Addictive Behaviors 40 (2015) 137–143

Contents lists available at ScienceDirect

Addictive Behaviors

Abnormal gray matter and white matter volume in 'Internet gaming addicts'

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HIGHLIGHTS

- Lower GMD in the inferior prefrontal cortex and cingulate gyrus in IGA group
- Lower GMD in the precuneus and amygdala in IGA group
- Structure atrophy in the right hippocampus and insula of IGA

ARTICLE INFO

Available online 16 September 2014

Keywords:
Internet addiction
Magnetic resonance imaging
Voxel-based morphometry
Gray matter density
White matter density

ABSTRACT

Internet gaming addiction (IGA) is usually defined as the inability of an individual to control his/her use of the Internet with serious negative consequences. It is becoming a prevalent mental health concern around the world. To understand whether Internet gaming addiction contributes to cerebral structural changes, the present study examined the brain gray matter density and white matter density changes in participants suffering IGA using voxel-based morphometric analysis. Compared with the healthy controls ($N = 36$, 22.2 ± 3.13 years), IGA participants ($N = 35$, 22.28 ± 2.54 years) showed significant lower gray matter density in the bilateral inferior frontal gyrus, left cingulate gyrus, insula, right precuneus, and right hippocampus (all $p < 0.05$). IGA participants also showed significant lower white matter density in the inferior frontal gyrus, insula, amygdala, and anterior cingulate than healthy controls (all $p < 0.05$). Previous studies suggest that these brain regions are involved in decision-making, behavioral inhibition and emotional regulation. Current findings might provide insight in understanding the biological underpinnings of IGA.

1. Introduction

Internet addiction disorder (IAD) is usually defined as the inability of an individual to control his/her use of the Internet with negative consequences to psychological, social, and/or work functioning aspects (Dong, Hu, Lin, & Lu, 2013; Young, 1999b). However, a standardized definition of IAD has not been uniformly agreed upon and this disorder is not included in the Diagnostic and Statistical Manual 4 (DSM-4) (Block, 2008; Lecrubier et al., 1997; Liu, Desai, Krishnan-Sarin, Cavallo, & Potenza, 2011; Shaw & Black, 2008). Though the DSM-5 is considering substance-use disorders and addictions generated criteria for IAD, this type of disorder still needs additional research for formal inclusion into the diagnostic manual (Association, 2013; Petry & O'Brien, 2013).

IAD consists at least three subtypes: Internet gaming addiction (IGA), Internet pornography, and email/text messaging (Block, 2006). Although these variants share four defining characteristics (i.e. excessive use, withdrawal, tolerance, and negative repercussions) (Beard & Wolf, 2001; Block, 2008), significant differences exist among these IAD subtypes. Internet gaming addiction is the most prevalent form of IAD in Asia (e.g. China and Korea) (Dong, DeVito, Du, & Cui, 2012), and South Korea identified IAD as a serious public health issue (Block, 2006). In China, the prevalence of IAD among college students is estimated to be 10.6%, whereas in Taiwan it is estimated to be 5.9% (Wu & Zhu, 2004; Chou & Hsiao, 2000). IGA may have specific neuropsychological characteristics (enhanced reward network, decreased executive control network), which differentiate it from other behavioral addictions (Dong, Huang, & Du, 2012; Grant, Potenza, Weinstein, & Gorelick, 2010).

Unlike substance use disorders, no chemical or substance intake is involved in IGA, although excessive Internet use may lead to physical dependence, similar to other addictions (Dong, Hu, & Lin, 2013; Goudriaan, Oosterlaan, de Beurs, & Van den Brink, 2004; Holden, 2001; Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003). People who engaged in playing Internet games may have some cognitive

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http://dx.doi.org/10.1016/j.addbeh.2014.09.010
0306-4603/

distortions, such as the belief that they cannot control themselves from using the Internet (i.e., loss of self-control) (Dong & Potenza, 2014). IGA is growing in prevalence as a serious mental health issue around the world, however, studies on the underlying neural mechanisms of this disorder are limited (Dong, Hu, Lin, & Lu, 2013; Murali & George, 2007; Yuan, Qin, Tian, & Jie, 2011; Zhou et al., 2011).

Previous studies have shown that IGA participants have some characteristics of behavior dysfunction, such as poor judgment and maladaptive decision-making ability (Dong, Lu, Zhou, & Zhao, 2010; Ko, Yen, Yen, Chen, & Chen, 2012). The decision to play Internet games involves a tradeoff between gratification in the short term and the expectation of experiencing negative effects in the long term. IGA group would appear to put more weight on the short term benefits of playing games, whereas healthy controls might be presumed to be more rational and place higher weight on long term benefits (Bai, Lin, & Chen, 2001). In addition to decision making ability, studies have also found that IGA participants show impaired impulsivity control ability compared with healthy controls (Dong et al., 2010). Cao, Su, Liu, & Gao (2007) have found that both behavioral and self-reported impulsivity are positively correlated with severity of IAD. Another issue that exists on IGA participant is their emotional management ability: the IGA is usually associated with depression, inability in controlling angry and anxiety disorders (Bai et al., 2001; Fischl & Dale, 2000; Young, 1999b).

According to the studies of the psychiatry, the dysfunction in behavior is often related to brain structure changes (Mansour et al., 2013; May, 2008). Thus, the IGA could not only be understood as a behavior dysfunction, but also understood as a consequence of central plasticity. Voxel-based morphometry (VBM) is the most commonly applied technique in detecting the morphological substrates, which can deepen our understanding of the relationship between brain structure and function, and even monitoring therapeutic interventions (Ashburner & Friston, 2000). In the present study, we used VBM to investigate the changes in the brain structure of the IGA, compared with healthy controls. Although a few neuroimaging studies have demonstrated the changes of brain structure in the IAD (Han et al., 2011; Zhou et al., 2011), several limitations exist in these studies: First, these studies focused on the general IAD group, but not the specific IGA group; second, these studies used relative small sample size. Thus, in order to overcome these limitations and achieve a more stable neurological conclusion, we recruited 35 IGA and 36 healthy participants in our study.

Based on prior studies, we focused on the neurological bases of these three characteristics of the IGA (i.e., the impaired decision making ability, the impaired impulsivity control ability, and the impaired emotional management ability). We hypothesized that the decision making related brain regions (such as the inferior prefrontal cortex (Remijnse et al., 2013)), cognitive demand related brain areas (such as the cingulate gyrus and the precuneus (Dong, DeVito, et al., 2012)) and emotional management related brain areas (such as the amygdala (Aggleton & Aggleton, 2000)) of IGA group should show structural deficiencies compared with healthy control group.

2. Methods

2.1. Participant selection

The experiment conformed to The Code of Ethics of the World Medical Association (Declaration of Helsinki). The Human Investigations Committee of Zhejiang Normal University approved this study. Seventy-one university students (35 IGA participants, 36 healthy controls [HC]) were recruited through advertisements in the area surrounding the East Normal University campus (Shanghai, China). Only males were included due to higher IGA prevalence among men than women (Adiele et al., 2014). All participants provided written informed consent and underwent structured psychiatric interviews (MINI) (Lecrubier et al., 1997) performed by an experienced psychiatrist with an administration time of approximately 15 min. The MINI was designed to meet the need for a short but accurate structured psychiatric interview for multicenter clinical trials and epidemiology studies. All participants were free of Axis I psychiatric disorders listed in MINI. IGA and HC did not meet DSM-4 criteria for abuse or dependence of substances, including alcohol, although all IGA and HC participants reported alcohol consuming in their lifetime. All participants were medication free and were instructed not to use any substances, including coffee, on the day of scanning. No participants reported previous experience with illicit drugs (e.g., cocaine, marijuana).

The diagnosis of IGA was determined based on scores of 50 or higher on Young's online Internet Addiction Test (Young, 1999b): the IAT consists of 20 items associated with online Internet use including psychological dependence, compulsive use, withdrawal, related problems in school or work, sleep, family and time management. For each item, participants were instructed to choose a number from the following scale: 1 = "Rarely" to 5 = "Always", or "Does not Apply". Scores over 50 indicate occasional or frequent Internet addiction problems and scores over 80 indicate severe Internet addiction problems (Young, 2009). As a special behavior addiction, the operational definition and diagnostic standards for IGA are still ambiguous (Blaszczynski, 2008; Griffiths, 2008). In the present study, the IGA group was composed of individuals who met the general IAD criteria (scores over 50 in the IAT) and reported "spending most of their online time playing online games (>50%)" (Weng et al., 2013; Zhou et al., 2011), and the IAT score of IGA group (72 ± 11.7) was much significantly higher than the healthy controls (29 ± 10.4), $t\ (69) = -16$, ($p < 0.001$).

2.2. Brain imaging acquisition

Magnetic resonance imaging scanning MRI data were acquired using a Siemens Trio 3T scanner (Siemens, Erlangen, Germany) in East China Normal University. Participants lay supinely with the head fixed snugly by a belt and foam pads to minimize head movement. Structural images covering the whole brain were collected by using a T1-weighted three-dimensional spoiled gradient-recalled sequence (176 slices, TR = 1700 ms, TE = 3.93 ms, slice thickness = 1.0 mm, skip = 0 mm, flip angle = 15°, inversion time 1100 ms, field of view = 240 × 240 mm, in-plane resolution = 256 × 256).

2.3. Data analysis

Imaging analysis was preprocessed and analyzed using Statistical Parametric Mapping SPM8 (http://www.fil.ion.ucl.ac.uk/spm). Images were slice-timed, reoriented, and realigned to the first volume. First, the images from all participants were normalized to the Montreal Neurological Institute (MNI) template resulting in an isometric voxel size of 3 × 3 × 3 mm and were segmented into gray matter, white matter, and cerebral spinal fluid (CSF). As well as spatial smoothing with a 12 mm full width at half maximum (FWHM) Gaussian kernel. In this study, we only focused on the gray matter destiny (GMD) and white matter destiny (WMD). The analysis of VBM data was focused on the effects of IGA by contrasting the GMD and WMD differences between participants with and without IGA. Voxel-wise comparisons of GMD and WMD were performed between the groups using the two-sample *t*-test with SPM8. The significance of group differences was estimated by the theory of random Gaussian fields, and significance levels were set at $^*p < 0.05$ (FDR corrected), while the cluster size was set at >10 voxels.

3. Results

In the present study, IGA and HC groups did not significantly differ in age (IGA: 22.2 ± 3.13 years; HC: 22.28 ± 2.54 years; $t\ (69) = 0.04$,