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ORIGINAL ARTICLE

Brain activation for response inhibition under gaming cue distraction in internet gaming disorder

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Abstract We evaluated neural substrates related to the loss of control in college students with internet gaming disorder (IGD). We hypothesized that deficit in response inhibition under gaming cue distraction was the possible mechanism for the loss of control internet use. Eleven cases of IGD and 11 controls performed Go/NoGo tasks with/without gaming distraction in the functional magnetic resonance imaging scanner. When the gaming picture was shown as background while individuals were performing Go/NoGo tasks, the IGD group committed more commission errors. The control group increased their brain activations more over the right dorsolateral prefrontal cortex (DLPFC) and superior parietal lobe under gaming cue distraction in comparison with the IGD group. Furthermore, brain activation of the right DLPFC and superior parietal lobe were negatively associated with performance of response inhibition among the IGD group. The results suggest that the function of response inhibition was impaired under gaming distraction among the IGD group, and individuals with IGD could not activate right

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DLPFC and superior parietal lobe to keep cognitive control and attention allocation for response inhibition under gaming cue distraction. This mechanism should be addressed in any intervention for IGD.

Introduction

The internet has become one of the most important tools in daily life. However, loss of control of internet use has been labeled as internet addiction and its diagnostic criteria have been developed [1]. Internet addiction is now prevalent worldwide [2—4]. Among internet addicts, internet gaming disorder (IGD) is most common [2,5]. IGD has been regarded as a behavior addiction [6]. However, until now, whether it is an addiction related to a deficit in impulse control has not been definitively established.

Internet addiction has been reported to be associated with substance use among adolescents and adults [4,7—9]. In a recent study with functional magnetic resonance imaging (fMRI), the brain activations of gaming craving for internet addiction are observed to be similar to those of substance craving [10]. Thus, IGD may share some common mechanisms with substance use disorders. Impairment of response inhibition is the core concept to explain the loss of control in substance use [11]. The deficit has been investigated with Go/NoGo tasks in fMRI [12—14]. An increased error rate in Go/NoGo tasks has been found in adolescents with internet addiction [15]. By contrast, better performance in Go/NoGo tasks has also been found among individuals with excessive internet use [16]. Only one previous study has demonstrated that adults with IGD have higher brain activation of anterior cingulate for interference inhibition in the Stroop task [17]. However, the neurobiological mechanism for proponent response inhibition in Go/NoGo tasks among adults or adolescents with IGD has not been studied. The proactive-control mechanism is underdeveloped in adolescents and matures progressively in adults [18]. Evaluation of adults with IGD could reveal the function of response inhibition in their mature stage.

Attention bias induced by substance cues has been shown to interfere with the Stroop task [19]. The neural mechanism of attention bias has been studied in substance users; its result suggests that attention bias caused by cocaine cue impairs the executive function and cognition control [20]. However, whether the gaming cue impairs the response inhibition has not been evaluated along with the neural substrates of this effect among individuals with IGD.

Thus, the aim of this fMRI study was to evaluate brain activation when performing a Go/NoGo task for college students with IGD, and compare it with a control group. Furthermore, we investigated the change in brain activations when the target of Go/NoGo tasks was distracted by gaming pictures.

Methods

Participants

Eleven men with IGD and 11 control male participants were recruited via an advertisement posted on the Bulletin Board System on the college campus. The inclusion criteria for the case group were: (1) diagnosis of internet addiction based on diagnostic criteria for Internet addiction for college students (DCIA-C)[1]; (2) addiction to the same popular online game in Taiwan; and (3) right-handedness. Those diagnosed with no internet addiction were classified as the control group. Exclusion criteria included: life-time substance use disorder, other than nicotine dependence; current major depressive episode; current psychotropic medication use; history of bipolar I disorder; psychotic disorder; neurological illness and injury; and mental retardation or intolerability to MRI. Sample sizes of 11 cases and 11 control participants were comparable to those of previous fMRI studies in behavior addiction [21]. The study was approved by the Institutional Review Board (IRB) of Kaohsiung Medical University.

Image acquisition

The fMRI scanning was performed in a 3 Tesla General Electric MR scanner (Sigma VH/I, software: version 4.0). Liquid crystal display goggles were placed over the eyes. The MR sequence for functional imaging was a gradient-recalled echo planar imaging (EPI) sequence [64 $\times$ 64 matrix; 24-cm field of view, echo time (TE) = 40 milliseconds; repetition time (TR) = 3 seconds; 3-mm thick slices with 0-mm gap]. Forty-one image planes were collected in an axial orientation with the aid of sagittal localizer images to encompass the whole head. Head motion $<$ 2 mm was corrected by post-processing using Statistical Parametric Mapping (SPM, Wellcome Department of Cognitive Neurology, London, UK) [2].

Procedure

All invited participants were interviewed by a psychiatrist for a diagnosis of online gaming addiction according to DCIA-C[1] and screening for exclusive criteria based on the Mini-International Neuropsychiatric Interview [22]. Then, they were arranged to complete the Chen Internet Addiction Scale (CIAS) [23], Fagerstrom Test for Nicotine Dependence (FTND) [24], and the level of gaming urge prior to entering block-design fMRI. All participants scored lower than the cut-off point of FTND ($\geq$ 5) for screening medium nicotine dependence.

Behavior task

The task included two sections of Go/NoGo performance: original and game-distracting sections (Fig. 1) that were separated by 30 seconds of rest. There were two conditions in each section: Block A — the Go condition, had 20 trials showing white polygons (except pentagons) on a black background; Block B — the NoGo condition, had 10 presentations of no-target (pentagons) and 10 presentations of