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Brain activity and desire for internet video game play

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Abstract

Objective—Recent studies have suggested that the brain circuitry mediating cue induced desire for video games is similar to that elicited by cues related to drugs and alcohol. We hypothesized that desire for internet video games during cue presentation would activate similar brain regions to those which have been linked with craving for drugs or pathological gambling.

Methods—This study involved the acquisition of diagnostic MRI and fMRI data from 19 healthy male adults (ages 18–23 years) following training and a standardized 10-day period of game play with a specified novel internet video game, “War Rock” (K-network®). Using segments of videotape consisting of five contiguous 90-second segments of alternating resting, matched control and video game-related scenes, desire to play the game was assessed using a seven point visual analogue scale before and after presentation of the videotape.

Results—In responding to internet video game stimuli, compared to neutral control stimuli, significantly greater activity was identified in left inferior frontal gyrus, left parahippocampal gyrus, right and left parietal lobe, right and left thalamus, and right cerebellum (FDR <0.05, p<0.009243). Self-reported desire was positively correlated with the beta values of left inferior frontal gyrus, left parahippocampal gyrus, and right and left thalamus. Compared to the general players, members who played more internet video game (MIGP) cohort showed significantly greater activity in right medial frontal lobe, right and left frontal pre-central gyrus, right parietal post-central gyrus, right parahippocampal gyrus, and left parietal precuneus gyrus. Controlling for total game time, reported desire for the internet video game in the MIGP cohort was positively correlated with activation in right medial frontal lobe and right parahippocampal gyrus.

Discussion—The present findings suggest that cue-induced activation to internet video game stimuli may be similar to that observed during cue presentation in persons with substance dependence or pathological gambling. In particular, cues appear to commonly elicit activity in the dorsolateral prefrontal, orbitofrontal cortex, parahippocampal gyrus, and thalamus.

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Keywords

internet video game play; functional MRI; frontal cortex; parahippocampal gyrus; thalamus

Introduction

With the rapid increase of internet usage over the last decade, the concept of internet addiction as a new diagnosis within the field of addictive disorders continues to be the subject of much debate. To date, internet addiction, similar to substance abuse and dependence, has been defined as the inability of individuals to control their internet use, resulting in marked distress and functional impairment in five domains: academic, social, occupational, developmental, and behavioral [1–3]. In addition, major depression, anxiety disorders, ADHD, and schizophrenia have been regarded as comorbid psychiatric disorders [1]. In severe cases, continuous internet video game play leading to death has been reported in both Korea [4] and the United States [5].

Numerous lines of research have been pursued to bolster our understanding of the neurobiological changes associated with drug, alcohol, and gambling addiction. Kalivas and Volkow [6] summarized the addiction circuits as consisting of dorsolateral prefrontal cortex (DLPFC), orbitofrontal cortex (OFC), thalamus, amygdala and hippocampus. Additionally, dopamine is considered to be a critical mediator in the underlying addiction network. The majority of drugs, as well as alcohol, induce large and rapid increases of dopamine in the nucleus accumbens, which in turn is associated with euphoria and craving [7,8].

Drug craving is defined as “the high desire for the previously experienced effects of a psychoactive substance” [9]. This desire can be compelled and increased in responding to internal or external cues. Craving can be divided into two domains. The first craving domain is associated with environmental factors such as the use of drug-priming or cue-induced reinstatement while the second domain is characterized by the state of protracted abstinence following acute withdrawal [9]. With respect to cue-exposure, recent neuroimaging studies have suggested that increased activity in DLPFC, OFC, thalamus, amygdala, and hippocampus is associated with craving (Table 1). Crockford et al [10] reported a dissociation in the visual processing stream, via a more active frontal, parahippocampal and occipital cortex, of pathological gamblers in response to cue-induced type stimuli. In response to substance cues, increased activity in DLPFC and OFC has been already reported in patients with alcohol, cocaine, nicotine, or online game addiction [11–16]. After drinking a small amount of alcohol, the left dorsolateral prefrontal cortex and the anterior thalamus in patients with alcohol dependence were activated while watching alcohol pictures, compared to social drinking controls [12]. In addition, Wrase et al [16] reported that basal ganglia and orbitofrontal gyrus in abstinent alcoholics were activated in response to alcohol pictures. Filbey et al [11] reported that the presentation of alcohol taste cues can activate brain regions such as prefrontal cortex, striatum, ventral tegmental area and substantia nigra in patients with alcohol dependence. During presentation of audiovisual stimuli containing cocaine-related scene to six subjects with a history of cocaine use, the anterior cingulate and left dorsolateral prefrontal cortex were activated [14]. Exposure to cigarette smoking cues induced the activation of striatum, amygdala, orbitofrontal cortex, hippocampus, medial thalamus, and left insula in smokers, compared to non-smoking stimuli [17]. In response to heroin related scenes, patients with opioid dependence, but not control subjects, showed increases in the activity of the hippocampus [18]. In response to gaming pictures, right orbitofrontal cortex, right nucleus accumbens, bilateral anterior cingulate and medial frontal cortex, right dorsolateral prefrontal cortex, and right caudate nucleus were activated in 10 internet addiction subjects, compared to healthy control group [13]. During presentation of a

gambling-related video, pathologic gambling subjects showed greater activity in the right dorsolateral prefrontal cortex (DLPFC), inferior and medial frontal gyri, the right parahippocampal gyrus, and left occipital cortex, compared to control subjects [10].

Based on previous reports that substance abuse and non chemical addiction would share similar brain circuitry (prefrontal cortex, orbitofrontal cortex, amygdala, hippocampus and thalamus), we hypothesized that the desire for internet video game play would be correlated with the activity of the dorsolateral prefrontal cortex, orbitofrontal cortex, amygdala, hippocampus, and thalamus in response to the presentation of game cues.

Method

Subjects

Through advertisement on the Bentley college campus, twenty-three students were recruited. Of these twenty-three, two students were excluded due to symptoms of major depression on the Beck Depression Inventory (BDI) scores. One subject missed the date of fMRI scanning and one subject did not follow the schedule for internet video game play. Finally, we evaluated nineteen male students (mean age= 20.5±1.5years, minimum 18, maximum 22) with a history of internet use (3.4±1.5 hour/day, minimum 0.5 hour, maximum 6 hours) and computer use (3.8±1.3 hours/day, minimum 1.5 hour, maximum 6 hours) but who did not meet criteria for addiction (Young internet addiction scale scores <40) 19 during the past 6 months. Of 19 subjects, 10 subjects drank alcohol (social drinking, frequency, 2.3±2.6/month) and all subjects were non-smokers (Table 2). All subjects were screened with the Structured Clinical Interview for DSM-IV, BDI [20] (cut off score=9, mean score=6.1±2.0), and Beck Anxiety Inventory [21] (cut off score=21, mean score=4.8±3.5). Exclusion criteria included (1) students with history or current episode of Axis I psychiatric disease (2) students with substance abuse history (except for alcohol) and (3) students with neurological or medical disorders. The McLean Hospital Institutional Review Board and the Bentley College Institutional Review Board approved the research protocol of this study. All students participating in the study provided written informed consent.

Study Procedure

Video game play and fMRI scanning—At the first screening visit, students participating in the study underwent an initial medical screening, which included a clinical MRI scan in order to make sure that subjects were comfortable in the scanner and to exclude individuals with evidence of significant central nervous system pathology. In addition, the severity of internet addiction was assessed by Young's Internet Addiction Scale (YIAS) [3]. The medical screening was followed by a brief training session for instruction on how to play the internet video game. This video game, "War Rock", is a first person shooter (FPS) game, which is played online with multiple other gamers at the same time. The game is styled after modern-day urban combat, using realistic characters, character movement, and weaponry. Each player is assigned to a team which has the mission to either eliminate members of the opposing team or destroy a target structure by planting an explosive. Because it was newly developed and launched in March 2007, volunteers in the current research study played "War Rock" for the first time. The students registering username and password were asked to play "War Rock" on their own computers, 60 minutes per day for 10 days. With the permission of subjects, the game company K2-Network monitored playing time, score, and game stage during a 10-day period. The mean of the total time "War Rock" was played of nineteen subjects was 795.5±534.3 minutes. At the end of the 10-day period, brain activity during game play watching was assessed with functional magnetic resonance imaging (fMRI) recordings, and desire for playing the internet video game was assessed with self-reports on a seven point visual analogue scale (VAS).

Assessment of brain activity and desire for internet video game play—All MR imaging was performed on a 3.0 Tesla Siemens Trio scanner (Siemens, Erlangen, Germany). This study was designed to parallel a number of fMRI craving studies that involve the presentation of drug cues [11–16]. Participants watched a single 450-second videotape without sound consisting of five continuous 90-second segments. Each 90-second segment contained the following three stimuli, each 30 seconds in length: a white cross in a black background (B); a neutral control (N, several animated war scenes); and the video game cue (C). The five segments were ordered accordingly: B-N-C, B-C-N, C-B-N, N-B-C, and C-N-B. The videogame cue consisted of video exhibiting the Internet video game “War Rock”. This tape was presented to each subject by means of a nonferrous reflective-mirror visual system during a single fMRI scanning session. For the fMRI session, 180 echo planar images (EPI, 40 coronal slices, 5.0 mm thickness, voxel size of $3.1 \times 3.1 \times 5.0$ mm, TE=30msec, TR=3000ms, Flip angle=90°, in-plane resolution=64×64 pixels, field of view (FOV)=200×200 mm) were recorded at 3 second intervals. For anatomical imaging, 3D T1-weighted magnetization-prepared rapid gradient echo (MPRAGE) data were collected with the following parameters: TR=2100 ms, TE=2.74 ms, FOV= 256 × 256 mm, 128 slices, $1.0 \times 1.0 \times 1.3$ mm voxel size, flip angle = 12°. To assess each student’s mean level of desire for “War Rock”™, a seven point visual analogue scale (ranging from 1=“not at all” to 7=“extreme”) was administered twice before and after scanning. Specifically, subjects were asked: “How much do you want to play War Rock game?” using a nonferrous reflective-mirror visual system and the subjects rated their desire to play the game using a joystick.

fMRI data analysis—Brain activity was analyzed using the Brain Voyager software package (BVQX 1.9, Brain Innovation, Maastricht, The Netherlands). The fMRI time series for each subject was co-registered to the anatomical 3D data set using the multi-scale algorithm provided by BVQX. The individual structural images were spatially normalized to standard Talairach space [22]. The same nonlinear transformation was subsequently applied to the T2*-weighted fMRI time series data. After the preprocessing steps of slice scan time correction and 3D motion correction, the functional data were spatially smoothed using Gaussian kernel with an FWHM of 6mm and temporally smoothed using Gaussian kernel of 4s using algorithms provided by BVQX.

Statistical analysis—Statistical analyses were performed by modeling the fMRI signal time-courses for different conditions (video game cue and neutral stimuli) as a boxcar function convolved with a hemodynamic-response function. The model functions were used as explanatory variables within the context of the general linear model (GLM) to apply multiple linear regression analysis to fMRI signal time-courses on a voxel by voxel basis. A random effects analysis yielded individual and group statistical parametric maps of brain activation contrasting video game cue vs neutral stimuli. For all analyses, associations were regarded as significant if the False Discovery Rate (FDR) was less than or equal to 0.05 (corrected for multiple comparisons) in forty adjacent voxels. Controlling total game time, the mean beta-weights associated with the model functions were used to investigate partial correlation between measures of desire for game play indices and localized brain activation. A second-level analysis of random effects ANOVA model with two within factors (video game cue vs neutral stimuli) and two between subject factors (excessive internet video game player vs general internet video game player) was used to show the different brain activation in an excessive internet video game player. Controlling for total game time, partial correlation between desire for the internet video game and mean beta weights was analyzed.

Results

Internet video game stimulation vs neutral control

The mean desire for the internet video game in nineteen subjects was 3.3 ± 1.6 (minimum 1 and maximum 5.5). In responding to internet video game stimuli, compared to neutral stimuli, significantly greater activity was identified in six clusters (FDR < 0.05 , $p < 0.0009243$): cluster 1 (Talairach x, y, z; 56, -35, 23; right parietal lobe, -59, -41, 23; left parietal lobe (Brodmann 7, 40), 32, -84, 23; right occipital lobe, -26, -84, 23; left occipital lobe), cluster 2 (38, -40, -29; right cerebellum anterior lobe, 39, -73, -29; left cerebellum posterior lobe), cluster 3 (14, -64, -39; right cerebellum semilunar lobe), cluster 4 (20, -31, 2; right thalamus), cluster 5 (-22, -25, 3; left thalamus, -38, -25, -17; left parahippocampal gyrus (Brodmann 36)), and cluster 6 (-17, 19, 25; left inferior frontal gyrus (Brodmann 9), dorsolateral prefrontal cortex that overlaps with the DLPFC in Callicott et al's and Cotter et al's research [23,24]) (Figure 1). The mean beta values between clusters 4, 5, and 6 were positively correlated with each other (cluster 4 vs cluster 5: $r = 0.67$, $p < 0.01$; cluster 4 vs cluster 6: $r = 0.63$, $p < 0.01$; cluster 5 vs cluster 6: $r = 0.64$, $p < 0.01$). The other clusters did not show any correlation between their beta values.

In a correlation analysis between the beta values of clusters and self-reported desire for the internet video game, desire was positively correlated with cluster 4 (right thalamus $r = 0.50$, $p = 0.03$), cluster 5 (left thalamus, left parahippocampal gyrus (Brodmann 36), $r = 0.56$, $p = 0.02$) and cluster 6 (left inferior frontal gyrus (Brodmann 9), $r = 0.54$, $p = 0.02$). There was no significant correlation between other clusters and desire for internet video game play (Figure 2).

Subjects who played more internet video game (MIGP) vs general internet video game player (GP)

We noticed that some study subjects played the video game to a much greater extent than others. Based on this observation, we divided the subjects into two groups, subjects who played more internet video game (MIGP) and a general player group (GP). Of nineteen subjects, six subjects who played the video game for over 900 minutes (150% of the recommended time, 600 minutes) were selected as subjects who played more internet video game (MIGP). The MIGP played the internet video game 1500.0 ± 370.9 minutes/10 days while the GP played the game for 517.5 ± 176.6 minutes/10 days. Compared to GP, in response to internet video game cue, MIGP showed significantly greater activity in six clusters (FDR < 0.05 , $p < 0.000193$): cluster 7 (Talairach x, y, z; 5, 48, -13; right medial frontal gyrus broadmann area (BA) 11), cluster 8 (52, -13, 38; right frontal pre-central gyrus), cluster 9 (20, -29, -5; right parahippocampal gyrus), cluster 10 (6, -52, 66; right parietal post-central gyrus), cluster 11 (-25, -13, 52; left frontal pre-central gyrus), cluster 12 (-17, -99, -17; left occipital lingual gyrus) (Figure 3). Controlling for total game time, desire for internet video game play was positively correlated with cluster 7 (right medial frontal gyrus, $r = 0.47$, $p = 0.047$) and cluster 9 (right parahippocampal gyrus, $r = 0.52$, $p = 0.028$) (Figure 4). There was no significant correlation between other clusters and desire for the internet video game.

Discussions

The present findings suggest that the neural circuitry that mediates cue-induced desire for internet video game play is similar to that observed following cue presentation to individuals with substance dependence or pathological gambling. In all game players, internet video game cues, in contrast to neutral cues, appear to commonly elicit activity in the dorsolateral prefrontal cortex, parahippocampal gyrus, and thalamus [6,25]. In response to internet video

game cues, MIGP had increased activation of the right medial frontal gyrus (orbitofrontal cortex), precentral gyrus, parahippocampal gyrus, and occipital lingual gyrus, compared to GP. In particular, the dorsolateral prefrontal, orbitofrontal cortex, parahippocampal gyrus, and thalamus were associated with desire for internet video game play.

Dorsolateral Prefrontal Cortex

As reported in patients with alcohol, cocaine, nicotine, and online game [10,12,13,14], dorsolateral prefrontal cortex was activated in response to game cues. With the evidence of DLPFC activation responding to a visual gambling cue, Crockford et al [10] suggested that visual gambling cues would be recognized as being salient for attention and reward expectancy. Barch and Buckner have suggested that the cues were associated with working memory [26]. The DLPFC has a role to maintain and coordinate representation by linking the present sensory experience to memories of past experience for generating appropriate goal-directed action [27,28]. Thus, game video cues might recall prior gaming experience and which is associated with an activation of DLPFC.

Orbitofrontal cortex and visuo-spatial working memory system

In response to internet video game cues, MIGP had increased activity of the right medial frontal gyrus (orbitofrontal cortex), precentral gyrus, parahippocampal gyrus, and occipital lingual gyrus, compared to GP. Interestingly, all the regions which activated in MIGP have been associated with visuo-spatial working memory [29]. Cocaine users show higher levels of right medial prefrontal activity and lower levels of attentional bias in responding to cocaine stimuli, suggesting that they have difficulty with disengaging attention from drug-related stimuli [29]. Moreover, activation in the orbitofrontal cortex and parahippocampal gyrus was associated with desire for internet video game in our study. A hyperactive OFC in drug-taking behavior [15] and a hyper-sensitized amygdala and hippocampus responding to cue-exposure [30] have been commonly reported in patients with substance dependence. In addition, a dissociation in the visual processing stream was also reported in pathological gamblers given a cue-induced type stimulus [10]. The present findings are consistent with results reported in patients with substance dependence. Through the connection with the striatum and limbic regions such as the amygdala [31], the OFC is thought to select appropriate behavior in response to external stimuli and reward processing in the process of goal-directed behaviors [32]. Activation of the OFC could explain the motivation for persisting internet video game play in the early stage.

Parahippocampal gyrus and thalamus

In addition to activation of DLPFC and OFC, viewing video game cues was associated with increased activity of the parahippocampal gyrus and thalamus, and those areas were positively correlated with reported desire. Kalivas and Volkow [6] suggest that limbic structures for learning and memory are the main brain circuits associated with desire for drugs that drive drug seeking behaviors. Drug associated cues can trigger craving in patients with drug addiction [33] and this reinforcement mechanism is associated with the dopamine reward system [7] as well as learning and memory functions in the hippocampus and amygdala [30,34]. King et al [35] have reported activation of the amygdala in subjects playing first-person shooter video games. Moreover, physiological and behavioral responses to visual stimuli for reward or punishment may be based on the value-laden information provided by the amygdala. [36] Although the amygdala and hippocampus themselves were not activated in the current study, parahippocampal gyrus activation may reflect the functions of the amygdala, especially memory-modulation during emotionally arousing situations [37], and the hippocampus in recognizing old configurations during visual associative recognition memory [38]

With the evidence supporting an association between dopamine and reward systems in internet video game play [35,36,39,40] internet video game play can be expected to involve similar reinforcement systems as those which mediate drug and alcohol use. The association between the dopaminergic reward system and internet video games has previously been suggested in a previous genetic study [39] and the release of dopamine in the thalamus during video game playing has been reported by Koepp [40].

Limitations

The current study has several limitations. First, we need a larger and more diverse sample (with women and adolescents) for confirming the exact response of brain to internet video game play. Second, we did not use a diagnostic tool for checking the severity of desire for the internet video game, though we did apply Young's internet addiction scale, total playing game time, and visual analogue scale ratings of desire. "Third, assessment during a single scanning session did not provide enough information to determine whether the amygdala and hippocampal activations in response to the video game were due to memory of past game play or to desire, although we found a significant correlation between desire and brain activity while controlling for total playing time. In addition, desire responses are thought to be developed under the process of conditioning and, as such, to represent a core symptom of addictive disorders [9]. In this study, the subjects did not have internet video game addiction but were healthy subjects who were asked to play a specific, novel game just for 10 days. We can not rule out that the brain response to game stimulation might arise from the emotional memory response to gaming play or represent an early engagement stage in the gaming learning process [41]."

Conclusion

The current study provides information with respect brain changes that support the motivation to continue playing an internet video game in the early stages. Based on previous studies of cue-induced craving in substance abusers, the present findings also suggest the neural circuitry that mediates cue-induced desire for internet video games is similar to that observed following cue presentation to individuals with substance dependence. In particular, cues appear to commonly elicit activity in the dorsolateral prefrontal cortex, orbitofrontal cortex, parahippocampal gyrus, and thalamus..

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Figure 1. Cluster of regional cerebral blood flow (rCBF) change

General Linear Model, $FDR < 0.05$, $p < 0.0009243$; video game cue > neutral stimuli;

Cluster1: Talairach x, y, z; 56, -35, 23; right parietal lobe, -59, -41, 23; left parietal lobe (Brodmann 7, 40), 32, -84, 23; right occipital lobe, -26, -84, 23; left occipital lobe, Cluster2: 38, -40, -29; right cerebellum anterior lobe, 39, -73, -29; left cerebellum posterior lobe, Cluster3: 14, -64, -39; right cerebellum semilunar lobe, Cluster4: 20, -31, 2; right thalamus; Cluster5: (-22, -25, 3; left thalamus, -38, -25, -17; left parahippocampal gyrus (Brodmann 36), Cluster6: -17, 19, 25; left inferior frontal gyrus (Brodmann 9).

Figure 2. The correlations between Cluster 4, Cluster 5, Cluster 6, and Craving (mean $\pm$ 0.95 C.I.)

A: Spearman correlation between the mean β value of voxels in cluster4 and craving, controlling total game time, $r=0.47$, $p=0.04$, right thalamus.

B: Spearman correlation between mean β value of voxels in cluster 5 and craving, controlling total game time, $r=0.62$, $p=0.01$, left thalamus, left parahippocampal gyrus.

C: Partial correlation between mean β value of voxels in cluster 6 and craving, controlling total game time, $r=0.51$, $p=0.03$, left inferior frontal gyrus.

Figure 3. The difference of regional cerebral blood flow (rCBF) between MIGP and GP
 Random effects ANOVA Model, $FDR < 0.05$, $p < 0.0001930$; subjects who played more internet video game (MIGP) > general internet video game player (GP); Cluster 7: 5, 48, -13; right medial frontal gyrus, broadmann area (BA) 11, Cluster 8: 52, -13, 38, right frontal pre-central gyrus, Cluster 9: 20, -29, -5; right parahippocampal gyrus; Cluster 10: 6, -52, 66; right parietal post-central gyrus, Cluster 11: -25, -13, 52; left frontal pre-central gyrus, Cluster 12: -17, -99, -17; left occipital lingual gyrus

Figure 4. The correlations between Cluster 7, Cluster 9, and Craving (mean $\pm$ 0.95 C.I.)
 A: Spearman correlation between the mean β value of voxels in cluster 7 and craving, controlling total game time, $r=0.47$, $p=0.047$, right medial frontal gyrus.
 B: Spearman correlation between mean β value of voxels in cluster 9 and craving, controlling total game time, $r=0.52$, $p=0.028$, right parahippocampal gyrus.

Table 1

Cue induced craving and brain regions in patients with substance abuse and pathological gambling.

Brain regions	Activity	Cue
DLPFC	Increased	Alcohol (George et al, 2001) Cocaine (Maas et al, 1998) Food (Schur et al, 2009) Online game (Ko et al, 2009) Gambling (Crockford et al, 2005)
OFC	Increased	Alcohol (Wrase et al, 2002; Filbey et al, 2008) Cocaine (Garavan et al, 2000) Nicotine (Franklin et al, 2007) Food (Schur et al, 2009) Online game (Ko et al, 2009)
Thalamus/Striatum	Increased	Alcohol (George et al, 2001) Cocaine (Volkow, 1997) Nicotine (Franklin et al, 2007) Food (Schur et al, 2009)
Amygdala	Increased	Alcohol (Schneider et al, 2001) Opioid (Zijlstra et al, 2009) Dextroamphetamine (Hariri et al, 2002) Nicotine (Franklin et al, 2007) Food (Schur et al, 2009) Gambling (Crockford, 2005 #17)
Hippocampus	Increased	Alcohol (Schneider et al, 2001) Opioid (Zijlstra et al, 2009) Nicotine (Franklin et al, 2007) Food (Schur et al, 2009) Gambling (Crockford et al., 2005)

DLPFC: Dorsolateral prefrontal cortex, OFC: orbitofrontal cortex

The demographic data, score of Yong Internet Addiction Scale, playing game time, and craving for video game among GP and EIGP.

Table 2

Groups	Age	Eyr	Alc	Smk	UCUt	UIUt	BDI	BAI	YIAS	WT	WL	bCr	aCr
GPI	19	12	0	n	4.5	4.5	7	1	28	345	16	3	4
GP2	22	15	0	n	3	3	8	1	25	328	11	1	1
GP3	22	15	6	n	4	4	6	5	38	673	15	2	2
GP4	20	13	2	n	1.5	1.5	8	2	35	732	15	4	5
GP5	19	12	4	n	4	4	8	10	28	612	14	4	6
GP6	22	15	1	n	4	0	7	5	34	350	5	1	3
GP7	22	15	7	n	4	3	5	12	32	658	16	4	5
GP8	18	12	0	n	5	5	2	1	27	351	15	2	2
GP9	21	14	0	n	4	4	8	4	24	330	7	3	5
GPI0	20	13	4	n	5	4	8	11	37	335	10	5	6
GPI1	21	14	4	n	4	4	7	6	30	670	9	3	4
GPI2	20	13	0	n	6	6	5	8	39	586	10	3	3
GPI3	22	15	0	n	5	5	5	1	32	757	9	1	1
MIGP1	22	15	6	n	4	4	3	7	38	1711	23	2	2
MIGP2	19	12	0	n	3	3	7	3	24	1705	16	4	5
MIGP3	22	15	0	n	5	5	7	1	36	1423	17	3	4
MIGP4	18	12	4	n	1.5	1.5	8	3	29	1028	20	5	6
MIGP5	21	14	5	n	1.5	1.5	3	4	32	1140	17	5	6
MIGP6	22	15	0	n	3	2	3	7	28	1993	26	1	3

General players (GP): subjects who played the video game, 'War Rock' for less than 900 minutes, subjects who played more internet video game (MIGP): subjects who played the video game, 'War Rock' for more than 900 minutes, Eyr: educational years, Alc: alcohol drinking frequency during past 30 days, Smk: smoking, UCUt: usual computer using time/day, UIUt: usual internet using time/day, BDI: Beck Depression Inventory scores, BAI: Beck Anxiety Inventory scores, YIAS: Young's Internet Addiction Scale score, WT: playing 'War Rock' time (minutes) during 10 days, the frequency of log in 'War Rock' during 10 days, bCr: craving for playing 'War Rock' before fMRI scanning, aCr: craving for playing 'War Rock' after fMRI scanning