FULL-LENGTH REPORT

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Exploring the Neural Basis of Avatar Identification in Pathological Internet Gamers and of Self-Reflection in Pathological Social Network Users

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Background and aims: Internet gaming addiction appears to be related to self-concept deficits and increased angular gyrus (AG)-related identification with one's avatar. For increased social network use, a few existing studies suggest striatal-related positive social feedback as an underlying factor. However, whether an impaired self-concept and its reward-based compensation through the online presentation of an idealized version of the self are related to pathological social network use has not been investigated yet. We aimed to compare different stages of pathological Internet game and social network use to explore the neural basis of avatar and self-identification in addictive use. *Methods:* About 19 pathological Internet gamers, 19 pathological social network users, and 19 healthy controls underwent functional magnetic resonance imaging while completing a self-retrieval paradigm, asking participants to rate the degree to which various self-concept-related characteristics described their self, ideal, and avatar. Self-concept-related characteristics were also psychometrically assessed. *Results:* Psychometric testing indicated that pathological Internet gamers exhibited higher self-concept deficits generally, whereas pathological social network users exhibit deficits in emotion regulation only. We observed left AG hyperactivations in Internet gamers during avatar reflection and a correlation with symptom severity. Striatal hypoactivations during self-reflection (vs. ideal reflection) were observed in social network users and were correlated with symptom severity. *Discussion and conclusion:* Internet gaming addiction appears to be linked to increased identification with one's avatar, evidenced by high left AG activations in pathological Internet gamers. Addiction to social networks seems to be characterized by emotion regulation deficits, reflected by reduced striatal activation during self-reflection compared to during ideal reflection.

Keywords: self-concept deficits, pathological Internet gaming, avatar identification, pathological social network use, striatum, angular gyrus

BACKGROUND

Internet use disorders are increasingly being recognized as a major health problem, particularly in industrialized nations throughout Asia, North America, and Europe (Khazaal et al., 2012). For the purposes of this study, we have decided to use the term "Internet addiction," although it should be noted that the justification for its inclusion as a disorder in Diagnostic and Statistical Manual of Mental Disorders, 5th edition and ICD-11, and its clinical classification as a "behavioral addiction," remain open questions (Billieux, Schimmenti, Khazaal, Maurage, & Heeren, 2015).

Internet games and social networks are the two most commonly used applications by Internet addicts (Bischof, Bischof, Meyer, John, & Rumpf, 2013; Griffiths & Szabo, 2014). Studies indicate that increased use of social networks is associated with immediate rewards as induced by positive social feedback (Meshi, Morawetz, & Heekeren, 2013). Internet games have been specifically linked to increased escapism into a virtual world via a graphical agent (avatar) used in the game (Schenk, 2002; Wünsch, 2006). Internet games are characterized by social interaction, allowing multiple players to simultaneously engage and interact with each other via their avatars in an online virtual world. In some games, the personal avatar can be chosen out of a large set of different unalterable characters and in other games, the avatars can be generated without restrictions and altered according to the player's own preferences and style.

All Internet game genres have the potential to become addictive, as they provide ample distraction from everyday

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problems. Several studies have reported an increased prevalence of social anxiety (i.e., the fear of being socially rejected; associated with a higher degree of loneliness; Anderson & Harvey, 1988; Caplan, 2007; van Rooij, Schoenmakers, & van de Mheen, 2015; Weinstein et al., 2015) as well as self-concept deficits (Lemenager et al., 2013) in Internet gaming addicts. Therefore, it might be assumed that Internet games help players to compensate for loneliness and dissatisfaction with their real self. The construct of the "self-concept" refers to an individual's perception of her own skills, interests, desires, emotions, values, actions, and physical attractiveness (Deusinger, 1996). Thus far, psychometric tests have suggested that Internet gaming addicts suffer from self-concept deficits and show a stronger identification with their own avatar than healthy controls (Bessière, Seay, & Kiesler, 2007; Davis, 2001; Lemenager et al., 2013). Neurobiological studies reflect these observations, showing that addicted Internet gamers exhibit increased activations in brain regions such as the angular gyrus (AG), the inferior frontal gyrus (IFG), the precuneus, and the medial prefrontal cortex (MPFC; BA 8, 9, 32), during avatar reflection compared to self-reflection (Dieter et al., 2015). Activation of the left AG has in particular been associated with identification processing and feelings of empathy (Ganesh, van Schie, de Lange, Thompson, & Wigboldus, 2011; Regenbogen et al., 2012; Regenbogen, Habel, & Kellermann, 2013), whereas the MPFC has been functionally linked to self-referential processing in healthy subjects (D'Argembeau et al., 2012). However, it remains unclear whether or not avatar identification (as indicated by activation of the AG) plays a role in the various stages of Internet gaming addiction, such as in problematic use (defined as continuous behavior despite the occurrence of negative consequences) and addictive use (Müller, Beutel, & Wolfling, 2014).

In addition to Internet gaming addiction, research into addictive use of social networks has increasingly become the focus of attention, given that social network use is among the most common activities of children and adolescents today (O'Keeffe, Clarke-Pearson, & Media, 2011). Social networks refer to any online platform that allows for social interaction (O'Keeffe et al., 2011), and for the purposes of this publication has been restricted to include only online chat and the use of forums and online communities (such as Facebook). The latter are member-based networks where an individual can create a profile by providing basic information such as her name and photograph, and can communicate with other members by sending public or private online messages or sharing photos and comments (Pempek, Yermolayeva, & Calvert, 2009). Facebook is the world's largest online social network, with 1.3 billion active users recorded in mid-2014, and is mainly used by adolescents (Murphy et al., 2014). These high usage rates indicate that social networks constitute a strong presence in the lives of adolescents, and that online interactions are likely to influence their development (Pempek et al., 2009).

Initial psychometric studies have linked social network use to enhanced self-esteem and well-being in adolescents, as a result of the positive feedback received in relation to one's social network profile (Valkenburg, Peter, & Schouten, 2006). A neurobiological study aiming to explore the reward component of Facebook use found that activity in the left nucleus accumbens could predict Facebook use, when regular users benefited from gains of reputation for the self (relative to gains of reputation for others; Meshi et al., 2013). The functional role of the nucleus accumbens (a part of the ventral striatum) in reward-guided and predictive learning (Montague, Hyman, & Cohen, 2004; Yin, Ostlund, & Balleine, 2008) has already been extensively documented in relation to the development of substance-related addictive disorders (Koob & Volkow, 2010; Vollstadt-Klein et al., 2010). Therefore, the findings of Meshi et al. (2013) may indicate that an increase in one's social reputation, which in effect "hijacks" the reward system, constitutes a strong motivational factor for increased Facebook use. However, it remains unclear whether brain activation in the ventral striatum upon the gain of social reputation is associated with addiction to social networks. The rewarding aspects associated with Internet gaming addiction seem to be less related to immediate social reputation but rather to advance in the game by gaining experience points ("leveling up") as well as by collecting valuables and weapons in the virtual world (Hilgard, Engelhardt, & Bartholow, 2013). Several studies suggest higher striatal grey matter volume in frequent gamers (Kuhn et al., 2011) as well as increased striatal activations during the presentation of game-related virtual world images (Ko et al., 2009; Sun et al., 2012) or during response inhibition in addicted Internet gamers (Ko et al., 2014). However, besides the strong ambition to gain immediate reward, self-concept deficits and the slowly adapting identification processing with the avatar in the game also seem to be essential factors in Internet gaming addiction.

Similar to Internet gaming addiction, social network addiction has also been indirectly linked to social anxiety (Weinstein et al., 2015), which negatively influences the development of the self-concept. However, users may compensate for this deficit by presenting a more socially acceptable and idealized version of themselves on social networks, and thus increase the possibility of receiving, rewarding, and self-concept-enhancing positive feedback. Indeed, healthy social network users have been found to express idealized aspects of themselves (Manago, Graham, Greenfield, & Salimkhan, 2008). However, research has not yet explored whether social network addicts tend to have a more negative self-concept and to present more strongly idealized versions of themselves than healthy users, nor how this behavior may be related to ventral striatal activation.

This study aims to assess the neural basis of self-concept-related characteristics between problematic and addicted users of Internet games or social networks relative to healthy controls.

First, we aimed to compare problematic and addicted Internet gamers to healthy controls, to explore the neural basis of identification with the self or with one's own avatar during the two different stages of Internet gaming addiction, i.e., problematic and addicted users. We hypothesized that the difference in brain activity in the left AG during avatar reflection vs. self-reflection would be the highest in addicted gamers, compared to problematic gamers and healthy controls.

Second, we aimed to assess any differences between problematic and addicted social network users and healthy controls during self-reflection and ideal reflection, to explore differences in neural activation both as regards the different stages of addiction, and between social network addicts, Internet gaming addicts, and healthy controls as a whole.

We hypothesized that addicted social network users' brain activation in the ventral striatum would be higher during reflection about the ideal than during self-reflection compared to problematic users and healthy controls.

METHODS

Participants

Following the study's approval by a local ethics committee (application number 2013-528N-MA), we recruited 19 healthy controls, 7 problematic, and 12 addicted (totaling 19 pathological) Internet gamers and 7 problematic and 12 addicted (totaling 19 pathological) social network users. They were recruited either via the day clinic for addictive disorders and addiction medicine at the Central Institute of Mental Health in Mannheim, or through advertisements.

The healthy control group included 11 participants who primarily used social networks, two participants who had previously used Internet games, and four participants who used other applications such as information platforms or e-commerce websites.

All participants were right-handed and had normal or corrected-to-normal vision. They did not exhibit any other axis-I psychiatric disorders or substance use disorders (apart from nicotine dependence) and were not taking any psychotropic medication. Potential comorbidities were assessed using the Structured Clinical Interview for DSM-IV (SCID I and II; Wittchen, Zaudig, & Fydrich, 1997).

Group assignment was carried out on the basis of an interview with an experienced psychologist, and using the scores obtained by participants on the two subscales of the interview for the Assessment of Internet and Computer game Addiction (AICA; Wölfling, Beutel, & Müller, 2012), as well as on the AICA's self-report counterpart, the scale for online addictive behavior for adults (Skala zum Onlinesuchtverhalten bei Erwachsenen, OSVe-S; Wölfling, Müller, & Beutel, 2010; see the following). Participants classed in the problematic and addicted categories of both Internet gaming and social networks had significantly higher AICA_30, AICA_lifetime and OSVe scores and averaged significantly longer periods of computer and/or Internet use per day (hr/day) than controls (see Table 1).

During the first appointment with participants, we ensured that they fulfilled the relevant inclusion and exclusion criteria as well as meeting general screening standards (age, gender, comorbidities as well as computer and Internet use behavior). During the second meeting, participants performed a self-reflection paradigm while undergoing a functional magnetic resonance imaging scan (fMRI; for a detailed description of the paradigm see the "Paradigm" section).

The group of Internet gamers played mainly either Internet games [e.g., World of Warcraft (WoW) or League of Legends] or first person shooter games (such as Counterstrike, Battlefield, or Call of Duty; Elverdam & Aarseth, 2007). The social network users mainly used Internet applications such as online chat, forums, or online communities such as Facebook.

Table 1. Sample description

	Total ($N = 57$)	Non-addicted Internet users ($n = 19$)	Pathological gamers ($n = 19$)	Pathological social network users ($n = 19$)	Test-statistic	*p*-Value	Post-hoc: Controls vs. pathological gamers MWU (*z*)	*p*-Value	Post-hoc: Controls vs. pathological social network users MWU (*z*)	*p*-Value	Post-hoc: Pathological gamers vs. pathological social network users MWU (*z*)	*p*-Value
Gender (n = male)	30 (52.63%)	7 (36.84%)	14 (73.68%)	9 (47.39%)	5.489 χ^2 (CT)	.064						
Age (SD)	26.05 (6.26)	27.68 (7.95)	25.68 (6.69)	24.79 (3.07)	.777 χ^2 (KW)	.678						
Education (years; SD)	15.07 (2.39)	15.74 (2.26)	14.50 (2.28)	14.95 (2.59)	2.516 χ^2 (KW)	.284						
Computer/Internet use (Ø, hr/day; SD)	2.65 (1.33)	1.79 (.92)	3.26 (1.20)	2.89 (1.41)	12.945 χ^2 (KW)	.002	−3.543	<.001	−2.493	.013		
AICA_30 (SD)	8.58 (7.09)	1.79 (1.72)	12.84 (6.88)	11.11 (5.60)	33.552 χ^2 (KW)	<.001	−5.088	<.001	−4.886	<.001		
AICA_lifetime (SD)	15.32 (10.17)	3.42 (2.06)	23.79 (5.21)	18.74 (7.28)	38.540 χ^2 (KW)	<.001	−5.282	<.001	−5.082	<.001	−2.268	.023
OSVe (SD)	8.48 (5.23)	2.50 (1.40)	11.47 (3.40)	11.47 (3.88)	37.280 χ^2 (KW)	<.001	−5.293	<.001	−5.306	<.001		

Note. SD = standard deviation, χ^2 (CT) = Chi-square crosstab, χ^2 (KW) = Chi-square Kruskal–Wallis test, MWU = Mann–Whitney *U* test.

Psychometric instruments

The existence and severity of participants' computer and/or Internet addiction was measured using the AICA checklist (Wölfling, Beutel, et al., 2012) as well as the OSVe (Wölfling et al., 2010). The AICA checklist is an established diagnostic clinical interview, which aims to assess the severity of participants' computer and/or Internet addiction. It does so by recording their computer or Internet use (e.g., "Is there any impairment in the personal area of life due to the usage of computer games/Internet offers?) over the previous 30 days (AICA_30) as well as their most extended computer or Internet use during their lifetime (AICA_lifetime). The AICA checklist has a high reliability as demonstrated by a Cronbach's α of .90. Based on the Kaiser–Guttman criterion and inspection of the scree-test, a principal component analysis revealed one single factor explaining 67.5% of variance that can be interpreted as "addicted Internet use" (Wölfling, Beutel, et al., 2012). The OSVe is a self-report questionnaire also used to screen adults for the existence and severity of Internet addiction (e.g., "How strong are you occupied by thoughts about online offers/activities per day?"). Participants with a score of ≥13 on the AICA_30 or of ≥13.5 on the OSVe were assigned to the addicted group. Given that the AICA_30 only identifies addictive computer and/or Internet use, we used OSVe scores only in defining problematic use. Following the study by Wölfling et al. (2010), we classed participants with OSVe scores of between 7 and 13 as problematic users. Accordingly, participants scoring <7 were assigned to the control group (Wölfling, Beutel, et al., 2012). The internal consistency (Cronbach's α) of α = .89 of the OSVe is assumed to be sufficient. A principal component analysis revealed one single factor explaining 43.9% of variance that can be interpreted as "addicted Internet use" (Müller, Glaesmer, Brähler, Wölfling, & Beutel, 2014).

In assessing the body-related aspect of self-concept, we used a body image questionnaire (Fragebogen zum Körperbild, FKB-20; Clement & Löwe, 1996), which measures "rejection of the body image" (e.g., "Sometimes I am disgusted by myself") and "vital body image" (e.g., "Overall, I perceive myself as robust and strong."). The internal consistencies (Cronbach's α) for the two subscales are α = .84 ("rejection of the body image") and α = .76 ("vital body image"). The cross-validation of the scales' factorial structure revealed a high stability across one clinical and two non-clinical sample populations (Clement & Löwe, 1996). In addition, participants were asked to rate their own physical attractiveness and that of their avatar on a visual analog scale ranging from 0 to 10.

Social anxiety was measured using the questionnaire for social anxiety and social competence deficits (SASKO; Kolbeck & Maß, 2009). It aims to assess the anxiety of speaking in front of others or of being the center of social attention (subscale "speaking"; e.g., "Being in the center of attention makes me nervous."), of being socially rejected ("rejection"; e.g., "Imagining of being criticized or rejected is hard for me to bear") and of socially interacting ("interaction"; e.g., "I feel uncomfortable in face-to-face interactions"), as well as measuring deficits in social perception ("information"; e.g., "I have problems in judging the behavior of others.") and feelings of loneliness ("loneliness"; e.g., "I suffer from having only little social contacts."). The internal consistencies of the subscales ranged between α = .76 and α = .87 for a healthy sample as well as between α = .80 and α = .89 for a clinical sample. Factorial validity was confirmed by a confirmatory factor analysis (Kolbeck & Maß, 2009).

Emotional competence was assessed by means of the emotional competence questionnaire (EKF; Rindermann, 2009), which comprises 62 items that participants must rate on a 5-point Likert scale (ranging from strongly agree to strongly disagree). This questionnaire consists of four subscales, measuring the participant's abilities in (a) recognizing and understanding one's own emotions (e.g., "Sometimes I feel sad without knowing why."), (b) recognizing and understanding the emotions of others (e.g., "I'm good in comprehending feelings of others."), (c) regulating and controlling one's own emotions (e.g., "When I'm angry, I can hardly control myself."), and (d) emotional expressiveness (e.g., "I can express my feelings well."). Internal consistencies of the scales ranged between α = .89 and α = .93 (Rindermann, 2009). The total EKF score reflects a person's self-rated emotional competence, as a subdomain of their self-concept.

Paradigm

In this study, we used a previously established and tested fMRI paradigm (Dieter et al., 2015). Carried out in a block design, it involves a 36-item self-assessment scale based on the Giessen-Test (GT; Beckmann, Brähler, & Richter, 1990), where participants are asked to evaluate the extent to which they associate specific personality traits with their "self", their "ideal" and their avatar on a bipolar scale ranging from –3 to 3. Social network users and healthy controls who had never played an Internet game were asked to create an avatar using the WoW online platform (https://wowmodelviewer.atlassian.net/wiki/display/WMV/Download+WoW+Model+Viewer).

The GT consists of six subscales measuring participants' "social response" (an estimation of how one is evaluated by others), "dominance" (e.g., frequency of interpersonal conflicts), "self-control" (e.g., handling of one's finances, orderliness), "general mood" (e.g., depressive), "permeability" (open-mindedness vs. mistrust) and "social impotency" (social skills), respectively. All blocks and conditions (self, ideal, or avatar) were presented in a randomized order, while the sequence of statements within each subscale remained the same (see Figure 1).

fMRI

The scans were conducted using a 3 Tesla whole-body tomograph (Trio; Siemens, Erlangen, Germany). Functional whole-brain images were collected by applying a T2*-weighted echo-planar imaging (EPI) sequence [repetition time (TR) = 2200 ms, echo time (TE) = 30 ms, flip angle (FA) = 80°, field of view (FOV) = 220 mm × 220 mm, matrix size 64 × 64, 36 slices, slice thickness = 3.00 mm, distance factor = 33%, and voxel size = 3.4 × 3.4 × 3.0 mm]. The number of acquired functional volumes varied between

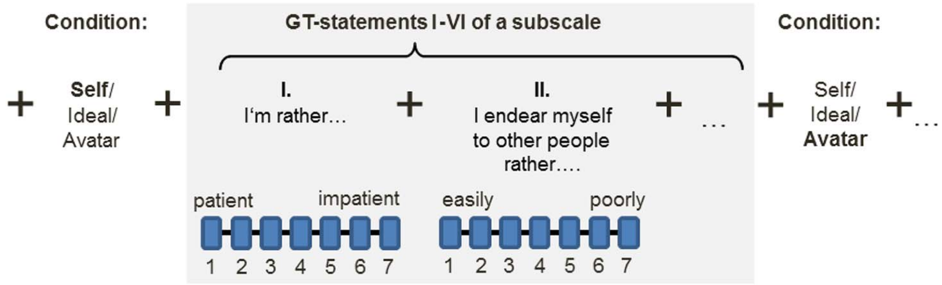


Figure 1. Schematic concept of the fMRI self-reflection paradigm

participants (with an average of 426.5 ± 49.83 volumes; the maximum was set to 1,000 volumes per participant) and depended on individual participants' pace in rating GT statements.

Structural images were acquired by means of a T1-weighted Magnetization Prepared Rapid Gradient Echo sequence (TR = 2300 ms, TE = 3.03 ms, FA = 9°, FOV = 256 mm × 256 mm, 192 slices, slice thickness = 1.00 mm, distance factor = 50%, and voxel size = 1 × 1 × 1 mm). Any magnetic field inhomogeneity was corrected by the automated Siemens multi-angle projection shim. The registration of scanner triggers as well as the recording of behavioral responses was carried out by the Presentation software (Version 16.3, Neurobehavioral Systems, Inc., Albany, CA, USA). Tasks were presented to participants in the scanner using digital goggles (Resonance Technology, Inc., Los Angeles, California).

Statistical analyses

Psychometric data. Psychometric data analyses were carried out using SPSS Statistics 20 (Statistical Package for the Social Sciences, SPSS Inc, Chicago, IL, USA; Release 20.0.0). We analyzed pathological Internet gamers (n = 19) and pathological social network users (n = 19) as aggregate groups, combining problematic and addicted users in each group. After having checked the variables for normality, differences between and within the three groups were assessed using non-parametric Kruskal–Wallis and Friedman tests, respectively, followed by post-hoc analysis using Mann–Whitney U and paired Wilcoxon tests, respectively. Furthermore, any Spearman–Brown correlations were considered to explore associations between specific variables (symptom severity and self-concept-related characteristics) and the eigenvariates of regions of interest (see the following).

Neurobiological data. To evaluate our neurobiological data, we used statistical parametric mapping (SPM, version SPM 8, Wellcome Trust Centre for Neuroimaging, University College London, London, UK) run on Matlab R2012b (The MathWorks, Inc., Natick, MA, USA).

In our first level analysis, we estimated the effects of each of the three conditions (self, ideal, and avatar), by applying the general linear model on a voxel-by-voxel basis, as well as calculating individual contrast images of condition-specific mean brain activation.

During second level analysis, individual contrast images were examined for any differences in blood oxygenation level dependent responses within and between the groups for each specific contrast (*avatar* vs. *self* for our first hypothesis; *ideal* vs. *self* for our second hypothesis), using one-sample t-tests and full-factorial Analysis of Variance (ANOVA) testing.

In exploring the neurobiological effects caused by the use of each Internet application (i.e., Internet games and social networks) and stages of problematic use, we first assessed all pathological users together, followed by an examination of each of the problematic and addicted subgroups separately. We applied an underlying threshold of $p < .001$ and an extent threshold of 10 voxels; results were reported at a cluster threshold of $p_{\mathrm{FWE}} \leq .05$. SPM's Automatic Anatomical Labeling (AAL) toolbox was used to assign clusters showing significant activation to their respective brain regions. The detection of Brodmann Areas (BAs) was conducted via the xjview-toolbox (run on MATLAB). Activation maps were generated by means of Chris Rorden's MRIcro brain image viewer, following the neurological convention (i.e., left = left and right = right). Hypothesis-driven region of interest (ROI) analyses were conducted for the left AG (underlying threshold $p \leq .001$, reported at $p_{\mathrm{FWE}} \leq .05$ on cluster level) using a mask generated by WFU PickAtlas (Maldjian, Laurienti, & Burdette, 2004; Maldjian, Laurienti, Kraft, & Burdette, 2003). To analyze any correlations between brain activation in the expected regions (the left AG and striatum including the caudate and the putamen) and psychometric variables of interest (attractiveness ratings for the avatar, addiction severity), WFU PickAtlas masks were generated.

Ethics. The study was approved by the ethics committee of Mannheim, Baden Württemberg (application number 2013-528N-MA). Before taking part in the study, all participants were informed about the procedures involved and provided informed written consent, in accordance with the Declaration of Helsinki.

RESULTS

Psychometric data

First, between-group comparisons of our psychometric data indicate that pathological Internet gamers (i.e., both problematic and addicted gamers) show a stronger rejection of their own body image [$\text{mean}_{\text{gamers}}$ (SD) = 25.32 (7.91), $\text{mean}_{\text{controls}}$ (SD) = 19.21 (4.53), $\text{mean}_{\text{social network users}}$ (SD) = 21.42 (5.05), $\chi^2 = 26.44$, $p < .001$; MWU post-hoc (gamers–controls): $z = -2.693$, $p = .007$] and rate themselves

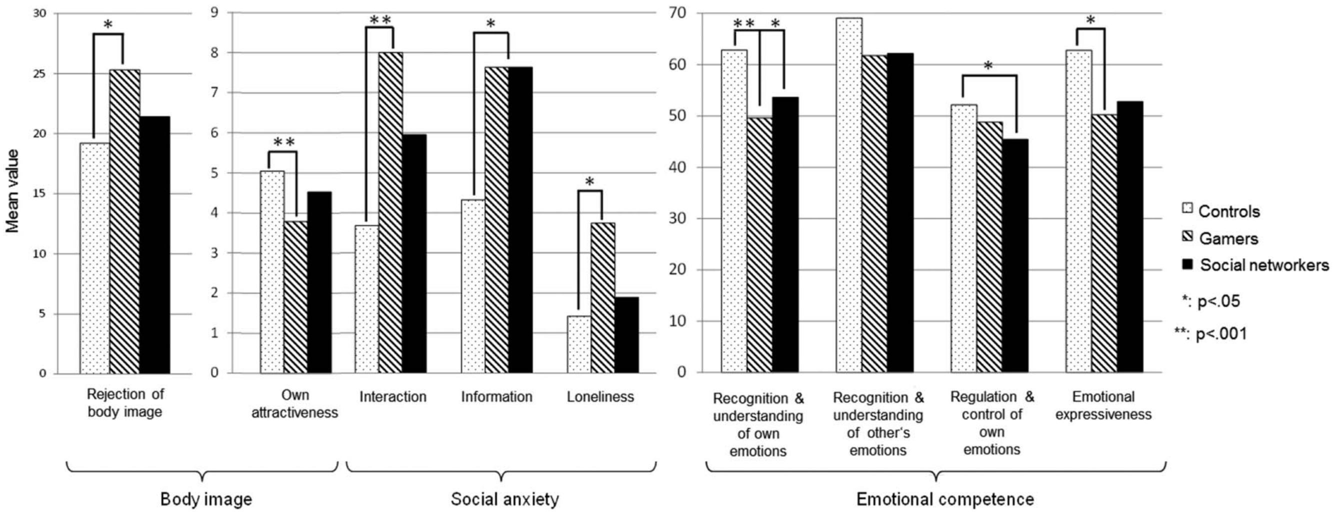


Figure 2. Mean group psychometric ratings regarding body image, social anxiety, and emotional competence

as less attractive [$\text{mean}_{\text{gamers}}$ (SD) = 3.79 (1.40), $\text{mean}_{\text{controls}}$ (SD) = 5.05 (0.97), $\text{mean}_{\text{social network users}}$ (SD) = 4.53 (1.22); $\chi^2 = 8.041$, $p = .018$; post-hoc MWU: $z = -2.738$, $p = .006$]), compared to healthy controls (see Figure 2).

Second, between-group analysis reveals that pathological Internet gamers have significantly more symptoms of social anxiety than healthy controls, in respect to the scales "interaction" [$\text{mean}_{\text{gamers}}$ (SD) = 8.00 (4.88), $\text{mean}_{\text{controls}}$ (SD) = 3.68 (3.65), $\text{mean}_{\text{social network users}}$ (SD) = 5.95 (4.67); $\chi^2 = 12.168$, $p = .002$; post-hoc MWU: $z = -3.408$, $p = .001$], "information" [$\text{mean}_{\text{gamers}}$ (SD) = 7.63 (5.23), $\text{mean}_{\text{controls}}$ (SD) = 4.32 (2.89), $\text{mean}_{\text{social network users}}$ (SD) = 7.63 (4.52); $\chi^2 = 6.345$, $p = .042$; post-hoc MWU: $z = -2.059$, $p = .040$] and "loneliness" [$\text{mean}_{\text{gamers}}$ (SD) = 3.74 (3.14), $\text{mean}_{\text{controls}}$ (SD) = 1.42 (1.89), $\text{mean}_{\text{social network users}}$ (SD) = 1.89 (2.16); $\chi^2 = 6.327$, $p = .042$; post-hoc MWU: $z = -2.448$, $p = .014$] (see Figure 2). The group of pathological social network users only showed significant deficits in "information" compared to healthy controls (post-hoc MWU: $z = -2.270$, $p = .023$).

In terms of emotional competencies, both pathological Internet gamers and pathological social network users ($n = 19$ problematic and addicted users) showed significant impairments in recognizing and understanding their own emotions, compared to the group of healthy controls [$\text{mean}_{\text{gamers}}$ (SD) = 49.63 (11.74), $\text{mean}_{\text{controls}}$ (SD) = 62.84 (7.40), $\text{mean}_{\text{social network users}}$ (SD) = 53.63 (8.40), $\chi^2 = 15.221$, $p < .001$; post-hoc MWU (gamers–controls): $z = -3.537$, $p \leq .001$, post-hoc MWU (social network users–controls): $z = -3.128$, $p = .001$]. Furthermore, both groups were found to be significantly less able to express their emotions [emotional expressiveness; $\text{mean}_{\text{gamers}}$ (SD) = 50.26 (15.59), $\text{mean}_{\text{controls}}$ (SD) = 62.79 (11.20), $\text{mean}_{\text{social network users}}$ (SD) = 52.79 (13.15), $\chi^2 = 7.623$, $p = .022$; post-hoc MWU (gamers–controls): $z = -2.323$, $p = .020$, post-hoc MWU (social network users–controls): $z = -2.440$, $p = .014$], and social network addicts also seemed to have problems in regulating and controlling their own emotions relative to healthy controls [$\text{mean}_{\text{gamers}}$ (SD) = 48.79 (7.14), $\text{mean}_{\text{controls}}$ (SD) = 52.16 (5.80), $\text{mean}_{\text{social network users}}$ (SD) = 45.42 (9.04), $\chi^2 = 6.118$, $p = .047$; post-hoc MWU (social network users–controls): $z = -2.356$, $p = .022$].

Neurobiological data

Avatar reflection in pathological Internet gamers. Within-group analysis of pathological Internet gamers and of the subgroup of addicted gamers shows a higher number of brain activations when participants reflect about their avatar (vs. self-reflection) in the MPFC, in the frontal, temporal, and occipital regions as well as in the left AG, which confirms our first hypothesis (see Table 2). Healthy controls exhibited higher activations in similar brain areas during avatar reflection; however, they did not show any significant activations in the left AG and the right MPFC. Pathological social networkers had significantly higher brain activation for this contrast (avatar > self) in the bilateral precuneus, the left superior occipital, and parietal lobe as well as in the bilateral cuneus (see Table 2), but did not show left AG activation either.

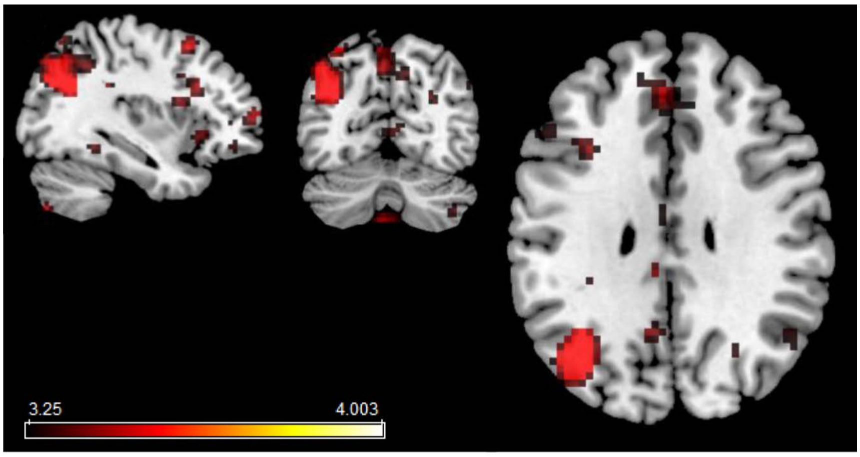
A full-factorial ANOVA for the contrast *avatar > self* between pathological Internet gamers, pathological social networkers, and controls revealed significant avatar-related brain activation in pathological Internet gamers relative to healthy controls (see Figure 3), while the results for the other comparisons (i.e., pathological social networkers vs. controls and pathological Internet gamers vs. pathological social networkers) remained without significance (see Table 3). The reverse contrast (self > avatar) did not reveal any differences in brain activations between pathological gamers and healthy controls. Furthermore, we observed a significant correlation between addiction severity (indicated by OSVe scores) and the values of the first eigenvariate in the left AG ($r_{OSVe,\ \text{AG}} = .348$, $p = .032$).

Our first hypothesis supposed that brain activity in the left AG would be higher in addicted Internet gamers than in both problematic gamers and healthy controls, during avatar reflection relative to self-reflection. To assess this hypothesis, we performed a full-factorial ANOVA that included healthy controls and problematic and addicted Internet gamers.

Table 2. Within-group brain activations for the contrast *avatar* vs. *self*

H	Lobe	BA	Brain region	Cluster size	MNI coordinates x	MNI coordinates y	MNI coordinates z	t_{max}	$p_{cluster}$
Pathological Internet gamers *avatar* > *self*									
L	Temporal/occipital	20, 21, 37	MTG, inferior occipital gyrus	116	–63	–52	–14	8.64	.005
L	Temporal/parietal/occipital	7, 19, 23, 30, 31, 39, 40	MTG, precuneus (L+R), middle/posterior cingulum (L+R), AG, superior/inferior parietal lobule, cuneus (L+R), middle/superior occipital gyrus	1598	–6	–34	31	7.97	≤.001
R	Temporal/parietal/occipital	39, 40	Superior/middle temporal gyrus, supramarginal gyrus, AG, middle occipital, inferior parietal lobule	253	57	–61	25	6.80	≤.001
R	Frontal	8, 9, 10	Middle/superior frontal gyrus (L+R), MPFC	398	3	41	55	6.61	≤.001
L	Frontal/temporal	10, 11, 47	Superior temporal gyrus, OFG, superior frontal gyrus	206	–39	38	–20	6.36	≤.001
Pathological Internet gamers *self* > *avatar*[a]									
Pathological social network users *avatar* > *self*									
L	Parietal/occipital	7	Precuneus (L+R), superior parietal lobe, cuneus (L+R), superior occipital lobe	222	–6	–76	49	6.06	≤.001
Pathological social network users *self* > *avatar*[a]									
Healthy controls *avatar* > *self*									
R	Temporal	20, 38	Parahippocampal gyrus, inferior temporal, fusiform	129	33	2	–41	6.77	.002
R	Parietal	7, 23, 31	Cuneus (L+R)	291	9	–46	37	6.50	≤.001
L	Temporal/parietal	20, 38	Superior/middle/inferior temporal gyrus, amygdala, fusiform gyrus, parahippocampal gyrus, hippocampus	173	–24	2	–35	6.05	≤.001
R	Temporal/parietal/occipital	39, 40	Superior/MTG, AG, inferior parietal lobule, middle occipital gyrus	96	57	–58	40	5.53	.009
Healthy controls *self* > *avatar*[a]									

Note. AG = angular gyrus, H = hemisphere, L = left, R = right, BA = Brodmann area, MNI = Montreal Neurological Institute, MTG = middle temporal gyrus, OFG = orbitofrontal gyrus, $p_{cluster}$ = FWE-corrected p values reported on cluster level ($p_{FWE} < .05$). [a]No values.



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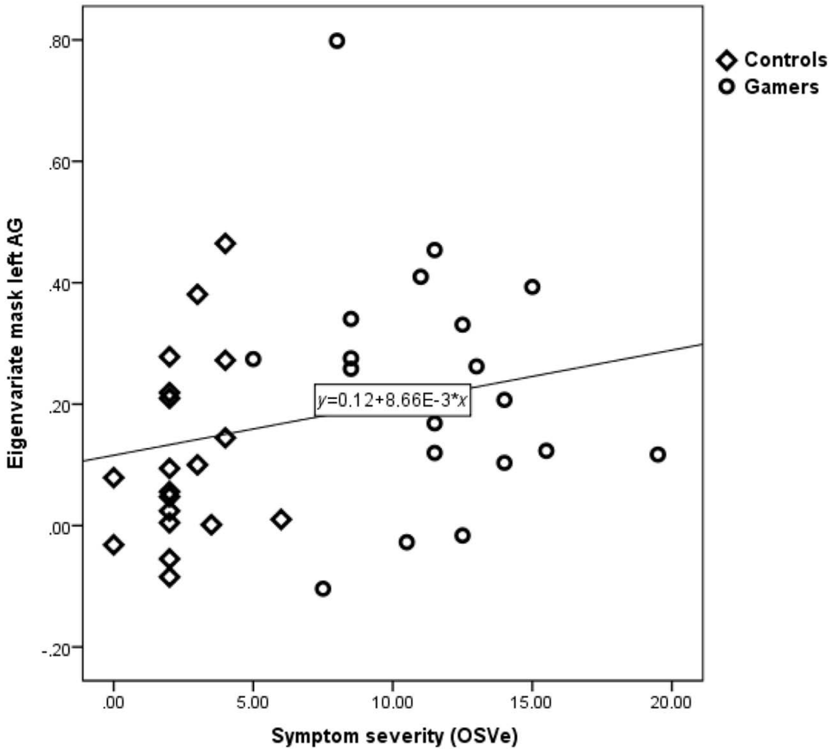


(b)

Figure 3. (a) Brain activation in pathological Internet gamers relative to healthy controls for the contrast *avatar* > *self* in the left AG ($z = 31$) as explored by an ANOVA between controls, pathological Internet gamers, and pathological social network users; brain-extracted chi-square template in MNI space with SPM contrast image overlay: $p_{uncorr} < .001$, $T = 3.39$, $\#_{voxel} \geq 10$ and (b) correlation ($n = 38$, pathological Internet gamers and healthy controls) between eigenvariate values in the left AG and OSVe scores.

Table 3. ANOVA for the contrast *avatar* > *self* in controls, pathological Internet gamers, and pathological social networkers revealed significant avatar-related brain activation in pathological Internet gamers vs. healthy controls

H	Lobe	BA	Brain region	Cluster size	MNI coordinates			t_{max}	$p_{cluster}$
					x	y	z		
Pathological Internet gamers > controls									
L	Parietal, occipital	19, 39, 40	AG, inferior parietal, middle occipital	140	–36	–67	31	4.99	.004[FWE]
Pathological social network users > controls[a]									
Pathological Internet gamers > Pathological social network users[a]									

Note. AG = angular gyrus, BA = Brodmann area, MNI = Montreal Neurological Institute, FWE = family wise error rate. [a]No values.

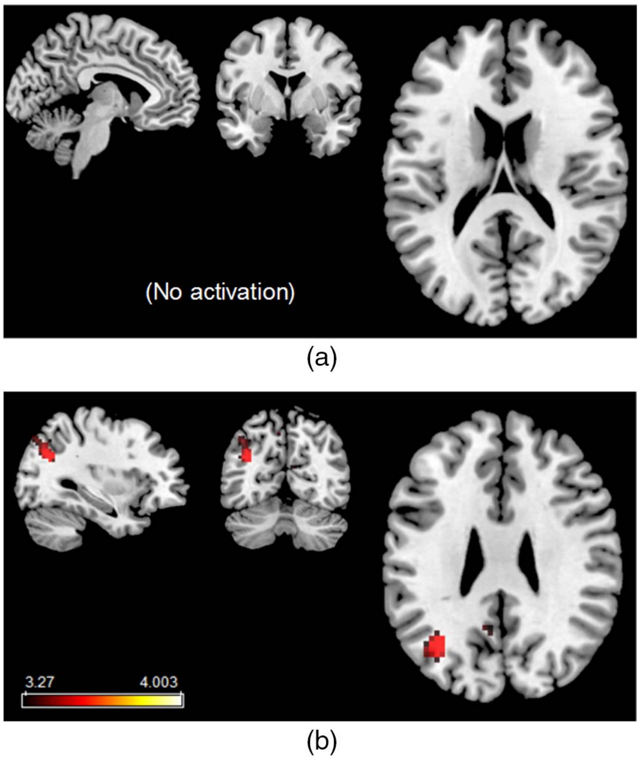


Figure 4. Results of a full-factorial ANOVA analyzing healthy controls and problematic and addicted Internet gamers showing (a) no significant differences in brain activation between addicted Internet gamers and problematic gamers, nor between problematic Internet gamers and healthy controls, respectively, and (b) significant activation in addicted Internet gamers relative to healthy controls in the left AG ($z = 28$) during *avatar* vs. *self-reflection*; brain-extracted chi-square template in MNI space with SPM contrast image overlay: $p_{\text{uncorr}} < .001$, $T = 3.39$, and $\#_{\text{voxel}} \geq 10$.

The data indicated that addicted gamers showed significant differences in brain activity in the left AG relative to healthy controls (BA 39, 19, 7; $p_{\text{FWE-corr (cluster level)}} = .004$, $T = 5.01$, $\#_{\text{voxel}} = 131$, Montreal Neurological Institute (MNI)−33−64 28; Figure 4). We found no significant differences in avatar-related brain activation between problematic and addicted gamers nor between problematic gamers and healthy controls.

Ideal reflection in the different subgroups. Analysis of within-group differences does not indicate a significant difference in brain activation during ideal reflection (vs. self-reflection) in pathological social network users, including in each of the addicted and problematic subgroups considered separately; nor were any significant differences found in the healthy controls.

Analysis of the reverse contrast (self > ideal) indicates that healthy controls show significantly more activity during self-reflection than ideal reflection in brain regions linked to self-reflection and reward processing, such as the MPFC, IFG and parietal regions as well as in the putamen, caudate nucleus, pallidum, and the anterior cingulate cortex (ACC), respectively (Table 4 and Figure 5).

Furthermore, the results indicate that pathological Internet gamers exhibit a higher number of brain activations in the inferior parietal lobe, as well as the addicted group showed increased activations in the bilateral AG during reflection about the ideal.

A full-factorial ANOVA of healthy controls, pathological Internet gamers, and pathological social network users also revealed a higher number of activations during self-reflection relative to ideal reflection in the right putamen, caudate, and thalamus ($p_{\text{FWE-corr (cluster level)}} = .001$, $T = 4.67$, $\#_{\text{voxel}} = 194$, MNI 9 −16 16) and the inferior and middle frontal gyrus (BA 45, 46; $p_{\text{FWE-corr (cluster level)}} =$ .001,

Table 4. Within-group results for brain activations in pathological and addicted Internet gamers as well as pathological and addicted social network users and healthy controls during *ideal reflection* vs. *self-reflection*

H	Lobe	BA	Brain region	Cluster size	MNI coordinates *x*	*y*	*z*	$t_{\max}$	p_{cluster}
Pathological Internet gamers *ideal > self*									
L	Parietal	40	Inferior parietal lobule	87	–45	–55	52	4.68	.018
Pathological Internet gamers *self > ideal*[a]									
Pathological social network users *ideal > self*[a]									
Pathological social network users *self > ideal*[a]									
Healthy controls *ideal > self*[a]									
Healthy controls *self > ideal*									
L	Parietal	23, 31	Precuneus (L+R), cuneus (L+R), posterior cingulum, middle cingulum (R), lingual gyrus	283	–6	–61	19	7.65	≤.001
R		–	Hippocampus (L), thalamus (L+R), putamen (L+R), caudate nucleus (L+R), pallidum (L+R)	577	3	–7	10	6.12	≤.001
L	Frontal	9	Middle/inferior frontal gyrus	122	–39	5	40	5.93	.001
L	Frontal	10, 32	MPFC, superior frontal, ACC (L+R)	142	0	41	13	5.56	≤.001

Note. ACC = anterior cingulate cortex, H = hemisphere, L = left, R = right, BA = Brodmann area, MNI = Montreal Neurological Institute, p_{cluster} = FWE-corrected p values reported on cluster level ($p_{\text{FWE}} < .05$). [a]No values.

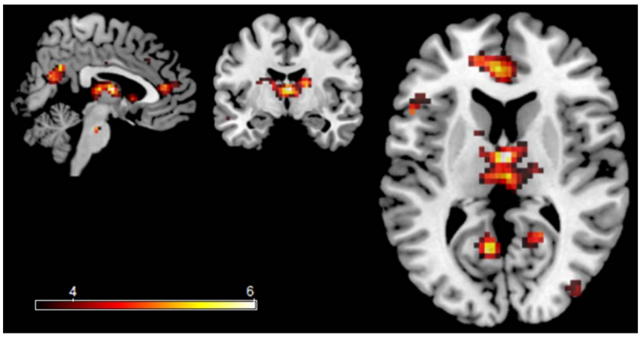


Figure 5. Within-group results of brain activations in healthy controls for the contrast *self* > *ideal* in the bilateral putamen, caudate, pallidum, ACC, and precuneus, as well as in the left MPFC and posterior cingulum ($z = 10$); brain-extracted chi-square template in MNI space with SPM contrast image overlay: $p_{\text{uncorr}} < .001$, $T = 3.61$, and $\#_{\text{voxel}} \geq 10$.

$T = 5.62$, $\#_{\text{voxel}} = 199$, MNI −36 17 22) of healthy controls, relative to pathological social network users (see Figure 6). Pathological Internet gamers did not show any significant differences in activation compared to healthy controls. Correlation analyses involving controls and pathological social network users ($n = 38$) revealed a significant correlation between addiction severity (indicated by AICA_30 and AICA_lifetime scores) and the first eigenvariate values of a mask obtained from the full-factorial ANOVA, which includes the bilateral putamen and caudate ($r_{\text{AICA\_30, bilateralputamen caudate}} = .440$, $p = .006$ and $r_{\text{AICA\_lifetime, bilateral putamen caudate}} = .523$, $p = .001$).

Next, to assess whether brain activity in the striatum during self-reflection is lower in addicted social network users than in problematic users and healthy controls, we performed a full-factorial ANOVA including controls and problematic and addicted social network users.

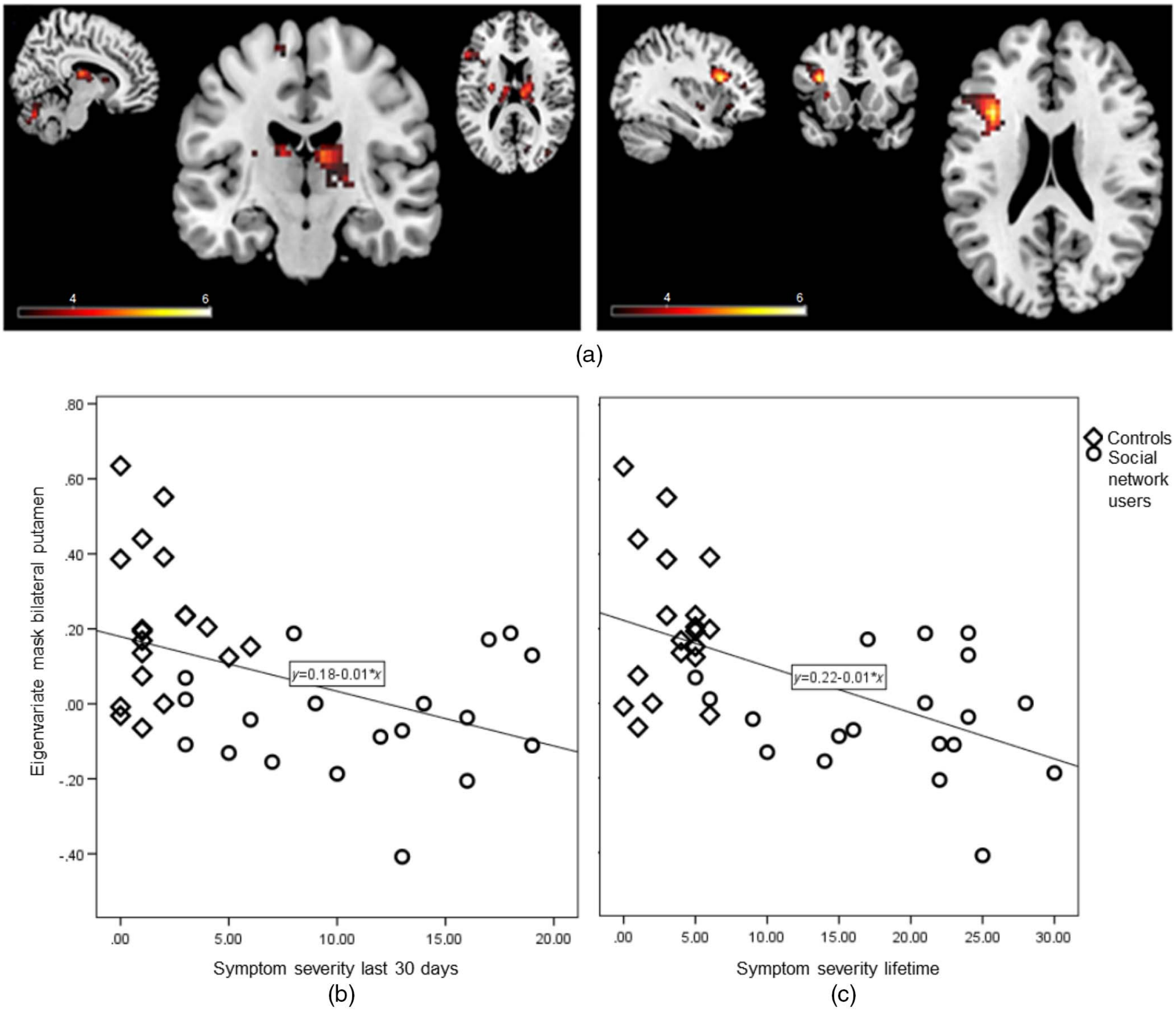
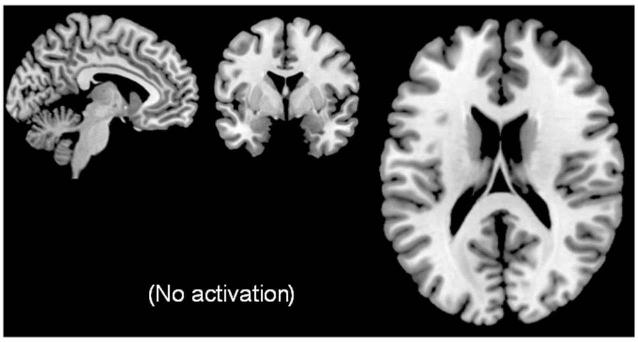


Figure 6. (a) Results of a full-factorial ANOVA of healthy controls, pathological Internet gamers and pathological social network users, showing significant differences in activation between healthy controls and pathological social network users in the right putamen and caudate as well as in the inferior and middle frontal gyrus (right image $z = 16$ and left image $z = 22$) for the contrast *self* > *ideal*; brain-extracted chi-square template in MNI space with SPM contrast image overlay: $p_{\text{uncorr}} < .001$, $T = 3.25$, $\#_{\text{voxel}} \geq 10$. (b) Non-parametric Spearman–Brown correlation between addiction severity and eigenvariates of the bilateral putamen and caudate.



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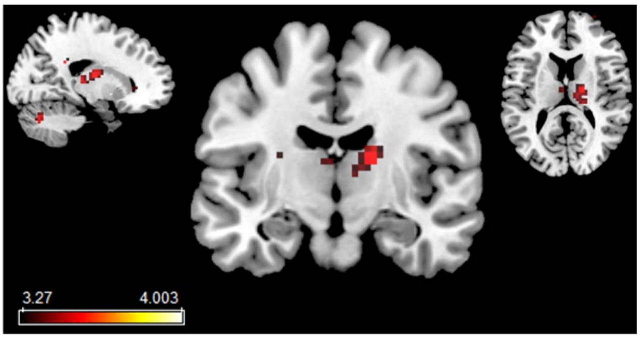

(b)

Figure 7. Results of a full-factorial ANOVA involving healthy controls and problematic and addicted social network users showing (a) no significant differences in activation between addicted and problematic social network users nor between problematic social network users and healthy controls, respectively and (b) significant activation in healthy controls relative to addicted social network users in the right caudate and thalamus ($z = 13$) during *self* vs. *ideal* reflection; brain-extracted chi-square template in MNI space with SPM contrast image overlay: $p_{\text{uncorr}} < .001$, $T = 3.34$, and $\#_{\text{voxel}} \geq 10$.

As illustrated in Figure 7, the only significant group difference observed indicates that healthy controls exhibit higher levels of brain activity than addicted social network users for the contrast *self* > *ideal* in the left inferior and middle frontal gyrus [BA 45, 46; $p_{\text{FWE-corr (cluster level)}} = .002$, $T = 4.77$, $\#_{\text{voxel}} = 154$, MNI −36 17 25], in the superior and inferior parietal lobules [BA 7; $p_{\text{FWE-corr (cluster level)}} = .011$, $T = 4.43$, $\#_{\text{voxel}} = 105$, MNI −30 −64 49] as well as in the right caudate and thalamus [$p_{\text{FWE-corr (cluster level)}} = .023$, $T = 4.34$, $\#_{\text{voxel}} = 88$, MNI 21 −25 7].

DISCUSSION

The aim of this study was to explore different stages of pathological Internet game and social network use to explore the neural basis of avatar and self-identification in addictive Internet use.

As far as we are aware, this is the first study comparing Internet gaming addiction and social network addiction as the two most prevalent application-specific subgroups of Internet addiction. Although our analyses used a relatively large total sample of pathological Internet users, the size of each application-specific subgroup was modest. Therefore, we used a two-step analysis method: first, pathological users (i.e., both problematic and addicted users) of each Internet application (i.e., Internet games or social networks) were psychometrically and neurobiologically assessed and compared to healthy controls. Second, comparisons in neural activations were conducted separately between problematic and addicted users of each Internet application and healthy controls.

In support of our findings from a previous study (Lemenager et al., 2013, 2014), our psychometric results suggest that pathological Internet gamers exhibit self-concept deficits in body image as well as in social and emotional competencies, compared to healthy controls. They also exhibit more social anxiety symptoms.

While pathological Internet gamers showed impairments in nearly all of the scales used to assess self-concept, pathological social network users, on the other hand, were characterized by deficits in dealing with their own emotions (recognition, understanding, regulation, and control) and in the interpretation of social situations. A recent study supports our results: addicted Facebook users were found to exhibit poor emotion regulation skills, including lack of acceptance of emotional responses, limited access to emotion regulation strategies, and poor impulse control (Hormes, Kearns, & Timko, 2014).

Given the broad deficits exhibited by Internet gamers in various aspects of self-concept, our psychometric findings may reflect a more severe psychopathology in pathological Internet gamers than in pathological social network users. However, further psychometric studies using larger sample sizes would be needed to confirm this supposition.

Analyses of neurobiological within- and between-group differences indicated a higher number of activations in the left AG during avatar reflection relative to self-reflection in the entire group of pathological Internet gamers, as well as in the subgroup of addicted gamers, relative to healthy controls. This confirms our findings from a previous study (Dieter et al., 2015). We further observed a significant positive correlation between avatar-related left AG activation and addiction severity.

Brain activation in the left AG, a part of the left inferior parietal lobe, has been reported in various studies exploring the neurobiological mechanisms of empathy, identification processing (Apperly, Samson, Chiavarino, & Humphreys, 2004; Regenbogen et al., 2012, 2013), and autobiographical reasoning (D'Argembeau et al., 2013; Kim, 2012). Empathy can be defined as the ability to understand the emotional state of others, and is rooted in the ability to emotionally identify oneself with others (Gallese, 2003).

The increased activity in the left AG observed in pathological as well as in addicted Internet gamers during avatar reflection (vs. self-reflection), taken together with the correlation between left AG activity and addiction severity, suggests that gamers increasingly identify with their own avatar as the transition from normal to addicted use, in line with our hypothesis.

We further hypothesized that addicted social network users tend to orient toward their ideal self and would therefore exhibit increased brain activation in the striatum during reflection about the ideal (i.e., how they would like to be) compared to during reflection about their real selves.

In contrast to our hypothesis, within-group comparisons did not reveal a higher number of ventral striatal activations during ideal reflection compared to self-reflection in pathological social network users, nor in each of the problematic or addicted subgroups. However, within- and between-group differences revealed a higher number of activations in the dorsal striatum during self-reflection in healthy controls, relative to pathological social network users as a whole as well as to the subgroup of addicted social network users, whereas such differences were not observed between controls and problematic users. These findings, coupled with the significant correlation observed between addiction severity and the decreased self-related dorsal striatal activation in the total sample of pathological social network users and controls, give rise to the question whether a subtle decrease in self (vs. ideal)-related dorsal striatal activation may mediate the transition from normal to addicted social network use.

The literature indicates an association between the ventral striatum and reward-guided and predictive learning (as occurs, e.g., during the reception of positive feedback; Meshi et al. 2013), as well as self-disclosure (i.e., the communication of one's own thoughts and feelings to others; Tamir & Mitchell, 2012). The dorsal striatum, on the other hand, has been functionally linked to habit formation, which involves the incremental strengthening of stimulus–response associations as a function of reinforcement (Devan, Hong, & McDonald, 2011; Rothemund et al., 2007; Yin, Knowlton, & Balleine, 2004). Dorsal striatal activation has also been associated with happiness (Mitterschiffthaler, Fu, Dalton, Andrew, & Williams, 2007; Muhlberger et al., 2011) and has been observed in healthy participants during self-reflection (Pfeifer, Lieberman, & Dapretto, 2007).

As such, the increased dorsal striatal activation during self-reflection (vs. ideal reflection) in our healthy controls, compared to the addicted social network users, may suggest that the healthy controls had habitually received more positive feedback to their real selves in real life, which may in turn have led to a more contented mood during self-reflection relative to ideal reflection. This raises the possibility that self-reflection may be less rewarding for addicted social network users than for healthy controls, and that the presentation of an ideal self may in fact be more rewarding. If this is indeed the case, it could possibly be explained by addicted social network users' reported emotion regulation deficits (Hormes et al., 2014), which could have led them to receive negative social feedback in real life which in turn could have decreased self-related dorsal striatal activation.

However, these suppositions should be further explored by future psychometric and neurobiological studies.

One limitation of our study is the use of small sample sizes, which resulted from the division of each pathological group into two smaller subgroups of addicted and problematic users, respectively. However, as our findings on avatar response in Internet gaming addicts replicate those of a previous study (Dieter et al., 2015), we may conclude that our results are meaningful despite the low sample sizes.

Another potential limitation is posed by the fact that we did not control for familiarity effects between addicts and their avatar. Potential familiarity effects may arise when addicted gamers have a higher number of avatar-related memories than non-addicted gamers, due to the much longer period of time they have spent playing. However, we did not find pathological gamers to have significantly shorter mean reaction times for avatar ratings than healthy controls, an observation also found in our previous study applying the same paradigm (Dieter et al., 2015). Therefore, we can assume that pathological gamers did not access their avatar-related memories faster during trials, which in turn suggests that familiarity effects did not influence the results. A more detailed discussion and further argument against the presence of any familiarity effects has already been presented in our previous study (Dieter et al., 2015).

CONCLUSION

Our results indicate different patterns of brain activation in relation to avatar-identification and self (vs. ideal)-reflection in problematic and addicted users of Internet games and social networks. Internet gaming addiction appears to be linked to slowly adapting left-AG-mediated identification processing in relation to one's own avatar, and a higher self-concept-related psychopathology, also including the physical self-concept. Addiction to social networks, on the other hand, seems to be characterized by deficits in emotion regulation stemming from negative social feedback and leading to reduced self-satisfaction, which is in turn reflected by a lower number of striatal activations during self- vs. ideal reflection relative to healthy controls. This study might suggest that Internet gaming and social network addiction-specific therapy approaches should lay a main focus on the self-concept to assist affected persons in finding their identity (including their interests, skills, and individual acceptance). In this context, therapy with addicted social networkers should include the goal to become more independent from social judgment and to learn how to deal with negative social feedback in real life. Therapy with addicted Internet gamers, on the other hand, should rather focus on the emotional detachment from the avatar and the physical self-image. An approach for the emotional detachment from the own avatar is described in the therapy manual of Wölfling, Jo, Bengesser, Beutel, and Müller (2012), where addicted Internet gamers discuss in a group setting all positive characteristics of their avatar and how they can transfer some of them into their own personality in a realistic way. Both groups should learn to integrate and accept positive and negative facets of the own personality and self-image.

Furthermore, the results may contribute to the implementation of non-invasive neurobiological treatment options, such as neuro-feedback training, which has already been successfully used in the treatment of ADHD (Arns, de Ridder, Strehl, Breteler, & Coenen, 2009; Duric, Assmus, Gundersen, & Elgen, 2012) and problematic alcohol consumption (Kirsch, Gruber, Ruf, Kiefer, & Kirsch, 2015).

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Authors' contribution: TL drafted the manuscript, supervised the study, and contributed to data collection and analysis. JD contributed to data collection, study management, data analysis, and manuscript preparation. HH programmed the fMRI paradigm. SH was involved in manuscript revision and psychometric data analysis. IR verified statistical data analyses. MB participated in study implementation and contributed to the manuscript preparation. SV-K supervised neurobiological data analyses and contributed to the implementation of the paradigms. FK supervised and contributed to the manuscript preparation. KM received funding for the study and supervised it. He was responsible for the final editing of the manuscript. All authors approved the final version of the manuscript.

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