Defining functional requirements for computer-based tests for assessing the psychological response of athletes to acute stress and early detection of overtraining

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***Abstract*—Coping with acute stress in sports and overtraining syndrome are extremely important concepts related to sports success. The aim of this paper is to consider the possibility of development and validation of tests within an online platform OpenClick that would assess these phenomena of athletes. Such tests would be reliable, fast, simple, undemanding, but above all, they would provide quality and usable information to coaches and athletes.**

I. Motivation

Stress, its sources, consequences and coping with stress are some of the central topics within psychology, and especially sports psychology. The inability to adequately regulate stress in sports is strongly associated with increased anxiety and the burnout syndrome, increased aggression and aggressive behavior, decreased self-esteem, lack of enjoyment in sports and problems with motor tasks, which lead to "chocking" under pressure and performance that is well below the athlete's ability [1]. Three theories have tried to explain the relationship between the intensity of arousal and stress in sports with success in performing motor skills tasks. The "drive" theory is first, and according to it, increased excitement increases performance [2]. The second theory is the inverted letter U [3], according to which the performance is the best at the optimal level of arousal, while by reducing or increasing arousal the performance becomes worse. The third is the catastrophe theory [4][5] which claims that as arousal increases, performance is increased up to a certain point (as in the inverse U theory), but as the arousal exceeds the optimal level, there is no gradual decrease in performance, instead it descends abruptly. Whichever of these theories is taken into consideration, the fact is that every athlete has its own comfort zone, and therefore the optimal intensity of stress at which athlete performs best. The dominant theoretical framework for considering the functioning of stress processes is still given by transactional theory [6], according to which the most important for causing a stress reaction is not the source of stress, but its characteristic subjective evaluation, as well as athlete's subjective evaluation of their own capacities to cope with particular stress situation [7]. So, different people react differently to the same stressor. One of the main sources of acute stress in a sports context is the observation that the opponent is performing well [8], in other words that the athlete is losing.

Regarding stress, one of the most pronounced problems that athletes experience is overtraining. It is a condition of the human organism in which there is a decrease in working ability and the manifestation of many symptoms of an organic and functional nature. The consequence is, among other things, the psychological tension (stress) of the athlete. The prevalence of overtraining ranges from 7 % [9] to as high as 64 % [10] depending on the sport type, gender, and level of competition. The causes and serious consequences of overtraining are well known, and the biggest challenge is early diagnosis. The authors in [11] believe that testing psychomotor speed and completing complex tasks given on a computer, keeping track of speed and number of mistakes, can contribute to the first signs of overtraining, because weakening of attention and some other cognitive factors are one of the first symptoms of overtraining.

From everything mentioned, it can be concluded that knowledge of stress reactions (determining stressors and the way they cope with them), as well as early diagnosis of overtraining in athletes are crucial for optimizing sports performance.

II. Research Question

The main objectives of this paper are to consider the potential of using computer tests on the online platform OpenClick [12] to determine coping styles in athletes and early detection of overtraining. OpenClick is an online platform that intends to assess physical status, skills and abilities of people based on human - computer interaction tests. There are nine simple tests in total, and each of them is performed using only mouse and/or keyboard.

The tests used to assess intensity and response to stress were mainly paper-pencil and self-reported, and it has long been established that objective indicator of stress do not correspond to test measures that are self-evaluative [13], and that better results can be achieved by computer-based tests [14]. What is characteristic of previous methods of assessing this phenomenon by computer (e.g., DT from Vienna Test System [15]) is that the source of stress arises from the need to maintain continuous, fast and adjustable responses to rapidly changing stimuli, while in our analysis it is based on the perception of the athlete to lose, win or be equal to the opponent. Also, our goal is to make tests as an online application, available in accordance with the principles of open science, and that access and testing do not require any software installations or additional, specific hardware equipment.

III. Methodology

In a situation where personal (and widely different) computers with specific hardware and software characteristics are used for testing, the test results can largely depend on these technical characteristics (processor speed, mouse and keyboard type, connection stability etc.). Having this on our minds, we decided that all the parameters we get from testing should be relative, not absolute. Therefore, it is not important for athlete being tested to perform particularly well, instead the change of athlete's performance within the same or successive attempt is being monitored and evaluated.

In describing the motivation for this work, we pointed out that one of the main sources of acute stress in the sports context is the observation that the opponent is performing well [8], or in other words, that the athlete is losing. Also, we noted that it is necessary to determine behavior of an athlete in situations when he is falling behind and when he is in the lead. The OpenClick test that would evaluate this is a "Mouse click" test in which a person simply needs to click left mouse button as fast as possible for a certain period of time, but in specific circumstances. At the beginning, the athlete receives instructions in which he is explained that his task should be to click the mouse as fast as possible to beat the computer, that the test result is important for assessing his sports abilities and that his result will be compared with other athletes. The goal of the instructions conceived in this way is to put the athlete in a state of stress as much as possible. Before moving on to the "competition" part, the athlete needs to do a ten-second click test to get acquainted with the test, check the mouse, connection and similar.

Determining the reaction to acute stress due to losing a competition could be implemented by adapting "Mouse click" test to a simple race game. The race would involve the use of two figures (racers) on the screen - the first clearly marked as a "computer" with which athlete competes by clicking, and the second marked as an "athlete". Both figures would initially be on the start line, and the figures would race to a finish line. The movement speed of athlete's figure is determined by the speed of mouse clicking. The movement speed of the computer's figure wouldn't be independent. Instead, it would be determined based on movement speed of athlete's figure and current stage of test. The complete section of the race would be divided into three stages (of the same distance) plus one additional shorter stage at the end of the race, and the athlete performing test would not be aware of this. The first stage is the "Win" stage, in which the computer's figure would remain behind athlete's figure, even if the athlete is clicking slower. The second stage would be the "Tie" stage, during which the computer's figure performs about same as the athlete's figure. The third stage is the "Lose" stage, with computer's figure taking over the lead and remain first in the race, no matter how fast the athlete is clicking left mouse button. The final shorter additional stage is the "Tie" stage, which is there simply to allow an athlete to sometimes win the race and sometimes lose, instead of always losing if "Lose" stage was the last one. When performing the test, the athlete should have a visual insight into what his current score is. It is enough to show two figures (athlete's and computer's) that move from left to right, from start to finish. There is no need to display any numbers, because they are difficult to track and process during the test. The click-behavior of the athlete during the stage in which the athlete is losing would be used for the analysis. Parameters relevant for stress response assessment would be the clicking speeds and tangent of angles of clicking speed regression lines during different stages ("Win", "Tie", "Lose"), in terms of their change across race stages. Based on these data, the athlete's response behavior would be classified as either being negatively, positively or not significantly affected by acute stress. Also, question is how long do each of the stages last - they must be long enough for the athlete to register stress and react to it, and yet short enough not to cause excessive fatigue of nerves and muscles involved in the clicking process, which could reflect on the athlete's performance, obtained results and their interpretation.

For early detection of overtraining in athletes, "Alternate mouse button selection" test is proposed. The task of the athlete is to press the mouse button (left, middle, right, double click) that is displayed on the screen. After selecting the correct mouse button, the next button that needs to be pressed is displayed. Measured values include time needed to press correct button, as well as number of made mistakes. This test evaluates concentration, decision-making process and psychomotor speed of reaction. The decline in these processes often indicates the beginning of overtraining in athletes.

IV. Solution

To be considered adequate, each test must meet four basic characteristics: objectivity (that the score does not depend on the evaluator), discrimination (to determine differences between respondents), reliability (that the results are stable and consistent over time) and validity (whether the test assesses / determines / measures what the authors have theoretically assumed). Computer-based testing generally has no problem with objectivity (performance is evaluated by the computer) and discrimination (outputs can be in seconds, milliseconds, or number of clicks). Also, determining reliability would not be a problem because it is quite easy to determine it by the test-retest method. The biggest challenge is to determine the validity of the proposed tests.

The validation of the test which aims to assess the reaction to acute stress in sports could be done in two ways. The first way would be to have a validation sample of athletes do the proposed test, as well as an existing computer-based test (e.g., DT from Vienna Test System [15]) and/or a paper-pen previously validated guide to assess the response to acute stress. Another and better way is for coaches who work with athletes from the validation sample for more than two years to make an assessment of how every athlete behaves in situations when he loses.

Suggestions for validating a test designed for early detection of overtraining are a little different. Here it is expected that the respondent solves the test on a daily basis and that his success is monitored. In parallel with completing this test, athletes from the validation sample would complete some of the questionnaires already used to detect overtraining such as the Profile of Mood States - POMS [10] or the Recovery-Stress Questionnaire for Athletes – RESTQ, [16]. One way to determine whether the test is valid for its purpose could be to give the test to athletes before and immediately after extremely hard training in the phase of functional overreaching. The two test attempts would be expected to provide statistically significantly different results.

The phenomena that would be assessed through these two proposed tests are extremely important for the athlete's competitive success. For this purpose, our first step would be to develop a concept application of adjusted "Mouse click" test which focuses solely on core requirements for test. This version could be used to determine reliability and validity of test, as well as to gather any additional feedback needed for making adjustments to final version, which would be available for use as an online test within OpenClick platform. In case of functional overtraining, "Alternate mouse button selection" test is already implemented in satisfying manner on OpenClick. We are convinced that through giving adequate test requirements and implementing proper validation methods we could come up with instruments that are simple, undemanding in terms of time and money, and on the other hand reliable and informative in terms of providing athletes and coaches with insight into current psychological preparedness, allowing good foundation for purposeful and timely interventions.

V. TESTS IMPLEMENTATION

As stated in previous sections, the test for assessment of athlete's response to acute stress is adaptation of "Mouse Click" test from OpenClick platform. In order to prove our idea, proof of concept version of test is implemented in Python programming language. This version has all the functionality determined in the methodology section of this paper, but is stripped of secondary functions the online version would need (e.g., running on server, database logging etc.). Fig. 1. represents the screenshot of "Try mouse click test" option. It is an option in which the user just clicks left mouse button as fast as possible for 10 seconds. The remaining time is displayed in the top left corner, and the average clicking speed is shown in the top right corner, after test time has passed. The user is allowed to click anywhere on the application screen, except on the "STOP" button which terminates the test. Fig. 2. shows the screenshot of an actual "Race against computer" option. In the lower part of the screen, there is a simplified race track consisting of vertical lines moving from right to left as the user's figure passes them by. Two figures (user's and computer's racer) distinguished by color are placed on the track and are moving from left to right. The top left corner shows the current race time, in the middle top is user's current race position, and in the top right corner remains the overall average clicking speed.

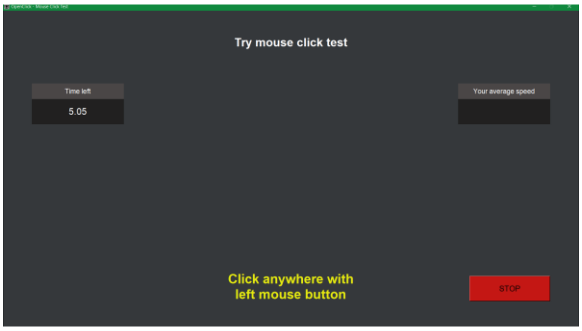

Figure 1. Concept application for assessment of acute stress, "Try mouse click test" option

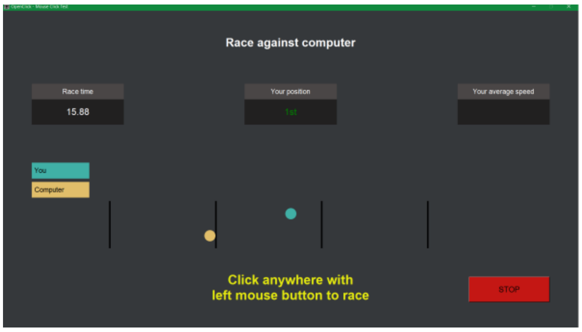

Figure 2. Concept application for assessment of acute stress, "Race against computer" option

The movement of user's figure is implemented using slightly modified standard kinematic equations for position (s_U), speed (v_U) and acceleration (a_U). Clicking speed represents acceleration of user's figure. The actual clicking is logged as a pair of values (T_U, M_U), where T_U is time occurrence of click within the race (in seconds), and M_U is clicking speed measurement (in clicks per second) calculated as one divided by difference of T_U values between two consecutive measurements. To account for clicking speed being a discrete measurement, time degrade of acceleration is introduced in order for actual acceleration to be calculable. Time degrade of acceleration (T_D) is calculated in the following manner:

$$T_D = T_{aDC} - \frac{T_T - T_U}{T_{aDC}} \qquad (1)$$

where T_{aDC} is time degrade constant of acceleration, T_T is current test time and T_U is the time of the last occurred user's mouse click. Acceleration of user's racers is now calculated as:

$$a_U = M_U \cdot \max(0, T_D) - b \cdot f(v_U) \qquad (2)$$

Where M_U is the last logged mouse click measurement, $f(v_U)$ is a variable friction component dependent on speed and b is a dumping coefficient of friction. It can be noted that when $T_T - T_U$ gets significantly greater than T_{aDC}, T_D is getting abruptly smaller, indicating that the clicking has stopped or became slower and that the user's figure continues to move in decelerating manner due to inertia. Maximum function in (2) ensures that acceleration due to user's clicking cannot be negative. Speed can be calculated as:

$$v_U = \max\left(0,\ v_{U_0} + a_U \cdot FPS\right) \qquad (3)$$

where *FPS* is frames per second, or the number of times race track updates in one second, while v_{Uo} is the speed in previous frame. Maximum function in (3) is implemented to account for possible negative speed occurring when the clicking stops and only friction component is present in (2). Finally, the position of user's racer (s_U) is given as:

$$s_U = s_{U_o} + V_U \cdot v_U \cdot FPS \qquad (4)$$

where s_{Uo} is the position in previous frame and V_U is a speed constant used to tune the pace of the race, making it faster or slower.

As explained in the methodology section, computer's racer speed is determined based on the race stage and user's racer speed. Also, relative distance (s_{rel}) from computer's to user's racer is taken into account. In addition, s_W, s_T and s_L, are threshold relative distances for "Win", "Tie" and "Lose" stages respectively. If $s_{rel} > s_W$ during "Win" stage or $s_{rel} > s_T$ during "Tie" stage, computer's racer is slowed down. If $s_{rel} < s_L$ during "Lose" stage or $s_{rel} < s_T$ during "Tie" stage, computer's racer is sped up. In all other cases, computer's racer speed is close to user's racer speed with small random oscillations permitted.

After the race is completed, measurements can be saved for offline analysis.

For early detection of overtraining, "Alternate mouse button selection" test from OpenClick platform [12] is chosen. This test could be used as it is already implemented. Fig 3. shows screen of an actual test. The user is given instructions on which mouse button to press. After the correct button is pressed, the next button is shown.

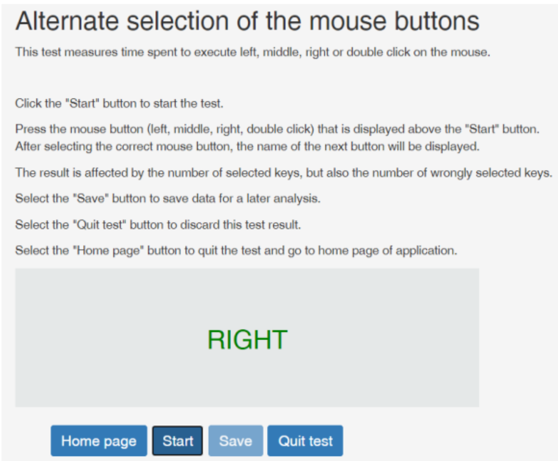

Figure 3. "Alternate mouse button selection" test from OpenClick platform [12]

VI. Future Work

The next step in our research is already stated in the solution section of this paper. Out of four basic characteristics, objectivity, discrimination, reliability and validity, the first two are already satisfied, while the need for latter two to be inspected. As mentioned, reliability could be easily tested with test-retest method. The challenge of validity testing for assessment of response to acute stress is also going to be to identify parameters that would give desirable results. Changes in clicking speed and regression lines are the obvious ones that could be tried, but if they are not enough, other ones must be found. One way this could be addressed is to have first a smaller group of athletes (e.g., 20-30 athletes) perform test in order to find parameters that give good correlation values with self-assessment test. After such parameters are identified, the testing could be scaled up to a larger number of athletes of different sport occupation, age and gender. Initial testing could also help to identify optimal length of test stages. If our concept application proves that the test is valid, the next step would be to implement it online within OpenClick platform.

For test used in early detection of overtraining, the situation is a bit clearer. Measured reaction time and number of mistakes should directly address athlete's ability to perform after overtraining. Validity testing could take some time as it might have an athlete perform the test for a prolonged period of time, but not too often, in order to avoid an athlete mastering the skills needed for this test.

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