A STUDY ON THE NEUROENDOCRINE HORMONE LEVELS AND PSYCHOPHYSIOLOGICAL PARAMETERS IN EXCESSIVE COMPUTER GAME PLAYING YOUNG MALE ADULTS

by

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ABSTRACT

A STUDY ON THE NEUROENDOCRINE HORMONE LEVELS AND PSYCHOPHYSIOLOGICAL PARAMETERS IN EXCESSIVE COMPUTER GAME PLAYING YOUNG MALE ADULTS

Excessive gaming may be considered a behavioral addiction similar to gambling. In order to test this hypothesis, the activity of the autonomic nervous system was recorded (heart rate and skin conductance) and neuroendocrine hormone levels were measured (cortisol, dopamine, β-endorphin) in 16 subjects who played computer games excessively ($>$28 hrs/wk) and in 16 subjects who played infrequently (ages: 19-27). ANOVA was used to study the factor effects.

The excessive players had significantly higher skin conductance fluctuations than non-excessive players. Their mean heart rates were also marginally higher than the heart rates of non-excessive players. For both subject groups, heart rate fluctuations were lower in game sessions compared to control sessions. Cortisol levels were found to be decreased in both groups after each session compared to the beginning of the session. In excessive game players, skin conductance fluctuations and β-endorphin levels were negatively correlated; heart rate mean and dopamine levels were positively correlated. In non-excessive players, skin conductance fluctuations and cortisol levels were positively correlated.

These results show clear differences of autonomic responses in excessive game players. Although we could not find a direct difference in excessive players regarding hormone levels, correlations show evidence of significant changes in their neuroendocrine systems.

Keywords: Computer game addiction, neuroendocrine, cortisol, β-endorphin, dopamine, psychophysiology, skin conductance, heart rate.

ÖZET

AŞIRI BİLGİSAYAR OYNAYAN GENÇ ERİŞKİN ERKEKLERDE NÖROENDOKRİN HORMON SEVİYELERİNİN VE PSİKOFİZYOLOJİK PARAMETRELERİN İNCELENMESİ

Aşırı bilgisayar oyunu oynama da kumar gibi davranışsal bağımlılık olarak düşünülmektedir. Bu hipotezi test etmek için 16 aşırı oyun oynayan (>28 saat/hafta) ve 16 nadiren oynayan deneklerin (yaş: 19-27) otonom sinir sistemi aktivitesi (kalp atış hızı ve deri iletkenliği) kaydedildi ve nöroendokrin hormon seviyeleri (kortizol, dopamin, β-endorfin) ölçüldü. Değişkenlerin etkilerini incelemek için ANOVA kullanıldı.

Aşırı oynayan deneklerin deri iletkenliğindeki salınımları normal deneklere göre daha yüksek çıkmıştır. Normal denklerin kalp ritm hızı değerleri aşırı bilgisayar oynayan deneklere göre daha az gözükmektedir. Hem normal hem aşırı oyun oynayan deneklerin kontrol seansına nazaran oyun seansı sırasında kalp ritm hızı salınımları azalmaktadır. Ancak oyun ve kontrol seansları arasında sadece kortizolun her seans sonrasında öncesine nazaran düştüğü görülmektedir. Aşırı oyun oynayan deneklerde deri iletkenliği salınımı ve β-endorfin arasında negatif korelasyon, kalp ritm hızı ve dopamin arasında ise pozitif korelasyon bulunmuştur. Yalnızca normal deneklerde ise deri iletkenliği salınımları ve kortizol arasında pozitif korelasyon bulunmuştur.

Bu sonuçlar aşırı oyun oynayan deneklerin otonom tepkilerinde belirgin farklar olduğunu göstermektedir. Aşırı oyun oynayan deneklerde hormon seviyeleri açısından doğrudan fark bulunamamasına rağmen istatistiksel anlamlı korelasyonlar dolaylı olarak kanıt sunmaktadır.

Anahtar Sözcükler: Bilgisayar oyunu bağımlılığı, nöroendokrin, kortizol, β-endorfin, dopamin, psikofijyoloji, deri iletkenliği, kalp atış hızı.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS

p	Significance value

LIST OF ABBREVIATIONS

HPA	Hypothalamic-pituitary-adrenal
CRH	Corticotropin-releasing hormone
ACTH	Adrenocorticotropin hormone
VTA	Ventral tegmental area
NAc	Nucleus accumbens
POMC	Proopiomelanocortin
RIA	Radioimmunoassay
ECLIA	Electrochemiluminescence immunoassay

1. INTRODUCTION

1.1 Motivation and objectives

Computer games have become an increasing part of many young people's daily lives. Since the 1980s, the impact of personal computers and Internet have been studied by researchers. Daily activities at home, work, and school are increasingly dependent upon computers. From the survey of the National Statistics Office on the use of Internet among children and youths in 2005, more than 50 percent of them across UK used the Internet for computer games [3]. The problems derived from excessive computer game playing among secondary school students were studied and it was found that about 16.6 percent of the students were considered to be "addicted" to computer games [4]. Because game addiction is a relatively new concept, more studies need to be conducted to evaluate its physiological psychosocial effects on its users.

In this thesis, we hypothesize that excessive computer game playing is a behavioral addiction like gambling and activates the dopaminergic reward system. In order to test this hypothesis, heart rate, skin conductance and hormone levels (cortisol, β-endorphin, dopamine) were measured from excessive and non-excessive game players. Significant differences between the subject groups which point out to the dopaminergic reward system will support this hypothesis that excessive computer game playing can be considered as a behavioral addiction. In contrast, one would expect no differences during control sessions not related with game playing. An increase in the heart rate and skin conductance may be expected with excessive game players. If there is an increase in dopamine level, it would show that the reward system neurons are activated. Similary, increase in cortisol levels would suggest that the HPA axis is activated. β-endorphin levels show the activity of the endogenous opioid system.

The results of this work may play an important role in the identification of impulse-control syndromes and help to understand the underlying mechanisms of game

addiction. Furthermore, this may help in the diagnosis and treatment of excessive computer gaming in psychiatry.

2. BACKGROUND

2.1 Computer game addiction

Male adolescents like playing computer games more than females since most games, e.g. first-person shooters, role playing, sport and strategy games, contain topics that are more interesting to males. Excessive playing starts with their interest in new technologies. Diagnostic criteria of identifying computer game "addiction" of adolescents have not been formulated. The ones who can limit and control themselves, and stop playing when they are interrupted by any event in real world can be classified as normal. Computer game "addiction" can be considered similar to the pathological gambling in a way that the players feel satisfied when they win games. According to a survey in 2003, with over 1000 participants ranging in ages from 10 to 24 years old, it was found that young people play video games because of competition to prove to others who is best, challenge reaching the next level, social interaction to meet their needs for interpersonal relationships, relaxation to avoid stress or responsibilities, fantasy to do things that they would not be able to do in real life, and general arousal, excitement and pleasure [5].

"Addicted" people want to play games all times and they can play continuously without giving any break, not even for basic needs like eating or sleeping. They may try to decrease the time spent on the computer, but are unable to succeed or they deny the problem. When they do not spent time on the computer, they may show inability to control their behavior, they have feelings of withdrawal, anxiety, and depression [6]. Most excessive players have past histories of psychological problems, including anxiety, poor self-esteem, and depression. Computers are used to compensate for feelings of loneliness, depression, marital and work problems, poor social life, and financial problems. An individual's need for tension reduction has been described as a mediating factor in addiction and a possible contributing characteristic of excessive gaming.

A study of New Zealand university students found that individuals who suffered from problem gambling were more depressed and do things suddenly without thinking about them carefully, compared to their nonproblem gambling peers [7]. Problem gamblers in this study reported tension, guilt, and feeling to prove themselves to others. The quality of interpersonal relationships decreases and the amount of social anxiety increases as the amount of time spent for playing increases [8]. Many parents have found it difficult to distract their children away from video games, and these games have been associated with many adverse effects as failing school, family and social problems. Additionally, some studies have investigated the influence of video games on aggressive behavior in children. Gaming may increase the aggressive potential in computer users. It has been reported that rewarding violent action increases aggressive behavior, hostile emotions as well as aggressive thinking [9].

It was proposed that playing games for a long period increases the risk of mental health problems. The player usually ignores his personal healthcare, relationship with his family and other people, quits studying and working. There may be physiological symptoms such as dry eyes, carpal tunnel syndrome, repetitive motion injuries in the hands, wrists, neck, back and shoulders, migraine headaches, and numbness and pain in the fingers, photosensitive epilepsy, obesity and enhancement of allergic responses [10].

2.2 Neuroendocrine hormone system

Addiction is one of the most important topics in neuroscience. Excessive gaming may be considered a behavioral addiction similar to gambling. Some biological parameters need to be studied more in depth in order to establish that excessive playing is a biological addiction.

The HPA axis is a central control and regulatory system of the organism. It is vital for supporting normal physiological functioning and it plays essential role in stress regulation. The hypothalamus, the pituitary gland, and the adrenal cortex form

this hierarchical hormone system (Figure 2.1).

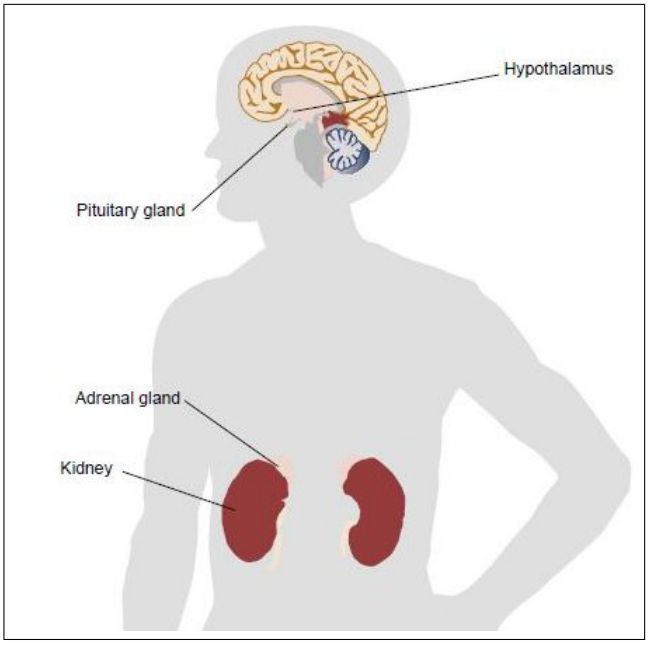

Figure 2.1 Location of the components of HPA axis [1]

It was found that addictive substances activate the HPA axis, and result in both positive and negative reinforcement of drug use [11]. Animal studies have shown that exposure to drug for long periods cause pathological neuroadaptation in the HPA axis and in the behavioral stress response [12]. CRH is produced in the hypothalamus under stress conditions. The brain stem, in particular the locus coeruleus and the nucleus tractus solitarius, the amygdala, and hippocampus are the main brain areas where important stimulation or inhibition of the hypothalamus takes place. CRH is transported to the anterior pituitary, where the POMC is cleaved into ACTH and ACTH then is released into the bloodstream. After release, ACTH is transported via the bloodstream to the adrenal cortex and triggers the secretion of glucocorticoids, principally cortisol. The increased level of cortisol affects the dopaminergic neurons in the VTA and NAc to release dopamine (Figure 2.2) [13].

The endogenous opioid system is involved in many physiological activities, including homeostatic functions such as temperature, food, and water regulation, normal pituitary function, regulation of the response to stress and painful stimuli, and sexual behavior. In addition, it is important in controlling and modulating reward processes in

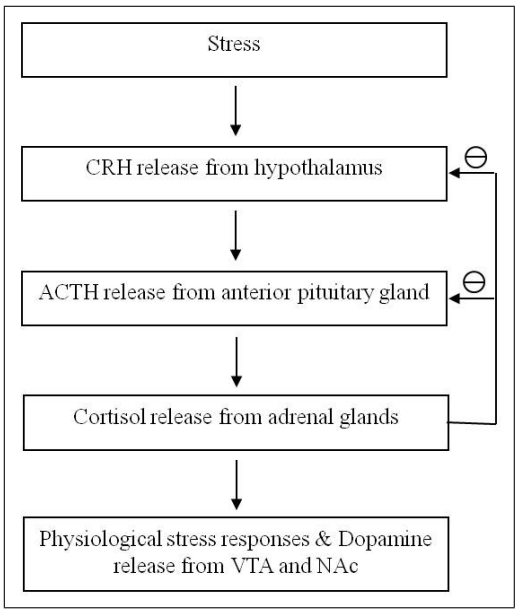

Figure 2.2 The major components of HPA axis

the brain [14]. It regulates mesolimbic dopamine and also modulates the HPA axis responses to stress, both of which are related to drug and alcohol reward. There are three major families of endogenous opioids: the enkephalins, the dynorphins, and the endorphins. Each family is derived from a specific precursor protein. β-endorphin is derived from POMC. POMC is synthesized only in limited areas of the brain. β-endorphin neurons are located mainly in the ventromedial arcuate nucleus in the hypothalamus but project to many brain areas, including the VTA, NAc, amygdala, and other parts of the hypothalamus [15].

Stress also stimulates the β-endorphin system. CRH increases the release of β-endorphin in the anterior pituitary and ACTH release from the anterior pituitary also leads to the release of β-endorphin. Endogenous opioids are pepdides produced in many organs but mostly by the pituitary gland and the brain. Activation of β-endorphin neurons removes GABAergic inhibition of VTA dopamine neurons, resulting in an increase in dopamine in the NAc. These areas are important in drug reward and reinforcement (Figure 2.3).

Cortisol is responsible for negative feedback inhibition of the pituitary, hypothalamus, and hippocampus. The largest proportion of cortisol is bound to transport

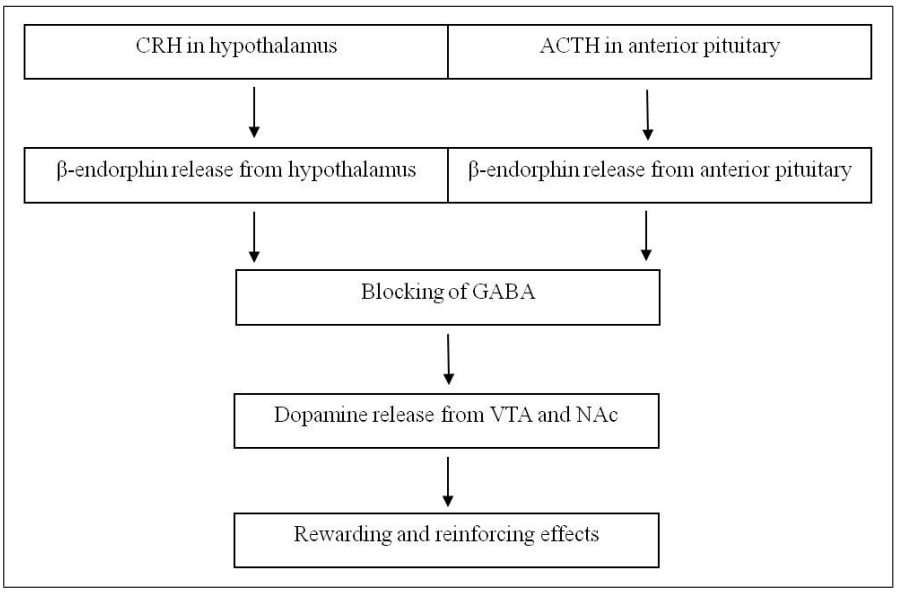

Figure 2.3 Relationship between wtih endogeneous opioid and dopamine system

proteins in blood, only small amount of plasma cortisol circulates as biologically active, free cortisol. In contrast to CRH [16] and cortisol [17], ACTH does not bind to transport proteins and therefore is subject to faster enzymatic degradation. Every nucleated cell has cortisol receptors and significant amounts of glicocorticoids pass the blood-brain barrier, thus it has a wide range of physiological effects [18]. It is responsible for energy usage in various organs under stress conditions and increases metabolic rate. Cortisol also plays role in other important physiological systems. By increasing the sensitivity for catecholamines, it promotes functioning of the cardiovascular system and also it has important effects on affective and cognitive processes and suppresses stress-induced increases in central neural levels of noradrenalin.

Dopamine is known as a neurotransmitter. Midbrain is the center where most of the dopamine neurons are located. Addictive drugs increase the extracellular levels of dopamine in the NAc and there is a positive correlation between the euphoria and level of extracellular dopamine in the striatum [19]. The mesocorticolimbic dopaminergic system, with its central component, the NAc, forms the brain reward system. The dopamine system plays a major role in rewarding effects of addictive drugs. When drug self-administration behavior increases, stimulation of the dopamine system also increases and it shows indirect evidence for a role of increased dopaminergic activity

in addiction. VTA, NAc, frontal cerebral cortex, amygdala, and septum-brain regions associated with mediating the rewarding and reinforcing effects of alcohol or drugs. (Figure 2.4).

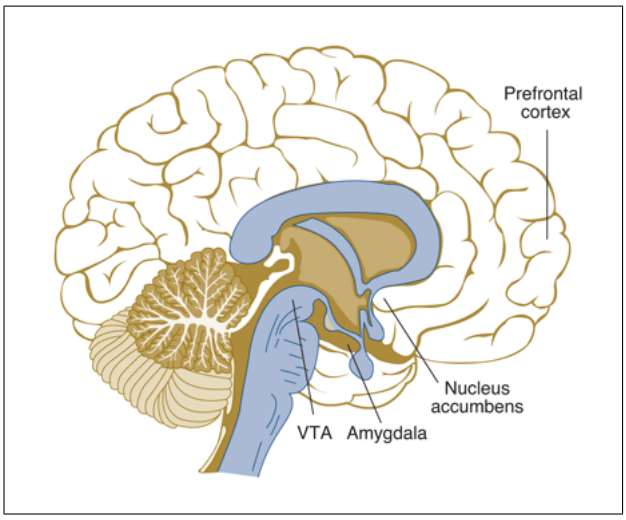

Figure 2.4 Location of the brain regions related to rewarding system [2]

Amygdala is responsible for memory and emotion; and frontal cortex is related with processes of planning and decision making. β-endorphin controls the VTA and NAc to stimulate the releasing of dopamine. The behavioral dopaminergic reward system is activated by the coordination between the brain areas mentioned above. The chemical or behavioral addicted person feels pleasure with rewarding effects and reinforcing effects cause the person seek the addiction source more to get the same level of pleasure. It works like a positive feedback mechanism to keep the function of neurons in the dopaminergic system at a high level.

2.3 Psychophysiological and neuroendocrine hormone changes in addiction

It was shown that physiological responses increase by observing heart rate during computer game sessions [20]. Additionally, prefrontal cerebral blood volume increases while playing video games [21]. Excessive game playing may also be related with dopaminergic reward system in the brain like chemical addiction [22]. For example,

alcohol addiction generally starts with stress, but then it activates the HPA axis and endogenous opioid system in the brain [23]. Neuroimaging studies have also reported abnormalities in the brain functioning of pathological gamblers. Increased excitement or sudden involuntary movement responses [24], increased activation in the right middle frontal gyrus [25] and autonomic arousal, immune and stress-related changes [26] were observed during gambling. Problematic gamblers were found to have higher levels of noradrenergic metabolites, higher epinephrine and cortisol levels and blood pressure differences [27]. Additional physiological studies of pathological gamblers have found higher skin conductance levels [28], lower basal levels of cardiovascular activity during gambling [29]; and higher heart rates [30]. Problematic gamblers appear to have problems in concentrating on a task and have a reduced capacity to consider the negative consequences of their actions. Their focus is only on the desire to play for tension reduction.

Physical performance, stress or pharmacological substances can increase the HPA axis activity. There is known to be a link between substance addiction and stress. Stressful person can abuse substance to cope with his/her problems. In the time of substance deprivation, exposure to stress condition or drug-related experiences can stimulate the HPA axis to remind the individual about the effects of the abused substance, thus producing craving and promoting relapse. When the HPA axis is stimulated without warning, the addict feels a loss of control and falls back again to drug use which helps the individual regain control over his HPA axis activation. Addictive drugs were found to change HPA axis activity. Cocaine [31], smoking [32] and alcohol consumption [1] increase HPA axis activity. Conversely, heroin users show a hypo-responsive HPA axis and decreased plasma cortisol [33].

It was shown in animal studies that dopamine neuron activity peaks right before animals start heroin self-administration behavior [34]. Similarly, dopamine release increases immediately prior to responding for cocaine and after exposure to a drug-related experience or the drug itself [35]. These suggest that an increase in dopamine activity promotes drug associated behavior. In addition to being important for self administration behavior, dopamine is also important in drug-seeking behavior. With-

drawal from long-period use of addictive drugs can cause hypo-dopaminergic state. It has been proposed that this hypo-dopaminergic state could decrease an individual's interest on experiences that are not related to drugs. At the same time, it would increase the interest in drug to counteract the decrease in dopaminergic level [36]. Reduced dopaminergic level can cause drug craving and relapse in the addicted individual and the individual would take more drugs to compensate decreased-dopaminergic level. Soft stressors increase the activity of the dopamine system by increasing extracellular concentrations of dopamine and neuronal firing, whereas intense, prolonged and unpredictable stressors decrease dopaminergic activity. Low levels of dopamine were observed in depressed women who had breast cancer [37]. Animals with increased reactivity to stress show higher activity of dopamine neurons compared with animals with low reactivity to stress. These animals with increased stress and dopaminergic transmission also show enhanced ability to acquire self-administration behavior [38]. This suggests that stress induces the development of addiction as a result of an interaction between stress and dopamine neurons.

Apart from addiction, this mechanism can be broken in different situations. In marmoset monkeys, infants deprived of parental care showed dopamine hyperactivation because of stress they were exposed to and demonstrated impaired behavioral inhibition in an object reaching with detour task [39]. Dopaminergic reward system was studied in gambling addiction [40]. During the gambling session, the subjects' heart rate and dopamine levels increased and similarly cortisol levels increased just at the beginning of game. However, β-endorphin levels remained constant during the gambling session. It was found that synaptic mesolimbic dopamine in the NAc of rodents increases with the rewarding effects of most drugs [41]. There is evidence that this effect also occurs in humans. For instance, positron emission tomography imaging has shown that drug excitement and desire show the same effect as alcohol-, amphetamine-, cocaine-induced release of dopamine in the brain [42]. The mesolimbic dopamine system is involved in the development of all addictions.

β-endorphin and enkephalin enhances dopamine release within the NAc and are thus take place in reward and reinforcement. It was demonstrated that ethanol

increases β-endorphin release from the hypothalamus [43]. Severe alcohol consumption promotes β-endorphin release in the pituitary and hypothalamus and also in other brain regions related with addiction, including in the NAc and VTA [44]. β-endorphin release stimulates dopamine release in the NAc. As a negative feedback, β-endorphin neurons inhibit GABA neurons, which in turn inhibit dopamine neurons in the VTA that project to the NAc.

The increase in β-endorphin release in the NAc and VTA following severe alcohol consumption may be important for the initiation of drinking. However, it may not be important for the maintenance of alcohol consumption, since this increase is not maintained with chronic alcohol exposure. In fact, several studies have suggested that chronic alcohol exposure decreases endogenous opioid activity. With chronic alcohol exposure, β-endorphin decreases. By causing feelings of discomfort, this may help to maintain alcohol consumption by negative reinforcement. It can be concluded that alcohol and cocaine change endogenous opioid activity, which can in turn modulate mesolimbic dopamine, reward, and craving. CRH neurons in the hypothalamus are regulated by several neurotransmitter systems, including direct and indirect inhibitory signals from β-endorphin-producing neurons. Changes in endogenous opioid activity have effects on the mesolimbic reward pathway. Genetic differences in the endogenous opioid system may also contribute to drug and alcohol addiction susceptibility since patients with positive family history of alcoholism were found to have greater withdrawal effects following ethanol treatment than patients with negative family history [45].

3. METHODOLOGY

3.1 Subjects

16 subjects who played computer games excessively (>28 hrs/wk) and 16 subjects who played infrequently (ages: 19-27) participated in the study. A questionnaire on excessive computer game playing was applied to all subjects. There was a significant difference between excessive and non-excessive players ($p<0.001$, parametric t-test). Average playing time per week and the most preferred game were determined by a survey conducted by Faculty of Education with 200 participants in the university. All the subjects were male, because there are not many female excessive players and most games are more suitable for males like first-person shooters, role playing, sport and strategy games. The study was approved by Boğaziçi University Committee on Ethical Conduct in Research with Human Participants.

3.2 Materials

Experiments were performed in the psychophysics laboratory of Biomedical Engineering Institute. A high speed PC computer which could present high quality audio and visual effects was used for game playing. Heart rate was measured by a pulse oximeter. Skin conductance was measured with a custom-made device by means of a constant-voltage circuit [46]. Heart rate and skin conductance were recorded to another PC through a data-acquisition card.

Hormone measurements were done in a professional clinical laboratory. β-endorphin and dopamine were measured by using RIA. Bio Source KIPERB301 kit was used for β-endorphin and Bio Source KIPL0300 kit was used for dopamine and activity was measured by a BERTHOLD LB 2111 gamma counter. Cortisol was studied by ECLIA with ROCHE Cobas kits. For cortisol, samples were processed by a

ELECSYS 2010 autoanalyzer.

3.3 Procedure

Since skin conductance varies considerably across people, calibration tests were performed for every subject. Balloon-bursting procedure was used to normalize subjects according to maximum skin conductance [46]. Subjects were instructed to blow a balloon to burst to obtain minimum and maximum skin conductance levels.

Heart rate and skin conductance were recorded continuously during the game and control sessions. Both sessions took 2 hr in duration and were held on different days. In game sessions, every subject played the same game. Since most young adults preferred first-person shooter games, Call of Duty II was used in the game sessions. In control sessions, subjects did not play a game, but used the computer to draw paintings in a relaxed mood in Photoshop software.

Experiments were performed in the morning hours, subjects came to the experiment after 12-hour-fasting. 15 ml blood samples were collected before and after the sessions. Each sample was aliquoted into special tubes. For cortisol, yellow-cap blood collection tubes with clot activator and gel were used. After the 5 ml of blood sample was collected into the tube, 15 min was waited for coagulation, and then the sample was centrifuged at room temperature/2000 rpm for10 min. The gel in the tube stayed in the middle and separated the serum from coagulated blood. Serum was transferred to another tube and saved for hormone analysis. For β-endorphin and dopamine, purple-cap EDTA tubes were used. EDTA was needed for anti-coagulation, since plasma was used for these hormone tests. 5ml of the blood sample was centrifuged at 4 degree/4000 rpm for 15 min, plasma was transferred to another tube and saved for hormone analysis. All the processed samples were saved at -20 degree for approximately one month and then tested at once.

3.4 Analysis

Skin conductance and heart rate time-series data were filtered off-line with Butterworth filters in MATLAB. The band-pass cut-off frequencies were 0.0159-5 Hz and 0.0027-5 Hz, respectively. Mean and root-mean-square values were calculated to reveal average trends and fluctuations. Time-series data were also segmented into successive 30 min periods for subsequent analysis. Peirce's criterion was used to eliminate outliers for the psychophysiological and hormone test results [47]. ANOVA was used to study the factor effects (subject group, session type, and time period) in MATLAB.

4. RESULTS

4.1 Psychophysiological parameters

4.1.1 Skin conductance fluctuations

Skin conductance fluctuations were calculated by root-mean-square analysis of band-pass filtered data. In both sessions, fluctuations somewhat decreased during the course of the experiment for non-excessive players as shown in Figure 4.1. However, this change was not statistically significant ($p>0.22$, time period factor main effect, 3-way ANOVA).

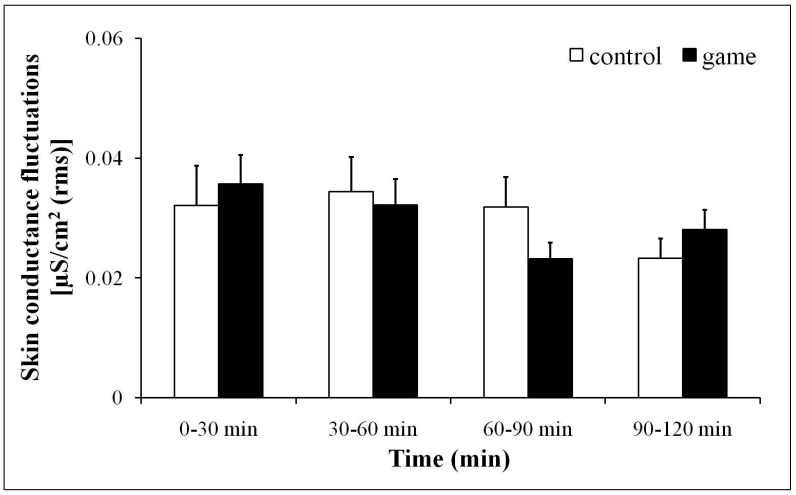

Figure 4.1 Skin conductance fluctuations in 30 min time intervals for control and game sessions in non-excessive players

Skin conductance fluctuations also seemed to decrease during both sessions for the excessive players as shown in Figure 4.2. However, this change was not statistically significant ($p>0.22$, time period factor main effect, 3-way ANOVA).

Skin conductance fluctuations between excessive and non-excessive players were found to be significantly different ($p<0.001$, subject groups main effect, 3-way ANOVA). The excessive players had significantly higher skin conductance fluctuations than non-

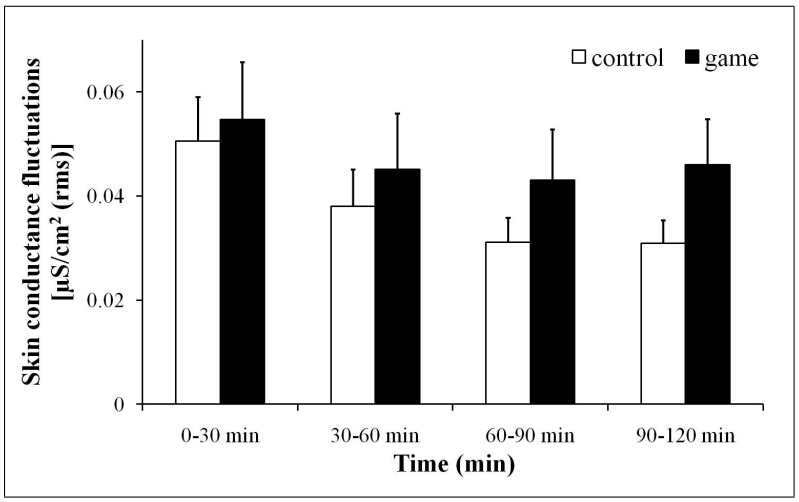

Figure 4.2 Skin conductance fluctuations in 30 min time intervals for control and game sessions in excessive players

excessive players as shown in Figure 4.3. However, there were no significant differences between control and game sessions ($p>0.16$, session type factor, 3-way ANOVA).

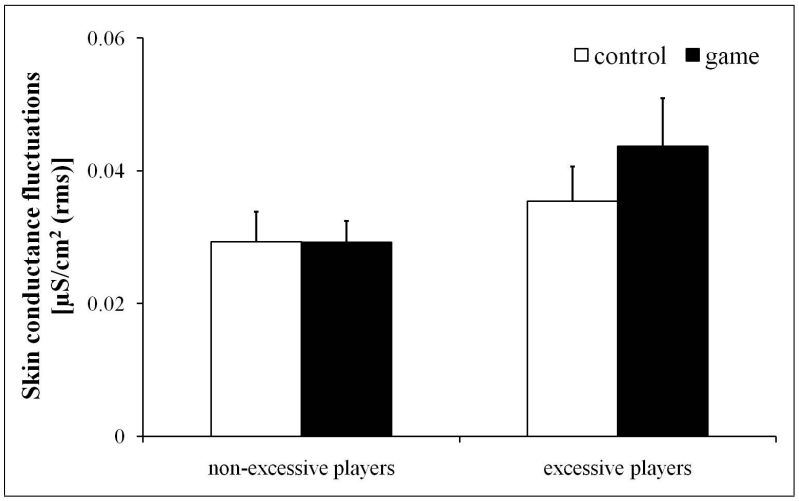

Figure 4.3 Skin conductance fluctuations for control and game sessions in both subject groups

4.1.2 Heart rate mean

Heart rate mean, in non-excessive players, appeared to show no trend as shown in Figure 4.4. There were no significant differences between time intervals during game and control sessions for non-excessive players ($p>0.6$, time period main effect, 3-way

ANOVA).

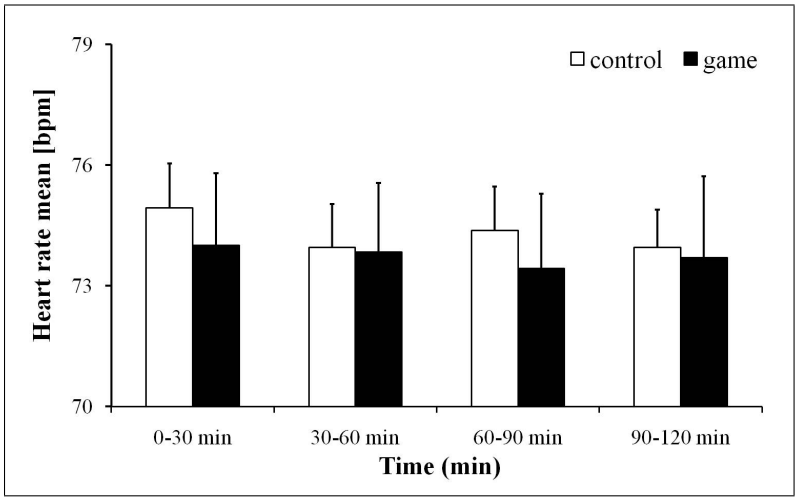

Figure 4.4 Heart rate mean in 30 min time intervals for control and game sessions in non-excessive players

Heart rate means somewhat decrease during control sessions in excessive players as shown in Figure 4.5. However, these changes were not statistically significant ($p>0.6$, time period main effect, 3-way ANOVA).

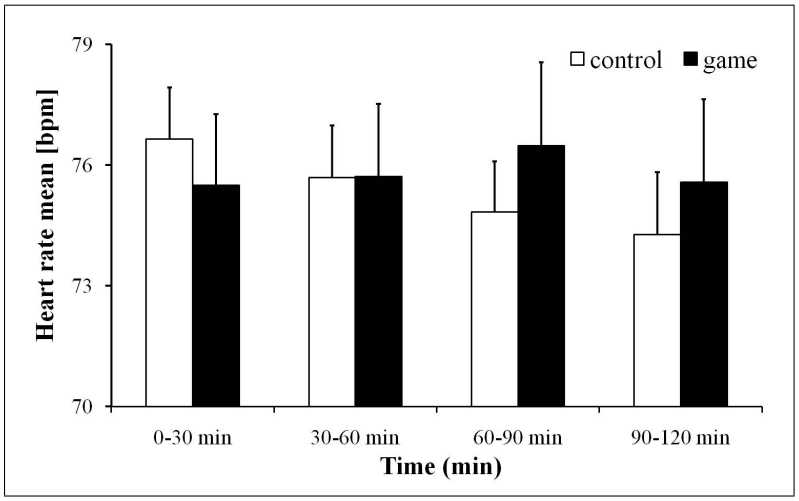

Figure 4.5 Heart rate mean in 30 min time intervals for control and game sessions in excessive players

Heart rate means of excessive players were marginally higher than the heart rate means of non-excessive players as shown in Figure 4.6 ($p=0.053$, subject group main effect, 3-way ANOVA). However, there were no significant differences between control and game sessions ($p>0.90$, session type main effect, 3-way ANOVA).

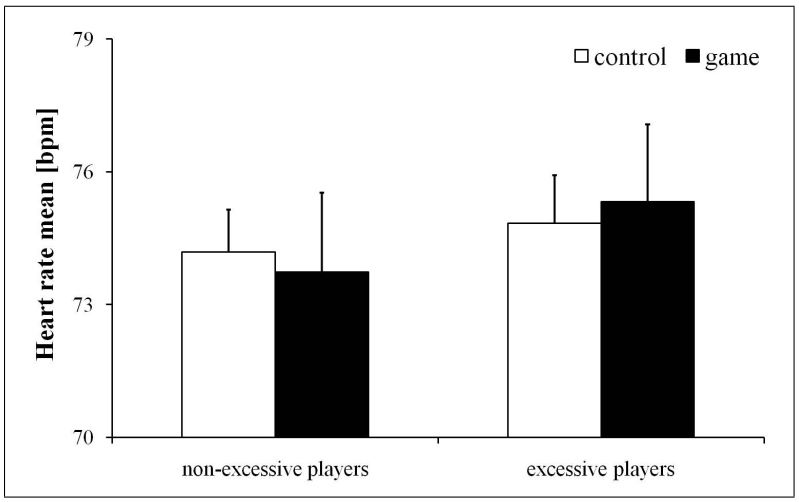

Figure 4.6 Heart rate mean for control and game sessions in both subject groups

4.1.3 Heart rate fluctuations

Heart rate fluctuations progressively increased within each session for non-excessive players as shown in Figure 4.7. Heart rate fluctuations were found to be significantly different between 0-30 min and 60-90 min, 0-30 min and 90-120 min, 30-60 min and 90-120 min time intervals ($p<0.001$, time period main effect, and post-hoc tests, 3-way ANOVA).

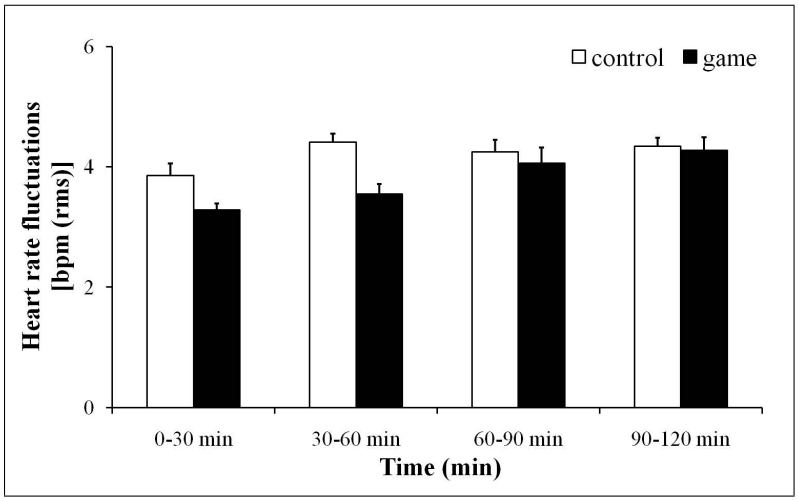

Figure 4.7 Heart rate fluctuations in 30 min time intervals for control and game sessions in non-excessive players

Heart rate fluctuations also progressively increased within each session for excessive players as shown in Figure 4.8. Heart rate fluctuations were found to be signif-

icantly different between 0-30 min and 60-90 min, 0-30 min and 90-120 min, 30-60 min and 90-120 min time intervals ($p<0.001$, time period main effect, and post-hoc tests, 3-way ANOVA).

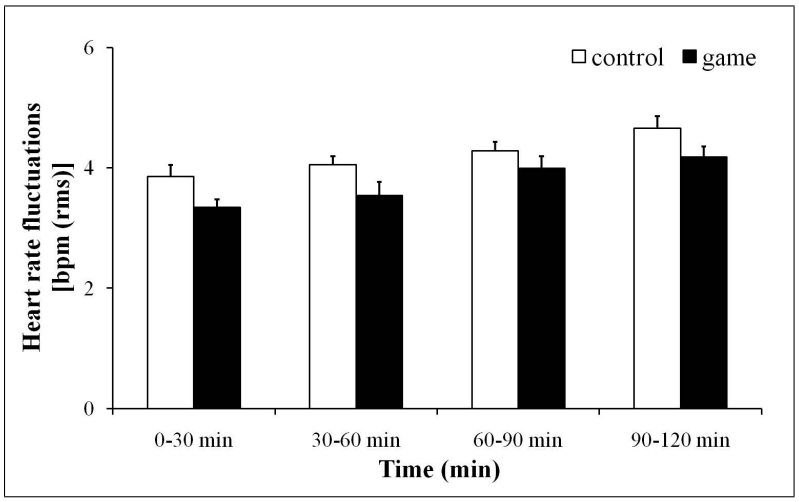

Figure 4.8 Heart rate fluctuations in 30 min time intervals for control and game sessions in excessive players

Heart rate fluctuations were found to be significantly different between control and game sessions ($p<0.001$, session type main effect, 3-way ANOVA). For both subject groups, heart rate fluctuations were lower in game sessions compared to control sessions as shown in Figure 4.9. Excessive and non-excessive players were not significantly different in heart rate fluctuations ($p>0.20$, subject group main effect, 3-way ANOVA).

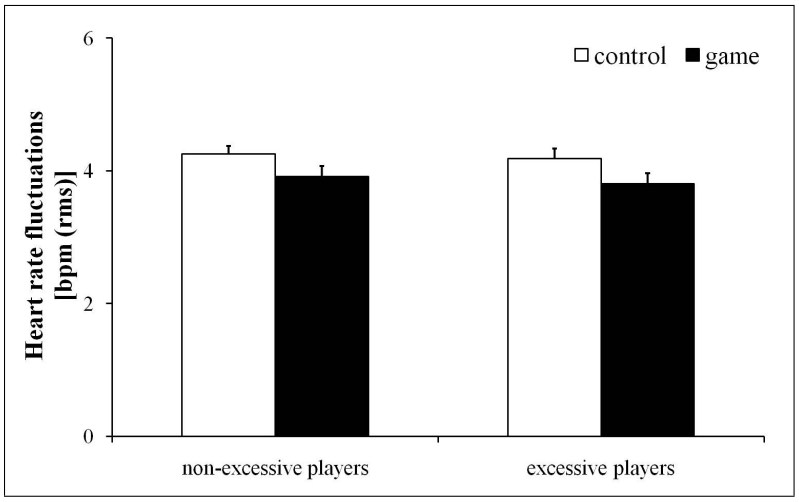

Figure 4.9 Heart rate fluctuations for control and game sessions in both subject groups

4.2 Neuroendocrine hormone levels

4.2.1 Dopamine hormone

Dopamine hormone levels appeared to be higher in non-excessive players before the experiment (before), but appeared to be the same after the game (after) and control (control) sessions as shown in Figure 4.10. However, there was considerable variance across subjects. According to the statistical tests, there were no significant differences between subjects groups ($p > 0.90$, 2-way ANOVA) or sessions ($p > 0.10$, 2-way ANOVA) for dopamine hormone levels.

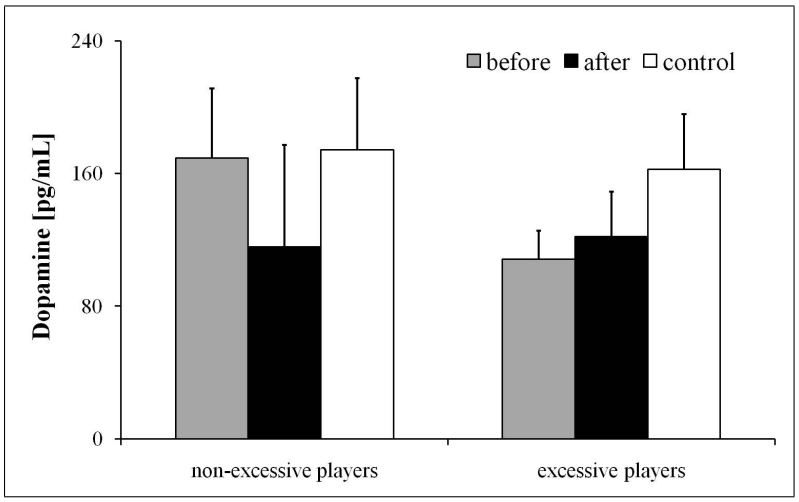

Figure 4.10 Dopamine hormone levels between excessive and non-excessive players

4.2.2 β-endorphin hormone

β-endorphin hormone levels appeared to be the same in both groups before the experiment (before). Excessive players appeared to have a lower level of hormone after the game experiment (after) and appeared to have a higher level of hormone after the control experiment (control) compared to non-excessive players as shown in Figure 4.11. However, none of these were statistically significant (subject groups: $p > 0.70$, 2-way ANOVA; session type: $p > 0.90$, 2-way ANOVA) due to high variance.

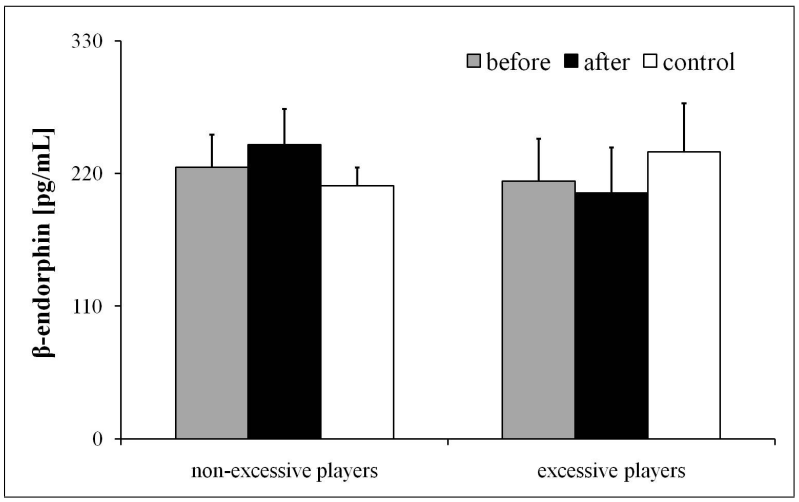

Figure 4.11 β-endorphin hormone levels between excessive and non-excessive players

4.2.3 Cortisol hormone

Cortisol hormone levels were significantly different between sessions ($p<0.001$, 2-way ANOVA). Cortisol hormone levels decreased in both groups after each session compared to the beginning of the session as shown in Figure 4.12. However, there were no significant differences between subject groups ($p>0.20$, 2-way ANOVA).

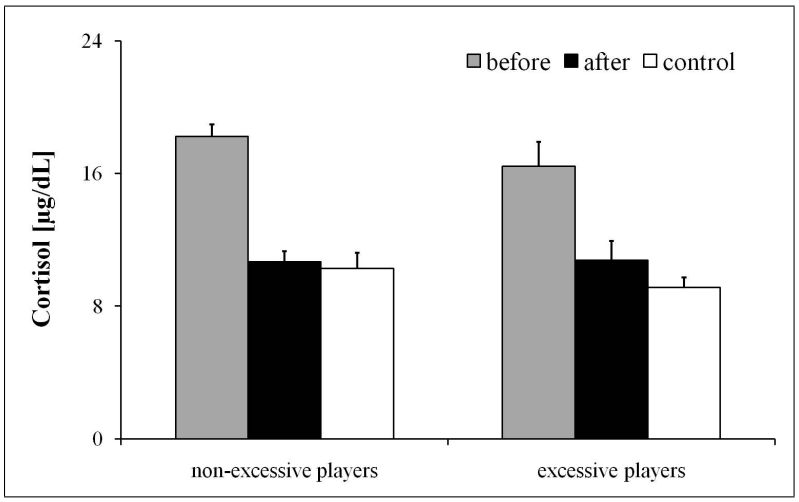

Figure 4.12 Cortisol hormone levels between excessive and non-excessive players

4.3 Cross-correlations

There were significant cross-correlations between psychophysiological parameters and neuroendocrine hormone levels. When all subjects and sessions were considered, there was a significant negative correlation between skin conductance fluctuation and β-endorphin level (r=-0.314, p=0.004) as shown in Table 4.1. However, when subgroups were considered, only excessive players showed the same correlation with increased correlation coefficient (r= -0.467, p=0.002) as shown in Table 4.2, and with even higher correlation (r= -0.657, p= 0.01) when only game sessions were considered. There was a positive correlation between heart rate mean and dopamine level in excessive players (r=0.302, p=0.046) as shown in Table 4.2. Similary, correlation coefficient increased when only excessive players and only game sessions were considered (r= 0.545, p= 0.035) as shown in Table 4.3. There was a significant correlation which was found only in non-excessive players. Skin conductance fluctuation was found to be positively correlated with cortisol hormone level (r=0.337, p=0.027) as shown in Table 4.4. There was also a negative correlation between heart rate fluctuation and cortisol hormone level in all subject groups as shown in Table 4.1, 4.2 and 4.4.

Table 4.1
Cross-correlation results for both subject groups in both sessions

	HR	HRF	Cortisol	Dopamine	β-endorphin
SCF	r= 0.096	r= -0.088	r= 0.165	r=-0.124	**r=-0.314**
	p= 0.495	p= 0.544	p= 0.129	p=0.260	**p=0.0036**
HR		r= 0.147	r= -0.078	**r=0.252**	r=0.051
		p= 0.281	p= 0.464	**p=0.017**	p=0.628
HRF			**r= -0.474**	r=-0.026	r=0.050
			p<0.001	p=0.810	p=0.647
Cortisol				r=-0.038	r=-0.038
				p=0.725	p=0.725
Dopamine					r=0.146
					p=0.177

Table 4.2
Cross-correlation results for excessive players in both sessions

	HR	HRF	Cortisol	Dopamine	β-endorphin
SCF	r= 0.074	r= -0.139	r= 0.163	r= -0.090	**r= -0.467**
	p= 0.725	p= 0.525	p= 0.302	p= 0.578	**p= 0.002**
HR		r= 0.062	r= -0.112	**r= 0.302**	r= 0.032
		p= 0.755	p= 0.461	**p= 0.046**	p= 0.832
HRF			**r= -0.436**	r= 0.189	r= 0.032
			p= 0.004	p= 0.236	p= 0.835
Cortisol				r= -0.227	r= -0.138
				p= 0.142	p= 0.370
Dopamine					r= 0.250
					p= 0.105

Table 4.3
Cross-correlation results for excessive players in the game session

	HR	HRF	Cortisol	Dopamine	β-endorphin
SCF	r= 0.091	r= -0.270	r= -0.352	r= 0.024	**r= -0.657**
	p= 0.776	p= 0.420	p= 0.216	p= 0.933	**p= 0.010**
HR		r= 0.250	r= -0.215	**r= 0.545**	r= 0.072
		p= 0.408	p= 0.440	**p= 0.035**	p= 0.796
HRF			r= 0.161	r= 0.375	r= 0.178
			p= 0.581	p= 0.205	p= 0.542
Cortisol				r= -0.188	r= 0.005
				p= 0.518	p= 0.985
Dopamine					r= 0.406
					p= 0.149

Table 4.4
Cross-correlation results for non-excessive players in both sessions

	HR	HRF	Cortisol	Dopamine	β-endorphin
SCF	r= 0.053	r= 0.057	**r= 0.337**	r= -0.186	r= 0.086
	p= 0.792	p= 0.780	**p= 0.027**	p= 0.224	p= 0.582
HR		r= 0.246	r= -0.020	r= 0.267	r= 0.089
		p= 0.206	p= 0.894	p= 0.076	p= 0.557
HRF			**r= -0.517**	r= -0.136	r= 0.094
			p= 0.0003	p= 0.375	p= 0.546
Cortisol				r= 0.113	r= 0.133
				p= 0.467	p= 0.401
Dopamine					r= 0.087
					p= 0.576

5. DISCUSSION

5.1 Comparison with previous studies

Cortisol levels decreased in both groups after each session compared to the beginning of the session ($p<0.001$). It shows that subjects relaxed when they concentrated on the game even the game type was a first person shooter. The cortisol levels of both groups were about the same before the experiment, this is in contradiction with the activity of HPA axis and suggests that excessive playing may not be a behavioral addiction. Problematic gamblers were found to have higher levels of cortisol levels [27], and during a gambling session, the subjects' cortisol levels increased at the beginning of the game and then decreased towards the end of the session [40].Thus, cortisol levels were expected to be higher in the excessive player group before the experiment. The level of cortisol decreased similar to the gambling towards the end of the session. According to the self medication model of addiction, addicted subjects are expected to have more stress in their daily lives, and they get addicted to cope with their problems [48]. Stress would increase the release of CRH from hypothalamus. CRH would then promote the ACTH release from anterior pituitary which finally would increase cortisol release from adrenal glands, and cortisol may trigger the person to play the game in order to get relaxed.

β-endorphin levels were about the same before the session for both subject groups. After the game session, this hormone level appeared to decrease by a small amount in excessive players. Diminished β-endorphin levels may represent a state of underarousal in excessive players; however, these differences failed to be statistically significant. With chronic alcohol exposure, β-endorphin levels decrease [49]. By causing feelings of discomfort, it may help maintain alcohol consumption by negative reinforcement. Our findings were consistent with the gambling study that β-endorphin levels remained constant during the gambling session [40].

It has been proposed that reduced dopaminergic level can cause drug craving and relapse in addicted person and the person would take more drugs to compensate decreased dopaminergic level [36]. Similarly, it was expected from excessive players to be in hypo-dopaminergic state before the experiment since hypo-dopaminergic state could decrease an individual's interest on subjects that are not related to the game, at the same time, it would increase the interest in playing game to counteract the decrease in dopaminergic level. It was found that dopamine levels increased in problematic gamblers during gambling session [40]. However, our results were not statistically significant in this respect.

Significant differences were found in psychophysiological measurements between excessive and non-excessive players. Problematic gamblers were found to have higher skin conductance levels [28]. Our findings are consistent with previous studies. The excessive players had significantly higher skin conductance fluctuations than non-excessive players ($p<0.001$). This shows their autonomic systems react more to computer playing. Similarly, heart rate means of excessive players were marginally higher than the heart rate means of non-excessive players ($p=0.053$). If the number of subjects were increased, this result may be statistically significant. Pathological gamblers also showed higher heart rates than controls [40]. Heart rate fluctuations were found to be significantly different between our control and game sessions. For both subject groups, heart rate fluctuations were lower in game sessions compared to control sessions ($p<0.001$). This can be due to the effect of mental concentration on the autonomic system. Heart rate fluctuations progressively increased within each session. Excessive and non-excessive player groups were barely different from each other.

Significant differences regarding the neuroendocrine hormone levels could not be directly found between excessive and non-excessive players, but there were significant cross-correlations between the autonomic and hormone variables. These created a significant contrast between the subject groups. Specifically in excessive game players, skin conductance and β-endorphin levels were negatively correlated which suggests that excessive players are more likely to have low level of β-endorphin since they have high skin conductance fluctuations. Decreased β-endorphin levels may represent a state

of underarousal in excessive players. Similarly, heart rate mean and dopamine levels were positively correlated which suggests that excessive players are more likely to have higher level of dopamine secretion since their heart rate means are higher than non-excessive players. Increase in dopamine level shows that the reward system neurons were activated. In non-excessive players, on the other hand, skin conductance and cortisol levels were positively correlated which suggests that low level of fluctuations could be result of low level of cortisol. These results show clear differences in autonomic responses of excessive game players and non-excessive players.

5.2 Skin conductance in autonomic system

Skin conductance level is linearly related to the rate of sweat secretion [46]. Sudomotor activity is the source of changes in skin conductance by connecting to the efferent nerves that control the activity of sweat glands. When applying the electrodes onto the body, it should be considered that the amplitude of the skin conductance depends on the density of sweat glands in the skin area chosen and the degree of psycho-activity of the sweat glands in that region. Since sweat gland density and psycho-activity are greatest on the finger tips, finger tips were used in the measurements. There are wide differences in the range of variation of skin conductance, it is apparent that the same level of activity can produce very different skin conductance levels in different individuals [46]. In general, different levels of skin conductance represent different states of the person; if a subject's skin conductance is high, it can be concluded that subject is in a state of higher arousal than when it is low. When comparisons are to made between individuals, measurements of skin conductance should first be corrected for individual differences in the range of skin conductance variation by obtaining each individual's maximum and minimum skin conductance.

5.3 Hormone measurement method, variance, time effects

Cortisol hormone test was done by ECLIA method. Since this is a routine procedure, measurements were straightforward. Serum normal cortisol levels are in the range of 6.2-19.4 μg/dL in the mornings. Our subjects' cortisol levels were more or less in this range. Cortisol levels rise during the early morning hours, they drop very low in the evening and during the early phase of sleep. Thus, cortisol hormone is a time dependent hormone. All experiments were done in the morning in order to eliminate this time effect.

β-endorphin and dopamine hormone tests were done by RIA method. Since these hormones are studied only for special purposes, there is no established normative values in the general population. Dopamine levels were found to be $<$0.1 ng/mL in the plasma. In the reference study with problematic gamblers [40], dopamine levels were between 30-50 pg/mL and β-endorphin levels were between 200-300 pg/mL in subjects that were involved in the study. Our subjects' hormone levels varied considerably; there were subjects with low or high amounts of hormone levels compared to the gambling study. This may be due to procedures. Blood samples were collected after 2-hour experimental sessions. 2 hours may not be enough to detect differences. In addition, the samples were saved for later analysis which may have caused some degredation.

Although RIA method is used mostly for hormone tests, it may not be sufficient to determine some neuroendocrine hormones effectively. The blood-brain barrier restricts the passage of dopamine and other catecholamines. Thus, plasma hormone levels may not reflect the central monoaminergic activity. Direct measurements from the brain may be more appropriate and accurate, but this is very difficult for ethical and technical reasons.

5.4 Other limitations

Subjects and experimental conditions were balanced. Subjects' ages were in the range of 19-27 and they were all men, in order to keep their physiologic activity rates similar. They were all university students, their mental capabilities were also similar. Experiments were done at the same period of the day, since hormone levels could change during the day according to clock cycle. Experiments were done in the mornings, subjects came to experiment after 12-hour fasting since plasma from blood samples should be lipid free and clear in color for hormone tests. They all played the same game, Call of Duty II, game type can also affect the individuals' responses. These were precautions taken to obtain reliable results.

There were still some uncontrolled variables. Neuroendocrine hormone and physiological basal levels may change from person to person. Life conditions may affect these parameters or these parameters can be genetically determined. We did not control the history of our subjects. In addition, psychological tests can be applied in order to understand their baseline states. Game difficulty was not controlled. Standardizing the years of playing may reduce the variance in the results. Selecting a homogenous subject sample is likely to increase the significance of the results.

Experiments were done after 12-hour fasting and blood samples were collected before and after the sessions, this procedure may have caused additional stress unrelated to game playing. Finally, experiments were done in the laboratory environment which was unnatural from the point of view of subjects.

6. CONCLUSIONS

This study aimed to study the effects of excessive computer game playing on autonomic and neuroendocrine activity. Specifically, we analyzed skin conductance, heart rate, blood concentration of dopamine, cortisol and β-endorphin before and after game sessions. We tested the hypothesis of increased activity in the HPA axis and activation of the dopaminergic reward system due to excessive computer game playing. Plasma level of cortisol decreases with computer game playing which is inconsistent with the activation of the HPA axis theory. The observed high heart rate mean and skin conductance fluctuations in excessive players compared to non-excessive players indicate that there is a high psychophysiological activation in these subjects. This suggests higher autonomic arousal during game playing. Interestingly, heart rate fluctuations decrease during computer game playing in both groups which may be due to increased concentration during playing. Although we could not find a direct difference for excessive players regarding hormone levels, there were significant cross-correlations between the autonomic and hormone variables. We are working to refine our technique and to increase the sample size for investigating this further, before we can conclude excessive game playing as behavioral addiction.

6.1 Future work

Since we could not detect any significant differences in dopamine levels between excessive and non-excessive players, another method can be used instead of RIA. Extracellular level of dopamine may be measured directly from brain by MR spectroscopy, principally from midbrain, VTA and NAc, where it is secreted mostly. EEG can also be measured in order to record the brain's spontaneous electrical activity during computer game playing.

Withdrawal syndromes may be induced in excessive players after playing for a certain time of period. Since withdrawal from long-period use of addictive drugs can

cause hypo-dopaminergic state, dopamine levels can be examined in excessive players to test whether they will show similar outcomes.

Behavioral addiction in animals may be investigated if an animal model can be developed. Then, more invasive tests can be performed, which would give more direct results.

APPENDIX A. GRAPHICAL DATA

A.1 Heart rate measurement

Figure A1 shows typical raw data of heart rate against time. The mean heart rate was calculated from this data.

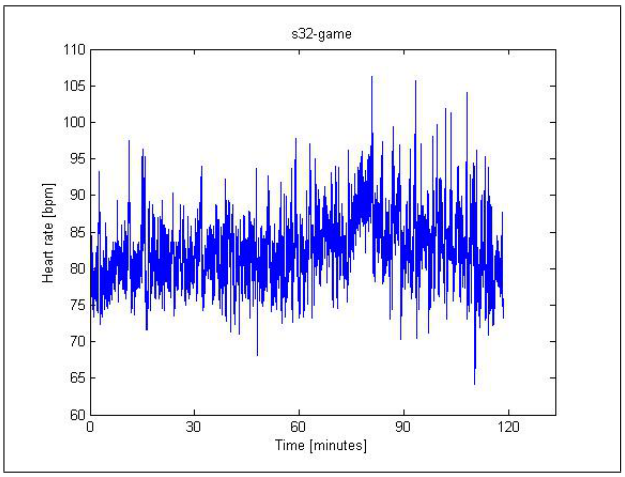

Figure A.1 Raw heart rate measurement for subject 32 during the game session

Figure A2 shows typical band-pass filtered heart rate against time. Heart rate fluctuation (rms) was calculated from this data.

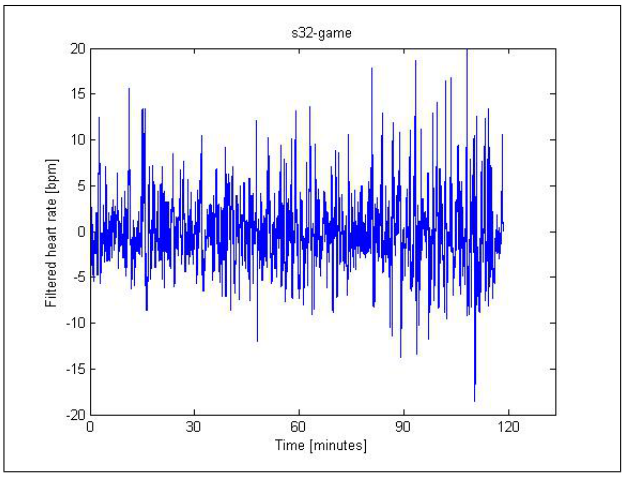

Figure A.2 Filtered heart rate measurement for subject 32 during the game session

A.2 Skin conductance measurement

Figure A3 shows typical raw skin conductance against time. Since there is always drift due to the changes in electrode-skin interface, mean skin conductance was not calculated. This data set was band-pass filtered to get rid of drift and high-frequency noise.

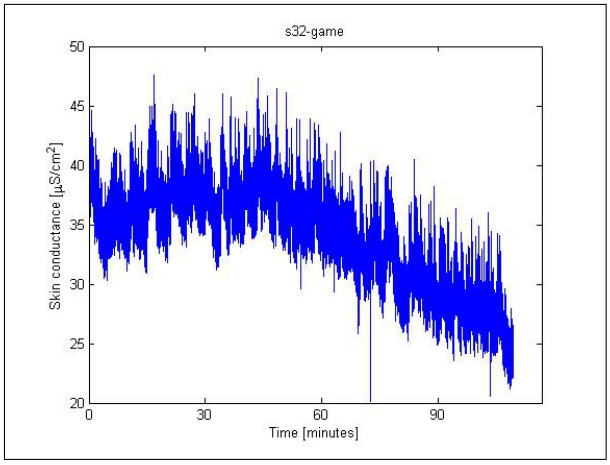

Figure A.3 Raw skin conductance measurement for subject 32 during the game session

Figure A4 shows typical band-pass filtered skin conductance against time. Skin conductance fluctuation (rms) was calculated from this data. The data was also normalized based on the maximum skin conductance measured from each subject during a calibration test.

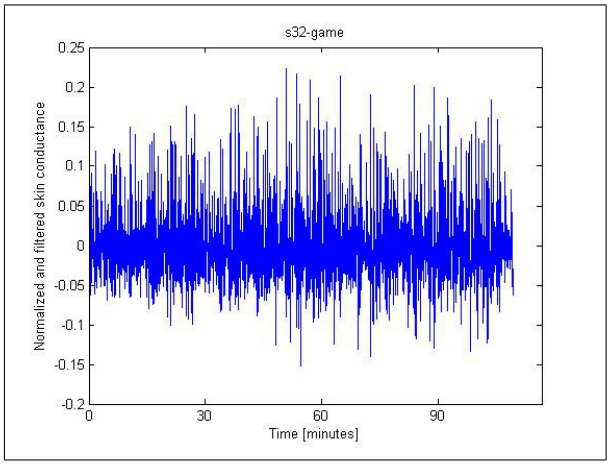

Figure A.4 Filtered skin conductance measurement for subject 32 during the game session

APPENDIX B. NUMERICAL DATA

Table B.1
Skin conductance fluctuation data [μS/cm^2 (rms)] for non-excessive players during the control session

Subject	Overall	0-30 min	30-60 min	60-90 min	90-120 min
9	0.0218	0.0254	0.0268	0.0197	0.0121
22	0.0644	0.088	0.0732	0.0508	0.0305
23	0.0173	0.0026	0.015	0.0238	0.02
25	0.0245	0.0299	0.025	0.0227	0.0194
26	0.053	0.0481	0.0569	0.0685	0.0315
27	0.0445	0.0373	0.0535	0.0462	0.0392
40	0.006	0.0061	0.0059	0.0059	0.0063
41	0.0388	0.0514	0.0465	0.0299	0.0175
42	0.0262	0.0242	0.0278	0.0259	0.0267
43	0.0735	0.0838	0.0733	0.0681	0.0678
44	0.0349	0.0334	0.0351	0.0321	0.0385
45	0.0515	0.0469	0.0557	0.0539	0.0491
46	0.0195	0.003	0.0253	0.0218	0.0199
47	0.0041	0.0048	0.0014	0.0053	0.0039
48	0.018	0.0206	0.0207	0.0145	0.0152
49	0.0154	0.0082	0.0088	0.0208	0.0194
mean	**0.032088**	**0.032106**	**0.034431**	**0.0318688**	**0.0260625**
std	**0.020488**	**0.026618**	**0.022925**	**0.0199104**	**0.0164948**
se	**0.005122**	**0.006655**	**0.005731**	**0.0049776**	**0.0041237**

Table B.2
Skin conductance fluctuation data [μS/cm^2 (rms)] for excessive players during the control session

Subject	Overall	0-30 min	30-60 min	60-90 min	90-120 min
17	0.0156	0.02	0.0136	0.0146	0.0131
18	0.0099	0.0054	0.0035	0.0121	0.0144
19	0.0283	0.0299	0.0322	0.0263	0.0241
20	0.0155	0.0142	0.0119	0.0163	0.0187
21	0.0467	0.0703	0.032	0.037	0.0371
28	0.0651	0.0886	0.0723	0.0509	0.036
30	0.0747	0.0852	0.0828	0.0649	0.063
31	0.1132	0.1151	0.1279	0.1107	0.0969
32	0.0448	0.0448	0.0485	0.0462	0.0393
33	0.1056	0.1042	0.0947	0.1078	0.1148
34	0.0197	0.0209	0.0237	0.0207	0.0112
35	0.043	0.0573	0.0341	0.0233	0.0492
36	0.0498	0.0533	0.0495	0.0509	0.0454
37	0.0117	0.0176	0.013	0.005	0.007
38	0.0382	0.0428	0.0367	0.0353	0.0376
39	0.0331	0.0395	0.0221	0.0321	0.0362
mean	**0.044681**	**0.050569**	**0.043656**	**0.0408813**	**0.04025**
std	**0.031433**	**0.033701**	**0.034493**	**0.0312216**	**0.0300261**
se	**0.007858**	**0.008425**	**0.008623**	**0.0078054**	**0.0075065**

Table B.3
Skin conductance fluctuation data [μS/cm^2 (rms)] for non-excessive players during the game session

Subject	Overall	0-30 min	30-60 min	60-90 min	90-120 min
9	0.0467	0.0703	0.032	0.037	0.0371
22	0.0665	0.0974	0.058	0.059	0.0371
23	0.0127	0.0171	0.0138	0.0111	0.0065
25	0.0374	0.0623	0.0301	0.021	0.0195
26	0.0139	0.0203	0.0145	0.0099	0.0073
27	0.0248	0.037	0.0213	0.0167	0.019
40	0.0353	0.031	0.0494	0.0254	0.0308
41	0.0384	0.0447	0.0348	0.0327	0.0402
42	0.0323	0.0333	0.0352	0.0275	0.0329
43	0.0552	0.0338	0.0644	0.0655	0.0511
44	0.0291	0.0331	0.0257	0.0163	0.037
45	0.0349	0.0428	0.0332	0.0298	0.0322
46	0.0155	0.015	0.0111	0.0179	0.017
47	0.0111	0.0051	0.0128	0.0121	0.0124
48	0.0532	0.0654	0.057	0.0442	0.0428
49	0.0235	0.0235	0.0219	0.0229	0.0254
mean	**0.033156**	**0.039506**	**0.0322**	**0.0280625**	**0.0280188**
std	**0.016338**	**0.023986**	**0.017079**	**0.0164329**	**0.0131977**
se	**0.004084**	**0.005997**	**0.00427**	**0.0041082**	**0.0032994**

Table B.4
Skin conductance fluctuation data [μS/cm^2 (rms)] for excessive players during the game session

Subject	Overall	0-30 min	30-60 min	60-90 min	90-120 min
17	0.0333	0.0299	0.0331	0.0337	0.0363
18	0.0144	0.0166	0.0137	0.0144	0.0128
19	0.032	0.0409	0.0322	0.0238	0.0286
20	0.0154	0.029	0.0064	0.006	0.0058
21	0.0734	0.1118	0.0429	0.0235	0.0815
28	0.141	0.1568	0.173	0.1391	0.0752
30	0.0903	0.0722	0.0553	0.1019	0.1181
31	0.0905	0.0878	0.0893	0.0838	0.1003
32	0.0375	0.0338	0.0378	0.0373	0.0408
33	0.3107	0.3256	0.2769	0.3397	0.2968
34	0.0286	0.037	0.0219	0.0283	0.0251
35	0.0653	0.0705	0.0687	0.0605	0.0609
36	0.0391	0.0487	0.0368	0.0334	0.0358
37	0.0117	0.0087	0.0153	0.009	0.0126
38	0.0218	0.0229	0.0191	0.0197	0.0252
39	0.0304	0.0279	0.0309	0.0308	0.032
mean	**0.064713**	**0.070006**	**0.059581**	**0.0615563**	**0.0617375**
std	**0.074509**	**0.078538**	**0.07051**	**0.0826267**	**0.0706385**
se	**0.018627**	**0.019635**	**0.017627**	**0.0206567**	**0.0176596**

Table B.5
Heart rate mean data [bpm] for non-excessive players during the control session

Subject	Overall	0-30 min	30-60 min	60-90 min	90-120 min
9	81.8	87.1	85.2	79.4	75.7
22	77.9	81.9	80	75.7	73.9
23	72.2	74.5	72.7	71.2	70.5
25	78.6	81	79.6	77.3	76.5
26	78.4	76.8	75.2	80.9	80.4
27	78.4	78.7	78.5	78.3	78.1
40	74.6	76.2	72.3	74.7	75.2
41	68.3	67.5	69.2	68	68.4
42	73.4	74.1	72.8	73.4	73.2
43	71.5	73.2	70.4	69.8	72.5
44	79.3	76.1	80	81	79.9
45	73.1	74.2	72	73.6	72.8
46	60.8	60.6	61.7	60.9	60
47	72.6	73.4	73.3	71.7	72
48	68.9	67.7	68.3	69	70.7
49	71.4	73.8	71	71.5	69.4
mean	**73.825**	**74.8**	**73.8875**	**73.525**	**73.075**
std	**5.266308**	**6.190315**	**5.713011**	**5.3233448**	**4.9629964**
se	**1.316577**	**1.547579**	**1.428253**	**1.3308362**	**1.2407491**

Table B.6
Heart rate mean data [bpm] for excessive players during the control session

Subject	Overall	0-30 min	30-60 min	60-90 min	90-120 min
17	74.9	81.6	76	72.9	69.3
18	74.4	83.6	74.9	70.9	68.4
19	74	74.5	74	71.8	75.9
20	67.4	71.6	68.3	66.4	63.4
21	77.3	81.1	77.5	75.4	75.3
28	71.7	72.1	70.9	71	72.8
30	73.2	74.3	73	73.2	72.3
31	76.8	77.6	77.6	76.7	75.4
32	78.3	77.3	81.7	78.4	75.8
33	67.3	69.5	67	67.8	65.1
34	78.5	77	78.2	82.2	76.7
35	70.4	70.8	69.7	71.2	69.8
36	77	73.5	74.4	78.9	81.4
37	86.5	91.1	84.3	83.6	86.8
38	78.5	79	79.8	76.5	78.8
39	82.8	86.2	83.7	80.5	81.1
mean	**75.5625**	**77.55**	**75.6875**	**74.8375**	**74.26875**
std	**5.09678**	**5.990214**	**5.202291**	**5.0241915**	**6.1950215**
se	**1.274195**	**1.497554**	**1.300573**	**1.2560479**	**1.5487554**

Table B.7
Heart rate mean data [bpm] for non-excessive players during the game session

Subject	Overall	0-30 min	30-60 min	60-90 min	90-120 min
9	77.3	81.1	77.5	75.4	75.3
22	69.5	67.2	70.9	70.7	69.3
23	84.8	82.6	84	84	88.7
25	76.9	78.6	76.8	76.1	76.3
26	82.8	81.1	82.6	82.9	84.6
27	80.7	80.3	80.3	81.6	80.5
40	79.3	81.3	79.6	78.4	77.6
41	63.8	60.6	65	65.2	64.4
42	76.6	78.7	76.6	76.5	74.7
43	72.7	71.8	72	71.9	74.9
44	78.8	74.1	78.1	81.3	81.9
45	70.1	73.8	70.6	69.5	66.4
46	61.4	63.1	61.3	60	61
47	65.8	65.8	66.4	65.9	65.2
48	64.6	67.9	64.6	62.6	63.3
49	74.7	76	75.1	72.9	75
mean	**73.7375**	**74**	**73.8375**	**73.43125**	**73.69375**
std	**7.169833**	**7.159888**	**6.846106**	**7.4064583**	**8.1108544**
se	**1.792458**	**1.789972**	**1.711526**	**1.8516146**	**2.0277136**

Table B.8
Heart rate mean data [bpm] for excessive players during the game session

Subject	Overall	0-30 min	30-60 min	60-90 min	90-120 min
17	92.5	93.6	94.9	91.6	89.7
18	68.4	67.4	68.8	68.5	69
19	78.4	73.4	76.7	81.2	82.2
20	63.3	63.8	65.6	62.8	61.2
21	82.4	86	83.3	80	80.2
28	80.7	78.8	83.6	82.9	77.7
30	80.8	80	81.5	81.1	80.9
31	74.4	76.3	77.2	73.7	70.2
32	82.6	80.6	81.6	85.3	83.2
33	69.2	69.8	68.8	70.8	67.3
34	67.4	69.8	66.6	65.9	67.3
35	65.2	65.5	65.1	64.6	65.7
36	81.1	80.4	80.7	80.5	82.7
37	81.4	81.7	81.8	81.7	80.5
38	72.7	76.3	73	71.8	69.6
39	81.8	82.6	81.4	81.3	81.8
mean	**76.39375**	**76.625**	**76.9125**	**76.48125**	**75.575**
std	**8.01386**	**8.003291**	**8.292075**	**8.310894**	**8.2401861**
se	**2.003465**	**2.000823**	**2.073019**	**2.0777235**	**2.0600465**

Table B.9
Heart rate fluctuation data [bpm (rms)] for non-excessive players during the control session

Subject	Overall	0-30 min	30-60 min	60-90 min	90-120 min
9	4.9	4.4	5.1	5.6	4.3
22	4.4	3.5	4.8	4.6	4.8
23	4	3.2	3.8	4.4	4.5
25	4.2	3.8	4.4	4.2	4.5
26	4.8	4.4	4.8	4.9	5
27	4.4	4.3	4.2	4.1	5
40	4.8	4.6	4.4	5.3	4.8
41	3.8	3.2	3.7	4.2	4
42	5.6	5	5.2	5.3	5.3
43	4.9	4.7	4.9	4.8	5.2
44	3.4	2.6	3.3	3.6	3.8
45	4.3	3.8	4.6	4.3	4.3
46	3	2.2	3	3.1	3.4
47	3.7	3.6	4	3	4.2
48	3.8	3.7	4.4	3.4	3.6
49	4.1	4.7	4.6	3.1	3.7
mean	**4.25625**	**3.85625**	**4.325**	**4.24375**	**4.49375**
std	**0.653165**	**0.794958**	**0.627694**	**0.8278235**	**0.8176949**
se	**0.163291**	**0.19874**	**0.156924**	**0.2069559**	**0.2044237**

Table B.10
Heart rate fluctuation data [bpm (rms)] for excessive players during the control session

Subject	Overall	0-30 min	30-60 min	60-90 min	90-120 min
17	3.4	2.9	3.4	3.6	3.7
18	3.7	3	3.1	3.7	4.7
19	4.2	4.2	3.7	4.4	4.4
20	4.9	3.9	4.4	4.8	6.2
21	4.4	3.6	4.5	4.6	4.9
28	5.4	5.2	5.1	5.2	6
30	3.7	3.4	3.6	3.8	4.2
31	4.7	4.5	4.7	4.6	4.9
32	4	3.4	4.3	3.9	4.5
33	4.5	4.8	4.3	4.1	4.7
34	4.4	4.1	4.6	4.5	4.2
35	3.5	3.9	3.3	3.5	3.3
36	2.8	2.9	4	1.9	1.8
37	5.4	5.2	5.7	5.5	5.3
38	3.6	3	3.8	3.7	3.9
39	4.2	3.7	3.9	4.3	4.9
mean	**4.175**	**3.85625**	**4.15**	**4.13125**	**4.475**
std	**0.719722**	**0.770254**	**0.689928**	**0.8300351**	**1.040833**
se	**0.179931**	**0.192564**	**0.172482**	**0.2075088**	**0.2602082**

Table B.11
Heart rate fluctuation data [bpm (rms)] for non-excessive players during the game session

Subject	Overall	0-30 min	30-60 min	60-90 min	90-120 min
9	4.4	3.6	4.5	4.6	4.9
22	3.3	3.2	3.3	2.9	3.6
23	4.8	3.7	3.5	5.8	5.6
25	3.5	3	3.6	4	3.3
26	3.6	3.4	2.8	3.9	4
27	3	2.8	2.3	3.3	3.6
40	4.4	3.8	4.7	4.4	4.5
41	3.4	2.8	3.5	3.7	3.5
42	3.9	3	3.6	4.5	4.3
43	5.2	3.6	4.5	6.1	6.1
44	3.7	3	3.8	3.4	4.2
45	3.9	3.8	3.9	4.2	3.8
46	2.5	2.1	2.4	2.3	3.1
47	3.5	2.8	3.2	4.2	3.7
48	3.5	3.1	3.2	2.8	4.5
49	4.6	3.7	3.9	4.9	5.6
mean	**3.825**	**3.2125**	**3.54375**	**4.0625**	**4.26875**
std	**0.701902**	**0.47592**	**0.69279**	**1.0242884**	**0.8874824**
se	**0.175476**	**0.11898**	**0.173198**	**0.2560721**	**0.2218706**

Table B.12
Heart rate fluctuation data [bpm (rms)] for excessive players during the game session

Subject	Overall	0-30 min	30-60 min	60-90 min	90-120 min
17	3.5	2.6	3	4.5	3.9
18	3.7	3	3.2	4.2	4.3
19	4.7	4.8	5.2	4.5	4.4
20	3.7	3.4	3.2	4.4	3.9
21	4.5	4.3	4.1	4.7	4.9
28	4.4	3.6	4.3	4.7	4.7
30	3.5	3.2	3.5	3.2	4
31	2.9	2.9	2.5	3.3	2.8
32	4	3.4	3.5	3.5	5.4
33	4.7	4.2	4.5	5.5	4.6
34	3.9	3.3	4.1	3.6	4.5
35	3.4	3.3	3.1	3.2	4
36	1.6	1.4	1.7	1.7	1.5
37	4.8	3.7	4.7	4.6	6
38	3	3.1	2.7	2.9	3.3
39	3.3	2.8	3.3	3.1	3.8
mean	**3.725**	**3.3125**	**3.5375**	**3.85**	**4.125**
std	**0.829859**	**0.773628**	**0.901018**	**0.9458682**	**1.0363397**
se	**0.207465**	**0.193407**	**0.225254**	**0.2364671**	**0.2590849**

Table B.13
Dopamine hormone levels [pg/mL] for non-excessive players

Subject	Before	After	Control
9	231	208	215
22	44	21	88
23	512	1609	477
25	347	188	216
26	26	128	150
27	156	942	843
40	447	41	5
41	159	37	128
42	74	15	62
43	11	1	19
44	1	1	134
45	231	9	40
46	1	17	37
47	355	5	515
48	74	113	421
49	41	9	107
mean	**169.3588**	**209.0185**	**215.9977**
std	**167.543**	**438.8976**	**232.2715**
se	**41.88574**	**109.7244**	**58.06788**

Table B.14
Dopamine hormone levels [pg/mL] for excessive players

Subject	Before	After	Control
17	79	268	83
18	44	31	230
19	24	74	9
20	42	21	183
21	44	244	4.1
28	102	282	176
30	245	38	50
31	164	83	95
32	234	162	455
33	70	1	185
34	799	255	434
35	79	1	78
36	135	113	623
37	87	209	122
38	152	48	78
39	121	1220	169
mean	**151.3241**	**190.5903**	**191.3264**
std	**184.6093**	**292.4721**	**169.6536**
se	**46.15232**	**73.11802**	**42.41341**

Table B.15
β-endorphin hormone levels [pg/mL] for non-excessive players

Subject	Before	After	Control
9	439	44	183
22	295	72	268
23	180	287	268
25	132	101	204
26	77	310	149
27	288	217	255
40	444	254	453
41	203	419	507
42	247	294	161
43	182	313	154
44	275	311	228
45	183	74	160
46	99	347	59
47	267	172	323
48	179	326	170
49	112	364	203
mean	**225.0608**	**244.0785**	**234.0024**
std	**107.9038**	**116.9818**	**114.5666**
se	**26.97595**	**29.24545**	**28.64166**

Table B.16
β-endorphin hormone levels [pg/mL] for excessive players

Subject	Before	After	Control
17	199	317	380
18	190	56	400
19	41	330	100
20	243	390	209
21	190	254	161
28	147	94	268
30	194	4	134
31	8	6	11
32	14	179	126
33	258	152	54
34	367	469	535
35	236	16	436
36	337	598	411
37	528	286	295
38	254	235	20
39	693	267	266
mean	**243.6711**	**228.287**	**237.8896**
std	**178.1297**	**172.3129**	**161.4203**
se	**44.53242**	**43.07822**	**40.35507**

Table B.17
Cortisol hormone levels [μg/dL] for non-excessive players

Subject	Before	After	Control
9	22.1	9	15.7
22	17.6	11.6	5.8
23	15.5	8	15.7
25	15.9	13.1	11.7
26	15.6	22.3	16.2
27	17.1	13.2	9.2
40	16.8	11.3	6.3
41	18	10.8	12.8
42	17.4	13.3	7.8
43	10.4	12.2	6.8
44	23.9	7.4	8.7
45	23.1	7.2	10.8
46	17.7	13.6	15.3
47	19.5	7.2	5.9
48	19.3	22.5	7.4
49	13.8	11.4	8.2
mean	**17.73125**	**12.13125**	**10.26875**
std	**3.416571**	**4.602133**	**3.805911**
se	**0.854143**	**1.150533**	**0.951478**

Table B.18
Cortisol hormone levels [μg/dL] for excessive players

Subject	Before	After	Control
17	10.6	9.1	7.8
18	20.7	17.4	9.8
19	17.8	7.8	11.3
20	22.5	11.9	7.2
21	7.6	8.4	5.6
28	25	33.9	6.5
30	17.2	10.8	11.2
31	21	6.2	15.9
32	7.3	14.4	7.4
33	22.6	7.3	9.6
34	9.9	10.7	9.6
35	13.2	8	8.4
36	14.2	9.8	8.2
37	11.5	8.6	8.4
38	22.3	23.2	12.5
39	19.7	7.7	13.6
mean	**16.443751**	**12.2**	**9.5625**
std	**5.846705**	**7.248448**	**2.755086**
se	**1.461676**	**1.812112**	**0.688772**

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