

# Fear stress in computer games caused brain waves, oxytocin and brain-derived neurotrophic factor changes among woman



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## ABSTRACT

**Introduction:** Stress and fear caused by computer games have been shown to have various effects on the cognitive system. This work was aimed to investigate the effects of short-time horror computer games on cognitive indicators.

**Methods:** A total of twenty female subjects were recruited and divided into experimental and control groups. All required tests were performed before and after the intervention (playing or watching horror game) on the control and experimental groups. The saliva samples were collected before and after the intervention to measure levels of cortisol and alpha-amylase. Also, blood was taken before and during the game from each subject to evaluate plasma levels of oxytocin and brain-derived neurotrophic factor. The Brain waveforms were acquired by Emotive brain signal recording device before and after the intervention. Data analysis was conducted using R and MATLAB software.

**Results:** The cortisol and alpha-amylase levels were shown to significantly increase after the horror game playing. Also, the levels of oxytocin were significantly higher after the experimentation. The levels of brain-derived neurotrophic factor were displayed to reduce after the experimentation. The results of the brainwave analysis revealed that the average stress index was significantly higher, while the average attention index was lower after playing the game. No significant difference in the study variables was observed in the control group.

**Conclusion:** Horror computer games may have adverse effects on the activity of the stress system in the central nervous system. Fear-induced stress was shown to relatively undermine some cognitive elements.

### Keywords:

Cortisol  
Alpha-amylase  
Oxytocin  
Horror computer game  
Brain-derived neurotrophic factor

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## Introduction

Computer games have been shown to have various effects on cognitive elements and lead to biological changes. This has allowed the development of a wide range of games with different styles and content for various needs. Computer games with different content may have diverse cognitive effects on the audience. Thus, the contents and styles of computer games have significant impacts on the overall health of the gamers. Therefore the pathological use of computer games and related health impacts on gamers should be investigated by health experts (Aliyari et al., 2020; Primack et al., 2012; Tang and Fox, 2016). Computer games may have positive or negative cognitive effects or both. Computer games as an environmental factor can stimulate the endocrine system. Changes in the normal secretion of hormones, including cortisol and oxytocin (OXT), as well as enzymes such as salivary alpha-amylase (s-AA) may lead to behavioral and cognitive impairments. According to the literature, environmental stimuli can cause changes in the secretion of hormones such as cortisol and impaired secretion of these hormones may lead to behavioral and cognitive disorders in humans and animals (Aliyari et al., 2019a; Aliyari et al., 2019b). Stress is linked with activation of the hypothalamic–pituitary–adrenal (HPA) axis (Aliyari et al., 2019c). Hypothalamus and brain stem directly control the stress responses. Computer games change the levels of cortisol as a stress marker and alpha-amylase as a fear marker (Dickerson and Kemeny, 2004; Haddad et al., 2002; Nater and Rohleder, 2009). It is important to note that chronic stress may generate free radicals of reactive oxygen species, resulting in impaired dendritic connections and toxicity inside the neurons (Ma et al., 2010). Moreover, stimulation of the HPA system activates the neuro-pituitary to release OXT. According to literature, this hormone plays a facilitating role in social relationships, decision-making, reduction of stress, anxiety and has a therapeutic effect on psychiatric disorders such as schizophrenia and autism. It is interesting to note that OXT is thought of as a marker of love and hatred (Guastella and Hickie, 2016; Heinrichs et al., 2003). Brain-derived neurotrophic factor (BDNF) plays an important role in neurological development and activity of neurons. As such, increased BDNF increases the ability and the reconstruction of brain neurons, whereas decreased BDNF may cause the inability to rebuild the dendritic spine connections and

prevent the creation of new synapses between brain neurons leading to mental illness, such as depression and schizophrenia (Angelucci et al., 2005; Lu et al., 2013).

There is evidence that environmental factors cause changes in brain waves and indicators of cognitive ability (Aliyari et al., 2019b; Aliyari et al., 2015). Computer games also cause changes in brain signals. Brainwave signal test is the only way to reveal cognitive indicators online (Aliyari et al., 2015; Bos et al., 2010; Haynes and Rees, 2006). Based on the content of computer games, cognitive indicators can be considered in a positive or a negative direction in brain signals. Based on the analysis of data obtained from the processing of brainwave signals, the game can be pathologically evaluated (Griffiths, 2002; Krepki et al., 2007; Tan and Nijholt, 2010). The present study was carried out to investigate the effects of short-time horror computer games on cognitive indicators through performing biological tests and brainwave signal analysis.

## Materials and methods

### *Study protocol*

Thirty women with a mean age of 25 years participated in the study by recall. After screening, 10 people in the experimental group and 10 people in the control group were studied. Ten people who did not meet the inclusion criteria were excluded from the study. It was explained to all participants in a confidential manner and after signing the informed consent, based on the entry and screening criteria, individuals entered the study. The study was conducted at the Neurogame laboratory. All ethical standards regarding blood sampling and other types of tests were observed under the international laws and regulations with an ethics code from Baqi-yatallah University of Medical Sciences ethics committee (Ethics code: IR. BMSU.REC.12345). First, all participants were required to complete forms consisted of demographic data, general and specific information regarding the specific game. Then, a total of twenty selected subjects were divided into an experimental group (n=10) and control group (n=10). All required tests including biological tests (salivary cortisol and salivary alpha-amylase; serum levels of oxytocin and serum levels of BDNF) and brainwave signal tests were performed before and after the experimentation on the experimental group. Also, the tests were performed on the control group in which participants were not allowed to

play the game. The inclusion criteria were not being in the menstrual phase, no assigned diseases and no illicit drug use. Before and after the experimentation, saliva samples were collected from all the participants in the study in Falcon tubes of 10ml volume and were maintained at  $-20^{\circ}\text{C}$  in the fridge. On the experiment day, samples first were melted at room temperature and after centrifuging at 3000g for 5min, 20 $\mu\text{l}$  of each sample were separated for testing. Then, the cortisol ELISA kit was used for the measurement of human salivary cortisol (Cortisol ELISA KIT, Diagnostics Biochem Canada Inc, dbc), and specific salivary kit (Alpha-Amylase ELISA KIT, Pars Azmoon Inc.) for the measurement of salivary alpha-amylase (sAA). A total of 5ml of blood was taken during each intervention from the femoral artery of each subject and kept in heparinized tubes. The OXT and BDNF levels were measured using a specific ELISA kit based on kit-specific protocol. The horror game was played (the experimental group) or watched (the control group) for 35min. The EEG signals were recorded online before, during and after playing the horror game using EEG-Emotive device to record the subject's brainwaves. Then extracted data were filtered and the noise and disturbances of the signals were removed and the required properties were extracted and classified by different machine learning algorithms. Eventually, data were analyzed and algorithms were tested.

#### Stress and attention quantification

The results of previous studies showed that the activity of the right hemisphere in the frontal lobe is significantly higher in individuals with social stress and anxiety or those exposed to social threats. Accordingly, these results and neurofeedback references suggest that the best way to assess the level of stress is to define the proportion of brain activity between the two hemispheres in frontal lobe (Aliyari et al., 2019b).

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

It should be noted that the activity of the right hemisphere relative to the left indicates the relatively higher activity of alpha in the left hemisphere. According to the formulation for the stress index, the brain signals of different people were analyzed.

All BCI, clinical and lab researches employ theta band in FC region and ratio of  $\frac{\theta}{\beta}$  to measure attention.

Increased energy of theta in FC region and the ratio of  $\frac{\theta}{\beta}$  were shown to decrease attention.

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

Where, pow (Ab) is the signal power of electrode A in band b

#### Statistical analysis

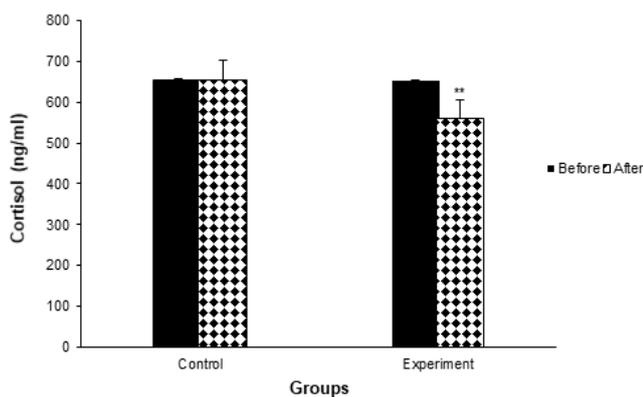
Data analysis was performed using R and data on brainwaves functions were analyzed by MATLAB. The data were expressed as mean $\pm$  SEM. The paired t-test was used to determine the significance of the within-group differences. The significance level was set at  $P \leq 0.05$ .

## Results

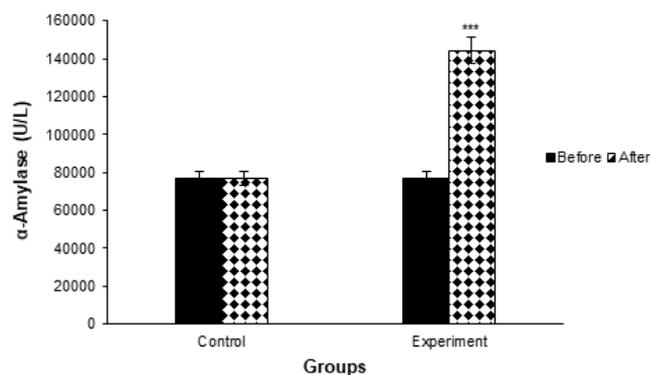
The salivary level of cortisol was shown to significantly increase after the playing horror computer game ( $P \leq 0.01$ ). However, there was no significant difference in the control group (Figure 1). The sAA levels were shown to significantly increase after the experimentation in the experimental group ( $P \leq 0.001$ ). However, there was no significant difference in the control group (Figure 2). Also, the serum levels of OXT were significantly higher after the experimentation in the experimental group ( $P \leq 0.05$ ), with no significant difference in the control group (Figure 3). The serum levels of BDNF were displayed to reduce after the experimentation in the experimental group ( $P \leq 0.05$ ), with no significant difference in the control group (Figure 4). The results of brainwave analysis also revealed that the average index of stress was significantly higher ( $P \leq 0.01$ ), while the average index of attention was significantly lower ( $P \leq 0.01$ ) after playing the game. However, no significant differences were observed in the control group (Figures. 5 and 6).

## Discussion

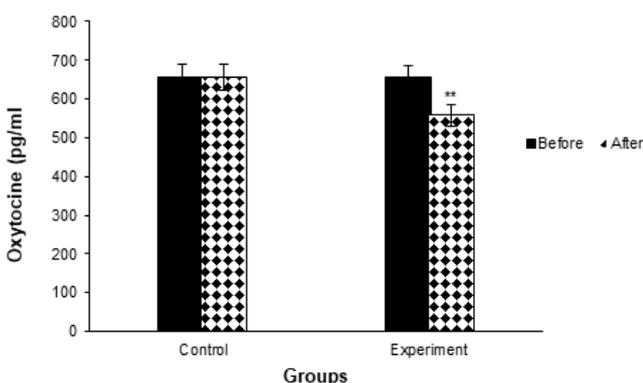
According to literature, the increasing variety of computer games with specific playing styles and different contents have different cognitive and physiological effects on the audiences (Anderson, 2004; Anderson and Bushman, 2001; Ivory and Kalyanaraman, 2007). The findings of the present study suggest that the level of sAA was significantly higher after playing the horror



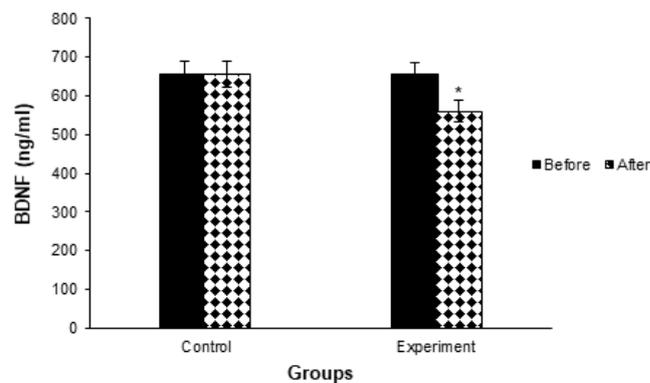
**FIGURE 1.** Changes in salivary cortisol levels in the experimental group. The salivary levels of cortisol were significantly higher after playing the horror game in the experimental group (\*\* $P \leq 0.01$ )



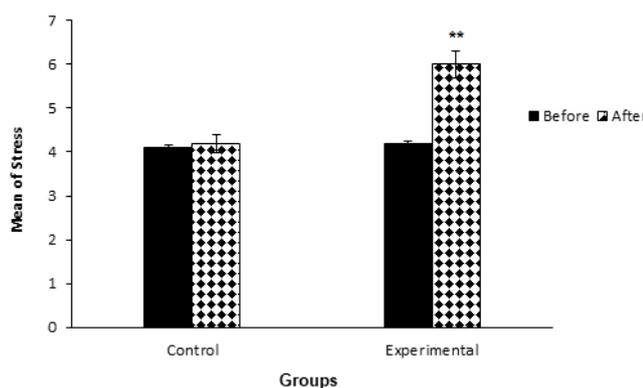
**FIGURE 2.** Changes in salivary alpha-amylase levels in the experimental group. The salivary levels of alpha-amylase were significantly higher after playing the horror game in the experimental group (\*\*\*) $P \leq 0.001$ )



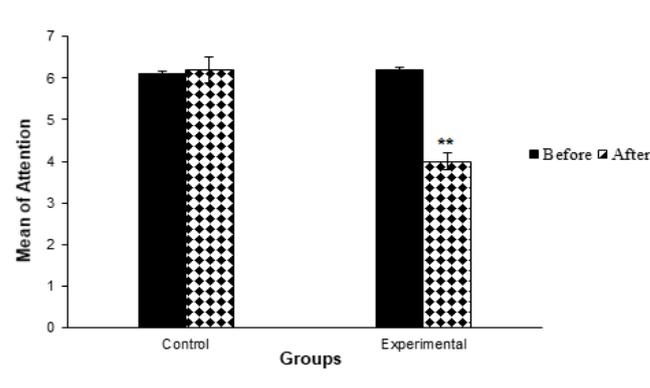
**FIGURE 3.** The serum concentration of oxytocin in the experimental group. The serum levels of oxytocin were significantly higher after playing the horror game in the experimental group (\*\* $P \leq 0.01$ )



**FIGURE 4.** Changes in serum level of brain-derived neurotrophic factor in the experimental group. The serum levels of BDNF showed a decreasing process after playing the horror game (\* $P \leq 0.05$ ).



**FIGURE 5.** Changes in stress index level in the experimental group (\*\* $P \leq 0.01$ ). The average changes in power of stable brainwaves energy, construct of stress among players, showed an increasing process after playing the horror game (\*\* $P \leq 0.01$ )



**FIGURE 6.** Changes in attention index level in the experimental group. The average changes in the power of stable brainwaves energy, construct of attention in players, showed a decreasing process after playing the horror game (\*\* $P \leq 0.01$ )

game. However, the level of sAA was not significantly different after watching the horror game in the control group (Nater and Rohleder, 2009). Increased levels of sAA reflects abnormal activity of the amygdala. Besides, horror computer games may act to significantly increase cortisol secretion through stimulation of the HPA axis.

In fact, playing horror games activates the fear-stress system leading to increased secretion of cortisol and alpha-amylase (Nater et al., 2006; Sharma et al., 2006). A number of previous studies showed that stress may have positive or negative impacts on the cognitive abilities of the individuals. according to studies by Neurogame, fear

stress is a type of destructive stress that impairs cognitive functions of the players (Aliyari et al., 2018; Lupien et al., 2009). Previous studies also revealed that the level of OXT is significantly increased after playing horror games in experimental subjects. Oxytocin is a neuropeptide hormone produced in the hypothalamus and released by the neurohypophysis. According to research, this hormone plays a key role in social communication, satisfaction and treatment of people with mental or psychiatric disorders. Results of many studies have shown that fear-derived stress and anxiety cause an increase in oxytocin release to deal with the disasters (Aliyari et al., 2018; Lupien et al., 2009). It has also been shown that increased levels of cortisol may cause a marked increase in OXT release (Gordon et al., 2010; Heinrichs et al., 2003). Hence, increased levels of OXT after playing the game can be attributed to increase cortisol levels in the experimental group. Accordingly, increased levels of OXT may limit the activity of fear-stress system after playing horror games. Oxytocin is secreted in states of high love, fear and stress to balance the stress system (i.e. cortisol). When the stress system and the sympathetic system are severely stimulated, the hormone oxytocin is released to further balance the body's activity so that cortisol levels return to normal (Varga and Kekecs, 2014). However, the secretion of OXT largely relies on gender, that is OXT release is remarkably higher among women than in men. Studies have shown that the impact of computer games depends on many factors including gender, biological status of the player and length of playing (Driscoll et al., 2005; Lupien et al., 2009). The levels of BDNF were shown to decrease after playing horror games in the experimental group, with no significant difference in the control group. Every person loses thousands of brain cells per day. BDNF plays an important role in the maintenance and reconstruction of brain neurons. This factor can be recognized as a brain fertilizer. BDNF can override the negative effects of stress. However, high levels of cortisol inhibit BDNF production, resulting in less production of new brain cells. Therefore, a low levels of BDNF is associated with psychological conditions, including depression, obsessive-compulsive disorder, schizophrenia, dementia and Alzheimer's disease (Angelucci et al., 2005; Lu et al., 2013).

Brainwaves recording test is the only non-aggressive method to display and measure emotions such as fear,

stress and attention. EEG signals represent the electrical activities of the brain. These signals contain useful information regarding brain function and can be widely utilized in many different fields, especially medical applications and recognition of various pathological conditions and brain abnormalities (Hassan et al., 2018; Ubuluz et al., 2018). Results from brainwave signal analysis revealed a higher level of stress and signal power after playing a horror game. Moreover, these analyses showed lower levels of attention after playing a horror game. According to literature, the level of cortisol considerably increases during playing runner games which may be due to the limited duration of these types of games. As such, limited length of playing further activates fear-stress system resulting in improved attention, response speed and hand-eye coordination among players, which is known as limit stress (Aliyari et al., 2018). Unlike fear stress, the limit stress contributes to decrease attention among players. Puzzle games are designed based on logic, reasoning and problem-solving approaches. During playing these types of games, the stress system is inactivated and levels of cortisol and alpha-amylase decrease due to activation of decision-making spots of the brain such as frontal lobe. This type of stress is called logic stress (Russoniello et al., 2009). The findings of the present study show that cortisol and sAA levels significantly increased after experimentation in the experimental group; however, no significant difference was observed in the control group in levels of cortisol and sAA. Moreover, results from brainwave signal analysis revealed increased average stress power after playing horror games. Besides, after playing a horror game, increased levels of OXT in female players were observed and decreased levels of BDNF led to impaired synaptic connections and reduced activity of neurons. It can be concluded that playing horror games can be harmful to brain neurons. Since during the game, players are constantly excited, stressed and fearful, the HPA axis of the adrenal gland is on standby and so we observed abnormal release of cortisol as shown by increased levels of salivary cortisol in our study. However, the impact of computer games differs depending on the length of play (van Stegeren et al., 2008; Yuen et al., 2012). There is scientific evidence that playing, in the long run, disrupts cognitive elements such as concentration, attention, decision making, memory, and learning. Fear stress may impair the stress-fear system and damage neuromuscu-

lar synapses leading to harmful consequences, such as the appearance of violent behavior, anxiety and depression (Aliyari et al., 2018; Duman and Aghajanian, 2012; Hunter et al., 2009; Vasterling et al., 1998).

## Conclusion

The results of this study showed that levels of cortisol and sAA significantly increased after experimentation, indicating abnormal activity of fear-stress system and impaired nervous system of subjects in the experimental group. Furthermore, OXT release is increased in response to increased cortisol secretion. Also, decreased levels of BDNF during playing horror games is associated with impaired reconstruction of new neurons and synapses leading to decreased positive cognitive elements such as attention. Accordingly, brainwave signal analyses reveal increased stress and decreased attention after playing horror games which supported these findings. Thus, further research is required to precisely examine various pathological conditions of computer games, especially horror and brutal games to prevent negative cognitive features and improve the positive cognitive features of the games.

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## Conflict of interest

The authors declare that they have no conflict of interest.

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