Chapter 1
Violent Video Games and Cognitive Processes: A Neuropsychological Approach

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Abstract The effects of violent video games on cognitive processes are still not clear. The main goal of this study was to investigate the effect of violent video games on different cognitive processes. A neuropsychological battery which consists of response inhibition, emotional memory, working memory, object recognition, and visual-spatial perception task was used to measure cognitive functions. Ninety eight participants were separated into three groups (namely addicted, risk group, and controls) based on the amount of time they spent for violent game playing (per week). DSM-based pathological game addiction symptoms and their scores are measured on game addiction scale. We found significant effects of excessive video game playing on working memory, object recognition, and response inhibition, whereas no significant differences were found among the groups on emotional memory and visual spatial perception.

Keywords Violent video game • Memory • Response inhibition • Neuropsychology

1.1 Introduction

Playing video games either through computers, game consoles (e.g., Nintendo Wii, Sony PlayStation), or handheld devices (cellular phones, tablets) are among the most popular leisure activities not just for adolescents but also for adults (Kirsch et al. 2005). Research has suggested that in American households, 93 % of children ages 8–18 have access to computer (Boot et al. 2008) and those children are playing video games 7–13 h/week (Bailey et al. 2010; Gentile and Anderson 2003). In one of the earliest studies Lynch (1983) stated that cognitive abilities (e.g., attention,

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concentration, reaction time, visual tracking, memory, hand-eye coordination, mathematical ability, and verbal ability) are the determinants of playing video games; therefore, such cognitive processes could be affected by playing video games either positively or negatively. Ever since 1980s, a growing number of studies that investigate individual, cognitive, neurobiological, and societal outcomes of playing video games are observed.

The term addiction is misused frequently to refer to substances such as alcohol or drugs. However, the concept is much broader and it spreads to other constructs such as Internet, sex, gambling, television, or game. Over the past decades, Internet addiction (in a broad spectrum from gaming, shopping, and gambling to social networking) has been studied within the context of addictive behavior (Block 2008). Clinical investigations have shown that Internet addicts, like substance addicts, also experience a variety of bio-psychosocial symptoms including salience, mood modification, tolerance, withdrawal, conflict, and relapse (Sussman and Sussman 2011). With the growing Internet and game industries over the past decades, there have been increasing numbers of people considered as addicted to Internet and video games.

In addition to increasing arousal and aggressive thoughts, feelings, and behaviors, many studies have shown that obsessive-like behaviors (e.g., gambling addiction) also cause changes in brain activity as same as the substance abuse. Hence, video game addiction may create some significant changes in cognitive processes, lead to long-term behavioral problems, and adversely affect the natural development of brain (Basak et al. 2008). While some studies argue that playing video games positively affects visual spatial perception, attention, and memory (e.g., Boot et al. 2008; Coltazo et al. 2013), other studies (e.g., Castel et al. 2005; Irons et al. 2011; Murphy and Spencer 2009) indicate playing video games has no or limited effect on cognitive factors (Anderson and Bushman 2001).

Gaming addiction is also categorized based on the contents, namely violent and nonviolent. Today, majority of the popular video games have violent content. One of the well-known results from both neuropsychology and cognitive psychology area is that cognitive functions are strongly related with emotions. Emotional content of the addictive games could differentiate the relationship between game addiction and cognitive processes. Wells (2000) has suggested that individuals show memory and attention bias regarding to the different emotional stimuli matching with their emotional states. Therefore, emotional content could affect cognitive performances of the individuals' both positively and negatively (Wells and Matthews 1994). Based on this hypothesis, being constantly exposed to emotionally violent stimuli, like in violent game addiction, might lead to biases in cognitive processes even if the individuals do not have any cognitive problems. Therefore, the goal of this study is to investigate the effects of playing violent video games on different aspects of cognitive processes such as working memory, object recognition, visual spatial perception, response inhibition, and emotional memory. Violent game addicted group, violent game risk group, and non-players (controls) are compared on above-mentioned cognitive performances using a complex neuropsychological task battery.

1.1.1 Neurobiology of Game Addiction

Brain imaging studies assume that Internet and game addiction share similar mechanisms and changes which take part in brain with those substance related addiction and pathological gambling (Kuss and Griffiths 2012). Results generally suggest that individuals who have symptoms of Internet or game addiction display greater activation in brain regions related to reward, addiction, craving, and emotion during playing the games and presentation of the game cues (Han et al. 2010b; Hoeft et al. 2008). According to that, among addicted Internet users and gamers, especially the nucleus accumbens, amygdala, anterior cingulate, dorsolateral prefrontal cortex, right caudate nucleus, right orbitofrontal cortex, insula, premotor cortex, and precuneus are the brain regions in which increased activations were observed (Ge et al. 2011; Han et al. 2010a, b; Hoeft et al. 2008; Ko et al. 2009). Liu et al. (2010) have stated that Internet addicts' gray matter volume in dorsolateral prefrontal cortex, cerebellum, and supplementary motor region is significantly smaller relative to control groups. Internet addicts are assumed to process sensorimotor and perceptual information better, probably as a result of excessive exposure to applications such as games and leads to increased connectivity between brain regions (Liu et al. 2010).

1.1.2 Video Games and Cognitive Processes

Previous studies about the relationship between video game playing and cognitive functions showed inconsistent results. Those studies could be divided into three groups based on their methods and findings. First group of studies suggest superior cognitive abilities in a number of sensory, perceptual, and attentional domains (Appelbaum et al. 2013). According to that, action video game players respond more rapidly to the relevant stimuli (Dye et al. 2009), track a greater number of items (Green and Bavelier 2006), have better spatial (Boot et al. 2008; Green and Bavelier 2003, 2006) and temporal abilities (Donohue et al. 2010), and are better at task switching (Boot et al. 2008; Cain et al. 2012) relative to non-players. They perform better on working memory (measured by N-back tasks) and detect changes more efficiently (Boot et al. 2008), but do not show enhancements in short-term verbal recall (Cain et al. 2012) or visual short-term memory (Wilms et al. 2013). Second group of studies reports negative effects of engaging in video games frequently, on visuospatial perception, attention, and memory (Boot et al. 2008). On the other hand, third group of studies comparing video game players with non-players state no significant differences between the groups regarding the cognitive processes (e.g., Castel et al. 2005; Murphy and Spencer 2009; Irons et al. 2011).

1.1.2.1 Memory

Previous studies have frequently investigated the role of playing video games on working memory and emotional memory. The differential effects of playing violent video games on various memory performances have become an issue of concern. According to the studies, violent and nonviolent video game experts perform better on short-term memory and working memory tasks (Boot et al. 2008) but they are not different than non-game players on emotional long-term memory (Bowen and Spaniol 2011), whereas they perform worse on verbal memory tasks (Maass et al. 2011).

One of the main conclusions regarding the performance of working memory is that, playing video games might enhance working memory ability of players, since players should store and remember many stimuli at the same time in order to be successful in violent video games (Mahncke et al. 2006). Boot et al. (2008) found that expert video game players had better performance on visual memory task than non-video game players. In their following study (Boot et al. 2010), the participants, who play video games less than 3 h a week, were trained for a new nonviolent video game. They reported that the participants showed superior performance on various memory tasks (e.g., visual, working, and short-term memory) after the training. Recently, Coltazo et al. (2013) observed increased working memory performance measured by video game players compared to non-game players. Conversely, Powers et al. (2013) have failed to find evidence about beneficial effects of playing video games on certain aspects of executive functioning such as multitasking, nonverbal intelligence, task switching, and working memory.

1.1.2.2 Attention and Visuo-Spatial Perception

Playing video games also requires selective attention and concentration. Therefore, performing well on computer games requires being good at those cognitive abilities. Results suggested that when video game players are exposed to a target with distracters during the display, they answer quicker than non-video game players. Boot et al. (2008) study showed that video game players were faster and more accurate in object tracking relative to non-gamers, and game-players detected changes more easily, switching more quickly from one mission to another compared to other groups. Such findings suggested that video game players might be significantly faster in conditions requiring visual search and differentiating the target (Castel et al. 2005; Chrisholm et al. 2010). Green and Bavelier (2003, 2006) compared reaction times of divided and selective attention tasks between video game players and non-players. Video game players were better in detecting at localization of the target and monitoring their attention. Also, they had more control on task switching and temporal attentional processing. This superior performance on visual processing tasks was assumed to be a consequence of changes in the fundamental characteristics of the visual system. Feng et al. (2007) also used a training program and observed participants' improvement on the spatial attention performance. On the other hand, Irons et al. (2011) compared video game players and non-players using Erikson flanker task, however, did not find any significant differences between the groups on processing irrelevant peripheral stimuli. Similarly Ravenzwaaij et al. (2014) reported that playing excessive video games did not increase speed of the information processing during simple perceptual tasks. However, it is still unclear if there are improvements in attentional capabilities as a result of excessive game playing which might increase higher-order processing and cognitive control mechanisms.

1.1.2.3 Inhibition

Inhibition refers to the ability to sustain goal directed information processing in the face of distraction. With regard to the effects of video games on response inhibition, Decker and Gay (2011) have stated that although violent video game players had more difficulty in response inhibition compared to non-players, they showed better reaction time and they had the ability to discriminate targets from distracters. Similarly, Coltazo et al. (2013) observed faster reactions during the N-back task of the video game players compared to controls but there was no difference between two groups on inhibitory control conditions. They concluded that playing video games could be related to enhancements in working memory but not action inhibition. Bailey et al. (2010) reported no differences between high and low gamers in terms of Stroop interference effect and conflict adaptation effect, whereas they found that proactive inhibition was negatively affected by video game experience but reactive inhibition did not. In contrast, Littel et al. (2012) stated that video game players might have a deficiency in response inhibition. In their study, video game players displayed faster reaction times than non-video game players but they also made more errors. As well as it is seen in the other type of addictions (e.g., substance-related addictions), game addiction is assumed to result in poor inhibition, poor error processing and high impulsivity (Kuss and Griffiths 2012). Likewise, Irvine et al. (2013) mentioned that video game-addicted individuals are more impulsive, give premature responses, and prefer immediate rewards even if the delayed reward is more satisfactory.

As a summary, a great deal of studies mentioned the associations between video game playing and improvements in cognitive processes. However, recent behavioral findings suggest that Internet and game addiction leads to problems in impulse control, behavioral inhibition, working memory, and attentional capabilities. Whereas some skills are clearly open to improvements as a result of an extensive involvement with the technology (e.g., integration of perceptual information into brain, hand-eye coordination), disadvantages should not be ignored. Moreover some common methodological differences should be addressed in interpreting the controversial results. First problem is that, various cognitive tasks and/or tests have been used in different studies. Second and more important problem is the lack of accepted inclusion and exclusion criteria regarding the addicted group. Thus homogeneity of participants either within or between the studies becomes a problem because of the difficulty in creating neuropsychological profile of addicted individuals. We used three different measures (hours of playing video game per week, Game Addiction Symptoms List, and Game Addiction Scale) while creating the groups in order to control that problem and to be able to see the cognitive differences between the game addicted, risk, and control groups. Therefore, the present study has two main objectives. First one is to reveal the possible relationships between violent game addiction and different cognitive abilities. Second one is to investigate any differences in terms of the cognitive performances of the individuals among three different groups.

1.2 Method

1.2.1 Participants

The current study was carried out with 98 participants (44 female; 54 male; 18–31 years; $M=22.47$; SD = 3.09). Majority of the participants ($n=84$; 85.7 %) had undergraduate degree, and 14.3 % ($n=14$) of participants had graduate degree at the time of testing. Participants were separated into three groups (namely addicted, risk, and control) based on the time they spend for violent game playing (per week), DSM-based pathological game addiction symptoms (Gonnerman and Lutz 2011), and their scores on the Game Addiction Scale developed by Lemmens et al. (2009). All the participants in this study were right-handed, had normal or corrected-to-normal vision, and had no history of neurological, psychological, or memory diseases.

Game-addicted group consisted of 41 participants with mean age of 21.98 (SD = 3.021). For this group, the first criterion was playing violent video games more than 16 h/week ($M=41.95$; SD = 22.87; min. 20 h, max. 130 h), the second criterion was reporting more than three symptoms on the Pathological Game Addiction Symptoms List (Gonnerman and Lutz 2011), and the last criterion was obtaining more than 55 total score ($M=61.27$; SD = 14.51) on the Game Addiction Scale (Lemmens et al. 2009). Risk group consisted of 25 students (age $M=21.36$; SD = 3.21). For this group, the first criterion was playing violent video games for 5–16 h a week ($M=11.32$; SD = 3.91), the second criterion was reporting 1 or 2 symptoms on DSM-based Game Addiction Symptoms List (Gonnerman and Lutz 2011), and the last criterion was obtaining total score between 38 and 54 ($M=37.96$; SD = 14.2) on the Game Addiction Scale. Finally control group consisted of 32 participants (age $M=23.97$; SD = 2.57). For this group, the first criterion was not having any experience with any type of video games, the second criterion was obtaining a less than 37 total score ($M=28.25$; SD = 3.55) on the Game Addiction Scale, and the last criterion was reporting no symptoms on the Game Addiction Symptoms List.

1.2.2 Materials

1.2.2.1 Game Addiction Symptoms List

Game Addiction Symptoms List comprised of the pathological gambling symptoms according to DSM-IV (Gonnerman and Lutz 2011). The word "gambling" was replaced with the word "gaming" in the sentences and the sentences have been transformed to "yes" or "no" questions. Adaptation of the list into Turkish culture was completed by Arslan-Durna (2015) and Başer (2015). The list consists of 16 items. The scores that could be obtained from the list range from 0 to 16.

1.2.2.2 Game Addiction Scale

Game Addiction Scale was developed by Lemmens et al. (2009) in order to measure the degree of game addiction. The scale has 21 items with seven factors, which are salience, tolerance, mood modification, relapse, withdrawal, conflict, and problems. Participants give their responses on a 5-point Likert scale from 1 (never) to 5 (very often). Internal consistency of the scale has been reported with range from 0.80 to 0.94. Adaptation of the scale into Turkish culture was completed by Arslan-Durna (2015) and Başer (2015). Participants could obtain a minimum score of 21 and maximum score of 105 on the scale. High scores indicate high levels of game addiction.

1.2.2.3 Working Memory Task

The task was adapted from Harkin and Kessler (2009). It consisted of three phases. The stimuli were capital letters and were presented against a gray back-ground within a 2 (columns) by 3 (rows) matrix covering an area of 300 × 420 pixels. In the first phase, a 1000-ms fixation cross was shown and four letters were presented randomly in four of the six possible locations. Participants had 1000 ms to encode the identity and the location of each letter. After 500 ms, the probe-1 question requested the location of a specific letter in the second phase. Participants indicated the location via mouse and were instructed that they had little time to answer (2000 ms). In the third phase, whether the probe-1 letter had or had not been part of the encoded set created resolvable versus misleading (irresolvable) trials. In base-line condition, probe-1 was omitted to measure working memory performance on the primary task under ideal conditions. A 500-ms inter-stimulus interval separated probe-1 and probe-2. Since baseline trials did not include the intermediate probe-1, a gray screen was shown for 5500 ms between encoding and probe-2 (equaling the ISI between encoding and probe-2 on the other trial types). Probe-2 was the actual memory test for each trial and required participants to indicate if a letter was correctly located with respect to the originally encoded set (2000 ms). In all of the trials the probe-2 letter had been a part of encoded set in terms of identity while the probe location was correct only on 50 % of the trials. Finally, a scale was displayed prompting participants to indicate their degree of confidence in their probe 2 response (6 levels: 1 = totally certain to 6 = totally uncertain).

1.2.2.4 Object Recognition Task

The task was adapted from Arslan-Durna (2015) and Başer (2015), which consisted of two phases. In the first phase, 15 unfamiliar geometric shapes were shown one at a time in the middle of the computer screen against a gray back-ground. Participants had 1000 ms to encode and learn the shapes. After every shape presented, participants were given a 4 (columns) by 4 (rows) matrix, which boxes filled with 15 distractor shapes and one target shape. Participants were asked to indicate the target shape by using the mouse as quickly as possible in 2000 ms. Then 49 shapes were presented within a 7 (columns) by 7 (rows) matrix and the participants were asked to indicate the target shapes which they have seen previously by using the mouse among them. There is no time limit in this phase. The task lasted about 10 min. High response accuracy and short reaction time indicated higher performance on the object recognition task.

1.2.2.5 Visual Spatial Memory Task

The visual spatial memory task which was adapted from Slotnick and Schacter (2004, 2006) consisted of 40 nonsense shapes. Shapes were generated by using custom software written in MATLAB (The MathWorks Inc.), which were comprised of four pseudo-randomly generated Bezier curves each with end-points on adjacent sides of a bounding square and they had an edge length of 5.5° of visual angle (Slotnick and Schacter 2004, 2006). In the first phase, shapes were presented for 2000 ms with an intertrial interval of 1000 ms on a black computer screen divided by a white line in the middle. Participants were instructed to remember each shape and its spatial location (left or right side of the screen), while always maintaining fixation at the central cross at a time for 1000 ms. In the second phase (recall), same 40 nonsense shapes were presented in different order, and participants were instructed to remember each shape and its spatial location, while always maintaining fixation at the central cross. During this phase, participants had to click on left button of the mouse whenever a shape was presented in the same place than the previous phase, or right button of the mouse whenever a shape was presented in a different place than the previous phase. Duration of the presentation of each shape was 2000 ms. For each participant, a practice section was carried out before the experiment.

1.2.2.6 Response Inhibition Task

The Go/No-Go task was used as a response inhibition measurement. In this study, the Go/No-Go task involved the presentation of letters, one at a time on a screen, for a period of 75 ms, with an inter-stimulus interval of 925 ms. Fifty percent of the stimuli was "X," and the other 50 % was other capital letters randomly selected from the remainder of the alphabet. "X" and "non-X" stimuli were presented in random order. There were two types of Go/No Go task. In the "Respond to X" task, the subject was instructed to press the button when an "X" is presented, and refrain from pressing for all other letters. In the "Respond to non-X" task, the subject was instructed to refrain from pressing for X, and to press for all other letters. Both Go/No-Go tasks were presented in epochs of 20 s duration. Each Go/No-Go epoch was preceded by a 5-s instruction epoch, and followed by a 20-s rest epoch. During instruction epochs, the instruction "Press for X" or "Press for all letters except X" was presented on the screen. During rest epochs, the word "RAHATLAYINIZ" ("Rest" in English) was presented, and the subject was not required to make any motor response. Within the scanning session, there were five "Respond to X," and five "Respond to non-X" epochs, presented in a counterbalanced order. In this task, response times and accuracy scores for Go and No-Go phases were calculated. Individuals who had shorter reaction times in Go trials and more accurate responses in No-Go trials were considered to conduct response inhibition more effectively (Hirose et al. 2012).

1.2.2.7 Emotional Memory Task

A word list was used to assess emotional memory. Sixty violent (e.g., dangerous) and 68 nonviolent (e.g., peaceful) adjectives were chosen as target words from Turkish Word Frequency Dictionary (Göz 2003). The task consisted of three phases. In the first phase, 20 violent and 24 nonviolent words were shown randomly to the participants for 2000 ms. In this phase, participants were asked to learn the presented words on the screen which they will be asked later. In the second phase, a stem completion test was used, and the participants were shown first and third letters of each word (e.g., D_N______ for the word DANGEROUS) one by one and asked to complete the word. After that, they were asked to indicate how confident they are of their answers using a 6-point Likert-type scale from 1 "not at all" to 6 "extremely strong." In the third phase, 44 previously shown words (20 violent, 24 nonviolent) were presented to the participants with 20 violent and 20 nonviolent new words. All 80 words, except the first and last 2 constant positive words, were presented randomly for 2000 ms. As a part of the classical recognition paradigm, participants were asked to evaluate whether they have seen the presented word previously. In the last phase, participants were requested to indicate how confident they are of their answers using a 6-point Likert-type scale from 1 "not at all" to 6 "extremely strong." Response time, accuracy scores, and the level of confidence rates were calculated. The first and last two words at recall and recognition phases were positive and were not used during statistical analyses in order to control primacy and recency effects.

1.2.3 Procedure

The study was conducted following the approval of the ethics committee at the University. At first, individuals filled out the surveys that inquire about the frequency of playing video games per week and the most frequent games played in general. Based on the information they have given, individuals who match with the inclusion criteria were contacted via phone and those who seem appropriate and accepted to participate to the study were invited. Before the experiment, all participants were given detailed information about the procedure and they were requested to read and to sign the consent form. The experiment was completed in one session separately for each participant in a quiet laboratory room using an IBM compatible 15 in. computer running Windows XP. A comprehensive cognitive battery including working memory, visual spatial memory, emotional memory, response inhibition, and object recognition tasks were given to the participants. Order of the tasks was counterbalanced and detailed instructions and a practice session were given before each task. Administration took approximately 35–40 min for each participant.

1.3 Results

Prior to analyses, the data were screened for missing values, as well as univariate and multivariate outliers (Tabachnick and Fidell 2007). There were no outliers identified as multivariate using Mahalanobis distance with $p < 0.001$, nor univariate using z scores ($|z| \geq 3.30$).

In order to compare neuropsychological task performances of addicted group, risk group, and control group, separate MANOVAs were used. In the analyses group status (three groups) was independent variable, performances, which were measured under each task, were dependent variables. Since multiple analyses were made on the data set, a Bonferroni type adjustment was made for inflated Type 1 error for each comparison separately. For this, α was assigned the value of 0.05 for each p among a set of *ps*, such that for a set of *ps* it did not exceed a critical value.

1.3.1 Group Comparisons on Working Memory Task

During the task, number of correct response, incorrect response, reaction time (RT; ms) for correct and RT for incorrect responses of the participants were calculated for probe-1 and probe-2. MANOVA results indicated that group status had

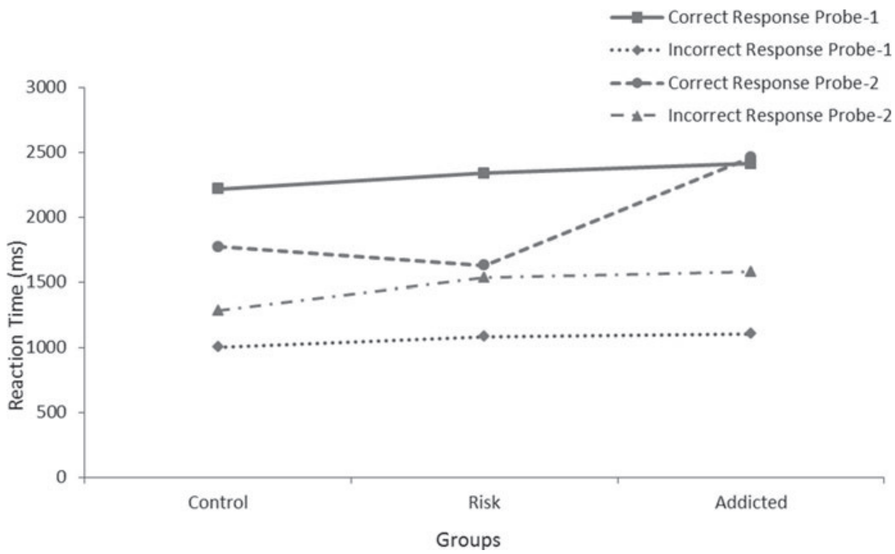

Fig. 1.1 Participants' reaction time during working memory performance according to group status

significant effect on RT for correct response at probe-2, $F(2, 81) = 4{,}64$; $p < 0.05$; $\eta_2 = 0.15$ (see Fig. 1.1). Post-hoc test indicated that addicted group' RT ($M = 1800.38$; $SD = 295.39$) was significantly higher than control group ($M = 1764.86$; $SD = 208.78$) and risk group ($M = 1567.87$; $SD = 244.79$). After the Bonferroni correction, the differences remain significant ($p < 0.05$).

1.3.2 Group Comparisons on Object Recognition Task

During the object recognition task, number of correct response, incorrect response, RT (ms) for correct and RT for incorrect responses of the participants were calculated on immediate recall and recognition phases. Result indicated that correct recognition performance of the participants was significantly different, $F(2, 85) = 4{,}99$; $p < 0.05$; $\eta_2 = 0.105$. Recognition performance of the control group ($M = 13.66$; $SD = 4.88$) was significantly lower than the risk group ($M = 17.14$; $SD = 4.18$) and addicted group ($M = 16.54$; $SD = 4.31$). After the Bonferroni correction, the differences were significant ($p < 0.05$).

1.3.3 Group Comparisons on Response Inhibition Task

Numbers of correct and incorrect responses and RT for correct and incorrect responses of the participants were calculated for both go and no-go trials. MANOVA results showed that group status's main effect was significant on number of correct

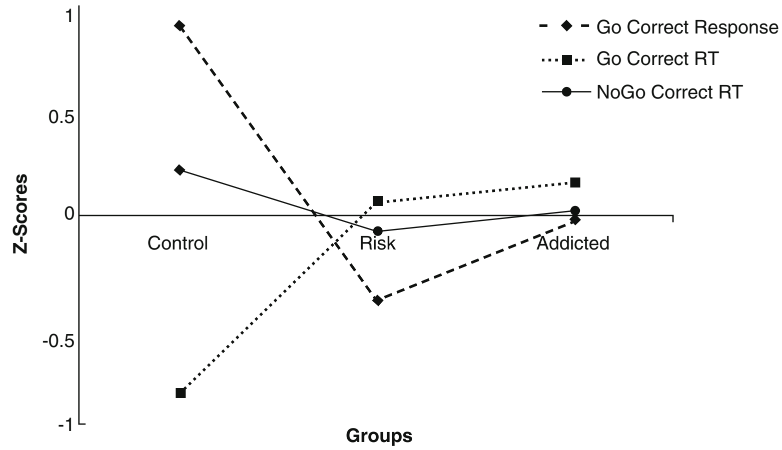

Fig. 1.2 Participants' number of correct response at go phase, reaction time (RT) for correct response at go phase, and RT for correct response at No-Go phase according to group status

response at go phase $F(2, 91) = 4.21$; $p < 0.05$; $\eta_2 = 0.107$; RT for correct response at go phase $F(2, 85) = 4.99$; $p < 0.05$; $\eta_2 = 0.105$ and RT for correct response at no-go phase F(2, 85) = 3.63; $p < 0.05$; $\eta_2 = 0.08$ (see Fig. 1.2). Post-hoc comparisons indicated that during go phase, correct response of the control group ($M = 49.93$; SD = 2.27) was significantly higher than the risk group ($M = 40.33$; SD = 1.83), and the addicted group ($M = 45.18$; SD = 3.24). On the other hand RT for both correct and incorrect responses during the go and no-go phases the control group ($M = 507.75$; SD = 53.78; $M = 518.47$; SD = 50.02, respectively) was significantly slower than the risk group ($M = 485.66$; SD = 62.29; $M = 493.41$; SD = 61.15, respectively), and the addicted group ($M = 475.91$; SD = 55.51; $M = 490.90$; SD = 59.16, respectively). After the Bonferroni correction the differences remain significant ($p < 0.05$). Group comparisons were also conducted on emotional memory performance and visual-spatial memory performance, but no statistically significant differences were found.

1.4 Discussion

The main goal of the present study was to reveal whether excessive video game playing results in differential changes in certain aspects of cognitive abilities. We compared cognitive performances of violent game-addicted group, risk group, and non-game players (control group) by using a complex neuropsychological test battery, including working memory, object recognition, visual spatial perception, response inhibition, and emotional memory. We found significant effects of excessive video game playing on working memory, object recognition, and response inhibition, whereas no significant differences were found among the groups on emotional memory and visual spatial perception. In details, addicted group showed better performance during object recognition task and their RT was faster during response inhibition (for both go and no-go conditions). On the other hand, during working memory task, addicted group's RT for correct response were significantly slower and their correct responses during response inhibition task were lower compared to risk and control groups.

Video game playing in general requires more than pressing a button at the right time. In order to be successful, game players should monitor and react quickly to the fast moving stimuli, select rapidly the relevant information while filtering out the irrelevant information, and should also avoid inaccurate actions and switch between tasks. Therefore it was consistently hypothesized that more extensive experience with video games could result in increased performance on tasks, which need monitoring and updating of working memory (Coltazo et al. 2013). Contrary, our results have revealed significant group effects on RT for correct responses at probe-2 during working memory task. In this phase, participants were required to indicate if a letter was correctly located with respect to the originally encoded set. According to this, participants in the risk and the addicted groups had higher RTs than control group. Also, video-game addicts did not show any increase in the number of correct responses compared to non-gamers. Also, they were slower while correctly indicating the location of the previously encoded stimuli that indicates that addicted group was slower to recognize previously encoded stimuli compared to other groups. This finding was contradictory to the previous studies, which suggested improvements (e.g., Barlett et al. 2009; Boot et al. 2008; Coltazo et al. 2013; Kearney and Pivec 2005) or no changes (Irons et al. 2011) on working memory performance by individuals experienced in video games.

Since object recognition involves recognition memory, sustained concentration and selective attention, the other hypothesis might be that excessive engagement in video games leads to improvements in object recognition abilities. Expectedly, significant differences in the object recognition performances were observed between the groups. In detail, correct recognition performances of the risk group and the violent video-game addicted group were found better than the control group. This finding was supportive of the Blumberg's (1998) findings in which video game players were found better at focusing on particular cues in the games, which resulted in increased recognition performance. Similar results were found in the studies conducted thereafter. However, these studies generally reported faster reactions by the video game players to targets appeared with distractors in the display (e.g., Castel et al. 2005; Clark et al. 1987; Goldstein et al. 1997).

Previous studies found that video-game practice had little or no effect on object recognition task performance (e.g., Peters et al. 1995), implying that improved performance on visuo-spatial tasks after video-game practice may depend on the kind of spatial abilities needed in the game and in the spatial task (Ogakaki and Frensch 1994). Chrisholm et al. (2010) suggested that experienced video-game players were significantly faster in conditions that require visual searching and classifying the targets. They stated that having experience in video games improves top-down attentional control of individuals. Green and Bavelier (2003, 2006) found consistently that video game players were better in detecting the location of the target and controlling the center of their attention. Such findings supported the idea of video game players having better attentional capacity and effective field of view. On the other hand, even we found better recognition performance in the risk and the addicted groups; their RTs were not different. Our finding suggests improved visuospatial recognition performance by the experienced video-game players. These results are inconsistent with previous studies (e.g., Boot et al. 2008; Donohue et al. 2012).

One possible explanation for the differences between the results could be related to different methods employed by the studies. Previous studies with significant effects of playing video games on working memory and visuo-spatial recognition performance used mostly a practice or a training strategy (e.g., Barlett et al. 2009; Boot et al. 2008). In our study and similar to Irons et al.'s (2011) study, addicted, risk, and control groups were divided based on the self-report of the individuals about their approximate amount of time spent on playing video games per week. Thus, duration of training and time spent for playing video games should be controlled in experimental laboratory studies. Additionally, different from the previous studies, in this study how long individuals engage in violent video games (on-set) was not taken into consideration. In our sample, there might be participants who have been playing violent video games for a short period of time or for years and this could be a factor, which influence the task performance. Finally, the differences (e.g., duration and intensity) between our task and the tasks used in previous studies may account for the discrepancy among results. Therefore, standard methodology should be used in future studies to eliminate this limitation.

We found significant differences among addicted, risk, and control groups on their response inhibition performance. Although individuals in the addicted group showed faster RT during both go and no-go conditions, their correct responses during go condition were lower compared to risk and control groups. Additionally, although it was not significant, higher numbers of incorrect responses for both go and no-go conditions of the addicted group and risk group was remarkable. The results pointed out that experienced video gamers had difficulty in inhibiting their responses compared to non-players. Our results indicated that although experienced video-game players were faster than the non-gamers, it does not increase the number of correct responses. Impulsivity is used to explain maladaptive behaviors including deficits in response inhibition, problem in processing of errors, such as, inability to monitor continuous performance in order to detect and fix errors (Groman et al. 2009; Ridderinkhof et al. 2004). Some impulsive-like behaviors (e.g., drug use) diminished response inhibition and poor error processing contribute to difficulties to resist consumption of a substance and continuation of the behavior despite its negative consequences (Dave et al. 2004; Lubman et al. 2004).

These results might be explained by higher impulsivity and perseveration in excessive video-game players. They could have poor inhibition and error processing abilities when compared to non-gamers. In fact, a number of studies have supported that idea (e.g., Littel et al. 2012; Kuss and Griffiths 2012; Decker and Gay 2011). Similar to our study, Decker and Gay (2011) indicated that video-game players had faster RTs and better ability to discriminate targets from distracters than non-game players, but they showed greater disinhibition than non-players. Additionally, Littel et al. (2012) found that excessive video game players had more errors than controls on no-go trials even they were faster than controls on go trials. They investigated error processing and response inhibition among excessive gamers via ERP recordings. Results showed that addicted gamers had reduced frontocentral event-related negativity (ERN) amplitudes during incorrect trials compared to correct trials and they also had poor error processing similar as in substance dependence and impulse control disorders. The ERN amplitude is associated with perceived accuracy (Scheffers and Coles 2000). Therefore increased errors were interpreted with the reduced awareness and cognitive control regarding the errors by excessive gamers Also, Dong et al. (2010) found that during no-go condition, Internet addicts had lower N2 amplitudes (representing response inhibition-conflict monitoring), higher P3 amplitudes (inhibitory processes-response evaluation), and longer P3 peak latency compared to controls. They stated that Internet addicts had lower activation in conflict detection stage; they were less efficient at information processing and had lower impulse control.

Therefore, these neuroimaging studies indicated that video-game addiction shares some similarities with substance dependence and impulse control disorders in relation to poor inhibition and high impulsivity (Kuss and Griffiths 2012; Treuer et al. 2001). Neuroimaging studies have provided evidence to the idea that excessive gaming might be related to abnormal neurobiological mechanisms in the orbitofrontal cortex and sensory regions, which are associated with impulse control (Park et al. 2010). In their fMRI study Han et al. (2012) found that gaming addicts had more errors as a result of increased impulsiveness.

As conclusion, there have been researches to suggest that video games may lead to some specific benefits, most notably improved visuospatial skills (e.g., Castel et al. 2005; Green and Bavelier 2006). Ferguson and Rueda (2010) mentioned the effect sizes for this research appear to be considerably stronger than for the relationship between violent video games and aggression. Thus, a careful balancing of pros and cons of video games should be undertaken. Our study made important contributions to the literature by extensive knowledge on how cognitive processes are affected by violent gaming addiction. It is difficult to say whether gaming addiction has either negative or positive effects on cognitive processes. But our study indicated that different cognitive functions are affected by gaming in different way. However, the results of the risk group are also remarkable. For many variables, performance of individuals in the risk group was similar (or close) to the addicted group and they were different than the non-players. Therefore, further longitudinal studies are needed in order to observe actual results of gaming addiction on cognitive functions for both risk and addicted groups.

The current study is not without limitations. The first limitation was unequal group sizes. Secondly while categorizing the groups, how long individuals (onset) play video games was not considered. Future research should control these issues in order to attain clear understanding of the relationships between gaming addiction and cognitive processes.

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