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Original Article

Exploring the short-term visual memory of esports athletes across various levels of expertise

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Abstract:
This study aimed to investigate and analyze short-term visual memory indicators among esports athletes at different levels of sportsmanship. The research involved 29 athletes with an average age of 19 ± 0.65 years, categorized based on sportsmanship levels. Group 1 comprised elite players from semiprofessional teams in Counter-Strike: Global Offensive (CS:GO) and DOTA 2 disciplines n = 10, age: 19.2 ± 0.50 years, while Group 2 included amateur players of CS:GO and DOTA 2 n = 19, age: 19.1 ± 0.43 years. Short-term visual memory was assessed using a specialized iOS program on tablet computers developed by the departments of martial arts, computer science, and biomechanics of KhSAPC. Elite esports athletes have better indicators than amateurs in all the studied criteria: by the number of accurate clicks by 5.61% ($p<0.05$), by the number of inaccurate clicks by 36.40% less ($p<0.05$), coefficient short-term visual memory is higher by 6.50% ($p<0.05$), the duration of the entire test is less by 15.61% ($p<0.001$). Results in the group of elite athletes are characterized by a greater degree of homogeneity than among amateurs. In both groups, there was a trend towards a decrease in reaction time from stages 1 to 4, with a slight increase in the last stage. Elite esports athletes made fewer mistakes at all stages of the test, compared to amateurs. Elite athletes showed faster reactions combined with fewer errors. The presence of a significant difference with the indicators of amateurs indicates a reservation of these indicators by a great playing experience. Therefore, indicators of short-term visual memory informatively characterize the level of preparedness of esports athletes and can be included in monitoring the physical condition of players in cybersport. The possibility of using the tested program TestSTMemory (Short-Term Memory) for tablet computers as a tool for monitoring the functional state of cyber-athletes of different skill levels is proved. The convenience and adequacy of the program allow you to receive the necessary operational information about the condition of athletes, determine the level of readiness for competitions and assess the need for correction of training.
Key Words: short-term visual memory, sports, elite esports athletes, amateur esports athletes, reaction time, psychophysiological study.

Introduction.

Esports is a discipline that is gaining increasing popularity in the contemporary world. Proponents argue that e-sports are a fast-growing "non-traditional sport" which requires "careful planning, precise timing, and skillful execution". Others claim that sports involve physical fitness and physical training, and prefer to classify esports as a mind sport (e.g. like chess) (Jóźwiak, 2022). Esports is not just a research topic, but an area of knowledge that encompasses several themes from different areas. In fact, it is a modern human phenomenon that uses information or communication technologies (Yamanaka et al., 2021; Elasri-Ejjaberi et al., 2020).

Esports places high demands on the skills of perception, attention, memory, cognitive functions and fine motor skills (McDermott et al., 2014). Professional players have a well-defined training program through which they systematically improve their skills. An important factor in planning a training program is to prevent overtraining of athletes. The training process of the players includes all types of training that are inherent in traditional sports: theoretical, technical, tactical, psychological, physical, integral. Only the percentage of time allotted for each of these types differs. So, integral (playing) training takes about 50% of the time, it is often connected in a certain way with the technical and tactical training of the players. In second place is psychological preparation - since the game has a high level of mental stress and is characterized by a significant load on sensory systems. Therefore, much attention is paid to the study of the psychological and psychophysiological aspects of esports activities (Oei & Patterson, 2013; Scharfen & Memmert, 2019; Strobach et al., 2012).

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In modern scientific research, there are two main directions for studying the effect of video games on the human body. The first is an analysis of the opportunities for improving the professional skills of esports athletes. The second is an assessment of the overall impact of this type of activity on physiological and mental functions. It should be noted that there are much fewer studies of the sports direction than the second, general direction (Piatysotska et al., 2023a). The most common research design is to compare players with different levels of playing experience (in terms of playing time) and skill levels (amateur, semi-professional and professional players), as well as those with no playing experience at all (usually as a control group) (Clark et al., 2011; Mishra et al., 2011; Wilms et al., 2013).

Research shows that, when used in moderation, games can improve players' memory, processing speed, concentration skills, and finding ways to solve tactical problems (Guimarães et al., 2018). So, players have to memorize and understand the skills of different characters, the game strategies of opponents and different maps. Games can also build information-processing and concentration skills – honing adaptability, mental flexibility, and mindfulness (Hubert-Wallander et al., 2010).

Green and others argue that not all video games have the same effect on the cognitive properties of players. Action video games have a number of qualitative characteristics, including extreme speed (both in terms of very fleeting events and the speed of moving objects), a high degree of perceptual, cognitive and motor load in the service of an accurate motor plan (significant number of items to be tracked and/or stored in memory, multiple action plans to be considered and executed quickly through accurate and timely targeting), unpredictability (both temporal and spatial) and emphasis on peripheral processing (with important elements most often appearing away from the center of the screen) (Green et al., 2010).

Blacker & Curby determined that playing action video games may enhance visual cognition in general, including abilities related to visual attention and processing speed, providing some potential basis for this benefit of visual short-term memory (Blacker & Curby, 2013).

A study by Clark et al. showed that more experienced players outperform amateur players on various tasks of attention and perception. However, it remains unknown why and how such differences arise. Previous research has shown that improvements in experienced players are the result of improvements in basic perceptual processes. Other work indicates that they may be due to improved attentional control (Clark et al., 2011).

The presence of differences in the biochemical parameters of saliva in players of different levels was proved in the work of Podrigalo L. et al. Players with a higher gaming load were characterized by an increase in the concentration of lipid peroxidation products, a violation of the antioxidant defense system, a decrease in local immunity, and pronounced signs of stress (Podrigalo L. et al., 2020).

In a study by Mishra et al. studied the neural basis of the performance advantage of video game players over non-players in a task requiring attention. The task required identifying targets presented in quick sequences. Electrophysiological evidence suggests that video game players' better ability to identify targets is due at least in part to enhanced suppression of irrelevant distracting information and more efficient perceptual processes. Researchers believe that the spatial and temporal aspects of top-down endogenous attentional selection are improved as a result of active play (Mishra et al., 2011).

One area that has received significant attention is the impact of action games on visual cognition. Such players have been reported to exhibit improved hand-eye coordination, peripheral visual processing, greater divided attention, and better visuospatial memory. A series of published accuracy studies have found that playing action video games improves performance on tasks that measure various aspects of visual attention, including the ability to distribute attention in space, perform dual tasks effectively, track multiple moving objects simultaneously, and process streams of a briefly presented visual stimulus (Green & Bavelier, 2006, 2010, 2012).

Among the cognitive abilities studied in esports athletes, a small number of studies are devoted to the function of memory, in particular, short-term visual memory. Short-term visual memory is defined as the ability to store a small amount of visual information in memory for a short period of time. Short-term memory acts as an obligatory intermediate storage and filter that passes the necessary, already selected information to long-term memory (Podrigalo L. et al., 2019; Romanenko et al., 2020).

Interest in the study of athletes’ short-term memory is driven by the integral nature of this factor and its relationship with a range of factors important for estimating what state they are in Hudac et al. (Hudac et al., 2018) point out that working memory comprises the capacity to retain short-term information and to be integrated with high-order cognitive processing for planning and executing behaviour and critical skills both for effective cognitive and athletic activities. The condition of short-term memory is also used as a criterion in assessing the efficiency of fitness training (Hülsmann et al., 2018).

Romanenko and others presented a comparative analysis of the short-term memory of martial arts players and involved 45 participants in the martial arts (taekwondo, karate, judo, sambo, Greco-Roman wrestling) with different levels of skill. Their short-term memory was tested using the «TestSTMemory» computer application and their heart rate was monitored at the same time. It was found that results depend on levels of skill. The results obtained confirmed greater stress adaptation among novice sportsmen. Masters athletes had a higher level of short-term memory and a greater ability to process information rapidly (Romanenko et al., 2020).

In a comparative analysis of the indicators of short-term visual memory among athletes of a high level of preparedness in short track, martial arts and esports, certain patterns and similarity of results were established. The same type of reaction time dynamics, regardless of the type of sport, illustrates the test's compliance with their specificity. Esports athletes and martial arts athletes were characterized by better adaptive abilities than short track athletes, which is due to the specificity of these sports, where there is a rapid change in circumstances, which requires sudden changes in tactics. Esports athletes are also characterized by a better ability to keep reaction times at the desired level. The specifics of esports athletes' sports activities determined the best results in the most difficult stage of the test, both in terms of speed and accuracy (Piatysotska et al., 2023b).

The specificity of gaming activity in the popular esports disciplines CS:GO and DOTA 2 is a high level of situationality and the need to instantly remember the location of the main enemy forces on the map (Piatysotska et al., 2021). Thanks to the effect of remembering game situations for a long time, players form a game experience regarding possible tactical decisions in accordance with the position of the players on the map, the type of weapon or the properties of an individual character, the number and location of teammates currently remaining in the game (Piatysotska et al., 2020).

The study of the properties of short-term visual memory allows us to determine its features in esports athletes of different skill levels and its relationship with the level of sports achievements, which determined the chosen direction of research.

Purpose of the study. This study aimed to investigate and analyze short-term visual memory indicators among esports athletes at different levels of sportsmanship.

Material & methods.

This study was approved by the Bioethics Committee for Clinical Research and conducted according to the Declaration of Helsinki (protocol of the Commission on Bioethics of the Kharkov State Academy of Physical Culture No. 38).

Participants: The research involved 29 athletes with an average age of 19 ± 0.65 years, categorized based on sportsmanship levels. Group 1 comprised elite players from semiprofessional teams in Counter-Strike: Global Offensive (CS:GO) and DOTA 2 disciplines n = 10, age: 19.2 ± 0.50 years, while Group 2 included amateur players of CS:GO and DOTA 2 n = 19, age: 19.1 ± 0.43 years.

Methods. Short-term visual memory was assessed using a specialized iOS program on tablet computers developed by the departments of martial arts, computer science, and biomechanics of KhSAPC.

Testing procedure: the participant was asked to complete the task in 5 stages of 10 attempts. At the first stage, on the first five attempts, it is necessary to react to one monochrome signal, remember its location and press the corresponding circle. On the second five attempts, it was necessary to respond to a color signal. At each subsequent stage, the number of simultaneously appearing signals increased by one. At the fifth stage, it was necessary to memorize the location of the five signals and press the corresponding circles.

The following parameters were used to evaluate the results: the number of accurate clicks (n), the percentage of accurate clicks (the coefficient of short-term visual memory is the ratio of the number of accurate clicks to their total number, %), the number of errors (n), the duration of the test (s), the duration per 1–5 stages (s), reaction time at stages 1–5 (ms), percentage of errors at stages 1–5. Taking into account the methodological features of the test, the comparison was carried out in the dynamics of its performance and between the studied groups.

Statistical analysis of the results was carried out using the Statistica 13 program, the following methods were used: descriptive statistics, verification of the conformity of the distribution of the electoral population to the normal law according to the Shapiro-Wilk criterion, testing of statistical hypotheses according to the Mann-Whitney and Student's criteria, depending on the nature of the distribution of data in the aggregate.

Research.

The verification of compliance with the normal distribution of populations was carried out using the Shapiro-Wilk test. This criterion is highly sensitive and helps to identify deviations from the normal distribution already at $n \geq 10$. It has been established that in the group of elite athletes the distribution corresponds to the normal one at the level of $\alpha=0.05$ only in terms of test duration (s), in the group of amateurs – in all indicators. Therefore, to compare the two groups, the nonparametric Mann-Whitney test was chosen (Table 1).

Table 1. Generalized characteristics of the results of the test of short-term visual memory in esports athletes of different levels of sportsmanship

Indicators	Group	$\bar{X} \pm m$	σ	ν	Shapiro-Wilk	*Mann-Whitney U Test* / t-Test
Number of accurate clicks (n)	elite	130.90±3.15	9.46	7.22	0.76	*46.0**
	amateurs	123.95±2.12	9.11	7.35	**0.96**	
Number of inaccurate clicks (n)	elite	19.10±3.15	9.46	49.51	0.76	*46.0**
	amateurs	26.05±2.15	9.11	34.96	**0.96**	
Short-term visual memory ratio (%)	elite	87.27±2.10	6.31	7.23	0.76	*46.0**
	amateurs	82.64±1.43	6.07	7.34	**0.96**	
Test duration (s)	elite	124.60±2.10	6.31	5.06	**0.85**	4.40***
	amateurs	144.05±4.05	17.18	11.93	**0.90**	

Note: * reliability of differences p<0.05, ** p<0.01, *** p<0.001

It has been established that elite athletes have significantly better results of short-term visual memory than amateurs in all respects. Thus, during the test, elite athletes performed 5.61% more accurate clicks than amateurs (p<0.05), 36.40% less inaccurate clicks (p<0.05), the coefficient of short-term visual memory is higher by 6.50% (p<0.05), and the duration of the entire test was less by 15,61% (p<0.001).

The results in the group of elite athletes turned out to be more uniform in all test parameters than in amateurs: in terms of the duration of the test in the group of elite athletes, as well as in terms of the number of precise clicks and the coefficient of short-term visual memory in both groups, the coefficient of variation was up to 10%, for the number of inaccurate clicks in both groups, the coefficient of variation was more than 20%.

According to the duration of each stage of the test in both groups, compliance with the normal distribution at the level of α=0.05 was found only in the last two stages (Table 2). An analysis of the duration of each stage of the test showed that at the first two stages the difference between the groups has no statistical significance (p>0.05), however, the execution time for elite athletes is less than for amateurs: at the 1st stage, elite athletes showed a time of 4.55% less, on the 2nd – by 4.14%.

At the next stages of the test, the difference between the groups becomes significant: at the 3rd stage, elite athletes showed the time by 17.59% less than amateurs (p<0.05), at the 4th stage – by 28.88% (p<0.01), on the 5th – by 16.53% (p<0.05). With each subsequent stage, the time increases in both groups, while the coefficient of variation in the 1st group is at an average level within 10-15%, while in the 2nd group it tends to increase to a high level – 17-26% (Table 2, Figure 1).

Table 2. The duration of each stage of the test of short-term visual memory in esports athletes of different levels of sportsmanship

Test stage	Group	$\bar{X} \pm m$, c	σ	ν	Shapiro-Wilk	*Mann-Whitney U Test* / t-Test
1	elite	17.81±0.70	2.11	11.83	0.76	*55.5*
	amateurs	18.62±0.45	1.92	10.29	0.81	
2	elite	22.45±1.11	3.32	14.78	0.85	*93.0*
	amateurs	23.38±1.29	5.46	23.36	0.78	
3	elite	24.26±1.10	3.29	13.54	0.74	*43.0**
	amateurs	28.53±1.45	6.15	21.56	0.85	
4	elite	28.04±1.14	3.42	12.21	**0.89**	3.28**
	amateurs	36.14±2.19	9.27	25.66	**0.88**	
5	elite	32.08±1.56	4.67	14.55	**0.87**	2.40*
	amateurs	37.38±1.57	6.67	17.85	**0.88**	

Note: * reliability of differences p<0,05, ** p<0,01

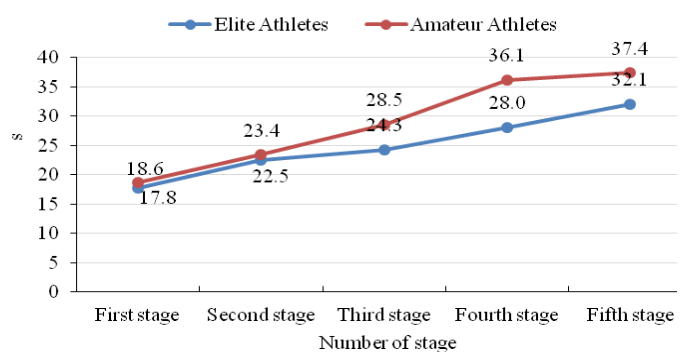

Figure 1. The duration of each stage of the test of short-term visual memory in esports athletes of different levels of sportsmanship

According to the reaction time at different stages of the test, compliance with the normal distribution at the level of α=0,05 was revealed in both groups of 2-5 stages of the test. It has been established that elite esports athletes have less reaction time than amateurs at all stages of the test, except for the 1st one. In both groups, there was a trend towards a decrease in reaction time from stages 1 to 4 with a slight increase in the last stage. So, at the 1st stage of the test, elite athletes showed a reaction time 9.25% less than amateurs (p>0.05), at the 2nd stage - by 13.46% (p<0.05), at the 3rd - by 20,24% (p<0.001), on the 4th - by 23.84% (p<0.001), on the 5th - by 22.95% (p<0.01). According to the coefficient of variation, group 1 had a greater homogeneity of results at 2-4 stages of the test (<11%) than group 2 (13-17%). At the 1st stage of the test, both groups have high values of the coefficient of variation (25-31%), which indicates a low homogeneity within the groups (Table 3, Figure 2).

Table 3. Reaction time at each stage of the test of short-term visual memory in esports athletes of different levels of sportsmanship (ms)

Test stage	Group	$\bar{X} \pm m$, ms	σ	ν	Shapiro-Wilk	*Mann-Whitney U Test* / t-Test
1	elite	694.00±71.28	213.83	30.81	0.71	*58.0*
	amateurs	758.21±45.92	194.80	25.69	0.81	
2	elite	447.80±14.56	43.67	9.75	**0.93**	2.14*
	amateurs	508.05±19.52	82.80	16.30	**0.94**	
3	elite	397.80±12.39	37.17	9.34	**0.91**	3.55***
	amateurs	478.32±15.55	65.96	13.79	**0.94**	
4	elite	374.20±8.68	26.04	6.96	**0.96**	4.08***
	amateurs	463.42±15.55	65.98	14.24	**0.96**	
5	elite	391.60±13.98	41.94	10.71	**0.93**	3.13**
	amateurs	694.00±71.28	213.83	17.66	**0.94**	

Note: * reliability of differences p<0.05, ** p<0.01, *** p<0.001

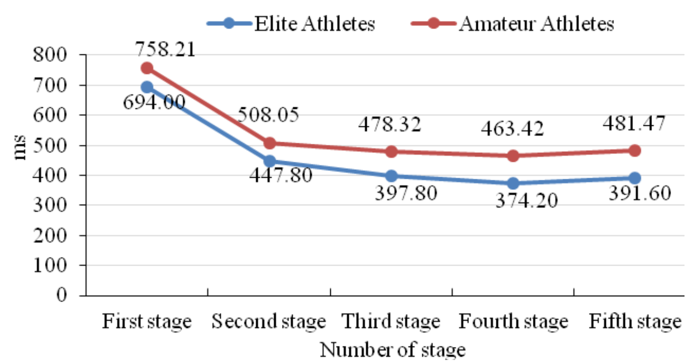

Figure 2. Reaction time at each stage of the test of short-term visual memory in esports athletes of different levels of sportsmanship

In terms of the number of errors, compliance with the normal distribution at the level of α=0.05 was found in the group of amateurs at the 3rd stage and in both groups at the last two stages of the test (Table 4). More qualified esports athletes made fewer mistakes at all stages of the test compared to amateurs (Figure 3). In both groups, there was a tendency to an increase in the number of errors at each next stage, however, significant differences between the groups were found only at the 4th stage of the test. So, at the 1st stage of the test, elite athletes made 0.05% fewer mistakes than amateurs (p>0.05), at the 2nd stage – by 2.68% (p>0.05), by 3 – by 3.53% (p>0.05), on the 4th – by 8.09% (p<0.05), on the 5th – by 4.22% (p>0.05).

Table 4. The number of errors at each stage of the test of short-term visual memory in esports athletes of different levels of sportsmanship

Test stage	Group	$\bar{X} \pm m$, %	σ	Shapiro-Wilk	*Mann-Whitney U Test* / t-Test
1	elite	1.00±1.05	3.16	0.37	*57.5*
	amateurs	1.05±1.08	4.59	0.24	
2	elite	1.00±0.70	2.11	0.51	*47.5*
	amateurs	3.68±0.95	4.03	0.77	
3	elite	7.34±3.51	10.53	0.70	*61.0*
	amateurs	10.87±1.83	7.77	**0.88**	
4	elite	13.75±2.49	7.48	**0.95**	2.35*
	amateurs	21.84±2.38	10.10	**0.97**	
5	elite	22.20±2.78	8.35	**0.87**	1.27
	amateurs	26.42±1.80	7.65	**0.97**	

Note: * reliability of differences p<0.05

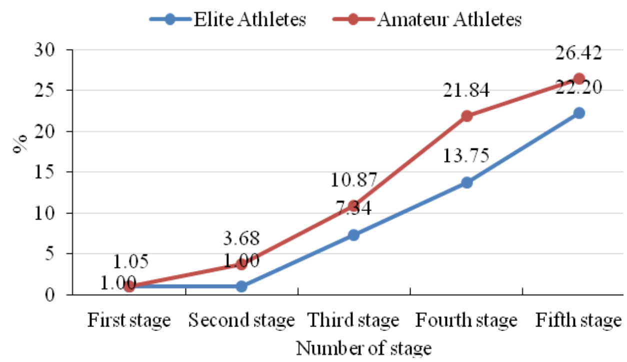

Figure 3. The percentage of errors at each stage of the test of short-term visual memory in esports athletes of different levels of sportsmanship

Discussion

Today, video games are one of the most common forms of play. The massive proliferation of video games in today's society has led to considerable interest in their effects on the brain and human behavior, as well as the possibility of using games in a positive way. Regardless of the characteristics of the game, the improvement in cognitive function may be due to the emotions associated with the game. Establishing causal relationships between play and cognitive improvement leads to the inclusion of play in therapeutic, preventive and educational programs (Franceschini et al., 2022).

Action video games, which are practiced by both gamers and esports athletes, are of considerable popularity. In the cognitive realm, playing action video games is associated with requirements for a range of abilities, including perception, top-down attention, multitasking, and spatial cognition (Large et al., 2019). Meta-analysis of publications by Bediou et al. is devoted to this game genre and is of particular interest to the scientific community (the period from 2000 to 2015 is covered). First, cross-sectional studies are reviewed that inform the cognitive profile of typical video game players and document a positive mean effect of about half a standard deviation (g=0.55). We then analyzed long-term intervention studies that inform about the possibility of a causal change in cognition with the help of video games and show a smaller average effect of one third of the standard deviation (g=0.34). The analysis showed that action video games significantly improve the areas of top-down attention and spatial cognition, stimulate perception, that is, positively affect the improvement of cognitive skills (Bediou et al., 2018).

Despite its central role in cognition, the amount of visual working memory is limited to about three to four elements. Curby & Gauthier (Curby & Gauthier, 2007) tested whether perceptual experience can help overcome this limit by providing more efficient encoding of visual information. Consistent with this, they observed higher ability scores for upright than inverted faces, suggesting that perceptual experience improves visual working memory. The results of Scolari et al. suggest that perceptual experience improves resolution but does not increase the number of representations that can be stored in working memory. This also explains the effect of perceptual experience on working memory and supports the suggestion that quantity and resolution represent different aspects of working memory capacity (Scolari et al., 2008).

The used design – comparison of the state of athletes of different skill levels is the main thing in sports research. It allows you to highlight the factors that ensure success, rebuild the training process taking them into account. The use of this design in the analysis of the state of gamers of different levels made it possible to identify homeostasis indicators that are most adversely affected by computer games (Podrigalo L. et al., 2020).

The results of our study prove that the indicators of short-term visual memory are at a higher level in elite athletes compared to amateurs. In our opinion, this testifies to the conditionality of these characteristics by the great gaming experience and skill level of elite players.

Most researchers come to the conclusion that playing a video game contributes to the development of the cognitive qualities of video game players, in particular esports athletes. According to Green & Bavelier, engaging in video games, in particular action games, provides new learning opportunities that go far beyond learning (Green & Bavelier, 2012). However, it is noted that this aspect is of considerable interest among those interested in rehabilitation, such as after a stroke or the treatment of amblyopia, or training for various jobs that require high precision, such as endoscopic surgery (Rosser et all., 2007) or piloting unmanned aerial vehicles devices. Gaming practice does not provide an immediate advantage in completing new tasks (better performance on the first try), but rather it can increase the ability to learn new tasks. In earlier work, Green & Bavelier (Green & Bavelier, 2010) experimentally proved that action video games improve visual attention and its spatial distribution, increasing the number of visual elements that can be accurately perceived. They also suggest that this improvement is mediated by changes in visual short-term memory skills (Green & Bavelier, 2006).

Green and others established a causal relationship between playing video games and improving task switching, namely in manual and vocal responses, in perceptual and cognitive tasks, for direction change and motor switching (Green et al., 2012). Data from an electrophysiological study by Mishra et al. (Mishra et al., 2011) pointed out two mechanisms that may underlie the performance advantage of video game players (VGP) over non-players. (NVGP). First, the ability to suppress irrelevant distracting information has been enhanced, which would likely reduce the obstacles to completing the main task. The second is an excellent ability to make accurate distinctions and make decisions under high load. Therefore, according to the authors, the differences observed here between players (VGP) and non-players (NVGP) can most confidently be attributed to the experience of playing video games, and not to initial propensity and self-selection. Several preliminary behavioral studies have also convincingly demonstrated a causal relationship between video game training and attention spans (Hubert-Wallander et al., 2010; Green et al., 2010).

The choice of the RPG research test as a tool is also due to its psychophysiological significance and the available literature data. This test allows you to evaluate the amount of visual perception in the face of a gradual increase in the complexity of visual loads. To a certain extent, this models the situation in which the player is. Wilms et al. (Wilms et al., 2013) explored the effects of video games on visual attention centrals using Bundesen's (1990) theory of visual attention. Testing included three tasks that affect the central functions of visual attention and short-term memory: a test based on the theory of visual attention (TVA), an enumeration test, and an attention test (ANT). The authors found that action video games do not affect the capacity of visual short-term memory, but improve the speed of encoding visual information into visual short-term memory, and this improvement depends on the time devoted to the game (game experience). Wilms et al note that intense video games improve basic attentional functions, and this improvement extends to other activities. The study was conducted in a group of young men, as in our study. However, the men were not esports athletes, but played video games at the level of gamers. Sungur & Boduroglu also compared the cognitive abilities of action video game players (VGP) and non-players (NVGP) by examining changes associated with representation resolution for both dynamic and stationary objects. In the color circle task, where test-takers were asked to freely mention the color of shortly presented objects, VGPs were found to be more accurate than NVGPs. In addition, in the Multiple Identity Tracking task (Horowitz et al., 2007), it was found that VGPs can not only track more objects, but also maintain the identity of tracked objects better than NVGPs. Also, VGPs have a larger attention span and higher spatial resolution (Sungur & Boduroglu, 2012). In many everyday situations, speed is of fundamental importance. However, quick decisions usually mean more mistakes. An important question in the training of esports athletes is whether it is possible to reduce reaction time with appropriate training to perform a number of tasks without sacrificing accuracy. Our study found that elite esports athletes show better reaction times combined with fewer errors compared to amateurs. Analysis of Figure 1 allows us to draw conclusions about the features of the graphs. In addition to these differences (shorter duration of the stages), elite players, starting from the 3rd stage, had a smaller graph rise angle. In our opinion, this should be assessed as the formation of attraction to the test. This illustrates the better ability of these participants to adapt, greater adaptive potential.

An analysis of the nature of the graphs in Figure 2 allows us to draw certain conclusions about the features of the reaction of esports athletes. Firstly, this is the closeness of the dynamics of the results, characterized by the coincidence of the nature of the curves. It illustrates the similarity of the psychophysiological state of all esports athletes. Secondly, there is a significant difference in indicators. She justifies that elite players have the best characteristics of reaction speed. First of all, this is due to the experience and skill level of the participants. It also once again testifies to the best adaptive potential of elite esports athletes. This confirms the data of Dye et al. (Dye et al., 2009) that playing an action video game itself significantly reduces reaction time without sacrificing accuracy. What is important is that this increase in speed is observed in various tasks outside of gaming situations. Thus, video games can provide an effective training regimen to induce an overall increase in perceptual response without compromising execution accuracy.

Strobach et al. (Strobach et al., 2012) investigated the relationship between video game practice and the optimization of executive control skills required to coordinate two different tasks. The results obtained indicate performance advantages for experienced video game players compared to non-gamers in situations where two different tasks were processed simultaneously or sequentially. This advantage was not available in single task situations. These results point to optimized executive control skills in video game players and clarify a causal relationship between gaming practice and optimization of executive control skills. The hypothesis that the participation in action games, in particular first-person shooters (FPS), contributes to the development of cognitive flexibility was proved by Colzato et al (Colzato et al., 2010). Oei & Patterson concluded that frequent training of certain cognitive abilities in a video game improves performance on tasks that share common basic requirements. In general, their results suggest that many of the cognitive improvements associated with video games may not come from the training of general broad cognitive systems, such as executive attentional control, but by the frequent use of certain cognitive processes during play. Thus, many of the cognition enhancements associated with video game learning can be attributed to effects close to transference. At the same time, the researchers note that the cognitive improvements of the players were not limited only to learning in action games, but different games improved different aspects of cognition (Oei & Patterson, 2013).

West and others argue that visuospatial experience and long-term involvement in a complex visual task acquired while playing video games improves several visual and cognitive processes. In their work, they determined that the action game experience modulates early sensory processing, resulting in increased sensitivity to noticeable visual events that draw attention. In two experiments, they showed, using temporal order judgment (TOJ) and a signal detection paradigm (d'), that video game players show greater sensitivity to exogenous sensory events in the visual array. These results suggest that visuospatial experience modulates the first sensory aspects of visual processing (West et al., 2008).

The high accuracy of the test performance in elite esports athletes indicates a higher level of special performance, once again proves the assumption made about the optimal state of adaptation. This is evidenced by the graphs in Figure 3 at the beginning of the test, all participants did not differ in the number of errors. At stage 2, amateurs experience a gradual deterioration in accuracy. At the same time, elite athletes continue to maintain a level of accuracy that is virtually at baseline. Starting from stage 3, all participants experience a significant increase in the number of errors. But amateurs have many more. In our opinion, it is experience and skill that allows elite players to keep this indicator at a fairly stable level. At the fifth stage, the number of errors for all participants is quite large and close to each other. In our opinion, this illustrates the fatigue resulting from a fairly complex task. The results obtained are consistent with the available literature data.

Boot and others determined that experienced gamers differed from inexperienced gamers in a number of basic cognitive skills: they could track objects moving at a faster rate, better detect changes in objects stored in visual short-term memory, switch from one task to another faster, and mentally rotate objects more efficiently. Although Boot et al. argue that at least some of the differences between experienced and inexperienced gamers in basic cognitive performance are the result of significantly greater video game experience or pre-existing group differences in ability (Boot et al., 2008). In a study by Appelbaum et al. the capacity and time course of visual sensory memory was measured using partial performance reporting tasks as a means to distinguish between these three possible mechanisms. Sensitivity scores and estimates of parameters describing sensory memory capacity and memory decay rate were compared in individuals with high and low video game experience. A uniform increase in the partial accuracy of the report was found in all delays from stimulus to prompt for players, but no differences were found in the rate or time course of memory impairment. Our results suggest that action game practice may be associated with increased baseline sensitivity to visual stimuli, but not with more information stored in symbolic memory buffers (Appelbaum et al., 2013).

Large et al. confirmed our findings about the similarities between MOBAs and action video games in terms of their cognitive requirements. A study of the cognitive abilities of more than 500 MOBA League of Legends players found positive associations between player performance (quantified by the game's matchmaking rating) and a range of cognitive abilities, including processing speed and attentional ability (Large et al., 2019).

Hilla et al. compared the cognitive functions of action game players (AVG), those who do not play action games (NAVG), and those who do not play video games at all (NVG). Forty male volunteers did the visual short-term memory paradigm, where they memorized shape stimuli depicted on circular displays. Their EEGs were recorded at six different durations of exposure. Accuracy data was analyzed using TVA algorithms. A positive correlation was found between the degree of post-stimulus fading of EEG alpha power (10–12 Hz) and the speed of information processing in all participants. At the same time, video gamers showed greater EEG alpha power attenuation and faster information processing over time than non-players (NVG), with action game players (AVG) showing the largest increase in performance (Hilla et al., 2020). The benefits associated with video games have been investigated by Schubert et al. using the theory of visual attention (TVA). Parameters related to various aspects of visual attention were assessed, for example, perception threshold, processing speed, short-term memory capacity, spatial distribution of attention. They found that video game experts improve perceptual threshold and processing speed, and the best processing speed of video game experts is in lower visual positions. However, overall improvements in visual attention associated with video training are limited (Schubert et al., 2015). The limitation of this study is the survey of only male contingent, as well as two esports disciplines. A separate property of the memory function is considered - in the context of this study, the emphasis is on the manifestation of instantaneous, iconic memory (duration from 0.1 to 0.5 s) associated with remembering the location of visual stimuli directly related to the specifics of game fights.

Conclusions

The study of the cognitive functions of people involved in video games at different levels is a current area of scientific research. Studying the positive and negative aspects of the influence of video games on the human body will reduce the risk of pre-nosological conditions and formulate recommendations for optimizing this specific type of activity. Determining the characteristics of the manifestation of cognitive properties of esports athletes of different skill levels and establishing a connection with indicators of their gaming effectiveness will make it possible to develop a system for monitoring the physical condition of such athletes with the subsequent possibility of predicting sports results and professional selection.

It was found that elite esports athletes prevail over amateurs in all studied indicators: the number of accurate clicks is 5,61% more ($p<0.05$), the number of inaccurate clicks is 36,40% less ($p<0,05$), the coefficient of short-term visual memory is 6.5% higher. ($p<0.05$), the duration of the entire test is 15,61% less ($p<0,001$). The results in the group of elite athletes are characterized by a greater degree of homogeneity than in amateurs. In both groups, there was a trend towards a decrease in reaction time from stages 1 to 4, with a slight increase in the last stage.

Elite athletes showed faster reactions combined with fewer errors. The presence of a significant difference with the indicators of amateurs indicates the conditionality of these indicators by a large experience of games. Therefore, indicators of short-term visual memory informatively characterize the level of preparedness of esports athletes and can be included in monitoring the physical condition of players in cybersport. The possibility of using the tested program TestSTMemory (Short-Term Memory) for tablet computers as a tool for monitoring the functional state of esports athletes of different skill levels is proved. The convenience and adequacy of the program make it possible to obtain the necessary operational information about the condition of athletes, determine the level of readiness for competitions and assess the need for correction of training.

Conflict of interests The authors declare that there is no conflict of interests.

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