Original Paper

DE GRUYTER OPEN

Biomedical Human Kinetics, 7, 58–65, 2015

DOI: 10.1515/bhk-2015-0010

The autotelic involvement of attention induced by EEG neurofeedback training improves the performance of an athlete's mind

Mirosław Mikicin

Józef Piłsudski Academy of Physical Education, Warsaw, Poland

Summary

Study aim: the aim of this study was to analyse the effects of neurofeedback-EEG, which consisted of visual stimulation with immediate feedback concerning brain activity on autotelic engagement attention and the performance of athletes' minds.
Material and methods: the experimental group (25 subjects) underwent twenty neurofeedback-EEG training sessions (in the relaxation armchair) and athletic training for four months (every 7 days). The control group (25 subjects) underwent athletic training sessions. Before and after the four months of neurofeedback-EEG training sessions, the athletes were evaluated using an involvement questionnaire and Kraepelin's work curve test.
Results: the results of the analysis showed that changes in autotelic engagement were observed with an improvement in the performance of the mind ($p < 0.01$), which points to increased speed and mental work speed and efficiency. Among three measures of performance, we observed a significant correlation between the total number of addition operations in the test with autotelic experience ($r = 0.769$).
Conclusions: neurofeedback-EEG training opens up new opportunities for improvement in the performance of athletes' minds.

Keywords: Autotelic experience – Autotelic engagement attention – Kraepelin's work curve – Neurofeedback-EEG – Performance of the mind – Athletes

Introduction

The benefits of the neurofeedback-EEG method in improving the performance of the mind are evaluated in particular through the measurement of the speed and accuracy of the action to be performed [30]. Similar views have been presented by Mihaly Csikszentmihalyi [2, 8, 9], who stressed that being active requires engagement, which is understood as 'a Self which determines the goals', easily transforming perception into *challenges, thus sustaining an internal harmony.* Csikszentmihalyi developed a method of measuring experiences that helps to describe the subjective feelings of people who experience varied states of mind during activities. Examples of these feelings are expressed with the following phrases: 'My mind is not thinking it over. I'm not thinking about anything else. I'm totally engrossed with what I'm doing. My body feels excellent. I seem not to hear anything. I'm cut off from the world. I'm becoming less aware of my Self and my own problems. I'm engaged in what I'm doing. I seem to be a part of what I'm doing'. Therefore, when people experience a particular mental state, they start to see phenomena that others do not, have a feeling of connection with the whole world and are filled with a unique emotional state [25].

Since the essence of autotelic engagement is the flow of the attention needed to be involved in the action performed, neurofeedback-EEG training might reinforce this experience [11]. A natural manifestation of this reinforcement is feedback from a person who experiences the engagement and autotelic character of the action the person performs [26]. The term 'autotelic' stems from the Greek word *Auto,* meaning self or self-oriented, whereas *telos* means 'goal'. Therefore, autotelic activities are performed because they are rewarding in themselves [10, 26]. Autotelic engagement is connected with the behavioural experiencing of perception supported by automated attention which follows the mind. Autotelic engagement occurs in the state of mind where no differentiation occurs between the subject and object, or the acting person and action. It causes a state of excitement, full satisfaction, engagement and unity of the body and mind.

Author's address Mirosław Mikicin, Józef Piłsudski University of Physical Education, ul. Marymoncka 34, 00-968 Warsaw, Poland
miroslaw.mikicin@awf.edu.pl

The relationships between engagement and personality [2, 13, 24, 26], which reveal the level of autotelicity, are in a varied manner and are revealed by aspects of engagement and factors of personality. The most typical of these relationships (the autotelic personality of athletes) is the structure where common components, including conscientiousness (with a positive correlation to conscious activity), concentration on current tasks, autotelic experience, balance between abilities and challenges, a lack of confusion, the paradox of control and time transformation as well as extroversion (introversion and neuroticism) and emotional stability, are negatively correlated with an unequivocal understanding of information and clarity of goals. Balanced relationships were also observed between abilities and challenges and between agreeableness and self-consciousness [1, 26].

The study used methods of measuring experiences [2, 18] to describe changes in professional athletes' levels of autotelic engagement in sports competitions after neurofeedback-EEG training. With regard to the fact that the factors that are conducive to or adverse for autotelic engagement have genetic origins, engagement is understood to mean an emotional aspect of an athlete's attitude towards his or her own activity. It reflects an identification with the activity performed, or a degree of loyalty, and defines the level of satisfaction and feeling of 'emotional attachment'. It also represents a level of 'participation' reflected by positive valuation and the undertaking of goal-oriented actions. Therefore, autotelic engagement represents a predictor of satisfaction and an indicator of perceived physical health [37].

In recent years, neurofeedback-EEG training has been increasingly used to optimize various cerebral functions [39]. For instance, studies have documented that training in the range of SMR frequencies (12–15 Hz) improves the body's ability to maintain balance [40]. Increasing the power of SMR waves with a simultaneous reduction of power in the theta (4–7 Hz) and beta 2 (21–35 Hz) bands has also been found to be effective in improving the results obtained in attention tasks [38]. Similar training helps maintain attention for a longer time [11] and ensures concentration on particularly important actions which necessitate the maintenance of agility and endurance for a long period of time [23, 33]. Neurofeedback-EEG training in the range of SMR waves considerably improved the results of tests of working memory [38], concentration of attention [11], psychological well-being [17] and mood [29], as well as a better ability to cope with time pressure[14]. Furthermore, neurofeedback-EEG training plays an increasingly creative role in art [15], music [11] and an improvement in the effectiveness of physical work [22, 36]. Other studies have researched the effect of neurofeedback-EEG training on improved function of the parietal lobe, motor reactions connected with movement coordination [4] and stress-related emotional reactions [4, 6].

These studies are supported by the fact that neurofeedback-EEG training has also been used to improve achievement in sport. Therefore, it is very likely that this occurs through the increased autotelic engagement of an athlete during a competition. Previous studies have demonstrated that neurofeedback training has helped athletes improve their performance in sports [5, 12, 15, 16, 17, 28, 31]. It has been shown, for instance, that neurofeedback-EEG training used to enhance the power of beta 1 and SMR waves in archers, gymnasts, ice skaters and skiers reduces anxiety and improves concentration and control of emotions and motor coordination [16]. It was also found that increasing the power of beta 1 and SMR bands in the area of the motor cortex in competitive pistol shooters and a reduction in the activity of the muscles that are not directly involved with this activity results in the optimization of psychomotor function and cognitive control [20]. Hanslmayr et al. [17] have demonstrated that the use of neurofeedback for improving activity in the visual cortex of the brain in the range of beta and SMR frequencies leads to better results in cognitive tests. Neurofeedback-EEG training in SMR, beta 1 and theta bands has also been found to improve the autotelic engagement of athletes during swimming competitions.

Autotelic engagement attention is closely related to work (athletic training), where, by matching opportunities to the difficulty of the task, it translates into a maximization of the experience. This state might lead to the achievement of the highest levels of individual performance. The speed and accuracy of the intended action [30] were measured before and after neurofeedback training in order to evaluate the related behavioural improvement. Similar criteria were used in the evaluation of work performance in the beginning of the twentieth century. Kraepelin [21], who attempted to find the causes of individual differences in labour effectiveness, drew a 'work curve' where he took into consideration a number of positive (motivation) and negative (fatigue) indices that determined levels of effectiveness. The profile of the work curve has been shown to continue with time (up to eight months) and provides a specific characterization of the person examined [3]. In the present study, we used indices of Kraepelin's work curve in order to evaluate changes in the performance of professional athletes following neurofeedback-EEG training.

Materials and methods

All of the procedures were approved by the Bioethical Committee at the University of Physical Education in Warsaw and were consistent with the standards of the Declaration of Helsinki.

The subjects (25 athletes: 15 men and 10 women) underwent twenty neurofeedback-EEG training sessions (in the relaxation armchair) for four months (every 7 days). The control group (25 athletes: 15 men and 10 women) underwent athletic training sessions similar to those in the experimental group but without neurofeedback-EEG sessions for four months between the examinations. Before and after 20 neurofeedback-EEG training sessions or four months, all of the athletes were evaluated using an engagement questionnaire and the Kraepelin work curve test.

Flow State Scale-2 FSS-2, (Engagement questionnaire, Kwabata, 2008) is used for evaluation of subjective feelings of the state of engagement. There are nine dimensions of this state on a scale of 1 to 5. Each scale has four statements assigned to it. The individual dimensions are: 1) Challenge-Skill Balance (balance between ability level and challenge – BA) – adjustment of individual abilities to a challenge; 2) Merging of Action and Awareness (loss of the feeling of self-consciousness – LF) – a deep engagement in action so that it becomes spontaneous and automated; 3) Clear Goals (a clear definition of goals – CG) – tasks that raise no doubts; 4) Unambiguous Feedback (unequivocal understanding of information, intrinsic rewarding – IR) – the information provided is clear to the individual and allows for the evaluation of the highest possible goals and achievements; 5) Concentration on the Task at Hand (concentration and focusing – CF) – concentration on current tasks or the exclusion of insignificant tasks; 6) Sense of Control (potential ability of control – C) – while experiencing the state of engagement, the individual knows that control is possible and has a feeling of potential control over and effect on his/her own activities; 7) Loss of Self-Consciousness (lack of confusion feedback – F) – the task engages the attention of the individual so that he or she cannot think of the past and can reject other disturbing stimuli; 8) Transformation of Time (distorted sense of time – DS) – the objective external time flow becomes insignificant compared to the rhythm of a particular activity; 9) Autotelic Experience (action awareness merging – AA) – the experience of flow as a state which is satisfying in itself so that performing the task becomes a reward and results in positive reinforcement. The raw results on each scale equal the number of points from individual statements (4 to 20).

The **'work curve test'** [3, 21] was created to measure speed, effectiveness and work accuracy. The aim of this task is to perform as many addition operations of two digits in the adjacent columns as possible within one hour. The total of the correct results calculated in consecutive three-minute time periods was used to form the work curve. The shape of the curve, based on the general number of addition operations performed and the number of mistakes and corrections, provided the basis for interpretation of the results. The values in the work curve allowed for the calculation of six separate and largely independent factors (partial measures, see below). Their interpretation was based on Kraepelin's studies [3], in addition to others [19, 35]: a) Performance measurements – the total number of addition operations (number of operations a person performed during the test, including mistakes and corrections), the number of operations in the first three-minute time period (Y1, the score obtained during the first three minutes of the test, which is the indicator of previous experience in addition), the maximum number of addition operations in a three-minute time period (without the first time period, which reflects the subject's highest possible working rate); b) Measurements of energy and persistence – percentage increase (the difference between means of the first and last four three-minute time periods expressed in percentage terms), half ratio (the quotient of the total number of addition operations from the period that consists of the ten final three-minute time periods [11–20] and the first ten periods [1–10]) and location of the maximum (the three-minute period when the subject performed the highest number of addition operations, not including the first period); c) Measurements of quick adaptation and effort without self-restraint – convexity I (the difference between the general number of addition operations during the first four and last four time periods multiplied by the mean elevation of the curve and divided by the number of time periods), convexity II (the difference between the overall number of addition operations in time for the first five and last five time periods and the number of addition operations in the other middle ten time periods); d) Measurements of variability (or constancy), which determine indices of oscillation around the even curve (average deviation from the third to the eighteenth time period); e) Measurements of accuracy and diligence are determined by the mistake ratio (the overall number of mistakes as a percentage of a general number of addition operations) and the correction ratio (the percentage of the overall number of addition operations); f) Measurements of additional factors are determined by the initial decline (the difference between the number of addition operations in the first time period and the lowest number in the first through the fourth time periods) and the duration of decline (determined in the four first periods when the fewest addition operations were performed).

The training paradigm used in our experiment required a concentration of attention in visual and auditory modalities. During neurofeedback-EEG training, subjects were asked to perform a task that consisted of controlling images displayed on a screen so that four balls were placed in the middle of the screen. The proper movement of the balls on the screen was accompanied by an acoustic reinforcing signal (0.5 s long pitch repeated every 1 s under conditions fulfilled at the same time for all three frequency bands) and occurred as a result of the feedback from an EEG amplifier when the amplitude of the EEG signal recorded from electrodes C3 and C4 (in the system of 10–20) in the theta band (4–7 Hz) and beta 2 band (21–35 Hz) was decreasing and the amplitude of the SMR band (12–15 Hz) and the beta 1 band (15–20 Hz) was increasing. The voltage threshold for decreasing the theta and beta 2 bands was set at 40% (2.6 μV and 2 μV, respectively) above the mean of the recorded theta and beta 2 amplitudes (6.5 μV, and 5 μV, respectively) and the threshold for SMR and beta 1 bands was set at ~35% (1.4 μV) below their mean amplitudes (~ 3.5 and 4.5 μV).

Statistical analysis

Descriptive statistics were also computed, including means and standard deviations for the variables. The significance of the differences was calculated using a non-parametric Wilcoxon signed-rank test. The Pearson's r correlation coefficient, which determines the level of linear correlation and evaluates the correlations between variables, was also used. The significance of individual indices of the work curve and parameters of Kraepelin's measures were calculated using a t-test for dependent samples.

Results

The analysis carried out in the study demonstrated that neurofeedback-EEG training is conducive to experiencing autotelic engagement during sports competitions. After undergoing twenty neurofeedback-EEG training sessions using the procedure of amplifying the SMR and beta 1 bands and weakening the theta band, the subjects displayed improved autotelic engagement, and changes in Kraepelin's work curve were observed. Since there were no significant differences between genders, the data were connected.

Changes in engagement level after neurofeedback-EEG training

The mean values of the recorded variables and their relationships are presented in table 1, showing that concentration on a task, the setting of clear goals and autotelic experience have the greatest effect on autotelic engagement. Table 1 illustrates mean values and standard deviations for various levels of the engagement of athletes from the experimental group before and after neurofeedback-EEG training sessions. These results point to a high ($p < 0.01$), yet varied level of engagement among the athletes in competition after the experiment. The results obtained in the control group (insignificant differences before and after four months) seem to demonstrate that changes in the levels of engagement are caused by neurofeedback-EEG training. The initial data before the experiment in both groups did not differ significantly, whereas after four months of neurofeedback-EEG training, the experimental group differed from the control group significantly at $p < 0.01$.

Changes in work-curve parameters resulting from neurofeedback-EEG training

Changes observed in the work curve were originally evaluated with a series of partial measures which describe changes in performing a task in a better way [3, 21]. Most of mean indices that describe partial measures of the work curve changed significantly ($p < 0.05$) following neurofeedback-EEG training. The measures are their interpretation is based on Kraepelin's studies [3, 19, 35]. We found a significant ($p < 0.05$) increase in two out of three "performance measures" (see Methods): total number of addition operations performed in the test that indicated an improved working rate and an increase in the number of operations in the first three-minute time period that indicated better skills in addition (table 2). Apart from the measures of performance, two of the three parameters used as a measure of energy and persistence were also changed significantly ($p < 0.05$): the difference in mean elevation of the work curves as well as half ratio and first ten time periods were reduced. These changes in partial measures suggest that the work curve became less steep, which might result from

Table 1. Involvement variables ranked by mean values, before and after training neurofeedback EEG, (N = 25)

Involvement variables	pre ± SD	post ± SD	Z	p
Challenge-Skill Balance	13.60 ± 3.30	18.64 ± 1.82	3.888	<0.001
Merging of Action and Awareness	13.92 ± 3.51	17.36 ± 2.76	3.371	<0.001
Clear goals	14.16 ± 3.55	18.16 ± 1.97	3.343	<0.001
Unambiguous Feedback	13.52 ± 3.08	17.32 ± 1.74	3.551	<0.001
Concentration on the Task at Hand	14.84 ± 3.18	18.64 ± 1.55	3.652	<0.001
Sense of Control	14.32 ± 4.12	18.44 ± 1.52	3.636	<0.001
Loss of the Self-Consciousness	13.72 ± 3.52	17.20 ± 3.06	3.315	<0.001
Transformation of Time	10.04 ± 4.41	14.84 ± 4.51	3.071	0.002
Autotelic Experience	15.32 ± 4.38	19.64 ± 0.75	3.977	<0.001

Table 2. Indices of the work curve before and after training neurofeedback-EEG in experimental group (n = 25). The comparison with the use of Wilcoxon signed rank test

Variable	pre	post	T	Z	p
First three minute	277.00	389.00	97.00	–1.756	0.049
Total number	271.00	395.00	96.00	–1.946	0.042
Period I	265.50	364.50	112.50	–1.320	0.187
% increment	358.00	272.00	101.00	1.700	0.089
II/I ratio	401.00	265.00	94.00	2.136	0.033
Peak location	395.00	271.00	100.00	1.946	0.052
Convexity I	349.50	316.50	95.50	0.506	0.033
Convexity II	372.50	293.50	122.50	1.234	0.217
Oscillation I	351.00	315.00	94.00	0.554	0.040
Mistake ratio	294.00	234.00	81.00	1.737	0.082
Correction ratio	263.50	402.50	92.50	–2.183	0.029
Initial decline	350.50	315.50	144.50	0.538	0.591
Duration of the decline	398.00	268.00	97.00	2.041	0.041

fatigue with the high rate of work in the first half hour of performing the test.

Both parameters of the measures of adaptation and exercise without self-restraint (convexity I and II) were reduced significantly ($p < 0.05$). This might mean ability to maintain individual working rate for a longer time [3, 21]. The index of oscillation around the work curve ($p < 0.05$) was also reduced; it is presented as a measure of variability that points to the consequence and reduction in the level of emotional distress during the test [3, 21].

The increase in the correction ratio ($p < 0.05$), calculated as a percentage of the total number of addition operations, is regarded as an improvement in the measure of accuracy and diligence of the work performed. Another significant observation was an increase in the percentage of corrections that occurs with a reduction in the percentage of mistakes.

With respect to the additional measures, a reduction in the duration of the initial decline, $p < 0.05$) occurred, which was explained as an experience and better adaptation to the new situation [3, 21]. In the control group after four months from the first test without neurofeedback training, none of the indices changed significantly. These findings are consistent with the previous Kraepelin's observation that the profile of the work curve changes in time (in the range of up to eight months) and provides a specific characterization of the person examined [3].

Relationships between the work curve and autotelic engagement

Among three measurements of performance, we observed a significant correlation between the total number of addition operations in the test with autotelic experience ($r = 0.769$) after twenty neurofeedback training sessions. The positive correlation between these variables points to a faster work rate observed for increasing autotelic engagement (Fig. 1). This correlation might indicate a tendency to engage attention during the performance of a task.

Discussion

The study demonstrated that a twenty-week neurofeedback-EEG training of athletes, consisting of the reinforcement of the amplitude of SMR and beta 1 bands as well as the weakening of theta band amplitudes, results in the expected changes in the levels of engagement and is conducive to improvement in athletic performance. Therefore, the paradigm adopted before neurofeedback-EEG training which assumed changes in autotelic engagement [2, 26] in a positive direction was supported by the results of the study. The results also show that the neurofeedback-EEG training of athletes is competitive compared to the mental reinforcement of the effectiveness of athletic training using psychological methods. Therefore, neurofeedback-EEG training opens up new opportunities for improvement in athletic performance.

The changes observed in theta, SMR and beta 1 bands were also correlated with changes in certain behavioural measures as defined in the Kraepelin test. The specific changes in amplitude of these bands were associated with an improvement in measures of performance which reflect the tendency to quickly begin and perform

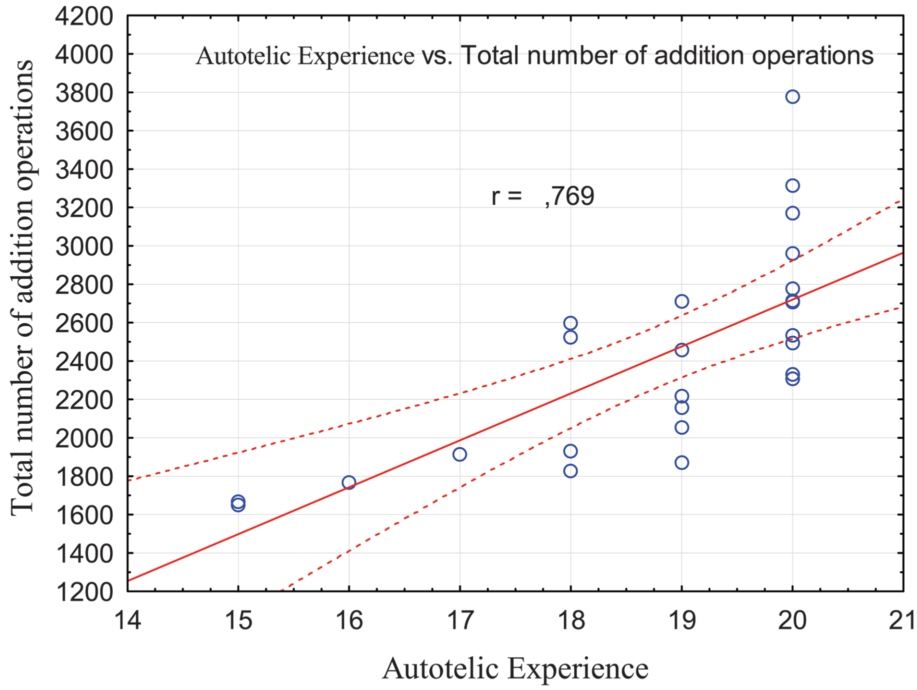

Fig. 1. Spearman correlations the Autotelic Experience vs. Total number of additions operations

work [3, 21]. Similarly, in past investigations that used the Kraepelin test to evaluate personality traits in mountaineers, researchers found that athletes obtained better results in the components of the test that measured the ability to maintain concentration and persistence compared to the control group [19, 27, 35]. Furthermore, Arnold [3] found that a reduction in the measurement of variability is connected with an improvement in the consistency of actions and a reduction in the level of emotional distress when performing Kraepelin's test, since the consistency of actions determines the ease of maintaining interest in a monotonous task and patience in achieving goals [21].

In our experiment, we observed significant changes in the measurements of fast adaptation and exercise without self-restraint (convexity indices) and the measurement of variability/consistency (oscillation index). A high convexity index in the work curve of the athletes in our experiment before neurofeedback-EEG training might be interpreted, according to Kraepelin [3], as the tendency to begin work very quickly and then quickly become fatigued, resulting in impulsiveness and low accuracy in action. The results obtained by the athletes after training were characterized by lower measures of convexity for the work curve and a lower level of variability (oscillation index), which can be interpreted as an increase in the ability to maintain the rate of the performed activities longer and to adapt to monotony in work more easily.

The Kraepelin test was relatively popular and was often used in the twentieth century [3]. Scientific data from the seventies demonstrates its usefulness in both vocational counselling and clinical and psychological diagnostics, even for military purposes and judicial medicine [3]. However, the test has been criticized more recently due to the fatigue observed in subjects who perform the test [7, 32, 34], and the frequency of its use has declined dramatically. Our study demonstrated that, with regard to healthy and motivated young people, an analysis of the test based on the criteria suggested by its creators allows for the achievement of convincing conclusions. Also, the specific changes in levels of autotelic engagement were found to be correlated with the work curve, which was reflected by an increased working rate [3, 21]. A high level of performance, which is a general number of additions, connected with a high level of autotelic experience indicates a higher level of energy, which was interpreted by Kraepelin [21] as the tendency to delay fatigue.

Conclusions

The changes observed in the study were accompanied by changes in the work curve that point to the increased rate and effectiveness of mental work (addition of digits). Therefore, the neurofeedback-EEG training paradigm that assumed changes in the amplitudes of the theta, SMR and beta 1 bands in order to improve the results obtained in behavioural tests towards the effect demanded by the athletes was fully confirmed.

References

1. Asakawa K., Csikszentmihalyi M. (2000) Feelings of connectedness and internalization of values in Asian American adolescents. *J. Youth Adolesc.*, 29: 121–145.
2. Asakawa K. (2004) Flow experience and autotelic personality in Japanese college students: how do they experience challenges in daily life? *J. Happiness Stud.*, 5: 123–154.
3. Arnold W. (1975) Der Pauli-Test. Anweisung zur sachgemäßen durchführung, Auswertung und Anwendung des Kraepelinschen Arbeitsbesuches 5, korrigierte Aufl. Springer-Verlag: Berlin, 1–184.
4. Bazanova O.M., Mernaya E.M., Shtark M.B. (2009) Biofeedback in psychomotor training. *Electrophysiologic. Basis Neurosci. Behav. Physiol.*, 39(5): 437–448.
5. Besserve M., Philippe M., Florence G., Laurent F., Garnero L., Martinerie J. (2008) Prediction of performance level during a cognitive task from ongoing EEG oscillatory activities. *Clin. Neurophysiol.*, 119: 897–908.
6. Bradley R.T., McCraty R., Atkinson M., Tomasino D., Daugherty A., Arguelles L. (2010) Emotion self-regulation, psychophysiological coherence, and test anxiety: results from an experiment using electrophysiological measures. *Appl. Psychophysiol. Biofeedback*, 35(4): 261–83.
7. Brandstätter H. (1995) Die Arbeitskurve nach Kraepelin-Pauli – doch ein Willenstest? *Zeitschrift für Arbeits – und Organisationspsychologie*, 39: 54–66.
8. Csikszentmihalyi M. (1988) The flow experience and its significance for human psychology. In: M. Csikszentmihalyi, I.S. Csikszentmihalyi (eds.), *Optimal Experience: Psychological Studies of Flow in Consciousness*. Cambridge University Press: New York, 15–35.
9. Csikszentmihalyi M., LeFevre J. (1989) Optimal experience in work and leisure. *J. Personal. Social Psychol.*, 56: 815–822.
10. Csikszentmihalyi M., Rathunde K. (1993) The measurement of flow in everyday life. *Nebraska Symposium on Motivation*, 40: 57–97.
11. Egner T., Gruzelier J.H. (2004) EEG Biofeedback of low beta band components: frequency-specific effects on variables of attention and event-related brain potentials. *Clin, Neurophysiol.*, 115: 131–139.
12. Fan J., Byrne J., Worden M.S., Guise K.G., McCandliss B.D., Fossella J., Posner M.I. (2007) The relation of brain oscillations to attentional networks. *J. Neurosci.*, 27: 6197–6206.
13. Fournier J. (2007) French translation of flow state scale-2: factor structure, cross-culture invariance, and associations with goal attainment. *Psychol. Sport Exerc.*, 8: 897–916.
14. Gibson A., Boulton M.G., Watson M.P., Moseley M.J., Murray P.I., Fielder A.R. (2005) The first cut is the deepest: basic surgical training in ophthalmology. *Eye*, 19: 1264–1270.
15. Gruzelier J.H., Egner T., Vernon D. (2006) Validating the efficacy of neurofeedback for optimizing performance. *Progress in Brain Research*, 159: 421–431.
16. Hammond D.C. (2007) Neurofeedback for the enhancement of athletic performance and physical balance. *J. Amer. Board Sport Psychol.*, 1: 27–36.
17. Hanslmayr S., Sauseng P., Doppelmayr M., Schabus M., Klimesch W. (2005) Increasing individual upper alpha power by neurofeedback improves cognitive performance in human subjects. *Appl. Psychophysiol. Biofeedback*, 30: 1–10.
18. Kwabata M. (2008) The flow state scale-2 and dispositional flow scale-2: Examination of factorial validity and reliability for Japan's adults. *Psychol. Sport Exerc.*, 9: 465–485.
19. Kashiwagi S., Tanaka Y., Tsubokura K., Okuyama K., Shinrigaku K. (2007) Evaluation of the Uchida-kraepelin psycho-diagnostic test based on addition work from the view of the Big Five. *Josai International University*, 78: 125–132.
20. Kerick S.E., Douglass L.W., Hatfield B.D. (2004) Cerebral cortical adaptations associated with visuomotor practice. *Med. Sci. Sports Exerc.*, 1: 118–129.
21. Kraepelin E. (1922) Gedanken über die Arbeitskurve, *Psychologische Arbeiten*, 7: 535–547.
22. Larsen C.R., Soerensen J.L., Grantcharov T.P., Dalsgaard T., Schouenborg L., Ottosen C., Schroeder T.V., Ottesen B.S. (2009) Effect of virtual reality training on laparoscopic surgery: randomized controlled trial. *BMJ*, 14: 1802.
23. Leff D., Aggarwal R., Rana M., Nakhjavani B., Purkayastha S., Khullar V., Darzi A.W. (2008) Laparoscopic skills suffer on the first shift of sequential night shifts: program directors beware and residents prepare. *Ann. Surg.*, 247: 530–539.
24. McCrae R.R., Terracciano A. (2008) The Five Factor Model and its correlates in individuals and cultures. In Van de Vijver F.J.R., van Hemert D.A., Poortinga Y.H. (eds.), *Individuals and cultures in multi-level analysis*. Mahwah, NJ: Erlbaum, 247–281.
25. Mikicin M. (2007) Relationships between experiencing flow state and personality traits, locus of control and achievement motivation in swimmers. *Phys. Edu. Sport*, 4: 315–322.
26. Mikicin M. (2013) Autotelic personality as a predictor of engagement in sports. *Biomed. Hum. Kinet.*, 5: 65–71.
27. Mikicin M. (2014) Work curve as a distinguishing mark of athletes' work performance. *Biomed. Hum. Kinet.*, 6: 69–76.
28. Monastra V.J. (2005) Electroencephalographic biofeedback (neurotherapy) as a treatment for attention deficit hyperactivity disorder: rationale and empirical

foundation. *Child and Adolescent Psychiatric Clinics of North America*, 14(1): 55–82.
29. Raymond J., Sajid I., Parkinson L.A., Gruzelier J.H. (2005) Biofeedback and dance performance: a preliminary investigation. *Appl. Psychophysiol. Biofeedback*, 30: 65–73.
30. Saleh G.M., Voyazis Y., Hance J., Ratnasothy J., Darzi A. (2006) Evaluating surgical dexterity during corneal suturing. *Archives of Ophthalmology*, 124: 1263–1266.
31. Sobral D.T. (2004). What kind of motivation drives medical students' learning quests? *Med. Edu.*, 9: 950–957.
32. Steinborn M.B., Flehmig H.C., Westhoff K., Langner R. (2009) Differential effects of prolonged work on performance measures in self-paced speed tests. *Adv. Cogn. Psychol.*, 5: 105–113.
33. Sugden C., Aggarwal R., Darzi R. (2010) Sleep deprivation, fatigue, medical error and patient safety. *Amer. J. Surg.*, 199(3): 433–434.
34. Sugimoto K., Kanai A., Shoji N. (2009) The effectiveness of the Uchida-Kraepelin test for psychological stress: an analysis of plasma and salivary stress substances. *Biopsychosocial Medicine*, 3: 5–15.
35. Takigasaki T. (2006) The work curves of Uchida – Kraepelin test in the time of mountaineering. Nippon Institute of Technology Research Report, 35(3/4): 7–12.
36. Van Herzeele I., Aggarwal R., Neequaye S., Darzi A., Vermassen F., Cheshire N.J. (2008) Cognitive training improves clinically relevant outcomes during simulated endovascular procedures. *J. Vasc. Surg.*, 48: 1223–1230.
37. Vecina M.L., Chacón F. (2013) Is engagement different from satisfaction and organizational commitment? Relations with intention to remain, psychological well-being and perceived physical health in volunteers. *An. Psicol.*, 29(1): 225–232.
38. Vernon D.J., Egner T., Cooper N., Compton T., Neilands C., Sheri A. (2003) The effect of training distinct neurofeedback protocols on aspects of cognitive performance. *J. Psychophysiol.*, 47: 75–85.
39. Vernon D.J. (2005) Can neurofeedback training enhance performance? An evaluation of the evidence with implications for future research. *Appl. Psychophysiol. Biofeedback*, 30: 347–364.
40. Zijlstra A., Mancini M., Chiari L., Zijlstra W. (2010) Biofeedback for training balance and mobility tasks in older populations: a systematic review. *J. Neuroeng. Rehabil.*, 7: 58–73.

Received 21.04.2015
Accepted 10.06.2015

Acknowledgments
The study was financed from budgetary means for scientific research in 2011–2014 as a research project No. NRSA1 000751.