THE ANALYSIS OF THE POSSIBILITIES OF USING A VIRTUAL REALITY SYSTEM IN FITNESS TRAINING

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Abstract

Virtual Reality (VR) is an amazing tool in the field of interaction, simulation, and entertainment between humans and computers. This technology is often used for recreational purposes in combination with physical activities. The main objective of this study was to compare intermittent training with continuous training on the shooting range. The first part of the article presents the essence of virtual reality and the possibilities that arise from its use. Then the created virtual environment, in which the shooter is located, and the way the study has been carried out are presented. The attempts of the participants were shown and evaluated. The realistic physics of movement and environment interactions have been designed into this map. The main aspects of the modelled and programmed shooting range were presented and their use has been described. The following section describes the research process and the analysis of the results of the test carried out on eight participants who had not previously been exposed to virtual reality. The test subjects were divided into two groups, one intermittent training and the other continuous training. The results of these groups were compared to assess which forms of training in a virtual reality environment were more beneficial.

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Introduction

A virtual reality environment is an interactive computer-generated space that simulates the user's sense of presence in a virtual world. Special devices, such as VR goggles along with controllers, that allow the user to experience immersive experiences that activate their senses, including sight, hearing, and touch. The main feature of VR is the creation of the illusion of presence in a virtual environment, which distinguishes it from traditional ways of presenting information (VINCE 2004). We can see this emerging technology in more and more areas of life, for example: education (BONIELLO et al. 2019), therapy and rehabilitation (HAYRE et al. 2020), architecture and design (VILAR et al. 2022), training and simulation (KALTENBORN, RIENHOFF 1993). The potential of virtual reality in the context of health-promoting physical activity has also been noted (KOEKOEK 2018), as well as applications in sports, where movement analysis, capacity, and even training can be addressed. Performed workouts in virtual reality are able to bring positive effects, for example, improving fitness, performance, mobility. This is possible thanks to appropriate applications or games created specifically for action and activity. Training with the help of virtual reality does bring greater results than classic training.

This modern technology can be a useful tool for diagnosing and analysing parameters during the operations of a particular physical activity. The possibilities provided by VR are much larger than those of standard computerised tests. This allows to create an environment reflected in the athlete's current training conditions, and tests can be performed in different positions and various measurements. One of the main advantages of VR is that you can control various parameters of the user's experience in the virtual world. In addition, the user is insulated from external stimuli that can interfere with the test process.

The type of training has a significant impact on the results. With virtual reality, it is possible to replicate a given task and conduct a study of which training is most beneficial. You can do continuous training, where no longer breaks are introduced between series, approaches, and workouts. There is also training as intermittent, where at some point there is a longer break that allows you to recuperate, mentally set up for the next approach. The use of proper training is particularly important in sports, as it significantly affects performance.

This study compares these types of training performed in a developed VR environment and based on measurements taken on people who have not been exposed to this environment and VR in general. An attempt was made to answer the question of whether intermittent training is more effective than continuous training using VR.

Materials and methods

To perform the test, a virtual environment was created containing a simple shooting range shown in Figure 1, with a gun, a start/reset button, a target, and a scoreboard. Real-time results are recorded on the board. Eight subjects were involved in the study and they had no experience with VR hardware and the environment created. The subjects also had not used similar immersive technology in the past. The study used an autonomous VR headset, the Oculus Quest 2 (Facebook Technologies, LLC. 1 Hacker Way, Menlo Park, CA 94025, USA), composed of two controllers and a head-mounted display (HMD).
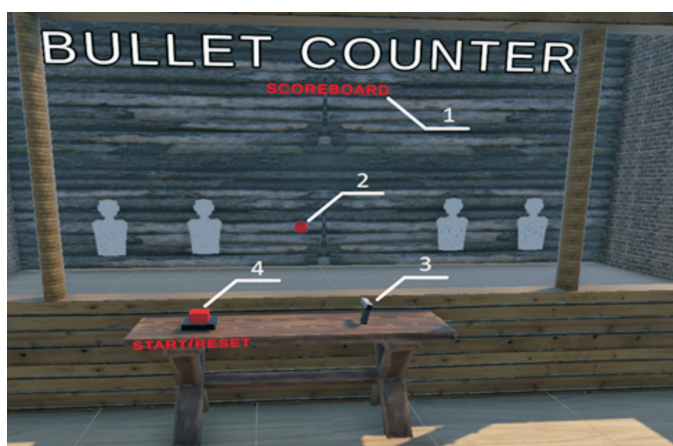

Fig. 1. Appearnce of the shooting range; *1* – place where results appear, *2* – target, *3* – gun, *4* – start/restart button

Each person was of a similar age, namely 25 ±1 year. Before the trial, each player was instructed and informed about the rules for the use of the hardware and the environment created. The test consisted of the player having to prepare to shoot, i.e., position himself approximately in the centre of the area and take his weapon. The next step was to press the start button and then hit eight targets that appear at different places. As soon as the button was pressed, a time count started and the player had to hit eight targets with the minimum amount of bullets fired. The less time and fewer shots the player needed to complete the game, the higher score he got. The target, when hit, would appear in another predefined location that the player did not know about. Therefore, the player had to show quick reflexes and high precision to hit the new target as quickly as possible. After the eighth target was knocked down, the results appeared on the wall (scoreboard) in front of the player. The number of bullets needed to shoot a given target and the total time required to complete the game were displayed.

To carry out the test, it was decided to involve 8 people who had not previously been exposed to the developed software. Their task was to complete the test on the shooting range. Each person was assigned to complete six approaches, the results of which were recorded. These individuals were divided into two groups. Four people in group one performed three approaches one day, then a week later another three. The other four people in group two performed six approaches one after the other, on the same day. Based on these data, it is possible to determine the learning process, the familiarisation with virtual reality, the effect of the one-week break on the player's muscle memory, the speed of progression, and much more.

Similar measurements were made using classic computer tests. Subjects were asked to press the appropriate keys on the keyboard after the white squares appeared on the computer screen (KLOCEK et al. 2002). The testing procedure is similar to that performed using VR.

After each player completed the game, the board displayed the number of shots fired at each target and the total time to complete all levels. Based on this data, scoreboards with the player's score. It was calculated using equation (1) to determine how many points the player scored in a given approach. It looks as follows:

$$x = \frac{10{,}000}{t \cdot n} \tag{1}$$

where:
    x – the score in a given approach [points],
    10,000 – a constant selected to obtain results between 0-200 points,
    t – final time of the approach [s].
    n – the sum of shots needed to hit eight targets.

Scores of more than 150 points were considered very high. Such scores could only be obtained by hitting all eight targets with the first shot and doing so in a statistically short period of time, that is, spending less than a second on each target. Scores of 120-149 were considered high. Those who scored this high usually made at least one mistake or performed the task too slowly. Scores at the 90-119 level were considered average, since an average of almost two bullets was needed to hit each target, and as a result the time to complete the task was long. Scores at the 50-89 level were considered low, usually one of the players' first attempts, and they were getting used to the functioning of the equipment and environment. Scores at level 0-49 were considered very low, these are usually the first approaches, the first contacts with the task.

Based on the results obtained, column charts were created to illustrate how users became accustomed to the environment and the task set before them. Through its shape, it is easy to distinguish between the results obtained through continuous and intermittent training and to evaluate their effectiveness.

Creation of a virtual shooting range

The Unity engine version 2021.3.16f1 was used to create the virtual reality environment, and the template chosen for the project was 3D (URP). Universal Render Pipeline provides an artist-friendly working environment that allows you to quickly and easily create optimised graphics on a variety of platforms, from mobile devices to high-end consoles and PCs. This template is great for virtual reality because of its built-in optimised graphics and many built-in resources. After that, to be able to handle all VR hardware and conduct interactions with the created elements, such elements and scripts were added, among others: **Locomotion System** (responsible for handling user movement, it provides user interaction with the virtual environment, allowing the user to move and move inside the virtual space), **Continuous Move Provider** (allows the user to move smoothly with the controller continuously over time, using a specified input from the 2D axis), **Continuous Turn Provider** (allows the user to smoothly turn their rig continuously over time using a specified input action), **Character Controller Driver** (reads the position and height at which the VR goggles are placed during gameplay), **Rigidbody** (used to simulate the physics of objects in the scene). In addition to the interaction functions, hand models have been added, given animation, collision volume, and included the **XR Poke Interactor** component, which is responsible for the poke interaction. This is an important component for interacting with various types of buttons, etc. The game manager is the most important part of any game; newly created scripts related to the functioning of the shooting range are referred to this place, where a reference to it was placed. This is where all the main functions of the environment are managed, that is, changing the position of the target, reset, and start of the game, the results are calculated and displayed. In short, it is a script that manages the logic of the game, and by referring to it in another script, you can change the states that occur in it. The gun is the main component of the shooting range, and its model was downloaded from free resources available on the Web. Standard components were added to the model, namely the Rigidbody, to keep its natural physics, as well as a collider in the shape of a cuboid to match its size. A script was also created to define the grasping position of each hand and the ability to grasp this model with the left and right hands.

Next, a bullet was created that will be generated when pressing the button on the controller responsible for firing the gun. It is simply a bullet that contains a spherical collider, as well as a Rigidbody with the gravity option disabled. An additional component is Audio Source, into which the sound of a gunshot from a 9mm calibre pistol has been imported. A Trail Renderer component was also added, with the help of which a dark orange track line for 0.5 seconds will be visible behind the bullet. Next, a script was created by which a bullet will be fired from the weapon. It mainly determines the point at which the bullet

should appear, as well as the direction and speed at which it should be fired. The direction of the bullet's launch is simply an extension of the barrel, and its speed is set to twenty units. The point of origin of the projectile was created at the very end of the barrel of the gun. An invisible element was also created where a collider was added, which was set as a trigger. It was created just behind the projectile origin, so that there is always a collision between them. This will be used to count the fired projectiles, so a new script was created for scoring. A target has been created that moves along eight created positions (points on the shooting area shifted on all three axes). The target is a maroon sphere given a 0.55-meter diameter spherical collider, a zero-mass Rigidbody component with gravity disabled and continuous dynamic collision detection. An Audio Source component has also been added with a bell strike sound that will herald a target hit. The most important component of the target is a script that is responsible for detecting the collision of the target with the projectile and moving it to the next position.

The last element of the shooting range is the button that starts and resets the game. Admittedly, it does not reset the entire environment, but individual parameters and settings of the shooting range. It is used to restore the game to its original state, i.e. it resets scores and gameplay progress. It resets the timer, clears the scoreboard, and returns the target to its initial position. The button is mainly made of two elements. The first is a visual element, and the second is a responsive element with which interaction will take place. The grid removed so that it is invisible. It is the one that sends information based on which the visual element will change its position. To it was added the XR Simple Interactable component, which is only used so that a specific function will be called when interacting with this object. Here, it is defined that when the button is pressed, it will turn green, and if it will turn not pressed, it is red. Another component added here is the **XR Poke Filter**, which is used to select the direction in which the button should be pressed, so the negative Y-axis was chosen. The last component here is the script created, which is responsible for visualising the button pressing and calling the corresponding method in the game manager. The index fingers of both hands were chosen as the trigger elements of the created button. Bringing the hand closer to the button, when the index finger of the hand model collides with the created button, it is pressed. When it is fully pressed and turns green, the attributes mentioned attributes are reset.

Test and analysis of results

Intermittent test

The first to participate in the test were those who will take six approaches with a one-week break in the middle. Their results are shown in Tables 1-6.

Based on the data obtained from the study participants, graphs of the results obtained by individual players were created (shown in Figure 2). With individual charts, it is easier to analyse the progress of a person, the results obtained before the break and after the break, the speed of familiarisation with the virtual world.

Table 1

Results of the first approach of group one (first week)

Person	Target 1	Target 2	Target 3	Target 4	Target 5	Target 6	Target 7	Target 8	Total bullets	Time [s]	Score [pt]
Player 1	3	2	4	1	2	2	5	1	20	10.61	47.13
Player 2	3	2	5	2	2	3	1	3	21	10.61	44.88
Player 3	4	3	5	4	1	2	5	3	27	14.9	24.86
Player 4	1	2	1	6	1	1	2	2	16	11.83	52.83

Table 2

Results of the second approach of group one (first week)

Person	Target 1	Target 2	Target 3	Target 4	Target 5	Target 6	Target 7	Target 8	Total bullets	Time [s]	Score [pt]
Player 1	3	3	2	2	2	3	4	2	21	9.34	50.98
Player 2	2	1	1	1	1	2	1	1	10	9.33	107.18
Player 3	4	1	3	1	2	1	2	1	15	9.59	69.52
Player 4	4	1	2	3	1	1	1	2	15	9.98	66.80

Table 3

Results of the third approach of group one (first week)

Person	Target 1	Target 2	Target 3	Target 4	Target 5	Target 6	Target 7	Target 8	Total bullets	Time [s]	Score [pt]
Player 1	1	1	1	1	1	2	1	1	9	8.3	133.87
Player 2	2	1	1	2	1	1	1	1	10	9.34	107.07
Player 3	2	1	2	1	2	1	1	2	12	8.19	101.75
Player 4	1	2	1	2	1	1	1	1	10	7.99	125.16

Table 4

Results of the fourth approach of group one (second week)

Person	Target 1	Target 2	Target 3	Target 4	Target 5	Target 6	Target 7	Target 8	Total bullets	Time [s]	Score [pt]
Player 1	2	2	1	3	1	1	3	1	14	9.86	72.44
Player 2	3	2	1	2	2	2	1	1	14	9.18	77.81
Player 3	5	1	3	3	2	1	3	3	21	12.2	39.03
Player 4	3	2	2	2	1	2	2	2	16	11.25	55.56

Table 5

Results of the fifth approach of group one (second week)

Person	Target 1	Target 2	Target 3	Target 4	Target 5	Target 6	Target 7	Target 8	Total bullets	Time [s]	Score [pt]
Player 1	1	1	1	2	1	1	2	2	11	8.44	107.71
Player 2	2	3	1	1	3	1	1	1	13	9.4	81.83
Player 3	3	2	2	2	3	1	1	2	16	9.24	67.64
Player 4	1	1	2	1	1	1	2	1	10	8.24	121.36

Table 6

Results of the sixth approach of group one (second week)

Person	Target 1	Target 2	Target 3	Target 4	Target 5	Target 6	Target 7	Target 8	Total bullets	Time [s]	Score [pt]
Player 1	1	2	1	1	1	1	1	2	10	7.02	142.45
Player 2	2	1	1	2	2	1	2	1	12	8.95	93.11
Player 3	2	1	1	2	1	2	1	1	11	8.85	102.72
Player 4	1	1	1	1	1	1	1	1	8	7.49	166.89

In the resulting graphs, it can be seen that each of the survey participants in the first sample performed the worst. This was the first contact of these people with the virtual world, so it was a predictable result. Participants became familiar with how the environment worked and were able to correct their mistakes in subsequent trials. In the next attempt, each person improved his or her score, everyone completed the second attempt in less time, and all but one person used fewer bullets. The third attempt for all but one person was the best of the week. Player two was the only one with a worse score than before, but it was a very comparable approach, differing by only 0.01 seconds, with the same number of shots fired. It can be concluded that it was an even approach. After even seven days, the same people took three more approaches. During this break,
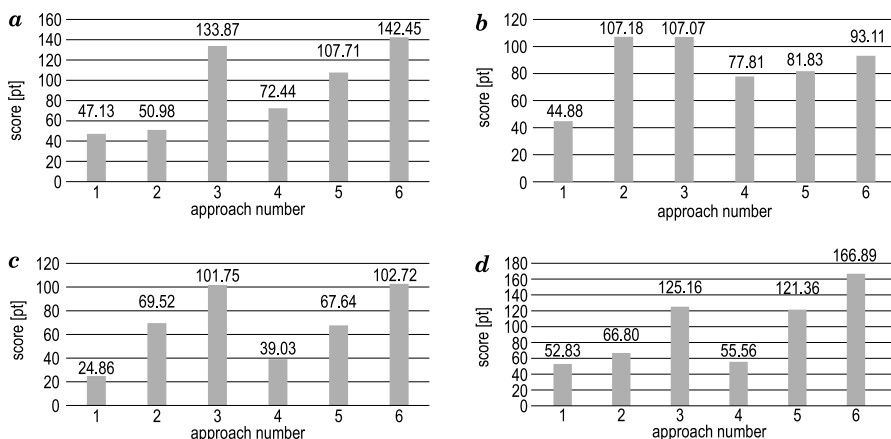
Fig. 2. The results obtained in each approach by the first group players: *a* – player 1 score, *b* – player 2 score, *c* – player 3 score, *d* – player 4 score

they were able to take new tactics, rest, analyse previous attempts. The first attempt in the new week for each player was slightly better than the first attempt last week. This may be due to the fact that users were already familiar with the physics of the game, but the result was not satisfactory. It can be noted that in each user's new week, the second approach was better than the first, and the third approach was the best one. Each person, in the last approach, got the best score ever, except Player two, who reached his limit in the first week. However, everyone shows progress from approach to approach. In Player three, you can clearly see increasingly higher scores in the first three attempts, after a week's break a significant drop to further improve their score, and in the last attempt set a personal best.

Continuous test

Another four people (group two) had the same task to perform, with one difference, namely, they performed six approaches on one day and had no break. Their results are shown in Tables 7-12.

Table 7

Results of the first approach of group two

Person	Target 1	Target 2	Target 3	Target 4	Target 5	Target 6	Target 7	Target 8	Total bullets	Time [s]	Score [pt]
Player 5	5	4	2	3	3	1	2	3	23	19.06	22.81
Player 6	3	2	3	3	1	1	3	1	17	18.99	30.98
Player 7	3	2	1	3	1	1	1	2	14	9.94	71.86
Player 8	2	2	1	4	3	1	4	1	18	21.04	26.40

Results of the second approach of group two

Person	Target 1	Target 2	Target 3	Target 4	Target 5	Target 6	Target 7	Target 8	Total bullets	Time [s]	Score [pt]
Player 5	3	3	2	2	1	2	1	2	16	11	56.82
Player 6	5	4	1	2	1	2	4	1	20	19.77	25.29
Player 7	1	1	2	2	1	2	1	2	12	9.45	88.18
Player 8	3	1	1	3	1	2	2	1	14	16.21	44.06

Results of the third approach of group two

Person	Target 1	Target 2	Target 3	Target 4	Target 5	Target 6	Target 7	Target 8	Total bullets	Time [s]	Score [pt]
Player 5	1	2	2	1	3	1	1	4	15	11	60.61
Player 6	4	1	1	1	1	1	4	1	14	13.41	53.27
Player 7	1	2	2	2	1	2	1	1	12	9.47	88.00
Player 8	4	2	1	1	1	2	1	1	13	12	64.10

Results of the fourth approach of group two

Person	Target 1	Target 2	Target 3	Target 4	Target 5	Target 6	Target 7	Target 8	Total bullets	Time [s]	Score [pt]
Player 5	6	1	2	4	1	1	2	2	19	11.86	44.38
Player 6	5	1	1	1	1	1	2	1	13	12.28	62.64
Player 7	2	2	1	1	1	1	2	1	11	9.38	96.92
Player 8	2	1	1	1	1	3	1	2	12	12.39	67.26

Results of the fifth approach of group two

Person	Target 1	Target 2	Target 3	Target 4	Target 5	Target 6	Target 7	Target 8	Total bullets	Time [s]	Score [pt]
Player 5	4	1	3	4	3	1	3	3	22	10.05	45.23
Player 6	1	1	1	1	1	2	1	3	11	8.81	103.19
Player 7	2	2	2	1	1	1	1	1	11	8.94	101.69
Player 8	1	1	2	1	1	1	1	2	10	12.2	81.97

Results of the sixth approach of group two

Person	Target 1	Target 2	Target 3	Target 4	Target 5	Target 6	Target 7	Target 8	Total bullets	Time [s]	Score [pt]
Player 5	3	2	1	2	1	2	3	1	15	9.01	73.99
Player 6	2	2	1	2	1	1	2	1	12	8.52	97.81
Player 7	3	1	1	1	1	1	1	1	10	9.44	105.93
Player 8	1	1	2	1	1	1	2	1	10	12.1	82.64

As before, individual charts were created for each person based on the data obtained, as shown in Figure 3.
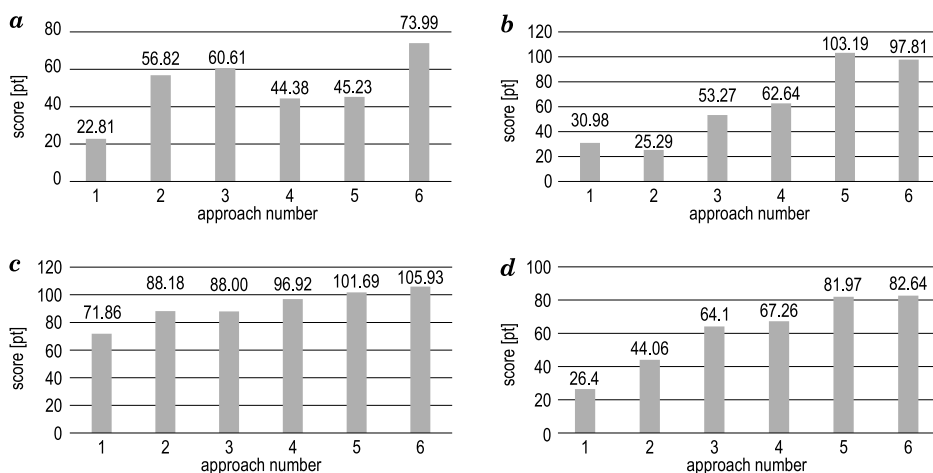
Fig. 3. The results obtained in each approach by two players: *a* – player 5 score, *b* – player 6 score, *c* – player 7 score, *d* – player 8 score

It can be seen that the results are significantly different from those obtained in the first group of people. In this sample, each participant in the study made six approaches one after another, without interruption. You can see the progress of the players in each successive approach, but there are not so large decreases and increases in the results between the following approaches. A gradual increase is visible, and if there was a decrease, it was minimal, within the limits of error. As in the previous test, most players scored their highest on the last attempt, except for one person whose last attempt was minimally worse than the previous one.

Analysis of the results of both groups

Table 13 shows the average scores of all players in each approach. Figure 4 shows column charts of the groups' average scores in the given approaches.

Looking at the data obtained, earlier assumptions are immediately confirmed. Subjects in group one improved their results for the first three approaches, and after the third, there was a one week break. During this break, the study participants did not have access to the created environment, so they could not prepare during this time to improve their results. After re-entering virtual reality, the results dropped significantly, but were slightly better than the first time. Subsequent attempts were characterised by a sudden increase in performance, and in the last attempt the result was the highest; records were broken here. People in the second group gradually improved their scores from trial to trial, and in no subsequent trial was the average score lower than the previous one. Each attempt resulted in an improvement in the average score. In the end, those in the first group achieved a much higher score in the final attempt, a difference of dozens of points, giving them a huge advantage.

Table 13
Average performance of groups in each approach

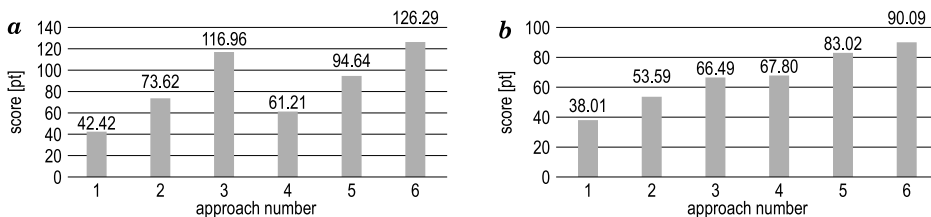| Group	I	II
	average score	
Attempt 1	42.42	38.01
Attempt 2	73.62	53.59
Attempt 3	116.96	66.49
Attempt 4	61.21	67.80
Attempt 5	94.64	83.02
Attempt 6	126.29	90.09

Fig. 4. Average performance of group one and two in each approach:
a – first test, *b* – second test

Conclusions

The paper presents the virtual environment created to test whether intermittent training is more effective than continuous training. This was evaluated based on the results obtained after six attempts were made. Higher scores were obtained by those who completed the task faster and with fewer bullets.

In conclusion, those who took a one-week break in the middle of the study obtained better results than those who did not. It can be concluded that the one-week break had a positive effect on the performance of group one. This group had time to rest, recuperate, and reflect on past performance. When they returned to the study after the break, their results improved significantly compared to group two, which did not have a break.

According to the scoring, which is described in Materials and Methods, both groups started from a very weak level with scores within 40 pt. and in the next attempt had already reached one level higher, but it was rated as weak. In the third attempt, the intermittent test group scored a significant jump, in effect reaching the upper limit of the average level - 116.96 pt., which is already an interesting result looking at the fact that this is only the third attempt. On the other hand, group two continued to perform poorly in the third, fourth, and fifth attempts with scores between 60-80 pt., even though their average score was getting higher. At the same time, after a week's break, group one scored a huge drop to the weak level, and in the next trial returned to the average level with a score of 94.64 pt., but this time to its lower limit. In the last test, the continuous training group broke the barrier of the average level, and it was their highest score in the entire test, 90.09 points. Group one in the last trial scored mostly the highest individual scores so far, resulting in a high level, as high as 126.29 pt.

Looking at the individual results of the participants, it can be seen that in the first group two players achieved above-average results, where in the last attempt they completed the game in just over 7 seconds and nailed all eight targets in 8 and 10 shots. This is an amazing result, and one of them ranks very high level with a score of 166.89 points. This may be due to their very good motor coordination, good reflexes, and possibly experience shooting in reality.

These findings suggest that regular breaks and rest can be important for efficiency and productivity. They provide an opportunity to recover, avoid burnout, and allow you to better focus on the task at hand when you return to training, since you know what to expect.

It is important to note that the above conclusions are only speculation based on the data obtained. Factors such as, for example, participants' motivation, physical conditions or manual skills, and speed of familiarisation with the environment

may also affect the results. To gain a more complete understanding, more thorough research or analysis would be necessary.

It was not possible to evaluate these results with real shooting range because of it's construction and formal conditions regarding use. In further works the authors would like to determine these findings.

Acknowledgments

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