Baltic Journal of Health and Physical Activity 2018; 10(3): 72-79
Journal of Gdansk University of Physical Education and Sport
e-ISSN 2080-9999

ORIGINAL

doi: 10.29359/BJHPA.10.3.08

Neurofeedback needs support! Effects of neurofeedback-EEG training in terms of the level of attention and arousal control in sports shooters

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
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abstract

Background: Achievements in sports shooting are associated with the level of attention and agitation control, which improve to a significant extent the effectiveness of shooters in sports competition. The purpose of this study was to analyse changes in the level of attention and activation in sports shooters after neurofeedback-EEG training.

Material and methods: The study included students of the Military University of Technology (27 subjects). The Vienna Test System was used: a test for assessing attention (COG) and a test for assessing the functional activation (FLIM). The measurements were carried out before and after 20 neurofeedback-EEG training sessions oriented towards strengthening the beta frequency (12-22 Hz). To reduce any non-specific effects, investigators were informed not to motivate the subjects. All sessions consisted of 10 rounds.

Results: The differences between the first and the second measurement show that the shooters included in the study improved their abilities in terms of the attention level. The subjects performed the task more quickly and accurately during the second measurement. No significant changes were observed in terms of the arousal level.

Conclusions: Neurofeedback-EEG training improved the level of attention in shooters but it had no effect on the optimal arousal level in shooters.

Key words: neurofeedback-EEG, attention, arousal, shooting sports.

article details

Article statistics: **Word count:** 2,556; **Tables:** 4; **Figures:** 1; **References:** 35
Received: February 2018; **Accepted:** June 2018; **Published:** September 2018

Full-text PDF: http://www.balticsportscience.com

Indexation: Celdes, Clarivate Analytics Emerging Sources Citation Index (ESCI), CNKI Scholar (China National Knowledge Infrastructure), CNPIEC, De Gruyter - IBR (International Bibliography of Reviews of Scholarly Literature in the Humanities and Social Sciences), De Gruyter - IBZ (International Bibliography of Periodical Literature in the Humanities and Social Sciences), DOAJ, EBSCO - Central & Eastern European Academic Source, EBSCO - SPORTDiscus, EBSCO Discovery Service, Google Scholar, Index Copernicus, J-Gate, Naviga (Softweco, Primo Central (ExLibris), ProQuest - Family Health, ProQuest - Health & Medical Complete, ProQuest - Illustrata: Health Sciences, ProQuest - Nursing & Allied Health Source, Summon (Serials Solutions/ProQuest, TDOne (TDNet), Ulrich's Periodicals Directory/ulrichsweb, WorldCat (OCLC)

Funding: The study was supported by the Polish National Science Centre grant UMO-2012/07/B/NZ7/04383.

Conflict of interests: Authors have declared that no competing interest exists.

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INTRODUCTION

The role of attention is diverse: it controls interactions with the environment and serves as an adaptive tool. Of significance is also the fact that it connects the past and the present, as well as controls and plans future actions [1]. Attention enhances the effectiveness of learning during training as well as the effectiveness of athletes during sports competition. This process, as a component of an athlete's motivation, orients his/her receptive ability selectively towards stimuli which are relevant to achieving the sporting goal. This also reduces his/her sensitivity to factors which are of no significance in terms of this goal [2, 3].

Some forms of physiological adaptation, both with insufficient and excessive stimulation as compared to the optimal level, are associated with adjustment of the optimal activation level [4, 5]. Of significance is the theorem about curvilinear relationship between the level of emotional tension and performance, as defined by the Yerkes–Dodson law. This law states that an average arousal level is associated with greatest performance, which declines as arousal increases or decreases [6, 7]. Studies [8] showed that during sports competition the level of motivation has an impact on motor features. In highly excitable persons, when exposed to intense emotional arousal, some motor features may deteriorate, while in athletes who have a strong nervous system, they improve and stabilize [2, 6].

Neurofeedback-EEG is a scientific method for improving the functions of the peripheral nervous system. The biological feedback helps subjects to observe changes related to a specific parameter and to have an influence on their performance. This influence, exerted in a volitional manner, makes it possible to control the psychophysiological status of the body. Repeating a training series leads to the acquisition of an ability to regulate psychophysiological changes through learning mechanisms [9, 10, 11] using the brain's flexibility which originates from the capacity to create completely new synaptic pathways. Various ranges of generated frequencies show that the brain is ready to acquire new information and reflect the level of concentration, stress, fear and anxiety. Neurofeedback-EEG training can improve cerebral functions by weakening unwanted frequencies and strengthening the desirable frequency [9, 12, 13].

It has been demonstrated in a number of sources [13,14,15] that neurofeedback-EEG training helps athletes to achieve better concentration, improve their resistance to stress, enhance their sense of well-being, attain an inner calmness and relaxation, and eliminate their inner tension. Landers et al. [16] confirmed the hypothesis that neurofeedback-EEG training improves the level of performance in archers. The shooting accuracy improved significantly in the experimental group. On the other hand, Arns et al. [17] compared the improvement of the golfing stroke in golf players who participated in neurofeedback-EEG training and those who received no such training. The golfing strokes were better performed in the group which was provided with neurofeedback-EEG training. Studies of Dupee and Werthner [18] confirm that neurofeedback-EEG training helps to achieve an optimal arousal level. As seen by a group of 15 Olympic athletes, their control of stress and emotions improved.

In sports shooting, the static work and the need to perform technical components precisely are correlated with the nervous system's performance.

Achievements in sports shooting are associated with attention which improves to a significant extent the effectiveness of learning as well as the effectiveness of shooters in sports competition. In this process, their receptive ability is selectively oriented towards stimuli which are relevant to achieving the sporting goal. Of considerable importance to this process is an optimal arousal level and high mental efficiency [19, 20].

Nevertheless, it is considered that neurofeedback-EEG training should be given by a properly trained person with considerable knowledge of neuroscience [13, 21]. Of key importance is also the training methodology – how the training effects are explained, how trainers cooperate with participants and guide them through the training, and whether relaxation techniques are used to support the training effects [22, 23, 24, 25].

The purpose of the study was to examine if neurofeedback-EEG can help shooters to improve their attention and the optimal arousal level. An additional purpose of the study was to determine the trainer's impact on the effects of neurofeedback-EEG training.

MATERIAL AND METHODS

The study was carried out at the University of Physical Education (AWF) in Warsaw and the Military University of Technology (WAT). The study group consisted of 27 students of the Military University of Technology, who are professional soldiers and attend additional shooting classes. The subjects' age ranged from 19 to 21 years. The experimental group consisted of 17 students, and the remaining participants were assigned to the control group (n = 10). The subjects were randomly chosen into both groups. The study was anonymous and approved by the Bioethics Committee at the Military Institute of Hygiene and Epidemiology (WIHiE).

The COG and FLIM tests of the Vienna Test System (see description below) were performed twice by the subjects. The first measurement was carried out before the neurofeedback-EEG training started, and the second measurement – after all training sessions. The training was provided using the EEG DigiTrack Biofeedback system to beginning shooters in 20 sessions which took place 1-2 times a week. During each session the subjects were sitting in armchairs in front of 17" LCD computer screens. In the experimental group, the aim was to strengthen the beta frequency (12–22 Hz) as recorded via electrodes F3, F4, P3 and P4 in the standard 10–20 system, with ear-clip electrodes as a point of reference and grounding. The beta band shows the readiness of the cerebral cortex and its involvement in the cognitive activity. This is associated with better concentration, increased attention and vigilance [26, 27]. All sessions consisted of 10 rounds (3 minutes each) preceded by a short rest period (about 2 minutes). The training was provided by qualified therapists. They were instructed neither to motivate the subjects nor provide them with any information about how to correctly perform neurofeedback-EEG training. In the experimental group, the subjects received positive or negative feedback only on the computer screen. In the control group, feedback was unrelated to the actual actions of the subjects. This means that a subject received positive or negative feedback whether or not he/she properly relaxed and concentrated. The average testing period was about 90 minutes, and one neurofeedback-EEG training session lasted about 40 minutes.

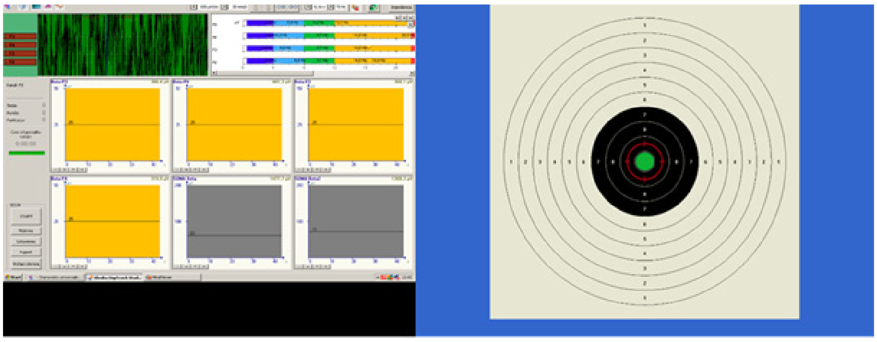

Fig. 1. The therapist's display (left) and the subject's display (right) during neurofeedback-EEG training. The subjects were to move four points, initially located at the outer edges of the shooting target, into the centre of the target. The award was given when the shooting target was filled with all the black points

COG (COGNITRONE)

The test is designed to measure the level of attention and concentration, and the general ability of "being vigilant". The programme displays four square fields in a single row (display fields) and one field below (task field). In the subtests with free working time, the subjects were to determine if the shape shown in the bottom row is the same as one of the shapes shown in the upper row, and to press the right button [28].

The test provides the following indicators:

- COG 1 – A total of correctly accepted responses – the number of cases when the data were identical and the subject pressed the green button.
- COG 2 – A total of correctly rejected responses – the number of cases when the data were not identical and the subject pressed the red button.
- COG 3 – Mean time of correct acceptance (s) – the mean time in seconds, which is needed for a respondent to decide that the shapes being compared are identical.
- COG 4 – Mean time of correct rejection – the mean time in seconds, which is needed for a respondent to decide that the shapes being compared are not identical.

FLIM (FLICKER/FUSION FREQUENCY)

The FLIM testing procedure makes it possible to determine the functional activation of the central nervous system in terms of the arousal level. The flicker frequency (steady -> flickering) or the fusion frequency (flickering -> steady) of a point light source is one of the criteria (in addition to e.g. EEG, galvanic skin response) which indicate the functional readiness of the central nervous system. The subject should accept any observed change in the light frequency (flickering -> steady or vice versa) by pressing a button [28].

The empirical indicators in the FLIM test are as follows:

- FLIM 1 – Fusion frequency (Hz) – presented fusion frequency in hertz, a point at which a flickering light is subjectively perceived to change into a steady light.
- FLIM 2 – Flicker frequency (Hz) – presented flicker frequency in hertz, a point at which a steady light is subjectively perceived to start flickering.

STATISTICAL ANALYSIS

A series of variance analysis tests were performed using Statistica, version 13. First, however, a statistical description of variables was developed for the individual groups (experimental and control) and measurements (measurement 1, measurement 2). After dividing the data according to groups and measurements, the following values were calculated: mean, standard deviation, minimum and maximum, and the Shapiro-Wilk test for normal distribution was performed. Research problems were verified based on ANOVA parametric tests for the significance of differences.

RESULTS

The purpose of the analysis was to compare the experimental and the control groups before and after neurofeedback-EEG training in terms of their level of attention and arousal.

Table 1. Descriptive statistics – experimental group

	Avg ± Std	Min-Max	Avg ± Std	Min-Max
	before		after	
COG 1	69.29 ±17.42	23 - 79	68.29 ±17.12	24 - 79
COG 2	106.53 ±26.84	35 - 120	106.82 ±27.08	35 - 119
COG 3	2.00 ±0.43	1.35 - 2.93	1.77 ±0.41	1.24 - 2.62
COG 4	2.00 ±0.47	1.41 - 3.03	1.77 ±0.42	1.27 - 2.52
COG 5	365.94 ±115.67	117 - 558	328.53 ±120.08	84 - 514
FLIM 1	37.69 ±2.47	34.14 - 43.53	38.62 ±3.25	33.98 - 46.13
FLIM 2	40.91 ±4.65	29.11 - 48.96	40.41 ±2.47	34.16 - 47.33

Table 2. Descriptive statistics – control group

	Avg ± Std	Min-Max	Avg ± Std	Min-Max
	before		after	
COG 1	43.9 ±26.38	23 - 78	44.2 ±28.71	20 - 80
COG 2	67.8 ±41.49	35 - 117	67.6 ±41.71	33 - 119
COG 3	1.82 ±0.35	1.33 - 2.36	1.67 ±0.19	1.41 -1.96
COG 4	2.02 ±0.39	1.36 - 2.67	1.77 ±0.27	1.4 - 2.26
COG 5	214.5 ±125.35	106 - 424	198.6 ±123.26	88 - 377
FLIM 1	38.77 ±2.5	35.4 - 44.75	37.99 ±1.65	34.72 - 39.8
FLIM 2	41.34 ±2.55	38.4 - 44.83	41.06 ±3.20	35.03 - 47

Table 3. Analysis of variance for the mean time of correct acceptance (COG 3) before and after training, and between the experimental and the control groups Sequences with repeated measurements, effects and power levels

	SS	F	*p*	Eta^2	Perceived power
GROUP	1	0.991	0.329	0.038	0.160
R1	1	13.172	**0.001**	0.345	0.937
R1*GROUP	1	0.609	0.442	0.024	0.117

*Group – differences between the experimental and the control groups. R1 – differences between the first and the second measurements. R1*GROUP – interaction between a group and the measurement; p < 0.05*

Table 4. Analysis of variance for the mean time of correct rejection (COG 4) before and after training, and between the experimental and the control groups. Sequences with repeated measurements, effects and power levels

	SS	F	*p*	Eta^2	Perceived power
GROUP	1	0.008	0.928	0.000	0.051
R1	1	13.534	**0.001**	0.351	0.942
R1*GROUP	1	0.029	0.867	0.001	0.053

*Group – differences between the experimental and the control groups. R1 – differences between the first and the second measurements. R1*GROUP – interaction between a group and the measurement; p < 0.05*

The mean time of correct rejection and correct acceptance improved significantly ($p < 0.05$) in the COG test in the experimental and the control groups. A high level of the effect size was observed. It was $\eta^2 = 0.35$ in both cases. The test power was also high at 0.93 in both cases.

During the FLIM test, which measures the optimal arousal level, no significant differences were observed between the groups and the measurements before and after training ($p > 0.05$).

DISCUSSION

After 20 neurofeedback-EEG training sessions, the subjects in the experimental and the control groups tended to perform tasks of the COG test, which measures general attention, more quickly and accurately. This suggests that the subjects improved their concentration and arousal level. This phenomenon can be related to the theory of signal detection. In general, vigilance is needed when a relevant stimulus appears rarely, and when it does, immediate attention is required. Reduced arousal is considered to result not from reduced sensitivity, but from being more doubtful about one's own observations or fatigue. Consistent training can help to improve vigilance. In this case, the only way to improve signal detection is to provide more frequent rest periods [29]. The results of our study correspond to those obtained by Arns [17], Perry [30], Veron [15], Egner [31], which confirm the improvement of cognitive functions in terms of the attention level.

A placebo effect may have been triggered in the control group. The subjects were convinced that if they exercised their concentration on a regular basis, the exercises would produce measurable results. It seems, therefore, that the mere concentration on the exercise, even with false feedback, can help to improve the attention level [32,33].

Shooters in the experimental group achieved no improvement in the test aimed to determine the functional activation of the central nervous system in terms of the arousal level. This is contrary to results reported by Dupee and Werthner [18], who considered that neurofeedback-EEG training helps to achieve an optimal arousal level. Both investigators provided training to a group of 15 Olympic athletes from Vancouver. Competitors observed a significant improvement in their ability to control stress and emotions.

According to Michael and Lynda Thompson [10], a therapist should actively interact with a subject; he/she should help and model, and always show a positive attitude. The strategy suggested in the neurofeedback-EEG guidebook [34] is based on interventions of a trainer who should instruct training participants to relax, take an appropriate comfortable position and avoid muscle spasms. Trainers are expected to visually assess EEG and FFT recordings to detect any transfer of EMG activity and to instruct participants to correct their behaviour. The therapist should teach his/her client not to attempt to regulate his/her cerebral activity by unwanted muscle tensions [35]. Neurofeedback-EEG provides the best results when it is combined with relaxation training [22, 23]. On the other hand, Cherapkina [25] pointed out that it is necessary to explain what in-session relaxation involves for the future success of biofeedback. The studies and literature referred to above show that the data resulting from our study are not unambiguous. This could be due to the absence of active interaction on the part of the therapist.

CONCLUSIONS

The purpose of the study was to examine if neurofeedback-EEG can help shooters to improve their attention level and to maintain an optimal arousal level. An additional purpose of the study was to confirm that a trainer has a significant impact on neurofeedback-EEG training. Based on the study results, it can be concluded as follows:

1. Neurofeedback-EEG training improved the level of attention in shooters.
2. Neurofeedback-EEG training had no effect on the optimal arousal level in shooters.

The tests described in this paper would also produce measurable effects;, however, after a greater number of training sessions. It may be that the training procedures were not properly customized. The above results can provide the basis for new research in sports shooting.

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Cite this article as:

Mikicin M, Szczypińska M, Skwarek K.
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