CASE STUDY

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THE DYNAMICS OF COGNITIVE FUNCTIONING IN THE PROCESS OF PREPARING A CONTESTANT FOR A TRIATHLON. A CASE STUDY WITH THE USE OF THE AUTHOR'S NEUROPSYCHOLOGICAL SUPPORT PROGRAM

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SUMMARY

Background: The aim of the research project was to prepare a person who does not do much sport and has never taken part in a triathlon, to become a contestant in Ironman, i.e., swim for 3.86 km (2.4 miles), ride a bike for 180.2 km (112 miles) and run for 42.195 km (26.2 miles – the marathon distance). The preparatory period was from January 2015 to June 2016. The author's neuropsychological training program was applied. It consists of exercises increasing attention span, enhancing episodic and spatial memory.

Material/ Methods: The authors of the project assumed that three Ironman disciplines, i.e., swimming, cycling and running, should be enriched with two additional modules which would ensure the optimum training of the contestant: psychological training and diet. All this should be supported by biological regeneration and relaxation. For the first three months the future contestant was exercising his attention and taking part in relaxation sessions once a week. For the subsequent six months the frequency of the former increased to two times a week, and the latter – three times a week.

Results: It was found that the neuropsychological training program was effective; already after half a year from the implementation of the training plans, the contestant improved the scope of memorized material significantly, enhanced the level of attention focus and achieved a higher level of visualisation when imagining himself in a relaxing place; meanwhile, a lower level of attention focus was observed when he was visualising swimming, which may indicate that this activity was automated.

Conclusions: Multidimensional preparation for a sporting competition, including neuropsychological training, was effective for an increased level of attention focus and visual-spatial memory improved visualisation skills, the ability to relax quickly and effectively, and the ability to enter the flow state were effective for our sportsman.

Key words: visualisation skills, attention, visual-spatial memory, Biofeedback

BACKGROUND

Doing sports has a favourable influence on all body systems, including: the motor, circulatory, respiratory, hormonal, immunological and nervous system. Due to this, it stimulates the maturation of motor centres in the brain, which in turn affects the development of motor skills and increases the transmission pace of nervous stimuli (Ponczek, Olszowy, 2012). The amount of neurohormones (which are substances produced by the hypothalamus neurons and transported by blood or cerebrospinal fluid) is also increased, and they have a significant impact on the excitability of neurons forming a synapse (Hollmann, Strüder, 2000).

Scientists have also emphasized that aerobic exercises affect executive functions, which control the processes responsible for forming simple terms, turning movements into complex activities and making actions purposeful. In addition, they are related to creative thinking, insight, the processes of analysing human needs, desires and the means of fulfilling them (Pąchalska, 2007; Bidzan, 2014). They enable one to set a goal and perform an action plan (including modifying it), which allows us to achieve our aims (Pąchalska, 2007; Brzezińska, Nowotnik, 2012; Bidzan, 2014; Lipowski, Zaleski, 2015).

On the basis of the studies on the impact of sports on the cognitive functioning of individuals in the period of mid- and late adulthood and during the elderly period, it can be concluded that physical activity decreases the risk related to a deteriorating cognitive functions and the development of the neurodegenerative disease which is dementia (Gajos et al., 2014; Wienert, Kuhlmann, Lippke, 2015). Doing sports systematically throughout life seems also important, as it is beneficial for executive functioning and decreases the amount of brain tissue lost in the areas responsible for visual-spatial functioning, motor control and working memory (Tseng et al., 2013), which is also important for making tactical decisions (Furley, Memmert, 2012). Models explaining the impact of sports on executive functions have been described in the subject literature. One of them is the model developed by T. McMorris, P. Tomporowski (2009). It demonstrates the significant impact of aerobic and endurance exercises which stimulate the nervous tissue and hence increase the amount of the BDNF protein secreted by neurons. This increase improves motor skills. It is worth bearing in mind that during this process new cells and capillaries are formed, which affects executive functioning in a positive way.

Attention has to be mentioned here, as it is the system responsible for selecting information and preventing the negative consequences of the cognitive system's overload by an excessive amount of data (Nęcka, Orzechowski & Szymura, 2008; Pąchalska, Kaczmarek & Kropotov 2014). The aim of attention is to select the most significant stimuli and analyse them further. Thanks to this process we can achieve the effectiveness of other cognitive functions. Selection can be automatic (when e.g., a new stimulus appears and we direct our attention towards it) or intentional (e.g., when searching through the visual field). In addition, attention plays an important role through selecting the stimuli important for further

actions and ignoring distractors (Pąchalska, Kaczmarek & Kropotov 2014; Borkowska et al., 2016; Mikicin, 2016).

COGNITIVE FUNCTIONS IN INDIVIDUALS DOING THE TRIATHLON (THE FLOW STATE)

There are few studies investigating the cognitive functioning of triathletes. However, according to Rostowski, concentration/attention focus leads to an increased activity of the frontoparietal areas (Pąchalska 1993; Rostowski, 2012), which is related to the flow concept of Mihály Csíkszentmihályi (1997). According to this concept, it is assumed that the flow state, related to the internal motivation, combines elements of satisfaction and euphoria and is evoked by a total commitment to one single activity. The performed activity is autotelic by its nature, hence it is a means to an end. An individual performing an activity does not aim at any external result, as the activity becomes the means to an end (Cornejo, 2013).

Attention increases the activity of the frontal and temporal regions (Rostowski, 2012). Shücker et al. (2014) investigated attention strategies in triathletes. It turned out that different types of attention are involved depending on the kind of activity performed. When cycling and swimming, triathletes use mostly external auditory attention (connected with listening to the sounds surrounding us), while running involves mainly the internal auditory attention (connected with listening to one's own thoughts).

In sportsmen, contrary to individuals not doing sports professionally, the achieving of better results in such areas, such as inhibition and problem solving skills (related to executive functions), correlates with the higher level of cognitive functioning. However, in the light of the research, it turns out that there is a correlation between executive functioning and the regulation of emotions (Denny, 2012). Numerous studies on factors contributing to the achievement of the flow state by a sportsman have been conducted. According to Stavrou et al. (2015), sportsmen achieving the flow state are characterised by a task-oriented attitude and appropriate abilities to perform a task. Low ego strength and a low level of the task-oriented attitude do not help athletes in achieving this state (Stavrou et al., 2015). In addition, other factors significant for experiencing the flow state are: a high level of optimism and toughness, which translate directly into setting clear objectives, focusing on a task, experiencing its autotelic nature, a sense of control (Vealey, Perritt, 2015).

Macías et al. (2015) emphasize the significance of mindfulness training, which – just like the flow state - in the case of triathletes is characterized as focusing on the here and now. This method (in this case involving the 8-week mindfulness training) proved efficient for cyclists, who later reported a higher level of concentration and a lower level of experienced pessimism (Scott-Hamilton, Schutte, Brown, 2016).

ROLE OF MENTAL TRAINING IN ACHIEVING SPORTS AIMS

Studies on Olympic athletes have shown the significance of implementing the mindfulness training in the preparatory period before championships, in order to improve one's results.

It can be concluded from the studies conducted by Burton et al. (2013) that an Olympic athletes devoting more time to mental preparations, had much greater achievements. According to the Harwood model (2009), the basic principle of the mental training is building one's effectiveness in sports by means of: enhancing attention, control of emotions and increasing the contestant's motivation.

'The mental training is a set of methods and techniques, which – if applied systematically and for a long period of time – lead to an increase in the control of the behaviour, actions, emotions and physiological processes taking place in the contestant's organism. Not only do they develop the precision of moves, economical expenditure of energy, emotional control, but they also teach quick energy recovery.' (Nowicki, 1991, p. 153-154).

The most significant psychological training techniques include: relaxation techniques, which increase the level of attention focus, as well as the ability to master the ideo-motor training related to the given sports discipline, and learning the relevant emotional-volitional skills (Blecharz, 2006).

Visualization is the key element of the mental training. Allan Paivio, the creator of the visualisation model, emphasizes two roles of visualization: cognitive (related to thought processes) and motivational. The cognitive role is connected with developing strategies before the championships and visualizing the given sports skill. On the other hand, the motivational functions are related to setting objectives, an effective coping with demands, as well as managing the level of agitation (Karageorghis & Terry, 2014). Visualization means recalling situations experienced in the past, which were recorded in the long-term memory. What is important, five senses are involved in the visualization process (Karageorghis, Terry, 2014). When a movement is visualized, electromyographic activity in certain muscle parts is observed, which is due to the transmission of impulses from the brain to the muscular system, which resembles making an actual move. Imagining moves leads to the activation of the supplementary motor area (SMA), motor area of the superolateral premotor cortex (PM) and frontal-tectorial premotor cortex, and the posterior insula.

Slightly different brain areas are also activated when a movement is being prepared to be performed. In this case the following structures are activated: the supplementary motor area (SMA), premotor cortex (PM) and primary motor cortex (MI) (Rostowski, 2012). Statements connected with imagining oneself training or upcoming championships have an impact on the involvement of the right hemisphere, which affects creativity and the idea generation process (Karageorghis & Terry, 2014).

AIM OF THE RESEARCH

The aim of this research was to evaluate the dynamics of cognitive functioning in an amateur contestant preparing for a triathlon with the use of the author's neuropsychological support program.

It was assumed that the applied author's neuropsychological program is connected with a change (improvement) of cognitive functioning, especially in terms of attention focus and executive functioning, which would have an impact on sports achievements.

CASE STUDY

A man, aged 39 years, an engineer, professionally active, with family: wife, 3 children, body mass 116 kg, height 189 cm, not doing much sports, had never taken part in a triathlon. Medical history revealed no chronic illnesses and no head traumas, which is important, (according to Pachalska, Kaczmarek and Kropotov, 2014) for the research procedures and therefore for final results.

RESEARCH PROCEDURES AND METHODS

The study was conducted twice at a half-year interval. Each study was preceded by a psychological interview and talk. The following methods were used to conduct the neuropsychological examination:

The Trail Making Test (TMT) Parts A & B – to assess the correct functioning of the frontal lobes. In Part A of the test psychomotor speed is assessed, along with the level of attention focus and visual-spatial functions. In Part B the ability to select two criteria is assessed, alongside the executive functioning, visual-spatial functions and working memory (Reitan, 1985).

The Wisconsin Card Sorting Test – to assess executive functioning (supervisory functions, control functions, managing a man's cognitive activity). The test was conducted using the 128-card set. Four parameters were taken into account in order to assess executive functioning: the number of achieved categories, total number of errors, the number of perseverative errors and non-perseverative errors (Jaworowska, 2002).

The Diagnosis of Brain Injury Test (DUM) – to assess the episodic memory of visual material. Firstly, the respondent sees a series of 9 images presenting figures, which he has to put together from wooden sticks after the demonstration (Weidlich, Lamberti, 1996).

The Rey Auditory Verbal Learning Test (AVLT) – to assess the episodic memory of verbal material (the pace of acquiring new information, consolidation (moving from the short-term to long-term memory), spontaneous and assisted retrieval) (Rey, 1964; Schmidt, 1996; Spreen, Strauss, 1998).

Biofeedback – used to measure the frequencies and amplitudes of different brain waves, which is possible due to small electrodes attached to the skin. The electrode registers the symptoms of neuron electric activity (Thompson, Thomp-

son, 2003), which can be read on a computer. This method was used to compare, during which visualisation attempt were the levels of relaxation and attention focus higher (in the first case the respondent was imagining making a selected movement, and in the second case he was imagining being transferred to a happy place). In biofeedback both slow waves (which include all waves whose frequencies are lower than 12 Hz) and fast waves (with frequencies higher than 12 Hz) are analysed.

The slow waves include:

– Delta (0.5-3 Hz) – which most probably originate in the cerebral cortex and occurs during sleep.
– Theta (3-7 Hz, 4-7 Hz or 4-8 Hz) – which originate mainly in the thalamus and limbic system; waves with a frequency of 7Hz are observed during visualizations).
– Low wave Alpha (8-10 Hz) – can occur in the state of relaxation, meditation, when we are deeply involved in what is happening in our minds.

On the contrary, the fast waves include:

– High Alpha (11-12 Hz or 11-13 Hz) – frequency 11-12 Hz is connected with the state of being highly conscious of the surrounding environment; in sports it is related to quick reflexes and accurate reactions, as well as calmness in the state of readiness before performing an action.
– Beta (above 12 Hz) – are connected with the state of wakefulness, alertness, external orientation, logical thinking, problem solving and attention focus. Meanwhile, a high Beta is observed in distressing situations.
– SMR (13-15 Hz) – the sensorimotor rhythm, connected with the state of peace, external attention (Thompson, Thompson, 2003; Mikicin, M., Kowalczyk, 2015).

RESULTS

Ilona Bidzan-Bluma's neuropsychological training program was implemented, which included exercises increasing the level of attention focus, episodic memory and spatial material. For the first three months, the contestant was doing attention-stimulating exercises and relaxation exercises once a week. For the following six months the above numbers increased respectively to two and three trainings a week. The example of the wellness plan in the micro-cycle (one week), including neuropsychological support, is presented in Annex 1.

Table 1. Results achieved by the contestant in different tests

Tests	Measurement 1°	Measurement 2°
Trail Making Test (TMT) Parts A & B	Part A: 17 seconds Part B: 45 seconds	Part A: 13 seconds Part B: 31 seconds
Wisconsin Card Sorting Test	Number of achieved categories: 6	-
Diagnosis of Brain Injury Test (DUM)	Pace of learning (test version 1°) Attempt 1: 7 Attempt 2: 9	Pace of learning (test version 2°) Attempt 1: 9
Rey Auditory Verbal Learning Test (AVLT)	Pace of learning: Attempt 1: 13 Attempt 2: 15	Pace of learning: Attempt 1: 13 Attempt 2: 15

After half a year from the implementation of the training plans, the contestant increased the scope of memorized material and improved his level of attention focus (the Trail Making Test Parts A & B); in March 2015 the contestant solved part A in 17 seconds, and part B in 45 seconds. In September 2015 he solved part A in 13 seconds and part B in 31 seconds. Apart from that, according to the DUM test, the pace of learning equalled 7-9. However, after 6 months the contestant was able to memorize all the elements at the first attempt.

BIOFEEDBACK

In order to compare the frequencies and amplitudes of different brain waves, two visualisation sessions were conducted (relaxation and specific cognitive visualisation), each 10 minutes long.

A significant difference was observed in the case of the following waves: Theta, Alpha, Beta 1, Beta 2 and the coefficient Theta/Beta. The comparison of the achieved results reveals that the respondent achieved a higher level of attention focus, as well as a higher level of visualisation when imagining himself in a relaxing place. However, the lower level of attention was revealed when he

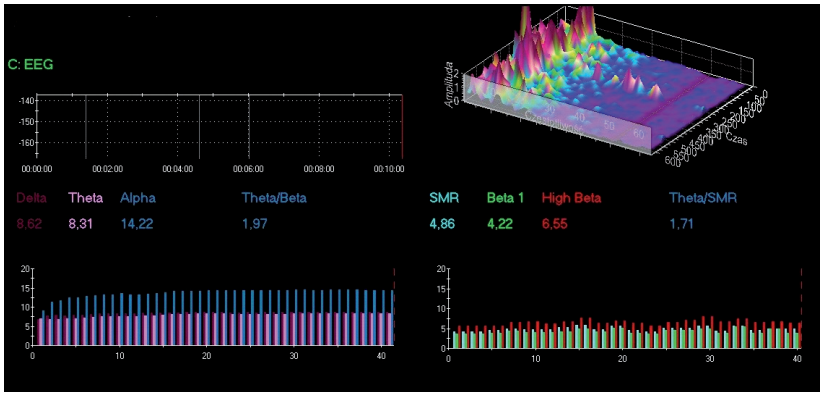

Fig. 1. Relaxation – visualisation – Diagnosis screen

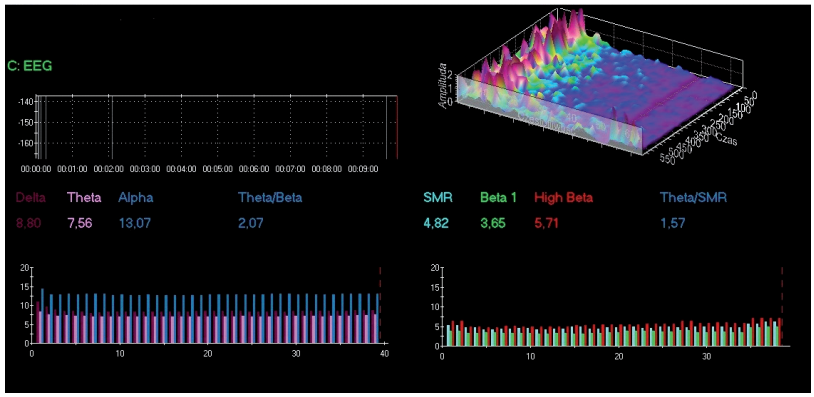

Fig. 2. Specific cognitive visualisation 'swimming' – Diagnosis screen

was visualising swimming, which could indicate the automation of this activity. The test was repeated 2 weeks later. The results differed only in the case of the Alpha wave, which was lower in the case of the automated activity visualisation (Alpha = 12.16), while in the case of the happy place visualisation it equalled 14.30. The results confirm the thesis about swimming being automated.

DISCUSSION

There are no studies investigating cognitive functioning in the process of preparing a contestant to a triathlon with the support of the author's neuropsychological program. However, the results of other studies, where the scientists examined the effect of neurofeedback-EEG training which consisted of a reduction in the amplitude of the beta2 band (20-30 Hz) during exercise, on the results of behavioural tests that evaluated attention, reaction time and the shape of the work curve, confirmed the effectiveness of this procedure (Graczyk, Pąchalska, Ziólkowski et al. 2014; Pąchalska, Kaczmarek & Kropotov 2014).

The effectiveness of implementing neuropsychological support in a group of 20 subjects performing exercise on a swimming ergometer (10 people) and an elliptical ergometer (10 people) was confirmed by Mikicin & Kowalczyk (2015). The authors emphasize that the neurofeedback-EEG training in motion might be an effective method of improving work performance, connected with the involvement of attention while doing exercise. Petersen et al. obtained similar results (2001). In addition the research conducted by Mikicin (2016) on a group of 73 student athletes involved in swimming, fencing, track and field, taekwondo and judo, revealed that a twenty-week neurofeedback-EEG training course aimed at the reinforcement of the amplitude of the SMR and beta 1 bands while reducing the amplitude of the theta and beta 2 bands in athletes, causes changes in brain activity at rest and, consequently, in the states of mind. The amplitude of the alpha band changed after relaxation training sessions. Former experience in working with athletes has shown that the biofeedback training should be enriched with other elements, including the training of visualisation and attention focus during sports effort implemented by us, ideo-motor training – in the case of an extreme weakening of the relaxation exercises, including musical activities (see also: Pąchalska, Kaczmarek & Kropotov 2014). Therefore, multidimensional preparation for a sporting competition, including neuropsychological training, is very important.

CONCLUSIONS

The exercises applied during the project contributed to an increased level of attention focus and visual-spatial memory improved visualisation skills, the ability to relax quickly and effectively, and the ability to enter the flow state were effective for our sportsman. It was not necessary to motivate him in the contestant in any additional way, due to high level of internal motivation and task-oriented attitude.

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Annex 1. Example of the wellness plan in a micro-cycle (one week)

Micro-cycle 18 (02.05 - 08.05.2016)				
Day	**Focus**	**Visualisation**	**Relaxation**	**Other**
Mon	10-15 minutes of attention focus exercises	10 minutes of visualisation	30 minutes of relaxing music	
Tue			5-10 minutes of relaxing music	
Wed	10-15 minutes of attention focus exercises			Swimming pool (water jets on legs + whole body + 2x10 min of sauna)
Thur		15 minutes of visualisation	15-20 minutes of relaxing music	
Fri				Leg massage + Swimming pool (water jets on legs)
Sat		2x10-15 minutes of visualisation	30-40 minutes of relaxing music	Swimming pool (water jets on legs + whole body + 2x10 min of sauna)
Sun	Visualisation and focus training during sports effort. Visualisation training- in cases of extreme 'wall' weakening.			

Annex 2. Ad. 2 – Texts of sample visualisations developed for the project

Visualisation of the training (aim: to increase the level of motivation) Ilona Bidzan-Bluma

Lie down and make yourself comfortable.
Close your eyes and focus on your breathing. Breath in and breath out slowly. And once more – breath in and out.
You are now breathing slowly and peacefully.
You are starting slowly to move to the training session.
Imagine yourself driving to the pool, getting out of the car and walking to the changing room. Once you are there, you will come up with a positive feature or behaviour starting with a letter.
Think of the letter 'A', what positive trait of yours do you associate it with, which trait beginning with this letter will help you to achieve your goals?
Now think of the letter 'B'. What behaviour, trait beginning with this letter will help you to finish each triathlon?
Now think of the letter 'C' and a trait beginning with exactly this letter.
Keep in mind all the words you came up with. You will be recalling them during the course of your training periods.
Your are now walking towards the pool. You are immersing yourself in the water, putting on your goggles, breathing in and out, and starting to swim.
You are full of energy, focused fully on what you are doing right now. You know that you are getting better and better, and the neatly developed training plans and your attitude make you achieve your aims.
During the training period you are recalling the words beginning with 'A,' 'B' and 'C' which you came up with. You are fully in control, your technique is better and better. You are calm. You are focusing on the here and now.
The training session is nearly over. Despite the intense effort, you are feeling at ease and relaxed. You are now getting out of the pool and walking to the changing room.
I will now count from 1 to 5... Open your eyes and tell yourself: I can achieve and I want to achieve what is the best for me and it depends on me only.

Specific cognitive visualisation (aim: improving swimming technique and swimming faster) Ilona Bidzan-Bluma

I am in the water, next to the starting block, I am setting off.
The first 600 meters is a warm-up, free style.
I am focusing on the technique of movement.
I am looking down,
grabbing the water and stretching my arm onwards as far as possible.
My fingers are directed towards the bottom of the pool,
I am bending my elbow, pulling my hand towards my chest.
I am working hard with my legs,
I balance my body and stretch my elbow.
My hand emerges from the water near my thigh,
I am now catching my breath.
The elbow is the highest point of my hand above the water.
My hand and forearm move forward loosely, entering the water.
At the same time the other hand grabs the water.
My fingers are directed towards the bottom of the pool,
I am bending my elbow, pulling my hand towards my chest.
I am working hard with my legs,
I balance my body and stretch my elbow.
My hand emerges from the water near my thigh,
I am now catching my breath.
The elbow is the highest point of my hand above the water.
My hand and forearm move forward loosely, entering the water.