Alterations of Cognitive Functions Following Violent and Football Video Games in Young Male Volunteers: By Studying Brain Waves

Running Head: The cognitive study of computer game players

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Highlights:

- The concentration of cortisol saliva was determined by the type of game (football and rough) in different players.
- Football game increased response speed and decreased sustained attention and mental fatigue.
- Violent game reduced reaction time and increased sustained attention and mental fatigue.
- The violent game engaged more brain regions than football game.

Plain Language Summary:

Publicity of video game contents is increasing and there is a high tendency toward video games. Moreover, evidence shows that video games can improve life skills and also affect cognition. The purpose of this study was to compare the effects of playing video games (football and violent games) on the stress hormone and cognitive performance of the players. Moreover, the effect of these two games on the brain activity was assessed using EEG. The results showed that these video games have different effects on the cognitive function of changes of the player.
Abstract

This research investigated the effects of violent and football video games on the cognitive functions, cortisol level, and brain waves. A total of 64 participants were competed in a single-elimination tournament. Saliva samples of all players were obtained before and after games for the assessment of cortisol levels. The cognitive performances of player were also assessed by PASAT cognitive test. Moreover, EEG recording was conducted during the games. Analysis showed that salivary cortisol levels were significantly decreased after playing both games. In addition, football game increased reaction time, while decreased sustained attention and mental fatigue. Conversely, following violent game, the reaction time was decreased and sustained attention and mental fatigue were increased. Furthermore, the results of EEG recording revealed that violent game engaged more brain regions than football game. In conclusion, violent game more effectively improved cognitive performances in the players than football game.

Keywords: Cognitive; Cortisol; PASAT; Football game; EEG; Violent game
Introduction

Nowadays, video games are not only the means of entertainment and relaxing, but also form one of the biggest industries in the world of information and communication technology (Newman, 2015). Publicity of video game contents is increasing and there is a high tendency toward video games in almost all children and adolescents (Lenhart et al., 2008).

A grow body of evidence showed that video games can improve life skills such as problem-solving, learning and memory, attention, decision-making, and self-confidence (Green and Bavelier, 2003; Aliyari et al., 2015). However, adverse effects of video games can lead to an inability to acquire personal and social life skills and may result in psychological disorder including stress and depression (Anderson et al., 2010). In addition, the type of video games can differently influence the audience. Recent studies have indicated that complicated, serious, strategic, and action games improve communications between different brain regions, especially the hippocampus, prefrontal cortex, cerebellum, and optic tracts (Spook et al., 2016; Anderson, 2004; Bisoglio et al., 2014; Buelow et al., 2015). It has also been shown that playing violent video games increases hostility and aggressive behaviors in the players (Hollingdale and Greitemeyer, 2013; Anderson and Carnagey, 2009). Moreover, it has been shown that several video games through continuous stimulation of the stress system, hypothalamus-pituitary-adrenal (HPA) axis influence the brain functions such as memory and decision-making (Lupien et al., 2005; Lupien and Lepage, 2001). Several studies have also reported that video games result in arousal and physiological reactions including increased heartbeat, blood pressure, and blood flow to muscles, as well as increased breathing responses (Hébert et al., 2005; Segal and Dietz, 1991; Wang and Perry, 2006).
Recording of the brain wave patterns by an electroencephalogram (EEG) is increasingly used by researchers in different areas as a conventional approach to assess the brain signals variations (Wehbe and Nacke, 2013; Aliyari et al., 2017). The EEG signal provides online and real-time information about the brain status and activity (Mullen et al., 2015). In addition, this method is currently used for cognitive state monitoring, clinical diagnostics, and therapeutics (Fairclough, 2009; Debener et al., 2012).

In the present study, we investigated the effects of different styles of video games, violent game and football game, on cognitive performance, hormonal change, and the brain activity during continuous playing the games using EEG in the players.

Methods

Participants

A total of 64 volunteer male participants (32 per each game) were registered and screened through an invitation for undergraduate students aged between 20-25 years. All participants had not played the game formerly. A research questionnaire which covered personal information, favorite games, game types, and the average time spent playing during a day were completed by the participants. In the beginning, players completed a form covering their personal information and were given the instructions to play each game before starting the game. All ethical considerations were met in the maintenance and working with the human subjects and prior to data collection an informed consent was obtained from each participant. This research carried out according to a certain code (ir.bmsu. rec. 1394. 112) of ethical rules.

Cortisol Assay
Saliva samples of all players were obtained before and after the games to measure the levels of cortisol. Salivary cortisol was measured using human cortisol enzyme-linked immunosorbent assay (ELISA) kits (Diagnostics Biochem Canada Inc, dbc).

**PASAT Assay**

The PASAT cognitive test was also conducted before and after the game to assess the cognitive performance of the participants and analyzed in PASAT software. In this test, 61 random numbers between 1 and 9 were presented to the subjects with 3-second intervals. The respondent had to sum every two consecutive final numbers and answer the question before a new number was announced. For instance, if numbers 2 and 6 were announced in the mentioned order, the respondent’s correct answer should be 8. The answers to questions were compared before and after playing the game. The mean time to respond (reaction time), the longest chain of correct answers (sustained attention), and the longest chain of wrong answers (mental fatigue) were also evaluated in this research.

**EEG recording**

**Data Collection**

In this study, EEG data were collected from 64 male participants. The participants were healthy with no history of mental disease and the average age of 20-25 years. For data collection, we used Emotiv EPOC headset, a recently developed wireless EEG acquisition device. The device had 14 electrodes located and labeled according to the international 10-20 system. The device further consisted of two reference electrodes for noise reduction. The available electrode positions for the device were as follows: AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC5, F4, F8,
and AF4. The EEG data was transmitted wirelessly to the Bluetooth device and saved on the hard disk for further processes.

**Data Classification**

In order to determine the type of the games the participants played from the EEG data, we assessed two well-studied features: arousal and valence. These features have been used in the context of emotion detection and proven to be useful in the emotion recognition (Choppin, 2000). Arousal refers to the state of excitability of a person and indicates whether the subject is alert or relaxed. On the other hand, affective valence indicates the positive or negative state of the mind. According to Ramirez & Vamvakousis study (Ramirez and Vamvakousis, 2012), we used following relations to extract arousal and valence features from the EEG data:

\[
\text{arousal} = \frac{\beta_{AF3} + \beta_{F4} + \beta_{AF4}}{\alpha_{AF3} + \alpha_{F3} + \alpha_{F4} + \alpha_{AF4}}
\]  
(Eq.1)

\[
\text{valence} = \frac{\alpha_{F4}}{\beta_{F4}} - \frac{\alpha_{F3}}{\beta_{F3}}
\]  
(Eq.2)

In which \(\alpha\) and \(\beta\) indicate the power of the signal in alpha (8-12Hz) and beta (12-30Hz) bands, associated with the electrodes denoted by subscripts.

To obtain the power of signals in the specific bands of interests, initially, we pre-processed the EEG signals. The main source of artifacts was mostly due to the eye blinks/movements, heartbeats, muscle activities, and power line noise. By referencing the EEG signals and exploiting a band-pass filter, the power of the signals in alpha and beta bands were extracted and the artifacts components were mainly removed. The level of arousal and valence in participants were determined using the power of EEG signals for specified electrodes in the alpha and beta bands.
The EEG signal was acquired by a sampling frequency of 128Hz. To analyze the EEG data, we apply a temporal window on the EEG signals and shift it every 0.0625 seconds. Therefore, each data point corresponds to the power of the signal in alpha and beta bands at the time interval of $[t,t+1]$ seconds for all channels and the next data points were generated with specific increments of $t$. The increments of $t$ should be small enough to capture fast dynamics of the brain activity. For this matter, we used increments of 0.0625 seconds.

In the present study, Support Vector Machine (SVM) classifier was used to discriminate the specific video-games (tasks) that the participants played. We utilized statistics toolbox in MATLAB and specifically SVM learning algorithms to implement the SVM classifier.

**Data Analysis**

Data was expressed as mean ± standard error of means (Mean ± SEM) and analyzed with SPSS software. The paired sample t-test analysis was used to determine the difference between before and after playing the games. In addition, $p<0.05$ was considered statistically significant.

**Results**

**Salivary Cortisol**

The results showed that playing the football video game significantly ($p<0.05$) decreased cortisol concentration as compared to before playing the game. However, after playing violent gameno significant difference in salivary cortisol was observed as compared to before the game (Fig. 1).
**Fig. 1** Effect of playing violent and football video games on salivary cortisol concentration. Data are shown as mean ± SEM, Paired t-test, *p<0.05.

**Mental health**

The number of correct answers to questions, index of mental health, provided by the participants playing violent game and football game revealed no significant difference between before and after playing the games (Fig. 2).
Fig. 2 Effect of playing violent and football video games on mental health. Data are shown as mean ± SEM.

**Reaction time**

Our results also showed that the mean time spent to answer reaction time of the players after playing football game was increased (p<0.05) indicating increased reaction time. However, a considerable decrease was observed in the reaction time of participants playing violent game demonstrating a high speed of response (Fig. 3).

![Reaction Time Graph](image)

**Fig. 3** Effect of playing violent and football video games on reaction. Data are shown as mean ± SEM. Paired t-test, *p<0.05.

**Sustained attention**

We also found that playing football game slightly increased sustained attention (the longest chain of correct answers) of the participants as compared to the pre-playing status. However, sustained attention of violent game players was slightly decreased after playing (Fig. 4).
Fig. 4 Effect of playing violent and football video games on sustained attention. Data are shown as mean ± SEM.

Mental fatigue

The result of paired t-test analysis revealed that mental fatigue (the longest chain of wrong answers) was slightly decreased in the players of football video game, whereas this indicator was slightly increased in the participants who played violent game (Fig. 5).
Fig. 5 Effect of playing violent game and football video games on mental fatigue. Data are shown as mean ± SEM.

**Brain mapping**

Given arousal and valence as main features, the average accuracy of the classifier was 78.76%. Since the training data consists of nearly equal data points of each class, the expected accuracy of a naïve classifier was 50%. The training data, support vectors, as well as the boundary of margin are depicted in Fig. 6.

![Plot of classification](image)

**Fig. 6** Plot of classification. Training data for football and violent video game are given in red and green, respectively. The encircled data demonstrate support vectors and the solid line illustrates the boundary of margin which the data is classified. Please note that the data
dispersion for two classes exhibits a clear distinction between two classes, i.e. football and violent games data.

Selecting other sets of features may result in better classifiers. Arousal and valence represent a family of features that exploit ratio of the power of distinct bands, e.g. $\frac{\beta}{\alpha}$. We used other feature candidates that may result in better classification accuracies. In the Table 1, the accuracies of classifiers for different feature sets have been summarized. Each vector comprises power of alpha and beta bands of the same electrode, e.g. $(\alpha_{AF4}, \beta_{AF4})$. The result of this analysis demonstrated that $(\alpha_{F4}, \beta_{F4}), (\alpha_{AF3}, \beta_{AF3}), (\alpha_{FC6}, \beta_{FC6}), (\alpha_{AF4}, \beta_{AF4})$ feature vectors offer classifiers with the accuracy of 88%, 87%, 84%, and 83%, respectively.

Table 1 Accuracy of the classifiers trained by $(\alpha, \beta)$ paired features for various channels.

<table>
<thead>
<tr>
<th>Electrodes</th>
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<td>Accuracy (%)</td>
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Furthermore, we used sole alpha and beta band powers to assess the detect ability of the tasks according to the level of relaxation and alertness, respectively. The logic behind this feature selection was the fact that alpha activity is associated with relaxed state of mind and is more prominent in the occipital and parietal lobes. On the other hand, beta activity is associated with alertness and active mental state and is predominantly observed in the frontal cortex. To this aim, trained SVM classifiers with two sets of features $(\alpha_i, \alpha_j)$ and $(\beta_i, \beta_j)$ in which $i$ and $j$ are subscripts
denoting distinctive electrodes. The accuracy of the classifiers is displayed in Table 2 and Table 3 for alpha and beta activities, respectively. Power of alpha band in AF3, FC6, F4, and AF4 channels are better features in which more accurate classifiers are trained. In addition, \((\alpha_{F4}, \alpha_{P7})\) and \((\alpha_{AF4}, \alpha_{F4})\) result in the best classifiers in the family of alpha band features with 90% accuracy. Moreover, the power of beta band in AF3, F7, FC5, and F4 channels (red columns and rows in Table 3) also are better features on which more accurate classifiers are trained. Moreover, \((\alpha_{F4}, \alpha_{P8})\) and \((\alpha_{F4}, \alpha_{FC6})\) results in the best classifiers in the family of beta band features with the accuracies of 87% and 85%, respectively.

**Table.2** The accuracy of the classifiers trained by alpha band features \((\alpha_i, \alpha_j)\) for various paired channels.

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Table 3 Accuracy of the classifiers trained by beta band features \((\beta_i, \beta_j)\) for various paired channels.

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| F4     | 87  | 89 | 88 | 87  | 88 | 90 | 87 | 88 | 89 | 88 | 89  |    |    |
| F8     | 83  | 77 | 75 | 76  | 78 | 78 | 75 | 73 | 77 | 76 | 83  | 88 |    |
| AF4    | 83  | 80 | 81 | 82  | 81 | 84 | 79 | 83 | 80 | 79 | 83  | 90 | 80 |

|        |     |    |    |     |    |    |    |    |    |    |     |    |    |
| AF3    | 76  |    |    |     |    |    |    |    |    |    |     |    |    |
| F7     | 74  | 73 |    |     |    |    |    |    |    |    |     |    |    |
| F3     | 77  | 77 | 73 |     |    |    |    |    |    |    |     |    |    |
| FC5    | 74  | 73 | 64 | 73  |    |    |    |    |    |    |     |    |    |
| T7     | 76  | 77 | 67 | 77  | 57 |    |    |    |    |    |     |    |    |
| O1     | 74  | 74 | 64 | 77  | 59 | 63 |    |    |    |    |     |    |    |
| O2     | 74  | 73 | 63 | 72  | 56 | 59 | 61 |    |    |    |     |    |    |
| P8     | 78  | 72 | 68 | 74  | 53 | 59 | 59 | 56 |    |    |     |    |    |
| T8     | 73  | 73 | 64 | 75  | 54 | 55 | 60 | 57 | 51 |    |     |    |    |
| FC6    | 76  | 75 | 65 | 74  | 63 | 64 | 67 | 64 | 68 | 65 |     |    |    |
| F4     | 81  | 80 | 79 | 81  | 80 | 84 | 78 | 79 | 84 | 80 | 85 |    |    |
| F8     | 78  | 74 | 68 | 75  | 59 | 62 | 60 | 59 | 63 | 59 | 65 | 87 |    |
Discussion

The results of the present study revealed a significant decrease in the stress hormone, cortisol levels, after playing football and violent games. Moreover, playing football game increased response speed and decreased sustained attention and the number of wrong answers as a marker of mental fatigue. However, the violent game reduced reaction time and increased sustained attention and mental fatigue. Furthermore, EEG recording demonstrated that violent game involved more brain regions than football game.

According to the previous studies, different types of video games significantly improve cognitive functions of the players in the long run (Gray, 2015; Spence and Feng, 2010). It has been proven that video games are included different forms of active learning. In other words, logical problem statement or problem-solving methods train and activate the central nervous system and improve cognitive functions more effectively than passive learning methods (Bisoglio et al., 2014). Moreover, learning takes different concurrent forms, which exponentially reinforce cognitive functions (Basile and Hampton, 2013). Most video games offer a dynamic level of difficulty, which not only increases the player’s skills but also constantly challenges the player. Video games use a combination of internal boosters (e.g. positive social interactions and feelings) and external forces (e.g. scores and medals). These motivational forces are precisely embedded in games and are accessed at different times on certain gradients to attract and encourage the audience to continue the game (Baddeley and Longman, 1978). Video games also constantly keep the brain’s reward system active, resulting in increased brain flexibility (Bao et al., 2001;
Kilgard and Merzenich, 1998). Numerous studies have examined the positive effects of action games on the brain functions and almost all of these studies suggested that these games improve the brain functions including contrast sensitivity, vision and power of vision (Green and Bavelier, 2007), peripheral vision (Buckley et al., 2010), time processing (Donohue et al., 2010), and many others. In the present study, results of comparing violent and football games revealed that these two games have a different effect on cognitive function of the participants.

Stress can disturb several cognitive factors such as memory, learning, attention, and concentration (Pechtel and Pizzagalli, 2011; Sandi and Pinelo-Nava, 2007). Cortisol is the most important hormone secreted by human adrenal gland in response to stress. When the brain considers a factor as a threat (a stress factor), the amygdala and hypothalamus are activated resulting in corticotropin-releasing hormone (CRH) and adrenocorticotropic hormone (ACTH) release (Keegan et al., 2007). Due to the fat-soluble nature of cortisol, it easily flows in the saliva. Therefore, salivary cortisol and its variations can be used as a measure of changes of plasma cortisol and activity of the HPA axis and the adrenal gland (Smeets et al., 2008; Kazemi et al., 2017). In addition, the adrenal-sympathetic stress axis, the second stress response axis, stimulates the sympathetic system and increases the secretion of noradrenalin (Chrousos, 2009; Feinstein et al., 2011). Previous studies found that salivary cortisol decreased after playing the games, which reflects tranquility of the players during the games. In this study, comparison of the effects of violent game and football game on the players indicated that salivary cortisol decreased after playing these games (Fig. 1). It seems that as a result of the game arrangement, players were highly concentrated on the accuracy of the game and the attention of gamers was increased. Hence, playing-induced emotions were suppressed in the gamers and the activity of stress systems are subsided (Feinstein et al., 2011).
PASAT is commonly used as a research software for examining the natural cognitive activity of the brain (Aliyari et al., 2015). It was used for the first time by the American army to assess the cognitive readiness of soldiers who survived blasts (Tombaugh, 2006). Results of various studies have revealed the ability of this test to assess cognitive factors including sustained attention, working memory, dual processing, information processing speed, speed of digit retrieval, speed of mathematical facts retrieval, and time components (Aliyari et al., 2015; Tombaugh, 2006). In this research, PASAT test also revealed the positive effects of football and violent games on cognitive function of the participants, and the mental health of the players was improved by playing both games (Fig. 2). Baniqued et al. (2014) found the positive effects of casual video games and demonstrated that casual games can improve cognitive functions (Baniqued et al., 2014). In a study by Nouchi et al. the effects of two extremely popular games, the Brain Age game (Nintendo Co. Ltd) and puzzle game called Tetris (Nintendo), on 8 major cognitive functions of the brain including short-term memory, working memory, executive functions, fluid intelligence, attention, processing speed, visual ability, and reading ability, were studied. Their findings revealed that Brain age game was related to improved executive functions, working memory, and processing time in young participants, whereas the puzzle game improved attention and spatial visual abilities of the players (Nouchi et al., 2013). In our study, PASAT test revealed that football and violent games had different effects on reaction time of the participants. Although football increased reaction time, sustained attention, and mental fatigue of the players, violent game reduced these factors following the game. It seems that being in the presence of stress deteriorates capability of the brain to collect exact and acceptable answers and disrupts memory resulting in increased the numbers of wrong answers (Lupien et al., 2005; Maheu et al., 2005).
Previous studies demonstrated that frontal lobe largely involves in the processing of attention and executive functions and playing video games can facilitate its function (Stuss and Alexander, 2000; Smith and Jonides, 1999). Several studies used EGG recording to explore brain activity during different computer games (He et al., 2008; Bakaoukas et al., 2016). In the current study, SVM classifiers were used to classify EEG signals based on various spectral features. All of the proposed features contributed to a significant accuracy in the classification of the EEG signals. Among these feature families, paired alpha band features resulted in most accurate classifiers and suggested a variety of features with significantly accurate classifiers. Moreover, paired beta band features presented classifiers with proper performance, even though the results were not as good as previous feature family. Interestingly, the best performance of classifiers occurred in frontal channels (AF3, AF4, FC6, and F4 for paired alpha band features and AF3, F7, FC5, and F4 for paired beta band features). It seems that these two games provoked distinct cognitive demands which in turn reflected differently in the EEG recordings suggesting that cognitive signatures of games may be detectable in EEG signals. Another exciting fact about these families of features was the fact that the alertness or relaxation state of the mind is a reliable candidate to train accurate classifiers (Aliyari et al., 2017; Aliyari et al., 2018). In this case, the paired alpha band features lead to more accurate and robust results, suggesting that the relaxation pattern predicts type of the tasks more accurately. Further research is needed to validate the latter prediction behaviorally. Furthermore, F4 channel is an electrode that presents reliable features both in alpha and beta bands proposing the potential of this channel in assessing cognitive task using EEG signals more precisely. The (α, β) pairs also offer dependable features in the frontal channels especially in AF3, FC6, F4, and AF4 channels. Again, F4 feature presents significant potential in the precise classification of EEG signals. Additionally, arousal and valence features illustrated
acceptable classification accuracy, but less than previous features; however, their significance was due to the fact that these features are more indifferent from subjects to other subjects. Due to the difference in electrode installation and skin impedance, EEG signals may differ in amplitude and frequency content and different levels of signal to noise ratio. This may make former features useless because due to individual difference and the signals may be already distinct enough hence the difference in EEG pattern would not be a matter (Aliyari et al., 2017; Aliyari et al., 2018). On the other hand, ratio features like arousal and valence could resolve this problem, since they are normalized and hence more indifferent between subjects. It is important to take this problem into our consideration when working with specific scenarios depending on our specific application.

**Conclusion**

Our data indicated that football and violent games decreased salivary cortisol levels. However, these two games had different effects on cognitive performance of the players. Response speed, sustained attention, and mental fatigue were increased by playing football game, whereas these factors were decreased after playing violent game. Moreover, we found that spontaneous brain activity was changed in response to video games. These positive and negative effects show the necessity of further research, further investment, and proper policies which may result in more comprehensive results.

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**Conflict of interest**
The authors have no potential conflict of interest pertaining to this journal submission.

References


