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Research Report

Reduced fiber integrity and cognitive control in adolescents with internet gaming disorder

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ABSTRACT

The association between the impaired cognitive control and brain regional abnormalities in Internet gaming disorder (IGD) adolescents had been validated in numerous studies. However, few studies focused on the role of the salience network (SN), which regulates dynamic communication among brain core neurocognitive networks to modulate cognitive control. Seventeen IGD adolescents and 17 healthy controls participated in the study. By combining resting-state functional connectivity and diffusion tensor imaging (DTI) tractography methods, we examined the changes of functional and structural connections within SN in IGD adolescents. The color-word Stroop task was employed to assess the impaired cognitive control in IGD adolescents. Correlation analysis was carried out to investigate the relationship between the neuroimaging indices and behavior performance in IGD adolescents. The impaired cognitive control in IGD was validated by more errors during the incongruent condition in color-word Stroop task. The right SN tract showed the decreased fractional anisotropy (FA) in IGD adolescents, though no significant differences of functional connectivity were detected. Moreover, the FA values of the right SN tract were negatively correlated with the errors during the incongruent condition in IGD adolescents. Our results revealed the disturbed structural

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connectivity within SN in IGD adolescents, which may be related with impaired cognitive control. It is hoped that the brain–behavior relationship from network perspective may enhance the understanding of IGD.

1. Introduction

Adolescence is a tumultuous time, accompanied by significant changes in emotional and cognitive function (Arain et al., 2013; Spear, 2000). As one of the common mental health problems amongst adolescents, Internet gaming disorder (IGD) has been increasingly recognized both in public and the scientific community worldwide (Christakis, 2010; Durkee et al., 2012; Flisher, 2010; Ko et al., 2010). Data from a survey about adolescents' Internet gaming disorder (IGD) in China, released on 2 February 2010, demonstrated that the incidence of internet addiction among Chinese urban youths was about 14.1%, with the total number of 24 million (http://edu.qq.com/edunew/diaocha/2009wybg.htm). Overuse of online gaming is marked by an inability to control excessive gaming habits, which was associated with detrimental social and emotional consequences, such as poor psychological well-being, academic failure and reduced work performance (Chou et al., 2005; Young, 2010, 1998, 1999; Yuan et al., 2013a). Unfortunately, there is currently no standardized treatment for IGD. Clinics in China have implemented regimented timetables, strict discipline and electric shock treatment, which gained notoriety for these treatment approaches (Yuan et al., 2011b). Developing effective methods for intervention and treatment of IGD will require first establishing a clear understanding of the mechanisms underlying this disorder. However, the neurobiological mechanisms of IGD remain poorly understood (Flisher, 2010).

Although IGD has not been officially codified within a psychopathological framework (Christakis, 2010; Yuan et al., 2011a), the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) identified IGD in Section 3 as a condition warranting more clinical research to provide mechanistic insight into its etiology and treatment (Meng et al., 2014). Moreover, regardless of whether IGD is conceptualized as a behavioral addiction or an impulse-control disorder, it is speculated to be associated with impaired cognitive control (Dong et al., 2012). Previous IGD studies have revealed cognitive impairments among online gamers by using cognitive control tasks, such as color-word Stroop task, GO/NOGO task and gambling task (Dong et al., 2010, 2011b, 2012, 2013, Yuan et al., 2013a, 2013b). However, the majority of studies only focus on the regional brain abnormalities and impaired cognitive control in IGD, such as the correlation between the abnormal OFC and response errors during incongruent condition measured by Stroop task (Yuan et al., 2013a, 2013b), few studies mentioned that whether the cognitive control behavioral deficits can be regulated by connectivity of brain network.

Neuroimaging studies have indicated that both ACC and insula are involved in the performance of the Stroop task (Leung et al., 2000). Meanwhile, the ACC and insula have shown functional and structural alterations in IGD (Feng et al., 2013; Weng et al., 2013; Zhou et al., 2011). As far as we know, brain regions do not work in isolation, they work in concert, forming neural networks to produce subjective perception, motivation and behavior. More and more scientific evidences demonstrated that the high-level cognitive control processes rely on the integrity of, and dynamic interactions between, core neurocognitive networks (Bressler and Menon, 2010; Meehan and Bressler, 2012). One theory is that the salience network (SN) – which includes the anterior cingulate cortex (ACC) and insula – regulates dynamic changes in other brain core networks to modulate cognitive control (Menon, 2011; Uddin et al., 2011). Consistent with this viewpoint, one traumatic brain injury study suggested that the disruption of white matter in the SN tract lead to inefficient cognitive control (Bonnelle et al., 2012). Therefore, we hypothesized that the connections within SN network was disrupted in IGD adolescents. In addition, the abnormal connection was correlated with the impaired cognitive control.

In the present study, first, we combined multimodal MRI approach to investigate whether the structural connectivity and functional connectivity within SN were disturbed in IGD adolescents. Then, we assessed impaired cognitive control

Table 1 – Subject demographics for adolescents with internet gaming disorder (IGD) and control groups.

Items	IGD $N=17$	Control $N=17$	t/χ^2	P value
Age (years)	19.1±0.7	19.8±1.3	1.889	0.071
Gender (M/F)[a]	10/7	11/6	0.245	0.621
Education (years)	12.2±0.6	12.4±0.7	0.768	0.448
IAT	65.7±11.6	29.2±4.5	−12.067	<0.005*
Hours of online gaming (/day)	9.5±1.3	2.2±1.4	−15.304	<0.005*
Days of online gaming (/week)	5.4±1.2	2.9±2.3	−3.972	<0.005*
IQ	102.4±10.4	103.1±7.7	0.243	0.810

Values are expressed as mean±standard deviation (SD). IGD=internet gaming disorder. IAT=internet addiction test. IQ=intelligence quotient.

[a] The P value for gender distribution in the two groups was obtained by chisquare test.