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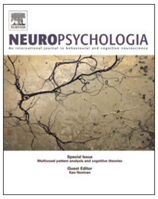

Brain structures and functional connectivity associated with individual differences in Internet tendency in healthy young adults

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ABSTRACT

Internet addiction (IA) incurs significant social and financial costs in the form of physical side-effects, academic and occupational impairment, and serious relationship problems. The majority of previous studies on Internet addiction disorders (IAD) have focused on structural and functional abnormalities, while few studies have simultaneously investigated the structural and functional brain alterations underlying individual differences in IA tendencies measured by questionnaires in a healthy sample. Here we combined structural (regional gray matter volume, rGMV) and functional (resting-state functional connectivity, rsFC) information to explore the neural mechanisms underlying IAT in a large sample of 260 healthy young adults. The results showed that IAT scores were significantly and positively correlated with rGMV in the right dorsolateral prefrontal cortex (DLPFC, one key node of the cognitive control network, CCN), which might reflect reduced functioning of inhibitory control. More interestingly, decreased anticorrelations between the right DLPFC and the medial prefrontal cortex/rostral anterior cingulate cortex (mPFC/rACC, one key node of the default mode network, DMN) were associated with higher IAT scores, which might be associated with reduced efficiency of the CCN and DMN (e.g., diminished cognitive control and self-monitoring). Furthermore, the Stroop interference effect was positively associated with the volume of the DLPFC and with the IA scores, as well as with the connectivity between DLPFC and mPFC, which further indicated that rGMV variations in the DLPFC and decreased anticonnections between the DLPFC and mPFC may reflect addiction-related reduced inhibitory control and cognitive efficiency. These findings suggest the combination of structural and functional information can provide a valuable basis for further understanding of the mechanisms and pathogenesis of IA.

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1. Introduction

Once individuals spend too much time on Internet-related activities, they may have a problem of Internet tendency, which could lead to Internet addiction (IA). IA is considered as the inability to control one's use of the Internet, which could be considered as an impulse-control spectrum disorder and one type of behavioral addiction, and always results in social, psychological and/or work difficulties (Holden, 2001; Young, 1997; Young and Rogers, 1998). One study found that 11% of adolescents in Greece exhibited behaviors that corresponded to the criteria for IA (Siomos et al., 2008), and about 18% of teenagers in Korea who play computer games were diagnosed as patients suffering from IA (Whang et al., 2003). IA also has become a serious threat to the mental health of teenagers in China in recent decades. Current data suggests that 2.4% of adolescents show Internet addiction (Cao and Su, 2007), and 19.1% of Chinese adolescents in Hong Kong are classified as having IA (Shek et al., 2008). These findings might indicate that IA is prevalent worldwide, especially amongst adolescents, suggesting that it is a serious mental health problem which has expanded incredibly and gathered widespread attention. Moreover, a variety of psychiatric disorders, such as depression (Kim et al., 2006; Young and Rogers, 1998), anxiety (Greenfield, 1999) and maladaptive cognitions (Bidi et al., 2012; Spada et al., 2008) have been found to be related to Internet addiction. It is important to recognize that psychological interventions and behavioral treatments for IA are not very efficacious

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(Block, 2007), which might be at least partly due to the fact that the cognitive and neural mechanisms underlying individual differences in IA are unclear.

Numerous studies have explored the brain structural and functional correlates of Internet addiction disorder (IAD) in recent years, by utilizing structural and functional magnetic resonance imaging (MRI). These neuroimaging studies of IAD usually have identified abnormalities in frontal brain regions (especially the dorsolateral prefrontal cortex, DLPFC) that are believed to be responsible for cognitive control and control of inhibition (Bechara, 2005; Feil et al., 2010; Hayashi et al., 2013; Kuss and Griffiths, 2012; Widyanto and Griffiths, 2006). For example, a voxel-based morphometry (VBM) study showed that decreased gray matter volumes (GMVs) in the bilateral DLPFC, the supplementary motor area (SMA), the orbitofrontal cortex (OFC), the cerebellum, and the left rostral anterior cingulate cortex (rACC) were associated with IA, suggesting that the brain structural abnormalities involved in IAD might be related to a dysfunction of cognitive control (Yuan et al., 2011). Another study found that the right DLPFC, right OFC, right nucleus accumbens, bilateral ACC and medial frontal cortex were activated stronger in response to gaming cues in a group addicted to Internet gaming compared to a control group (Ko et al., 2009). Moreover, patients suffering from IA had more brain activation in the left DLPFC, left occipital lobe cuneus, and left parahippocampal gyrus relative to healthy subjects when exposed to game cues (Han et al., 2010). Overall, these findings revealed that abnormal brain structure and function of frontal brain regions (especially the DLPFC) were closely related to IA, the aggravation of which might be associated with weakened cognitive control and stronger craving responses (Caplan, 2002; Davis, 2001; Dong et al., 2012; Kuss and Griffiths, 2012; Şenormancı et al., 2010; Widyanto and Griffiths, 2006).

Other studies have revealed that a number of regions in the cognitive control network (CCN), such as the DLPFC, play an important role in substance addiction, suggesting that structural deficits and functional abnormalities in individuals with substance addiction might be similar to those in IAD (e.g., similar behavior symptoms, such as tolerance, withdrawal, preoccupation, and negative repercussions; Feng et al., 2013; Hong et al., 2013; Ko et al., 2009; Ng and Wiemer-Hastings, 2005; Young, 1997). Studies of alcohol-dependent patients found DLPFC volume abnormalities and abnormal functional connectivity between the DLPFC and the striatum, which may reflect impairments in reward-related learning and the magnitude of alcohol craving (Makris et al., 2008). A recent study have reported the alterations in the fronto-striatal circuitry associated with higher IAT scores, which could reflect the striatal over-activation and the diminished top-down modulation of prefrontal areas (Kühn and Gallinat, 2014). Similarly, cocaine-dependent abusers also show reduced cortical thickness in the DLPFC, which has been found to be associated with abnormal decision making (Makris et al., 2008). In conclusion, all the above studies suggest that the DLPFC (a core region of the CCN) plays an important role in addiction, which includes increased addiction-related weakened cognitive control and impulsive decision making (Hooker et al., 2010; Kühn et al., 2012).

Moreover, in addition to the core regions of the CCN (especially the DLPFC), a close correlation between the core regions of the default mode network [DMN; such as the posterior cingulate cortex (PCC) and medial prefrontal cortex (mPFC)] and addiction has attracted more attention. For instance, Ding et al. (2013) reported the DMN in adolescents with Internet gaming addiction was altered. They found connectivity with the PCC (the key node of the DMN) was positively correlated with IA scores in the right precuneus, SMA, thalamus, PCC, caudate, nucleus accumbens and lingual gyrus, while it was negatively correlated with the right cerebellar anterior lobe and the left superior parietal lobule (Fransson and Marrelec, 2008). Furthermore, Dong et al. (2012) reported diminished efficiency of response-inhibition processes in patients suffering from IA, which has been associated with increased neural activity in the ACC (a region within the CCN; Cole and Schneider, 2007). Another study found that patients suffering from IA engaged more cognitive processes in a decision-making task because of insufficient executive functioning during this task (Dong et al., 2013a). Subsequently, it has been shown that compared with controls, IAD subjects exhibit higher superior frontal gyrus activity after continuous wins and decreased PCC activity after continuous losses (Dong et al., 2013b). In addition, previous studies also found the DMN and rACC network of heroin-dependent individuals were different compared with healthy subjects, which might suggest that the aberrance of the DMN and rACC might be linked to addiction (Yuan et al., 2010). Moreover, Ma et al. (2011, 2010) also found enhanced resting-state functional connectivity (rsFC) in the hippocampus (a prominent node within the DMN) and reduced connectivity in the ACC (within the DMN) in drug addicts, which might reflect addiction-related abnormally increased memory processing, or diminished cognitive control related to attentional orientation and self-monitoring. It should be noted that in previous neuroscientific studies, the regions associated with addiction were mostly the core regions of the DMN (such as the PCC and mPFC) and the CCN (such as the DLPFC and dACC), and these two networks were considered to be anti-correlated (Cole and Schneider, 2007; Fox et al., 2005; Jović and Đinđić, 2011; Ma et al., 2010; Volkow et al., 2004).

However, up until now, the majority of previous research has studied individuals whose behaviors corresponded to the diagnostic criteria for IA (i.e., the Internet usage was causing significant problems in their life), and compared these IA subjects with healthy controls. These studies focused on the consequences of enhanced behavioral addiction and considered the control sample to be a heterogeneous group. In addition, strictly speaking, video gaming or Internet gaming addiction (IGA) is only a subtype of IAD and significant difference may exist among the different IAD subtypes (Block, 2008). We can therefore only generalize the observed volumetric and activity differences in Kühn et al. (2011) and Dong et al. (2012) to the specific IGA subgroup but not to general IAD subjects. More importantly, although the relevant clinical studies already existed, there were some discrepancies in healthy sample. Evidently, non-addicted, healthy individuals who score high on IA tests (i.e., potential problematic Internet users) might be more susceptible to IAD, so investigation of the neural basis underlying individual differences in IA tendencies in young healthy subjects is important. Although a recent study has linked IA tendency (excessive but non-pathological Internet use) to GMV and functional connectivity (Kühn and Gallinat, 2014), it investigated relatively small sample consisting of only male participants. To increase the power of the statistical analyses and enhance generalization of the findings, structural and functional investigations with larger sample sizes for both genders are necessary.

Therefore, in light of the above findings, we wanted to test the relationship between individual differences in IA and GMV at a whole-brain level in the healthy population, using voxel-based morphometry (VBM) on structural magnetic resonance images. The VBM is regarded as non-invasive structural MRI to identify brain anatomy associated with differences in behavior (Kanai and Rees, 2011; Takeuchi et al., 2012). Since neuroimaging measures of brain structure could be used to provide better insights into brain mechanisms about stable individual personality traits, the examination of anatomical features using structural imaging (e.g. VBM) might be more efficacious than using fMRI for investigating the tendency toward IA (Ashburner and Friston, 2000; Hayakawa et al., 2013; Hong et al., 2013; Takeuchi et al., 2012). Furthermore, other studies have indicated that most altered structural regions in IA patients may be related to aspects of the CCN associated with inhibitory control, and aspects of the DMN associated with self-referential processing (Han et al., 2012; Yuan et al., 2010; Zhou et al., 2011). Thus, we hypothesized that in the healthy population, individual differences in IA scores might be associated with rGMV variations in the DLPFC or dACC (key nodes of the CCN) and the mPFC or PCC (key nodes of the DMN), and these structural alterations may be, at least in part, associated with cognitive control and goal-directed behavior dysfunctions.

Moreover, in light of the fact that studies have shown a correlation between volumetric reduction and decreased brain activity (Johnson et al., 2000; Thomsen et al., 2004; Yang and Raine, 2009), functional and structural imaging studies are thought to complement each other well (Drevets et al., 2008; Wang et al., 2012a, 2012b; Watkins et al., 2008). Several studies have already combined structural MRI and rs-fMRI by choosing the structurally affected areas for subsequent resting-state functional connectivity analysis (Di et al., 2012; Jung et al., 2013; Liao et al., 2011; Lui et al., 2009; Wang et al., 2012a, 2012b). For instance, Yuan et al. (2010) combined VBM and rsFC analysis to study heroin addicts and found a reduction in the gray matter density (GMD) of the right DLPFC and a decrease rsFC between the right DLPFC and the left inferior parietal lobe (IPL), which might indicate that the volumetric and rest-state functional abnormalities in the DLPFC were related to heroin addiction. Thus, we also tried to use rsFC to investigate the relationship between rsFC and IA scores, and we hypothesized that inter-individual differences in IA scores would be associated with altered rsFC within the CCN (i.e., DLPFC) and DMN (i.e., mPFC/PCC), or would be associated with altered anticorrelations between the CCN-DMN (e.g., DLPFC and mPFC/PCC) (Bjork et al., 2011; Kehagia et al., 2010; Schlagenhauf et al., 2009). Recently, a systematic review and a meta-analysis of fMRI studies of Internet gaming disorder (IGD) revealed that subjects with IGD showed an abnormal activation in the medial frontal gyrus (MFG)/cingulate gyrus (included ACC and PCC), the left middle temporal gyrus and fusiform gyrus when compared with healthy controls. Furthermore, the symptom severity (the on-line time) was associated with activations in the left MFG (dorsolateral prefrontal cortex) and the right cingulate gyrus (Meng et al., 2014). These findings were consistent with some of the aforementioned structural and functional neuro-imaging studies (Feng et al., 2013; Han et al., 2012; Kuss and Griffiths, 2012; Zhou et al., 2011), which implicate the important role of dysfunctional prefrontal lobe in the neurophysiological mechanism of IGD.

Hence, we combined structural (GMV) and functional (rsFC) information in the present study to examine the neural substrates of inter-individual differences in IA scores in a sample of 260 healthy young adults. In sum, the combination of morphometric results and functional connectivity findings could provide a valuable basis for further understanding of the neural mechanisms underlying individual differences in IA, which could help to explain the neurobiological variations that might place certain people at greater risk of developing IAD.

2. Materials and methods

2.1. Subjects

A total of 260 right-handed, healthy subjects (120 male; 19.9 ± 1.2 years; range, 18–27 years) participated in the study as part of our ongoing project to examine the associations among brain imaging, creativity and mental health (Li et al., 2014; Wei et al., 2014). All subjects were undergraduates or postgraduates from the Southwest University, China. None of them had a history of neurological or psychiatric illness, or substance abuse by a self-report questionnaire before the scan. The study was approved by the Institutional Review Board of Southwest University Imaging Center for Brain Research, and written informed consents were obtained from all participants.

2.2. Assessment of Internet addiction levels

The Internet Addiction Test (IAT; Young, 1998) is a 20-item questionnaire which covers an individual's Internet use habits, their thoughts about the Internet as well as the influence of Internet use on their lives (such as compulsive use, withdrawal, related problems in school, work, and sleep). The IAT was found to be a valid and reliable instrument for assessing IA (Widyanto et al., 2011; Widyanto and McMurran, 2004). For each item, a scaled selection (1=“not at all” to 5=“always”) can be made with the higher total item scores suggesting a tendency toward addictive usage. The following cut-off points were applied to distinguish the extent of Internet use: normal (0–30 points), mild (31–49 points), moderate (50–79 points), and severe range (80–100 points) (Young, 2011). One's Internet usage is causing significant problems in one's life when his/her IA score was above 80 (Alavi et al., 2011; Chang and Man Law, 2008). The test–retest reliability of IAT was 0.83 and a significant correlation with time spent on the Internet was demonstrated (Barke et al., 2012). Many studies have reported that time online is an important predictor of Internet addiction (e.g., Wang et al., 2011; Yang and Tung, 2007). Furthermore, the two-wave longitudinal findings lent support for stability of Internet addiction tendency (i.e., one's prior pathological use of the Internet significantly predicted their later Internet addictive behaviors and the probability of being classified as Internet addicts, with all possible influence of demographic factors being excluded) (Shek and Yu, 2012). All these studies indicate that individuals with higher IAT score might have higher risk of IAD. In the present study, the internal reliability of this test was good (Cronbach's alpha=0.901).

2.3. Assessment of psychometric measures of general intelligence

In order to eliminate the effect of general intelligence on brain structures (Haier et al., 2004), the Combined Raven's Test (CRT; Raven and Court, 1998) was used to assess individuals' intelligence. The CRT, which with a high degree of reliability and validity (He-ming, 2008; Raven, 2000), consists of 72 items (Raven's standard progressive matrix and Raven's colored progressive matrix) as revised by the Psychology Department of East China Normal University in 1989. The total score of this test (number of correct answers in 40 min) was used as a psychometric index of individual intelligence (Takeuchi et al., 2011; Wei et al., 2014).

2.4. Assessment of depression and anxiety

Given that IA was closely associated with anxiety and depression (Ha et al., 2007; Kim et al., 2006; Young, 1998), and these factors might have contributed to the increased severity of brain atrophy, adjustments were made to exclude the possibility that any significant correlations between rGMV and IA were caused by associations between (a) IA and anxiety/depression and (b) rGMV and anxiety/depression.

The State-Trait Anxiety Inventory (STAI, Spielberger et al., 1970) was used to measure individuals' anxiety levels. The trait scale (STAI-T) which consists of 20 items was administered to assess individual differences in the frequency and intensity with which anxiety is experienced over time. Each item is rated on a 4-point frequency scale ranging from “almost never” to “almost always”. Subjects who get high scores in trait anxiety tend to perceive more situations as dangerous or threatening than subjects who have lower trait anxiety scores (Spielberger, 1972; Spielberger et al., 1983). The STAT-T has been shown to have good psychometric properties, with high internal consistencies (Cronbach's alpha = 0.835) in the present study.

Depressive symptomatology was evaluated using the Self-rating Depression Scale (SDS, Zung, 1965). The SDS is a 20-item self-report questionnaire purported to measure depressed affect and related symptoms. Subjects use a 4-point scale to rate each item based on how they felt during the preceding week, with a response format ranging from 1 “a little of the time” to 4 “most of the time”. The total scores can range from 20 to 80, and a higher score means a higher level of depressive symptoms. The SDS demonstrated good internal consistency (Cronbach's alpha = 0.8) in the present study.

Furthermore, it should be noted that, based on Chinese youth norms, there were no clinically depressed or anxious patients included in our samples.

2.5. Assessment of Stroop task

To further examine whether the changes of the brain was effected by the weakened cognitive control ability or not, a color-word Stroop task was assessed. Programmed with E-prime software, the classic Stroop conflict paradigm (Jensen, 1965; MacLeod, 1991) was presented to participants using a DELL computer. Stimuli consisted of one of four words in Chinese (red, orange, blue, or green) printed in one of four colors. The trials were either congruent (e.g., the word “blue” in blue ink) or incongruent (e.g., the word “blue” in green ink). Participants are required to categorize a color (red, orange, blue, or green) in the presence of a word, by using the “SDJK” keys, respectively. They were instructed to be accurate with speed. After an exercise, a formal program comprises 108 trials divided by two blocks. Each trail was 2.75 s long and consisted of a color word for 150 ms followed by a fixation cross (+) for 600 ms and a blank for 2 s. The Stroop interference effect (ΔRT) reflects the cognitive control ability (MacLeod, 1991) and was calculated by subtracting the mean reaction time on congruent trials from the mean reaction time on incongruent trials. Trials with incorrect responses and responses with reaction times less than 200 milliseconds and greater than 1000 milliseconds were excluded to avoid rapid or slow responses unduly influencing average response time. Participants completed a practice session which continued until they reached an accuracy rate of 90% or higher (Dong et al., 2012) to assure that participants understood the instructions and were performing the task appropriately.

All the 260 subjects completed the IAT, the CRT, the STAI-T, and the SDS. Because some participants gave up the ongoing project, only 188 of these 260 participants completed the procedures related to the Stroop task. Thus, data from all the 260 subjects were included in structural and functional imaging data analyses; data from 188 subjects were included in investigation of associations between cognitive control (the Stroop color-word task) and the volume of the DLPFC, IAT scores and the connectivity between DLPFC and mPFC.

2.6. Image data acquisition

All magnetic resonance imaging (MRI) data were acquired on a 3.0-T Siemens Trio MRI scanner (Siemens Medical, Erlangen, Germany). During data acquisition, subjects were instructed to keep their heads still. Earplugs and foam padding were used to reduce scanner noise and head motion. High-resolution T1-weighted anatomical images were obtained with a magnetization-prepared rapid gradient echo (MPRAGE) sequence (repetition time [TR] = 1900 ms; echo time [TE] = 2.52 ms; inversion time = 900 ms; flip angle = 9°; resolution matrix = 256×256; field of view (FOV) = 256×256 mm^2; slices = 176; thickness = 1.0 mm; voxel size = $1 \times 1 \times 1$ mm^3).

During resting-state scanning, subjects were instructed to close their eyes, remain still and relaxed, but not sleep. The whole-brain resting-state functional images were acquired using gradient-echo echo planar imaging (EPI) sequences with the following parameters: TR = 2000 ms, TE = 30 ms, flip angle = 90°, resolution matrix = 64×64, FOV = 220×220 mm^2, slices = 32, slice gap = 1 mm, voxel size = $3.4 \times 3.4 \times 4$ mm ^{3}.

2.7. Structural imaging data analysis

Preprocessing of structural image data was performed with the SPM8 software (Wellcome Department of Cognitive Neurology, London, UK; www.fil.ion.ucl.ac.uk/spm) which was implemented in MATLAB 7.8 (MathWorks Inc., Natick, MA, USA). Structural images from each subject were displayed in SPM8 to check artifacts or gross anatomical abnormalities and manually coregistered to anterior commissur-poterior commissure. Gray matter (GM), white matter (WM) and cerebrospinal fluid (CSF) was segmented using the new segmentation toolbox in SPM8. Subsequently, we performed registrations, normalization, and modulation using Diffeomorphic Anatomical Registration through Exponentiated Lie algebra (DARTEL) in SPM8 (Ashburner, 2007). Then the study-specific brain template was created with all the subjects in our sample. To facilitate the determination of regional differences in the absolute amount of GM, the image intensity of each voxel was modulated by the Jacobian determinants (Ashburner, 2007). Subsequently, registered images were transformed to Montreal Neurological Institute (MNI) space. Finally, the normalized and modulated images (GM and WM images) were smoothed with an 8 mm full width at half maximum (FWHM) Gaussian kernel to increase the signal to noise ratio.

The association between GMV and individual differences in IA tendency was investigated. Statistical analysis of imaging data was performed with SPM8. In the analysis, we used whole brain multiple regression analysis, in which the IA score was the variable of interest. Total GM volume, age, gender, general intelligence score, STAI-T and SDS scores were covariates. Absolute voxel signal intensity threshold masking of 0.2 was used to minimize gray matter/white matter boundary effects. In other words, voxels with probability to be GM which lower than 0.2 were excluded from the analysis. The voxel-level false discovery rate (FDR) method was used at the whole-brain level. The significance threshold was set at $p < 0.05$, corrected for multiple comparisons.

2.8. Functional imaging data analysis

Processing of the resting-state image data was performed using the data processing assistant for resting-state fMRI (DPARSF) software (http://www.restfmri.net/forum/DPARSF) (Yan et al., 2009) and the REST toolkit (Song et al., 2011). Both toolboxes work on the basis of the SPM8 software package. To ensure signal equilibrium and participants' adaptation to their immediate environment, the first 10 volumes of the functional images were excluded. The remaining 232 scans images were preprocessed including slice timing, head motion correction, and spatial normalization to a standard template. Global mean signal, white matter, cerebrospinal fluid, and 24 motion parameters for head movement were regressed out as nuisance variables to cancel out the potential impact of physiological artifacts. Moreover, the Friston 24-parameter model (i.e., 6 head motion parameters, 6 head motion parameters one time point before, and the 12 corresponding squared items; Friston et al., 1996) was utilized to regress head motion effects out of the realigned data based on recent reports that higher-order models demonstrated benefits in reducing head micro movements effect (Satterthwaite et al., 2013; Yan et al., 2013). The images were then resampled to 3-mm cubic voxels, followed by spatial smoothing (8 mm FWHM). The smoothed data was linear detrended and filtered using a band pass filter (0.01–0.08 Hz) to eliminate low frequency fluctuations. The preprocessing steps of functional connectivity followed the standard protocol reported by Yan and Zang (Chao-Gan and Yu-Feng, 2010; Chen et al., 2012; Tian et al., 2012)

The significant encephalic region on GMV analysis was selected as a seed region for functional connectivity analysis, which is the DLPFC (peak MNI coordinate, $x, y, z = 39, 6, 47$) and including 296 voxels. Functional connectivity analysis was performed for the selected seed region. For the detailed procedure, first, the averaged blood–oxygen-level-dependent (BOLD) time series in the DLPFC seed was extracted. Then the correlation coefficient between the seed time course and the time course from all brain voxels was calculated using a voxel-by-voxel method to get the whole brain correlation maps. Finally, the correlation maps were transformed to z-scores using Fisher r-to-z transformation. To obtain the brain regions which were significantly correlated with the seed region, we performed a random effect one-sample t-test of individual z-valued functional connectivity maps. In this way, composite functional connectivity maps were obtained with a threshold of $p < 0.05$, corrected for FDR. Further, positive and negative functional connectivity maps were saved respectively as masks for subsequent multiple linear regression analysis. In order to make results more accurate and credible, another two seed regions in the CCN (Cole and Schneider, 2007) [right inferior frontal junction (IFJ); radius, 6 mm; central coordinates, 44, 13, 30; right pre-supplementary motor area (pSMA); radius, 6 mm; central coordinates, 3, 16, 50] were selected for functional connectivity analysis.

Finally, multiple linear regression analysis was performed to identify the brain regions in which the strength of the functional connectivity to the seed region (DLPFC) significantly correlated with IA scores. The multiple comparison corrections were performed at $p < 0.05$ using the FDR approach, and gender, age, general intelligence score, SDS score, and STAI-T score were included as regressors of no interest. To further explore whether the associations seen between IA tendency and DLPFC connectivity were generally the same as those seen between IA tendency and the other regions in the CCN, the right IFJ and right pSMA were chosen as seed regions using the same procedure described above.

In addition, a complementary analysis was carried out in order to ascertain the possible link between the structural and functional results. Firstly, correlation analysis was carried out to investigate the relationship between altered GMV in DLPFC and the anticorrelations between DLPFC and mPFC. Subsequently, to examine whether the functional abnormalities between DLPFC and mPFC about IA would explain the relationship between the GMV in seed area (the altered DLPFC) and IA, a mediation analysis was conducted using the indirect macro designed for SPSS (Preacher and Hayes, 2008). In this analysis, 5000 bootstrapped samples using bias-corrected and accelerated 95% confidence intervals (CI) were reported. CIs without zero indicate a significant indirect effect of the independent variable on the dependent variable through the mediators (Preacher and Hayes, 2008).

3. Results

3.1. Behavioral data

The average IAT score of all subjects was 40.82 ($SD = 11.22$), and none of the scores was higher than 80, which means there were no clinical patients suffering from IA in this sample. IAT scores were significant related to STAI-T scores ($r = 0.175$, $p < 0.05$) and SDS scores ($r = 0.231$, $p < 0.05$), which was consistent with previous studies that have reported the association of IA with anxiety and depression (Ha et al., 2007; Tao, 2003; Young and Rogers, 1998) (Table 1).

Table 1
Demographic variables and behavioral data.

Subjects characteristic	Mean	SD	Range
Age (years)	19.89	1.22	18–27
General intelligence	66.32	3.30	52–72
STAI score	41.15	7.66	22–61
SDS score	35.15	6.94	22–55
IA score	40.82	11.22	22–78

Note: STAI, State-Trait Anxiety Inventory; SDS, Self-rating Depression Scale; IA, Internet Addiction Test.

3.2. Correlation between GMV and IAT scores

We investigated individual differences in IA behaviors associated with rGMV. A multiple regression analysis controlling for age, gender, total brain GMV, general intelligence, anxiety and depression as no interest revealed that IAT scores were significantly and positively correlated with rGMV in the DLPFC [MNI coordinates, $x, y, z = 39, 6, 47$, $t\ (260) = 5.25$, p (corrected) < 0.05; 296 voxels] (Fig. 1).

3.3. DLPFC connectivity and its relations to IAT scores

As seen in Fig. 2, one-simple t-tests were performed to explore which regions were positively/negatively connected with the DLPFC. Subsequently, we used the positively connected regions as a positive mask, and the negatively connected regions as a negative mask.

Then, to explore whether the DLPFC functions in concert with other brain regions for IA, we performed seed-voxel-based correlation analysis between the DLPFC region that was found to be clearly associated with IA scores and all other voxels in the two masks. In the negative mask, the rACC (MNI coordinates, $x, y, z = 9, 42, -3$, $t\ (260) = 4.72$, $p < 0.05$) was found to be connected with the DLPFC, correcting for multiple comparisons at voxel-level FDR, and 92 voxels alive with $p < 0.05$ (for more information, see Fig. 3) (Table 2).

Moreover, IFG was found to be connected with mPFC ($p < 0.001$, uncorrected, 111 voxels; Fig. 4a), and pSMA was found to be connected with mPFC ($p < 0.001$, uncorrected, 45 voxels; Fig. 4c). We compared these regions with the mPFC/rACC which was obtained before, and a similar overlapping mPFC/rACC was found (for more information, see Fig. 4). This provided more evidence indicating that the anticorrelation between the CCN and mPFC/rACC was associated with IA tendencies.

In addition, our complementary analysis showed that the altered GMV in the DLPFC was significantly and positively related with the anticorrelation between the DLPFC and mPFC/rACC ($r = 0.19$, $p < 0.05$), which may indicate that individuals with higher IA are more likely to have a higher GMV in the DLPFC and abnormal functional connectivity between the DLPFC and mPFC/rACC. Moreover, mediation analysis showed a significant indirect effect of IA on GMV in the DLPFC and anticorrelation between DLPFC and mPFC/rACC [CI: 0.0138, 0.0757], which may suggest that the structural and functional abnormalities interacted in IA.

Moreover, to investigate whether the structural and functional changes of the brain were associated with weakened cognitive control ability or not, we additionally investigated the association

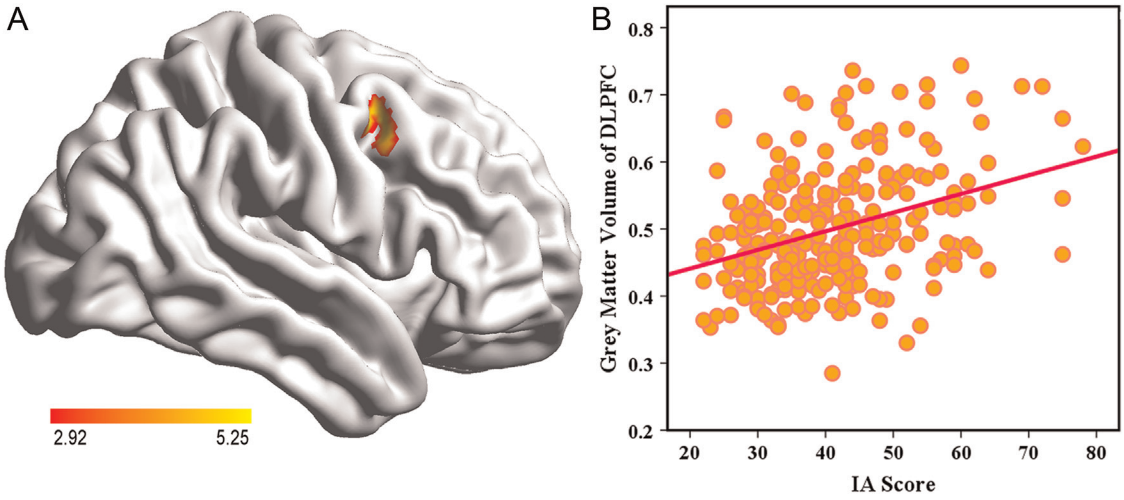

Fig. 1. Anatomical association with IA. (A) GMV was positively correlated with individual IA scores in the right DLPFC. Results are shown with $p < 0.05$ (corrected for voxel level FDR). The corresponding partial correlation scatterplot between IA and DLPFC is adjusted for total brain volume, age, gender, general intelligence score, STAI-T score and SDS score for illustration purpose only. (B) A scatter plot of the relationship between the IA scores and rGMV values in DLPFC (x, y, z=39, 6, 47). DLPFC, dorsolateral prefrontal cortex; FDR, false discovery rate; IA, Internet addiction; rGMV, regional gray matter volume; STAI-T, State-Trait Anxiety Inventory- Trait scale.

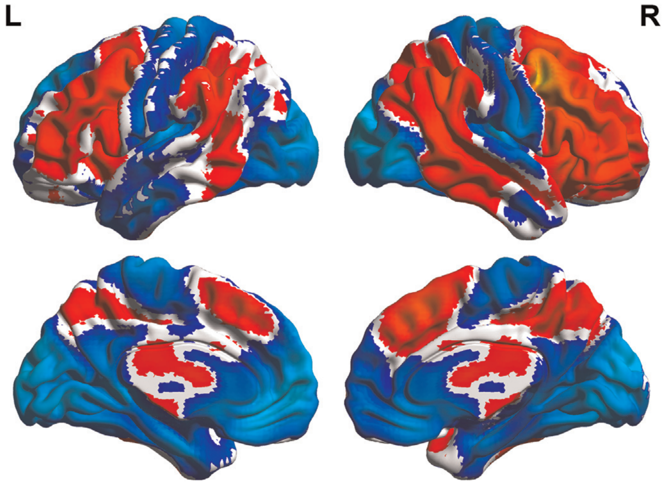

Fig. 2. Resting state functional connectivity maps with seed at the right DLPFC (x, y, z=39, 6, 47). The results are shown for $p < 0.05$ (corrected for FDR). The red tracts show the positive connectivity maps that were saved as a positive mask; the blue tracts show negative connectivity maps that were saved as a negative mask (L=left; R=right). DLPFC, dorsolateral prefrontal cortex; FDR, false discovery rate. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

between altered regions and cognitive control and executive processes using a classical Stroop color-word task (Jensen, 1965; MacLeod, 1991). We found that the ΔRT was positively related with the volume of the DLPFC (r=0.159, $p < 0.05$) as well as the IAT scores (r=0.246, $p < 0.05$), and the connectivity between DLPFC and mPFC was also positively related with the ΔRT of the Stroop color-word (r=0.188, $p < 0.05$).

4. Discussion

To the best of our knowledge, this is the first study to simultaneously investigate structural and functional brain alterations in a large sample of healthy young adults with an IA tendency. Structural data showed that higher IA scores were associated with a larger rGMV in the right DLPFC. Furthermore, resting-state fMRI data demonstrated that decreased anticorrelations between the right DLPFC (a key node of the CCN) and the mPFC/rACC (a key node of the DMN) were also associated with higher individual IA scores. Taken together, our results suggest that structural and functional brain variations may be important neurobiological mechanisms of overuse and/or abuse of the Internet in individuals with higher IA scores. The implications of these findings in a nonclinical population will be discussed in detail below.

Numerous functional brain imaging studies have revealed that the DLPFC is involved in working memory (Daskalakis et al., 2008; Hoppenbrouwers et al., 2013; Smith et al., 1998), executive functioning (Wagner et al., 2001), and automatic regulation of emotional responses (Hoshi, 2006; Mansouri et al., 2009; Miller and Cohen, 2001; Sakai and Passingham, 2004). Particularly, the prefrontal cortex (PFC) is suggested to play a key role in addiction, not only based on its regulation of limbic reward regions, but also its involvement in higher-order executive functions (for example, self-control, salience attribution, and awareness) (Goldstein and Volkow, 2011). Previous addiction studies showed that heroin-dependent individuals had a reduction in rGMD in the right DLPFC compared with healthy controls (Zhou et al., 2011). Moreover, previous VBM results indicate that the decreased rGMV in the bilateral DLPFC (especially in the right DLPFC) of patients suffering from IA, and the structural abnormalities of the DLPFC were all significantly correlated with the duration of Internet addiction in the adolescents with IAD (Yuan et al., 2011). However, in this study, we found that increased rGMV in the DLPFC might contribute to a higher IA score. It is worth noting that several recent studies have indicated that the notion that “the larger the volume, the better the function” does not always hold true (Kanai and Rees, 2011; Takeuchi et al., 2011). An early study (Kanai and Rees, 2011) revealed that decreased cortical volume is sometimes associated with increased functioning and better task performance. Indeed, the gray matter of certain brain regions, for example, prefrontal regions, show developmental thinning over time in studies of normal development (Amodio and Frith, 2006; Buckner et al., 2008; Decety et al., 2004; Schulte-Rüther et al., 2011; Sowell et al., 2003). That is, the reduction in GMV in the prefrontal regions among nonclinical populations of young adults during adolescence, which is a part of normal development, might reflect an effective synaptic and/or neuronal pruning process (i.e., the process of removing inefficient synapses and neurons over a lifetime; Kanai and Rees, 2011; Takeuchi et al., 2012). Moreover, Takeuchi et al. (2013a) found that larger rGMV in the sgACC of subjects with

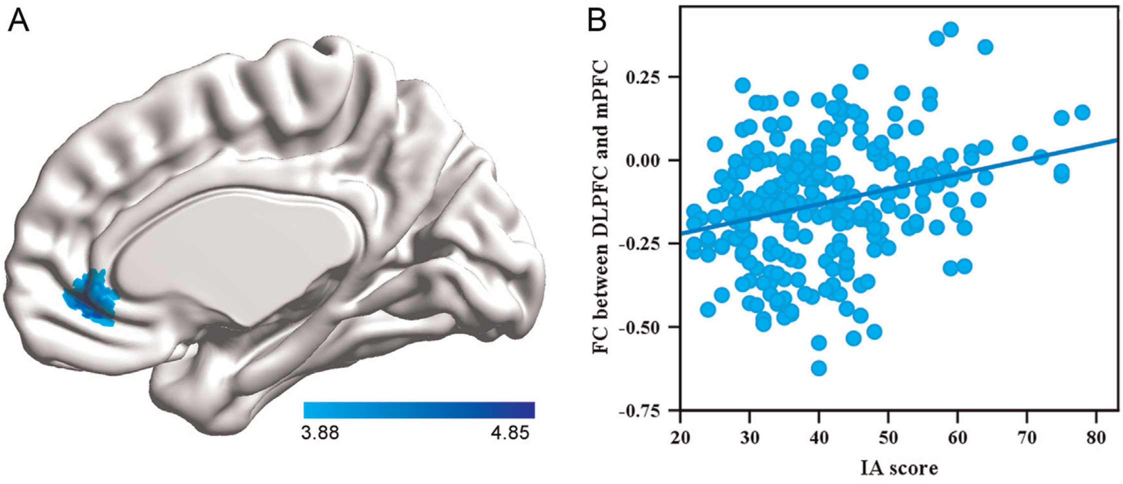

Fig. 3. DLPFC resting state functional connectivity (rsFC) strength is correlated with IA scores (the results are shown for $p < 0.05$, corrected for multiple comparisons using the voxel-level FDR at the whole brain level). (A) In the negative mask, the rsFC strength of the mPFC/rACC (MNI coordinates, $x, y, z = 9, 42, -3$, $t = 4.72$, $p < 0.05$, 92 voxels alive) and DLPFC was significantly and positively related to IA scores. (B) A scatter plot of the relationship between IA scores and rsFC strength for illustration purpose only. DLPFC, dorsolateral prefrontal cortex; FDR, false discovery rate; IA, Internet addiction; mPFC/rACC, medial prefrontal cortex/rostral anterior cingulate cortex.

Table 2
Neural association with Internet addiction.

Brain regions	H	Peak MNI coordinate			*T* score	Corrected *p* value*	Cluster size (voxels)
		X	*Y*	*Z*			
Voxel-based morphometry							
DLPFC	R	39	6	47	5.25	0.004	296
Functional connectivity							
mPFC/rACC	R	9	42	−3	4.72	< 0.001	92

Note: ROI, region of interest; MNI, Montreal Neurological Institute; H, hemisphere; R, right; DLPFC, dorsolateral prefrontal cortex; mPFC/rACC, rostral anterior cingulate cortex/medial prefrontal cortex.

* FDR correction for multiple comparisons at $p < 0.05$ voxel level.

a higher self-handicapping tendency may reflect immature functioning of this region, which might result in emotional fragility and lead to self-handicapping behaviors. Based on the above accumulating evidence, increased rGMV in the right DLPFC within prefrontal areas in this study might be related to lower functioning, which is mainly due to brain maturation characterized by cortical thinning, such as effective synaptic pruning. Our observations may suggest that, the larger rGMV in the DLPFC in subjects with higher IA scores might reflect diminished functioning of this region in terms of inhibitory control and executive ability, which could be associated with the emergence of compulsive craving and relapse. The fundamental symptoms of IA behaviors – the craving for immediate rewards from Internet activities – are associated with impulse-control disorders (e.g., intense preoccupation with Internet use, lack of control over the amount of time spent online and compulsive Internet use) as well as behavioral addictions (e.g., development of euphoria, craving, or tolerance) (Brenner, 1997; Feil et al., 2010; Goldstein and Volkow, 2011; Hayashi et al., 2013; Kuss and Griffiths, 2012).

Furthermore, the ΔRT of classical Stroop color-word task was found to be positively related to the volume of the altered DLPFC and the IA scores, which could support the abovementioned notion that the volume of the DLPFC and the IA scores were both negatively related with participants' cognitive control and executive function. In other words, those who scored higher on the IAT could not inhibit their dominant/habitual Internet use successfully (manifested as the increased volume of the DLPFC), and hence they demonstrate an inability to control their compulsive Internet use in life settings.

More interestingly, we also found decreased anticorrelations between the DLPFC and areas in the mPFC/rACC (i.e., key nodes of the CCN and DMN, respectively) were associated with higher IA scores. As discussed above, the DLPFC is considered as the core region of the CCN (Cole and Schneider, 2007), which might be related to executive function and inhibition control. Specifically, the DLPFC is associated with decision-making, impulse control, and loss of willpower to resist drugs (Bechara, 2005). This region also has been shown to be involved in predicting future rewards (Tanaka et al., 2004) and successful emotion regulation or impulse control processes (Staudinger et al., 2011). In addition, research has found that abnormal functional connectivity between the striatum and the DLPFC predicts impairments in learning and the magnitude of alcohol craving (Lee et al., 2007; Park et al., 2010). On the other hand, the mPFC and adjacent rACC regions are considered to be parts of the DMN that is relevant to attention, self-monitoring, and introspective thoughts (Buckner et al., 2008; Gusnard et al., 2001; Raichle et al., 2001). Generally, the DMN (e.g., mPFC/rACC) is involved in internally focused tasks, including self-monitoring, self-referential processing, and mind wandering (Buckner et al., 2008; Fox et al., 2005). Indeed, Fox et al. (2005) revealed the anticorrelation between the two intrinsic networks [e.g., the task-positive network (TPN) and the DMN] might be functionally more important than DMN activity itself, which might differentiate the neuronal processes that subserve opposite goals or competing representations (Broyd et al., 2009; Fox et al., 2005; Uddin et al., 2008; Zhou et al., 2007). Specifically, Fox (2005) found that regions belonging to the DMN showed negative connectivity with regions in cognitive control during resting state. To further clarify whether the anticorrelation between CCN and DMN on IA also existed when the seed region was changed, we also chose another two regions in the CCN as seed regions and found that they were all negatively connected with the mPFC. Therefore, the results of this study could reflect the balance between the DMN and CCN (two types of brain states that compete against each other during resting state) in higher IA scoring healthy subjects was impaired. Partly congruent with this, the reduced anticorrelations between the two networks is associated with conditions with reduced working memory capacity and aging (Broyd et al., 2009; Sambataro et al., 2010). Previous studies have found reduced anticorrelations between the mPFC and DLPFC in both patients with attention deficit/hyperactivity disorder and

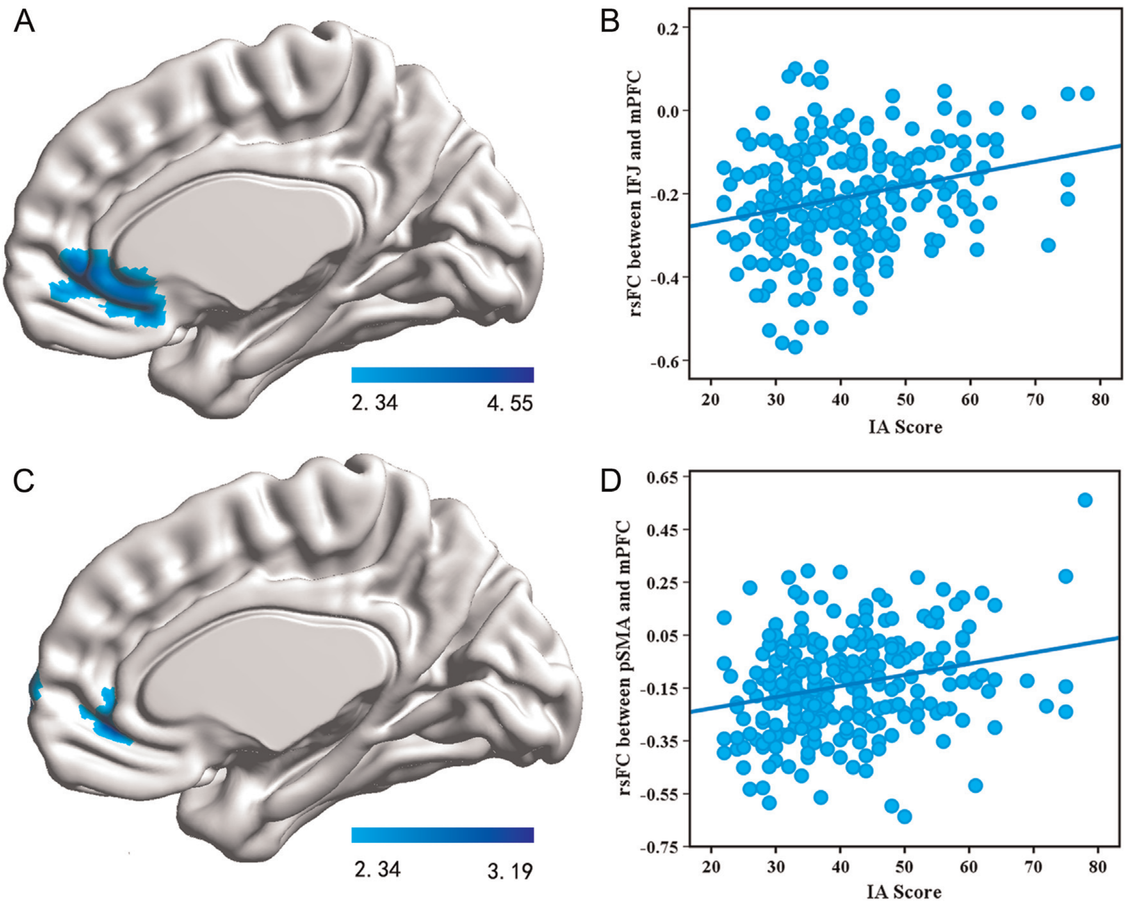

Fig. 4. Resting-state functional connectivity between the other brain regions in the CCN and the mPFC. The seed region is located at the right IFJ (A; radius, 6 mm; central coordinates, 44, 13, 30), and the right pSMA (C; radius, 6 mm; central coordinates, 3, 16, 50). The right IFJ and the right pSMA were both found to be negatively connected with the mPFC. The statistical threshold was $p < 0.05$ (corrected for Alphasim, voxel wise $p < 0.01$, cluster size > 74 voxels). The results are shown uncorrected for visualization purposes. (B and D) Scatter plots of significant positive relationships between IA scores and connectivity strength. CCN, cognitive control network; IFJ, inferior frontal junction; pSMA, pre-supplementary motor area; mPFC, medial prefrontal cortex.

schizophrenia, suggesting that the cognitive deficits (e.g., inefficient use of attentional resources) in these patient groups are due, in part, to a decoupling of the mPFC and DLPFC at baseline, which was also manifested during task execution (dysfunction in activating the DLPFC and suppressing the mPFC) (Chai et al., 2011; Daprati et al., 1997; Irani et al., 2006; Whitfield-Gabrieli et al., 2009). Comparatively, reduced anticorrelations might reflect disparity between the networks, and might arise from dysfunction in one or both of the networks, most likely indicating aberrant DMN activity (Broyd et al., 2009). Disruption of these functions could impair an individual's ability to monitor and inhibit inappropriate behavior (Broyd et al., 2009). In the present study, the connectivity between DLPFC and mPFC was also positively related the ΔRT of the Stroop color-word test (external measure of cognitive performance), which indicated that decreased anticonnnections between the DLPFC and mPFC may reflect reduced cognitive control ability and executive functioning. This notion may give a possible explanation about addiction-related impaired executive attention and cognitive control toward goal-directed activities (Dong et al., 2011; Shapira et al., 2000). This conclusion is indirectly supported by cognitive training studies. Previous study demonstrated that working memory and multitasking training may lead to an increase in anticorrelations between nodes of EAS and DMN, which may reflect reallocation of cognitive resources from the network active during rest (DMN) to the network actively involved in the task (the network involving DLPFC) (Takeuchi et al., 2013b, 2014).

IA is associated with an exaggerated negative self-representation (e.g., self-doubt, low self-efficacy and negative self-appraisal; Ko et al., 2008) that leads one to use the Internet to get more positive feedback and emotional support from other people without taking a risk, which might be also due to a lack of social support and/or social isolation. Patients suffering from IA tend to have automatic thoughts about themselves such as “I am good only at using the Internet” and “The only place where I am respected is the Internet” (Caplan, 2002; Davis, 2001; Şenormancı et al., 2010; Widyanto and Griffiths, 2006; Young, 1997). In fact, the DMN has been demonstrated to be active in situations involving self-referential mental activity, introspective thoughts, attention and decision-making (Andrews-Hanna et al., 2010; Buckner et al., 2008; Buckner and Carroll, 2007). As we discussed above, previous studies have revealed that several DMN regions (e.g., PCC, mPFC) exhibit structural and functional abnormalities in patients, which might indicate that the brain circuits of self-monitoring and attentional orientation are impaired in addiction patients (Ding and Lee, 2013; Ma et al., 2011; Sutherland et al., 2012). Thus, it was reasonable to speculate that higher IA scores might be associated with decreased anticorrelations between the DLPFC and areas in the mPFC/rACC (arising from dysfunctions in one or both of the DMN and CCN networks) which, in turn, develops a sustained blurring of perceptions about one's self and the world (apart from impaired impulse control, as discussed above). Interestingly, we also found that there was a mediation effect between GMV in the DLPFC and IA through the anticorrelation between the DLPFC and mPFC, which indicated that regional functional connectivity accounts for a statistically significant portion of the relationship between regional structural abnormalities and IA. Consequently, people with a high IA tendency would seek continuous self-validation, which involves the DMN, and immediate rewards from the Internet frequently, which would then affect their tolerance, withdrawal and inhibitory control, ultimately resulting in problematic Internet usage.

Although the present findings provide one piece of evidence about the neurobiological mechanisms of individual differences in IA tendencies, a few methodological limitations should be noted. First, in order to eliminate the effect of general intelligence on brain structures and functional connectivity, the Combined Raven's Test that had a high degree of reliability and validity was used to assess individuals' intelligence. Nonetheless, it should be noted that the Combined Raven's Test may be slightly simple for the investigated sample. Although this did not affect the conclusions of the study, future studies need to avoid potential ceiling effects in general intelligence testing for some subjects. In addition, as we used a cross-sectional rather than a longitudinal design, the observed structural and functional brain variations are still to be clarified. Further prospective studies should investigate the influence of excessive Internet use longitudinally over time and clarify the causal relations between IAD and psychological measures, which could provide a more definitive interpretation of our present findings.

5. Conclusion

The present study combined structural (GMV) and functional (rsFC) information to explore the neural basis of IA tendencies in a large healthy sample. Among the healthy subjects, the DLPFC volume was significantly and positively correlated with individual difference in IA scores, which might reflect immature functioning of this region related to inhibitory control. Meanwhile, there was a significant association between DLPFC atrophy and IAT scores. Interestingly, decreased anticorrelations between the DLPFC and mPFC were associated with higher IA scores, which might lead to dysfunctions of the CCN and DMN networks (i.e., diminished inhibitory control and cognitive efficiency), and cause an unrestrained cycle that lead individuals to devote excessive time and effort devoted to the Internet. These results indicate that there are differences between the neural correlates of the IA tendencies of healthy individuals and the pathophysiology of patients with IAD. In sum, the combination of morphometric results and functional connectivity findings can provide a valuable basis for further understanding of the pathogenesis of IA and aid in improving the effective methods for prevention and intervention of IAD.

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References

Alavi, S.S., Maracy, M.R., Jannatifard, F., Eslami, M., 2011. The effect of psychiatric symptoms on the internet addiction disorder in Isfahan's University students. J. Res. Med. Sci.: Off. J. Isfahan Univ. Med. Sci. 16 (6), 793.
Amodio, D.M., Frith, C.D., 2006. Meeting of minds: the medial frontal cortex and social cognition. Nat. Rev. Neurosci. 7 (4), 268–277.
Andrews-Hanna, J.R., Reidler, J.S., Sepulcre, J., Poulin, R., Buckner, R.L., 2010. Functional-anatomic fractionation of the brain's default network. Neuron 65 (4), 550–562.
Ashburner, J., 2007. A fast diffeomorphic image registration algorithm. Neuroimage 38 (1), 95–113.
Ashburner, J., Friston, K.J., 2000. Voxel-based morphometry – the methods. Neuroimage 11 (6), 805–821.
Barke, A., Nyenhuis, N., Kröner-Herwig, B., 2012. The German version of the internet addiction test: a validation study. Cyberpsychol. Behav. Soc. Netw. 15 (10), 534–542.
Bechara, A., 2005. Decision making, impulse control and loss of willpower to resist drugs: a neurocognitive perspective. Nat. Neurosci. 8 (11), 1458–1463.
Bidi, F., Namdari-Pejman, M., Kareshki, H., Ahmadnia, H., 2012. The mediating role of metacognition in the relationship between internet addiction and general health. Addict. Health 4 (1-2), 49.
Bjork, J.M., Smith, A.R., Chen, G., Hommer, D.W., 2011. Psychosocial problems and recruitment of incentive neurocircuitry: exploring individual differences in healthy adolescents. Dev. Cogn. Neurosci. 1 (4), 570–577.
Block, J., 2008. Issues for DSM-V: internet addiction. Am. J. Psychiatry 165 (3), 306–307.
Block, J.J., 2007. Lessons from Columbine: virtual and real rage. Am. J. Forensic Psychiatry 28 (2), 5.
Brenner, V., 1997. Psychology of computer use: XLVII. Parameters of Internet use, abuse and addiction: the first 90 days of the Internet Usage Survey. Psychol. Rep. 80 (3), 879–882.
Broyd, S.J., Demanuele, C., Debener, S., Helps, S.K., James, C.J., Sonuga-Barke, E.J., 2009. Default-mode brain dysfunction in mental disorders: a systematic review. Neurosci. Biobehav. Rev. 33 (3), 279–296.
Buckner, R.L., Andrews-Hanna, J.R., Schacter, D.L., 2008. The brain's default network. Ann. N. Y. Acad. Sci. 1124 (1), 1–38.
Buckner, R.L., Carroll, D.C., 2007. Self-projection and the brain. Trends Cogn. Sci. 11 (2), 49–57.
Cao, F.-l, Su, L.-y, 2007. Internet addiction among Chinese adolescents: prevalence and psychological features. Child: Care, Health Dev. 33 (3), 275–281.
Caplan, S.E., 2002. Problematic Internet use and psychosocial well-being: development of a theory-based cognitive–behavioral measurement instrument. Comput. Hum. Behav. 18 (5), 553–575.
Chai, X.J., Whitfield-Gabrieli, S., Shinn, A.K., Gabrieli, J.D., Castañón, A.N., McCarthy, J.M., et al., 2011. Abnormal medial prefrontal cortex resting-state connectivity in bipolar disorder and schizophrenia. Neuropsychopharmacology 36 (10), 2009–2017.
Chang, M.K., Man Law, S.P., 2008. Factor structure for Young's Internet Addiction Test: a confirmatory study. Comput. Hum. Behav. 24 (6), 2597–2619.
Chao-Gan, Y., Yu-Feng, Z., 2010. DPARSF: a MATLAB toolbox for “pipeline” data analysis of resting-state fMRI. Front. Syst. Neurosci. 4:13.
Chen, S., Wu, X., Lui, S., Wu, Q., Yao, Z., Li, Q., et al., 2012. Resting-state fMRI study of treatment-naive temporal lobe epilepsy patients with depressive symptoms. Neuroimage 60 (1), 299–304.
Cole, M.W., Schneider, W., 2007. The cognitive control network: integrated cortical regions with dissociable functions. Neuroimage 37 (1), 343–360.
Daprati, E., Franck, N., Georgieff, N., Proust, J., Pacherie, E., Dalery, J., et al., 1997. Looking for the agent: an investigation into consciousness of action and self-consciousness in schizophrenic patients. Cognition 65 (1), 71–86.
Daskalakis, Z.J., Farzan, F., Barr, M.S., Rusjan, P.M., Favalli, G., Levinson, A.J., et al., 2008. Evaluating the relationship between long interval cortical inhibition, working memory and gamma band activity in the dorsolateral prefrontal cortex. Clin. EEG Neurosci. 39 (3), 150–155.
Davis, R.A., 2001. A cognitive-behavioral model of pathological Internet use. Comput. Hum. Behav. 17 (2), 187–195.
Decety, J., Jackson, P.L., Sommerville, J.A., Chaminade, T., Meltzoff, A.N., 2004. The neural bases of cooperation and competition: an fMRI investigation. Neuroimage 23 (2), 744–751.
Di, X., Zhu, S., Jin, H., Wang, P., Ye, Z., Zhou, K., et al., 2012. Altered resting brain function and structure in professional badminton players. Brain Connect. 2 (4), 225–233.
Ding, W.-n, Sun, J.-h, Sun, Y.-w, Zhou, Y., Li, L., Xu, J.-r, et al., 2013. Altered default network resting-state functional connectivity in adolescents with Internet gaming addiction. PloS One 8 (3), e59902.
Ding, X., Lee, S.-W., 2013. Changes of functional and effective connectivity in smoking replenishment on deprived heavy smokers: a resting-state fMRI study. PloS One 8 (3), e59331.
Dong, G., DeVito, E.E., Du, X., Cui, Z., 2012. Impaired inhibitory control in 'internet addiction disorder': a functional magnetic resonance imaging study. Psychiatry Res.: Neuroimaging 203 (2), 153–158.
Dong, G., Hu, Y., Lin, X., 2013a. Reward/punishment sensitivities among internet addicts: implications for their addictive behaviors. Progr. Neuro-Psychopharmacol. Biol. Psychiatry 46, 139–145.
Dong, G., Hu, Y., Lin, X., Lu, Q., 2013b. What makes Internet addicts continue playing online even when faced by severe negative consequences? Possible explanations from an fMRI study. Biol. Psychol. 94 (2), 282–289.
Dong, G., Zhou, H., Zhao, X., 2011. Male Internet addicts show impaired executive control ability: evidence from a color-word Stroop task. Neurosci. Lett. 499 (2), 114–118.
Drevets, W.C., Price, J.L., Furey, M.L., 2008. Brain structural and functional abnormalities in mood disorders: implications for neurocircuitry models of depression. Brain Struct. Funct. 213 (1–2), 93–118.
Feil, J., Sheppard, D., Fitzgerald, P.B., Yücel, M., Lubman, D.I., Bradshaw, J.L., 2010. Addiction, compulsive drug seeking, and the role of frontostriatal mechanisms

in regulating inhibitory control. Neurosci. Biobehav. Rev. 35 (2), 248–275.

Feng, Q., Chen, X., Sun, J., Zhou, Y., Sun, Y., Ding, W., et al., 2013. Voxel-level comparison of arterial spin-labeled perfusion magnetic resonance imaging in adolescents with internet gaming addiction. Behav. Brain Funct. 9 (1), 33.

Fox, M.D., Snyder, A.Z., Vincent, J.L., Corbetta, M., Van Essen, D.C., Raichle, M.E., 2005. The human brain is intrinsically organized into dynamic, anticorrelated functional networks. Proc. Natl. Acad. Sci. USA 102 (27), 9673–9678.

Fransson, P., Marrelec, G., 2008. The precuneus/posterior cingulate cortex plays a pivotal role in the default mode network: evidence from a partial correlation network analysis. Neuroimage 42 (3), 1178–1184.

Friston, K.J., Williams, S., Howard, R., Frackowiak, R.S., Turner, R., 1996. Movement-related effects in fMRI time-series. Magn. Reson. Med. 35 (3), 346–355.

Goldstein, R.Z., Volkow, N.D., 2011. Dysfunction of the prefrontal cortex in addiction: neuroimaging findings and clinical implications. Nat. Rev. Neurosci. 12 (11), 652–669.

Greenfield, D.N., 1999. Psychological characteristics of compulsive internet use: a preliminary analysis. CyberPsychol. Behav. 2 (5), 403–412.

Gusnard, D.A., Akbudak, E., Shulman, G.L., Raichle, M.E., 2001. Medial prefrontal cortex and self-referential mental activity: relation to a default mode of brain function. Proc. Natl. Acad. Sci. 98 (7), 4259–4264.

Ha, J.H., Kim, S.Y., Bae, S.C., Bae, S., Kim, H., Sim, M., et al., 2007. Depression and Internet addiction in adolescents. Psychopathology 40 (6), 424–430.

Haier, R.J., Jung, R.E., Yeo, R.A., Head, K., Alkire, M.T., 2004. Structural brain variation and general intelligence. Neuroimage 23 (1), 425–433.

Han, D.H., Hwang, J.W., Renshaw, P.F., 2010. Bupropion sustained release treatment decreases craving for video games and cue-induced brain activity in patients with Internet video game addiction. Exp. Clin. Psychopharmacol. 18 (4), 297.

Han, D.H., Lyoo, I.K., Renshaw, P.F., 2012. Differential regional gray matter volumes in patients with on-line game addiction and professional gamers. J. Psychiatr. Res. 46 (4), 507–515.

Hayakawa, Y.K., Sasaki, H., Takao, H., Mori, H., Hayashi, N., Kunimatsu, A., et al., 2013. Structural brain abnormalities in women with subclinical depression, as revealed by voxel-based morphometry and diffusion tensor imaging. J. Affect. Disord. 144 (3), 263–268.

Hayashi, T., Ko, J.H., Strafella, A.P., Dagher, A., 2013. Dorsolateral prefrontal and orbitofrontal cortex interactions during self-control of cigarette craving. Proc. Natl. Acad. Sci. 110 (11), 4422–4427.

He-ming, L., X.-f, Z., 2008. Analysis of original scores and IQ value of Combined Ravens Test in 10 years old group. Chin. J. Control Endem. Dis. 2, 017.

Holden, C., 2001. 'Behavioral' addictions: do they exist? Science 294 (5544), 980–982.

Hong, S.-B., Kim, J.-W., Choi, E.-J., Kim, H.-H., Suh, J.-E., Kim, C.-D., et al., 2013. Reduced orbitofrontal cortical thickness in male adolescents with internet addiction. Behav. Brain Funct. 9, 11.

Hooker, C.I., Gyurak, A., Verosky, S.C., Miyakawa, A., Ayduk, Ö., 2010. Neural activity to a partner's facial expression predicts self-regulation after conflict. Biol. Psychiatry 67 (5), 406–413.

Hoppenbrouwers, S.S., De Jesus, D.R., Stirpe, T., Fitzgerald, P.B., Voineskos, A.N., Schutter, D.J., et al., 2013. Inhibitory deficits in the dorsolateral prefrontal cortex in psychopathic offenders. Cortex 49 (5), 1377–1385.

Hoshi, E., 2006. Functional specialization within the dorsolateral prefrontal cortex: a review of anatomical and physiological studies of non-human primates. Neurosci. Res. 54 (2), 73–84.

Irani, F., Platek, S.M., Panyavin, I.S., Calkins, M.E., Kohler, C., Siegel, S.J., et al., 2006. Self-face recognition and theory of mind in patients with schizophrenia and first-degree relatives. Schizophr. Res. 88 (1), 151–160.

Jensen, A.R., 1965. Scoring the Stroop test. Acta Psychol. 24, 398–408.

Johnson, C.A., Cioffi, G.A., Liebmann, J.R., Sample, P.A., Zangwill, L.M., Weinreb, R.N., 2000. The relationship between structural and functional alterations in glaucoma: a review. Paper Presented at the Seminars in Ophthalmology.

Jović, J., Đinđić, N., 2011. Influence of dopaminergic system on internet addiction. Acta Med. Median. 50 (1), 60–66.

Jung, W.H., Kim, S.N., Lee, T.Y., Jang, J.H., Choi, C.-H., Kang, D.-H., et al., 2013. Exploring the brains of Baduk (Go) experts: gray matter morphometry, resting-state functional connectivity, and graph theoretical analysis. Front. Hum. Neurosci., 7.

Kühn, S., Gallinat, J., 2015. Brains online: structural and functional correlates of habitual Internet use. Addict. Biol. 20 (2), 415–422.

Kühn, S., Romanowski, A., Schilling, C., Lorenz, R., Mörsen, C., Seiferth, N., et al., 2011. The neural basis of video gaming. Transl. Psychiatry 1 (11), e53.

Kühn, S., Vanderhasselt, M.-A., De Raedt, R., Gallinat, J., 2012. Why ruminators won't stop: the structural and resting state correlates of rumination and its relation to depression. J. Affect. Disord. 141 (2), 352–360.

Kanai, R., Rees, G., 2011. The structural basis of inter-individual differences in human behaviour and cognition. Nat. Rev. Neurosci. 12 (4), 231–242.

Kehagia, A.A., Murray, G.K., Robbins, T.W., 2010. Learning and cognitive flexibility: frontostriatal function and monoaminergic modulation. Curr. Opin. Neurobiol. 20 (2), 199–204.

Kim, K., Ryu, E., Chon, M.-Y., Yeun, E.-J., Choi, S.-Y., Seo, J.-S., et al., 2006. Internet addiction in Korean adolescents and its relation to depression and suicidal ideation: a questionnaire survey. Int. J. Nurs. Stud. 43 (2), 185–192.

Ko, C.-H., Liu, G.-C., Hsiao, S., Yen, J.-Y., Yang, M.-J., Lin, W.-C., et al., 2009. Brain activities associated with gaming urge of online gaming addiction. J. Psychiatr. Res. 43 (7), 739–747.

Ko, C.-H., Yen, J.-Y., Yen, C.-F., Chen, C.-S., Weng, C.-C., Chen, C.-C., 2008. The association between Internet addiction and problematic alcohol use in adolescents: the problem behavior model. CyberPsychol. Behav. 11 (5), 571–576.

Kuss, D.J., Griffiths, M.D., 2012. Internet and gaming addiction: a systematic literature review of neuroimaging studies. Brain Sci. 2 (3), 347–374.

Lee, D., Rushworth, M.F., Walton, M.E., Watanabe, M., Sakagami, M., 2007. Functional specialization of the primate frontal cortex during decision making. J. Neurosci. 27 (31), 8170–8173.

Li, H., Li, W., Wei, D., Chen, Q., Jackson, T., Zhang, Q., et al., 2014. Examining brain structures associated with perceived stress in a large sample of young adults via voxel-based morphometry. Neuroimage 92, 1–7.

Liao, W., Xu, Q., Mantini, D., Ding, J., Machado-de-Sousa, J.P., Hallak, J.E., et al., 2011. Altered gray matter morphometry and resting-state functional and structural connectivity in social anxiety disorder. Brain Res. 1388, 167–177.

Lui, S., Deng, W., Huang, X., Jiang, L., Ma, X., Chen, H., et al., 2009. Association of cerebral deficits with clinical symptoms in antipsychotic-naive first-episode schizophrenia: an optimized voxel-based morphometry and resting state functional connectivity study. Am. J. Psychiatry 166 (2), 196–205.

Ma, N., Liu, Y., Fu, X.-M., Li, N., Wang, C.-X., Zhang, H., et al., 2011. Abnormal brain default-mode network functional connectivity in drug addicts. PloS One 6 (1), e16560.

Ma, N., Liu, Y., Li, N., Wang, C.-X., Zhang, H., Jiang, X.-F., et al., 2010. Addiction related alteration in resting-state brain connectivity. Neuroimage 49 (1), 738–744.

MacLeod, C.M., 1991. Half a century of research on the Stroop effect: an integrative review. Psychol. Bull. 109 (2), 163.

Makris, N., Gasic, G.P., Kennedy, D.N., Hodge, S.M., Kaiser, J.R., Lee, M.J., et al., 2008. Cortical thickness abnormalities in cocaine addiction – a reflection of both drug use and a pre-existing disposition to drug abuse? Neuron 60 (1), 174–188.

Makris, N., Oscar-Berman, M., Jaffin, S.K., Hodge, S.M., Kennedy, D.N., Caviness, V.S., et al., 2008. Decreased volume of the brain reward system in alcoholism. Biol. Psychiatry 64 (3), 192–202.

Mansouri, F.A., Tanaka, K., Buckley, M.J., 2009. Conflict-induced behavioural adjustment: a clue to the executive functions of the prefrontal cortex. Nat. Rev. Neurosci. 10 (2), 141–152.

Meng, Y., Deng, W., Wang, H., Guo, W., Li, T., 2014. The prefrontal dysfunction in individuals with Internet gaming disorder: a meta-analysis of functional magnetic resonance imaging studies. Addict. Biol.

Miller, E.K., Cohen, J.D., 2001. An integrative theory of prefrontal cortex function. Annu. Rev. Neurosci. 24 (1), 167–202.

Ng, B.D., Wiemer-Hastings, P., 2005. Addiction to the internet and online gaming. CyberPsychol. Behav. 8 (2), 110–113.

Park, S.Q., Kahnt, T., Beck, A., Cohen, M.X., Dolan, R.J., Wrase, J., et al., 2010. Prefrontal cortex fails to learn from reward prediction errors in alcohol dependence. J. Neurosci. 30 (22), 7749–7753.

Preacher, K.J., Hayes, A.F., 2008. Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. Behav. Res. Methods 40 (3), 879–891.

Raichle, M.E., MacLeod, A.M., Snyder, A.Z., Powers, W.J., Gusnard, D.A., Shulman, G. L., 2001. A default mode of brain function. Proc. Natl. Acad. Sci. 98 (2), 676–682.

Raven, J., 2000. The Raven's progressive matrices: change and stability over culture and time. Cogn. Psychology 41 (1), 1–48.

Raven, J.C., Court, J.H., 1998. Raven's Progressive Matrices and Vocabulary Scales. Oxford Psychologists Press, Oxford.

Sakai, K., Passingham, R.E., 2004. Prefrontal selection and medial temporal lobe reactivation in retrieval of short-term verbal information. Cerebr. Cortex 14 (8), 914–921.

Sambataro, F., Murty, V.P., Callicott, J.H., Tan, H.-Y., Das, S., Weinberger, D.R., et al., 2010. Age-related alterations in default mode network: impact on working memory performance. Neurobiol. Aging 31 (5), 839–852.

Satterthwaite, T.D., Elliott, M.A., Gerraty, R.T., Ruparel, K., Loughead, J., Calkins, M.E., et al., 2013. An improved framework for confound regression and filtering for control of motion artifact in the preprocessing of resting-state functional connectivity data. Neuroimage 64, 240–256.

Schlagenhauf, F., Sterzer, P., Schmack, K., Ballmaier, M., Rapp, M., Wrase, J., et al., 2009. Reward feedback alterations in unmedicated schizophrenia patients: relevance for delusions. Biol. Psychiatry 65 (12), 1032–1039.

Schulte-Rüther, M., Greimel, E., Markowitsch, H.J., Kamp-Becker, I., Remschmidt, H., Fink, G.R., et al., 2011. Dysfunctions in brain networks supporting empathy: an fMRI study in adults with autism spectrum disorders. Soc. Neurosci. 6 (1), 1–21.

Şenormancı, Ö., Konkan, R., Sungur, M.Z., 2010. Internet addiction and its cognitive behavioral therapy. Anat. J. Psychiatry 11, 261–268.

Shapira, N.A., Goldsmith, T.D., Keck Jr, P.E., Khosla, U.M., McElroy, S.L., 2000. Psychiatric features of individuals with problematic internet use. J. Affect. Disord. 57 (1), 267–272.

Shek, D.T., Tang, V.M., Lo, C., 2008. Internet addiction in Chinese adolescents in Hong Kong: assessment, profiles, and psychosocial correlates. Sci. World J. 8, 776–787.

Shek, D.T., Yu, L., 2012. Internet addiction phenomenon in early adolescents in Hong Kong. Sci. World J., 2012.

Siomos, K.E., Dafouli, E.D., Braimiotis, D.A., Mouzas, O.D., Angelopoulos, N.V., 2008. Internet addiction among Greek adolescent students. CyberPsychol. Behav. 11 (6), 653–657.

Smith, E.E., Jonides, J., Marshuetz, C., Koeppe, R.A., 1998. Components of verbal working memory: evidence from neuroimaging. Proc. Natl. Acad. Sci. 95 (3), 876–882.

Song, X.-W., Dong, Z.-Y., Long, X.-Y., Li, S.-F., Zuo, X.-N., Zhu, C.-Z., et al., 2011. REST: a toolkit for resting-state functional magnetic resonance imaging data processing. PloS One 6 (9), e25031.

Sowell, E.R., Peterson, B.S., Thompson, P.M., Welcome, S.E., Henkenius, A.L., Toga, A. W., 2003. Mapping cortical change across the human life span. Nat. Neurosci. 6 (3), 309–315.

Spada, M.M., Langston, B., Nikčević, A.V., Moneta, G.B., 2008. The role of metacognitions in problematic Internet use. Comput. Hum. Behav. 24 (5), 2325–2335.

Spielberger, C.D., 1972. Anxiety: Current Trends in Theory and Research: I.

Spielberger, C.D., Gorsuch, R.L., Lushene, R.E., 1970. Manual for the State-trait Anxiety Inventory.

Spielberger, C.D., Jacobs, G., Russell, S., Crane, R., 1983. Assessment of anger: the state-trait anger scale. Adv. Pers. Assess. 2, 159–187.

Staudinger, M.R., Erk, S., Walter, H., 2011. Dorsolateral prefrontal cortex modulates striatal reward encoding during reappraisal of reward anticipation. Cerebr. Cortex 21 (11), 2578–2588.

Sutherland, M.T., McHugh, M.J., Pariyadath, V., Stein, E.A., 2012. Resting state functional connectivity in addiction: lessons learned and a road ahead. Neuroimage 62 (4), 2281–2295.

Takeuchi, H., Taki, Y., Nouchi, R., Hashizume, H., Sekiguchi, A., Kotozaki, Y., et al., 2013a. Anatomical correlates of self-handicapping tendency. Cortex 49 (4), 1148–1154.

Takeuchi, H., Taki, Y., Nouchi, R., Hashizume, H., Sekiguchi, A., Kotozaki, Y., et al., 2013b. Effects of working memory training on functional connectivity and cerebral blood flow during rest. Cortex 49 (8), 2106–2125.

Takeuchi, H., Taki, Y., Nouchi, R., Sekiguchi, A., Kotozaki, Y., Miyauchi, C.M., et al., 2014. Regional gray matter density is associated with achievement motivation: evidence from voxel-based morphometry. Brain Struct. Funct. 219 (1), 71–83.

Takeuchi, H., Taki, Y., Sassa, Y., Hashizume, H., Sekiguchi, A., Fukushima, A., et al., 2011. Regional gray matter density associated with emotional intelligence: evidence from voxel-based morphometry. Hum. Brain Mapp. 32 (9), 1497–1510.

Takeuchi, H., Taki, Y., Sassa, Y., Hashizume, H., Sekiguchi, A., Nagase, T., et al., 2012. Regional gray and white matter volume associated with Stroop interference: evidence from voxel-based morphometry. Neuroimage 59 (3), 2899–2907.

Tanaka, S.C., Doya, K., Okada, G., Ueda, K., Okamoto, Y., Yamawaki, S., 2004. Prediction of immediate and future rewards differentially recruits cortico-basal ganglia loops. Nat. Neurosci. 7 (8), 887–893.

Tao, Z., 2003. A study of correlation between interaction anxiety and internet addiction disorder in college student. J. Educ. Sci. Hunan Normal Univ. 3, 019.

Thomsen, T., Specht, K., Hammar, Å., Nyttingnes, J., Ersland, L., Hugdahl, K., 2004. Brain localization of attentional control in different age groups by combining functional and structural MRI. Neuroimage 22 (2), 912–919.

Tian, L., Ren, J., Zang, Y., 2012. Regional homogeneity of resting state fMRI signals predicts Stop signal task performance. Neuroimage 60 (1), 539–544.

Uddin, L.Q., Kelly, A., Biswal, B.B., Margulies, D.S., Shehzad, Z., Shaw, D., et al., 2008. Network homogeneity reveals decreased integrity of default-mode network in ADHD. J. Neurosci. Methods 169 (1), 249–254.

Volkow, N.D., Fowler, J.S., Wang, G.-J., Swanson, J.M., 2004. Dopamine in drug abuse and addiction: results from imaging studies and treatment implications. Mol. Psychiatry 9 (6), 557–569.

Wagner, A.D., Maril, A., Bjork, R.A., Schacter, D.L., 2001. Prefrontal contributions to executive control: fMRI evidence for functional distinctions within lateral prefrontal cortex. Neuroimage 14 (6), 1337–1347.

Wang, H., Zhou, X., Lu, C., Wu, J., Deng, X., Hong, L., 2011. Problematic internet use in high school students in Guangdong province, China. PLoS One 6 (5), e19660.

Wang, Z., Liang, P., Jia, X., Jin, G., Song, H., Han, Y., et al., 2012a. The baseline and longitudinal changes of PCC connectivity in mild cognitive impairment: a combined structure and resting-state fMRI study. PloS One 7 (5), e36838.

Wang, Z., Zhang, Z., Jiao, Q., Liao, W., Chen, G., Sun, K., et al., 2012b. Impairments of thalamic nuclei in idiopathic generalized epilepsy revealed by a study combining morphological and functional connectivity MRI. PloS One 7 (7), e39701.

Watkins, K.E., Smith, S.M., Davis, S., Howell, P., 2008. Structural and functional abnormalities of the motor system in developmental stuttering. Brain 131 (1), 50–59.

Wei, D., Yang, J., Li, W., Wang, K., Zhang, Q., Qiu, J., 2014. Increased resting functional connectivity of the medial prefrontal cortex in creativity by means of cognitive stimulation. Cortex 51, 92–102.

Whang, L.S.-M., Lee, S., Chang, G., 2003. Internet over-users' psychological profiles: a behavior sampling analysis on internet addiction. CyberPsychol. Behav. 6 (2), 143–150.

Whitfield-Gabrieli, S., Thermenos, H.W., Milanovic, S., Tsuang, M.T., Faraone, S.V., McCarley, R.W., et al., 2009. Hyperactivity and hyperconnectivity of the default network in schizophrenia and in first-degree relatives of persons with schizophrenia. Proc. Natl. Acad. Sci. 106 (4), 1279–1284.

Widyanto, L., Griffiths, M., 2006. 'Internet addiction': a critical review. Int. J. Ment. Health Addict. 4 (1), 31–51.

Widyanto, L., Griffiths, M.D., Brunsden, V., 2011. A psychometric comparison of the Internet Addiction Test, the Internet-Related Problem Scale, and self-diagnosis. Cyberpsychol. Behav. Soc. Netw. 14 (3), 141–149.

Widyanto, L., McMurran, M., 2004. The psychometric properties of the internet addiction test. CyberPsychol. Behav. 7 (4), 443–450.

Yan, C.-G., Cheung, B., Kelly, C., Colcombe, S., Craddock, R.C., Di Martino, A., et al., 2013. A comprehensive assessment of regional variation in the impact of head micromovements on functional connectomics. Neuroimage 76, 183–201.

Yan, C., Liu, D., He, Y., Zou, Q., Zhu, C., Zuo, X., et al., 2009. Spontaneous brain activity in the default mode network is sensitive to different resting-state conditions with limited cognitive load. PloS One 4 (5), e5743.

Yang, S.C., Tung, C.-J., 2007. Comparison of Internet addicts and non-addicts in Taiwanese high school. Comput. Hum. Behav. 23 (1), 79–96.

Yang, Y., Raine, A., 2009. Prefrontal structural and functional brain imaging findings in antisocial, violent, and psychopathic individuals: a meta-analysis. Psychiatry Res.: Neuroimaging 174 (2), 81–88.

Young, K.S., 1997. What makes the Internet addictive: potential explanations for pathological Internet use. Paper presented at the 105th Annual Conference of the American Psychological Association.

Young, K.S., 1998. Internet addiction: the emergence of a new clinical disorder. CyberPsychol. Behav. 1 (3), 237–244.

Young, K.S., 2011. CBT-IA: the first treatment model for internet addiction. J. Cogn. Psychother. 25 (4), 304–312.

Young, K.S., Rogers, R.C., 1998. The relationship between depression and Internet addiction. CyberPsychol. Behav. 1 (1), 25–28.

Yuan, K., Qin, W., Dong, M., Liu, J., Liu, P., Zhang, Y., et al., 2010. Combining spatial and temporal information to explore resting-state networks changes in abstinent heroin-dependent individuals. Neurosci. Lett. 475 (1), 20–24.

Yuan, K., Qin, W., Wang, G., Zeng, F., Zhao, L., Yang, X., et al., 2011. Microstructure abnormalities in adolescents with internet addiction disorder. PloS One 6 (6), e20708.

Zhou, Y., Liang, M., Tian, L., Wang, K., Hao, Y., Liu, H., et al., 2007. Functional disintegration in paranoid schizophrenia using resting-state fMRI. Schizophr. Res. 97 (1), 194–205.

Zhou, Y., Lin, F.-c, Du, Y.-s, Qin, L.-d, Zhao, Z.-m, Xu, J.-r, et al., 2011. Gray matter abnormalities in Internet addiction: a voxel-based morphometry study. Eur. J. Radiol. 79 (1), 92–95.

Zung, W.W., 1965. A self-rating depression scale. Archiv. Gen. Psychiatry 12 (1), 63–70.