Arns, de Ridder, Strehl, Breteler, & Coenen, 2009; Gevensleben et al., 2009; Leins et al., 2007; Monastra et al., 2005; Sherlin, Arns, Lubar, & Sokhadze, 2010), the efforts in the scientific application of neurofeedback training for the improvement of performance in non-clinical populations is limited. Only a few studies have been done, mostly in training students (Gruzelier, 2009; Gruzelier, Inoue, Smart, Steed, & Steffert, 2010; Hoedlmoser et al., 2008; Pop-Jordanova & Chakallaroska, 2008; Vernon et al., 2009) and occasionally

other professionals (Ros et al., 2009). Most of these studies were uncontrolled case series, and some used relatively low number of neurofeedback sessions, had methodological flaws, and can hardly be accepted as sufficiently convincing. There is an urgent need to conduct controlled randomized studies to prove the effectiveness of neurofeedback in non-clinical populations and to support the claim that specific neurofeedback protocols (with selected EEG frequencies at specific topographical sites) are capable of improving behavioral performance and subjective perception of well being in individuals without any clinical symptoms. The task is relatively more challenging in comparison to neurofeedback in clinical populations because the goal is not to restore a function impaired due to illness or trauma (from bad to normal), but rather to enhance the normal state and improve function from typical to better, and ultimately to the best possible. We report below two studies using the previously described Focus, Alertness, and Neureka! measures and their combination both in clinical (ADHD) and non-clinical populations.

Study 1. Training of Focused Attention and Alertness Level in ADHD

Neurofeedback has been shown to be an efficacious and specific treatment of Attention Deficit Hyperactivity Disorder (ADHD), according to recent meta-analysis (Arns et al., 2009; Sherlin et al., 2010). Positive effects of neurofeedback on behavior and performance in ADHD were achieved with several different training protocols. However, in most studies it was concluded that the number and length of sessions, location of electrodes, and motivation of participants are important factors determining success of treatment in ADHD. In this pilot study, we investigated the effects of 12 sessions of prefrontal neurofeedback on behavioral performance in the audio-visual selective attention task in 12 patients with an ADHD diagnosis using IVA+PlusTM (Sandford & Turner, 2005). Patients with ADHD diagnosis were referred from the Weisskopf Child Evaluation Center and from the Health Care Outpatient Center of the University of Louisville. Diagnosis of ADHD/ADD was confirmed by adequate clinical evaluations. We enrolled 12 children and adolescents with ADHD (range 11–18 years old, mean age 14.1 years, $SD = 4.1$, all of them boys). Eleven completed the course, while one was withdrawn. Six subjects were taking stimulant medication.

All participants in this group received twelve 30-minute long sessions of neurofeedback. Five minutes were set to record baseline and establish thresholds for neurofeedback training. The ADHD group received 12 sessions of Focus/

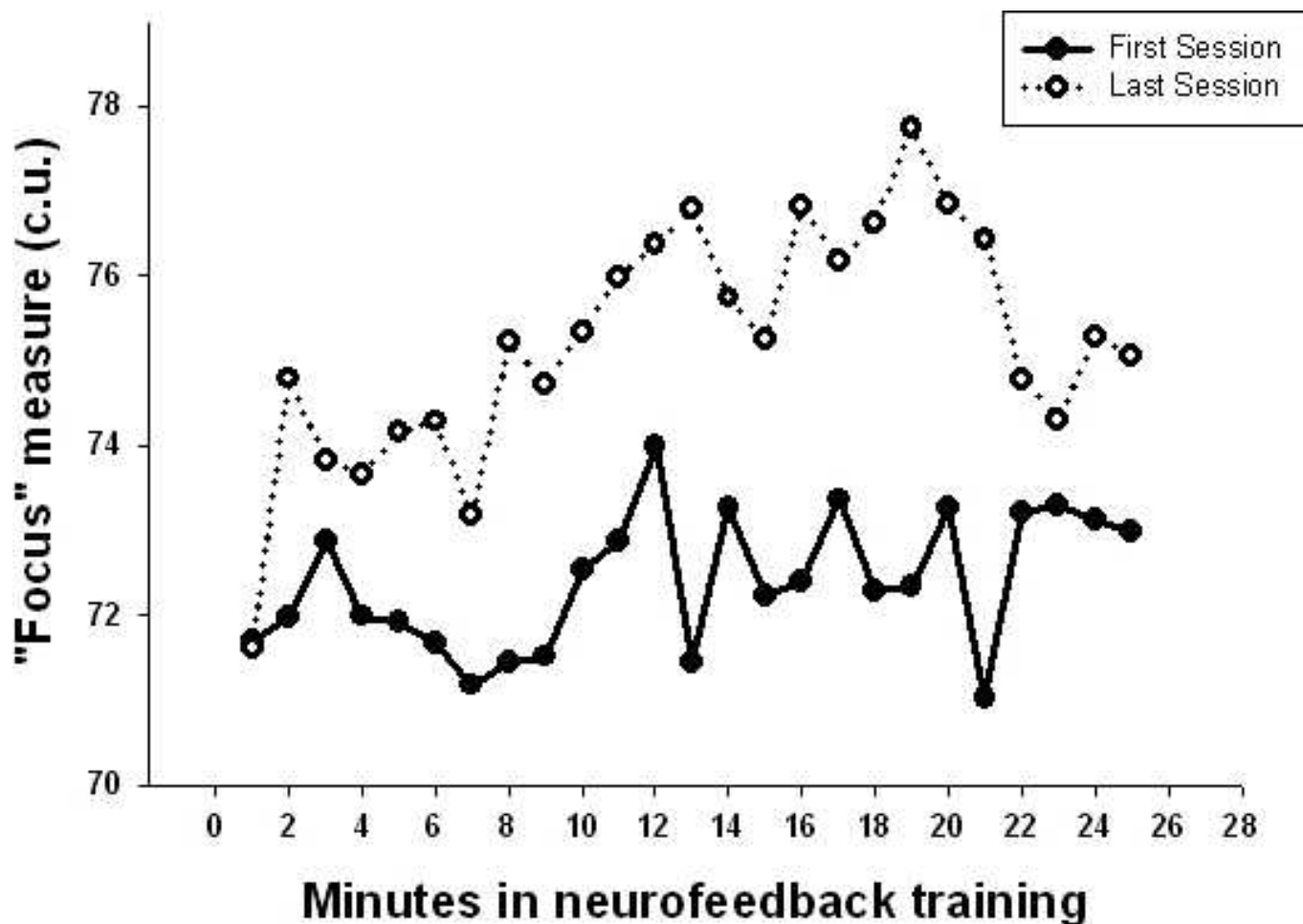


Figure 1. Focus measure during 25 minutes of the first and the last (12th) session of Focus/Alertness neurofeedback training in patients with ADHD ($N = 11$).

Alertness enhancement training at the prefrontal EEG (FPz) site. The reference electrode was placed at the left earlobe, while the ground was at the right earlobe. Visual feedback was arranged using DVD image size and brightness controls which responded to the Focus measure by making the picture bigger. Enhancing the Alertness measure made it brighter. Auditory feedback was provided via earphones, using MIDI sounds to inform the trainee that selected measures are out of the range (i.e., lower or higher than preset thresholds.). The DVD feedback incorporates the BBC "Planet Earth" and "Life" series. During each session, the 25-minute long episode of the nature scenes was different to maintain participant's motivation and engagement. During the training session the threshold was adjusted as needed to keep the same level of difficulty. Treatment was provided once a week by a master's level graduate student assistant supervised by the investigators. Changes of the Focus and Alertness measures during 25 min of the first and the last (12th) session are shown in Figures 1 and 2. The study protocol was approved by the University of Louisville IRB.

The continuous performance IVA+Plus selective attention test was administered before and after the 12 session Focus/Alertness neurofeedback course. This 20-minute long test provides accurate measures of sustained auditory and visual attention quotients and is widely accepted as neurocognitive test of attention. Neurofeedback training aimed at enhancement of focus and alertness measures in ADHD was accompanied by statistically significant improvements in performance on IVA+Plus test. As shown in Figure 3, increases both in auditory and visual sustained attention quotients were statistically significant at $p < 0.05$.

Another clinical behavioral outcome in ADHD patients included measures from the *Aberrant Behavior Checklist (ABC)*. The ABC (Aman & Singh, 1994) is a clinician-administered rating scale assessing five problem areas: Irritability, Lethargy/Social Withdrawal, Stereotypy, Hyperactivity, and Inappropriate Speech, and is based on caregiver reports. Results showed significant decrease ($p < .05$) of Lethargy/Social Withdrawal, Hyperactivity, and Inappropriate Speech rating scores (Figure 4).

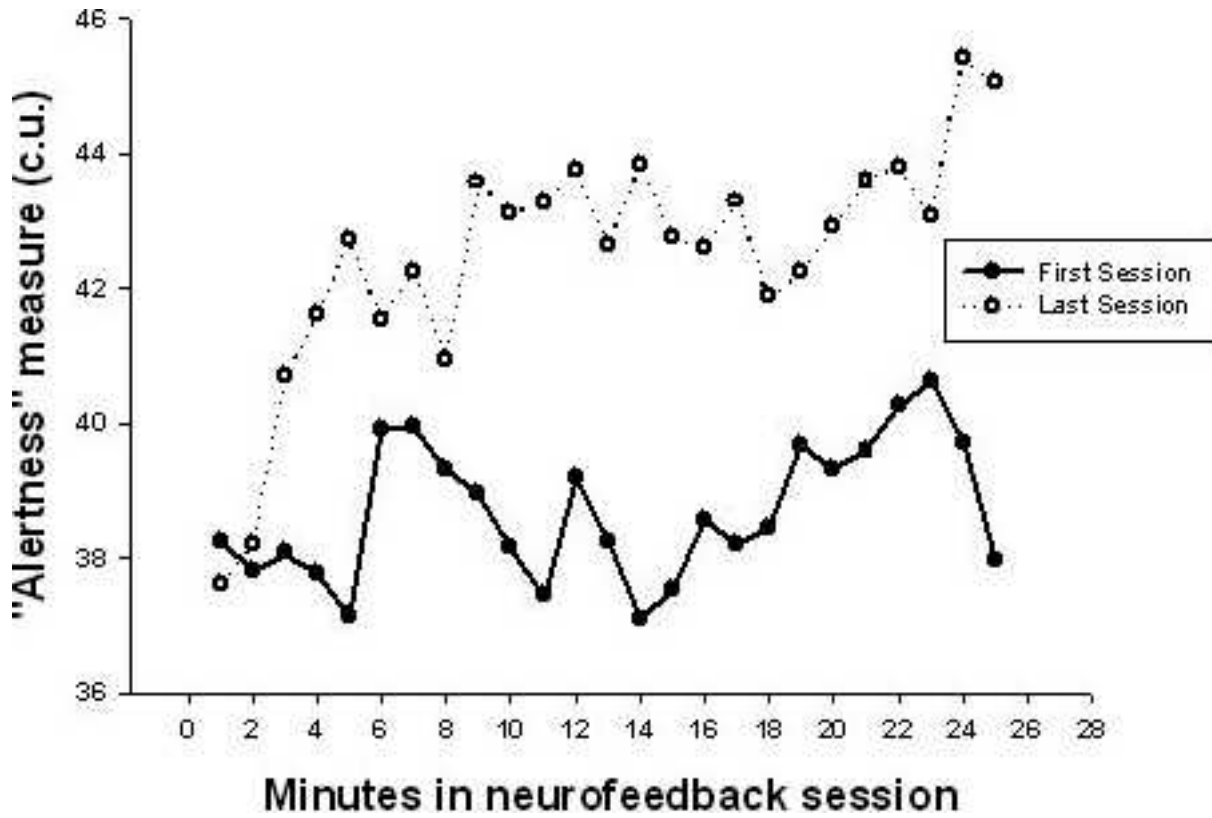


Figure 2. Alertness measure during 25 minutes of the first and the last (12th) session of Focus/Alertness neurofeedback training in patients with ADHD (N = 11).

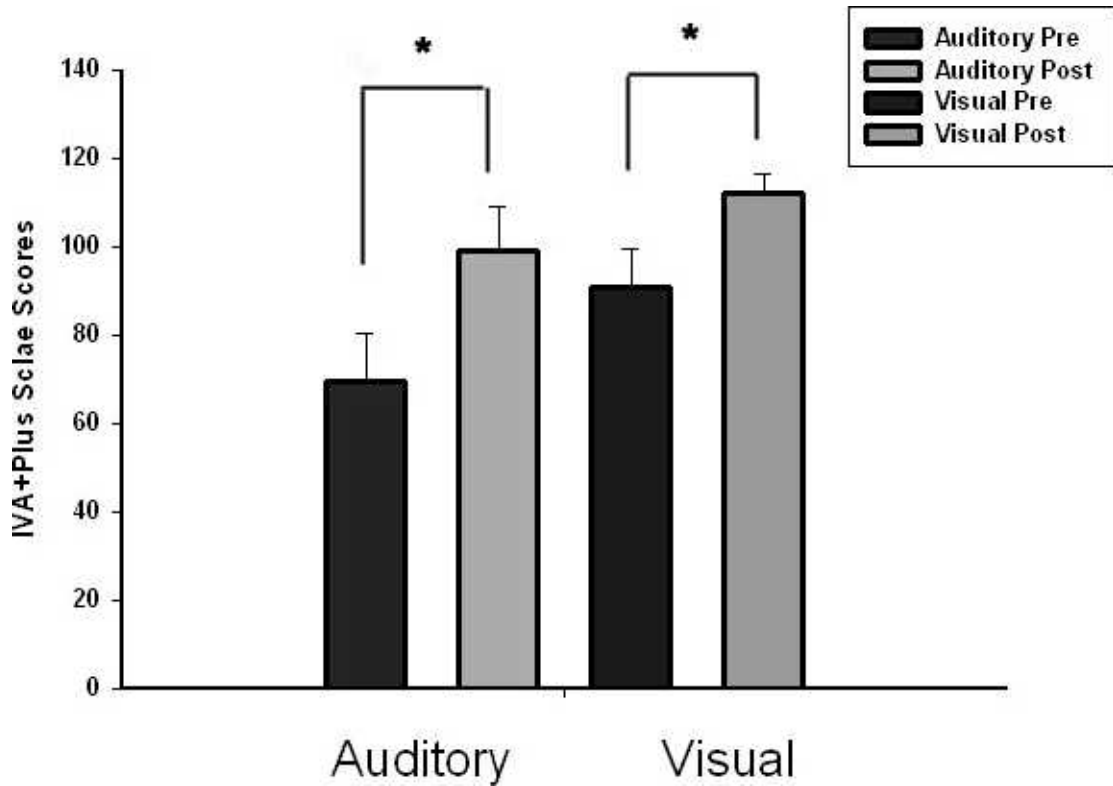


Figure 3. IVA+Plus selective audio-visual sustained attention quotients pre- and post-12 sessions of Focus/Alertness neurofeedback training in patients with ADHD (N = 11).

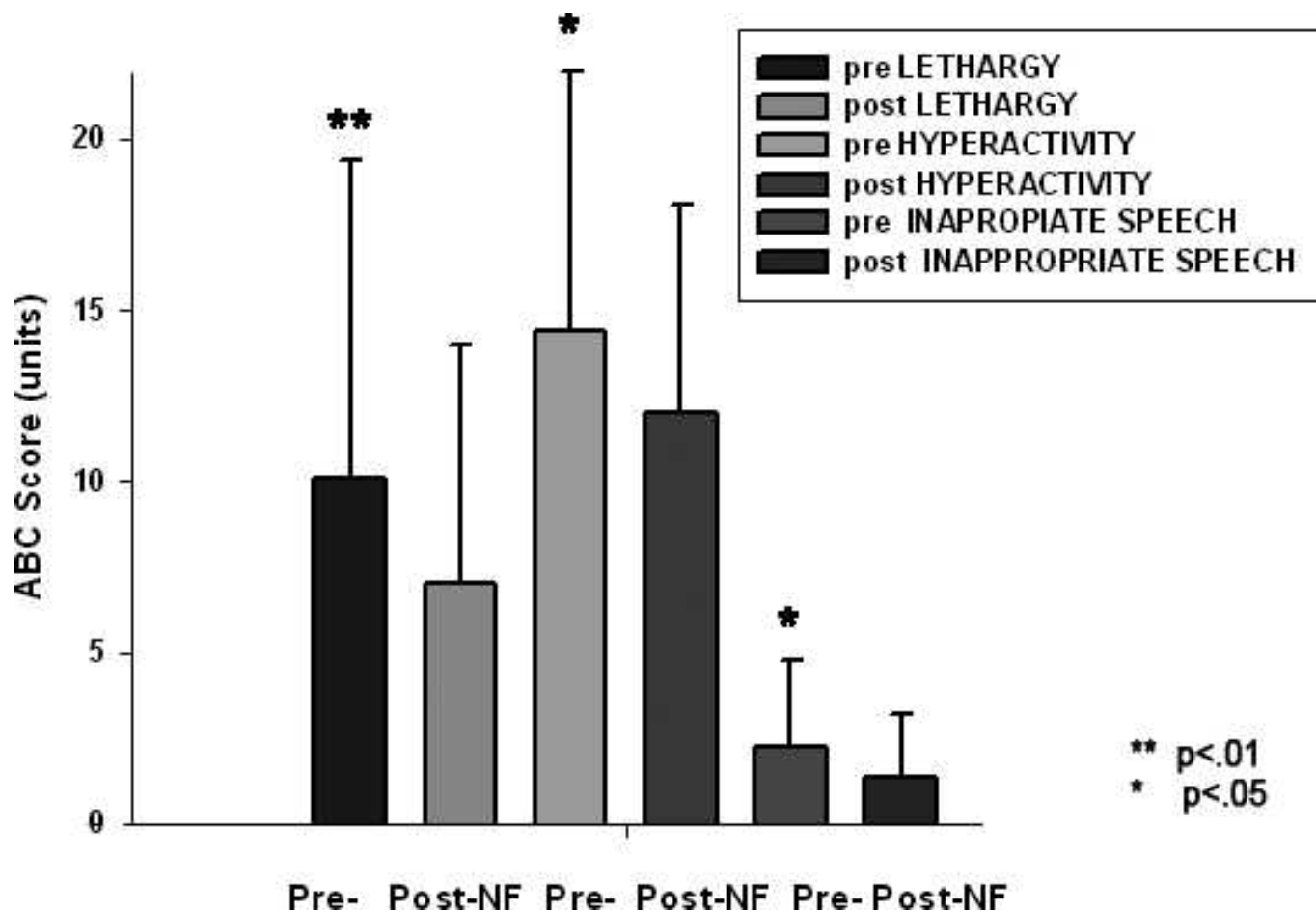


Figure 4. Aberrant Behavior Checklist (ABC) scores pre- and post-12 sessions of Focus/Alertness neurofeedback training in patients with ADHD ($N = 11$).

Prefrontal Focus/Alertness neurofeedback protocol with DVD-control as a visual feedback and auditory MIDI feedback (when values of controlled measures were out of the threshold range) were effective in maintaining motivational engagement of subjects with attention deficits. As shown in Figures 1 and 2 comparing the dynamics of controlled parameters during the initial and the last session, the patients showed visibly enhanced ability to control both Focus and Alertness measures during their 12th session of Focus/Alertness neurofeedback training.

Six out of our 11 children with ADHD opted to continue neurofeedback training to 18 sessions. They demonstrated significant increase of the Focus measure (Figure 5) and to a lesser extent, Alertness. Post-18-session IVA+Plus test scores showed only a few further improvements (e.g., Response Control Quotient, Auditory Reaction Time), whereas most IVA+Plus scores did not yield statistical differences between outcomes of the 12th and 18th sessions. This might be an indicator that even 12 sessions of Focus/Alertness neurofeedback might be sufficient to achieve improvements in behavioral performance. However, an extension of the number of sessions

beyond 12 might be important for the consolidation of the acquired self-regulation abilities to maintain focused attention and alertness.

Study 2. Training of 40 Hz Gamma (Neureka!) Level and Focused Attention in Control Subjects

This study used a similar procedure and training regimen (EEG sites, reference, timing) except that instead of Alertness measure we used the 40 Hz gamma measure (called Neureka!), which increased the size of the DVD picture as it became larger. The threshold of the Focus measure was kept rather low, since the real aim here was to train Neureka! The Focus measure was added as a reminder to pay attention. When Focus approached the threshold, the DVD picture became dim, and the DVD stopped below the threshold. The 6 subjects enrolled in the study were mostly University of Louisville students, research assistants, and high school students (mean age 18.7 years old, $SD = 3.9$, all boys). All were reported to be in good health and free of any medication.

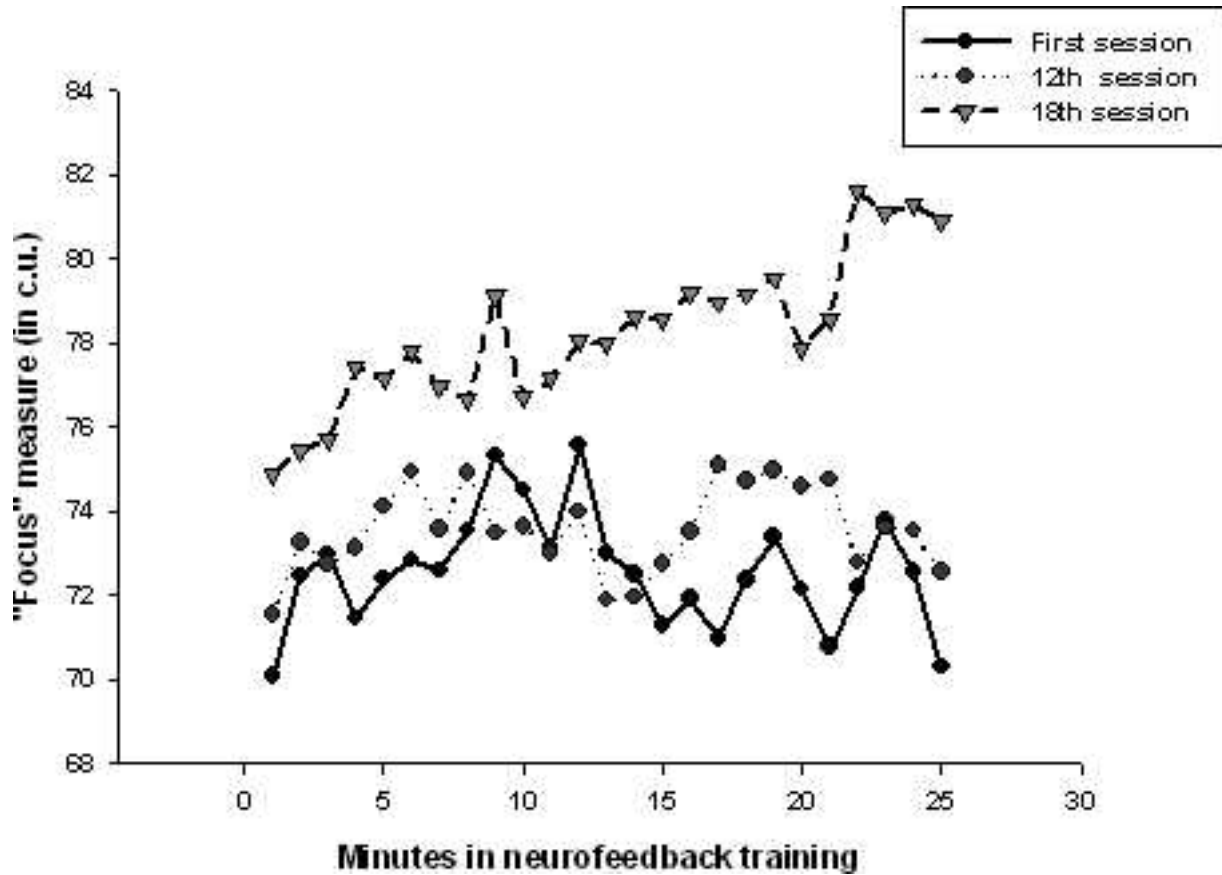


Figure 5. Focus measure during 25 minutes of the first, the 12th, and the last (18th) session of Focus/Alertness neurofeedback training in 6 patients with ADHD who extended number of neurofeedback sessions to 18.

This group showed an ability to learn control of the Focus and Neureka! measures using prefrontal neurofeedback. As is depicted in Figure 6, 40 Hz gamma was higher in magnitude and gradually increased during the last session of the neurofeedback training course.

The IVA+Plus selective attention test pre–post neurofeedback showed a statistically significant increase of visual sustained attention quotient score (Figure 7). Here, we also used the MicroCog™ neurocognitive test battery (Powell et al., 2003). The MicroCog is a brief computerized assessment of cognitive functioning, developed at Harvard and primarily intended to screen for impairments in thinking. It produces an overall summary score, General Cognitive Functioning (GCF), combining processing speed and accuracy measurements for all the tests it offers. After 12 sessions of Focus/Neureka! neurofeedback training, there was a very significant ($p < .001$) 8.4% increase in this score. General Cognitive Processing (GCP) was also increased by 8.5%. The next level of summary indicated that the improvements were all due to a better Information Processing Accuracy (IPA) trend (16.6% increase, $p = .08$), rather than Information Processing Speed (APS; 2.5% change). More specifically, one

of the largest increases was in Memory function (15.2%), while Reaction Time shortened by 6.3%, both significant at the $p < .05$ level. There was also one more improvement—Spatial Processing—that was almost significant ($p = .07$). The other two categories, Attention and Reasoning, were not improved statistically even though they showed a tendency to increase. This indicates a very selective improvement in general cognitive function, particularly centered on memory accuracy and information processing speed. Figure 8 illustrates a summary of changes in the MicroCog measures.

Discussion of Potential Benefits of Neurofeedback for Mental Function and Performance Improvements

Neurofeedback training can be used to develop memory function, control peak mental functioning, increase focused concentration and attention, lower consequences of stress, develop more creative thinking abilities, increase positive emotions, and improve mood, thus becoming more productive in all areas of life, including activities at school or at work.

Another potential application of neurofeedback is in the areas of under-pressure activity, where peak performance

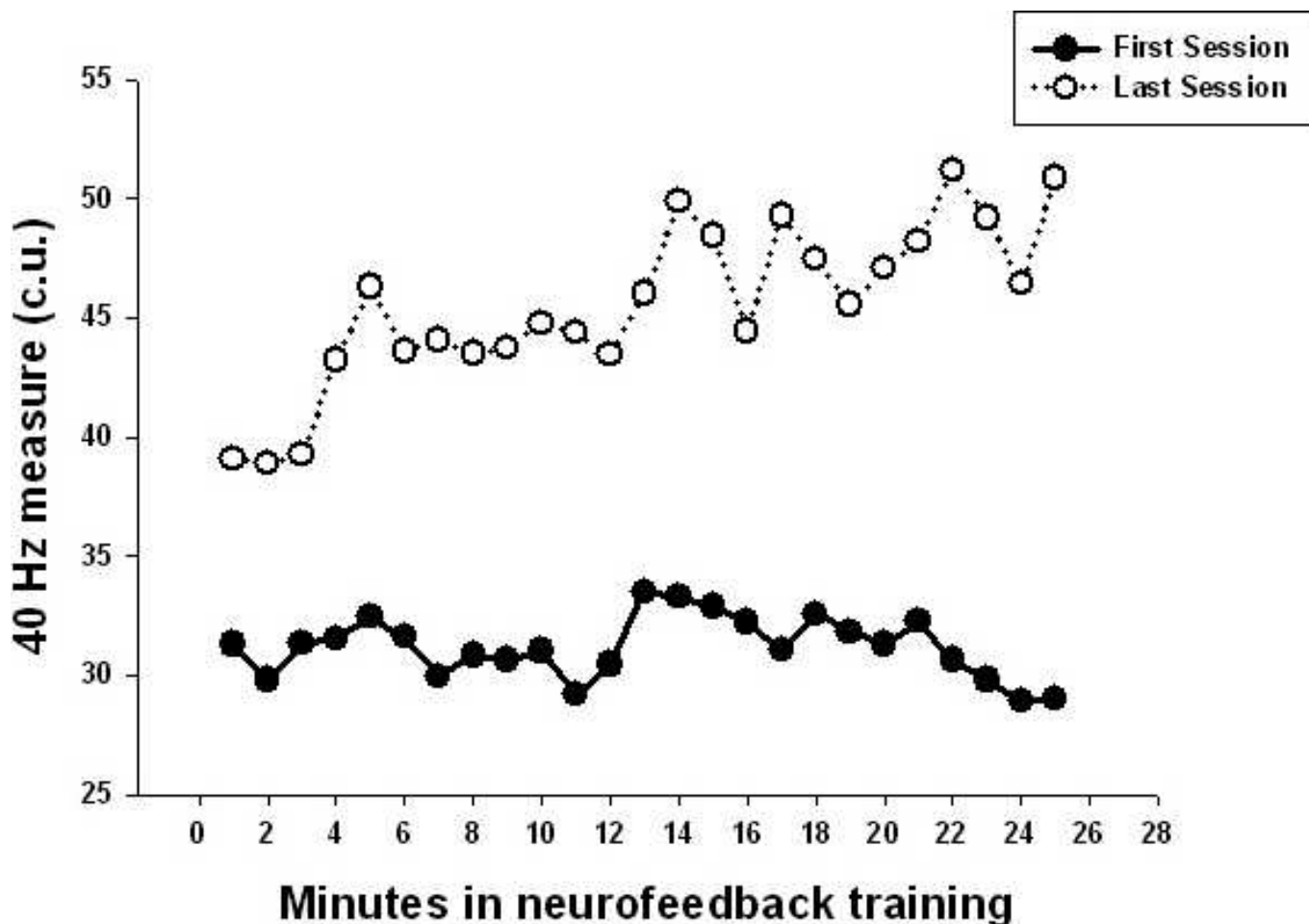


Figure 6. Neureka! measure during 25 minutes of the first and last (12th) session of Focus/Neureka! neurofeedback training in the healthy control group ($N = 6$).

state is an essential part of the job, such as in sports or the performing arts, as well as for human operators, such as air traffic dispatchers and military personnel on duty. One of the most promising strategies of neurofeedback training may focus on peak performance training for the individuals who have commitment to excellence, and yet are experiencing problems preventing them from achieving their own best personal performance form on demand. For example, a corporate executive may need to perform at his best to be on top in stressful situations, such as when closing the deal, or a sportsman may face challenges in situations when his mental toughness and ability to focus make a huge difference in the outcome of the competition. In such extreme situations, the ability to reproduce skills acquired during neurofeedback peak performance training can be extremely useful. There are several neurofeedback protocols available that are specially designed to help individuals overcome performance anxiety and to help in stress management, and there are also protocols aimed at improving

focused concentration ability. Benefits of all neurofeedback training protocols typically include increased confidence and self-assurance. The activities of a sportsman or performing artist are always associated with a sequence of mental states, which can be analyzed and refined by using EEG data. To maximize the benefit of neurofeedback training for the athlete, it is not enough to adjust his state through neurofeedback training at the beginning of the activity. The entire psychophysiological progression during the sequence, from anticipation to action to recovery, needs to be addressed in a comprehensive analysis and training effort. Combining EEG monitoring with video recording of the sequence of actions can provide very valuable neurofeedback combined with recorded action video for subsequent review. Analysis during the review can provide a template for the ideal sequence of mental states and its coordination with key actions. Training the athlete to remember and consistently execute this sequence is valuable for achieving better results.

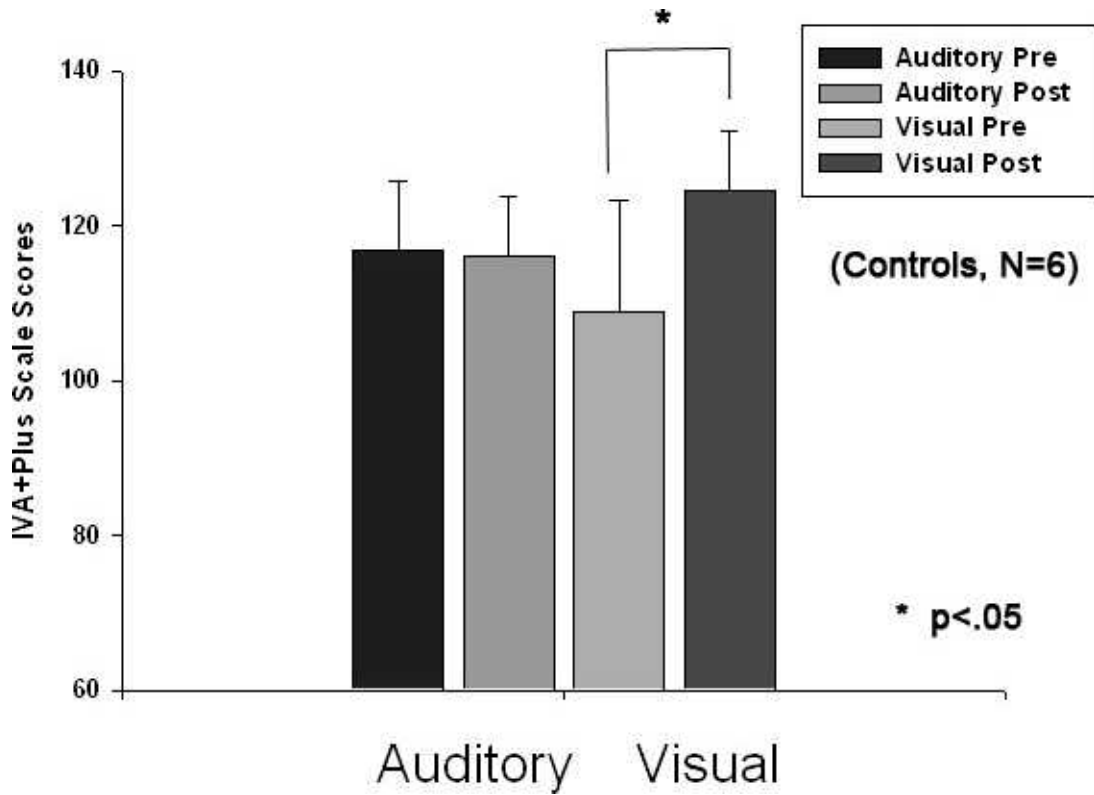


Figure 7. IVA+Plus selective audio-visual sustained attention quotients pre- and post-12 sessions of Focus/Neureka! neurofeedback training in 6 control patients.

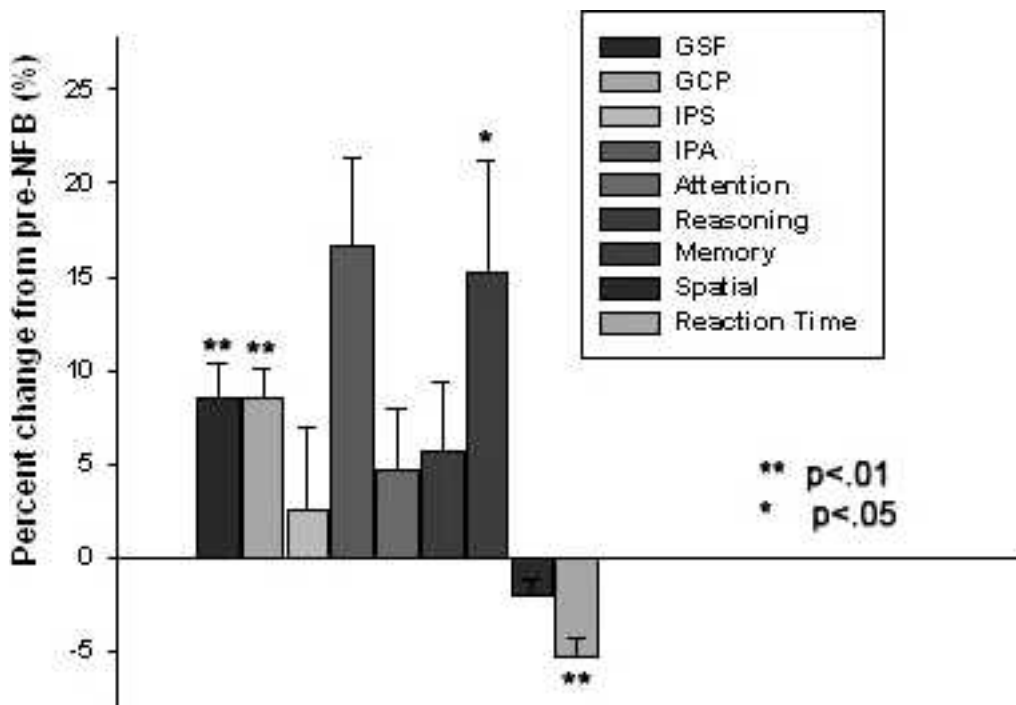


Figure 8. MicroCog neurocognitive functioning measures changes following 12 sessions of Focus/Neureka! neurofeedback training in 6 control patients.

Conclusion

Our preliminary study of 11 patients with ADHD showed that prefrontal neurofeedback using Focus and Alertness measures of the Peak BrainHappiness Trainer was effective in increasing performance on the IVA selective attention test. The group of 6 healthy control subjects trained using Focus and Neureka! measures also showed improvement on a selective attention test, but their improvement was less pronounced than in the ADHD group. Twelve sessions of neurofeedback were sufficient to achieve ability to control several EEG parameters of interest both in ADHD and control subjects groups. In my experience, this is a really fast result, because usually more training sessions (>18) are recommended for successful management of attention symptoms in ADHD. This particular type of brainwave neurofeedback can be used both in ADHD and healthy subjects to improve behavioral performance, focused concentration, and alertness. Neurofeedback training can be used in individuals with attention problems to develop and control peak mental function capacity, increase focused concentration and sustained attention, and maintain alertness and vigilance, thereby becoming more productive in all areas of life, including activities at school or at work. Neurofeedback can also be used for peak performance in sport and in other activities requiring ability to self-control vigilance and alertness.

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