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Original Article

Evaluation of Stress and Cognition Indicators in a Puzzle Game: Neuropsychological, Biochemical and Electrophysiological Approaches

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Abstract

Video games have significant and diverse effects on stress and cognitive systems based on the game style. The effect of this media on the central nervous system is significant because of its repetition. Nowadays, video games have become an important part of human life at different ages, and therefore, assessing their effects (good and bad) on stress factors, cognition, and behavior can be an important help in understanding the nature of these games and managing their impact on humans. Consequently, this study aimed to investigate the effect of a puzzle game on the player's stress and cognitive indicators in neuropsychological, biochemical, and electrophysiological approaches. A total of 44 participants were entered into the study and randomly assigned to control and experimental groups. Our interventions were watching (control group) and playing (experimental group) the game. Salivary biomarkers (cortisol and alpha-amylase) were measured using the enzyme-linked immunosorbent assay method. Electrophysiological assessment of attention and stress was performed using electroencephalography. Neuropsychological assessments for the evaluation of mental health, mental fatigue, sustained attention, and reaction time were conducted using paced auditory serial addition test. All tests were administered before and after the interventions. The findings revealed that the salivary cortisol and alpha-amylase significantly reduced after playing the game. There were significantly higher levels of attention after playing the game. Mental health and sustained attention significantly increased after game playing. It can conclude that puzzle-style computer games can strengthen and empower the perceptual-cognitive system and suppress the stress system of players. Therefore, they can be used purposefully as a positive cognitive therapy approach.

Keywords: Puzzle games, Electroencephalogram, PASAT, Stress, Cognition

1. Introduction

Video games have a direct and immediate effect on an individual's cognitive activities. Players are required to make decisions and take actions at any moment according to the game context (decision-making as a cognitive behavior is planned in the prefrontal cortex) to achieve personal development in-game goals (1-3). Video games are an interactive medium spreading throughout the globe and act as an environmental factor to enhance or attenuate the cognitive function of the brain. The cognitive function

is the integrity of the mind and brain, representing the impact of biological, electrophysiological, molecular, and physiological brain functions on behavior. Video games have remarkably drawn the attention of researchers and neuroscience experts due to their effects on the nervous system. They can affect many cortical and subcortical areas that are involved in controlling behavior (1, 4-7).

There is evidence that the puzzle and runner style of games helps improve cognitive functions (1, 8). Stress affects mental and physical health and the social decision-making process. Therefore, control and reduction of stress levels both at individual and community levels significantly improve the lifestyle of the individuals, leading to the promotion of community health (9-11). Video games play a magnificent role in brain function, especially in specific brain areas responsible for decision-making, problem-solving, attention, and learning, such as the frontal cortex. Problem-solving skill is the most important cognitive activity and a major contribution to mental abilities and improvement of cognitive indices, such as attention, thinking, and decision-making.

Attention is the basis of problem-solving and one of the main cognitive processes. It is the base of thinking and learning that is associated with storing and recreation information in the brain. Attention is increased through the repetition of a specific task and enhancement of decision-making parts of the brain (5, 12, 13). Any video game capable of improving attention may serve to enhance other cognitive indicators and can be identified as an activator of the brain cortex in a positive direction (14, 15). Attention is a significant brain function that has a major role in the development of cognitive functions, including intelligence, memory, and perception.

Electroencephalography (EEG) is a way to record and identify cognitive functions. Brainwave analysis during playing video games may be effective to investigate changes in cognitive processes, such as attention and concentration. Any type of change in the central nervous system (CNS) caused by playing video games can influence the behavior of the player. Consequently, research in this area includes examining a broad range of human behaviors and cognitive abilities (13, 16, 17). Among all investigated tests, the Paced Auditory Serial Addition Test (PASAT) is a prevalent test to determine cognitive and conceptual characteristics. This progressive test has been widely used since 1974 as a feasible measurement tool in the U.S. military and has been utilized in numerous studies (1, 18, 19). Given the widespread popularity of video games and the large proportion of waking hours spent on them, careful scientific studies on the effects of different video games are important for both practical and theoretical reasons. Therefore, the present study aimed to evaluate the effects of a puzzle game on the stress and cognition of players based on changes in biomarkers and brain wave functions.

2. Materials and Methods

2.1. Participants and Study Protocol

A total of 44 out of 56 male student volunteers with an average age of 20 years were included in the experimental (playing the puzzle game) and control (only watching the puzzle game) groups. All tests were conducted before and after the interventions. Subjects were screened for eligibility to participate in this study. The inclusion criteria were lacking a previous history of playing this puzzle game, illicit drug use, any medical conditions, and drug consumption.

2.2. Neuropsychological Assessment

The PASAT was used to assess perceptual-cognitive readiness. First, all participants were trained and taught the PASAT, and then, PASAT was performed on the subjects to measure their mental health, continuous attention, response time, and mental fatigue. The PASAT was performed before and after the interventions in the experimental and control groups. Recorded high-quality auditory stimuli were presented via an external speaker at the most comfortable level for the listener in PASAT administration. During the presentation, the participants summed the two last digits recited and provided their responses. The subjects needed to add every two successive end numbers up together and answer their question before proposing a new number. For example, if numbers 2 and 6 were

presented consecutively, the correct response was 8. Each participant would give some correct answers in each test (the accuracy of the answers). The answers were compared before and after the interventions. The average time for answering (reaction time or response speed), the longest chain of correct answers (sustained attention), the longest chain of incorrect answers (mental fatigue), and the number of correct answers (mental health) were analyzed. The analysis of the obtained results was performed using R software (R 3.4.0).

2.3. Biochemical Evaluations

The saliva samples of all participants were collected before and after the interventions using 10-mm Falcon tubes and were stored at -20ºC in a fridge. On the test day, samples were first melted at room temperature, and after being centrifuged at 3,000 g for 5 min, 20 µl of each sample were separated for testing. Cortisol and alpha-amylase enzyme-linked immunosorbent assay kits (Diagnostics Biochem Canada Inc, Canada) were used for assessing salivary levels of cortisol and alpha-amylase. The collected data were analyzed using the R system.

2.4. Electrophysiological Monitoring

The 14-channel EEG-Emotive device was applied to record the brainwaves of the subjects. All electrodes placed in certain areas on the scalp and brain waves were recorded from all participants in the baseline state (closed and open eyes). The brain activity of the experimental group was recorded by EEG device before, during, and after the gameplay. Brainwave analysis was performed by MATLAB software (MATLAB and Statistics Toolbox Release 2016b, The MathWorks, Inc., Natick, Massachusetts, USA). To extract characteristics, the EEG power of various bands and electrodes was calculated and compared.

Attention and stress were assessed based on data on brainwave analyses acquired in previous studies. Researchers used the power of the Theta band in the frontal cortex and the ratio of Theta/Beta to measure attention (9).

Attention:

$$attention = \frac{Pow(AF3_{beta}) + Pow(AF4_{beta})}{Pow(AF3_{theta}) + Pow(AF4_{theta})}$$

where pow (Ab) is the signal power of electrode A in band b.

According to the results of previous studies, the activity of the right hemisphere in the frontal lobe is significantly higher in people with social stress and anxiety or those exposed to social menaces. Findings from previous studies suggest that the best way to evaluate the stress level is to analyze brainwave signals of the individuals because it indicates the proportion of brain activity between the two hemispheres in the frontal lobe (7, 9).

Stress:

$$stress = \frac{pow(F_3(\alpha))}{pow(F_4(\alpha))}$$

(2).

2.5. Statistical Analysis

The results were expressed as mean and standard error (Mean±SEM). The Wilcoxon test was used to determine the significance of the within-group differences. The significance level was set at $P \leq 0.05$. Moreover, data on brainwaves signals were analyzed using MATLAB software.

3. Results

Figure 1 depicts the mean of attention based on EEG analysis in control and experimental groups. Our results indicated that the attention feature in puzzle game players significantly increased after the gameplay ($^{**}P<0.01$).

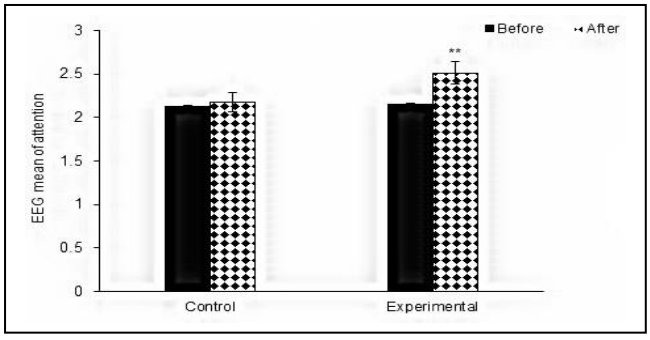

Figure 1. Mean of attention
Figure 1 depicts the mean of attention based on EEG analysis in control and experimental groups. The horizontal axis shows study (control and experimental) groups. The vertical axis shows the mean of attention. Accordingly, a significant increase was observed in the mean of attention after puzzle gameplay ($^{**}P<0.01$)

Figures 2A and 2B represents salivary cortisol and salivary alpha-amylase levels in the control and experimental groups. Based on the biochemical analysis, a significant decrease was observed in salivary cortisol and salivary alpha-amylase levels after the gameplay in the experimental groups ($^{***}P<0.001$ and $^{**}P<0.01$, respectively).

Figures 3A and 3B shows PASAT results for mental health and mental fatigue assessments in the control and experimental groups. The mental health of the puzzle game players increased significantly after the game ($^{*}P<0.05$). Nevertheless, the mental fatigue did not change significantly in the experimental and control groups after the interventions.

Figures 4A and 4B is the representation of PASAT results for sustained attention and the reaction time evaluations in the control and experimental groups. Based on the results, the sustained attention of the puzzle game players increased significantly after the game ($^{**}P<0.01$). However, the reaction time did not change significantly in the experimental and control groups after the interventions.

In the control group, none of the assessed features changed after the intervention.

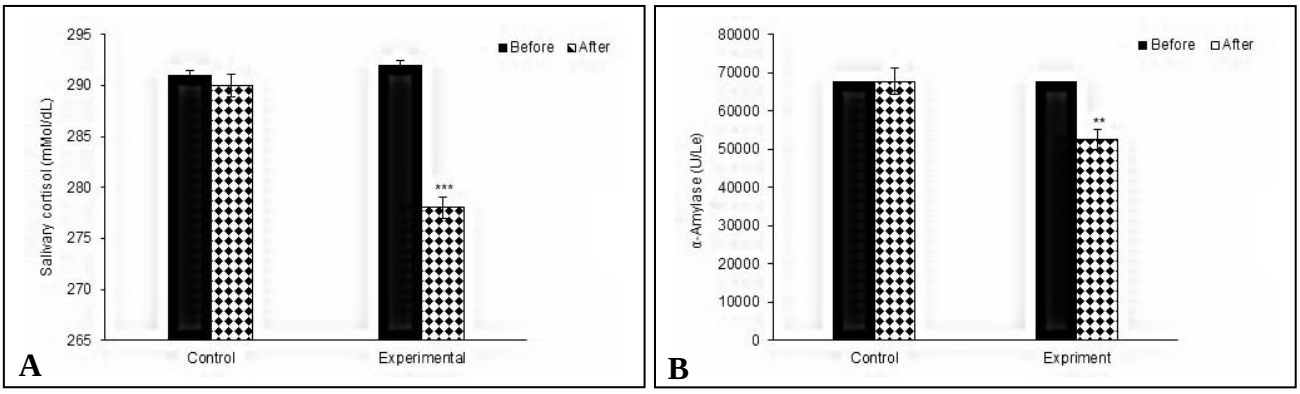

Figure 2. A. Salivary cortisol and **B.** Salivary alpha-amylase levels

Figure 2 represents salivary cortisol and salivary alpha-amylase levels in control and experimental groups. The horizontal axis shows study (control and experimental) groups. The vertical axis shows salivary levels of cortisol (mMol/dL) and alpha-amylase (U/L). Salivary levels of cortisol and alpha-amylase showed a significant decrease after puzzle gameplay ($^{***}P<0.001$ and $^{**}P<0.01$, respectively).

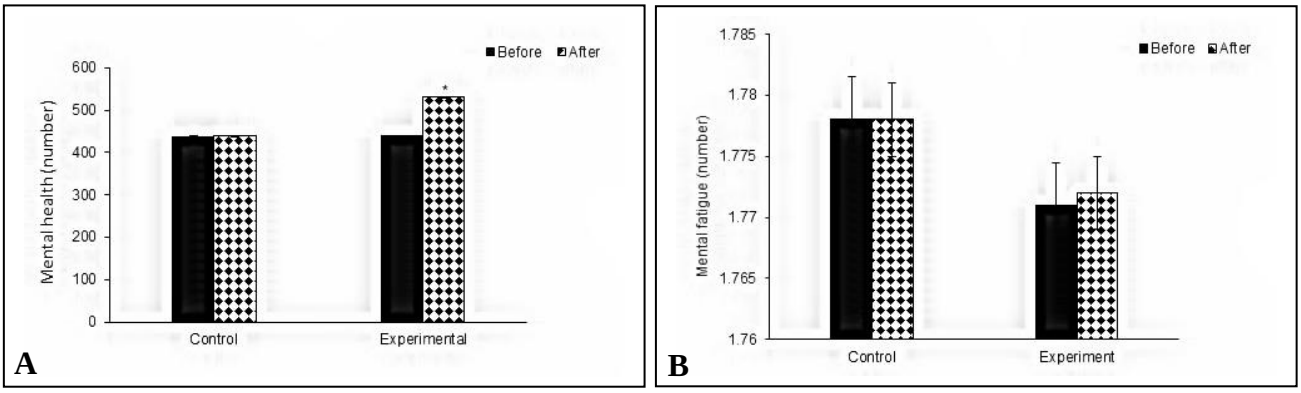

Figure 3. A. Mental health and **B.** Mental fatigue evaluations

Figure 3 is a representation of PASAT results for mental health and mental fatigue assessments in the control and experimental groups. The horizontal axis shows study (control and experimental) groups and the vertical axis shows mental health (the number of correct answers) and mental fatigue in number (the longest chain of incorrect answers). The mental health of the puzzle game players increased significantly after the game ($^{*}P<0.05$); however, their mental fatigue did not change after the game

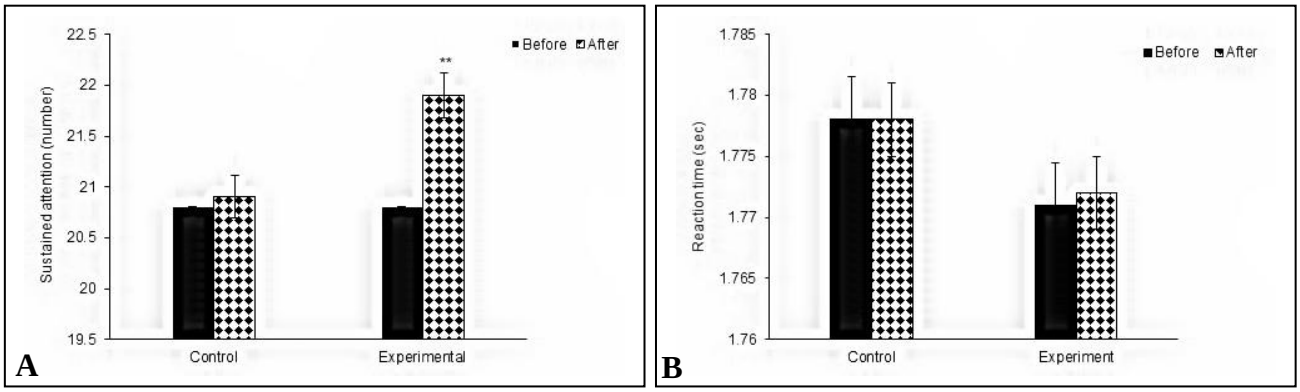

Figure 4. A. Sustained attention and **B.** Reaction time evaluations

Figure 4 depicts PASAT results for sustained attention and reaction time assessments in the control and experimental groups. The horizontal axis shows study groups (control and experimental). The vertical axis shows sustained attention in numbers (the longest chain of correct answers) and reaction time in seconds. The sustained attention of the puzzle game players increased significantly after the game ($^{**}P<0.01$); nevertheless, their reaction time did not change after the gameplay.

4. Discussion

Video games have diverse audiences in terms of age, gender, location, and time zone. The importance of video games lies in their impact on the CNS. Video games, featuring vibrant colors and breathtaking sound effects, provide the players with high excitement. This attraction and stretch of video games can efficiently contribute to the useful application of these games to achieve better cognitive and behavioral outcomes (20). Cortisol and alpha-amylase are the most biochemical factors whose secretion changes under the influence of environmental factors. Cortisol is known as the body's built-in alarm system (5, 6). The body has a stress management system known as the sympathetic-adrenal-medullary system. Activation of this system increases norepinephrine secretion, which in turn, boosts the concentration of salivary cortisol and alpha-amylase (measures of stress). There is evidence that chronic stress impairs mental ability. Abnormal stress causes psychological and neurological disorders. Different types of stimulus may cause various EEG signal changes, which reflect impaired electrical brain activity (1, 2, 7). The EEG signals provide useful information about brain function and are widely used for multiple medical applications and pathological diagnosis of brain and cognitive impairments and psychological problems (20). The results of previous studies have shown that video games change the levels of cortisol and alpha-amylase based on their game style, which is horrible and violent games significantly increase cortisol and alpha-amylase concentration (20, 21). Increased cortisol level is associated with impaired cognitive abilities as elevated cortisol levels create changes to help weaken positive cognitive elements and strengthen negative elements (1, 22). According to the literature, some types of runner and puzzle games reduce stress and alpha-amylase. This reduction empowers cognitive abilities. Therefore, this style of games (runners and puzzles), from a neurological point of view, plays an important role in increasing the cognitive capacity of players as a positive logic stress (8, 15). Hormonal tests performed in this study showed that after playing a puzzle game, the salivary levels of cortisol and alpha-amylase significantly decreased in players. According to the results of pieces of research, in puzzle games, stress and fear are not imposed on the player (unlike horror and violent games). Players lack the fear and stress of time constraints or the stress and fear of losing the game. Puzzle video games are designed based on mathematical logic, reasoning, problem-solving, and decision-making. In this respect, puzzle game playing activates the prefrontal lobe of the brain that is involved in thinking,

attention, and decision-making, leading to improved cognitive intelligence, learning abilities, and decision-making. There is scientific evidence that puzzle games, as a type of intellectual games that challenge the brain and enhance the functioning of cognitive indices, result in reduced activity of stress-fear system and the concentration of cortisol and alpha-amylase (5). Researchers have demonstrated that brainwaves signals of the players may change after playing video games based on the game style. Accordingly, changes in brainwave signals caused by horror and violent video games increase stress levels, whereas changes caused by runner and puzzle video games reduce stress. Consequently, the results of the hormonal analysis were consistent with those of the brainwave analysis (1, 20). Based on the analysis performed on the brain signals of puzzle game players, the attention index showed a significant increase after gameplay, which was consistent with the results of hormonal tests that also indicated an improvement in attention after playing the puzzle game. The results of the data obtained from PASAT for measuring cognitive indicators of mental health revealed an increase in these indicators. The mental fatigue of the puzzle game players did not change after the game. This result can be evaluated in a positive direction and means improving cognitive ability. The results of the study of continuous attention in players showed that the continuous attention of players after the puzzle game increased significantly, which means that brain teasers can strengthen people's attention and concentration. The last PASAT evaluation was assessing the response time of players after the puzzle game, which showed that the response time did not change after the game. Considering that there is no time limit and fear of losing in puzzle games, this finding can be justified. It can be concluded that playing puzzle video games can improve cognitive elements, such as attention and concentration among players. Moreover, puzzle games are indicated to reduce and control stress. This type of stress is called logic or useful stress. Puzzle games can be used to provide stress relief.

Authors' Contribution

Contributed to conceptualization and project administration: H. A., H. S., M. K., B. M. B., and M. R. D.

Contributed to writing the original draft: H. A., M. K., and S. G.

Contributed to the methodology, data collection, and investigation: H. T., H. A., and M. K.

Contributed to the review and edition of the manuscript: S. G., H. A., and M. K.

Ethics

The Ethics Committee of the Neuroscience Research Center of Baqiyatallah University of Medical Sciences (Ethics code: IR. BMSU.REC.12345) approved this study.

Conflict of Interest

The authors declare that they have no conflict of interest.

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References

1. Aliyari H, Kazemi M, Tekieh E, Salehi M, Sahraei H, Daliri MR, et al. The effects of fifa 2015 computer games on changes in cognitive, Hormonal and brain waves functions of young men volunteers. Basic Clin Neurosci. 2015;6(3):193.
2. Badcock NA, Mousikou P, Mahajan Y, De Lissa P, Thie J, McArthur G. Validation of the Emotiv EPOC® EEG gaming system for measuring research quality auditory ERPs. PeerJ. 2013;1:38.
3. Chaddock L, Erickson KI, Prakash RS, Kim JS, Voss MW, Vanpatter M, et al. A neuroimaging

investigation of the association between aerobic fitness, hippocampal volume, and memory performance in preadolescent children. Brain Res. 2010;1358:172-83.

4. Badcock NA, Preece KA, de Wit B, Glenn K, Fieder N, Thie J, et al. Validation of the Emotiv EPOC EEG system for research quality auditory event-related potentials in children. PeerJ. 2015;3:907.
5. Szubert MaWJ, editor Temporal difference learning of n-tuple networks for the game 2048. Computational Intelligence and Games (CIG), 2014 IEEE Conference 2014; IEEE.
6. Ballard ME, Wiest JR. Mortal Kombat (tm): The effects of violent videogame play on males' hostility and cardiovascular responding. J Appl Soc Psychol. 1996;26(8):717-30.
7. Ramirez R, Vamvakousis Z, editors. Detecting emotion from EEG signals using the emotive epoc device. International Conference on Brain Informatics; 2012: Springer.
8. Hamed Aliyari HS, Marjan Erfani, Elaheh Tekieh, Maryam Salehi, Masoomeh Kazemi, Mohammad Reza Daliri, Behroz Minaei, Hassan Agaei, Nahid Srahian, Mohammad Mehdi Hadipour, Meysam Ronagh, Asghar Ranjbar Aghdam. The Impacts of Video Games on Cognitive Function and Cortisol Levels in Young Female Volunteers. 2019;6(1):1-5.
9. Lupien SJ, Fiocco A, Wan N, Maheu F, Lord C, Schramek T, et al. Stress hormones and human memory function across the lifespan. Psychoneuroendocrinology. 2005;30(3):225-42.
10. Lupien SJ, Lepage M. Stress, memory, and the hippocampus: can't live with it, can't live without it. Behav Brain Res. 2001;127(1):137-58.
11. Tekieh E, Riahi E, Kazemi M, Sahraei H, Tavakoli H, Aliyary H, et al. Role of basal stress hormones and amygdala dimensions in stress coping strategies of male rhesus monkeys in response to a hazard-reward conflict. Iran J Basic Med Sci. 2017;20(8):951-7.
12. Seung HS. Learning in spiking neural networks by reinforcement of stochastic synaptic transmission. Neuron. 2003;40(6):1063-73.
13. Wang Y-K, Jung T-P, Chen S-A, Huang C-S, Lin C-T, editors. Tracking attention based on EEG spectrum. International Conference on Human-Computer Interaction; 2013: Springer.
14. Hamed Aliyari HS, Marjan Erfani, Mohammad Mohammadi, Masoomeh Kazemi, Mohammad Reza Daliri, Behrouz Minaei-Bidgol, Hassan Agaei , Mohammad Sahraei, Seyed Mohammad Ali Seyed Hosseini, Elaheh Tekieh, Maryam Salehi , Fereshteh Farajdokht. Changes in Cognitive Functions Following Violent and Football Video Games in Young Male Volunteers by Studying Brain Waves. Basic Clin Neurosci. 2020;11(3):279-88.
15. Hamed Aliyari HS, Sahar Golabi, Masoomeh Kazemi, Mohammad Reza Daliri, Behrouz Minaei-Bidgoli. The Effect of Brain Teaser Games on the Attention of Players Based on Hormonal and Brain Signals Changes. Basic Clin Neurosci. 2020.
16. Green CS, Bavelier D. Action video game modifies visual selective attention. Nature. 2003;423(6939):534-7.
17. Rodrak S, Wongsawat Y, editors. EEG brain mapping and brain connectivity index for subtypes classification of attention deficit hyperactivity disorder children during the eye-opened period. Engineering in Medicine and Biology Society (EMBC), 2013 35th Annual International Conference of the IEEE; 2013: IEEE.
18. Gevensleben H, Holl B, Albrecht B, Schlamp D, Kratz O, Studer P, et al. Distinct EEG effects related to neurofeedback training in children with ADHD: a randomized controlled trial. Int J Psychophysiol. 2009;74(2):149-57.
19. Lubar JF, Swartwood MO, Swartwood JN, O'Donnell PH. Evaluation of the effectiveness of EEG neurofeedback training for ADHD in a clinical setting as measured by changes in TOVA scores, behavioral ratings, and WISC-R performance. Appl Psychophysiol Biofeedback. 1995;20(1):83-99.
20. Aliyari H, Sahraei H, Daliri MR, Minaei-Bidgoli B, Kazemi M, Agaei H, et al. The Beneficial or Harmful Effects of Computer Game Stress on Cognitive Functions of Players. Basic Clin Neurosci. 2018;9(3):177-86.
21. Hamed Aliyari MK, Hedayat Sahraei, Mohammad Reza Daliri, Behrouz Minaei-Bidgoli, Sahar Golabi. Enhancement of Cognitive Index with Computer Game Using Brain Signals and Hormonal Analysis: Randomized Controlled Trial. J Res Rehabil Sci. 2019;15(3):144-51.
22. Aliyari H, Sahraei H, Erfani M, Mohammadi M, Kazemi M, Daliri MR, et al. Alterations of Cognitive Functions Following Violent and Football Video Games in Young Male Volunteers: By Studying Brain Waves. Basic Clin Neurosci. 2018;11.