

Comparison of Biofeedback Modalities for Better Achievement in High School Students

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Abstract

Key words:

Peak performance; EEG biofeedback; electrodermal resistance; heart rate variability.

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Received: 19-Sep-2008

Revised: 19-Nov-2008

Accepted: 23-Nov-2008

Online first: 25-Nov-2008

The aim of this pilot study was to compare three biofeedback methods for enhancement of cognitive abilities (concentration and attention) in high school students. The sample comprises 50 students in high school for nurses, aged 16-18 years, devised in three groups: I - 30 students trained with EEG-Peak Achievement Trainer (EEG-PAT); II - 10 students trained with Electrodermal Response Biofeedback (EDR); and III - 10 students trained with Heart Rate Variability (HRV). The EEG-PAT is supposed to activate the Executive Attention Network, while HRV and EDR were supposed to influence indirectly, through the stabilization of autonomous nervous system. As psychometric tests we used: Trail Making Test (form A and form B) and numbering forward and backward, each one applied prior and after the experiment. The obtained results suggested that EEG-PAT can be successfully used for improving the concentration and attention and to a less extend the Short Term Memory Span. The HRV showed modest improvement (only for numbers), and EDR group did not show significant improvement in the concentration, attention and the Short Term Memory Span. However, all the three methods are highly cost-benefit and very comfortable for application and can be used for stabilization of the homeostasis.

Introduction

High arousal due to stress influences the cognitive processes such as attention, concentration and short term memory. The use of biofeedback has been shown to be an effective method for monitoring and regulating arousal (1).

Biofeedback is defined as a technique that uses information about the unconscious bodily functions in order to achieve a conscious control over them (2).

The basic statement for biofeedback is that instruments should provide three types of information: (1) to monitor physiological process of interest; (2) to

measure (objectively) what has been monitored; and (3) to give back the results as an understandable information. In other words, the role of biofeedback methods is to demonstrate to the patient his or her stress/tension and concentration levels during performance.

Generally, biofeedback can be peripheral or central. The *peripheral biofeedback* measures the electrodermal activity-conductivity or resistance (EDR), muscle tension (EMG), body temperature, heart rate (HR) or the breathing. On the other hand, *central or EEG biofeedback* means measuring of the electric brain activity. EEG biofeedback or brainwave biofeedback is also known as neurofeedback.

Biofeedback is noninvasive adjuvant therapy used world wide in numerous psychophysiological, psychiatric or neurological disorders. Some of our results, for fifteen years of experience, obtained for different disorders in children have been already published (3-6).

This method is also being used for achieving peak performance in sportsman, musicians, actors, dancers, or in students (7-10). For example, using this kind of training, the Italian representation soccer team has been prepared for achieving better results; indeed, this team won the World Champion in soccer in 2006.

In previous studies we used EEG biofeedback (alpha/theta training) and EMG training for obtaining high performance in musical students (11, 12).

The aim of this study was to inter-compare three biofeedback modalities (EEG, HR or EDR) for enhancement of cognitive abilities (concentration and attention) in high school students.

Material and Methods

The paper can be considered as a randomized and prospective pilot study. It introduces a new instrument - Peak Achievement Trainer, for the first time in our country. The sample comprised 50 high-school students from Skopje, aged 16-18 years, randomly grouped in three groups: First group (n = 30) – trained with EEG-PAT (Peak Achievement Training); Second group (n = 10) – trained with EDR (Electrodermal Resistance) biofeedback; Third group (n = 10) - trained with HRV (Heart Rate Variability) biofeedback.

The inclusive criteria were psychophysically healthy students, well rested and not hungry during the training sessions. Exclusive criteria were history of mental or neurological disorders, taking of psychoactive substances, and acute or chronic diseases.

All examinees were tested with Trail Making Tests forms A and B for concentration and attention, as well as Verbal Span Assessment (Wechsler Memory Scale-R) Numbering - forward and backward.

The training sessions of the first group were with EEG -PAT (NeuroTek, LCC 2003 USA), which enables improving the concentration, alertness and relaxation in short period of time (after only 5 training sessions), that has been claimed by the author of this instrument (13, 14). The application of the active electrode is on the frontal part (in Fz) of the head. Figure 1 shows the typical changes of concentration time before and after training where the duration of concentration (in sec.)

below the threshold (20 mV^2) was evaluated (13). The aim of this type of EEG biofeedback training is to suppress alpha brain waves (relaxation) and produce beta brain waves (attention and concentration).

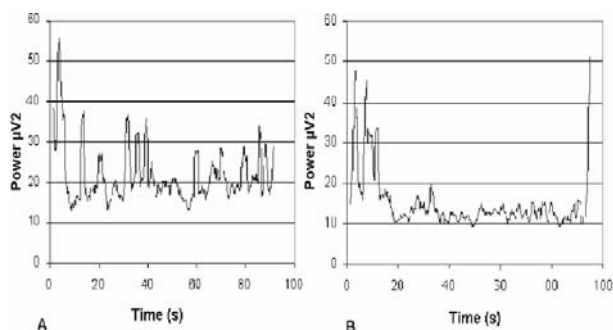


Figure 1: Changes of the concentration line in the beginning and in the end of EEG-PAT session.

It can be seen from Fig. 1 that the concentration time could reach 80 seconds after only one session with EEG- PAT. The most important skill in learning with EEG-PAT is achieving a right combination of the cycles of concentration and micro rest. In this way a more efficient functioning of the brain is been enabled.

The second training group had a Heart Rate Variability (HRV) biofeedback, which is a methodology that uses the heart cycle as a biofeedback signal. HR is calculated from finger pulse. For this study we used the "Freeze Framer" (Boulder Creek, California USA). The assignment is to breathe properly (about 6 breaths per minute), which results in synchronization (coherence) of the heart and respiratory activity, both regulated by the sympathetic and parasympathetic paths of the Autonomous Nervous System (ANS). In this way, through reducing the stress level, indirectly better conditions could be attained.

Electrodermal resistance (EDR) biofeedback was a training method in the third group. As instrument we used Inner Tuner Expert System, Ultra Mind International, Ltd, UK version-2.10. The signal gives the electrodermal resistance of the skin, related to the activity of the Autonomic Nervous System (ANS), whereby the higher the resistance, the lower the stress level is.

In fact, by both peripheral biofeedback modalities (HRV and EDR) we aimed to regulate Sy/PaSy branches of the ANS and indirectly, through stress diminishing to improve nervous system balance and achieve better concentration time.

Results

In the next figures and tables we show the results obtained after five training sessions using the three types of biofeedback training. The statistics is made on the difference between baseline results and results obtained after five training sessions.

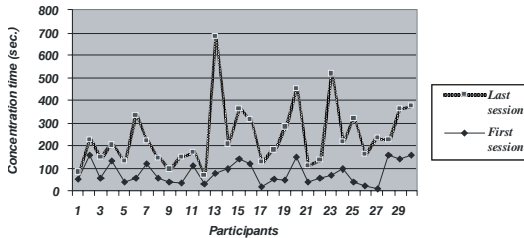


Figure 2: Concentration time during the first and last session of training with EEG-PAT.

It is clear that training with EEG-PAT increased the concentration time in all participants (the difference is statistically significant on the level 0.05). In addition, this technique is much easier to understand and faster to meet the demands than other EEG multichannel biofeedback techniques. It detects the brainwaves from the Executive Attention Network, applying the active electrode on the frontal region (in Fz), and converts the measured signal to audio and video outputs (Fig. 2).

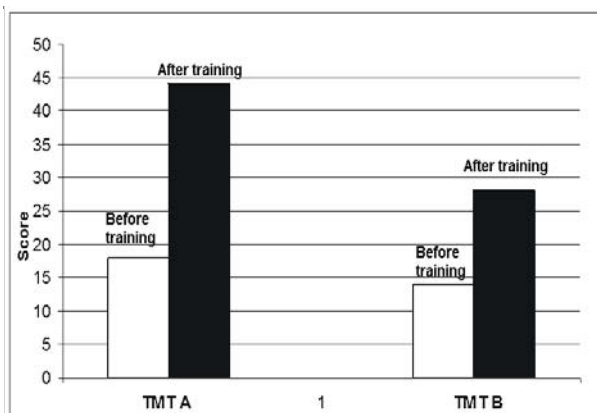


Figure3: Changes in psychometric test TMT (forms A and B) obtained with EEG-PAT training.

Figure 3 shows statistically significant improvement of scores obtained by psychometric test TMT (A and B forms) for participants using EEG-PAT training.

On Table 1 improvement of numbering forward and backward after 5 sessions of EEG-PAT training is shown. The statistical significance of the difference is on level 0.05. Other, no significant results are not shown.

Table 1: Scores obtained on test for numbering before and after EEG- PAT training ($p < 0.05$).

Score	Numbering Forward	Numbering Backward
Before training	7	4
After training	8	4.5

The HRV is an excellent measure of nervous system balance. The training improves the coherence of heart and respiratory cycles. It is supposed that skilled people at HRV in the same time can calm their brain waves and increase their power to adapt, which is important for diminishing stress level. The obtained scores after training are much better than before corresponding to better coordination of body/mind functioning.

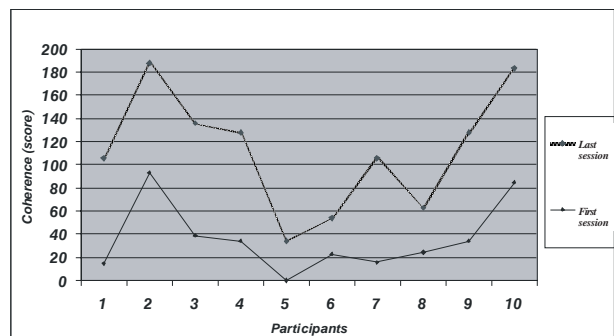


Figure 4: Changes of coherence in respiratory/heart cycles before and after training with HRV.

On Fig. 4 we presented only HR changes from baseline and after training. However, this methodology also measures heart spectra power as well as zone-accumulated entrainment score.

Electrodermal resistance is related to activation of skin glands producing sweat (Fig. 5). The training comprises the diminishing of sympathetic activation

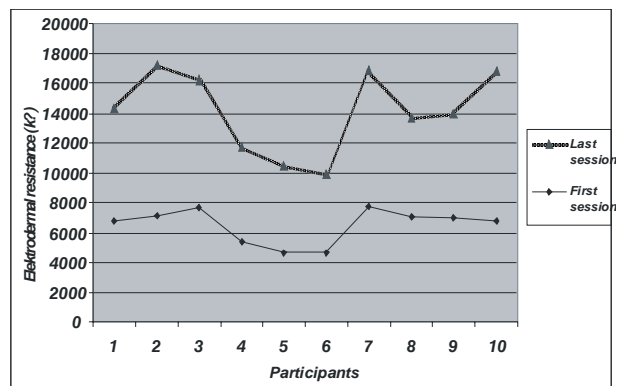


Figure 5: Electrodermal resistance during the first and last session of EDR biofeedback.

and reducing the production of sweat. In our previous studies we obtained very optimistic results using this methodology especially for dealing with somatoform disorders in children (7).

As seen from the figures 2-5 the training with the three different types of biofeedback enables: a) improvement of the duration of concentration, b) stabilization of the heart beat and breathing, c) lowering of the skin resistance. The first one is achieved with activation of the frontal brain network, while the last two are connected with the control of the ANS.

Table 2: Psychometric results obtained with different BF modalities (* $p < 0.05$).

	TMT A	TMT B	WMS-R	
			Numbers Forward	Numbers Backward
PAT	$t = 8.302^*$	$t = 5.137^*$	$t = 3.521^*$	$t = 2.168^*$
HRV	$t = 0.297$	$t = 0.104$	$t = 2.323^*$	$t = 0.717$
EDR	$t = 0.267$	$t = 1.302$	$t = 0$	$t = 0.797$
Control	$t = 1.253$	$t = 1.612$	$t = 0$	$t = 0.649$

On Table 2, the psychometric results obtained by the three BF modalities are summarized. It can be seen that the training with EEG-PAT improves all psychometric results, while training with HRV is positively related only with the test Numbers forward (short time memory span). In other words, when the frontal brain network is being trained, it influences directly the concentration and gives better conditions for achieving peak performance. Training with peripheral type of biofeedback enables stability of the ANS, lower the stress level, but does not influence directly the duration of concentration. It enables reduction of stress while taking exams, tests, or other school activities. Related to concentration, HRV is more efficient than EDR but still less efficient than EEG biofeedback training.

Discussion

Applied psychophysiology and biofeedback are disciplines which help people to solve or mitigate different health problems. In addition, biofeedback methods are used for obtain better achievement in school, sport, and music and dance performance as well as in business.

It was shown that the arousal and performance are strongly correlated following Yerkes-Dodson Law.

It says that the performance increases with the level of arousal only to a certain point: when the level of arousal become too high, the performance decreases. Graphically it is demonstrated as an inverted U-shaped curve (15).

Initially, the peak achievement training was used for improving learning skills through optimal sequence of concentration, alertness and relaxation for various activities in military service and in NASA aerforce pilots. EEG studies of Air Force pilots in B2 simulators showed that as they focused on a particular aviation task, the alpha brainwave decreased. There was an alpha burst as focus ended, and then suppression as the next task began. This phenomenon was called the "micro break". The greater alpha suppression followed the more difficult tasks.

Other applications involved attention skills of business executives as part of a broader peak performance and leadership development program.

The experience showed that contemporary work needs so called "attention economy" as a new currency of business. Namely, the daily overload of information produces attention deficit, and the concentration training could help coping with this problem (16).

The differentiation of people in extrovert and introvert is depending also on the level of arousal in the attention system: extravert have lower level of arousal. In agreement with this arousal theory of extraversion, introvert showed larger P300 component to attended stimuli than extravert (1). If the introversion as psychological characteristic is related to high arousal level, we suppose that training with peripheral modalities of biofeedback will be more effective. In extroverts, low arousal level need stimulation of the brain activity which means that the neurofeedback (EEG biofeedback) will be more appropriate.

Professionally significant enhancement of music and dance performance and mood, has followed training with an EEG-neurofeedback protocol which increases the ratio of theta to alpha waves using auditory feedback during eyes closed condition. It was supposed that this state is associated with creativity, reduced depression and anxiety in some mental health problems such as alcoholism, PTSD etc. In optimal performance studies it was confirmed associations with creativity in musical performance. The alpha/theta training protocol involves recording the occurrence of alpha and theta activity in the EEG while participant relaxes with eyes closed. The production of theta in same condition is well known as a state of deep

relaxation, meditation and hypnosis. It was confirmed in many studies that creative writers produced the best novels upon conditions producing a borderline conscious state (17-25). We used similar alpha/theta training for treatment of PTSD in children. Needed session of this type of training differs from 10-20 (26).

Usually neurofeedback treatment takes about 20 sessions of training for obtaining the optimal improving of the brain activity needed for some specific function (hyperactivity, focused attention, diminishing depression, overcome learning difficulties etc). Here, we have healthy students without mental problems and the aim was to improve the duration of concentration. So, only 5 session of training were sufficient for obtaining better concentration time.

Conclusion

The results suggest that EEG-PAT can be used for improving the concentration and attention and to a less extend the Short Term Memory Span

Both, HRV and EDR groups have achieved a reduction in arousal and stress levels. However, no significant improvement in the concentration, attention and Short Term Memory Span was shown in EDR group, while in HRV group the improvement was modest (expressed in the numbering forward results).

This outcome may be explained by the fact that EEG-PAT is designed especially for peak achievement through central biofeedback, while the other two modalities are peripheral aimed wider applications.

Still, for more efficient research and training of cognitive functions, the Q-EEG multichannel biofeedback would be a better choice.

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