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Gaming-addicted teens identify more with their cyber-self than their own self: Neural evidence

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ABSTRACT

According to existing neuroimaging studies of social cognition, individuals use knowledge about themselves to infer the mental states of others and to mentalize in a different way when the other is perceived to be similar versus dissimilar to oneself. In this study, we examined whether adolescent boys make mental state inferences for their online game characters and whether adolescents who were diagnosed as addicted to the internet game perceived their personal game character to be similar to themselves. Twelve internet-addicted adolescents and fifteen adolescents without addiction reported whether short phrases described themselves, a well-known historical person, or their own game character while undergoing a functional magnetic resonance imaging (fMRI). Different patterns of activity emerged for adolescents with internet game addiction compared to healthy adolescents when they were thinking about themselves, another person, and their game characters. Specifically, when addicted adolescents were thinking about their own game characters, more global and significant medial prefrontal (MPFC) and anterior cingulate (ACC) activations were observed, than even when compared to thinking about themselves. The ACC activation was correlated with the symptom severity. The activation patterns demonstrated that addicted adolescents were most attached to their game characters and equated their game characters to human.

1. Introduction

1.1. Neural bases for cognition of self and other people

Self-concept, as a stable essence, is based on the beliefs of individual's cognitive uniqueness, constancy and continuity (Erikson, 1959; Yi, 2002). Recognizing oneself as a being with cognitive, social and emotional characteristics distinct from other people is a starting point of self-awareness and a basis of self-knowledge.

Since the 1970s, a considerable body of social cognition research has studied differences in processing information relevant to one's self versus information relevant to others. More recently, researchers have reached the conclusion that self-knowledge and knowledge about others are not separate but should be viewed along a continuum on which one extreme represents oneself, the other extreme represents a generalized other or a stranger of some kind, and in between are people with whom one has interactions and relationships (Aron and Aron, 1996). Thus, individuals recognize that others not only experience beliefs, feelings and desires, but that their mental states can be comparable to those experienced by oneself (Tomasello, 1999). This awareness that the inner workings of others' minds overlap meaningfully with one's own allows humans to use their own thoughts and feelings as a guide to those of others (Mitchell et al., 2006). In other words, "simulation" (or "projection") toward others' minds have posited that perceivers may infer mental states, in part, by assuming that others experience what they themselves would think or feel in a comparable situation (Adolphs, 2002).

Recent neuroimaging research has also investigated these

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constructs. Numerous studies related to the self have reported activation in the medial prefrontal cortex (MPFC) for conditions that involve some aspect of self (Cabeza et al., 2004; Heatherton, 2011; Macrae et al., 2004; Mitchell et al., 2006; Northoff et al., 2006; Pfeifer et al., 2007). Other neuroimaging studies have reported several regions of the brain that are activated when making inferences about the mental states of other people: MPFC, temporoparietal junction (TPJ), temporal poles, and medial parietal cortex (Amodio and Frith, 2006; Denny et al., 2012; Gallagher and Frith, 2003; Heatherton, 2011; Mitchell et al., 2006; Saxe, 2006; Saxe et al., 2004). The dorsomedial prefrontal cortex (DMPFC) is associated particularly with making inferences about the mental characteristics of others who have no similarities or relationships with the subject (De Brigard et al., 2015; Iacoboni et al., 2004; Mitchell et al., 2006). On the other hand, some researchers have studied whether a "familiar other" may become incorporated into one's self-concept on this spectrum (Krienen et al., 2010). They hypothesized that the frontal midline including the MPFC and ACC would be activated when individuals reflect upon familiar others such as parents, who have established close relationships with themselves. Some studies have demonstrated the MPFC and ACC activation for familiar others as well as the self (Krienen et al., 2010; Mitchell et al., 2006; Ochsner et al., 2005; Schmitz et al., 2004; Seger et al., 2004; Taylor et al., 2009; Wang et al., 2012; but see Heatherton et al., 2006), but with differences across family members (Arsalidou et al., 2010; Wang et al., 2012). This is associated more with the extent of attachment and familiarity than with similarity of appearance (Krienen et al., 2010).

1.2. One's own game character: is it me or is it someone else?

With the development of high-speed internet communications networks, the online role-playing game (typically called Massively Multiplayer Online Role-Playing Games; MMORPGs) has become a significant leisure activity for many adolescents. In MMORPGs, users organize virtual communities through a guild and cooperate with one another to achieve game-related goals. One of the most distinctive features of MMORPGs is that in-game characters, such as avatars in the form of magicians or warriors, are used to establish interactions among the game users (Kuss et al., 2012). The user's game character is the agent which interacts with other users in the virtual world; thus, the virtual character can be easily equated with the user (Israelashvili et al., 2012; Jin, 2011). However, it is still unclear to what extent the game user equates the game character to oneself. Moreover, a game user who is immersed excessively in these games may display a greater vulnerability to equating oneself with the game character (Allison et al., 2006; Bacchini et al., 2017; Bessiere et al., 2007; Yee et al., 2009). A few neuroimaging studies have investigated the neural processes mediating avatar-referencing compared with self- or other-referencing in addicted players of MMORPGs and reported bilateral activations of angular gyrus during avatar-perception (Dieter et al., 2015; Leménager et al., 2014, 2016). However, there has been a call for developmental study since there is a significant concern for gaming addiction in younger populations. According to one national study conducted in Korea (Ministry of Gender Equality and Family, 2011), more than 90% of male adolescents enjoy internet games as a leisure activity, while the average number of hours spent on games was 1.5 h per day. Over 10% of Korean adolescents were classified as definitive internet over-users, in that they spend an excessive amount of time in cyber communities as a game character with an entirely different appearance, personality, and abilities; this could be in contrast to their daily experience of themselves (e.g., Allison et al., 2006). In such cases where significant disparities exist between the real world and virtual world, these young gamers may have a higher chance of having significantly atypical perceptions of themselves and their game characters compared to non-addicted users; this study examined these possibilities.

The current study had three goals. First, we examined whether adolescent users of internet games make mental state inferences for their online game characters. Second, we determined whether adolescents diagnosed with the internet game addiction perceived their game character to be similar to themselves. Third, we compared the two groups (i.e., addicted vs. non-addicted group) in terms of their brain activity to their game characters versus themselves and another individual. We hypothesized that different neural patterns of activity would be observed in the addicted vs. non-addicted group when they thought about themselves, others and their game characters.

2. Material and methods

2.1. Participants

Seventeen right-handed male adolescents who were diagnosed with internet gaming addiction by board-certified child and adolescent psychiatrists were recruited from Seoul National University Children's Hospital via posted flyers among outpatients. Also, seventeen right-handed healthy male adolescents for comparison were recruited among the students currently enrolled in middle and high school in Seoul and played internet games more than 2 h a week. The internet game addicted adolescents ranged in age from 11 to 18 years (M = 13.83, SD = 2.69), and non-addicted healthy adolescents ranged in age from 14 to 17 years (M = 15.33, SD = 0.98). There was no significant difference in age between the two groups ($t = -1.837$, $p > 0.05$). This study was approved by the institutional review board for human subjects at the Seoul National University. All the adolescents and their parents provided written informed consent prior to study entry.

2.2. Diagnosis and neuropsychological assessments

Internet addiction has been defined as the inability of individuals to control their internet use, resulting in marked distress and functional impairment in five domains: academic, social, occupational, developmental and behavioural (Young, 1996). However, internet gaming disorder has not been included as a psychiatric disorder in the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) and was recommended for the further research. In this study, we used the definition of 'Internet addiction' that focuses on the abnormal use of online games considering the criteria of Internet gaming disorder in DSM-V. To establish the diagnosis of internet addiction and exclude other potentially comorbid psychiatric disorders, we used the Kiddie-Schedule for Affective Disorders and Schizophrenia-Present and Lifetime Version (K-SADS-PL) and the Young Internet Addiction Scale (YIAS). The K-SADS-PL is a semi-structured diagnostic interview tool based on the DSM-IV criteria; its validity and reliability have been established (Kaufman et al., 1997; Kim et al., 2004). Exclusion criteria were other axis I psychiatric disorders including substance abuse, epilepsy or other neurological disorders, and past history of severe head trauma. The YIAS is a 20-item scale with each item score based on a 5-point Likert scale evaluating the degree of problems caused by the usage of internet. Higher scores are indicative of more severe problems, and its validity and reliability have also been established (Widyanto and McMurran, 2004). The Korean version of this scale (YIAS-K) was validated in previous studies (internal consistency, alpha = 0.92) (Ha et al., 2006) and YIAS-K scores over 50 show internet addiction. In addition, participants in the internet addiction group were limited to those reporting to have experienced typical components of addiction with their online gaming: tolerance, withdrawal, preoccupation with playing, repeated unsuccessful attempts to reduce or stop playing, negatively influenced mood when attempting to reduce; and neglecting important relationships or activities because of playing (Christakis, 2010; Flisher, 2010). Healthy controls were screened using the same assessment tools described above.

Trained clinical psychologists conducted psychological intelligence quotient (IQ) assessments (Korean Educational Development Institute's Korean Wechsler Adult Intelligence Scale [K-WAIS] for those over 16 years of age and Korean Educational Development Institute's Wechsler Intelligence Scale for Children-Revised [KEDI-WISC] for those under 16) and a frontal executive function test (KIMS frontal executive function test developed and standardized by Hong-keun Kim in 2001). All participants included in the fMRI study were in the normal range for IQ and frontal lobe functions. The self-reported questionnaires for the recent use of internet game, Children's Depression Inventory (Cho and Lee, 1990; Kovacs, 1983) and Oiettolie Propensity Scale (Lee, 2001), were also administered to all participants.

Of the seventeen adolescents with internet addiction, three were excluded according to the exclusion criteria of this study. Fourteen adolescents with internet addiction and seventeen healthy male adolescents who had no history of significant medical, psychiatric, or neurological disorders on the basis of all assessments above were included for fMRI scanning.

2.3. Task

The fMRI stimuli consisted of short phrases that were generated by modifying items taken from existing scales of self-concept development, including the Self Perception Profile for Children (Harter, 1985), the Self-Description Questionnaire I, II (Marsh, 1990, 1992) and other studies (Pfeifer et al., 2007; Pfeifer et al., 2009). The phrases assessed three domains for self-concept—general self, physical self, and social self—which were represented in equal numbers of positively and negatively valenced items. The items were evaluated for how stereotypical the phrase was for each category by experts in child development. Finally, 20 items (10 positive and 10 negative) were selected and modified to have clear meaning and similarity with Korean language structure and length of sentences. Twenty phrases were repeated three times with different targets in three experimental conditions: (1) self-condition: thinking about oneself, (2) other condition: thinking about Admiral Sun-shin Yi (a famous Korean historical hero who is a highly familiar other) and (3) game condition: thinking about one's own game character. Sample phrases included: “I am perceived as a good looking,” “He (Admiral Yi) is perceived as strong,” “That (their particular game character) doesn't have a nice face that girls like ”.

Before conducting the experiment, adolescents were asked to recall their favourite game character which was used most often and which fit the following requirements: (1) the game character had its own appearance, personality and role with which participants could identify; and (2) the game character could be manipulated according to the user's purpose and intention. It was ascertained that if the participants had such favourite game characters, the participants met the requirements prior to experiment. After the experiment, participants responded to a questionnaire asking them to write about their internet use and to describe their game character to which they referred or thought about during the scanning. While most adolescents described the game characters in a MMORPG (such as “Maple Story”) some reported the game character in a strategic simulation game such as a historical figure.

A baseline condition, without mental processing for self or other, was placed between each experimental condition as a control block. True and false sentences (such as “the train is faster than the car”) in the control block were also represented in equal numbers of positively and negatively valenced items. All tasks were presented with E-Prime 2.0 version.

2.4. Procedure

While being scanned, participants responded (yes/no) using their right index and middle fingers on a button box in response to a visual presentation of the phrases via monitor. Runs were presented twice for 5.4 min each, for a total of 11 min. Each run was composed of three experimental conditions and three baselines, six blocks total (see Fig. 1). Each condition block was followed by a block containing the same phrases but applied to the other target (self/Admiral Yi/participant's game character). Each of the three experimental conditions was 67.5 s long, and included 10 stimulus trials. Although this is somewhat long for block durations, we specifically constructed the design in this manner to reduce potential task-switching costs for the adolescents. Before each condition started, including experimental and baseline, participants were aware that the subject of each sentence would change, and instructions were repeated 13.5 s before condition-switching. Every sentence was presented for 6.25 s to enable sufficient time to read and reply. Before going on to the next sentence, a fixation cross of 500 ms was given. Each baseline block was 13.5 s long, and included the two stimulus trials to decide whether the sentence was true or false. Participants received instructions outside the scanner on the tasks and what they would do in the scanner and practiced using stimuli that were not shown in the scanner. Participants responded to the phrases based on their current physical and social identities and reported after the run that the phrases were easily interpretable and easy to answer.

2.5. fMRI data acquisition

Images were acquired using Siemens Tim Trio 3.0 T with 12 channel head coil. fMRI data were obtained using T2-weighted gradient-echo EPI pulse sequences. Sponge padding was placed around the head to minimize head movement and the lower jaw was fixed with tape. Participants watched the monitor through a mirror on the head coil, and held the button box in their right hand. MRI data were acquired using the following parameters: TR = 2700 ms; TE = 30 ms; flip angle, 90°, matrix, 64 × 64. Each volume was constructed in 36 3 mm thick interleaved slices parallel to anterior commissure-posterior commissure line. Prior to the fMRI study T2-weighted and high resolution T1-weighted (MPRAGE) whole brain images were obtained as an anatomical underlay.

2.6. fMRI data analysis

Using Statistical Parametric Mapping (SPM8: Wellcome Department of Cognitive Neurology, Institute of Neurology, London, UK; www.fil.ion,ucl.ac.uk/spm), all functional images for each participant were: (a) realigned to correct for head motion; (b) spatially normalized into an EPI image in SPM template for between-group analysis; and (c) smoothed using a 6-mm full-width, half-maximum isotropic Gaussian kernel. Before fMRI functional data analysis, four participants who showed more than 2 mm head motion during the functional run were additionally excluded. Thus, in the end, twelve adolescents in addiction group and fifteen adolescents in control group were included in within-group and between-group analyses. When we compared head motion between the two groups, there was no significant difference (Internet addicted group mean = 0.0082, SD = 0.436; non-addicted group mean = −0.0089, SD = 0.0559; $t = -0.864$, $p > 0.05$).

Following image conversion and preprocessing, the imaging data were analysed using SPM8. For each participant, condition effects were estimated according to the general linear model, using a canonical hemodynamic response function. The resulting contrast images were entered into second-level analyses using a random effects model to allow for inferences to be made at the population level (Friston et al., 1999). Comparisons between conditions in whole-brain activation maps were first thresholded at $p < 0.005$ or $p < 0.001$ for magnitude (uncorrected for multiple comparisons). To ensure that the patterns of activity seen in the random effects analyses were not due to the differences of participants’ ages, those were entered as a covariate in each analysis. Then, for the *a priori* identified regions where effects were hypothesized to occur, the MPFC, ACC, and DMPFC, small-volume correction based on a sphere of 8 mm radius centred on coordinate derived from the previous studies which used similar tasks was used. The MPFC ROI was centred at coordinates $x = -4$, $y = 56$, $z = 10$ in

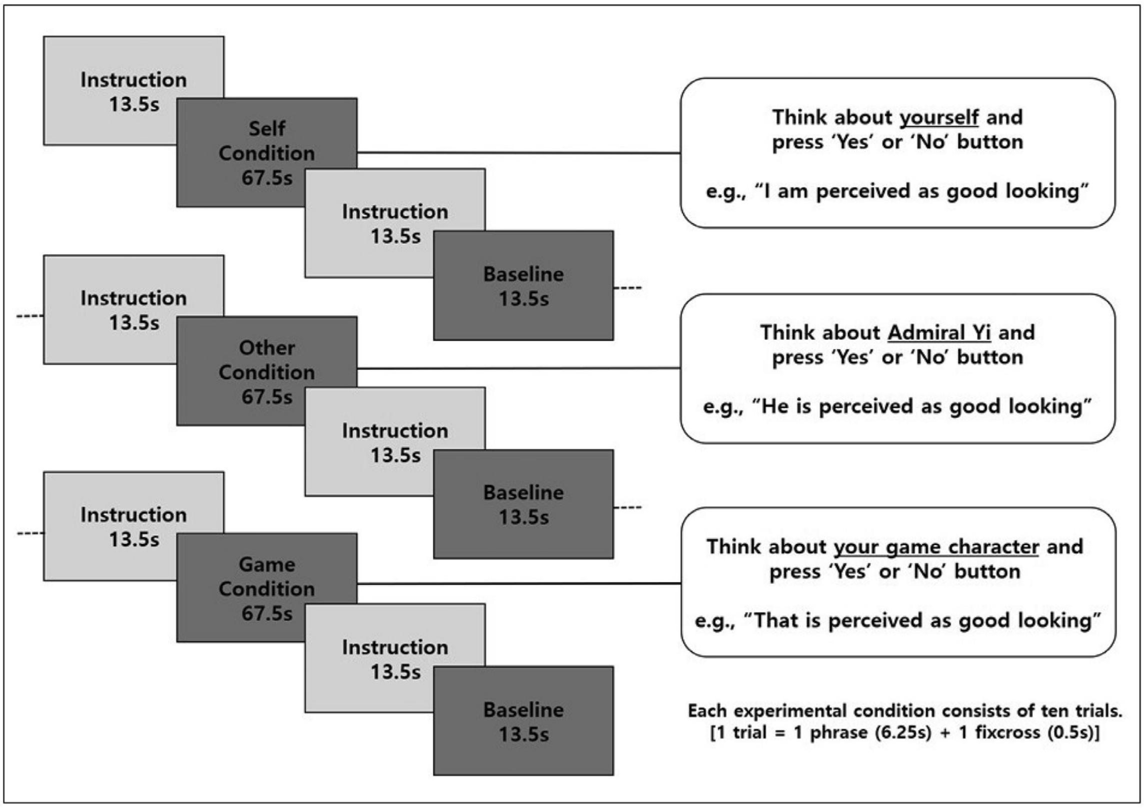

Fig. 1. Experimental procedure.

the MNI atlas (Krienen et al., 2010). The ACC ROI was centred at coordinates x = -4, y = 34, z = 0 in the MNI atlas (Krienen et al., 2010). The DMPFC ROI was centred at coordinates $x = -9$, $y = 45$, $z = 42$ in the MNI atlas (Mitchell et al., 2006).

3. Results

3.1. Recent use of Internet game and behavioural measures

All participants filled in the self-reported internet addiction scale, Young's Internet Addiction Scale-Korean version (YIAS-K) for their internet addictive qualities and significant differences were found between the Internet addicted group (M 57.25, SD = 17.88) and the non-addicted group (M = 36.60, SD = 10.01) (t = 3.802, $p < 0.001$).

All participants had prior experience in playing MMORPGs and could recall and describe their favourite game character. Participants were asked to write down their three most favourite games in current use. The responses were categorized into four types of games: (1) RPGs: third-person role playing games through players' characters, typically called MMORPGs such as "Maple Story"; (2) FPSs: first-person shooter games such as "Doom"; (3) STSs: Strategic simulation games such as "StarCraft"; (4) ACGs: arcade games which are the type of computer games most often played in amusement arcades but are now considered to be a type of simple game such as "KartRider Rush." In RPGs, the game characters are developed based on the players' long-lasting immersion and investment in such characters. For this reason, role-playing games are more addictive compared to other types of games. As shown in Table 1, while the non-addicted group preferred to play more strategic simulation games, the internet addicted group tended to play more third-person role-playing games, but all participants had experience with RPGs and had their own favourite character.

The addicted adolescents showed significantly higher depression in Children's Depression Inventory scale (Addicted group mean = 1.70, SD = 0.38; non-addicted group mean = 1.40, SD = 0.18; t = 2.616, $p < 0.05$) and felt more lonely in Oiettolie Propensity Scale (Addicted group mean = 2.64, SD = 0.97; non-addicted group mean = 1.88, SD = 0.35, t = 2.509, $p < 0.05$).

Table 1
Demographic information and the current use of internet game.

		Game Addicted group	Non-addicted group	
Age (mean)		13.83 (SD = 2.69)	15.33 (SD = 0.98)	$t = -1.837$
YIAS-K (mean)		57.25 (SD = 17.88)	36.60 (SD = 10.01)	$t = 3.802^{***}$
Father's education level (range 1 to 5)		median = 3	median = 4	$\chi^2 = 1.592$
Mother's education level (range 1 to 5)		median = 3	median = 5	$\chi^2 = 2.273$
Social economic status (range 1 to 8)		median = 4	median = 4.5	$\chi^2 = 6.534$
Current use of internet game (Type of game)	RPGs	11 (40.7%)	7 (25.9%)	
	FPSs	4 (14.8%)	4 (14.8%)	
	STSs	7 (25.9%)	14 (51.9%)	$\chi^2 = 4.5079$
	ACGs	5 (18.5%)	2 (7.4%)	
	Total	27 (100.0%)	27 (100.0%)	
General gaming time in a week (mean)		15.40 (SD = 14.22)	10.68 (SD = 9.28)	$t = -0.909$

*** $p < 0.001$.

3.2. Non-addicted adolescents

When non-addicted adolescents thought of themselves (in self condition), activity in the medial prefrontal cortex (MPFC) was seen (Table 2, Fig. 2A), consistent with studies that have reported increased activation of MPFC for conditions that involve some aspect of self

Table 2
Peaks of activity in non-addicted group during self-, other-, game condition, relative to baseline.

Region	Hemisphere	Self-baseline				Other-baseline				Game-baseline			
		x	*y*	*z*	*t*	*x*	*y*	*z*	*t*	*x*	*y*	*z*	*t*
Medial prefrontal Cortex (MPFC)	L	−10	52	14	3.49**								
	L	6	56	18	3.33**								
	L	−14	56	22	3.31**								
Dorsomedial prefrontal cortex (DMPFC)	L					−10	52	42	5.41***	−10	52	42	4.56***
	L					−14	24	58	4.81***	−18	56	38	4.82***
	L					−10	36	54	4.40***				
Middle temporal Gyrus	L									−58	−8	−14	5.25***
	L									−50	0	−26	4.71***

** uncorrected $p < 0.005$, ***uncorrected $p < 0.001$.

(Heatherton, 2011; Pfeifer et al., 2007). The MPFC activation in self condition was still found after small volume correction (left, $x = -10$, $y = 52$, $z = 10$, $T = 3.34$, $P_{\text{FWE}} = 0.038$). On the other hand, when the participants thought of Admiral Yi (in the other condition), activation of MPFC was not detected, but the dorsal medial prefrontal cortex (DMPFC) was significantly activated compared with baseline (Table 2, Fig. 2B). Previous studies reported that mentalizing about a dissimilar other engaged a more dorsal subregion of MPFC (Iacoboni et al., 2004; Mitchell et al., 2006). Thus, this finding supported that Admiral Yi was considered an unfamiliar and distant other. The DMPFC activation in other condition was also found after small volume correction (left, x = -10, $y = 52$, $z = 42$, $T = 5.42$, $P_{\text{FWE}} = 0.001$; left, $x = -6$, $y = 48$, $z = 46$, $T = 5.05$, $P_{\text{FWE}} = 0.003$). Finally, when participants thought of their own game characters, the pattern of activation was more similar to the other condition than to the self condition; activation was seen in DMPFC (Table 2, Fig. 2C) as well as in the middle temporal gyrus. The DMPFC activation in game condition was maintained with small volume of correction (left, x = -10, $y = 52$, $z = 42$, $T = 4.63$, $P_{\text{FWE}} = 0.005$).

3.3. Internet game addicted adolescents

In internet game addicted adolescents, the fMRI activation patterns of self and other conditions in internet game addicted group were relatively similar with those of non-addicted group, but no cluster survived the threshold at uncorrected $p < .005$. However, when internet addicted adolescents thought of their own game character, we found global and intense neural activation compared to the other two conditions. When internet game addicted adolescents thought of their game characters, the region of MPFC and anterior cingulate cortex (ACC) were strongly activated (Table 3, Fig. 3). The activation of inferior temporal, middle temporal, inferior frontal, and precentral gyri were also observed in the game condition of the internet addicted adolescent group. After the small volume correction for the MPFC ROI, two peaks in MPFC were significantly activated during game condition (left, $x = -6$, $y = 56$, $z = 14$, $T = 5.08$, $P_{\text{FWE}} = 0.005$; left, $x = -10$, $y = 52$, $z = 10$, $T = 4.90$, $P_{\text{FWE}} = 0.006$). In addition, the activation of ACC (left, x = -6, $y = 36$, z = -6, $T = 4.46$, $P_{\text{FWE}} = 0.011$) and DMPFC (left, x = -10, $y = 48$, $z = 42$, $T = 5.10$, $P_{\text{FWE}} = 0.005$) were also found in game condition after the small volume correction.

3.4. Comparison between internet game addicted and non-addicted adolescents

The final set of analyses compared patterns of neural activity during self-, other-, and game conditions relative to baseline between addicted and non-addicted adolescents. During self condition relative to baseline, occipital lobe and right inferior frontal gyrus were significantly more active in non-addicted than in addicted adolescents with the threshold at uncorrected $p < .001$ (Table 4); the latter is known as a region which differentiates between "self" and "others" (Hodzic et al., 2009). However no voxels survived small volume correction of the ROIs. In the other condition, there were no differences between two groups. However, during the game condition relative to baseline, significantly more activations were observed in addicted than non-addicted adolescents, including the postcentral, inferior frontal, and precentral gyri, cerebellum, occipital lobe, anterior cingulate cortex, temporal pole, and MPFC (Table 4). The activation of the ACC region remained after small volume of correction (left, $x = -2$, $y = 32$, $z = -2$, $T = 3.30$, $P_{\text{FWE}} = 0.021$) (Fig. 4) and was positively correlated with YIAS-K scores ($r = 0.431$, $p < 0.05$). This may be interpreted that internet addicted adolescents made more mental state inferences about their game characters than non-addicted adolescents.

4. Discussion

It is generally considered that self-knowledge and knowledge about other people are not separate but should be recognized along a continuum on which one extreme represents oneself, the other extreme represents a generalized other or a stranger, and in between are people with whom one has interactions and relationships that vary with the extent of familiarity. Many neuroimaging studies have demonstrated that "familiar others" such as one's mother and close friends can be incorporated into one's self-concept (Krienen et al., 2010; Mitchell et al., 2006). However, one's favourite game character has not been considered as an object which could be placed in the range of one's perception of self and others, as a player's game character is only a two- or three-dimensional avatar without an independent mind. In this study, we addressed the possibilities that player's game character could be considered as "a familiar other" and user's strong attachment with a game character could influence one's perception of the self and others. This study examined differences between activation patterns of the game addicted group and the non-addicted group while they were thinking about themselves, an historical figure and their own game characters.

4.1. Self-knowledge vs. knowledge about other people

The adolescents' patterns of brain activity differed between self-knowledge and knowledge about others conditions. The non-addicted group showed the activation of the MPFC during self-knowledge retrieval, consistent with findings that the MPFC is typically active when thinking about oneself (Moran et al., 2010; Turk et al., 2003). Although the addicted group also showed similar patterns of activity of the MPFC in self condition, no cluster survived threshold.

When the non-addicted adolescents were thinking about a famous person, the DMPFC was activated, as distinct from the condition of thinking about oneself. In this study, the subject that stood for the "other person" was Admiral Sun-shin Yi, a famous Korean historical figure who lived about 500 years ago. He rarely has elements that the subjects can identify with themselves in terms of appearance, age, role and so on except for gender, and the subjects rarely have episodic

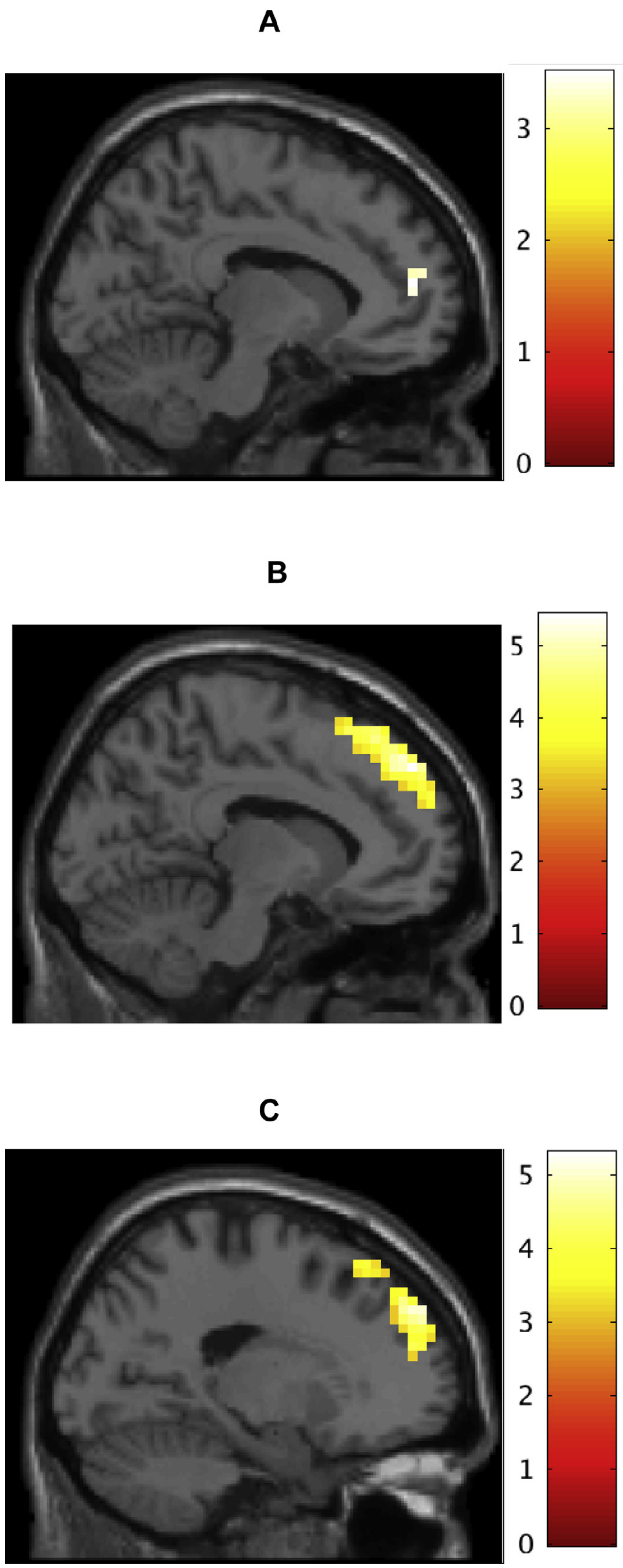

Fig. 2. The activities in self-, other-, and game- conditions relative to each baseline in non-addicted adolescents.
A. Greater activity in the medial prefrontal cortex (MPFC) was found during self-condition, B. in the dorsomedial prefrontal cortex (DMPFC) during other condition and, C. greater activity in the dorsomedial prefrontal cortex (DMPFC) during game condition.

Table 3
Peaks of activity in internet addicted group during game condition relative to baseline.

Region	BA	Hemisphere	Game-baseline			
			x	*y*	*z*	*t*
Medial prefrontal cortex (MPFC)	10	R	10	56	10	4.73***
		L	−6	56	14	4.87***
		L	−6	48	−2	8.25***
			−2	40	−6	6.63***
Anterior cingulate cortex (ACC)	32		14	44	−2	4.94***
		R	10	32	−2	4.42***
			−18	48	42	5.02***
Inferior temporal gyrus	20	L	−62	−20	−22	6.04***
Middle temporal gyrus	21	L	−62	−8	−18	5.86***
			−46	24	−14	6.27***
Inferior frontal gyrus	47	L	−50	16	−2	6.09***
			−38	24	−18	4.72***
Precentral gyrus	6	L	−38	−4	62	6.66***

*** $p < 0.001$.

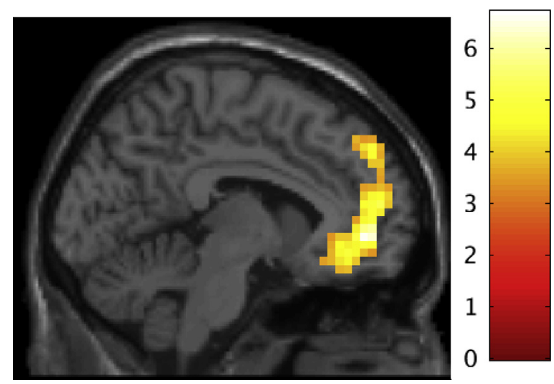

Fig. 3. The activity in the game condition relative to baseline in Internet game addicted adolescents.
There were no significantly activated voxels during other- and game- conditions This figure shows greater activity in the medial prefrontal cortex (MPFC), dorsomedial prefrontal cortex (DMPFC) and anterior cingulate (ACC) during game condition relative to baseline.

memories related to him. Therefore, this result implies that they actively used another set of social cognitive strategies separate from thoughts about oneself. Previous findings indicated that the dorsal subregion of MPFC (DMPFC) was associated with mentalizing about dissimilar others and their interactions (Iacoboni et al., 2004; Mitchell et al., 2006) whereas the ventro-medial part of PFC (VMPFC) is central not to the cognitive sympathy but to emotional sympathy (Shamay-Tsoory et al., 2005). Thus, in this study, the activation of DMPFC implies that adolescents did not exhibit feelings for or any familiarity with Admiral Yi as he is a social figure with no direct relation to themselves. Although the addicted group also showed similar patterns of activity of the DMPFC in this condition, again no cluster survived threshold.

4.2. *Cognitive processing of the game character*

4.2.1. *Is a player character alive?*

The main aim of this study, however, was the neural activity associated with internet game characters in the two groups. We found the activation of DMPFC in non-addicted adolescents which was similar with the activation of thinking about Admiral Yi. However, the medial prefrontal regions and the anterior cingulate cortex were activated when adolescents addicted to their internet game were thinking about their game characters. Although the game character is a two- or three-dimensional avatar, the activity implies that adolescents tried to infer

Table 4
Comparison between non-addicted and addicted group (controlling for participants' age).

Contrast	Group	Peak activation						
		Region	BA	Hemisphere	*x*	*y*	*z*	*t*
Self-baseline	non-addicted > addicted	Occipital lobe	18	R	2	−100	2	3.97***
				L	−10	−104	10	3.85***
		Inferior frontal gyrus	9	R	58	20	26	3.67***
		Corpus callosum	–		2	16	18	3.58***
	addicted > non-addicted	–	–	–	–	–	–	–
Other-baseline	non-addicted > addicted	–	–	–	–	–	–	–
	addicted > non-addicted	–	–	–	–	–	–	–
Game-baseline	non-addicted > addicted	–	–	–	–	–	–	–
	addicted > non-addicted	Postcentral gyrus	43	L	−62	−8	18	3.74**
			3	R	58	−16	50	3.37**
		Inferior Frontal gyrus	44	R	54	24	−2	3.25**
					62	8	18	3.02**
		Precentral gyrus	6	L	−62	4	18	3.07**
					−62	−8	34	2.95**
				R	66	0	18	2.89**
					26	−20	74	2.90**
					62	−8	34	2.87**
		Cerebellum	–	R	18	−36	−18	3.03**
		Occipital lobe	17	R	38	−92	−10	3.27**
					22	−104	2	2.90**
					2	−96	−6	2.86**
				L	−6	−100	−6	2.88**
		Anterior Cingulate	32	L	−2	32	−2	2.85**
		Temporal Pole	21	R	42	8	−26	2.84**
		Medial prefrontal cortex	10	R	14	52	6	2.80**

** uncorrected $p < 0.005$, ***uncorrected $p < 0.001$

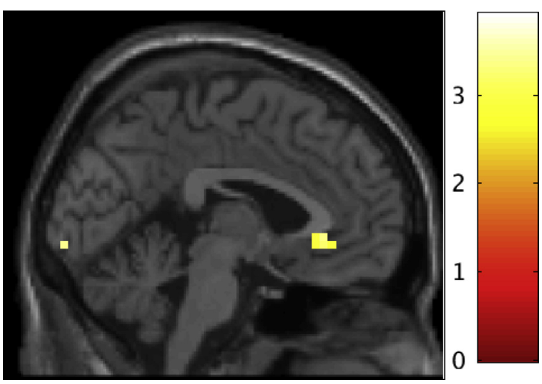

Fig. 4. The anterior cingulate cortex (ACC) activity in game condition relative to baseline in Internet game addicted adolescents compared to non-addicted adolescents after SVC.

the game character's mind as if it were a social being with a mind. In contrast to past generations, adolescents spend an unprecedented amount of time on games in cyber-space, and internet games have become one of their most important leisure activities. Internet game space is a huge cyber-space realm in which interactions with other people (their player characters) are at the core of their interests, and the player's characters are the principal agents for communicating with others. The game user is keen to accomplish feats such as obtaining a game item or attaining a higher level because the public in cyber-space evaluates them. They envy other users with a rare game item such as an expensive weapon, and the user can become a virtual monarch leading his or her online clique or guild by planning good strategies and securing victory in a virtual war. In this way, adolescents spend much time on an internet game that is similar in some respects to the real world, and communicate with invisible others through player characters. Although the space of the internet game and the players' characters do not actually exist, they exist in the adolescents' cognition and sometimes affect them more than other real social objects. If we consider that one of the most important developmental tasks during adolescence is identity development (Erikson, 1959), the cyber-self may be considered to be one of the elements of one's self, such as the academic self, the social self, and the physical self. In addition, adolescents' self-efficacy or sense of achievement in a game setting may affect their self-identity or self-esteem. Taken together, greater attention to cyber-self is needed.

4.2.2. The effects of internet game addiction

Internet addicted adolescents showed quite different patterns of activity when they were thinking of their game characters; activity was greater in magnitude compared to the other two conditions (thinking of oneself and another person). It also covered a larger spatial extent at relatively strict thresholds for magnitude compared to patterns of activity in the non-addicted adolescents. These results showed that game characters were very strong stimuli for adolescents addicted to internet games. Our results support the previous findings that pathological internet gamers show greater brain activity when they process avatar-related information than self-related information (Dieter et al., 2015; Ganesh et al., 2011; Leménager et al., 2014, 2016). However, in our study, the medial prefrontal cortex and anterior cingulate cortex were more activated when internet game addicted adolescents were thinking about their game character compared to themselves. Some research reported bilateral activations of angular gyrus during avatar-perception in addiction groups (Dieter et al., 2015; Leménager et al., 2014, 2016), but other research reported activations of medial prefrontal cortex, inferior frontal and anterior cingulate activations as well (Dieter et al., 2015; Ganesh et al., 2011). We suggest that these differences are attributable to study population, experimental paradigm and/or task stimuli. As no study has investigated adolescents, further study of developmental populations is needed to determine if activation of these brain regions is related to such a population difference.

In our study, the MPFC was strongly activated when the game addicted adolescents were thinking of their game characters. Previous findings demonstrated that the activation of the MPFC was related to self-reflective thinking and mentalizing process (Heatherton, 2011; Lieberman, 2007). Also, some researchers argued that according to the extent of familiarity, mental manipulation of the other people could also activate the frontal midline cortex (Krienen et al., 2010; Mitchell et al., 2006). Based on these findings, the strong activation of the MPFC in the addicted group could suggest that the game character is identified much closer to the self in this group. However, the results need to be carefully interpreted because MPFC is a complex region activated by many different contexts. For example, it also reflects attentional shift between default mode network and attention network. As, unlike the ACC, we did not find correlations between the MPFC activation and symptoms or behavioural measures, further research is needed to clarify the MPFC activation in addicted groups.

We also found strong activation of the rostral parts of the ACC while participants in the addicted group thought of their game characters. It survived after small volume correction and did correlate with symptom severity. Considerable research has suggested that the rostral ACC is specialized for affective processes (Shackman et al., 2011), whereas the dorsal ACC is specialized for cognitive processes (see Bush et al., 2000, for a review). ACC activation also reflects the response of salience or selective attention related to personal concerns (Cox and Klinger, 2004; Hickey et al., 2010). Thus, the activation of ACC in this study could reflect the addicted adolescents' strong emotional attachment or salient attention to their game characters. Given the subcortical areas of the limbic reward system mature relatively earlier in adolescence and atypical activation of ACC relates to severity symptom in addiction, further research should address atypical development of reward network in gaming addicted adolescents.

As these strong activations are not shown among non-addicted adolescents, this activity seems a result of internet addiction. The adolescents addicted to the internet were still spending excessive amounts of time on games during the time of the experiment, and they were mainly immersed in MMORPGs using their game characters. Because they lived much of their time as their player characters, active self-reflective thoughts might have occurred when they were thinking about them. However, it is uncertain that the internet addicted adolescents confused their real selves and their game characters. This confusion is a more complex and serious symptom and subjects in this study did not complain of this symptom concretely during or around the time of the experiment. Nevertheless, to the question, "While offline, I have thought about internet or had an illusion that I was online again," (among the questions of the YIAS-K), two participants in the internet game addicted group answered "yes," while no one in the non-addicted group answered "yes". Adolescents have not completely developed self–Identity, so it will have a dangerous effect on identity achievement if they are immersed in and too attached to their game characters without a clear recognition of their selves in the real world. In addition, the more they achieve in the internet game, the more their functioning in the real world decreases, which can ultimately cause problems with the achievement of a unified identity because of the gap between the real self and cyber-self. Therefore, the internet game addicted group should be considered as a group in a crisis of identity achievement and identity status.

4.3. Limitations

Despite several important implications, the present study also has some limitations. First, it was a relatively small sample, and only with male adolescents. Thus, caution is needed when making generalizations from the findings. In addition, there is a possible confound with the type of games played. Specifically, the two groups of adolescents showed different preferences for internet games; non-addicted adolescents preferred STSs, while addicted adolescents preferred RPGs. To determine that the different neural activity between the groups was related to the differential engagement with their own game character, other than the different preference for the games, we checked that non-addicted adolescents also had played RPGs and could imagine one of their own main characters in RPGs. We asked them to imagine one main character consistently during the scanning and also had a practice session before the actual scanning. Despite these efforts, a potential bias may remain because of a possible relation between the different preferences in internet games and the extent of the identification with the avatar in each individual. Future studies should use larger sample sizes with additional groups of nongaming controls, long-term online gamers but not-addicted controls, or controls who have the same gaming preference, to investigate various aspects of avatar-identification such as comparing physical images, social traits, mental-state, and the discrepancy between avatar and the real self.

4.4. Conclusions

Although the internet game character is an avatar that moves according to the user's manipulation, the user very accustomed to the reality of the game could think of it to be a real other like a human being. Internet game addicted adolescents are so attached to their game characters that their fMRI activation patterns suggested that they consider their game characters as beings similar to themselves. To answer to what extent the identification with the avatar is damaging to the individual, further research is needed but our study indicated that the identification with the avatar with excessive use of online role-playing game could damage the developing brain. Given the developmental trajectory where prefrontal control areas mature slowly compared to the subcortical areas of the limbic reward system in adolescence, atypical activation of MPFC and ACC seen in the addicted group might affect the development of the reward network. If we consider that one of the most important developmental tasks during adolescence is identity development, internet game addicted adolescents will need help to actively explore the real self to avoid immersion in the cyber-self and the impending identity crisis that results from the gap between the real self and the cyber-self. Finally, our results suggest a possible biomarker of internet gaming disorder which would help improve the diagnostic validity, as this is not yet a well-defined disorder in the DSM-V.

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Conflict of Interest

The authors have declared that no competing interests exist.

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