DOI: 10.22122/jrrs.v15i6.3460

Published by Vesnu Publications

Short-Term Effects of First Person Shooter Computer Game on Visual Focus Using Eye Tracking Tool: A Randomized Clinical Trial

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Original Article

Abstract

Introduction: Computer games today are widely used to improve cognitive performance. Selective attention is one of the cognitive skills whereby individuals can process certain events from among several driving factors and neglect others. The purpose of this study is to investigate the effect of the first-person shooting (FPS) computer game style on the level of selective attention (visual focus).

Materials and Methods: This study was an experimental study with experimental (n = 15) and control (n = 15) groups. The game was designed in the style of a first person sniper controlled by the eye tracker as an input tool. Data analysis was performed using univariate analysis of covariance (ANCOVA).

Results: There was no significant difference between the two groups before the study ($P \leq 0.502$). After participating in the study, the visual concentration in the control group did not change significantly ($P \leq 0.001$), meaning that the game scores improved after the intervention.

Conclusion: It seems that the FPS computer game using an eye-tracking tool improves visual focus through a cognitive-rehabilitation process.

Keywords: Eye tracker; First person sniper game; Eye gestures; Visual focus

Citation: Soltani T, Shahabi N, Sekhavat YA, Movahedi Y. **Short-Term Effects of First Person Shooter Computer Game on Visual Focus Using Eye Tracking Tool: A Randomized Clinical Trial.** J Res Rehabil Sci 2020; 15(6): 335-42.

Received: 31.12.2019 Accepted: 30.01.2020 Published: 04.02.2020

Introduction

Eye movements can be classified using two main approaches from an anatomical point of view and behavioral point of view (1). The human eye has 6 muscles that are connected to it in different directions and make its different movements possible. The eye's anatomical movements are classified into three general sections, including movements of one eye, movements of both eyes in parallel, and movements of both eyes in opposite directions (2). Behavioral eye movements are also divided into two main categories, including saccades and smooth pursuit movements. Saccades cause the eyeball to move rapidly and move the eye toward the stimulus with a short delay relative to the incoming stimulus. Smooth pursuit movements are subtle movements that are performed to maintain the image of a moving object on the retina and follow it; Like when a car is moving from left to right (3). Staring (gaze) means the amount of time a person collects the information needed for the brain to interpret an image. The components of gaze include the time, number, and place where the gaze occurs (4). The eye does not transmit visual signals to the brain when making saccades. Thus, saccade is made after obtaining information from gaze fixation (5).

Eye tracking means using eye movements to determine where the user is looking at (6); It processes a person's visual orientation of sight to identify the object on which he/she is focused (7). In other words, the process by which an observer's point of vision can be found, or by which his/her eye movements toward his/her head can be measured, is called tracking eye (1).

Wells used visual observations to understand eye movements (8). Javal observed eye movements as a

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set of saccades. Using a mirror and placing a microphone on the eyelid, he counted and recorded small saccades in eye movements while reading the text (9). Eye movement recording was started by Ahrens and optimized by Heuy. Heuy developed a device for recording eye movements using an invasive contact lens (10). There was a hole for the pupil in the middle of the lens, and an aluminum pointer was attached to it which moved as the eyeball moved. In this way, he measured some eye movements and small saccades, finding that the eyes pause on some words while reading a text (11). The first non-invasive eye tracker with head position recording appears to have been made by Buswell in Chicago, USA. He emitted light to the eye and recorded its reflection from the eye on a photographic film, and in this way conducted fundamental studies of reading and looking at a photograph (11). Dodge & Cline used a non-invasive method to record corneal reflection (8). A pilot's eye movements during landing were first recorded in 1947; A year later, the first head-mounted eye tracker was invented by Hartridge and Thomson. In fact, eye-tracking devices for military applications were first used in aerial maneuvers so that the pilot's hands were free while piloting aircraft or using weapons (8,9), and in the 21st century, the first eye-tracking record was performed using photographs and light reflection methods in a non-invasive manner (27).

In recent years, the use of content related to video games with eye trackers has increased dramatically in the field of education and treatment (1). Studies show that the future of education in order to promote creativity in future generations will inevitably be linked to games and combined learning (12,13). Video games also improve cognitive functions in individuals by stimulating mental processes (14). Attention is one of the most basic functions of the brain, the components of which are the basis of other cognitive functions (15). On the other hand, eye tracking is used in various fields of psychology and neuroscience to better understand how the eyes move and how to collect information (16). Nowadays, investigations of video games focus mainly on comparing trackers with traditional input devices such as mice and keyboards (17,18). The basic premise of all studies on eye trackers is the eye-mind hypothesis, proposed by Carpenter (19). There is a close relationship between the direction of the human gaze and focus and attention; This hypothesis states that the position of a person's eyes reflects his mental functions (20).

In many studies, the eye tracking-based video games have been used to assess (21,22) or improve attention in people with attention deficit hyperactivity disorder (ADHD) (22,23). These games are mainly designed for children and adolescents (21,23) and in addition, in most studies, due to the time consuming process of rehabilitation, the long-term effects of games have been investigated (24,26). The aim of this study is to investigate the effect of video game in first person shooting (FPS) style on the level of visual focus in healthy subjects who wanted to improve their level of concentration. The main hypothesis was a significant improvement in the level of the individuals' selective attention in the short term and following participation in the aforementioned video game.

Materials and Methods

This was a randomized clinical trial study with a control group conducted at Tabriz Islamic Art University, Tabriz, Iran in 2019. The study plan was approved by the ethics committee of the university and registered in the Iranian Registry of Clinical Trials (IRCT) website. The study population included all people who needed to improve their level of visual focus in order to increase their quality of life (QOL) and do their jobs better. A poster was published in the university bulletin calling for volunteers. The candidates were selected by the convenience sampling method from among the students of Tabriz Islamic Art University and were randomly divided into case (game) and control groups by lot. All participants consciously read and signed the consent form before the test.

The study inclusion criteria included mental and physical health and stability, lack ADHD or diseases related to concentration and attention, familiarity with computers, and not taking certain medications affecting concentration, based on interviews with the person and review of his medical record. Given the study of the effectiveness of neuropsychological rehabilitation on improving cognitive function (attention) in children with ADHD (25), the sample size was estimated to be 30 subjects.

Game design: When designing a game, along with the entertainment aspect for players, the rules, goals, and theory of the game should be specified. The game scenario was extracted from the training part of the Sound smart game. The Sound smart neuropsychological rehabilitation software is an attractive educational program designed by BrainTrain in the same way as video games and enhances cognitive abilities (4). One of the main parts of this game is to increase patience, which is controlled by time tools. Players do not have the right to react before a certain time has elapsed. Using this theory, the present game was implemented in the FPS manner and in a different environment to make it more attractive.

Prior to the game, the tracker calibration was performed for each player. In this game, balloon-shaped targets were displayed in an environment with limited elements to reduce distractions for the player. In this game, using the eye tracker, the players follow the targets by moving their eyes, and after a specified period of 15 seconds, by pressing the keyboard button, the cursor goes to the person's gaze location, and with another button, the gaze location is shot at. In case of early shooting, regardless of the penalty, the game starts from the beginning. The more balloons a player hits in proportion to the number of bullets, the more points he earns (Figure 1). The software used in this study was Unity game engine (Unity® 2019.2.2.13 f1 <DX11>, Unity Technologies, 2019, San Francisco, California, US) and Tobii eye tracker (Tobii C4, Tobii Dynavox LLC, Tobii Technology AB-Sweden 2001, greater Stockholm area, Stockholm, Sweden).

Figure 1. Images of the game stages

Evaluation: The players' visual focus level was measured prior to the start of the study and at the end of the second week by the Toulouse-Pieron accuracy test. The method of answering this test is that the subject should quickly find two or three squares with a special symbol or sequence that is presented at the top of the test page, in 3 minutes on the page in front of him/her. At the end of the 3 minutes, the number of correct answers is counted and the lower the number of correct answers, the more the subject's distraction. The validity and reliability of this test were reported to be satisfactory in the study by Pieron. For example, the concurrent validity of this test with Bourdon test was 0.74 (26).

Intervention: The group playing the video game played it for 10 sessions over two weeks, each session lasting 20 minutes. During this period, no intervention was performed in the control group. Before the start of the game, the subjects were explained about the test process without details of the operation of the eye tracker.

The normal distribution of the data was investigated for each variable using the Shapiro-Wilk test. The intragroup comparison was performed using paired t-test and the intergroup comparison with the control group relative to pretest scores was performed using analysis of covariance (AVCOVA) test and Tukey post hoc test in SPSS software (version 22, IBM Corporation, Armonk, NY, USA). Data analysis was performed at the significance level of $P < 0.050$ and the test power was determined with G*Power software (G*Power 3.1.5 freeware, University of Düsseldorf, Düsseldorf, Germany).

Results

Data obtained from the 30 subjects in the age range of 23-36 years were compared in the case and control groups. Out of the 36 participants, 4 were excluded from the study due to non-compliance with the inclusion criteria and 2 due to the lack of attendance (Figure 2).

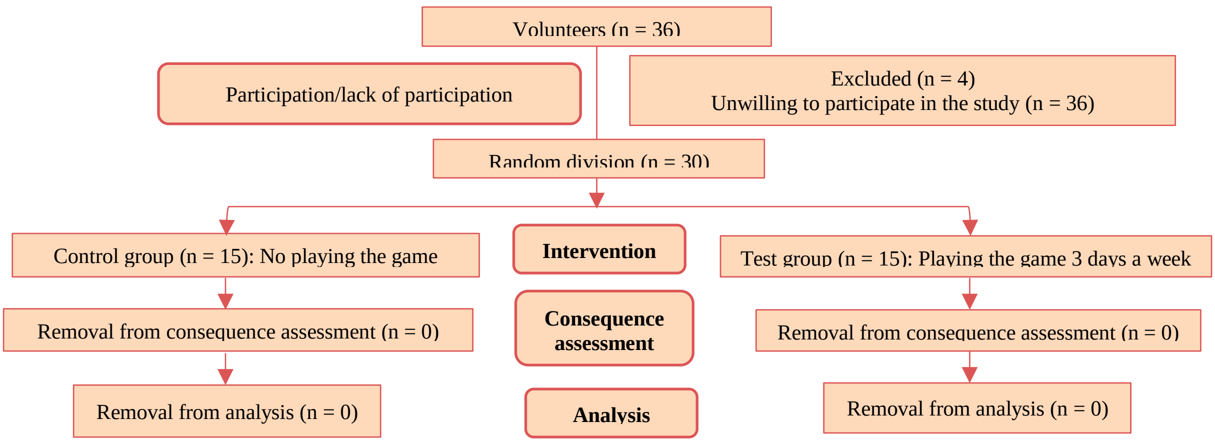

Figure 2. Study stages and drop of subjects during the study

The dropout rate of participants was zero and all subjects completed all stages of the study. Accordingly, no intention-to-treat (ITT) analysis was performed.

There was no significant difference between the frequency distribution of men and women in the two groups (P ≤ 0.775). The demographic characteristics of the samples of the two groups are given in table 1.

Table 1. Demographic characteristics of the participants

Group	Age (year) (Mean ± SD)	Men [n (%)]
Case	29.25 ± 3.72	7 (46.66)
Control	30.33 ± 3.25	6 (40.00)
Intergroup P value	0.121	0.775

SD: Standard deviation

Table 2 compares the results of the Toulouse-Pieron test in the two groups.

Table 2. Results of Toulouse-Pieron accuracy test in the study groups

Group	Before intervention	After intervention	Intragroup P value
Case	13.40 ± 2.58	11.53 ± 2.32	0.403
Control	12.00 ± 2.20	18.26 ± 3.30	0.001
Intergroup P value	0.502	0.001	-

Data are reported as mean ± standard deviation (SD).

In table 3, the univariate analysis of covariance (ANCOVA) test was employed to compare the effectiveness of the game on children's attention and focus between the case and control groups.

In order to investigate the homogeneity of regression and the lack of interaction between groups with pre-test scores, the homogeneity of regression assumption was examined and given the results of this hypothesis, it was confirmed. The findings revealed that visual focus was significantly different in the case group after the intervention (P < 0.001). In the case group, the post-test visual focus scores were better than those of the pre-test stage (P ≤ 0.001) and by participating in this study, the scores of the case group improved significantly compared to the control group (P ≤ 0.001); While the intergroup visual focus level in the control group did not change during this period (P ≤ 0.502). The results of the eta squared test in the visual test with an effect size of 0.011 and 0.327 were poor and good in the pre-test and post-test stages, respectively. Table 4 lists the saccades, fixations, and time to first attention in the case group. These variables were higher in the first session than in the last session.

Discussion

In the present study, a randomized trial was designed and performed to determine visual focus using eye tracking. Data analysis suggested that there was a significant difference between the mean scores of pre-test and post-test in the case and control groups; In this way, play may improve the subjects' visual focus in a cognitive rehabilitation process. This study showed that the use of eye tracker in the game as an input device improves the accuracy of players in leading the game; because the game play depends on it.

The use of eye trackers has been the focus of attention in previous studies (16,20-22,27,28). In his article, Arredal compared the mouse and eye tracker as a software input interface tool. Players played first with the mouse and then with the eye tracker. Then, the players' experience in using the eye tracker was assessed. He concluded that the mouse performed better in accuracy and timing of the game, and that the game with the tracker was better with fewer shots (5). There are different types of eye movements, but in general, for visual search, there are two modes of gaze and saccade movements (29). Saccade includes visual angle, speed (in degrees per second), and direction. The angle range of each saccade covers between 1-49 degrees, but is typically between 15-20 degrees (30). The state in which the eyes are relatively fixed is called fixation. In this case, viewing or encrypting information occurs. Fixation takes an average of 218 milliseconds and is in the range of 66-416 milliseconds (18).

The pattern of places where saccade is performed is called the traverse path (30). The traverse path is actually a measure of eye tracking that is a sequence of connected fixations and saccades (18). Attention refers to a series of complex mental operations that include focusing or engaging with the target, holding or enduring, and waiting for long periods of time, encoding stimulus characteristics, and shifting focus from one target to another (31).

Table 3. Univariate analysis of covariance (ANCOVA) test of the game in visual focus

		Sum of squares	Degree of freedom	Mean square	F	P value	Partial eta squared
Group	Visual focus	331.020	1	330.020	39.361	0.001	0.602
Interaction effect (regression slope)	Visual focus	260.502	2	130.251	5.100	0.059	0.201
Error pretest	Visual focus	218.654	26	8.410			

Table 4. In-game mean test of saccades, fixations, and time until the first attention

Variable	Stages	Minimum	Maximum	Mean ± SD
Number of saccades	First session	1691	2070	1887.83 ± 127.29
	Last session	1536	1924	1651.33 ± 145.25
	Intragroup P value	-	-	-
Number of fixations	First session	381	409	397.16 ± 10.72
	Last session	253	293	277.83 ± 18.95
	Intragroup P value	-	-	-
Time until the first attention (hundredth of a second)	First session	67.76	103.69	79.00 ± 17.13
	Last session	42.15	47.46	45.26 ± 2.37
	Intragroup P value	-	-	-

SD: Standard deviation

The basic types of attention are sustained attention, selective attention, and diffused attention (32). Focus is a process of attention and includes the ability to focus attention on doing something while ignoring other factors (33). The most important function of visual focus is to quickly direct the look at objects of interest in the visual environment and to be able to quickly orient to prominent objects in a scene (34). With visual focus, the visual system selectively processes only a small portion of the information received (35). Therefore, to improve visual focus, it is necessary to improve the selective attention level.

For selective visual focus, there are two models, Spotlight and Zoom-Linns, which describe the visual attention function. The Spotlight model likens the visual focus to the spotlight, in which the area around the focal point, known as the margin, is observed but not clearly seen (36).

In the Zoom-Linns model, the elements in the spotlight model can be focused like a camera lens. Visual search includes two types of bottom-up and top-down. The bottom-up attention is performed subconsciously (37). Eye movements are vital for awareness of the bottom-up (objective to mental) perceptual features of the external world and top-down cognitive processes (from mind to reality) (29). In a simpler sense, when the eye moves from the bottom up, it means that the eye moves subconsciously to see points that are visually appealing; while the movement of the eye from top to bottom reflects the viewer's previous decision and the eye moves towards the points that the observer has chosen consciously (mind to reality). With the bottom-up approach, the individual sees features that subconsciously attract attention. In fact, visual characteristics such as movement, color, brightness, orientation, shape, size, and lines have a major impact on the bottom-up visual focus process. For example, the red rose in the green bush subconsciously attracts attention because of the color contrast. The top-down attention is under the control of the observer and is drawn to the stimuli chosen by the observer (38).

Given the eye tracker data, the areas of interest to the players were identified. In the present study, three measures of eye tracker, namely the number of saccades, fixations, and time to the first attention were examined, and it was found that during the game sessions, the number of saccades, number of fixations, and time to the first attention of players decreased from the first to the last session. This indicates that the users have had a more efficient search and the players' visual focus level has improved. More efficient search, or optimal search, means that the person sees the targets faster and completes the game with fewer saccades and fewer fixations. In the first sessions, due to unfamiliarity with the game environment and less user experience in using the tracker, the players had intermittent fixations and saccades, but in the subsequent sessions, this number decreased significantly and there was more focus on the targets and time of the game and more efficient visual search was recorded compared to the initial sessions. This finding was consistent with the results of the study by Choi and Kim on the gradual increase of the skill of working with eye tracker with increasing gaming sessions (27).

Brain plasticity, or neuroplasticity, is the ability to reorganize neural networks in response to new life experiences. New information and skills acquired through learning or experience lead to functional changes within the brain (38). In fact, empowerment or cognitive training refers to training that is based on the findings of cognitive sciences, but in the form of games and mainly video games, try to improve or enhance cognitive functions including accuracy, attention, spatial visual perception, auditory distinguishing, memory types, especially working memory (WM), and other executive functions, all of which addressing neuroplasticity (40).

In general, based on the brain formation hypothesis, one can explain that the possible effects of this game are due to the cognitive exercises and repetition of these exercises. Based on this hypothesis, it can be concluded that playing video games with eye trackers improves the concentration among the players by creating new experiences for them. Therefore, to examine the long-term effect of the game, the game should be played in long sessions and for a longer period of time, but the hypothesis about the short-term effect was proven.

Smith and Graham examined three games with an eye tracker as input compared to a mouse. The games included Quake (Earthquake 2), Neverwinter nights, and Loner comment. In the Loner command and Neverwinter nights games, the performance of the eye tracker was better than that of the mouse (16).

Limitations

The present study was spatially limited to the School of Multimedia, Tabriz Islamic Art University due to the use of eye tracker. Besides, after reading the consent form and despite the commitment not to publish the results in their names, the subjects were afraid of disclosing their level of focus, which affected the study results in recording the saccades, fixations, and time to the first attention (45).

Recommendations

All four sections of the Sound smart software's basic theory regarding attention can be designed in varying degrees of difficulty in the FPS style and in three dimensions with different graphic designs. Since it seems that the player age cannot make a significant difference in eye control (30), based on the findings of the present study, one can design a similar study on children and adolescents with ADHD and evaluate this game as a therapeutic method along with medication. The eye tracker-based games can be applied in education, rehabilitation, and even entertainment of people with mobility disorders, and determining the scope of these clinical effects requires further studies.

Conclusion

The FPS video game using an eye-tracking tool appears to improve visual focus in a cognitive rehabilitation process.

Acknowledgments

This study was based on the information obtained from an MSc thesis conducted by Taban Soltani at Tabriz Islamic Art University, which was registered on IRCT. The authors would like to appreciate all the volunteers who contributed to this study.

This article is one of the articles submitted to the Secretariat of the Fifth International Conference on "Computer Games; Challenges and Opportunities" with a special focus on therapeutic games (February 2020, Isfahan, ran), which was praised by the editorial board of the Journal of Research in Rehabilitation Sciences (JRRS). The authors would like to appreciate the Cyberspace Research Institute of the National Cyberspace Center for supporting the publication of this article. The Entertainment Industry Innovation Center of University of Isfahan, which played an important role in collecting data and accomplishing this project is also appreciated.

Authors' Contribution

Taban Soltani: Study design and ideation, data collection, analysis and interpretation of results, manuscript preparation, specialized evaluation of manuscript in terms of scientific concepts, approval of the final manuscript to be submitted to the journal office, the responsibility of maintaining the integrity of the study process from the beginning to the publication, and responding to the referees' comments; Nasrin Shahabi: Study design and ideation, analysis and interpretation of results, manuscript preparation, specialized evaluation of manuscript in terms of scientific concepts, approval of the final manuscript to be submitted to the journal office, the responsibility of maintaining the integrity of the study process from the beginning to the publication, and responding to the referees' comments; Yazdan Movahedi: Study design and ideation, design of the game psychological-theoretical section, manuscript preparation, specialized evaluation of manuscript in terms of scientific concepts, approval of the final manuscript to be submitted to the journal office, the responsibility of maintaining the integrity of the study process from the beginning to the publication, and responding to the referees' comments; Yoones A. Sekhavat: study design and ideation, providing the necessary equipment, manuscript preparation, specialized evaluation of the manuscript in terms of scientific concepts, approval of the final manuscript to be submitted to the journal office, the responsibility of maintaining the integrity of the study process from the beginning to the publication, and responding to the referees' comments.

Funding

This study was based on the information extracted from an MSc thesis conducted by Taban Soltani at Tabriz Islamic Art University, which was registered on IRCT. The study was not funded by anyone and all costs were borne by the researchers. Tabriz Islamic Art University did not comment on data collection,

analysis, and reporting, manuscript preparation, and final approval of the article for publication.

Conflict of Interest

The authors declare no conflict of interest.

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