European Journal of Radiology 82 (2013) 1308–1312

Contents lists available at SciVerse ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad

Gray matter and white matter abnormalities in online game addiction

Chuan-Bo Weng[a,b], Ruo-Bing Qian[a,c,*], Xian-Ming Fu[a,c], Bin Lin[b], Xiao-Peng Han[d], Chao-Shi Niu[a,c], Ye-Han Wang[a,c]

[a] Department of Neurosurgery, Anhui Provincial Hospital Affiliated to Anhui Medical University, 17 Lujiang Road, Hefei, Ahui Province 230001, China
[b] School of Neurosurgery, Anhui Medical University, 81 Meishang Road, Hefei, Ahui Province 230032, China
[c] Anhui Provincial Institute of Stereotactic Neurosurgery, 9 Lujiang Road, Hefei, Ahui Province 230001, China
[d] Department of Psychology, Anhui Provincial Hospital Affiliated to Anhui Medical University, 17 Lujiang Road, Hefei, Ahui Province 230001, China

ARTICLE INFO

Article history:
Received 19 November 2012
Received in revised form 22 January 2013
Accepted 31 January 2013

Keywords:
Online game addiction
Voxel-based morphometry
Tract-based spatial statistics
Magnetic resonance imaging

ABSTRACT

Online game addiction (OGA) has attracted greater attention as a serious public mental health issue. However, there are only a few brain magnetic resonance imaging studies on brain structure about OGA. In the current study, we used voxel-based morphometry (VBM) analysis and tract-based spatial statistics (TBSS) to investigate the microstructural changes in OGA and assessed the relationship between these morphology changes and the Young's Internet Addiction Scale (YIAS) scores within the OGA group. Compared with healthy subjects, OGA individuals showed significant gray matter atrophy in the right orbitofrontal cortex, bilateral insula, and right supplementary motor area. According to TBSS analysis, OGA subjects had significantly reduced FA in the right genu of corpus callosum, bilateral frontal lobe white matter, and right external capsule. Gray matter volumes (GMV) of the right orbitofrontal cortex, bilateral insula and FA values of the right external capsule were significantly positively correlated with the YIAS scores in the OGA subjects. Our findings suggested that microstructure abnormalities of gray and white matter were present in OGA subjects. This finding may provide more insights into the understanding of the underlying neural mechanisms of OGA.

1. Introduction

With the rapid development of computer and network technology, online gaming has been considered as a mainstream recreational activity among internet users. Unfortunately, the online gaming also contributed to the creation of a negative habit in the form of online gaming addiction, which was characterized by an individual's inability to control his or her playing online games [1]. Data from a survey about adolescents' online gaming addiction in China, as of 2 February 2010, showed that the incidence of internet addiction among Chinese urban youths was about 14.1%, with the total number of 24 million. It is worth noting that online gaming is the main culprit in cases of adolescents' internet addiction (http://www.zqwx.youth.cn/). The adolescents with online game addiction suffered from a number of serious psychological and social problems, resulting in adverse effects on their social relationships and day-to-day living. A survey among 174 Taiwanese college-age online players reported that the quality of interpersonal relationships worsened and social anxiety increased as the amount of time spent on playing online games increased [2].

Current studies about OGA are primarily based on psychological self-reported questionnaires. These researches have demonstrated exactly the existence of online gamers who have psychological problems and cognitive impairments [3,4]. It is notable that most of these empirical studies have merely focused on proposing potential reasons of OGA, such as players' personal reasons, environmental factors, and characteristics of online games, instead of the underlying reasons of OGA. Furthermore, some researchers point out the necessity of investigating physical injuries of OGA but it is hard to include this dimension by means of a questionnaire. Few neuroimaging studies of internet addiction disorder (IAD) have demonstrated that some aspects of brain structure and function existed changes in IAD [5]. However, as one primary subtype of internet addiction, studies focused on the brain morphology changes of OGA specially have not been conducted. Voxel-based morphometry (VBM) technique and tract-based spatial statistics (TBSS) analysis were two widely used neuroimaging analysis techniques that allow investigation of focal differences in brain anatomy [6,7]. In this study we aimed to investigate the differences in the brain morphology between OGA subjects and healthy controls without OGA and to explore the possible mechanism of OGA by virtue of VBM technique and TBSS analysis.

* Corresponding author at: Anhui Provincial Institute of Stereotactic Neurosurgery, 9 Lujiang Road, Hefei, Ahui Province 230001, China. Tel.: +86 551 62284074.
E-mail addresses: send007@163.com (C.-B. Weng), rehomail@163.com (R.-B. Qian), 506537677@qq.com (X.-M. Fu), 274722758@qq.com (B. Lin), hanxiaopeng@163.com (X.-P. Han), niuchaoshi@163.com (C.-S. Niu), wangyehan@163.com (Y.-H. Wang).

0720-048X/$ – see front matter
http://dx.doi.org/10.1016/j.ejrad.2013.01.031

Table 1
Regions that showed significant differences in GMV and white matter FA between the OGA and controls.

	MNI coordinates (mm)			Hemisphere	Voxels	Corresponding cortical region	*p*-Value
	X	*Y*	*Z*				
VBM results							
	34	25	−21	R	334	Orbitofrontal cortex	0.02
	−31	−6	−3	L	177	Insula	0.00
	37	−7	−4	R	364	Insula	0.00
	2	−4	59	R	82	Supplementary motor area	0.03
TBSS results							
	14	25	19	R	238	Genu of corpus callosum	0.00
	−33	21	21	L	171	Frontal lobe white matter	0.00
	28	31	19	R	142	Frontal lobe white matter	0.00
	26	18	−7	R	149	External capsule	0.00

2. Materials and methods

2.1. Subjects

Seventeen subjects with OGA were recruited from the Department of Psychology, Anhui Provincial Hospital (13 females and 4 males, mean age = 16.25 ± 3.02), all of whom met the modified Young's diagnostic questionnaire (YDQ) for internet addiction criteria by Beard and Wolf [8]. Seventeen age- and gender-matched healthy individuals without OGA were selected as the control group (15 females and 2 males, mean age = 15.54 ± 3.19). The YDQ criteria consisting of eight "yes" or "no" questions were translated into Chinese. Beard and Wolf asserted that respondents who answered "yes" to questions 1 through 5 and at least to any one of the remaining three questions were classified as suffering from internet addiction, which was a universally accepted criterion for screening the subjects in the present study. We confirmed that playing online game was their primary activity when the OGA subjects used internet and verified this by investigating the time per day they spent in playing online games. All the OGA subjects and control groups were right-handed, never used illegal substances, and were native Chinese speakers. Exclusion criteria for both groups included (1) subjects with substance (alcohol, nicotine, or drug) abuse or dependence, (2) existence of neurologic or medical disorders (brain tumor, epilepsy, etc.), and (3) a history or current episode of major psychiatric disorders, such as depression, anxiety disorder, schizophrenia, or psychotic episodes. The demographic information of the subjects included was listed in Table 1.

The Ethics Committee of Anhui Provincial Hospital Affiliated to Anhui Medical University approved all experimental procedure, and informed consent was obtained from all participants after a complete description of the procedure.

2.2. Behavioral data acquisition and assessments

To probe the behavioral characteristics of online game players, we used the Young's Internet Addiction Scale (YIAS) and Barratt Impulsiveness Scale-11 (BIS-11) to assess all subjects. The YIAS was designed to identify the degree of OGA tendency as mildly, moderately or severely addicted, which consisted of 20 items including psychological dependence, compulsive use, withdrawal, and the related problems of school or work, sleep, family, and time management (for each item, a graded response was selected from 1 = "not at all" to 5 = "always"). The total score was in the range of 20–100, and a higher score implies a tendency toward addictive usage: ≤49 is considered normal, 50–79 is considered problematic and 80–100 is classed as significantly problematic [9]. The 11th version of the BIS was a 30-item (the items were scored on a 4-point scale: 1 = "rarely/never", 2 = "occasionally", 3 = "often", and 4 = "almost always/always") self-report measure assessing impulsiveness, or the tendency to lose control over one's thoughts or behaviors. All items were summed, with higher scores indicating greater impulsivity [10].

The differences in demographic characteristics between the OGA group and the control group were performed by means of independent *t*-test and chi-square test. Between-group comparisons of the YIAS and BIS-11 scores were analyzed using independent *t*-test. All tests were two-sided, and a *p* value of less than 0.05 was considered to indicate statistical significance. All analyses were performed with the use of SPSS software, version 12.0.

2.3. MR data acquisition and analysis

2.3.1. Data acquisition

MRI scans were performed using a Philips Intera 3.0 T MR imaging scanner (Philips Medical Systems, Netherlands) with a standard head coil in Anhui Provincial Hospital. 3D T1-weighted images were obtained using the following parameters (magnetization – prepared rapid gradient echo, MPRAGE): TR = 1900 ms, TE = 3.37 ms, field of view = 240 mm × 240 mm, flip angle = 8°, in-plane matrix resolution = 240 × 240, slices = 150, field of view = 240 mm^2. Diffusion tensor images were collected by using a single shot echo planar imaging with a twice-refocused spin echo pulse sequences with diffusion sensitization gradients applied in 30 non-collinear directions and a *b*-value of 1000 s/mm^2: TR = 7200 ms, TE = 104 ms, field of view = 240 mm × 240 mm, acquisition matrix = 128 × 128, 64 slices were acquired with a slice thickness of 2.0 mm and no gap. The same imaging parameters were applied to acquire T2 weighted (*b*-value = 0 s/mm^2) images to use as a reference image for signal attenuation measurement.

2.3.2. VBM data preprocessing and analysis

Structural data was processed with a FSL-VBM [6], a VBM style analysis carried out with FSL 4.1.4 (FSL 4.1.4; www.fmrib.ox.ac.uk/fsl) tools. First, all structural images were brain-extracted and tissue-type segmented to produce gray matter, white matter and cerebrospinal fluid. The gray matter partial volume images were aligned to MNI152 standard space, followed by nonlinear registration, which used a *b*-spline representation of registration warp filed. The resulting images were averaged to create a study-specific template, and the native gray matter images were nonlinearly re-registered to the template images. The registered partial volume images were then modulated by dividing the Jacobian of the warp field to correct for local expansion or contraction. All the modulated registered gray matter images were smoothed by a range of Gaussian kernel with a sigma of 3.0 mm for the threshold-free cluster enhancement (TFCE) based analysis. Regional changes in gray matter between the OGA group and control were assessed using permutation-based non-parametric testing with 5000 random permutations; in addition, age and gender effects were used for analysis of covariance (ANCOVA). Cluster-size shareholding at