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Neurobiological correlates of avatar identification processing and emotional inhibitory control in internet gaming disorder

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ABBREVIATIONS

ACC	Anterior cingulate cortex
ADHD	Attention deficit and hyperactivity disorder
AICA/AICA-C	Checklist for the assessment of internet and computer game addiction
AICA_30	Checklist for the assessment of internet and computer game addiction referring to the previous 30 days
AICA_lifetime	Assessment of internet and computer game addiction: Lifetime maximum
AG	Angular gyrus
AGN	Affective Go/No-Go task
ANOVA	Analysis of variance
APA	American Psychiatric Association
BA	Brodmann area
BIS	Barratt impulsiveness scale
BOLD	Blood oxygenation level dependent
CANTAB	Cambridge Neuropsychological Test Automated Battery
dACC	Dorsal anterior cingulate cortex
DLPFC	Dorsolateral prefrontal cortex
DSM-IV	Diagnostic and Statistical Manual of Mental Disorders, 4th edition
DSM-5	Diagnostic and Statistical Manual of Mental Disorders, 5th edition
EKF	Emotional competence questionnaire (German designation: Emotionale-Kompetenz-Fragebogen)
EPI	Echo planar imaging
EST	Emotional Stroop task
FA	Flip angle
fMRI	Functional magnetic resonance imaging
FOV	Field of view
FPS	First-person shooter
FWE	Family-wise error rate
GLM	General linear model
GT	Giessen-Test
HF	High frequency
HRF	Hemodynamic response function
IA	Internet addiction
IGA	Internet gaming addiction
IGD	Internet gaming disorder
IFG	Inferior frontal gyrus
IPL	Inferior parietal lobule
LoL	League of Legends
NMR	Nuclear magnetic resonance
MMORPG	Massively multiplayer online role-playing game
MNI	Montreal Neurological Institute
MPFC	Medial prefrontal cortex
MR	Magnetic resonance
MRI	Magnetic resonance imaging
MTG	Middle temporal gyrus
NEO-FFI	NEO-five factor inventory

OSVe/OSVe-S	Scale for online addictive behavior in adults, self-report (German designation: Skala zum Onlinesuchtverhalten bei Erwachsenen)
PIU	Pathological internet use
POSI	Preference for online social interaction
PSS	Perceived stress scale
ROI	Region of interest
RT	Reaction time
RTS	Real-time strategy
SASKO	Questionnaire for social anxiety and social competence deficits (German designation: Fragebogen zu sozialer Angst und sozialen Kompetenzdefiziten)
SCID	Structured clinical interview for DSM-IV (German designation: Strukturiertes Klinisches Interview DSM-IV; SKID)
SD	Standard deviation
SPM	Statistical parametric map / Statistical Parametric Mapping program
SPSS	Statistical Package for the Social Sciences
STG	Superior temporal gyrus
TE	Echo time
TR	Repetition time
WoW	World of Warcraft

1 INTRODUCTION

1.1 Definition and specification of terms

The term “**internet addiction**” **(IA)** is used interchangeably with “internet addiction disorder” (IAD; e.g. Dong, Zhou, & Zhao, 2010), “pathological internet use” (PIU; e.g. Davis, 2001), “compulsive internet use” (CIU; e.g. van Rooij, Schoenmakers, van de Eijnden, & van de Mheen, 2010) and “problematic internet use” (e.g. Caplan, 2003; Shapira, Goldsmith, Keck, Khosla, & McElroy, 2000). As IA seems to be the most frequently used term (K. Kim et al., 2006), it was applied in this thesis. The condition designates an excessive or uncontrolled internet use, entailing negative consequences mainly in psychological, social, and/or work functioning domains (Davis, 2001; Dong & Potenza, 2014; K. S. Young & Rogers, 1998). IA’s conceptualization is unclear to date (Pezoa-Jares, Espinoza-Luna, & Vasquez-Medina, 2012), but it might be considered as a behavioral addiction due to sharing similarities with substance addictions and the behavioral addiction of pathological gambling (itself exhibiting various overlaps with substance addictions; Potenza, 2001), especially regarding the characteristics of excessive use, withdrawal symptoms, tolerance and negative repercussions (Petry, 2007; Pezoa-Jares et al., 2012; for more details on IA see chapter 1.2).

Similarly, the condition of being addicted to internet games as the most prevalent subcategory of IA (Ding et al., 2014; Wölfling & Müller, 2008; K. Young, 2009) has been denominated with a variety of terms, including “online gaming addiction” (e.g. Kuss & Griffiths, 2012b) and “internet gaming addiction” (IGA; Kuss & Griffiths, 2012a). However, in concordance with the 5th edition of the Diagnostic and Statistical Manual of Mental Disorders [DSM-5; American Psychiatric Association (APA), 2013], the term “**internet gaming disorder**” **(IGD)** was applied in the presented work. IGD can be defined as a reduction or loss of self-control over internet game use (Dong, Lin, & Potenza, 2015) and similarly to IA has been described to share core characteristics with substance addictions, including increased time of immersion in the problematic behavior, withdrawal and craving (Grüsser, Thalemann, & Griffiths, 2007; K. Young, 2009). Reports about IGD-related negative consequences in social, health, academic or work-related life domains are accumulating (e.g. S. E. Allison, von Wahlde, Shockley, & Gabbard, 2006; Batthyány, Müller, Benker, & Wölfling, 2009; Rehbein & Mößle, 2012; K. Young, 2009; for more details on IGD see chapter 1.3).

1.2 Internet addiction (IA)

As envisioned by J.C.R. Licklider in his concept of a “Galactic Network” of globally interconnected computers for quick and location-independent data access (Leiner et al., 1997; Licklider & Clark, 1962), the Defense Advanced Research Projects Agency (DARPA) supported the development and setup of a long-distance telecommunication network between computers throughout the US, which was further extended and became known as ARPANET as the internet’s precursor around 1972 (Glowniak, 1998; Leiner et al., 1997). The internet was publicly available in the early 1990s (Petersen, Weymann, Schelb, Thiel, & Thomasius, 2009) and spread to connect about a quarter of the world’s total population 20 years later (Sagan & Leighton, 2010). Used as a fast and cheap multifunctional tool both for profession and recreation, including information search or dissemination, interaction, entertainment, shopping or gaming, the internet has taken up a basic and essential role in the everyday life of billions of people across the world (Leiner et al., 1997; Sagan & Leighton, 2010). Reports about individuals becoming addicted to the internet and showing similar behavioral patterns as people addicted to drugs or gambling began accumulating around 1996 (K.S. Young, 1996). Given the increasing prevalence of individuals drawn to the internet, K. S. Young developed an eight-item Diagnostic Questionnaire as a screening instrument for addictive internet usage (K.S. Young, 1998), comprising the central aspects of addiction including preoccupation, withdrawal symptoms, tolerance, loss of control (reflected in unsuccessful attempts to cut back or quit the problematic behavior), neglect of other leisure activities, deception, escapism or mood regulation (DSM-5; APA, 2013). Today, further screening instruments are available and include the checklist for the assessment of internet and computer game addiction (AICA-C; see below; Wölfling, Beutel, & Müller, 2012) as well as a self-report questionnaire assessing the online addictive behavior in adults (OSVe-S; Wölfling, Müller, & Beutel, 2008). IA was reported to have high comorbidity with attention deficit and hyperactivity disorder (ADHD), major depression, generalized and social anxiety disorder as well as borderline personality disorder (amongst others; Bernardi & Pallanti, 2009; Ha et al., 2007; Yen, Ko, Yen, Wu, & Yang, 2007). Clinical studies on the effectivity of IA-specific therapy concepts are scarce. So far, based on IA’s phenomenological overlap to substance addictions, both pharmacological (e.g. antidepressants, mood stabilisers and anxiolytics; Chakraborty, Basu, & Vijaya Kumar, 2010) as well as non-pharmacological treatments (individualized as well as group cognitive behavior therapy, family therapy, marital therapy and support groups; Chakraborty et al., 2010) have been recommended. Recent studies suggest the prevalence of IA to range between 1.4 %-1.7 % in Finland (12-18 year-olds, n=7229; Kaltiala, Lintonen, & Rimpela, 2004) and 37.9 % in Hong Kong (16-24 year-olds, n=699; Leung, 2004), but prevalence rates might vary with the applied measurement scale, sample, age and gender (Pezoa-

Jares et al., 2012). In Germany, the prevalence of IA seems to amount to 2.4 % (14-24 year-olds, as identified by a latent class analysis in a sample of n=15024 persons aged 14-64 years; Rumpf, Meyer, Kreuzer, & John, 2011). Affected individuals were found to suffer from academic failure (K.S. Young, 2004), reduced work performance (K.S. Young, 1998), marital discord and separation (K.S. Young, 1998), loneliness, depressed mood and compulsivity (Whang, Lee, & Chang, 2003). With regard to the professional life, the annual costs of internet abuse-related productivity loss during work among employees are assumed to mount up to billions of Dollars (K.S. Young, 2004). Thus, for the sake of every individual internet addict, but also for their social surrounding and society, further effort should be put into the condition's exploration as well as the development of specific prevention and therapy methods.

1.3 Internet gaming disorder (IGD)

The most prevalent subgroup of IA is the addiction to internet games (Ding et al., 2014; Wölfling & Müller, 2008; K. Young, 2009). This is reflected in its uptake into the DSM-5 as "internet gaming disorder" (IGD) as a "condition warranting more clinical research and experience" (section III; APA, 2013). The reduction or loss of self-control over internet game use in IGD (Dong et al., 2015) is reflected in internet gaming addicts' extended gaming hours of 10-20 hours per day and their suffering from sleep deprivation, loss of real-life relationships, unhealthy diet, lack of exercise and hygiene, back and eye strain, impaired performance in education or work, stress (Batthyány et al., 2009; K. Young, 2009; K.S. Young, 2004), dysfunctional coping (Batthyány et al., 2009), loneliness and introversion (Caplan, Williams, & Yee, 2009; Kuss & Griffiths, 2012a). Prevalence estimates of IGD are complicated by different study approaches (e.g. differing measurement scales and cutoff points, definitions of the term "addiction", sample composition) and therefore have been reported to range between 0.2 % in Germany (n=4382, ≥14 years, mean age=37.8 years; Festl, Scharkow, & Quandt, 2013; Kuss, 2013b) and 15.6 % in Hong Kong (n=503, mean age=14 years; C. W. Wang et al., 2014).

Massively multiplayer online role-playing games (MMORPGs; in this thesis referred to as internet games) such as World of Warcraft (WoW) are the most popular internet games and pose the highest risk for developing IGD (Kuss, 2013b; Rehbein, Kleimann, & Mössle, 2009). They developed from a game revolution around the 1990s, marked by a change from single-player games against the computer to the point of downright game experiences with self-immersion and evolvement of three-dimensional societies (K. Young, 2009). Multiple users simultaneously engage in a virtual reality via their graphical agent, or "avatar", which can be mostly constructed according to personal preferences by choosing certain properties such as race, powers, skills, appearance, philosophy or name prior to the start of the game

(Leménager et al., 2014; K. Young, 2009). The addictive potential of internet games might be mediated by fast achievements and incentives (Kuss, 2013a, 2013b; Yee, 2006a, 2006b) as well as by the characteristics of being endless, entertaining, time-consuming, adventurous and of a socially interactive style (Bessière, Seay, & Kiesler, 2007; Charlton & Danforth, 2010; Hsu, Wen, & Wu, 2009; Smahel, Blinka, & Ledabyl, 2008a). The concrete factors and their potential interaction in the pathogenesis of IGD remain unknown to date (Kuss, 2013b). However, current studies have repeatedly suggested the involvement of a deficient self-concept in the pathogenesis of IGD (Leménager et al., 2014; Leménager et al., 2013), which might be related to an increased identification with the own avatar (Bessière et al., 2007; Ganesh, van Schie, de Lange, Thompson, & Wigboldus, 2011; Leménager et al., 2014; Turkle, 1994). Besides, impaired inhibitory control (Yuan et al., 2015; for a definition of terms see chapter 1.3.2), emotional competence deficits (Leménager et al., 2013) and higher social anxiety (e.g. Lehenbauer-Baum et al., 2015) have been named as contributing factors, which might suggest that internet gaming addicts show deficits in the control of their own behavior, thoughts and emotions (emotional inhibitory control) in social contexts.
All these aspects might be linked to the cognitive-behavioral model of problematic online gaming (in this thesis referred to as cognitive-behavioral model of problematic internet gaming) in adolescents, as suggested by Haagsma et al. (Haagsma, Caplan, Peters, & Pieterse, 2013; see Figure 1).

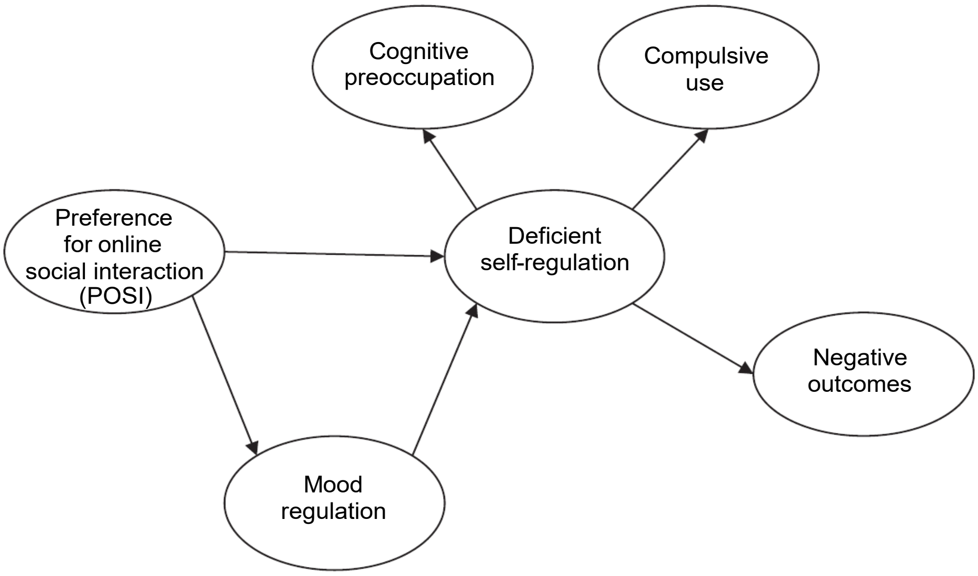

Figure 1: Cognitive-behavioral model of problematic internet gaming in adolescents (Haagsma et al., 2013)

This model is based on 1) the cognitive-behavioral model of PIU by Davis (2001), which integrates maladaptive cognitions besides behavioral aspects such as withdrawal and tolerance as PIU-driving factors and which is of high value as it is one of the first approaches differentiating causal factors (e.g. comorbidities and pre-existing pathologies) from the unique disease of IA resulting from them (Hall & Parsons, 2001), and 2) the cognitive-behavioral model of generalized problematic internet use by Caplan (2002, 2003) in its updated version (Caplan, 2010), itself being a derivative of Davis' model.

The model of Haagsma et al. (2013) is among the first internet gaming-specific ones and aims to increase the understanding of this condition and its negative consequences. The model refers to adolescents between 12-22 years, as problematic internet game use especially seems to be an issue in this life period (M. Griffiths & Wood, 2000; M. D. Griffiths, Davies, & Chappell, 2004). The cognitive and behavioral components "preference for online social interaction (POSI)", "mood regulation", "deficient self-regulation", "negative outcomes", "cognitive preoccupation" as well as "compulsive use" were derived from Caplan's cognitive-behavioral model of generalized problematic internet use (Caplan, 2010) and assessed in adolescent internet gamers in the study of Haagsma et al. (2013). Hypotheses about these components' relations were summarized in a conceptual model. The latter was then tested for its applicability to problematic internet gaming by means of structural equation analysis with maximum likelihood estimation, resulting in indices of model fit. POSI was revealed to be an important factor in the development of deficient self-regulation, both directly and indirectly via mood regulation (Haagsma et al., 2013). In addition, deficient self-regulation predicted negative outcomes from internet game use. As two subscales of deficient self-regulation, cognitive preoccupation and compulsive use were predicted by the latter (Haagsma et al., 2013; Figure 1; for a definition of terms see also chapter 5.3.2).

In more detail, given internet gamers' high social anxiety (e.g. Lehenbauer-Baum et al., 2015), an indirect social interaction as offered by internet games and their associated forums is possibly perceived as safer (Caplan, 2003, 2005, 2007). Additionally, a central factor for developing **POSI** might be internet game-related thoughts such as to perform better, feel better about oneself or to be treated better by others in the online virtual game world than offline in real life (M. Liu & Peng, 2009).

Internet games might be also played to relieve boredom, soothe troubling feelings, lessen loneliness or to escape from reality (Wan & Chiou, 2006; K. Young, 2009), i.e. for the relief of negative feelings and **mood regulation**. Negative mood regulation is closely related to general emotion regulation (Campbell-Sills & Barlow, 2007), which requires inhibitory control as a key mechanism (Falquez et al., 2015).

The model of Haagsma et al. (2013) assumes problematic internet gaming to comprise cases of various severities ("continuum perspective"), ranging from barely to severely affected behavior, instead of being an "all or nothing phenomenon" (i.e. "categorical perspective"; Haagsma et al., 2013). As the maximum severity of problematic internet gaming behavior is not fixed in the continuum approach, it might be assumed that the model is also applicable to IGD.

1.3.1 Self-concept and identification with avatars

Several psychometric studies on IGD suggested self-concept deficits to play a major role in the pathogenesis of this condition (Leménager et al., 2014; Leménager et al., 2013). The self-concept can be defined as the entirety of appraisals that one assigns to the own self, such as values, desires, emotions, interests etc. (Deusinger, 1996; Klein, 2003; Mummendey, 1990). Self-concept impairments in the sense of dissatisfaction with the own body, lower self-esteem, social and interpersonal problems as well as reduced social potency (among others; Leménager et al., 2014; Leménager et al., 2013) might contribute to POSI. Concordantly, Li, Liau, & Khoo (2011) proposed that for pathological internet gamers playing depicts a method to avoid their real self and to approach their ideal self (Li et al., 2011). This might be underlined by the findings of Leménager et al. (2013), who reported MMORPG addicts to show a higher discrepancy between their real and ideal self in comparison to non-addicted and naive gamers based on the corresponding ratings for self and ideal on the Giessen-Test (GT), a questionnaire for the assessment of self-concept-related characteristics. Extending this finding, Leménager et al. (2013) also found MMORPG addicts to rate their ideal self more closely to their avatar on the GT than non-addicted and naive gamers. This might indicate that addicted MMORPG players create their avatar similar to their ideal and that they identify with their own avatar significantly more than non-addicted and naive gamers (Leménager et al., 2013). The avatar might even be incorporated into gamers’ self-concept, as suggested by psychological considerations and descriptions of internet game users (Ganesh et al., 2011; Pearce, 2006; Taylor, 2002): Due to the possibility of customization, the avatar enables the expression of a preferred identity. The avatar is a prerequisite for the inhabitation of the virtual world and the social interaction therein. Through their own avatar, players experience a new kind of agency and body awareness that enables users to do things that their physical bodies can’t accomplish. These processes have even been described as embodiment and “proprioception” (Pearce, 2006; Taylor, 2002).

Neurobiologically, the self-concept can be assessed by means of self-reflection tasks, which for instance imply the evaluation of one's own attributes, preferences or thoughts, the retrieval of self-knowledge or the execution of self-referential judgements (D'Argembeau et al., 2007; Johnson et al., 2006; Macrae, Moran, Heatherton, Banfield, & Kelley, 2004; Ochsner et al., 2005; C. Sebastian, S. Burnett, & S.J. Blakemore, 2008). In an autobiographical reasoning paradigm asking healthy controls to reflect on the broader meaning and implications of their own memories (relative to sheer autobiographical remembering), increased brain activations were found in a left-lateralized network comprising the dorsal medial prefrontal cortex (MPFC), the inferior frontal gyrus (IFG) as well as the angular gyrus (AG; amongst regions; D'Argembeau et al., 2013).

Regarding IGD, only the body image as a physical self-concept facet has been investigated neurobiologically: In the corresponding paradigm, MMORPG addicts viewed whole-body images of themselves, their own avatar and unfamiliar persons. When seeing themselves, MMORPG addicts exhibited bilateral AG hypoactivations, possibly indicating a more negative body image (Leménager et al., 2014). Interestingly, upon the perception of their own avatar, MMORPG addicts showed significant left AG hyperactivations. Given the role of the left AG (as a part of the left inferior parietal lobe) in the self-identification from the third person perspective (Ganesh et al., 2011), it might be deduced that MMORPG addicts identify with their own avatar to a higher degree than with their real self (Leménager et al., 2014). However, the cognitive domain of the self-concept (i.e. the entirety of appraisals that one assigns to the own self without those referring to the own body; Deusinger, 1996, 1998; Klein, 2003; Leménager et al., 2014) has not been explored in internet gaming addicts on a neurobiological basis yet. In addition, the psychometric finding of a smaller ideal-avatar-discrepancy in MMORPG addicts relative to controls suggests that also the ideal and its relation to self and avatar might play a role in IGD, which needs to be investigated more closely.

1.3.2 Emotional inhibitory control

IGD is furthermore characterized by a loss of control over internet gaming behavior (Dong et al., 2015), which is likely mediated by increased impulsivity and reduced inhibitory control as central factors (Ding et al., 2014; Ko et al., 2014; Lee et al., 2015; Yao et al., 2015; Yuan et al., 2015). Inhibitory control has a behavioral and a cognitive component, which denote the inhibition of prepotent responses (i.e. response inhibition as the control of cognitive processes required to cancel an intended movement; Aron, Robbins, & Poldrack, 2004; Schulz et al., 2007) and the ability to suppress irrelevant information during cognitive performance (i.e. interference control as a facet of cognitive control; Aron et al., 2004; Derrfuss, Brass, & von Cramon, 2004; Miller & Cohen, 2001), respectively, and can be assessed by means of Go/No-Go as well as Stroop tasks (for task descriptions see chapters 3.2.1 and 3.2.2). In both of these tasks, internet gaming addicts revealed significant deficits relative to healthy controls, marked by significantly more errors in No-Go trials (i.e. response inhibition in the Go/No-Go task; G. C. Liu et al., 2014; Yao et al., 2015) and a longer reaction time (RT) during the interference condition of the Stroop task (Yuan et al., 2015; Yuan et al., 2016). The inhibitory control to withstand the use of internet games might be further weakened by internet gaming addicts' deficits in emotion regulation (Lee et al., 2015; Leménager et al., 2013), which might be utilized by internet games by relieving negative feelings and moods (Hussain & Griffiths, 2009) as well as by providing regular reward (at least in in the initial levels; Yee, 2002). These aspects clearly suggest a link between inhibitory control and emotions in IGD, possibly expressed as impaired emotional inhibitory control. The latter might be assessed by means of affective Go/No-Go (AGN) and emotional Stroop tasks (EST), which depict the Go/No-Go and Stroop tasks' emotional equivalent. They are constructed by replacing the conventional stimuli with emotional ones [for task descriptions see chapters 3.2.1 (AGN) and 3.2.2 (EST)]. First investigations in PIU suggested impairments in emotional inhibitory control, as reflected by longer RTs to internet-related and emotional word stimuli in an EST (Zheng, 2008). However, despite a seeming role of social anxiety in IGD (Lehenbauer-Baum et al., 2015), emotional inhibitory control has not been investigated in this context yet.

The inhibitory control deficits in IGD likely have their basis in an altered neurobiological processing within the brain circuits mediating inhibitory control (Dong et al., 2015).
In IGD, an association with impaired inhibitory control was repeatedly reported for several brain regions including the anterior cingulate cortex (ACC; involved in cognitive and emotional control; Bush, Luu, & Posner, 2000; Lee et al., 2015), the dorsolateral prefrontal cortex (DLPFC; response inhibition and cognitive control; G. C. Liu et al., 2014; Yuan et al., 2015; Yuan et al., 2016) as well as the superior parietal lobe (response inhibition; G. C. Liu et al., 2014). Among these, the dorsal ACC (dACC) seemed to be especially reactive to negative affect, pain and cognitive control (Shackman et al., 2011).
Functional investigations [i.e. functional magnetic resonance imaging (fMRI)] in internet gaming addicts relative to healthy controls applied different versions of the Go/No-Go task involving either symbols (G. C. Liu et al., 2014), letters (Ding et al., 2014) or numbers (Ko et al., 2014) as stimuli in order to assess the neural correlates of response inhibition. During No-Go trials, i.e. response inhibition, the superior parietal lobe (Ding et al., 2014; G. C. Liu et al., 2014) and the DLPFC (G. C. Liu et al., 2014) were found to be hypoactive in internet gaming addicts compared to healthy controls, while the right ACC (Ding et al., 2014), left orbitofrontal lobe and bilateral caudate nucleus (Ko et al., 2014) were hyperactive. It was suggested that the hyperactivation in these inhibitory control-related regions is to maintain response inhibition during task performance (Ko et al., 2014). Studies applying different versions of the Stroop task for the assessment of interference control deduced the latter to be impaired in IGD based on observations of reduced ACC activation during interference (Dong et al., 2015; Lee et al., 2015). It has to be considered that these functional studies with Go/No-Go and Stroop tasks explored different facets of inhibitory control and that they involved either adolescents or adults, who might differ in inhibitory control abilities due to age-dependent brain structure development (Konrad, Firk, & Uhlhaas, 2013).

Structural and resting state connectivity explorations in IGD revealed significant associations between the amount of response errors in the Stroop task (serving as another outcome measure besides the RT; H. Wang et al., 2015) and reduced ACC gray matter volume (GMV; H. Wang et al., 2015) as well as between response errors and reduced functional connectivity during resting state between the DLPFC and the caudate of the dorsal striatum (Yuan et al., 2016). These findings suggest inhibitory control to be reduced, which might also entail diminished prefrontal control over the striatum-mediated gaming urge, thereby entailing prolonged gaming despite negative consequences. However, despite a seemingly close link between IGD, social anxiety, impaired inhibitory control and emotion regulation (Carlson & Wang, 2007; Knyazev, 2007; Lee et al., 2015), the role of (social) anxiety-related emotions in these inhibitory processes has not been elucidated for IGD yet.

2 AIMS AND HYPOTHESES

The present work aimed at the neurobiological exploration of internet gaming addicts' concepts of self, ideal and avatar as well as their emotional inhibitory control abilities, which are regarded as relevant factors in the development and maintenance of IGD (Lee et al., 2015; Leménager et al., 2014; Leménager et al., 2013; H. Wang et al., 2015; Yuan et al., 2016).

2.1 Study 1

As outlined above, IGD has previously been associated with self-concept deficits (Leménager et al., 2013). Furthermore, psychometric studies also suggest that internet games depict a possibility for users to avoid their real self and to approach their ideal by creating their avatar according to personal preferences (Bessière et al., 2007; Smahel et al., 2008a). Concordantly, internet gaming addicts (in study 1 referred to as MMORPG players) are thought to identify with their avatar to a higher degree than with their own self (Bessière et al., 2007; Leménager et al., 2013; Smahel et al., 2008a). As these processes might be crucial for IGD development and maintenance, **study 1 aimed at the neurobiological exploration of the relation between internet gaming addicts' concepts of self, ideal and avatar as well as alterations relative to healthy controls.**
Hereby, it was focused on the left AG within the inferior parietal lobe. This region has previously been implicated in self-referential processing from a third-person perspective (David et al., 2006; Ganesh et al., 2011). Interestingly, the left AG has shown hyperactivity in a group of long-term internet gamers during the reflection on the own avatar (Ganesh et al., 2011) and in addicted internet gamers during avatar perception (Leménager et al., 2014). The left AG might therefore depict an important integration hub for the cognitive concepts of self, avatar and ideal in IGD.

The following hypotheses were deduced:

Hypothesis 1:
Internet gaming addicts exhibit higher brain activations in the left AG during the reflection on their own avatar compared to self-reflection.

Hypothesis 2:
Internet gaming addicts show similar neurobiological brain activations in the left AG during the reflection on their avatar and their ideal.

Hypothesis 3:
Non-addicted internet gamers exhibit higher brain activations in the left AG during the reflection on their ideal relative to the reflection on their avatar.

2.2 Study 2

Another central feature of IGD is the control loss over internet gaming behavior (Dong et al., 2015), possibly mediated by generally reduced inhibitory control (Lee et al., 2015; G. C. Liu et al., 2014; Yuan et al., 2016). The additional association of IGD with increased social anxiety and emotional competence deficits (Lehenbauer-Baum et al., 2015; Leménager et al., 2013) suggests internet gaming addicts to have inhibitory control deficits in emotional situations especially related to socially anxious and generally anxious contexts, which might be denoted as impaired emotional inhibitory control.

As a part of the ACC (itself assumed to be involved in cognitive and emotional control; Bush et al., 2000), the dACC was specifically suggested to play a role in pain and negative affect (Shackman et al., 2011). The dACC has also been associated with impaired inhibitory control in IGD (Lee et al., 2015) and might therefore be a specific region for the mediation of emotional inhibitory control.

However, despite the seeming interrelation between inhibitory control and emotions, the neurobiological correlates of emotional inhibitory control have not been explored in IGD yet. **Therefore, it was the aim of study 2 to assess the neuropsychological and dACC-related neurobiological basis of anxiety and social anxiety-related emotional inhibitory control processing between controls and internet gaming addicts, as well as in relation to social network addicts.** The hypotheses in this study were initially deduced for both groups of internet addicts (i.e. addicts of internet games and social networks) and explored for the two subgroups compared to healthy controls in a second step. However, the focus of the presented thesis is on internet gaming addicts.

The following hypotheses were deduced:

Hypothesis 1:
Internet addicts (including addicts of internet games and social networks) show behavioral deficits in emotional inhibitory control, especially in relation to anxious stimuli.

Hypothesis 2:
Internet addicts (including addicts of internet games and social networks) have to make more inhibitory effort than controls, especially on socially anxious stimuli, and show altered dACC brain activation during social anxiety-related emotional inhibitory control.

3 METHODS

An overview of the methods applied in studies 1 and 2 is given in Table 1, with a more detailed instrument description below. Information about the sample characteristics is presented in the respective chapters of studies 1 and 2 (see chapters 4.1.3.1 and 4.2.3.1).

Table 1: Overview of the methods applied in studies 1 and 2

	Approach	Investigated characteristics	Instruments
Study 1	Psychometry	Diagnostic for IA	Checklist for the assessment of internet and computer game addiction (AICA-C)
		Assessment of the self-concept	Giessen-Test (GT)
	Neurobiology (fMRI)	Neurobiological correlates of the concepts of self, ideal and avatar	GT-derived paradigm to induce reflection on the self, ideal and avatar
Study 2	Psychometry	Diagnostics for IA	– AICA-C – Scale for online addictive behavior in adults (OSVe-S)
		Assessment of the self-concept	– Questionnaire for social anxiety and social competence deficits (SASKO) – Emotional competence questionnaire (EKF)
		Measure of impulsivity	Barratt impulsiveness scale (BIS)
		Further personality-related measures	– Perceived stress scale (PSS) – NEO-five factor inventory (NEO-FFI)
	Neuro-psychology	Emotional inhibitory control	– Affective Go/No-Go task (AGN) – Emotional Stroop task (EST)
	Neurobiology (fMRI)	Neurobiological correlates of emotional inhibitory control	EST-paradigm

In both studies the experimental procedure at the first appointment involved a screening for the inclusion and exclusion criteria, the assessment of personal and psychometric variables as well as the neuropsychological testing (AGN). At the second appointment in the ensuing week participants underwent the fMRI exam and completed further psychometric questionnaires.

3.1 Psychometry

3.1.1 Diagnostics for IA

3.1.1.1 Checklist for the assessment of internet and computer game addiction (AICA-C)

The AICA-C (Wölfling et al., 2012) is an established diagnostic clinical interview and assesses the severity of an individual's computer and/or internet addiction during the previous 30 days (AICA_30) as well as over the lifetime (AICA_lifetime) by recording computer or internet use behavior (e.g. "Is there any impairment in the personal area of life due to the usage of computer games/internet offers?"). It differentiates between normal and addicted use ($cutoff_{addicted\ use} \geq 13$).

3.1.1.2 Scale for online addictive behavior in adults (OSVe-S)

The OSVe-S (German designation: Skala zum Onlinesuchtverhalten bei Erwachsenen; Wölfling et al., 2008) is a self-report questionnaire investigating internet use-related characteristics and feelings (e.g. "Do you feel bad if you cannot be online?"). It differentiates between normal (score<7), abusive and addicted use ($cutoff_{addicted\ use} \geq 13.5$).

3.1.2 Assessment of the self-concept

3.1.2.1 Giessen-Test (GT)

The GT is a 36-item self-rating questionnaire for the exploration of specific self-concept facets including "social response" (i.e. an estimation of how one thinks to be evaluated by others), "dominance" (e.g. frequency of interpersonal conflicts), "self-control" (e.g. handling of one's finances, orderliness), "general mood" (i.e. hypomanic vs. depressive), "permeability" (i.e. open-mindedness vs. mistrust) and "social competence" (i.e. social skills), which correspond to six separate subscales à six statements (Beckmann, Brähler, & Richter, 1990). The answers are to be graded on a seven point rating scale. As the self-related items can be transferred to other perspectives, the GT was extended by an ideal condition (i.e. an evaluation of how an individual would like to be) and an avatar condition (i.e. an evaluation which traits one assigns to the own avatar) in order to be applied as an fMRI paradigm within study 1 (for details see chapters 3.3.5 and 4.1.3.3).

3.1.2.2 Questionnaire for social anxiety and social competence deficits (SASKO)

The SASKO (German designation: Fragebogen zu sozialer Angst und sozialen Kompetenzdefiziten; Kolbeck & Maß, 2009) was applied to specifically assess the fear of social situations such as to speak in front of others or to be in the center of social attention (subscale “speaking”), to be socially rejected (“rejection”) and to socially interact (“interaction”) as well as deficits in social perception (“information”) and feelings of loneliness (“loneliness”). The items are rated on a four point scale including the gradations “never”, “sometimes”, “often” and “mostly/always”.

3.1.2.3 Emotional competence questionnaire (EKF)

Emotional competence was assessed by means of the emotional competence questionnaire (German designation: Emotionale-Kompetenz-Fragebogen, EKF; Rindermann, 2009), which comprises 62 items that are rated on a five point Likert scale (ranging from “strongly agree” to “strongly disagree”). The questionnaire consists of four subscales measuring the constructs of a) recognizing and understanding one’s own emotions, b) recognizing and understanding the emotions of others, c) the ability to regulate and control one’s own emotions and d) emotional expressiveness. The total EKF score reflects a person’s self-rated emotional competence as a subdomain of their self-concept.

3.1.3 Measure of impulsivity

3.1.3.1 Barratt impulsiveness scale (BIS)

The BIS-11 (Patton, Stanford, & Barratt, 1995) was applied to record impulsivity. It is a self-report questionnaire composed of 3 subscales including attentional-, motor- as well as non-planning impulsiveness. The BIS comprises 34 items that are to be rated on a four point scale (“rarely/never”, “sometimes”, “often”, “mostly/always”).

3.1.4 Further personality-related measures

3.1.4.1 Perceived stress scale (PSS)

The PSS [Cohen, Kamarck, & Mermelstein, 1983; German translation: K. Ackermann, S. Hollweger & J. Gordon (native speaker), Central Institute of Mental Health Mannheim, Germany, 1999], a 10-item self-rating questionnaire in the original version, was utilized to assess the degree to which one feels stressed by life events or capable of their regulation and control. The questionnaire makes use of a five point rating scale (“never”, “almost never”, “sometimes”, “fairly often”, “very often”).

3.1.4.2 NEO-five factor inventory (NEO-FFI)

The NEO-FFI is a short version of the original NEO Personality Inventory (Campbell et al., 1996; P. T. Costa, Jr. & McCrae, 1985) and comprises 60 items divided into five separate subscales for the assessment of neuroticism, extraversion, openness, agreeableness and conscientiousness as facets of personality (P.T. Costa, Jr. & McCrae, 1989; Robins, Hendin, & Trzesniewski, 2001). The answers can be rated on a five point Likert scale including the gradations “strongly disagree”, “disagree”, “neutral”, “agree” and “strongly agree”. In the present work the NEO-FFI’s German version was applied (Borkenau & Ostendorf, 1993, 2008). The “neuroticism” subscale served as a measure for unpleasant or negative emotions such as anxiety (P. T. Costa, Jr. & McCrae, 1980).

3.2 Neuropsychology

3.2.1 Affective Go/No-Go task (AGN)

The AGN, first described in 1978 by Reynolds and Jeeves (Reynolds & Jeeves, 1978; Schulz et al., 2007), was developed from classical Go/No-Go paradigms that are used for the assessment of response inhibition (Costantini & Hoving, 1973; Schulz et al., 2007; White, 1981). Go and No-Go stimuli are presented in irregular order one after another for short durations of about 200-500 ms (Ding et al., 2014; Elliott, Rubinsztein, Sahakian, & Dolan, 2000; Ko et al., 2014; G. C. Liu et al., 2014). The response to Go stimuli, such as a button press, is supposed to be carried out as fast as possible, while the reaction to No-Go stimuli has to be inhibited. An increased presentation of Go cues (≥75 % in relation to No-Go cues) creates a prepotent response tendency (Ko et al., 2014). The latter has to be inhibited at No-Go cues. A failed inhibition, i.e. a button press to No-Go stimuli, is denominated as commission error and reflects impairments in response inhibition if conducted in high quantity (Schulz et al., 2007).

The growing awareness of the importance of emotions in response inhibition led to the development of affective Go/No-Go tasks, which are constructed by the replacement of the conventional stimuli by emotional ones and yield the same inhibition measure as their classical counterpart (Schulz et al., 2007). A German version of the task was applied in study 2 and included blocks of either positive, negative or anxious words as Go stimuli as well as neutral words as No-Go stimuli. The amount of commission errors (in study 2 corresponding to the amount of button presses to neutral words as No-Go stimuli) served as outcome measure and indicator for an individual’s emotional response inhibition ability as a facet of inhibitory control. More details on the applied task are given in chapter 4.2.3.3.

3.2.2 Emotional Stroop task (EST)

The EST is based on the classical Stroop paradigm, which was first described in 1935 (Stroop, 1935; Williams, Mathews, & MacLeod, 1996) and implies naming the color in which words that denote colors themselves are written (e.g. the word "green" might be written in red ink, so that pressing the red button would depict the correct response). The task comprises congruent as well as incongruent conditions, which are marked by a match or mismatch of word meaning and ink color, respectively [example for a congruent condition (match): The word “green” is written in green ink color; example for an incongruent (mismatch): The word “green” is written in red ink color]. Corresponding studies involving the classical Stroop paradigm reported longer RTs (as the primary outcome measure) for color naming in the incongruent condition; a phenomenon denoted as interference (Stroop, 1935; Williams et al., 1996). It reflects the ability to inhibit the disturbance of irrelevant information during cognitive performance (Aron et al., 2004; Miller & Cohen, 2001; Ridderinkhof, van den Wildenberg, Segalowitz, & Carter, 2004) and is therefore a measure for inhibitory control.

The emotional version of the task (i.e. EST) began to be applied in the 1970s and 1980s and served the exploration of interference in relation to emotional stimuli. This became an important basis for the understanding of emotional disorders such as anxiety or depression, where the inability to inhibit the automatically preferred processing of disease-related stimuli seems to play a major role (Williams et al., 1996).

A similar phenomenon is indicated by the results of Zheng (2008), exploring emotional inhibitory control in PIU by means of an EST: Addictive and pathological internet users (as diagnosed by Young’s criteria; K.S. Young, 1998) showed longer RTs (i.e. increased interference) during the color-naming of internet and emotion-related words, suggesting impairments in the processing of these stimuli and therefore reduced cognitive inhibitory control (Zheng, 2008).

Extending this approach to IGD and integrating previous study findings of significantly reduced inhibitory control and increased social anxiety levels in internet gaming addicts, study 2 served the exploration of the neurobiological correlates of emotional interference control in relation to socially anxious stimuli in internet gaming addicts by means of an EST with positive, negative, neutral as well as socially anxious word categories under simultaneous fMRI accomplishment (Witthöft et al., 2013; for details on the fMRI paradigm see chapters 3.3.6 and 4.2.3.4).

3.3 Neurobiology

3.3.1 The principle of MRI

Magnetic resonance imaging (MRI) developed from nuclear magnetic resonance (NMR; originally applied in basic chemistry research) and has its beginnings in 1973, where Paul Lauterbur developed a strategy to use NMR signals for the creation of cross-sectional images of the human body (Raichle, 2010). MRI is a non-invasive imaging technique applied in various medical fields such as preoperative planning (Stippich, 2013) and diagnostics (Heiss & Drzezga, 2014) as well as in research (Eickhoff & Bzdok, 2013). The technique makes use of the nuclear spin properties of hydrogen atoms' proton-nucleus in strong magnetic fields, which together with the protons' positive charge render it with a magnet vector (in the following referred to as "spin"; C. G. Roth & Deshmukh, 2017; Weishaupt, Koechli, & Marincek, 2009).

As a first step in the MRI procedure, a magnetic field is applied, for instance in z-direction. This causes the spins of the protons to undergo precession and to align to the direction of the applied magnetic field, either in parallel or antiparallel orientation. As the parallel orientation is preferred energy-wise, more spins are aligned in this orientation and form a small excess magnetization. The magnetic resonance (MR) signal is produced by means of a high frequency (HF) pulse that possesses the same frequency as the precession of the hydrogen atoms (i.e. Larmour frequency) and which deflects the initially longitudinal excess magnetization of the spins (in z-direction) into a different, e.g. transverse (xy-) plane to form a transverse magnetization. At this moment the deflected spins all have a synchronous precession, i.e. they have the same phase (phase coherence). Therefore, the transverse magnetization behaves like an electric current and induces alternating current voltage in a receiver coil, which is recorded as MR signal. The selective imaging of specific body regions is enabled by means of a slice selection gradient. It applies three magnetic field gradients (in x, y and z-direction) that overlap at the region of interest, rendering it as the only region all over the human body where the spins rotate with Larmour frequency and where thus the HF pulse leads to excitation.

The contrast of MR images is determined by two processes that occur after the HF pulse and which are independent of each other: The decay of the transverse and the rebuilding of the longitudinal magnetization (Weishaupt et al., 2009).

The transverse magnetization and therefore the MR signal decays due to the spins losing their phase coherence, i.e. their precession does not have the same phase anymore. This signal loss is described by the time constant T2 (in an ideal homogenous magnetic field), with T2* being the constant in an inhomogeneous magnetic field caused by the presence of the human body (Siemens-AG, 2001; Weishaupt et al., 2009). T2 is defined as the time needed for the MR signal to be reduced by 63 % (Ramani, 2014).

The rebuilding of the longitudinal magnetization is the second process occurring after an HF pulse and implies the disposal of excess magnetic energy from the spins to the environment (Weishaupt et al., 2009). This process is described by the time constant T1, denoting the time needed to rebuild 63 % of the original longitudinal magnetization in z-direction after an HF pulse (Ramani, 2014). Both time constants (T1 and T2*) have an influence on the image contrast.

The influence of T2* can be regulated by the echo time (TE), while the impact of T1 can be modulated by the repetition time (TR).

The TE denotes the time between an HF pulse and an echo. Echos depict the generation of another MR signal (although weaker as the original MR signal due to some loss of phase coherence) without a second HF pulse. In this work, echos were produced by means of the gradient echo technique, which (after the reception of the first MR signal) implies the fast destruction and re-establishment (de- and rephasing) of the spins' phase coherence in the xy-plane by means of two successively applied frequency gradients (rendering the spins' frequency to increase from one direction of the field to the other) with inverse polarity, leading to a second MR signal. In order to accelerate image acquisition several pairs of de- and rephasing frequency gradients can be applied successively in order to produce several echos (echo trains) after one HF pulse. This principle is known as echo planar imaging (EPI; Siemens-AG, 2001; Weishaupt et al., 2009). Taken together, T2*-weighing of an image is achieved by long TEs, as T2*-differences of the various tissues have more time to become apparent (Siemens-AG, 2001; Weishaupt et al., 2009). In a T2-weighted image, water produces high signals and appears bright, as it has long T2 times (which are conveyed by the fast movement of water molecules that prevents an effective interaction between the spins and leads to a slow dephasing; Hendrick, 2008; Herring, 2016; C. G. Roth & Deshmukh, 2017).

The influence of T1 on the image contrast can be regulated by TR, denoting the time between two HF pulses. T1-weighting implies short TRs of HF pulses, as tissue components with fast T1 relaxation give high signals (Weishaupt et al., 2009). In T1-weighted images, fat tissue appears bright as it has short T1 constants (conferred by the huge number of macromolecules in fat tissue that absorb energy from the excited spins and transfer them to a lower energy state, thereby enabling a faster rebuilding of the longitudinal magnetization in z-direction and a higher signal at a subsequent HF-mediated excitation; Gefter, 2009; Hendrick, 2008; Herring, 2016).

3.3.2 The principle of fMRI and the BOLD signal

Functional MRI (fMRI) is a neuroimaging technique used to explore brain function (Buxton, 2002) and came up around 1990 (D'Esposito, 2006; Ogawa, Lee, Kay, & Tank, 1990; Van Horn & Poldrack, 2009). It is based on the MR signal’s susceptibility to measures that are associated with neuronal activity (Pinus & Mohamed, 2006). Blood oxygenation level dependent (BOLD) – fMRI is the most explored fMRI method and makes use of hemoglobin’s oxygenation state (i.e. oxygenated or deoxygenated) in the blood. The oxygenation state of hemoglobin has an influence on the MR signal, since deoxyhemoglobin's free iron atoms render it magnetic properties that cause magnetic field inhomogeneities between the blood vessel and the surrounding tissue, which influence the spins of the surrounding protons by dispersing their phase coherence and therefore lead to signal reductions. Neuronal activity leads to a local increase of blood flow and oxygen levels, which surpass the actual need. The high concentration of oxyhemoglobin reduces both deoxyhemoglobin's concentration and the magnetic field inhomogeneities associated with it, entailing higher signal intensities relative to the surrounding tissue (Ogawa et al., 1990; Weishaupt et al., 2009).

3.3.3 Preprocessing of fMRI data

As an initial step, usually the first 4-5 (Grüsser et al., 2004; McClernon, Kozink, Lutz, & Rose, 2009) volumes (the term “volume” refers to the sum of images, i.e. scans, acquired together at one measurement time point; Müller & Kassubek, 2008; Smith, 2004) are rejected in order to account for the time needed to increase the magnetic field homogeneity at the beginning of a measurement (Ritter, Franz, Dietrich, Miltner, & Weiss, 2013). To compensate for the sequential scanning process, implying a delay in the scanning of slices relative to each other and therefore rendering a comparison of their activation impossible, images have to be temporally realigned by means of a slice-time correction. This is achieved by resampling the data and shifting them to a reference time point. In case the resampling involves a time point between two measurement time points, linear interpolation is applied (Goebel, 2015). For the achievement of a more constant voxel location throughout the scans of one participant, obtained images are spatially corrected and realigned relative to the mean of all images of the respective participant (which serves as the individual template) by means of a motion correction. Motion algorithms iterate the motion parameters for translation and rotation to fit each image as accurate as possible to the template (Goebel, 2015). Images are then spatially normalized in order to enable inter-subject comparisons of brain activation patterns despite individual brain anatomy (Ashby, 2011). Spatial normalization comprises the fitting of every individual’s brain to a standardized brain template [mostly the standard EPI-template of the Montreal Neurological Institute (MNI) brain atlas; Brett, Johnsrude, & Owen, 2002] by means of size (linear or affine transformation algorithms) and shape (local stretching and shrinking: Non-linear transformation algorithms) adaptations. This implies, however, that voxel sizes and therefore their intensities are also changed (Ashby, 2011). Thus, a subsequent spatial smoothing step is conducted, accentuating extended brain activations and reducing noise (Kriegeskorte, Goebel, & Bandettini, 2006): Smoothing implies the convolution of the images with a Gaussian kernel function, which for each voxel calculates a weighted average value across the neighboring voxels that then replaces the original value of the specific voxel (Ashby, 2011). Thereby, the Gaussian kernel serves as a filter for the activation signal by having the same size and shape as the signal, while the noise is removed (Kriegeskorte et al., 2006).

3.3.4 Statistical analyses of fMRI data

3.3.4.1 First level analysis

It is the aim of fMRI to explore brain activity in response to certain experimental tasks (Friston, Jezzard, & Turner, 1994). Therefore, after preprocessing, fMRI data are statistically modeled individually for each participant at the voxel-basis by means of the general linear model (GLM), which expresses the assumption that the brain activations in fMRI are linearly related to the experiment effects at each voxel (Bénar, Bagshaw, & Lemieux, 2010). Given the complexity of the data, the latter are expressed as matrices (Haase, 2011; see Equation 1):

$$Y = X\beta + e$$

Equation 1: The general linear model

Y=Data matrix, X=Design matrix, β=Matrix of voxel values for all factors in X, e=Matrix of noise or residual errors. The data matrix Y contains the measured data. The design matrix X describes the design of the experiment and contains the time courses of all factors that are assumed to modulate the BOLD signal, i.e. explanatory variables such as the different conditions of the applied fMRI paradigm (Ashby, 2011; Y. M. Wang, Schultz, Constable, & Staib, 2003). The β-matrix contains voxel values for each hypothesized factor in X and has to be estimated by least square estimation (Y. M. Wang et al., 2003).

In order to detect the cognitive task-specific brain activation within the fMRI data and to differentiate these signals from noise (Friston et al., 1995), temporal basis functions including the hemodynamic response function (HRF) are applied that model evoked responses in fMRI (Friston, 2002). The HRF is the hypothetical BOLD response to an idealized impulse of neural activation (Ashby, 2011) and may vary from voxel to voxel as well as between brain regions (Friston, 2002). The HRF is convolved with a stimulus function (encoding the supposed neuronal responses), resulting in a regressor that is entered into the design matrix (Friston, 2002). Thus, the accommodation of the HRF into the GLM (Calhoun, Stevens, Pearlson, & Kiehl, 2004; Friston, 2002) serves the prediction of a BOLD response as a prerequisite for the identification of active brain regions (Wallisch et al., 2009).

It is then to be explored whether there exists a functional relationship between the measured data in Y (i.e. the BOLD signal) and the explanatory variables in X (e.g. conditions of the applied fMRI paradigm). Thereby, β is unknown and has to be estimated by least square estimation (Poldrack, Mumford, & Nichols, 2011). It indicates the degree of influence of a certain predictor, e.g. paradigm condition, upon the respective voxel value (Goebel, 2015).

In order to explore which conditions have a significant effect upon brain activation, the voxels' β-values in the GLM are compared between different paradigm conditions by means of t-tests. These comparisons are referred to as contrasts and are delineated in a contrast vector (Friston, Holmes, et al., 1994). The exploration of each contrast results in a whole-brain statistical parametric map (SPM) of t-values (SPM {T}; Friston, Holmes, et al., 1994). Each statistical map therefore indicates regionally specific responses to experimental conditions (Friston, Holmes, et al., 1994). Voxels within the SPM then need to be statistically tested for significance (i.e. for significant difference relative to another condition) by means the Student's t-test or the F-test (Kontos, Megalooikonomou, & Makedon, 2004). However, the huge number of statistical tests that are necessary to test all voxels increases the probability of falsely defining the activation of a voxel as significant (type I error; Nichols & Holmes, 2004; Worsley, Evans, Marrett, & Neelin, 1992). As a method for counteraction, the threshold p above which voxels are defined as significantly activated needs to be raised to a level that results in an appropriate rate of false-positive voxels (Brett, Penny, & Kiebel, 2004). In addition, dependent statistical tests need to be applied in order to consider the interrelation between neighbored voxel values (Flandin & Novak, 2013; Worsley et al., 1992). The family-wise error rate (FWE) is a statistical testing method taking both issues into account (Gamer, 2011) and corresponds to the probability of falsely defining one or more voxel as activated over the whole search volume (e.g. whole brain; Flandin & Novak, 2013). It can be controlled by the random field theory, where the p-value is a function of the search volume and the smoothness of the data (i.e. the interrelation of neighboring voxels due to the smoothing during preprocessing; Flandin & Novak, 2013) and where statistically significant activations are detected by the Euler characteristic that indicates sets of voxels with a value higher than a given threshold (rather than by local maxima; Worsley et al., 1992).

3.3.4.2 Second level analysis

The individual statistical maps of brain activation (i.e. first level output) are then subjected to within and between-group comparisons (i.e. second level analysis; Ashby, 2011; Penny & Henson, 2007). They involve the statistical voxel-by-voxel comparison either within the group (i.e. comparing different paradigm conditions in their effect on brain activation across individuals within a group) or between the groups (i.e. comparison of one paradigm condition; Goebel, 2015). Again, the results are depicted in an SPM (Ashby, 2011).

Brain regions whose involvement in the process of investigation is hypothesized a priori can be statistically analyzed for significant activation by means of region of interest (ROI) analyses. The selection of ROIs limits the number of statistical tests as there are less voxels, which reduces the probability of type I errors (Poldrack, 2007), i.e. to falsely defining the activation of a voxel as significant.

3.3.5 Giessen-Test (GT)-derived paradigm

As delineated above, the self-related perspective in the GT (as a means for the exploration of the self-concept; Beckmann et al., 1990; see chapter 3.1.2.1) was extended by an ideal as well as an avatar condition and applied as fMRI paradigm for study 1. A schema of the paradigm's sequence is given in chapter 4.1.3.3. First, there was announced the condition to which the subsequent statements were to be referred to (i.e. self, ideal or avatar). Then, the six statements were read and evaluated on a rating scale by the participant one after another, before the next condition was announced. The task was self-paced, i.e. the answering time depended on the individual participant's rating speed. The average paradigm duration amounted to 20 minutes. All blocks and conditions were presented in randomized order, while the sequence of the statements within a condition remained the same.

3.3.6 Emotional Stroop task (EST) paradigm

As described above, an EST with positive, negative, neutral as well as socially anxious words was applied as fMRI paradigm in study 2. The word stimuli were selected from a corpus of 486 emotional and neutral German adjectives, which had been rated for valence and arousal by a sample of N=45 students before (Herbert, 2006). It was ensured that the selected stimuli significantly differed in valence and arousal between the word categories of the EST paradigm and that there were no significant differences across categories regarding word length and frequency in the German language (as assured by corresponding inquiries in the corpora of the Institute for German Language; Institut für Deutsche Sprache, IDS). An overview regarding task design is given in Figure 2.

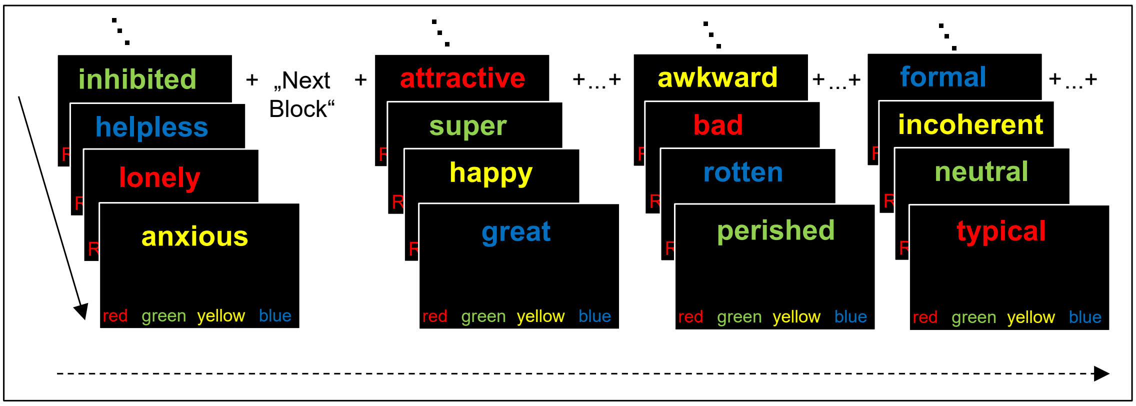

Figure 2: Sequence of the EST paradigm

The start of each block was announced by a corresponding notification on the testing screen ("Next Block"). Then, 10 different words per category (forming one block) were presented in different colors one after another in the middle of the screen, while the color assignment to the four buttons was displayed throughout the task at the bottom of the screen in smaller writing. Participants were asked to press the respective button representing the color of each appearing word's writing as fast as possible. After each block, a short notification for the beginning of the next block was displayed, followed by 10 words of another category (for further details on task design see chapter 4.2.3.4).

4 THE STUDIES

4.1 Study 1: Avatar’s Neurobiological Traces in the Self-Concept of Massively Multiplayer Online Role-Playing Game (MMORPG) Addicts[1]

[1]Published as:

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4.1.1 Abstract

Psychometric studies suggest that observed self-concept deficits in addicted massively multiplayer online role-playing game (MMORPG) players are compensated through the replacement of their ideal (i.e., how an individual would like to be) by their own avatar (i.e., graphical agent in the virtual world). Neurobiological studies indicate that increased identification with their own avatar in regular MMORPG gamers is possibly reflected by enhanced avatar-referential brain activation in the left angular gyrus (AG). However, the neurobiological correlates reflecting the relations of the avatar to addicted gamers' self and ideal are still unexplored. Therefore, we compare these relations between addicted and non-addicted MMORPG gamers. A sample of n=15 addicted and n=17 non-addicted players underwent functional MRI (fMRI) while completing a Giessen-Test (GT)-derived paradigm assessing self-, ideal-, and avatar-related self-concept domains. Neurobiological analyses included the comparisons *avatar versus self, avatar versus ideal,* and *avatar versus self, ideal*. Psychometrically, addicts showed significantly lower scores on the self-concept subscale of "social resonance", that is, social popularity. In all avatar-related contrasts, within-group comparisons showed addicted players to exhibit significantly higher brain activations in the left AG. The between-groups comparisons revealed avatar-related left AG hyperactivations in addicts. Our results may suggest that addicted MMORPG players identify significantly more with their avatar than non-addicted gamers. The concrete avatar might increasingly replace the rather abstract ideal in the transition from normal- controlled to addictive-compulsive MMORPG usage.

Keywords: massively multiplayer online role-playing games, identification with avatars, self-concept

4.1.2 Introduction

After the internet becoming publicly available during the early 1990s, the number of internet users rose to connect about a quarter of the world's total population today (Choi & Han, 2013; Petersen et al., 2009; Sagan & Leighton, 2010). Accordingly, the significance of internet overuse gains increasing importance, as reflected by the condition's uptake into the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) as "internet gaming disorder" (IGD), a "condition warranting more clinical research and experience" [see section III; American Psychiatric Association (APA), 2013]. Although not entirely classified based on the DSM-5 due to insufficient research, hitherto literature refers to the condition as "internet gaming addiction", what shall be adopted here.

Massively multiplayer online role-playing games (MMORPGs), the most prevalent sub-category of online gaming addiction, take up an outstanding role (Leménager et al., 2013;

Petersen et al., 2009). With their characteristics of being socially interactive, endless and time-consuming, as well as by enabling fast achievements and adventures unmet by real life, MMORPGs have addictive potential (Bessière et al., 2007; Charlton & Danforth, 2010; Smahel, Blinka, & Ledabyl, 2008). These online role-playing games can be understood as virtual worlds in which several players engage and interact via their graphical agent (avatar), who possesses a specific set of powers and skills. The particular configuration of avatar characteristics such as gender, race (e.g. dwarf, elf, human), class (e.g. shaman, priest), appearance and name is chosen by the player prior to the start of the game.

Previous psychometric studies suggest that MMORPG addicts have self-concept deficits that might be compensated by the own avatar (Bessière et al., 2007; Davis, 2001; Leménager et al., 2013). Thus, the avatar seems to be constructed towards the gamer's ideal (Bessière et al., 2007; Leménager et al., 2013). The self-concept is defined as an individual's perception of his or her skills, interests, desires, emotions, values, actions and physical attractiveness (Deusinger, 1996). Self-concept deficits might cause addicts to minimize social interactions and increasingly seek refuge in the internet's anonymity. This can lead to a vicious circle of computer- and internet overuse likely to culminate in social isolation, loneliness and depression (Shaw & Black, 2008).

Neurobiologically, the cognitive domain of the self-concept has been assessed in healthy participants by means of self-reflection or autobiographical reasoning paradigms. In particular, the medial prefrontal cortex (MPFC), mainly Brodmann areas (BAs) 8/9/10/32, was observed to be one of the main areas involved in the processing of self-related information such as the assignment of values to self-relevant information (D'Argembeau et al., 2012), as well as the reflection on personal significance and implications of autobiographical memories (D'Argembeau et al., 2013). In addition, self-concept-related activations were found in the inferior frontal gyrus (IFG), the inferior parietal gyrus [mainly the angular gyrus (AG), BA 39] as well as the precuneus (BA 7; D'Argembeau et al., 2013; Jenkins & Mitchell, 2011; Kelley et al., 2002; Northoff et al., 2006; Pfeifer, Lieberman, & Dapretto, 2007; C. Sebastian, S. Burnett, & S. J. Blakemore, 2008). In their corresponding study, D'Argembeau et al. (2007) induced self-reflection by means of a self-referential processing paradigm, asking participants to judge the extent to which trait adjectives were descriptive of themselves, a close friend or of themselves viewed from the third person perspective of their close friend. The results revealed an influence of judgment perspective on brain activation during self-reflection in the precuneus and left inferior parietal lobe (D'Argembeau et al., 2007). One main component of the inferior parietal lobe is the AG (Seghier, 2013), which seems to be associated with self-identification processing and distinguishing self from others (Decety & Chaminade, 2003; Decety & Grezes, 2006; Gazzaniga, 2008; Lamm, Batson, & Decety,

2007). In long-term regular MMORPG gamers, Ganesh et al. (2011) found increased activations in the left AG during the reflection about their avatar relative to self, close friends and distant others. Based on the previous findings regarding the left AG, the authors concluded a strong degree of self-identification in regular MMORPG gamers with their own avatar (Ganesh et al., 2011). However, the existence and severity of internet gaming addiction in these study participants have not been assessed, rendering the transfer of results to addicted MMORPG players impossible. One recent study on addicted gamers reported significantly higher brain activation in the left AG during the visual perception of their own avatar than when viewing their real self as well as unknown persons (Leménager et al., 2014), supporting the association of the left AG with MMORPG addiction. Previous psychometric studies on self-concept and identification with the own avatar in MMORPG addiction additionally included the evaluation of the ideal on self-concept-related scales in order to assess the ideal's relation to self and avatar (Bessière et al., 2007; Leménager et al., 2013). Since these findings suggest that the avatar becomes a more tangible version of the ideal, its neurobiological consideration seems to have a high relevance in the development of a multimodal explanatory model for the role of the avatar in MMORPG addiction.
However, the neurobiological correlates reflecting the relations of the avatar to addicted gamers' self and ideal during referential processing are still unexplored. Therefore, we compare these relations between addicted and non-addicted online role-playing MMORPG gamers.

Given the result of enhanced avatar-referential brain activity in the left AG of long-term MMORPG gamers (Ganesh et al., 2011) as well as an increased bilateral AG activation in addicted MMORPG players upon the perception of their own avatar (Leménager et al., 2014), the AG seems to play an important role in MMORPG addiction. Therefore, among other regions implicated in self-related processing, we focus on the AG and hypothesized that addicted MMORPG players would also exhibit higher brain activations during the reflection on their own avatar compared to the self in the left AG.
Given the avatar's psychometric resemblance to the ideal, we assumed addicted players to show similar neurobiological brain activations during the reflection on their avatar compared to their ideal in the left AG. Non-addicted gamers were assumed to exhibit higher brain activations during the reflection on their ideal relative to their avatar in this region, as they psychometrically rated their ideal to be superior to their avatar and showed a higher discrepancy between these two conditions compared to addicted gamers (Leménager et al., 2013).

4.1.3 Methods

4.1.3.1 Participants

After the study's approval by the local ethics committee (application number 2012-214N-MA), n=15 right-handed addicted MMORPG players and n=17 right-handed non-addicted controls were recruited through the local day hospital at the Central Institute of Mental Health in Mannheim and advertisements, respectively. Prior to the study participation, all participants were informed about the procedures and provided written informed consent according to the Declaration of Helsinki. Participants did not exhibit other axis-I psychiatric disorders or substance use disorders apart from nicotine dependence, were free of current psychotropic medication and had normal or corrected-to-normal vision. Screening for comorbidities was conducted by means of the Structured Clinical Interview for DSM-IV (SCID I and II; Wittchen, Zaudig, & Fydrich, 1997). The groups did not significantly differ in age, gender or education (see Table 1). Group-assignment was based on an interview with an experienced psychologist and the obtained score on the checklist for the Assessment of Internet and Computer game Addiction, reflecting an individual's computer and internet behavior within the previous 30 days (AICA_30; Wölfling et al., 2012; see below). The mean degree of addiction severity in the addicted group amounted to $AICA\_30_{Addicts}$=18.53±7.55, while non-addicted controls had a score of $AICA\_30_{Non\text{-}addicted}$=1.59±2.21. Addicted participants showed significantly longer periods of computer and internet use per day (h/day; see Table 1).

Table 1: Sample characteristics
MMORPG=Massively multiplayer online role-playing game, AICA_30=Addiction severity assessed based on the previous 30 days, SD=Standard deviation, χ²=Chi-Square test statistic, t=Independent samples t-test statistic, z=Mann-Whitney U test statistic, F=Fisher's exact test

	Total (N=32)	Addicted MMORPG players (n=15)	Non-addicted gamers (n=17)	Test-statistic	p-value
Gender (n=male)	26 (91.68 %)	13 (98.05 %)	13 (97.79 %)	5.44	$.39^F$
Age (SD)	26.72 (6.30)	28.73 (7.73)	24.94 (4.16)	-1.76^t	.11
Education ≤ 10 years	3 (n=29)	3 (n=13)	0 (n=16)		$.08^F$
Computer-/internet-use (Ø h/ day; SD)	4.25 (2.93) (n=27)	6.29 (2.09) (n=14)	2.05 (1.94) (n=13)	-3.86^z	<.001
AICA_30 (SD)	9.53 (10.10)	18.53 (7.55)	1.59 (2.21)	-4.89^z	<.001

At the first appointment, it was ensured that participants fulfilled the inclusion and exclusion criteria and met other general screening standards (age, gender, comorbidities as well as computer and internet use behavior). During the second appointment, participants performed the Giessen-Test (GT) during functional Magnetic Resonance Imaging (fMRI; for paradigm description see chapters 3.3.5 and 4.1.3.3). The whole group of the non-addicted and n=14 participants of the addicted gamers were World of Warcraft (WoW) players, while two participants within the group of the addicted gamers were League of Legends (LoL) gamers.

4.1.3.2 Psychometric instruments

The AICA_30, an established diagnostic interview, was applied to assess participants' severity of computer and internet addiction by investigating their habits of computer and internet use over the previous 30 days. Participants exhibiting an AICA_30-score of ≥7 were assigned to the group of addicted MMORPG gamers, while a lower score was indicative of affiliation to the non-addicted controls (Wölfling et al., 2012). For a description of the GT, see below.

4.1.3.3 Paradigm

The fMRI paradigm applied in this study was carried out in block design and was derived from the GT, a self-concept questionnaire showing high internal consistency estimates (0.86), good test-retest reliability scores (0.65 to 0.76) and high validity (Klaiberg, 2002; M. Roth, Körner, & Herzberg, 2008; Wischmann, 2002). It is a 36-item self-rating scale, where participants are asked to evaluate the extent to which they associate specific personality traits with their "self" and their "ideal" by responding to a bipolar scale ranging from -3 to 3. For the purpose of this study, identical items were added for the evaluation of the participants' avatars (see also Leménager et al., 2013). The GT consists of six subscales measuring the extent of participants' "social response" (i.e. 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" (i.e. hypomanic v. depressive), "permeability" (i.e. open-mindedness v. mistrust) and "social competence" (i.e. social skills).

Every block of the paradigm included the items of one GT-subscale per condition (self, avatar or ideal). All blocks and conditions were presented in randomized order, while the sequence of the statements within a scale remained the same. Taken together, 108 statements had to be rated by each participant within the GT (three conditions comprising six scales each, with each scale containing six statements). The total paradigm duration depended on participants' individual rating speed and approximated 20 minutes on average. In order to become familiar with the key pad-mediated rating, all participants conducted a standardized practice trial in the scanner prior to starting the actual task. Within the paradigm, the category of each condition (i.e. self, ideal or avatar) was displayed first. This was then followed by a fixation cross, a GT-statement and the respective rating scale (labeled on both ends) where the cursor could be moved for answer selection. Thereafter, another fixation cross was presented prior to the next statement of a scale. Conditions were announced for 2 seconds, fixation crosses were shown for 1.5-2.5 seconds within the blocks (randomized intervals) and for 2 seconds between the blocks (see Figure 1).

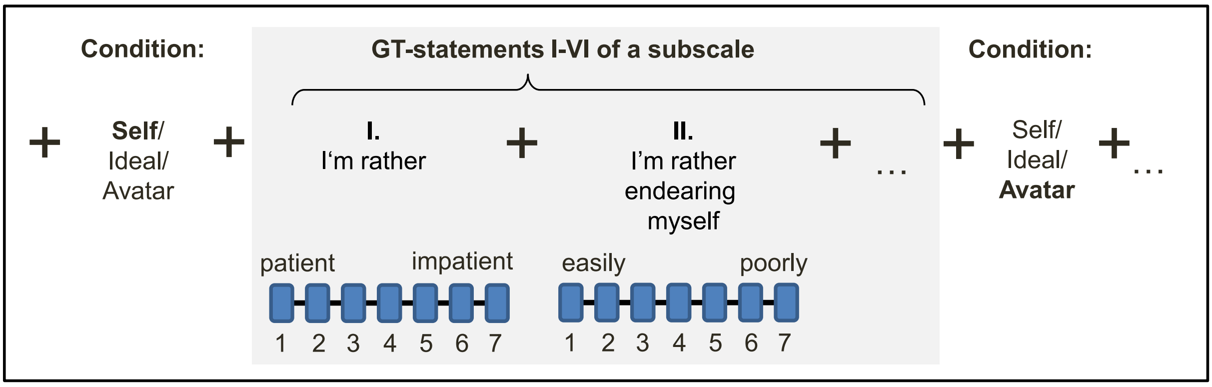

Figure 1: Schematic concept of the fMRI GT-paradigm

4.1.3.4 fMRI

The scanning sessions were conducted at a 3 Tesla whole-body tomograph (Trio; Siemens, Erlangen, Germany). Functional whole-brain images were collected under the application of 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 x 220 mm, matrix size 64 x 64, 36 slices, slice thickness 3.00 mm, distance factor=33 %, voxel size=3.4 x 3.4 x 3.0 mm]. The number of acquired functional volumes varied between participants (with an average of 426.5 ± 49.83 volumes; the maximum was set to 1000 volumes per participant) and depended on the individual rating pace of GT-statements. Structural images were acquired by means of a T1-weighted magnetization prepared rapid gradient echo (MPRAGE) sequence (TR=2300 ms, TE=3.03 ms, FA=9°, FOV=256 mm x 256 mm, 192 slices, slice thickness 1.00 mm, distance factor=50 %, voxel size=1 x 1 x 1 mm) in order to exclude participants exhibiting brain abnormalities. The correction of magnetic field inhomogeneity was mediated by the automated Siemens multi-angle projection (MAP)-Shim. The registration of scanner triggers as well as the recording of behavioral responses was accomplished by the Presentation® software (Version 16.3, Neurobehavioral Systems, Inc., Albany, CA, USA). Task presentation in the scanner was mediated by digital goggles (Resonance Technology, Inc., Los Angeles, California).

4.1.3.5 Statistical analyses

4.1.3.5.1 Psychometric data

Psychometric data analyses were accomplished by means of SPSS Statistics 20 (Statistical Package for the Social Sciences, SPSS Inc, Chicago, IL, USA; Release 20.0.0). After having checked the variables for normality, within and between-group differences were assessed with parametric paired and unpaired t-tests (normally distributed variables) or via non-parametric Wilcoxon signed rank and Mann-Whitney U tests (non-normally distributed variables), respectively.

4.1.3.5.2 Neurobiological data

For neurobiological evaluations, Statistical Parametric Mapping (SPM, version SPM 8, Wellcome Trust Centre for Neuroimaging, University College London, London, UK) was utilized at the basis of Matlab R2012b (The MathWorks, Inc., Natick, MA, USA). First level analyses included the evaluation of effect estimations for the three conditions (i.e. self, ideal, and avatar) by applying the general linear model on a voxel-by-voxel basis as well as the calculation of individual contrast images of condition-specific mean brain activation. During second level analyses, the individual contrast images were compared for significant differences in blood oxygenation level dependent (BOLD) responses within and between the groups for the specific contrasts (*avatar vs. self* for our first hypothesis; *avatar vs. ideal* and *avatar vs. self, ideal* for our second hypothesis) based on one- and two-sample t-tests. An underlying threshold of $p<.001$ as well as an extent threshold of 10 voxels were applied and results were reported at a cluster threshold of $p_{FWE}\leq.05$ (the subscript "FWE" denotes the family wise error rate). The Automatic Anatomical Labeling (AAL)-toolbox of SPM was applied for the assignment of significantly activated clusters to their respective brain regions. The detection of Brodmann areas (BAs) was conducted via the xjview-toolbox (run under Matlab). Activation maps were displayed by means of Chris Rorden's MRIcro brain image viewer in neurological convention (i.e. left=left, right=right). Hypotheses-driven region of interest (ROI) analyses were conducted for the left AG (underlying threshold $p\leq.001$, reported at $p_{FWE}\leq.05$ on cluster level) by means of a mask generated by the WFU PickAtlas (Maldjian, Laurienti, & Burdette, 2004; Maldjian, Laurienti, Kraft, & Burdette, 2003).

4.1.4 Results

4.1.4.1 Psychometric data

4.1.4.1.1 GT-ratings

The mean rating time amounted to 5.75 ± 1.02 s and did not differ significantly between the groups ($t=-1.61$, $p=.117$). Furthermore, a repeated measures analysis with condition as the within-group factor revealed no significant interaction effect between group and category. There only was a significant condition effect [$F(2,62)=3.229$; $p=.046$)], where contrasts showed a difference between self and ideal ($F=5.51$, $p=.025$). In the overall sample, the reaction time (RT) for the self-related ratings ($Mean_{RT,self}=5.69 \pm 0.18$ s) was significantly faster than for the ideal ($Mean_{RT,ideal}=6.07 \pm 0.23$ s), while the observed mean RT for self and avatar was similar ($Mean_{RT,avatar}=5.70 \pm 0.18$ s). Addicted MMORPG players were found to rate the social response of their self significantly lower than non-addicted controls (see Table 2).

Table 2: Comparison of between-group differences for the evaluation of the social response (Mann-Whitney U)

Condition	Controls	Patients	z-value	p-value
Ideal	36.24 ± 3.33	34.60 ± 5.45	-0.42	.677
Self	31.59 ± 4.00	25.47 ± 5.62	-3.15	.002
Avatar	26.82 ± 6.44	30.60 ± 5.03	-1.27	.204

Within-group statistical analyses of the social response ratings revealed divergent ranking hierarchies for the conditions of self and avatar: while non-addicted players assigned higher values to their self than to their avatar [Friedman Test, $\chi^2=17.28$, $p<.001$; post-hoc Wilcoxon test (Bonferroni-corrected, $\alpha=.017$) $z=-2.73$, $p=.006$], addicted gamers rated their avatar to be superior to their self [Friedman Test, $\chi^2=15.76$, $p=<.001$; post-hoc Wilcoxon test (Bonferroni-corrected, $\alpha=.017$) $z=-3.05$, $p=.002$]. We further observed significant differences in the non-addicted group between the avatar and the ideal (Bonferroni-corrected, $\alpha=.017$, $z=-3.47$, $p=.001$) as well as between ideal and self (Bonferroni-corrected, $\alpha=.017$, $z=-3.01$, $p=.003$). The addicted group showed significantly lower scores for the self in relation to their ideal (Bonferroni-corrected, $\alpha=.017$, $z=-3.17$, $p=.002$), but there was no significance between the avatar and the ideal (Bonferroni-corrected, $\alpha=.017$, $z=-1.91$, $p=.056$).

4.1.4.1.2 Correlations with the severity of addiction

Within the group of addicted MMORPG players, no significant correlation between a GT-subscale and the severity of addiction was found. However, the GT-ratings for the social response of the self was negatively associated with the severity of addiction (AICA_30) in the overall sample (r=-.469, p=.007).

4.1.4.2 Neurobiological data

4.1.4.2.1 Self-reflection

In the overall sample, analyses regarding the three self-focused contrasts (*self vs. avatar; self vs. ideal* and *self vs. avatar, ideal*) only revealed significant self-related brain activations relative to the ideal in the MPFC, IFG and inferior parietal lobule. In the opposite contrast comparable significant activations were observed (Table 3).

Table 3: Within-group brain activations for the contrast *self vs. ideal* in the overall sample
H=Hemisphere, L=Left, R=Right, BA=Brodmann area, MNI=Montreal Neurological Institute, $p_{cluster}$=FWE-corrected p-values reported on cluster level (p_{FWE}<.05)

H	Lobe	BA	Brain region	Cluster size	MNI coordinates x	y	z	t_{max}	$p_{cluster}$
Self>ideal									
R	Frontal	8, 9, 10, 45, 46	MPFC, IFG	1182	34	22	50	5.63	≤.001
R	Frontal	10, 11	MPFC, IFG	182	30	52	-8	4.51	.036
R	Parietal	40	Inferior parietal lobule	176	56	-38	44	4.42	.040
Ideal>self									
L	Frontal	9, 10, 11, 24, 32	MPFC, anterior cingulate, orbitofrontal cortex	1027	- 8	58	-8	5.85	≤.001
L	Parietal/ occipital	31, 23	Precuneus (L+R), posterior cingulum, calcarine, cuneus	389	-8	-56	12	5.77	.001

4.1.4.2.2 Avatar-reflection

In accordance with our first hypothesis, addicted MMORPG players exhibited significantly higher brain activations during the reflection of their avatar compared to their self (contrast *avatar>self*) in the AG (bilaterally, among others, see Table 4), while no significant brain activations were found in the control group for this contrast.

Table 4: Within-group brain activations for the contrast *avatar>self* in addicted MMORPG players
H=Hemisphere, L=Left, R=Right, BA=Brodmann area, MNI=Montreal Neurological Institute, $p_{cluster}$=FWE-corrected p-values reported on cluster level (p_{FWE}<.05)

H	Lobe	BA	Brain region	Cluster size	MNI coordinates			t_{max}	$p_{cluster}$
					x	y	z		
L	Temporal/ parietal/ occipital	22, 39, 40, 7, 19	MTG, AG, inferior parietal gyrus, middle occipital gyrus	1345	-40	-58	30	9.48	≤.001
R	Temporal/ parietal/ occipital	39	Middle and superior temporal gyrus, AG, middle occipital gyrus	203	38	-64	22	6.37	.009
L/ R	Parietal	31, 23, 30	Middle and posterior cingulum, precuneus	246	6	-40	28	4.85	.003

The explorative between-group comparison revealed addicted gamers to exhibit significantly higher brain activation in the left IFG [t=4.38, Montreal Neurological Institute (MNI) coordinates=-40 18 24, p_{FWE}=.036, $\#_{voxel}$=169, see Figure 2] compared to non-addicted controls. In line with our first hypothesis, an ROI analysis in the left AG revealed significantly higher avatar-related activations relative to self-reflection in the group of addicted gamers ($ROI_{left\ AG}$; $\#_{voxel}$=16; MNI=-38 -66 42; $p_{FWE,cluster}$=.043, see Figure 2).

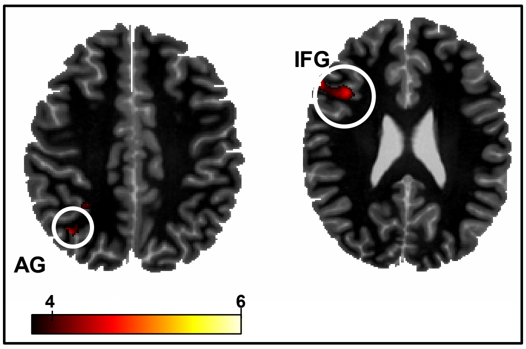

Figure 2: Axial view of brain activations in addicted- relative to non-addicted MMORPG players for the contrast *avatar>self*
in the left IFG (right image, z=25) as well as in the left AG as our region of interest (left image, z=45); brain-extracted chi-square template in MNI space with SPM contrast image-overlay: p_{uncorr}<.001, T=3.39, $\#_{voxel}$≥10

We further predicted addicted MMORPG players to exhibit similar brain activation patterns during the reflection on their own avatar and their ideal in the left AG. However, in contradiction to this prediction, our results revealed addicted gamers to exhibit significantly higher brain activations during the avatar condition relative to ideal in this self-reflection-associated region (see Table 5).

Table 5: Within-group analyses for the comparison of the conditions *avatar* vs. *ideal* showing significantly higher brain activations in addicted (for *avatar>ideal*) and non-addicted (for *ideal>avatar*) MMORPG players. H=Hemisphere, L=Left, R=Right, BA=Brodmann area, MNI=Montreal Neurological Institute, $p_{cluster}$=FWE-corrected p-values reported on cluster level (p_{FWE}<.05)

H	Lobe	BA	Brain region	Cluster size	MNI coordinates x	y	z	t_{max}	$p_{cluster}$
Addicted MMORPG players									
Avatar>ideal									
L	Temporal/ parietal/ occipital	22, 39, 19	MTG, AG, middle occipital gyrus	805	-42	-66	26	9.60	≤.001
L	Parietal/ occipital	31, 23, 30, 7, 29	Precuneus (L+R), middle and posterior cingulum (L+R), calcarine (L+R), cuneus (L+R), lingual gyrus	1028	-8	-54	14	7.62	≤.001
L	Temporal	36, 20, 37	Fusiform gyrus, parahippocampal gyrus, hippocampus	188	-28	-34	-20	6.31	.012
Ideal>avatar									
--									
Non-addicted MMORPG players									
Ideal>avatar									
L	Frontal	46, 9	Inferior and middle frontal gyrus, precentral gyrus	623	-34	10	26	8.49	≤.001
R	Frontal	9, 46, 8, 10, 6	MPFC, middle, inferior and superior frontal gyrus	1429	30	20	54	7.99	≤.001
R	Parietal	40, 2, 7, 39	Inferior and superior parietal gyrus, supramarginal gyrus, AG, postcentral gyrus	1084	54	-36	46	6.99	≤.001
L	--		Pallidum, thalamus	135	-16	-4	-2	6.90	.045
L	Parietal	40, 7; 39	Inferior and superior parietal gyrus, AG, precuneus	565	-36	-60	48	6.49	≤.001
Avatar>ideal									
--									

The result for non-addicted controls was in concordance with our second assumption, which proposed a significant discrepancy in brain activation patterns between the ideal and the avatar: The group showed significantly higher brain activations in the bilateral AG during the reflection of their ideal in relation to their avatar (*ideal>avatar*, see Table 5).

The respective between-group comparison (*avatar>ideal*) revealed significant group differences. Contrary to our second hypothesis, addicted gamers exhibited higher brain activations during avatar-related reflection in the left AG (left-lateral, among others, see Table 6 and Figure 3).

Table 6: Between-group comparison for the contrast *avatar>ideal*
showing significantly higher brain activations in addicted MMORPG players during avatar-related reflection relative to ideal. Non-addicted gamers did not exhibit higher brain activation during avatar-related reflection in any region. H=Hemisphere, L=Left, R=Right, BA=Brodmann area, MNI=Montreal Neurological Institute, $p_{cluster}$=FWE-corrected p-values reported on cluster level (p_{FWE}<.05)

H	Lobe	BA	Brain region	Cluster size	MNI coordinates			t_{max}	$p_{cluster}$
					x	y	z		
L	Frontal	46, 9	MPFC, inferior and middle frontal gyrus, precentral gyrus	691	-38	22	20	5.58	≤.001
L	Parietal/ temporal	40, 39	Inferior and superior parietal gyrus, AG, MTG	273	-38	-54	28	5.52	.004
L/R	Parietal/ occipital	7, 30, 23, 31	Precuneus (L+R), posterior cingulum (L+R), cuneus	449	0	-52	20	4.29	≤.001

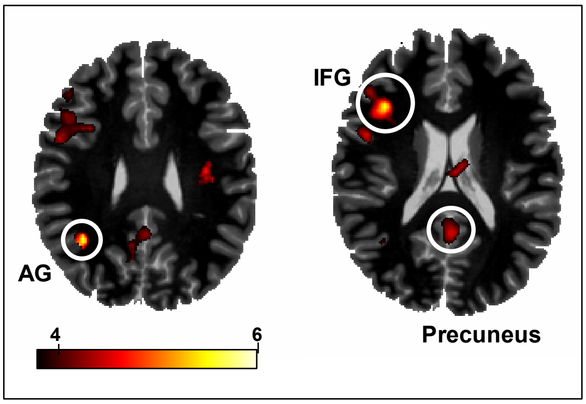

Figure 3: Between-group comparison for the contrast *avatar>ideal*
showing significantly higher brain activations in addicted MMORPG players during avatar-related reflection relative to ideal in the left AG (left image, z=29), the left IFG (right image) and the precuneus (right image; z=20; among others); brain-extracted chi-square template in MNI space with SPM contrast image-overlay: p_{uncorr}<.001, T=3.39, $\#_{voxel}$≥10

In addition, we observed higher activations in this group in the IFG, and the MTG, while non-addicted controls showed higher activations in the bilateral AG during the reflection of their ideal relative to their avatar.

Given addicted MMORPG players' significantly higher brain activations during the reflection on the avatar relative to the self or the ideal, we additionally examined the comparison of *avatar>self, ideal*. Within- and between-group analyses showed significant clusters of brain activation in the addicted MMORPG players similar to the contrast of *avatar>ideal* and included the left AG (t=5.96, MNI=-36 -62 46, p_{FWE}=.001, $\#_{voxel}$=350), IFG and middle frontal gyrus (t=6.35, MNI=-38 20 22, p_{FWE}<.001, $\#_{voxel}$=1175) as well as the precuneus (t=4.43, MNI=2 -32 32, p_{FWE}<.001, $\#_{voxel}$=698). Interestingly the non-addicted gamers exhibited higher left AG activation during the reflection about self and ideal compared to the avatar (t=5.41, MNI=-36 -60 48, p_{FWE}=.017, $\#_{voxel}$=182).

4.1.5 Discussion

The present study aimed at the examination of psychological and neurobiological correlates reflecting the relation of the avatar to addicted gamers' concepts of their self and ideal. To the best of our knowledge, this is the first study in addicted MMORPG players assessing the extent of identification processing with the own avatar in the left AG, a brain area that has been previously associated with self-identification and self-concept-related processing (Decety & Grezes, 2006; Ganesh et al., 2011; Ruby & Decety, 2001).

Our psychometric results revealed addicted MMORPG gamers to have feelings of low social popularity that were negatively associated with the degree of addiction severity. Furthermore, they seemed to consider their avatar's social popularity similar to the one of their ideal and significantly superior to their self. As expected, non-addicted gamers, on the contrary, assigned the significantly highest social popularity scores to their ideal. Although the analyses of between-group differences on the other GT-subscales did not reach significance, our results underline previous study findings proposing MMORPG addicts to particularly exhibit social competence deficits and a higher prevalence of comorbid social anxiety disorder (Caplan, 2007; Davis, 2001; C. Y. Liu & Kuo, 2007; Lo, Wang, & Fang, 2005; Whang et al., 2003). Additionally, C. Y. Liu & Kuo (2007) found that the quality of retrospectively assessed "parent-child relationships" and later "interpersonal relationships" has a high impact on social anxiety and that these factors all have an influence on the development of internet gaming addiction. In the light of these findings, our results of addicted MMORPG gamers' low social popularity scores might suggest a developmental predisposition in social competence deficits as an etiological factor for this gaming addiction: Socially anxious gamers might gravitate toward the virtual world, were they feel more secure due to anonymous and indirect avatar-mediated interaction with other players. Gamers might create their avatar similar to their ideal in order to experience a compensation for their often-observed social deficits. This short term relief from their social anxiety, which seems to be restricted to the virtual world, leads them to increased engagement with the game and into the vicious cycle of addictive MMORPG use. These findings emphasize the importance of social skill training in the psychotherapeutic treatment of MMORPG addicts. As a form of behavioral therapy, social skill training could enable them to improve their emotional and behavioral problems in social interactions.

On a neurobiological level, the extent to which our fMRI paradigm induced self-reflection cannot be determined completely. Potential self-reflection processes were observed in the overall sample only for the contrast *self>ideal* in the MPFC, IFG and inferior parietal lobule as a subset of brain regions previously associated with self-referential processing (D'Argembeau et al., 2013; Jenkins & Mitchell, 2011; Kelley et al., 2002; Northoff et al., 2006). This result could indicate similarities between our ideal-condition and the condition of a famous person applied in studies on self-referential processing in the literature (Jenkins & Mitchell, 2011; Kelley et al., 2002; Pfeifer et al., 2007). However, this assumption should be assessed in more detail in future studies by additionally including a self-unrelated control condition, such as famous and unknown real persons. The lack of significant within- and between-group differences in brain activations for the contrasts *self>avatar* or *self>avatar, ideal* could suggest that the avatar resembles the self in all gamers, as already indicated by Ganesh et al. (2011), who did not report self-related brain activations relative to the avatar either.

Supporting our first hypothesis, we found enhanced left AG activation in addicted MMORPG players during avatar-related reflection relative to self-reflection, which was also significant in the between-group comparison. Given the association of the left AG with self-identification (David et al., 2006; Ganesh et al., 2011), this finding might underline and validate our previous psychometric results suggesting a stronger identification with the own avatar than with the real self to play a central role in the development of MMORPG addiction (Leménager et al., 2013). However, the MPFC as a region most commonly associated with self-referential processing such as self-knowledge (D'Argembeau et al., 2013; D'Argembeau et al., 2012; D'Argembeau et al., 2007; Jenkins & Mitchell, 2011; Kelley et al., 2002; Northoff et al., 2006; Pfeifer et al., 2007; Sebastian et al., 2008) was not activated in this contrast of *avatar>self* and also did not reach significance for *self>avatar* or *avatar>self* in the within- and between-group comparisons. This could support our interpretation of the avatar-concept becoming closer to the one of the self in all MMORPG gamers. The discrepant results of significant left AG and failed MPFC activations might have their reason in different functions associated with these areas. While the MPFC seems to be involved in self-knowledge (Heatherton et al., 2006), the AG has been suggested to play a key role in self-identification and empathy

(Ganesh et al., 2011; Regenbogen, Habel, & Kellermann, 2013; Regenbogen et al., 2012). This was suggested by the fMRI studies of Regenbogen et al. (2012, 2013), who investigated brain network dynamics during empathy, induced by different communication channels. Healthy controls received different visual and auditory inputs with varying degrees of emotionality and were examined for their degree of empathy. The results indicated that the left AG might be a part of the empathy-mediating brain network particularly associated with the processing of emotional speech content and emotional facial expression. In the light of this, our finding of left AG activation in addicted MMORPG gamers during reflection about their avatar might therefore indicate that the addicted gamers empathize and identify with their avatar more strongly than the non-addicted gamers.

Contrary to our second hypothesis and psychometric study findings suggesting addicted MMORPG players' avatar to resemble their ideal (Leménager et al., 2013), the addicted group showed significantly increased brain activations during the reflection on their avatar in relation to their ideal in the left AG. This avatar-induced brain activation was also higher than in the non-addicted group. Furthermore, we found that the addicted group activated stronger on their avatar relative to their ideal in some of the aforementioned regions associated with the processing of self-related information, including the left MPFC, IFG and bilateral precuneus (Jenkins & Mitchell, 2011; Kelley et al., 2002). As mentioned above, previous studies of self-referential processing (Craik & Winocur, 1999; D'Argembeau et al., 2005; D'Argembeau et al., 2007; Fossati et al., 2003; Heatherton et al., 2006; Kelley et al., 2002; Kjaer, Nowak, & Lou, 2002) suggest that in particular the left MPFC (BA 9) was reported to play an important role in the representation of self-knowledge. Our findings of higher MPFC activation within the contrast *avatar>ideal* might indicate that the reflection on the avatar is associated with similar regions as the retrieval of self-knowledge. All these results may suggest a stronger subconscious identification with the avatar than with the ideal in addicted gamers, which might not be mirrored by conscious psychometric self-ratings. We assume that the avatar is more concrete due to its visualization and might increasingly replace the role of the ideal in the transition from normal-controlled to addictive-compulsive MMORPG usage. Thus, together with the finding of an increased identification with their own avatar relative to the self in addicted gamers (first hypothesis) we propose that the avatar of addicted MMORPGs players gradually fuses into gamers' self-concept, which becomes increasingly anchored in the virtual world. These findings possibly provide a starting point for the deduction of internet gaming addiction-specific psychotherapeutic treatment approaches. They could focus on the analysis of the avatar and its meaning for the individuals' concepts of self and ideal. Discrepancies between the avatar's abilities a gamer would like to possess and gamer's actually perceived skills should be determined and their importance reduced by improving self-acceptance and strengthening self-identity in the real world.

A limitation of our pilot study is the relatively small sample size, entailing a lower statistical power. Therefore, the obtained results should be interpreted with caution. In addition, no conclusions about the etiology can be drawn: It cannot be excluded that addicted gamers have a predisposition associated with brain alterations in these regions which may lead to their addictive MMORPG gaming. This can only be assessed by cohort studies. As another aspect, we did not control for familiarity effects between addicts and their avatar, which may be caused by increased avatar-related memories built due to addicted gamer's higher play duration in contrast to non-addicted gamers. However, we did not find any significant interaction effects between group and condition regarding the RT for the ratings. This is why we can assume that avatar-related memories in addicted gamers were not accessed faster compared to self and ideal, suggesting our results not to be influenced by familiarity effects. In addition, the issue of familiarity has been addressed by the comparable study of Ganesh et al. (2011), who contrasted controls' favorite cartoons with long-term gamers' avatars. The absence of significant differences suggested familiarity effects to be negligible. Ganesh et al. (2011) therefore interpreted the AG activation observed during avatar-referencing as stronger self-identification with the own avatar in regular gamers. This underscores our interpretation of even higher identification with the avatar in addicted gamers. Besides, future studies should also include the paradigm condition of "close others" and its relation to self-related activations in order to show that AG activations are specific to the identification with the own person and not a general pattern induced by judging the identity of close others. Furthermore, we did not include a group of naive, that is, nongaming controls. Rather, a group of non-addicted MMORPG players was examined for the benefit of exploring the transition from controlled to compulsive gaming.

In conclusion, this neurobiological study was the first to show psychological and neurobiological correlates reflecting the relation of the avatar to addicted gamers' concepts of their self and ideal. In line with previous psychometric findings, our neurobiological results suggest that the avatar plays an important role in the self-concept of addicted MMORPG gamers and might fuse into it with progressing severity of internet gaming addiction. Our results may also constitute a basis for future studies and the deduction of internet gaming addiction-specific treatment approaches aiming at the improvement of social skills, self-acceptance and self-identity in order to help MMOPRG addicts to find their own way in the real world.

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4.1.7 Contributors

Julia Dieter analyzed the data and wrote the main draft of the manuscript. Holger Hill programmed the fMRI paradigm. Madlen Sell was involved in participant recruitment and manuscript revision. Iris Reinhard verified statistical data analyses. Sabine Vollstädt-Klein, Falk Kiefer and Karl Mann were involved in the supervision of and assistance in the study- and manuscript-related proceedings. Tagrid Leménager designed and supervised the study, supervised and contributed to the manuscript preparation and data analyses. All authors contributed to the manuscript and approved of its final version.

4.1.8 Conflicts of interest

All authors have no conflicts of interests to declare.

4.1.9 Acknowledgments

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4.1.10 Bibliography

APA. (2013). *Diagnostic and Statistical Manual of Mental Disorders* (Fifth Edition (DSM-5™) ed.).

Bessière, K., Seay, A. F., & Kiesler, S. (2007). The ideal elf: identity exploration in World of Warcraft. *Cyberpsychol.Behav, 10*(4), 530-535.

Caplan, S. E. (2007). Relations among loneliness, social anxiety, and problematic Internet use. *Cyberpsychol Behav, 10*(2), 234-242. doi: 10.1089/cpb.2006.9963

Charlton, J. P., & Danforth, I. D. W. (2010). Validating the distinction between computer addiction and engagement: online game playing and personality. *Behaviour & Information Technology, 29*(6), 601–613. doi: 10.1080/01449290903401978

Choi, J. S., & Han, Y.-S. (2013). Representative reviewers for Internet social media. *Elsevier, 40*, 1274–1282.

Craik, F. I. M., Moroz, T. M., Moscovitch, M., Stuss, D. T.,, & Winocur, G., Tulving, E., & Kapur, S. . (1999). In search of the self: A positron emission tomography study. *Psychological Science, 10*, 26 –34.

D'Argembeau, A., Cassol, H., Phillips, C., Balteau, E., Salmon, E., & Van der Linden, M. (2013). Brains creating stories of selves: the neural basis of autobiographical reasoning. *Soc Cogn Affect Neurosci*. doi: 10.1093/scan/nst028

D'Argembeau, A., Collette, F., Van der, L. M., Laureys, S., Del Fiore, G., Degueldre, C., . . . Salmon, E. (2005). Self-referential reflective activity and its relationship with rest: a PET study. *Neuroimage, 25*(2), 616-624.

D'Argembeau, A., Jedidi, H., Balteau, E., Bahri, M., Phillips, C., & Salmon, E. (2012). Valuing one's self: medial prefrontal involvement in epistemic and emotive investments in self-views. *Cereb Cortex, 22*(3), 659-667. doi: 10.1093/cercor/bhr144

D'Argembeau, A., Ruby, P., Collette, F., Degueldre, C., Balteau, E., Luxen, A., . . . Salmon, E. (2007). Distinct regions of the medial prefrontal cortex are associated with self-referential processing and perspective taking. *J Cogn Neurosci, 19*(6), 935-944. doi: 10.1162/jocn.2007.19.6.935

David, N., Bewernick, B. H., Cohen, M. X., Newen, A., Lux, S., Fink, G. R., . . . Vogeley, K. (2006). Neural representations of self versus other: visual-spatial perspective taking and agency in a virtual ball-tossing game. *J Cogn Neurosci, 18*(6), 898-910. doi: 10.1162/jocn.2006.18.6.898

Davis, R. A. (2001). A Cognitive-Behavioral Model of Pathological Internet Use. *Computers in Human Behavior, 17*(2), 187-195.

Decety, J., & Chaminade, T. (2003). When the self represents the other: a new cognitive neuroscience view on psychological identification. *Conscious Cogn, 12*(4), 577-596.

Decety, J., & Grezes, J. (2006). The power of simulation: imagining one's own and other's behavior. *Brain Res, 1079*(1), 4-14.

Deusinger, I. M. (1996). "Locus of control" - ein Selbstkonzept. In I.M.Deusinger (Ed.), *Kognitionsforschung; Festschrift zum 65. Geburtstag von Fritz Süllwold* (pp. 86-110). Göttingen: Hogrefe. (Reprinted from: Not in File).

Fossati, P., Hevenor, S. J., Graham, S. J., Grady, C., Keightley, M. L., Craik, F., & Mayberg, H. (2003). In search of the emotional self: an fMRI study using positive and negative emotional words. *Am J Psychiatry, 160*(11), 1938-1945.

Ganesh, S., van Schie, H. T., de Lange, F. P., Thompson, E., & Wigboldus, D. H. (2011). How the human brain goes virtual: distinct cortical regions of the person-processing network are involved in self-identification with virtual agents. *Cereb Cortex, 22*(7), 1577-1585. doi: 10.1093/cercor/bhr227

Gazzaniga, M. S. (2008). *Human: The science behind what makes us unique*. New York: Harper Collins.

Heatherton, T. F., Wyland, C. L., Macrae, C. N., Demos, K. E., Denny, B. T., & Kelley, W. M. (2006). Medial prefrontal activity differentiates self from close others. *Soc Cogn Affect Neurosci, 1*(1), 18-25. doi: 10.1093/scan/nsl001

Jenkins, A. C., & Mitchell, J. P. (2011). Medial prefrontal cortex subserves diverse forms of self-reflection. *Soc Neurosci, 6*(3), 211-218. doi: 10.1080/17470919.2010.507948

Kelley, W. M., Macrae, C. N., Wyland, C. L., Caglar, S., Inati, S., & Heatherton, T. F. (2002). Finding the self? An event-related fMRI study. *J Cogn Neurosci, 14*(5), 785-794. doi: 10.1162/08989290260138672

Kjaer, T. W., Nowak, M., & Lou, H. C. (2002). Reflective self-awareness and conscious states: PET evidence for a common midline parietofrontal core. *Neuroimage, 17*(2), 1080-1086.

Klaiberg, A. (2002). GT. Gießen-Test. In E. Brähler, J. Schumacher & B. Strauß (Eds.), *In Diagnostische Verfahren in der Psychotherapie* (pp. 172-175). Göttingen: Hogrefe. (Reprinted from: Not in File).

Lamm, C., Batson, C. D., & Decety, J. (2007). The neural substrate of human empathy: effects of perspective-taking and cognitive appraisal. *J Cogn Neurosci, 19*(1), 42-58. doi: 10.1162/jocn.2007.19.1.42

Lemenager, T., Dieter, J., Hill, H., Koopmann, A., Reinhard, I., Sell, M., . . . Mann, K. (2014). Neurobiological correlates of physical self-concept and self-identification with avatars in addicted players of Massively Multiplayer Online Role-Playing Games (MMORPGs). *Addict Behav, 39*(12), 1789-1797. doi: 10.1016/j.addbeh.2014.07.017

Leménager, T., Gwodz, A., Richter, A., Reinhard, I., Kammerer, N., Sell, M., & Mann, K. (2013). Self-concept deficits in massively multiplayer online role-playing games addiction. *Eur Addict Res, 19*(5), 227-234. doi: 10.1159/000345458

Liu, C. Y., & Kuo, F. Y. (2007). A study of Internet addiction through the lens of the interpersonal theory. *Cyberpsychol Behav, 10*(6), 799-804. doi: 10.1089/cpb.2007.9951

Lo, S. K., Wang, C. C., & Fang, W. (2005). Physical interpersonal relationships and social anxiety among online game players. *Cyberpsychol Behav, 8*(1), 15-20. doi: 10.1089/cpb.2005.8.15

Maldjian, J. A., Laurienti, P. J., & Burdette, J. H. (2004). Precentral gyrus discrepancy in electronic versions of the Talairach atlas. *Neuroimage, 21*(1), 450-455.

Maldjian, J. A., Laurienti, P. J., Kraft, R. A., & Burdette, J. H. (2003). An automated method for neuroanatomic and cytoarchitectonic atlas-based interrogation of fMRI data sets. *Neuroimage, 19*(3), 1233-1239.

Northoff, G., Heinzel, A., de Greck, M., Bermpohl, F., Dobrowolny, H., & Panksepp, J. (2006). Self-referential processing in our brain--a meta-analysis of imaging studies on the self. *Neuroimage, 31*(1), 440-457. doi: 10.1016/j.neuroimage.2005.12.002

Petersen, K. U., Weymann, N., Schelb, Y., Thiel, R., & Thomasius, R. (2009). Pathological Internet use--epidemiology, diagnostics, co-occurring disorders and treatment. *Fortschr Neurol Psychiatr, 77*(5), 263-271. doi: 10.1055/s-0028-1109361

Pfeifer, J. H., Lieberman, M. D., & Dapretto, M. (2007). "I know you are but what am I?!": neural bases of. *J Cogn Neurosci, 19*(8), 1323-1337.

Regenbogen, C., Habel, U., & Kellermann, T. (2013). Connecting multimodality in human communication. *Front Hum Neurosci, 7*, 754. doi: 10.3389/fnhum.2013.00754

Regenbogen, C., Schneider, D. A., Gur, R. E., Schneider, F., Habel, U., & Kellermann, T. (2012). Multimodal human communication--targeting facial expressions, speech content and prosody. *Neuroimage, 60*(4), 2346-2356. doi: 10.1016/j.neuroimage.2012.02.043

Roth, M., Körner, A., & Herzberg, P. Y. (2008). Typological and dimensional approach at comparing the Giessen Test (GT) with the NEO-Five-Factor-Inventory (NEO-FFI). *GMS Psychosoc Med, 5*(06).

Ruby, P., & Decety, J. (2001). Effect of subjective perspective taking during simulation of action: a PET investigation of agency. *Nat Neurosci, 4*(5), 546-550.

Sagan, P., & Leighton, T. (2010). The Internet & the future of news. *Daedalus, American Academy of Arts & Sciences; MIT Press, 139*(2), 119-125.

Sebastian, C., Burnett, S., & Blakemore, S. J. (2008). Development of the self-concept during adolescence. *Trends Cogn Sci, 12*(11), 441-446. doi: 10.1016/j.tics.2008.07.008

Seghier, M. L. (2013). The angular gyrus: multiple functions and multiple subdivisions. *Neuroscientist, 19*(1), 43-61. doi: 10.1177/1073858412440596

Shaw, M., & Black, D. W. (2008). Internet addiction: definition, assessment, epidemiology and clinical management. *CNS Drugs, 22*(5), 353-365.

Smahel, D., Blinka, L., & Ledabyl, O. (2008). Playing MMORPGs: connections between addiction and identifying with a character. *Cyberpsychol Behav, 11*(6), 715-718. doi: 10.1089/cpb.2007.0210

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

Wischmann, T. (2002). Gießen-Test (GT). In E. Brähler, H. Holling, D. Leutner & F. Petermann (Eds.), *Handbuch psychologischer und pädagogischer Test* (3 ed., pp. 661-662). Göttingen: Hogrefe. (Reprinted from: Not in File).

Wittchen, H. U., Zaudig, M., & Fydrich, T. (1997). *Strukturiertes klinisches Interview für DSMIV (SKID)*. Göttingen: Hogrefe.

Wölfling, K., Beutel, M. E., & Müller, K. W. (2012). Construction of a Standardized Clinical Interview to Assess Internet addiction: First Findings Regarding the Usefulness of AICA-C *Addiction Research & Therapy, S6:003*. doi: 10.4172/2155-6105.S6-003

4.2 Study 2: The role of emotional inhibitory control in internet addiction - an fMRI study[2]

[2] Included in this thesis and submitted for publication as:

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4.2.1 Abstract

Background

Internet addiction is associated with social anxiety, emotional competence deficits and impaired prefrontal-related inhibitory control processing, so that internet addicts might have problems in emotional inhibitory control. The dorsal anterior cingulate cortex (dACC) likely plays an important role in this process due to its association with cognitive control and negative affect.

Aim

To assess (social) anxiety-related inhibitory control in internet gaming and social network addiction and its relation to altered dACC activation.

Methods

N=44 controls, n=30 internet gaming and n=21 social network addicts completed an anxious words-based affective Go/No-Go task (AGN). A subsample of n=23 healthy controls, n=13 internet gaming addicts and n=12 addicted social network users underwent functional magnetic resonance imaging (fMRI) while completing an Emotional Stroop task (EST) with socially anxious, positive, negative and neutral words. Psychometric measures of social anxiety, emotional competence and impulsivity were also assessed.

Results

Both addicted groups showed higher impulsivity, social anxiety and reduced emotional competence. Between-group differences in AGN and EST behavioral measures were not detected. No significant group differences were found in the dACC, but internet gaming addicts had decreased left middle and superior temporal gyrus activation compared to social network addicts during interference of socially anxious words.

Conclusion

Given the function of the left middle temporal gyrus in the successful retrieval of words or expressions during communication, our findings suggest that social words might be less retrievable in the semantic storage of internet gaming addicts, possibly indicating deficiencies in the handling of speech in social situations.

Key words: Internet gaming addiction; social network addiction; emotional inhibitory control; fMRI

4.2.2 Introduction

Internet addiction currently is the fastest growing addiction and gains worldwide attention due to its' rising prevalence [1]. Internet games and social networks (subsuming the excessive use of chats, forums and social networks such as Facebook) are the two most commonly used applications by internet addicts [2, 3]. The 5th edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association, [4]) refers to the condition of problematic internet game use as "Internet Gaming Disorder", while it is often designated as "Internet Gaming Addiction" (IGA) in the current literature. For reasons of uniformity as well as to underline the condition's addictive character, the terms IGA and "social network addiction" are applied in this manuscript.

Similar to substance addictions [5, 6], IGA has been associated with increased social and general anxiety [7, 8], impulsivity [9] and emotional competence deficits [10], the latter potentially impairing addicts in the recognition, control, regulation and expression of their own emotions and in the recognition of other's emotions. Furthermore, the few existing psychometric studies on social network use reported pathological Facebook use to be associated with poor emotion regulation skills, comprising a lack of acceptance of own emotional responses, limited access to emotion regulation strategies, poor impulse control and, similar to IGA, increased social and general anxiety [11-13]. Games and social networks might especially capture their users by facilitating the experience of positive social emotions [e.g. via social contacts in a game [14] or positive social feedback in social networks [11], which socially anxious individuals might not be able to gain in real life.

Therefore, it might be suggested that internet gaming and social network addiction is associated with an impairment of emotional inhibitory control processing, especially in socially and generally anxious contexts. Emotional inhibitory control processing is defined as the ability to control ones impulses, emotions and thoughts [15].

Thus, finding out more about the interlinkage of inhibitory control and (social) anxiety by investigating emotional response inhibition abilities might be crucial for understanding the etiology of internet addiction.

Emotional inhibitory control processing can be assessed by means of Affective Go/No-Go (AGN; e.g. [16, 17] as well as Emotional Stroop Tasks (EST; [18]).

In this study, we applied the AGN task to assess participants' emotional response inhibition ability by measuring the amount of response errors in terms of commission errors (defined as botton presses to No-Go stimuli and therefore mirroring failed inhibition [17]). The EST rather assesses interference (i.e. the ability to suppress irrelevant emotional information during cognitive performance) by measuring the RT for the color naming of differently valenced words (among other variables; [19]).

The brain region mainly associated with such measures of emotional inhibitory control processing is the ACC [20-22]. Structurally, several recent studies suggest reduced gray matter volume in the ACC of internet and internet gaming addicts relative to healthy controls [23-25]. Moreover, Wang et al. (2015) observed an association between reduced gray matter volume of the ACC and impaired cognitive inhibitory control processing in internet gaming addicts during the performance of a classical color-word Stroop task [24]. There are no comparable studies for emotional inhibitory control processing related to positive, negative or anxious affects in internet addicts, although increased social and general anxiety have been associated with internet gaming and social network addiction [7, 8, 11-13]. Thus, the psychological and neural basis of emotional inhibitory control processing in relation to social and general anxiety remains to be explored and compared between both subgroups. Based on previous study findings of increased social and general anxiety in internet gaming and social network addiction, more impaired inhibitory control processing on anxious as well as socially anxious stimuli should be neuropsychologically and neurobiologically detectable in addicted internet gamers and social network users relative to healthy controls. Specifically the dorsal ACC (dACC) has been functionally associated with both negative affect (such as social exclusion, pain or anxiety) and cognitive control [26-28]. By conducting a ‘coordinate-based’ meta-analysis of 939 studies in order to assess common or different activation clusters in the ACC during negative affect, pain and cognitive control, Shackman et al. (2011) observed that all these three domains activate a common region within the dACC [28].

Given the important role of social and general anxiety, emotion regulation deficits and impaired inhibitory control in internet addiction, the present study aims to assess neuropsychological and neurobiological differences in emotional inhibitory control processing induced by socially and generally anxious stimuli between internet gaming and social network addicts as well as healthy controls.

While we neuropsychologically assess social and general anxiety-related emotional inhibitory control by means of AGN (response inhibition) and EST (interference), interference in relation to socially anxious stimuli was additionally assessed by fMRI.

We hypothesize internet addicts to show impaired emotional inhibitory control, especially related to anxious stimuli, as reflected in worse emotional response inhibition (i.e. more commission errors; [17, 29]) during anxiety-related blocks of the AGN and a stronger interference (i.e. longer RTs; [19]) to socially anxious words relative to healthy controls in the EST. Furthermore, on the background of the dACC’s role in anxiety-related affect (e.g. social exclusion) and cognitive control as well as increased social anxiety in internet addiction, we hypothesize internet addicts having stronger inhibitory demands than controls in response to social anxiety-related stimuli (relative to positive, negative and neutral words), reflected in altered dACC activation during EST performance.

We further exploratively assess whether these measures differ between addicted online gamers and social network users and whether they are related to the severity of addiction as well as anxiety and social anxiety-related measures.

4.2.3 Methods

4.2.3.1 Participants

The study was approved by the local ethics committee (application number 2013-528N-MA). Participants were recruited at the local day clinic of the Department of Addictive Behavior and Addiction Medicine at the Central Institute of Mental Health in Mannheim, as well as by means of advertisements on the web pages of the Central Institute of Mental Health and Mannheim University. All participants were informed about the study procedures and gave written informed consent according to the Declaration of Helsinki prior to study participation. For this study, we included n=44 healthy controls and n=51 addicted internet users (comprising n=30 internet gaming addicts and n=21 social network addicts). Due to fMRI incapability (e.g. left handedness, metal parts in the body), the AGN sample was decimated to an EST subsample of n=23 healthy controls and n=25 internet addicts (subdivided into n=13 internet gaming addicts and n=12 addicted social network users). Decisive for group assignment was a clinical interview with an experienced psychologist and the obtained scores on the subscale of the checklist for the Assessment of Internet and Computer game Addiction (AICA_30, see “Psychometric Instruments”; [30]).

As an additional measure for addiction severity, we applied the OSVe (Skala zum Onlinesuchtverhalten bei Erwachsenen, OSVe-S; [31]; see below). Participants did not have any further axis-I psychiatric disorders or substance use disorders (except nicotine dependence), were not treated with any psychotropic medication and had normal or corrected-to-normal vision. Potential psychiatric comorbidities were assessed on the basis of the Structured Clinical Interview for DSM-IV (SCID I and II; [32]). There was no difference between groups in age. Internet addicts of the EST subsample were less educated than healthy controls (see Table 1). Regarding the three subgroups of internet gaming and social network addicts as well as healthy controls, the corrected Bonferroni post-hoc tests revealed no significance between the groups (Tables 2 and 3).

The hours of computer- and internet use per day, the addiction severity (AICA_30, AICA_lifetime and OSVe) as well as the degree of social anxiety were significantly different between internet addicts and controls (see Tables 1, 2 and 3).

Table 1 Sample description for healthy controls and internet addicts

The study was performed with a large (AGN) sample as well as with a subsample (EST) for fMRI explorations.

SD=Standard deviation, AICA_30=Assessment of Internet and Computer game Addiction of the previous 30 days, AICA_life-time=Lifetime maximum of Internet and Computer game Addiction, OSVe=Self-report questionnaire for internet addiction-related behavior (Skala zum Onlinesuchtverhalten bei Erwachsenen, Selbstreport), z=Mann-Whitney U test statistic, χ^2 (CT)=Chi^2 Crosstab test statistic; *p≤.05, **p≤.01

	AGN sample					**EST sample**				
	Overall sample (N=95)	**Healthy controls (n=44)**	**Internet addicts (n=51)**	**Test-statistic**	**p-value**	**Overall sample (N=48)**	**Healthy controls (n=23)**	**Internet addicts (n=25)**	**Test-statistic**	**p-value**
Gender (n=male)	52 (54.74 %)	20 (45.45 %)	32 (62.75 %)	2.850$^{\chi 2\ (CT)}$	.091	27 (56.25 %)	10 (43.48 %)	17 (68.00 %)	2.927$^{\chi 2\ (CT)}$	.087
Age (SD)	27.15 (8.21)	28.59 (9.80)	25.90 (6.39)	-1.198^{z}	.231	25.85 (5.67)	26.13 (5.49)	25.60 (5.93)	-.591^{z}	.554
Years of education (SD)	14.86 (2.39)	15.30 (2.30)	14.49 (2.42)	-1.626^{z}	.104	15.06 (2.43)	15.87 (2.26)	14.32 (2.38)	-2.216^{z}	.027*
Computer-/internet-use (Ø, h/ day; SD)	2.73 (1.36)	1.89 (.90)	3.45 (1.27)	-5.576^{z}	<.001**	2.63 (1.36)	1.91 (.90)	3.28 (1.40)	-3.348^{z}	.001**
AICA_30 (SD)	9.07 (7.90)	2.25 (1.95)	14.96 (6.13)	-7.818^{z}	<.001**	8.38 (7.53)	2.35 (1.87)	13.92 (6.41)	-5.455^{z}	<.001**
AICA_life-time (SD)	14.75 (10.67)	4.16 (2.60)	23.88 (4.96)	-8.386^{z}	<.001**	14.46 (10.08)	4.87 (2.58)	23.28 (4.86)	-5.945^{z}	<.001**
OSVe (SD)	8.25 (5.83)	2.93 (1.55)	12.84 (3.92)	-8.386^{z}	<.001**	7.64 (5.39)	3.09 (1.57)	11.82 (4.06)	-5.892^{z}	<.001**

Table 2 Sample description for the subgroups

SD=Standard deviation, AICA_30=Assessment of Internet and Computer game Addiction of the previous 30 days, AICA_life-time=Lifetime maximum of Internet and Computer game Addiction, OSVe=Self-report questionnaire for internet addiction-related behavior (Skala zum Onlinesuchtverhalten bei Erwachsenen, Selbstreport), χ^2 (CT)=Chi^2 Crosstab test statistic, χ^2 (KW)=Chi^2 Kruskal-Wallis test statistic; *p≤.05, **p≤.01

	AGN sample					EST sample				
	Healthy controls (n=44)	**Internet gaming addicts (n=30)**	**Social network addicts (n=21)**	**Test-statistic**	**p-value**	**Healthy controls (n=23)**	**Internet gaming addicts (n=13)**	**Social network addicts (n=12)**	**Test-statistic**	**p-value**
Gender (n=male)	20 (45.45 %)	22 (73.33 %)	10 (47.62 %)	6.147$^{\chi 2\ (CT)}$	.046*	10 (43.48 %)	11 (84.62 %)	6 (50.00 %)	5.965$^{\chi 2\ (CT)}$	.051
Age (SD)	28.59 (9.80)	27.07 (7.73)	24.24 (3.24)	2.387$^{\chi 2\ (KW)}$	.303	26.13 (5.49)	27.15 (7.39)	23.92 (3.34)	1.938$^{\chi 2\ (KW)}$	.380
Years of education (SD)	15.30 (2.30)	14.30 (2.38)	14.76 (2.51)	3.139$^{\chi 2\ (KW)}$	.208	15.87 (2.26)	14.69 (2.36)	13.92 (2.43)	5.420$^{\chi 2\ (KW)}$	.067
Computer-/internet use (Ø, h/ day; SD)	1.89 (.90)	3.67 (1.12)	3.14 (1.42)	32.975$^{\chi 2\ (KW)}$	<.001**	1.91 (.90)	3.69 (1.32)	2.83 (1.40)	13.434$^{\chi 2\ (KW)}$	.001**
AICA_30 (SD)	2.25 (1.95)	15.33 (6.60)	14.43 (5.51)	61.346$^{\chi 2\ (KW)}$	<.001**	2.35 (1.87)	14.69 (7.49)	13.08 (5.20)	30.024$^{\chi 2\ (KW)}$	<.001**
AICA_life-time (SD)	4.16 (2.60)	25.77 (3.58)	21.19 (5.47)	73.254$^{\chi 2\ (KW)}$	<.001**	4.87 (2.58)	25.85 (3.56)	20.50 (4.64)	37.075$^{\chi 2\ (KW)}$	<.001**
OSVe (SD)	2.93 (1.55)	13.28 (3.93)	12.21 (3.92)	70.230$^{\chi 2\ (KW)}$	<.001**	3.09 (1.57)	12.54 (4.40)	11.04 (3.68)	34.899$^{\chi 2\ (KW)}$	<.001**

Table 3 Post-hoc tests for the subgroups

P-values Bonferroni corrected.

SD=Standard deviation, AICA_30=Assessment of Internet and Computer game Addiction of the previous 30 days, AICA_life-time=Lifetime maximum of Internet and Computer game Addiction, OSVe=Self-report questionnaire for internet addiction-related behavior (Skala zum Onlinesuchtverhalten bei Erwachsenen, Selbstreport), z=Mann-Whitney U test statistic, m=Mean difference in the Tukey HSD post-hoc test, χ^2 (CT)=Chi^2 Crosstab test statistic; *p≤.05, **p≤.01

	AGN-sample						EST-sample					
	Healthy controls- internet gaming addicts		Healthy controls- social network addicts		Internet gaming addicts- social network addicts		Healthy controls- internet gaming addicts		Healthy controls- social network addicts		Internet gaming addicts- social network addicts	
Gender (n=male)	$5.649^{\chi2\ (CT)}$	.017	$.027^{\chi2\ (CT)}$	.870	$3.494^{\chi2\ (CT)}$	.062						
Age (SD)												
Years of education (SD)												
Computer-/internet use (Ø, h/ day; SD)	-5.601^{z}	<.001**	-3.411^{z}	.001**	-1.259	.208	-3.551^{z}	<.001**	-1.932^{z}	.053	-1.592^{z}	.111
AICA_30 (SD)	-6.756^{z}	<.001**	-6.128^{z}	<.001**	-.969	.333	-4.654^{z}	<.001**	-4.304^{z}	<.001**	$-.791^{z}$	.429
AICA_life-time (SD)	-7.283^{z}	<.001**	-6.498^{z}	<.001**	-3.181^{z}	.001**	-4.940^{z}	<.001**	-4.810^{z}	<.001**	-2.517^{z}	.012*
OSVe (SD)	-7.278^{z}	<.001**	-6.548^{z}	<.001**	$-.872^{z}$	.383	-4.879^{z}	<.001**	-4.816^{z}	<.001**	$-.872^{z}$	.383

4.2.3.2 Psychometric instruments

Participants were screened for existence and degree of computer- and internet addiction by means of an interview based on the AICA [30]. The latter is an established diagnostic clinical interview assessing the severity of participants' computer and/or internet addiction during the previous 30 days (AICA_30) as well as over the lifetime (AICA_lifetime) by recording participant's 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?"). Besides, it was made use of the OSVe-S [31]; e.g. "How strong are you occupied by thoughts about online offers/activities per day?"). Participants scoring ≥13 on the AICA_30 or ≥13.5 on the OSVe were assigned to the addicted group. Participants scoring <7 on the OSVe were assigned to the control group [30]. The Barratt Impulsiveness Scale (BIS-11; [33]) was used to record impulsivity, and feelings of stress were assessed by means of the Perceived Stress Scale (PSS, [34]). The neuroticism scale of the NEO-FFI served as an indicator for unpleasant emotions such as anxiety [35]. Participant's degree of social anxiety was explored by means of the questionnaire for Social Anxiety and social Competence Deficits (SASKO; [36]). The latter investigates the anxiety of speaking in front of others or being in the focus of social attention (subscale 'speaking'), of being socially rejected ('rejection'), of interacting socially ('interaction'), deficits in social perception ('information') as well as feelings of loneliness ('loneliness'). The emotional competence questionnaire was applied for the assessment of the self-rated emotional competence (EKF; [37]). The instrument comprises 62 items, which are divided into four subscales measuring the constructs of a) recognizing and understanding one's own emotions (EKF-EE), b) recognizing and understanding others' emotions (EKF-EA), c) the ability to regulate and control one's own emotions (EKF-RE) and d) emotional expressiveness (EKF-EX).

4.2.3.3 Affective Go/No-Go task (AGN)

The AGN task was applied in a validated German version [38] as part of the Cambridge Neuropsychological Test Automated Battery (CANTAB) to assess participant's emotional response inhibition. The AGN comprised 13 blocks of either 18 positive and neutral, negative and neutral, or anxious and neutral words, as already given in the German version. The valenced words (i.e. positive, negative and anxious) were target stimuli, while the neutral words represented distractor stimuli. The recognition of target stimuli was to be acknowledged by means of a button press, while the reaction to neutral stimuli was to be inhibited. The order of the block's valence (i.e. positive, negative or anxious blocks) was constant across participants, while the presentation of valenced vs. neutral words within each block was randomized. Single words appeared on the testing screen after intervals of 900 ms and were presented for 300 ms. The commission errors (i.e. amount of button presses to distractor stimuli, i.e. neutral words) served as test outcome. A lower number of commission errors reflects the ability to inhibit unwanted behavior in an emotional context (i.e. valenced words) and therefore serves as an indicator for an individuals' ability of emotional response inhibition.

4.2.3.4 Emotional Stroop task (EST)

The EST was carried out using fMRI. The task was adapted from Witthöft et al. (2013) and included the four categories of positive, negative, neutral as well as socially anxious words ([19]; see Table 4). Throughout the paradigm, each category was presented four times, resulting in a total of 16 blocks. Each of the word stimuli was presented once in one of the colors red, green, blue and yellow, distributed across the blocks. Participants were asked to indicate the color of each presented word as fast as possible by pressing one of the four buttons corresponding to the four colors (index finger=red, middle finger=green, ring finger=blue, little finger=yellow). Words were presented one after another in the middle of the screen, while the assignment of the four buttons to the respective color was displayed throughout the task at the bottom of the screen in smaller writing. These four color words were written in the respective color. For the behavioral analyses, RT differences of correct responses for socially anxious, positive and negative relative to neutral stimuli were used as the main behavioral outcome measure for emotional interference.

The word and color order within each block was randomized and the blocks of the different categories were presented in the order of a Latin square. The 10 words per category were matched category-wise for word length, frequency, valence and arousal in written German language. They were presented for 1.5 s, followed by a fixation cross as inter-stimulus interval with a mean duration of 0.3 s [19]. Between the blocks, a fixation cross and the information that a next block will follow were presented for 9 s and 1 s, respectively. The duration of each block amounted to 18 s and the complete paradigm took about 7 min. Prior to the actual task performance, participants completed a short training session without scanning, involving arrays of letters instead of real words in order to get used to the response buttons. The experiment was implemented with the program Presentation Version 16.3 (Neurobehavioral Systems, Albany, Calif., USA) and task presentation in the scanner was mediated by digital goggles (Resonance Technology, Inc., Los Angeles, California). After the scanning, all words presented as stimuli in the EST were rated via paper-pencil by each participant regarding each word's valence (i.e. emotional resonance) and arousal on a 9-point scale with the help of the "Self-Assessment Manikin" affective rating system [39].

Table 4 Original and English EST stimuli words

Social anxiety-related words	Positive words	Negative words	Neutral words
Original German words			
ängstlich	anziehend	verendet	förmlich
hilflos	super	habgierig	belanglos
einsam	lebenslustig	unangenehm	neutral
unterwürfig	euphorisch	zerfressen	zusammenhanglos
blamiert	großartig	böse	bürgerlich
sitzengelassen	interessant	verfault	solide
panisch	vergnügt	impotent	nichtssagend
gehemmt	glücklich	asozial	typisch
abstoßend	leidenschaftlich	herablassend	anatomisch
dämlich	witzig	verwahrlost	eckig
Translated words			
anxious	attractive	perished	formal
helpless	super	avaricious	insignificant
lonely	fun-loving	awkward	neutral
submissive	euphoric	eroded	incoherent
disgraced	great	bad	civil
abandoned	interesting	rotten	solid
panic-fueled	cheery	impotent	expressionless
inhibited	happy	antisocial	typical
repellent	passionate	dismissive	anatomical
dimwitted	funny	shabby	angled

A Kruskal-Wallis test for the exploration of between-group differences revealed that internet gaming addicts rated the valence of positive words significantly lower than social network addicts (χ^2=8.687; p=.013; post-hoc $z_{positive}$=-2.807, p=.005). Within-group analyses (Friedman tests) showed significant differences in valence and arousal between each category, except between negative and socially anxious word blocks for valence (in every group) as well as between socially anxious and negative ones in the group of social network addicts for arousal (see Figure 1).

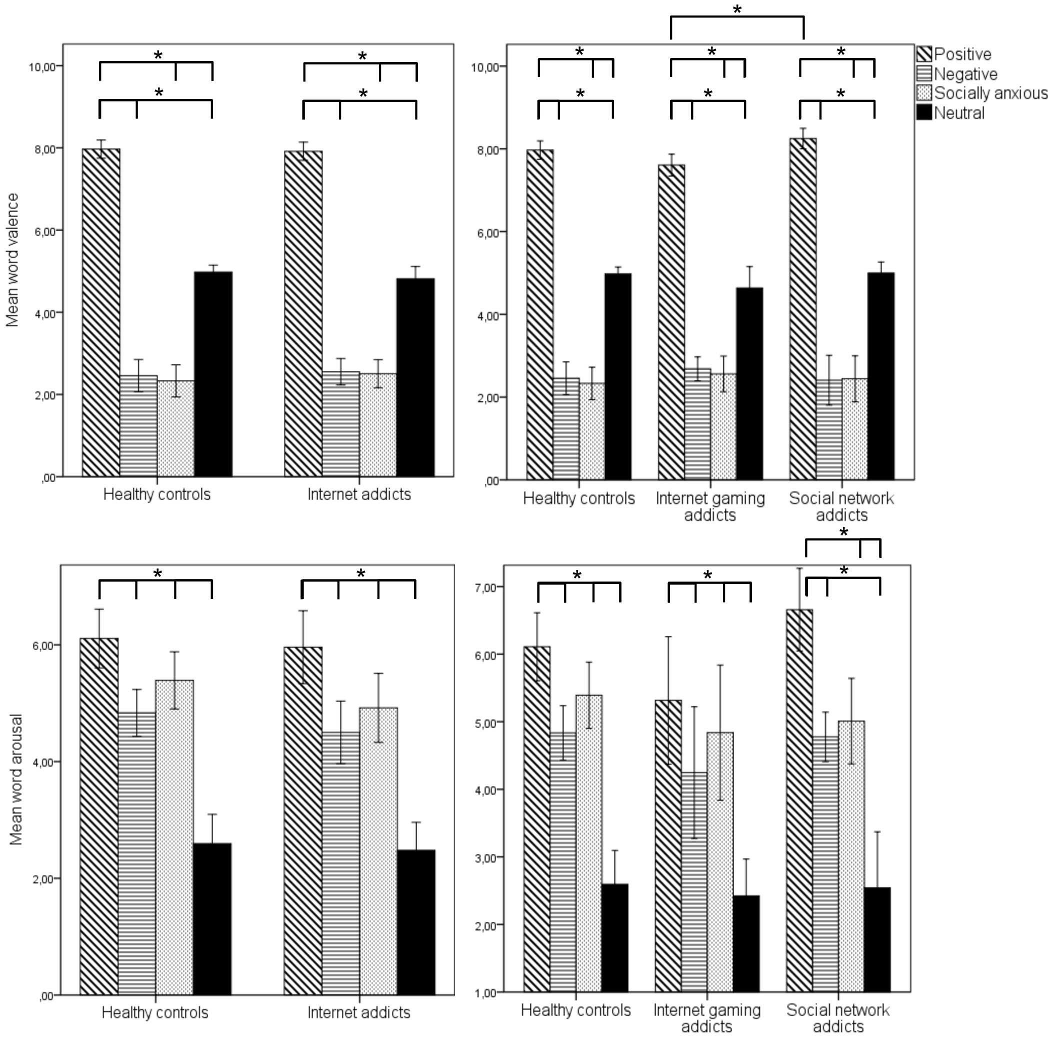

Figure 1 Ratings for valence and arousal of EST words

4.2.3.5 fMRI

The scanning sessions were conducted at a 3 Tesla whole-body tomograph (Trio; Siemens, Erlangen, Germany). Functional whole brain images were collected under the application of a T2*-weighted Echo-Planar Imaging (EPI) sequence [Repetition Time (TR)=2000 ms, Echo Time (TE)=30 ms, Flip Angle (FA)=80°, Field of View (FOV)=192 mm x 192 mm, matrix size 64 x 64, 32 slices, slice thickness 3.00 mm, distance factor=33 %, voxel size=3.0 x 3.0 x 3.0 mm]. The number of acquired functional volumes amounted to 219. Structural images were acquired by means of a T1-weighted Magnetization Prepared Rapid Gradient Echo (MPRAGE) sequence (TR=2300 ms, TE=3.03 ms, FA=9°, FOV=256 mm x 256 mm, 192 slices, slice thickness 1.00 mm, distance factor=50 %, voxel size=1 x 1 x 1 mm) in order to exclude participants exhibiting brain abnormalities (see [40]). The correction of magnetic field inhomogeneity was mediated by the automated Siemens multi-angle projection (MAP)-Shim. The registration of scanner triggers as well as the recording of behavioral responses was accomplished by the Presentation® software (Version 16.3, Neurobehavioral Systems, Inc., Albany, CA, USA).

4.2.4 Statistical analyses

The statistical analyses were conducted for the comparison between non-addicted controls and internet addicts. The comparisons between non-addicted controls and addicts of gaming as well as social networks were conducted exploratively.

4.2.4.1 Psychometry

Psychometric data analyses were accomplished by means of SPSS Statistics 20 (Statistical Package for the Social Sciences, SPSS Inc., Chicago, IL; Release 20.0.0). After having checked the variables for normality, within- and between group differences in the psychometric as well as in the behavioral outcome measures of the EST and the AGN were assessed with parametric paired and unpaired t-tests (normally distributed variables) or via nonparametric Wilcoxon's signed rank and Mann–Whitney U tests (non-normally distributed variables), respectively. For three-group comparisons, analyses of variance (ANOVAs) and Kruskal-Wallis tests as well as Friedman tests for the comparison across categories were applied. For post-hoc tests a Bonferroni α-correction was done.
Furthermore, Spearman's rho correlations were applied in order to explore associations between addiction severity and the outcome measures for emotional response inhibition (commission errors in the AGN task) and interference (RT of the correct responses in the EST task).
The differences in RT of the EST between emotional and neutral words (i.e. positive-neutral, negative-neutral, socially anxious-neutral) were used for statistical within- and between-group analyses. As described by Witthöft et al. (2013), extreme RTs of <300 ms and >1,000 ms were removed from the data [19].

4.2.4.2 Neurobiology

For neurobiological evaluations, Statistical Parametric Mapping (SPM, version SPM 8, Wellcome Trust Centre for Neuroimaging, University College London, London, UK) was utilized at the basis of Matlab R2012b (The MathWorks, Inc., Natick, MA, USA). The data preprocessing comprised motion correction, realignment, spatial normalization to the Montreal Neurological Institute (MNI) template with a new voxel size of 3 x 3 x 3 mm and smoothing with an 8 mm full width at half maximum kernel.
First level analyses included the evaluation of effect estimations for the four categories (i.e. positive, negative, neutral and socially anxious) by applying the general linear model with regressors for the onsets and duration of every condition as well as the six movement parameters obtained from the realignment preprocessing step on a voxel-by-voxel basis. In a succeeding step, individual contrast images of condition-specific mean brain activation for our contrast of interest, i.e. *social anxiety vs. positive+negative+neutral (rest)*, were calculated. By means of second level analyses, the individual contrast images were then

compared for differences in Blood Oxygenation Level Dependent (BOLD) responses within and between the groups for the specific contrasts based on one- and two-sample t-tests as well as on full factorial ANOVAs. A threshold of $p<.001$ as well as an extent threshold of 10 voxels were applied and results were reported at a cluster threshold of $p_{FWE} \leq .05$. The Automatic Anatomical Labeling (AAL)-toolbox of SPM was used for the assignment of significantly activated clusters to their respective brain regions. The detection of Brodmann Areas (BAs) was conducted via the xjview-toolbox (xjView Toolbox for SPM; http://www.alivelearn.net/xjview8/) run under Matlab. Activation maps were displayed by means of Chris Rorden's MRIcro brain image viewer in neurological convention (i.e. left=left, right=right) on the ch2bet-template (Chris Rorden, 1999-2005, version 1.40 build 1).

4.2.5 Results

Psychometrically, we observed significant deficits in impulsivity and perceived stress as well as on all scales of social anxiety and emotional competence in internet addicts compared to healthy controls. This pattern was also observed in both subgroups separately relative to healthy controls, except that social network addicts showed no differences in feelings of loneliness and the evaluation of others' emotions compared to controls. Internet gaming addicts showed significantly higher scores on the scale 'feelings of loneliness' compared to healthy controls and social network addicts. Furthermore, a subgroup comparison revealed that internet gaming addicts also had significantly higher scores of speaking and interaction anxiety than social network addicts (see Tables 5 and 6).

Table 5 Psychometric measures of the AGN and EST sample

Given are the means with standard deviations in brackets. SASKO=Social Anxiety and Social Competence deficits-scale, EKF=Emotional competence questionnaire, EKF-EE=Recognizing and understating the own emotions, EKF-EA=Recognizing and understanding others' emotions, EKF-RE=Regulation and control of the own emotions, EKF-EX=Emotional expressiveness, NEO-FFI=NEO Five Factor Inventory, χ^2 (KW)=Chi^2 Kruskal-Wallis test statistic, F=ANOVA test statistic, *p≤.05, **p≤.01

	AGN sample					EST sample				
	Healthy controls (n=44)	**Internet gaming addicts (n=30)**	**Social network addicts (n=21)**	**Test-statistic**	**p-value**	**Healthy controls (n=23)**	**Internet gaming addicts (n=13)**	**Social network addicts (n=12)**	**Test-statistic**	**p-value**
Social anxiety (sum SASKO)	21.95 (13.53)	55.10 (24.03)	42.57 (22.52)	36.027$^{\chi2\ (KW)}$	<.001**	22.96 (13.98)	48.92 (27.03)	43.92 (21.91)	14.240$^{\chi2\ (KW)}$	.001**
SASKO: Speaking	6.41 (4.27)	14.27 (8.08)	13.62 (7.88)	24.095$^{\chi2\ (KW)}$	<.001**	7.09 (3.85)	12.23 (8.11)	14.67 (7.27)	10.556$^{\chi2\ (KW)}$	.005**
SASKO: Rejection	5.68 (3.67)	13.67 (7.17)	11.38 (6.56)	28.227$^{\chi2\ (KW)}$	<.001**	6.00 (3.90)	11.46 (6.42)	11.42 (6.64)	10.223$^{\chi2\ (KW)}$	.006**
SASKO: Interaction	3.86 (3.49)	11.33 (5.35)	7.52 (4.57)	35.406$^{\chi2\ (KW)}$	<.001**	4.26 (3.73)	10.23 (6.21)	7.33 (4.62)	10.874$^{\chi2\ (KW)}$	.004**
SASKO: Information	4.70 (3.07)	9.80 (5.02)	7.62 (4.13)	20.069$^{\chi2\ (KW)}$	<.001**	4.65 (2.96)	9.15 (6.16)	8.25 (4.22)	7.700$^{\chi2\ (KW)}$	.021*
SASKO: Loneliness	1.30 (1.79)	6.03 (3.54)	2.43 (2.91)	31.425$^{\chi2\ (KW)}$	<.001**	.96 (1.46)	5.85 (3.44)	2.25 (2.26)	19.128$^{\chi2\ (KW)}$	<.001**
Emotional competence (mean EKF)	60.59 (6.37)	50.58 (7.79)	54.50 (6.90)	19.157^{F}	<.001**	60.90 (5.38)	48.94 (8.55)	53.67 (6.85)	14.014^{F}	<.001**

EKF-EE	60.80 (8.15)	49.67 (11.45)	53.38 (8.84)	13.130^{F}	<.001**	61.43 (7.27)	48.31 (11.70)	54.25 (7.90)	9.572^{F}	<.001**
EKF-EA	68.36 (9.19)	61.60 (13.15)	65.67 (10.15)	3.506^{F}	.034*	68.83 (8.24)	58.00 (13.02)	63.58 (11.91)	4.374^{F}	.018*
EKF-RE	51.89 (6.49)	43.30 (10.24)	46.33 (8.16)	10.299^{F}	<.001**	52.35 (6.45)	45.46 (7.40)	46.42 (9.72)	4.314^{F}	.019*
EKF-EX	61.30 (11.69)	47.73 (14.18)	52.62 (13.78)	10.222^{F}	<.001**	61.00 (11.26)	44.00 (17.27)	50.42 (12.29)	7.227^{F}	.002**
NEO-FFI Neuroticism	1.25 (.67)	2.07 (.78)	1.93 (.83)	$19.868^{\chi 2\ (KW)}$	<.001**	1.20 (.68)	1.92 (.68)	1.81 (.78)	$9.610^{\chi 2\ (KW)}$	.008**
Perceived stress (PSS)	12.98 (5.80)	20.50 (7.57)	19.19 (6.45)	13.691^{F}	<.001**	13.43 (6.13)	20.00 (7.44)	18.25 (7.81)	4.289^{F}	.020*
Impulsivity (Sum BIS)	56.09 (8.76)	64.03 (12.19)	62.90 (9.25)	$11.553^{\chi 2\ (KW)}$	.003**	54.65 (9.05)	68.23 (11.72)	61.92 (11.15)	$13.362^{\chi 2\ (KW)}$	.001**

Table 6 Post-hoc tests for the subgroups

P-values Bonferroni corrected

SASKO=Social Anxiety and Social Competence deficits-scale, EKF=Emotional competence questionnaire, EKF-EE=Recognizing and understating the own emotions, EKF-EA=Recognizing and understanding others' emotions, EKF-RE=Regulation and control of the own emotions, EKF-EX=Emotional expressiveness, NEO-FFI=NEO Five Factor Inventory, z=Mann-Whitney U test statistic, m=Mean difference in the Tukey HSD post-hoc test, *p≤.05, **p≤.01

	AGN-sample						**EST-sample**					
	Healthy controls-internet gaming addicts		Healthy controls-social network addicts		Internet gaming addicts- social network addicts		Healthy controls-internet gaming addicts		Healthy controls-social network addicts		Internet gaming addicts- social network addicts	
Social anxiety (Sum SASKO)	-5.545^{z}	<.001**	-3.867^{z}	<.001**	-1.886^{z}	.059	-3.015^{z}	.003**	-3.165^{z}	.002**	$-.572^{z}$	.567

SASKO: Speaking	-4.271^{z}	<.001**	-3.787^{z}	<.001**	$-.316^{z}$	.752	-1.838^{z}	.066	-3.234^{z}	.001**	$-.873^{z}$	.382
SASKO: Rejection	-4.918^{z}	<.001**	-3.559^{z}	<.001**	-1.141^{z}	.254	-2.515^{z}	.012*	-2.736^{z}	.006*	$-.136^{z}$	.892
SASKO: Interaction	-5.538^{z}	<.001**	-3.508^{z}	<.001**	-2.488^{z}	.013*	-3.027^{z}	.002**	-2.155^{z}	.031	-1.042^{z}	.297
SASKO: Information	-4.311^{z}	<.001**	-2.558^{z}	.011*	-1.412^{z}	.158	-2.274^{z}	.023	-2.272^{z}	.023	$-.247^{z}$	.805
SASKO: Loneliness	-5.424^{z}	<.001**	-1.638^{z}	.101	-3.489^{z}	<.001**	-4.181^{z}	<.001**	-1.967^{z}	.049	-2.576^{z}	.010*
Emotional competence (mean EKF)	10.010^{m}	<.001**	6.085^{m}	.004*	-3.925^{m}	.122	11.960^{m}	<.001**	7.236^{m}	.011*	-4.724^{m}	.196
EKF-EE	11.129^{m}	<.001**	7.415^{m}	.011*	-3.714^{m}	.355	13.127^{m}	<.001**	7.185^{m}	.067	-5.942^{m}	.222
EKF-EA	6.764^{m}	.026	2.697^{m}	.615	-4.067^{m}	.385	10.826^{m}	.014*	5.243^{m}	.358	-5.583^{m}	.396
EKF-RE	8.586^{m}	<.001**	5.553^{m}	.033	-3.033^{m}	.399	6.886^{m}	.033	5.931^{m}	.084	$-.955^{m}$	.947
EKF-EX	13.562^{m}	<.001**	8.676^{m}	.036	-4.886^{m}	.386	17.000^{m}	.002**	10.583^{m}	.078	-6.417^{m}	.459
NEO-FFI Neuroticism	-4.133^{z}	<.001**	-3.069^{z}	.002**	$-.355^{z}$	.723	-2.802^{z}	.005*	-2.210^{z}	.027	$-.436^{z}$	.663
Perceived stress (PSS)	-7.523^{m}	<.001**	-6.213^{m}	.002**	1.310^{m}	.762	-6.565^{m}	.024	-4.815^{m}	.136	1.750^{m}	.804
Impulsivity (Sum BIS)	-2.772^{z}	.006*	-2.858^{z}	.004*	$-.230^{z}$	.818	-3.447^{z}	.001**	-2.001^{z}	.045	-1.688^{z}	.091

4.2.5.1 AGN

Regarding the main outcome measure of emotional response inhibition, the AGN groups internet addicts and healthy controls showed significantly more commission errors at positive words than at negative or anxious ones (Friedman: $\chi^2_{Healthy\ controls}$=32.224, p<.001; post-hoc $z_{positive-negative}$=-4.118, p<.001; $z_{positive-anxiety}$=-4.432, p<.001; $\chi^2_{Internet\ addicts}$=40.923, p<.001, post-hoc $z_{positive-negative}$=-4.525, p=<.001; $z_{positive-anxiety}$=-4.931, p=<.001). The same holds for the subgroups of internet addicts ($\chi^2_{Internet\ gaming\ addicts}$=18.893, p<.001; post-hoc $z_{positive-negative}$=-3.052, p=.002; $z_{positive-anxiety}$=-3.172, p=.002; $\chi^2_{Social\ network\ addicts}$=23.570, p<.001; post-hoc $z_{positive-negative}$=-3.494, p<.001; $z_{positive-anxiety}$=-3.839, p<.001; see Figure 2).

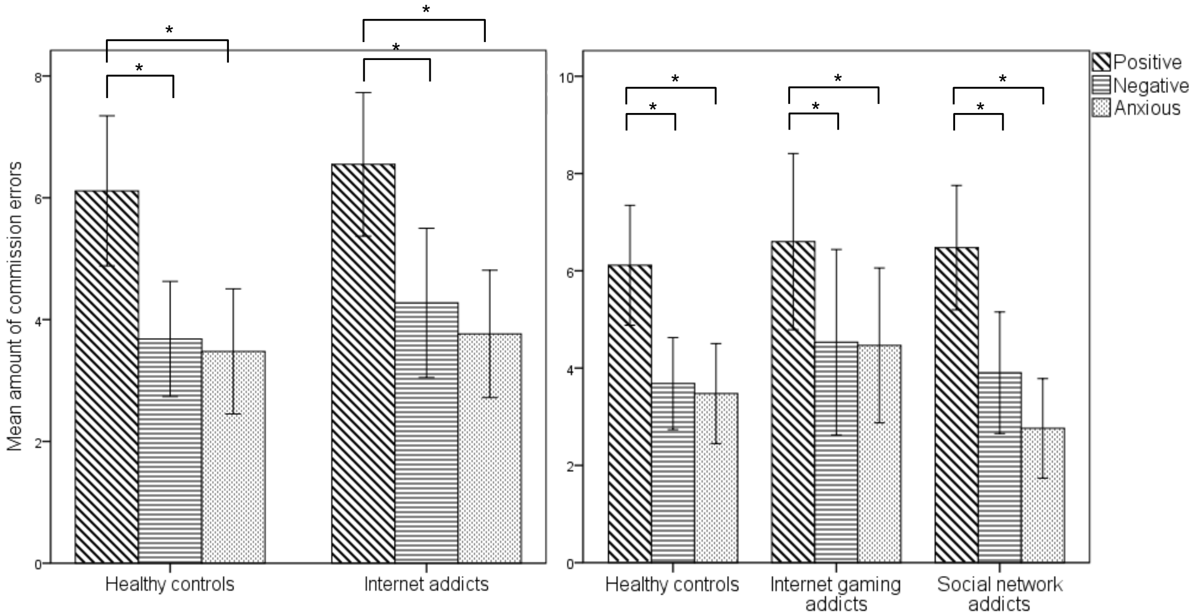

Figure 2 Number of commission errors

Kruskal Wallis tests for each category revealed no significant differences regarding the amount of commission errors between internet addicts and controls as well as between internet gaming addicts, social network addicts and controls.

Spearman correlations between addiction severity and AGN commission errors in each category in the overall sample revealed that the emotional response inhibition ability in anxiety-blocks decreased (i.e. more commission errors) with increasing addiction severity (i.e. higher OSVe scores; Spearman's rho correlation coefficient $r_{commissions\ anxiety-OSVe}$=.220, p=.032). There were no correlations detected in the subgroups.

4.2.5.2 EST

4.2.5.2.1 Behavior

Our data revealed 97.85 % correct responses in the overall sample. Between-group analyses by means of Mann-Whitney U and Kruskal-Wallis tests for internet addicts vs. controls as well as for internet gaming and social network addicts relative to healthy controls, respectively, did not indicate any significant group differences in RTs for each contrast (i.e. positive-neutral, negative-neutral and socially anxious-neutral). Also the between-group comparison for the contrast socially anxious-neutral minus the mean of positive-neutral and negative-neutral remained without a significant result.

Friedman tests for within-group comparison between the four categories revealed significantly longer RTs to socially anxious compared to positive and negative words as well as in relation to all other categories in internet addicts [χ^2=15.960, p=.001; socially anxious-neutral>positive-neutral: Wilcoxon signed rank post-hoc test: z=-2.731, p=.006; (socially anxious-neutral) minus (mean ((positive-neutral)+(negative-neutral)))>positive-neutral: z=-2.704, p=.007; socially anxious-neutral>negative-neutral: z=-2.677, p=.007; (socially anxious-neutral) minus (mean ((positive-neutral)+(negative-neutral)))>negative-neutral: z=-3.162, p=.002]. The same result was found internet gaming addicts [χ^2=8.723, p=.033; socially anxious-neutral>positive-neutral: z=-2.132, p=.033; (socially anxious-neutral) minus (mean ((positive-neutral)+(negative-neutral)))>positive-neutral: z=-2.411, p=.016; socially anxious-neutral>negative-neutral: z=-2.341, p=.019; (socially anxious-neutral) minus (mean ((positive-neutral)+(negative-neutral)))>negative-neutral: z=-2.760, p=.006; see also Figure 3]). Furthermore, a significantly higher difference in RTs for socially anxious relative to positive stimuli in healthy controls was observed (i.e. socially anxious-neutral>positive-neutral: Friedman χ^2=8.478, p=.037, Wilcoxon signed rank post-hoc test: z=-2.068, p=.039).

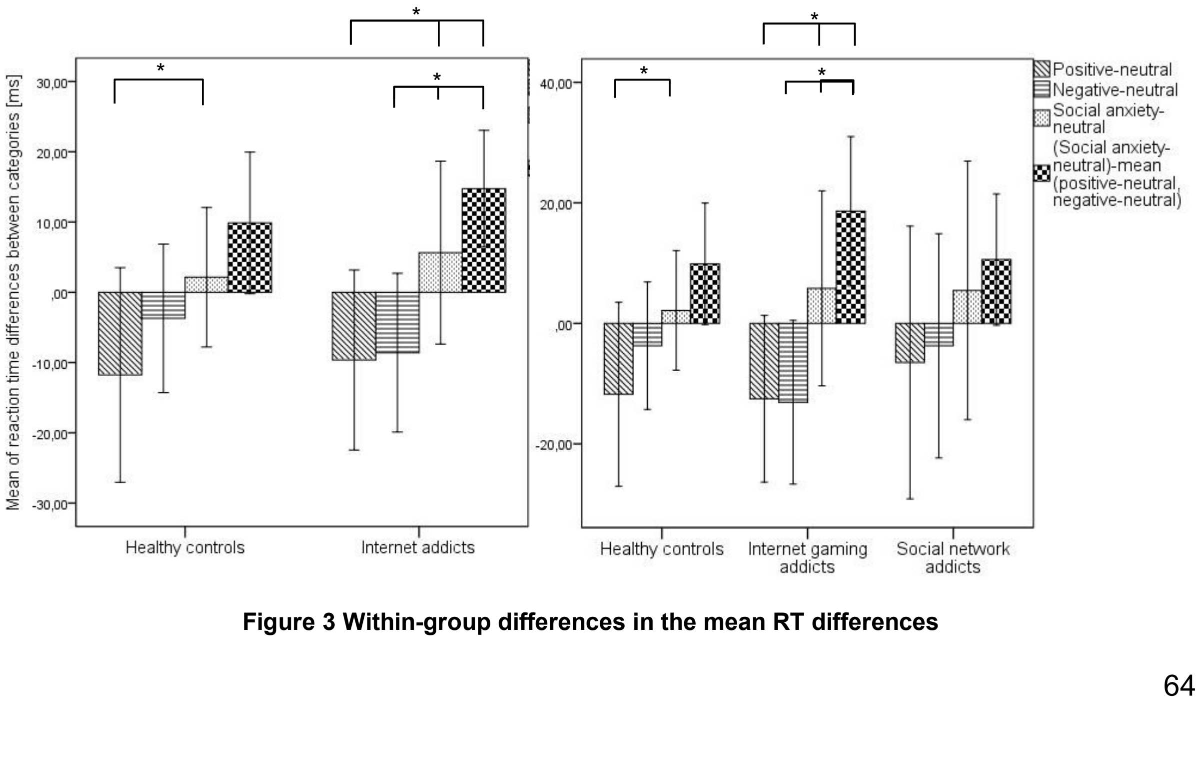

Figure 3 Within-group differences in the mean RT differences

In addition, we observed significant correlations between internet gaming addict's lifetime addiction severity (AICA_lifetime) and the EST RT differences between socially anxious-neutral words ($\rho_{socially\ anxious\text{-}neutral}$=.603, p=.029; see Figure 4).

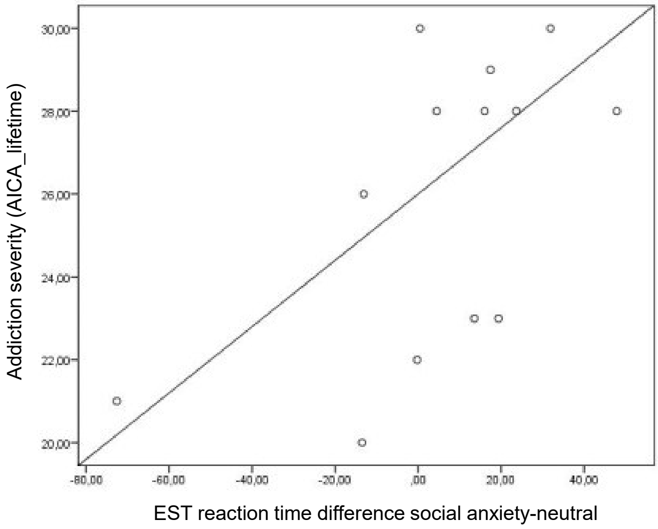

Figure 4 Spearman correlation for internet gaming addicts between lifetime addiction severity and RTs in the EST

4.2.5.2.2 Neurobiology

4.2.5.2.2.1 Overall sample

In the overall EST sample, the left DLPFC, superior frontal gyrus, superior temporal gyrus as well as the Inferior Parietal Lobe (IPL) were significantly higher activated during positive relative to neutral word blocks (see Figure 5 and Table 7).

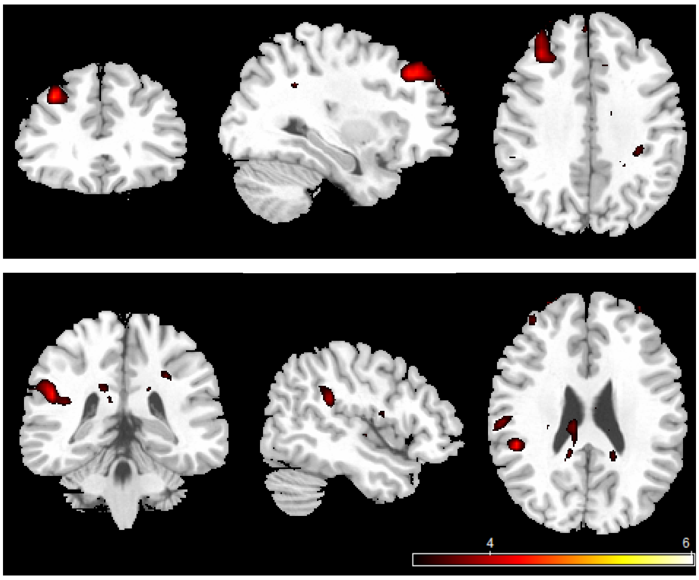

Figure 5 One-sample t-test for the overall EST sample

showing significantly higher brain activation in the left DLPFC and superior frontal gyrus (peak voxel MNI -33 32 37; BA 8/9; upper image), the left superior temporal gyrus and the left IPL (peak voxel MNI -48 -37 25; BA 13; lower image) during positive relative to neutral word blocks. Brain-extracted chi-square template in MNI space with SPM contrast image-overlay: p_{uncorr}<.001, T=3.27, #voxel≥10

Table 7 One-sample t-test for the overall EST sample for the contrast *positive>neutral*
H=Hemisphere, L=Left, R=Right, BA=Brodmann area, MNI=Montreal Neurological Institute, $p_{cluster}$=FWE-corrected p-values reported on cluster level (p_{FWE}<.05)

H	Lobe	BA	Brain region	Cluster size	MNI coordinates x	y	z	t_{max}	$p_{cluster}$
Positive>neutral									
L	Temporal	-	Supramarginal gyrus, superior temporal gyrus, rolandic operculum, insula	81	-48	-40	22	4.03	.047
L	Frontal	8/9	DLPFC and superior frontal gyrus	164	-33	32	37	4.57	.002
Neutral>positive									

4.2.5.2.2.2 Within-group comparisons

Within-group analyses revealed clusters of significant hypoactivations in the left middle and superior temporal gyrus of internet gaming addicts (n=13) for our contrast of interest (i.e. *social anxiety>rest*; BA 21, 22, 48, cluster size=75, MNI=-45 -19 -2, t_{max}=5.44, $p_{cluster}$=.014; see Figure 6).

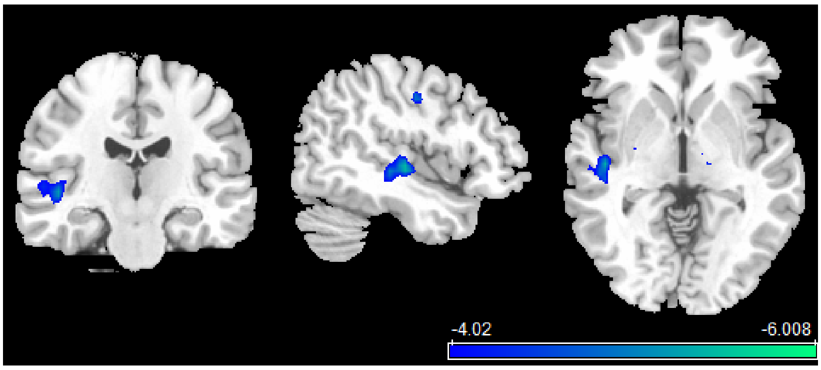

Figure 6 Within-group brain hypoactivation in the left middle and superior temporal gyrus of internet gaming addicts for the contrast *social anxiety>rest*
(in the peak voxel MNI 47 19 2). Brain-extracted chi-square template in MNI space with SPM contrast image-overlay: puncorr<.001, T=3.93, #voxel≥10

Within the group of social network addicts, no significant brain activations in the contrast of interest (i.e. *social anxiety>rest* and rest>*social anxiety*) were observed.

4.2.5.2.2.3 Between-group comparisons

In order to explore our second hypothesis of altered dACC brain activation in internet addicts during social anxiety-related word blocks, an ANOVA for the contrast *social anxiety vs. rest* was conducted between controls, internet gaming and social network addicts. Opposed to our assumption, significant alterations in brain activation were not observed between internet addicts and controls in the dACC within the corresponding post-hoc test. However, internet gaming addicts exhibited significantly lower brain activation in a cluster within the left middle and superior temporal gyrus during social anxiety words (vs. all other word categories) relative to social network addicts in the corresponding post-hoc comparison (see Figure 7 and Table 8).

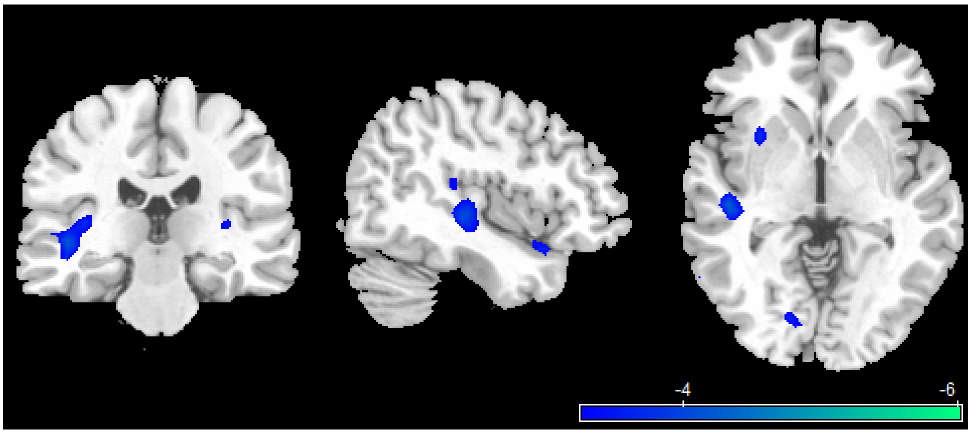

Figure 7 Full factorial ANOVA and post-hoc tests for the contrast *social anxiety>rest* showing decreased brain activation in internet gaming addicts relative to social network addicts in the left middle and superior temporal gyrus (peak voxel MNI -45 -25 -2, cluster size=101, t_{max}=4.39, $p_{cluster}$=.036). Brain-extracted chi-square template in MNI space with SPM contrast image-overlay: p_{uncorr}<.001, T=3.93, #voxel≥10

Table 8 Significant results of the between-group comparison involving controls, internet gaming as well as social network addicts for the contrast *social anxiety>rest*
H=Hemisphere, L=Left, R=Right, BA=Brodmann area, MNI=Montreal Neurological Institute, $p_{cluster}$=FWE-corrected p-values reported on cluster level (p_{FWE}<.05)

H	Lobe	BA	Brain region	Cluster size	MNI coordinates			t_{max}	$p_{cluster}$
					x	y	z		
Social network addicts>internet gaming addicts									
L	Temporal	21, 48	Middle/superior temporal	101	-45	-25	-2	4.39	.036
Internet gaming addicts>social network addicts									

This significant finding was also observed without the neutral condition in the applied contrast (i.e. *social anxiety>positive+negative*; result not shown).

4.2.5.2.2.4 Correlations

We further exploratively found a negative association between activation in the right precuneus in the contrast *social anxiety vs. rest* and the social anxiety subscale "speaking" in internet gaming addicts (see Figure 8 and Table 9) when correlating psychometric measures for social anxiety (i.e. the five subscales of the SASKO) with within-group social anxiety-related mean brain activation.

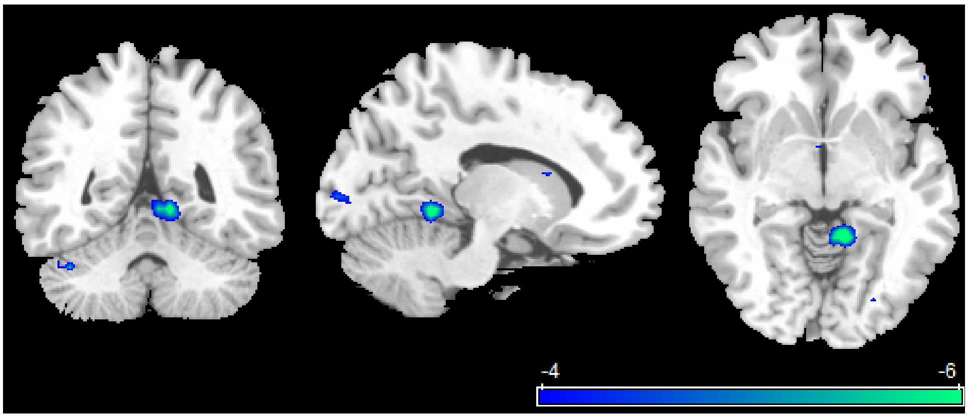

Figure 8 Negative correlation between right precuneus activation for the contrast *social anxiety>rest* and the social anxiety subscale "speaking" in internet gaming addicts

Brain-extracted chi-square template in MNI space with SPM contrast image-overlay: p_{uncorr}<.001, T=3.93, #voxel≥10

Table 9 Negative correlation between right precuneus activation for the contrast *social anxiety>rest* and the social anxiety subscale "speaking" in internet gaming addicts

H=Hemisphere, L=Left, R=Right, BA=Brodmann area, MNI=Montreal Neurological Institute, $p_{cluster}$=FWE-corrected p-values reported on cluster level (p_{FWE}<.05)

H	Lobe	BA	Brain region	Cluster size	MNI coordinates			t_{max}	$p_{cluster}$
					x	y	z		
R	Parietal	-	Precuneus, calcarine fissure, lingual gyrus (R+L)	83	12	-49	-5	8.22	.005

4.2.6 Discussion

Given the association of internet addiction with social anxiety, emotional competence deficits as well as impaired inhibitory control processing and the dACC's role in cognitive control over negative and anxious emotions, the presented study aimed to assess anxiety-related emotional inhibitory control processing and its relation to the dACC in internet addicts as well as in their subgroups of internet gaming and social network addicts.

In line with previous studies [8, 10, 41], our psychometric results revealed internet addicts to show higher social anxiety, impulsivity, perceived stress and to report more emotional competence deficits. Additionally, in concordance with Kuss (2013; [42]) as well as Caplan, Williams & Yee (2009; [43]), high ratings of loneliness were observed to be specific to internet gaming addicts, possibly indicating a higher tendency for social withdrawal, which has already been described for internet gaming addicts [44]. Besides their high social anxiety, previous studies suggest internet gaming addicts to have a negative body image, mirrored in stronger rejection of the own body image and feelings of being less attractive [45]. Furthermore, they seem to identify themselves stronger with their own avatar in the game compared to non-problematic gamers. It is understandable that these two aspects likely lead to higher social withdrawal and stronger feelings of loneliness in the offline world.

Regarding our assessment of inhibitory control processing, we assumed impaired anxiety-related inhibitory control in internet addicts, mirrored by stronger interference (i.e. longer RTs in the EST) on socially anxious and impaired response inhibition (i.e. more commission errors in the AGN) on anxious stimuli. In concordance with this assumption, we observed significantly longer RTs in the EST for socially anxious words which positively correlated with lifetime addiction severity in internet gaming addicts. In addition, although we did not detect any significant between-group differences in RT (EST) and commission errors (AGN), we found an association between reduced emotional response inhibition ability (i.e. more commission errors) to anxious stimuli in the AGN and addiction severity in the overall sample. These correlation analyses in both tasks might suggest an association between (social) anxiety-related impairments in emotional cognitive control processing in internet addicts and addiction severity.

There are more studies that showed no group differences by means of these types of tasks: Dong and colleagues did not find significant differences between internet addicts and controls neither during Go/No-Go task nor during Stroop task performance [21, 46]. However, our finding of a correlation between impaired anxiety-related response inhibition in the AGN in the overall sample as well as interference on socially anxious stimuli (EST) in internet gaming addicts and measures of addictive online behavior might indicate that the alterations in anxiety-related response inhibition in addictive internet use underlie a gradual process from non-problematic to addictive internet use [47]. Furthermore, the association between interference on socially anxious stimuli (EST) and addiction severity in internet gaming addicts might suggest that social anxiety-related interference especially plays a role in IGA.

Neurobiological analyses of the EST in the overall sample showed increased activations in the left DLPFC, a region engaged in inhibitory control processing and the superior frontal gyrus, the superior temporal gyrus as well as the IPL during positive relative to neutral word blocks. The DLPFC was found to be mainly associated with cognitive inhibitory control processing [48, 49]. Due to the generally higher salience of positive stimuli it might be possible that participants have to inhibit stronger on these word cues than on neutral ones. There are several hints in the literature indicating an activation in the left superior frontal gyrus (BA 8) to be induced by positive related emotional word pairs during a word priming task [50]. Concordantly, Shibata, Terasawa & Umeda (2014) suggest that this network plays a central role in a positive emotional response based on observed activation in the inferior frontal gyrus (IFG), middle temporal gyrus, superior temporal gyrus, superior frontal gyrus, and IPL during humor comprehension processing [51]. Besides, our psychometric results of significant differences in arousal and valence (positive>neutral>negative and socially anxious words) of the EST words indicates that the EST paradigm works sufficiently.

Neurobiologically, we hypothesized altered dACC activation in internet addicts during emotional interference by socially anxious words in the EST due to internet addict's increased social anxiety, which might have an influence on the dACC-mediated cognitive control in relation to socially anxious stimuli.

However, we did not find activation in the dACC in internet addicts, nor in their subgroups on socially anxious stimuli compared to the other conditions of the EST. Instead of altered dACC activation, we observed significant hypoactivations in the left middle and superior temporal gyrus of internet gaming addicts, which also consisted relative to social network addicts for our contrast of interest (i.e. *socially anxious>positive+negative+neutral* EST word blocks). These brain regions play a major role in the storage and retrieval of semantic, i.e. lexical knowledge [52-56]. Furthermore, in particular the left middle temporal gyrus has been associated with the successful retrieval of words or expressions during communication. Jeong et al. (2015) reported increased activation in the left middle and superior temporal gyrus during social interaction as well as a positive correlation between activation in the middle temporal gyrus during interaction in a second language and oral proficiency (i.e. how fluently appropriate words can be retrieved, sequences formulated or expressions formed in the communicative context; [55]). Communication requires pre-established discourse conventions or dialog schemas that have been acquired through intensive experiences with social interaction [57, 58]. Transferring these findings into our results of middle temporal gyrus hypoactivation during the interference of socially anxious stimuli in internet gaming addicts, we suggest that social words might be less retrievable than positive, negative or neutral words in the semantic storage of internet gaming addicts.

In addition, a previous study reported reduced superior temporal gyrus brain activation (among other regions) in social anxiety disorder patients relative to healthy controls during the cognitive emotional regulation (by actively thinking in a way that modifies negative emotions) when watching social threat stimuli (i.e. harsh facial expressions; [59]). Due to the association of IGA with social anxiety [8], this result might suggest that the observed hypoactivation in internet gaming addicts indicates reduced efficiency in the cognitive regulation of emotions (as a facet of emotional inhibitory control) related to socially anxious stimuli.

We further found a negative association between right precuneus activation during interference of social anxiety stimuli and the scores on the social anxiety subscale “speaking” in front of others in internet gaming addicts. The precuneus has been implicated in the theory of mind network and is thought to contribute to the understanding or generation of communicative messages by inferring and monitoring the intentions or beliefs of others based on the social context [60-62]. Therefore, we might also suggest internet gaming addicts to have problems in processing speech-related social information as a basis of communication in social situations. Given the precuneus’ role in the theory of mind network, our neurobiological result might mirror our psychometric finding of impaired emotional competencies in internet gaming addicts.

When interpreting our results, it has to be paid attention to the low sample size. Future studies might also explore the neurobiological correlates of the anxiety-related inhibitory control by means of an AGN task in order to compare them directly to the neurobiological correlates underlying the interference in EST paradigms. To the best of our knowledge, we investigated for the first time emotional inhibitory control processing in internet addiction and its two most prevalent subgroups.

In conclusion, our findings suggest that (socially) anxious stimuli might interfere with cognitive performance in internet addicts. Given the function of the left middle temporal gyrus in the successful retrieval of words or expressions during communication, our neurobiological findings suggest that in particular socially anxious words might be less retrievable in the semantic storage of internet gaming addicts and might indicate deficiencies in the handling of speech in social situations.

Based on our psychometric finding of significantly higher speaking and interaction anxiety in internet gaming addicts relative to healthy controls and social network addicts, insecurities in verbal expression in social contexts might especially be present in internet gaming addicts. This might lead them to communicate via a self-made identity (avatar) in the internet game.

4.2.7 Compliance with ethical standards

All authors have no conflicts of interests to declare.

This study involved human participants, who gave written informed consent prior to study participation.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

4.2.8 Acknowledgements

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4.2.9 Role of funding sources

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4.2.10 Contributions

Julia Dieter contributed to data collection, study management, data analyses and manuscript preparation. Sabine Hoffmann was involved in manuscript revision and psychometric data analyses. Daniela Mier provided the paradigm version and contributed to data analyses. Iris Reinhard verified statistical data analyses. Martin Beutel contributed to data collection and manuscript preparation. Sabine Vollstädt-Klein and Falk Kiefer were involved in the supervision of and assistance in the study and manuscript-related proceedings. Karl Mann supervised the manuscript preparation. Tagrid Leménager supervised the study and also supervised and contributed to data collection, data analyses as well as manuscript preparation. All authors approved of the manuscript's final version.

4.2.11 Bibliography

1. Dong, G., J. Huang, and X. Du, *Enhanced reward sensitivity and decreased loss sensitivity in Internet addicts: an fMRI study during a guessing task.* J Psychiatr Res, 2011. **45**(11): p. 1525-9.
2. Bischof, G., Bischof, A., Meyer, C., John, U. & Rumpf, H.J. , *Prävalenz der Internetabhängigkeit – Diagnostik und Risikoprofile (PINTA-DIARI) Kompaktbericht an das Bundesministerium für Gesundheit*. 2013.
3. Griffiths, M.D. and A. Szabo, *Is excessive online usage a function of medium or activity? An empirical pilot study.* J Behav Addict, 2014. **3**(1): p. 74-7.
4. APA, *Diagnostic and Statistical Manual of Mental Disorders*. Fifth Edition (DSM-5™) ed. 2013.
5. Buckner, J.D., et al., *Specificity of social anxiety disorder as a risk factor for alcohol and cannabis dependence.* J Psychiatr Res, 2008. **42**(3): p. 230-9.

6. Gross, J.J. and R.F. Munoz, *Emotion Regulation and Mental Health.* Clin Psychol Sci Prac, 1995: p. 151-164.
7. Kim, N., et al., *Resting-State Peripheral Catecholamine and Anxiety Levels in Korean Male Adolescents with Internet Game Addiction.* Cyberpsychol Behav Soc Netw, 2016.
8. Lehenbauer-Baum, M., et al., *Addiction and Engagement: An Explorative Study Toward Classification Criteria for Internet Gaming Disorder.* Cyberpsychol Behav Soc Netw, 2015. **18**(6): p. 343-9.
9. Ding, W.N., et al., *Trait impulsivity and impaired prefrontal impulse inhibition function in adolescents with internet gaming addiction revealed by a Go/No-Go fMRI study.* Behav Brain Funct, 2014. **10**: p. 20.
10. Leménager, T., et al., *Self-concept deficits in massively multiplayer online role-playing games addiction.* Eur Addict Res, 2013. **19**(5): p. 227-34.
11. Hormes, J.M., B. Kearns, and C.A. Timko, *Craving Facebook? Behavioral addiction to online social networking and its association with emotion regulation deficits.* Addiction, 2014. **109**(12): p. 2079-88.
12. Koc, M. and S. Gulyagci, *Facebook addiction among Turkish college students: the role of psychological health, demographic, and usage characteristics.* Cyberpsychol Behav Soc Netw, 2013. **16**(4): p. 279-84.
13. Lee-Won, R.J., L. Herzog, and S.G. Park, *Hooked on Facebook: The Role of Social Anxiety and Need for Social Assurance in Problematic Use of Facebook.* Cyberpsychol Behav Soc Netw, 2015. **18**(10): p. 567-74.
14. Yee, N., *Motivations for play in online games.* Cyberpsychol Behav, 2006. **9**(6): p. 772-5.
15. Friese, M., et al., *Suppressing emotions impairs subsequent stroop performance and reduces prefrontal brain activation.* PLoS One, 2013. **8**(4): p. e60385.
16. Elliott, R., et al., *Abnormal ventral frontal response during performance of an affective go/no go task in patients with mania.* Biol Psychiatry, 2004. **55**(12): p. 1163-70.
17. Schulz, K.P., et al., *Does the emotional go/no-go task really measure behavioral inhibition? Convergence with measures on a non-emotional analog.* Arch Clin Neuropsychol, 2007. **22**(2): p. 151-60.
18. Williams, J.M., A. Mathews, and C. MacLeod, *The emotional Stroop task and psychopathology.* Psychol Bull, 1996. **120**(1): p. 3-24.
19. Witthöft, M., et al., *Neuronal and behavioral correlates of health anxiety: Results of an illness related emotional Stroop task.* Neuropsychobiology submitted, 2013.
20. Albert, J., et al., *The role of the anterior cingulate cortex in emotional response inhibition.* Hum Brain Mapp, 2012. **33**(9): p. 2147-60.
21. Dong, G., H. Zhou, and X. Zhao, *Impulse inhibition in people with Internet addiction disorder: electrophysiological evidence from a Go/NoGo study.* Neurosci Lett, 2010. **485**(2): p. 138-42.
22. Egner, T., et al., *Dissociable neural systems resolve conflict from emotional versus nonemotional distracters.* Cereb Cortex, 2008. **18**(6): p. 1475-84.
23. Jin, C., et al., *Abnormal prefrontal cortex resting state functional connectivity and severity of internet gaming disorder.* Brain Imaging Behav, 2015.
24. Wang, H., et al., *The alteration of gray matter volume and cognitive control in adolescents with internet gaming disorder.* Front Behav Neurosci, 2015. **9**: p. 64.
25. Yuan, K., et al., *Microstructure abnormalities in adolescents with internet addiction disorder.* PLoS One, 2011. **6**(6): p. e20708.
26. Eisenberger, N.I. and M.D. Lieberman, *Why rejection hurts: a common neural alarm system for physical and social pain.* Trends Cogn Sci, 2004. **8**(7): p. 294-300.
27. Etkin, A., et al., *Resolving emotional conflict: a role for the rostral anterior cingulate cortex in modulating activity in the amygdala.* Neuron, 2006. **51**(6): p. 871-82.
28. Shackman, A.J., et al., *The integration of negative affect, pain and cognitive control in the cingulate cortex.* Nat Rev Neurosci, 2011. **12**(3): p. 154-67.
29. Lievaart, M., et al., *Trait anger in relation to neural and behavioral correlates of response inhibition and error-processing.* Int J Psychophysiol, 2016. **99**: p. 40-7.

30. Wölfling, K., M.E. Beutel, and K.W. Müller, *Construction of a Standardized Clinical Interview to Assess Internet addiction: First Findings Regarding the Usefulness of AICA-C* Addiction Research & Therapy 2012. **S6:003**.
31. Wölfling, K., K.W. Müller, and M.E. Beutel, *Skala zum Onlinesuchtverhalten bei Erwachsenen (OSVe-S)*. 2008. p. 3.
32. Wittchen, H.U., M. Zaudig, and T. Fydrich, *Strukturiertes klinisches Interview für DSMIV (SKID)*. 1997, Göttingen: Hogrefe.
33. Patton, J.H., M.S. Stanford, and E.S. Barratt, *Factor structure of the Barratt impulsiveness scale.* J Clin Psychol, 1995. **51**(6): p. 768-74.
34. Cohen, S., T. Kamarck, and R. Mermelstein, *A global measure of perceived stress.* J Health Soc Behav, 1983. **24**(4): p. 385-396.
35. Costa, P.T. and R.R. McCrae, *Normal Personality Assessment in Clinical Practice: The NEO Personality Inventory.* Psychological Assessment, 1992. **4**(1): p. 5-13.
36. Kolbeck, S. and R. Maß, *Fragebogen zu sozialer Angst und sozialen Kompetenzdefiziten: SASKO*. 2009: Hogrefe.
37. Rindermann, H., *Emotionale-Kompetenz-Fragebogen*. 2009, Göttigen: Hogrefe.
38. Buehler, M., C. Oberthuer, and H. Flor. *Standard Operating Procedure for IMAGEN, SOP-25/02/2008 version 2.2, WP2: Neuropsychological Testing*. 2008 [cited 2011 19.04.2011]; Available from: http://www.imageneurope. com/media/WP2_SOP_Neuropsychological_testing_250208.pdf.
39. Herbert, C., *Emotional words obtain priority in processing: Evidence from event-related brain potential and functional magnetic resonance imaging studies*, in *Psychology*. 2006, Konstanz.
40. Dieter, J., et al., *Avatar's Neurobiological Traces in the Self-Concept of Massively Multiplayer Online Role-Playing Game (MMORPG) Addicts.* Behav Neurosci, 2014.
41. Choi, J.S. and Y.-S. Han, *Representative reviewers for Internet social media.* Elsevier, 2013. **40**: p. 1274–1282.
42. Kuss, D.J., *Internet gaming addiction: current perspectives.* Psychol Res Behav Manag, 2013. **6**: p. 125-37.
43. Caplan, S.E., D. Williams, and N. Yee, *Problematic Internet use and psychosocial well-being among MMO players.* Computers in Human Behavior, 2009. **25**(6): p. 1312–1319.
44. Young, K., *Understanding Online Gaming Addiction and Treatment Issues for Adolescents.* American Journal of Family and Therapy, 2009. **37**: p. 355-372.
45. Lemenager, T., et al., *Neurobiological correlates of physical self-concept and self-identification with avatars in addicted players of Massively Multiplayer Online Role-Playing Games (MMORPGs).* Addict Behav, 2014. **39**(12): p. 1789-1797.
46. Dong, G., et al., *Impaired inhibitory control in 'internet addiction disorder': a functional magnetic resonance imaging study.* Psychiatry Res, 2012. **203**(2-3): p. 153-158.
47. Robinson, T.E. and K.C. Berridge, *Addiction.* Annu Rev Psychol, 2003. **54**: p. 25-53.
48. MacDonald, A.W., 3rd, et al., *Dissociating the role of the dorsolateral prefrontal and anterior cingulate cortex in cognitive control.* Science, 2000. **288**(5472): p. 1835-8.
49. Milham, M.P., et al., *Practice-related effects demonstrate complementary roles of anterior cingulate and prefrontal cortices in attentional control.* Neuroimage, 2003. **18**(2): p. 483-93.
50. Sass, K., et al., *The influence of emotional associations on the neural correlates of semantic priming.* Hum Brain Mapp, 2012. **33**(3): p. 676-94.
51. Shibata, M., Y. Terasawa, and S. Umeda, *Integration of cognitive and affective networks in humor comprehension.* Neuropsychologia, 2014. **65**: p. 137-45.
52. Binder, J.R., et al., *Where is the semantic system? A critical review and meta-analysis of 120 functional neuroimaging studies.* Cereb Cortex, 2009. **19**(12): p. 2767-96.
53. Hickok, G. and D. Poeppel, *Dorsal and ventral streams: a framework for understanding aspects of the functional anatomy of language.* Cognition, 2004. **92**(1-2): p. 67-99.

54. Indefrey, P. and W.J. Levelt, *The spatial and temporal signatures of word production components.* Cognition, 2004. **92**(1-2): p. 101-44.
55. Jeong, H., et al., *Neural correlates of second-language communication and the effect of language anxiety.* Neuropsychologia, 2015. **66**: p. 182-92.
56. Vigneau, M., et al., *Meta-analyzing left hemisphere language areas: phonology, semantics, and sentence processing.* Neuroimage, 2006. **30**(4): p. 1414-32.
57. Pickering, M.J. and S. Garrod, *An integrated theory of language production and comprehension.* Behav Brain Sci, 2013. **36**(4): p. 329-47.
58. Pulvermuller, F., et al., *Motor cognition-motor semantics: action perception theory of cognition and communication.* Neuropsychologia, 2014. **55**: p. 71-84.
59. Goldin, P.R., et al., *Neural bases of social anxiety disorder: emotional reactivity and cognitive regulation during social and physical threat.* Arch Gen Psychiatry, 2009. **66**(2): p. 170-80.
60. Noordzij, M.L., et al., *Neural correlates of intentional communication.* Front Neurosci, 2010. **4**: p. 188.
61. Sassa, Y., et al., *Cortical mechanism of communicative speech production.* Neuroimage, 2007. **37**(3): p. 985-92.
62. Willems, R.M., et al., *A dissociation between linguistic and communicative abilities in the human brain.* Psychol Sci, 2010. **21**(1): p. 8-14.

5 DISCUSSION

This thesis aimed at the neurobiological exploration of internet gaming addicts' concepts of self, ideal and avatar as well as their emotional inhibitory control abilities, which might depict relevant factors in the development and maintenance of IGD as indicated by previous findings (Ganesh et al., 2011; Lee et al., 2015; Lehenbauer-Baum et al., 2015; Leménager et al., 2014; Leménager et al., 2013; H. Wang et al., 2015). In the following, after separately discussing the results of studies 1 and 2 in the light of the current IGD-specific literature, the findings are related to the cognitive-behavioral model for problematic internet gaming of Haagsma et al. (2013), with the aim of expanding the understanding of IGD's pathogenesis.

5.1 Study 1

The results of study 1 confirmed previous psychometric findings of self-concept deficits in IGD by showing internet gaming addicts to evaluate their own social popularity as a GT-subscale as significantly lower compared to healthy controls. Furthermore, results revealed significantly increased left AG activation in addicted internet gamers (within-group and relative to healthy controls) during the reflection on their own avatar compared to self-reflection, confirming hypothesis I. Based on the left AG's role in self-identification from a third-person perspective, this result might be interpreted as a higher identification with the own avatar in IGD. This finding is also in line with the study of Leménager et al. (2014), suggesting physical self-concept deficits in internet gaming addicts and a higher identification with the own avatar based on AG hyperactivations during the visual perception of the own avatar (Leménager et al., 2014). Interestingly, contrary to the second hypothesis (assuming similar neurobiological brain activations in internet gaming addicts during the reflection on their avatar and their ideal in the left AG), internet gaming addicts showed significantly higher left AG activation during the reflection on their own avatar compared to the reflection on their ideal (within and between the groups). It was deduced that during IGD development, gamers' concept of ideal might be increasingly replaced by their own avatar, in the sense of a partial integration of the avatar into gamers' self-concept. This assumption might be supported by the additional finding of internet gaming addicts' hyperactivations relative to non-addicted controls during the avatar reflection condition (in relation to the reflection on their ideal) in the left MPFC, IFG and bilateral precuneus, which have been implicated in self-concept-related processing before (D'Argembeau et al., 2013; D'Argembeau et al., 2012; Jenkins & Mitchell, 2011; Kelley et al., 2002; Northoff et al., 2006; Pfeifer et al., 2007; Sebastian et al., 2008). These deductions might be underlined by previous psychological considerations and descriptions of internet game users (Ganesh et al., 2011; Pearce, 2006, 2007; Taylor, 2002) that highlighted feelings of embodiment and “proprioception” in relation to the own avatar (Pearce, 2006, 2007; Taylor, 2002).

Taken together, the interpretation of the results of study 1, i.e. self-concept deficits, increased identification with the own avatar as well as the replacement of the ideal by the own avatar, might be assigned to the model of Haagsma et al. (2013) in order to improve the understanding of IGD’s pathogenesis (see chapter 5.3.2, Figure 3). This is reasoned in the general discussion below.

5.2 Study 2

The psychometric results of study 2 suggested significantly increased social anxiety, neuroticism, perceived stress, impulsivity as well as emotional competence deficits (i.e. the recognition, control, regulation and expression of one’s own as well as the recognition of others’ emotions; Rindermann, 2009) to be associated with IGD, supporting previous study findings (Dong & Potenza, 2014; Lehenbauer-Baum et al., 2015; Leménager et al., 2013; Mehroof & Griffiths, 2010). Neuropsychologically, no significant differences in the amount of commission errors during positive, negative or anxious word blocks of the AGN were detected between internet gaming addicts and healthy controls. Additionally, the groups did not differ significantly in the RTs to the positive, negative, neutral and socially anxious conditions of the EST. Possible interpretations might be that the behavioral differences were too subtle in order to be detected by means of the applied tasks (see Dong et al., 2010) or that the alterations in anxiety-related inhibitory control abilities underlie a gradual process from non-problematic to addictive internet game use (Leménager et al., 2014; Robinson & Berridge, 2003). For the AGN, a methodological reason might additionally be supposed as an explanation for the absence of group differences: Opposed to other studies applying a Go/No-Go task, the paradigm in the presented work did not involve a predominant percentage of Go trials [e.g. Ko et al., 2014: 83.3 % or Ding et al., 2014: 87 %], but an equal ratio between Go and No-Go stimuli (i.e. 50 %). Therefore, a prepotent response tendency (Ko et al., 2014) might not have been created at all or not strongly enough in order to disclose group differences in emotional response inhibition.

Neurobiologically, instead of altered dACC activation in internet gaming addicts as well as relative to healthy controls during interference by socially anxious words compared to positive, negative and neutral words in the EST as a correlate of changed emotional inhibitory control abilities (hypothesized due to the dACC’s role in negative affect, pain and cognitive control and increased social anxiety levels in IGD; see hypothesis 2; Lehenbauer-Baum et al., 2015; Shackman et al., 2011), reduced left superior temporal gyrus (STG) and middle temporal gyrus (MTG) activation was detected within the group of internet gaming addicts and relative to social network addicts. Given the role of these temporal regions in the successful retrieval of words or expressions during communication (Jeong et al., 2015; Wise et al., 1991), this finding might suggest that social words are less retrievable from the semantic storage of internet gaming addicts than positive, negative or neutral words. Besides retrieval, the processing of social words might be also impaired, as suggested by the finding of a negative correlation between right precuneus activation during interference with socially anxious stimuli and the scores on the social anxiety subscale “speaking in front of others” in internet gaming addicts. With the precuneus’ assumed involvement in the theory of mind network and therefore its potential contribution to the understanding or generation of communicative messages by inferring and monitoring the intentions or beliefs of others based on the social context (Noordzij et al., 2010; Sassa et al., 2007; Willems et al., 2010), it might be suggested that internet gaming addicts have deficiencies in the handling of speech in social situations.

Besides language processing, the bilateral STG [BA 21 (Boddaert et al., 2004); BA 22/42 (T. Allison, Puce, & McCarthy, 2000; Calvert et al., 1997)] and the left MTG [BA 21 (Critchley et al., 2000)] have been suggested to play a role in social perception, including the analysis of other persons’ eye and mouth movements (STG; T. Allison et al., 2000; Calvert et al., 1997) as well as the active, conscious processing of emotional expressions such as happy and angry faces (MTG; Critchley et al., 2000). These findings were derived from studies in children with primary autism (as a disease with impaired social perceptual skills) in relation to healthy children (Boddaert et al., 2004) as well as from studies involving monkeys or healthy humans (T. Allison et al., 2000; Calvert et al., 1997; Critchley et al., 2000). Interestingly, in a study by Goldin et al. (2009), individuals with social anxiety disorder showed hypoactivations in the bilateral STG (among other regions) relative to healthy controls during the cognitive downregulation of their emotional reactivity to socially threatening stimuli conveyed by images of harsh facial expressions (Goldin et al., 2009). Given the STG and MTG hypoactivation in internet gaming addicts during the interference by socially anxious words compared to positive, negative or neutral words in the EST as a result of study 2 and considering the association of IGD with increased social anxiety as well as emotional competence deficits (Lehenbauer-Baum et al., 2015; Leménager et al., 2013) together with the suggestion that the STG might be involved in the downregulation of social anxiety (Goldin et al., 2009), it might be deduced that in IGD, social anxiety-related emotional inhibitory control is represented by brain regions that are implicated in the processing of social information (such as the STG and MTG). Furthermore, the STG and MTG hypoactivation during the inhibition of socially anxious stimuli found in internet gaming addicts possibly indicates deficiencies in the cognitive regulation of emotions as well as in the processing of social information and might depict a neurobiological correlate of IGD-associated social and emotional competence deficits as facets of self-concept impairments.

Taken together, the model of Haagsma et al. (2013) might therefore be extended by the factor of an altered processing of socially anxious stimuli as well as by increased social anxiety, neuroticism, perceived stress, impulsivity and emotional competence deficits (see chapter 5.3.2, Figure 3). This is more closely described in the general discussion below.

5.3 General discussion

5.3.1 Remarks on the cognitive-behavioral model of problematic internet gaming and its application to this thesis

The cognitive-behavioral model of Haagsma et al. (2013) is one of the first specifically addressing problematic internet gaming with the aim of increasing the understanding of the condition and the negative consequences resulting from it. In the attempt of extending the model to IGD as well as to expand the knowledge on IGD's pathogenesis as a prerequisite for the development of more specific therapy approaches and prevention methods, the results of studies 1 and 2 of this thesis were related to the model of Haagsma et al. (2013; see section below). The latter might be applicable to IGD, as it is based on a continuum approach, meaning that problematic internet gaming involves a broad variety of cases with different severity ranging from mild to heavily affected, instead of suggesting problematic internet gaming to be an "all or nothing phenomenon" (Haagsma et al., 2013).

Furthermore, the extension of the model by additional factors besides POSI seems to be legitimate, as it has already been suggested by Haagsma et al. (2013). The suggestion was based on a comparison of the strength of relationship between their model's components and the ones within Caplan's model of generalized problematic internet use (Caplan, 2010). The results of the comparison indicated that in the internet gaming-specific model, POSI predicted mood and self-regulation to a lesser degree than in the one for generalized problematic internet use, indicating a potential involvement of further factors.

Besides, it has to be considered that the model of Haagsma et al. (2013) is based on study results obtained from adolescent participants aged between 12-22 years, while the participants in studies 1 and 2 of this thesis rather were in emerging adulthood (Arnett, 2000), aged 26 years (study 2) and 27 years (study 1) on average. However, the model of Haagsma et al. (2013) might be applied to this thesis nonetheless, as both periods of life seem to be marked by an increased vulnerability for the acquisition of substance use disorders and (due to their shared characteristics such as withdrawal, tolerance or negative consequences) possibly also IGD (Chambers, Taylor, & Potenza, 2003).

5.3.2 The extended cognitive-behavioral model for IGD

Relating the IGD-specific results and interpretations of studies 1 and 2, i.e. self-concept deficits, increased identification with the own avatar and the replacement of the ideal by the own avatar (study 1) as well as increased social anxiety, impulsivity, neuroticism and perceived stress, emotional competence deficits and an altered processing of socially anxious stimuli (study 2) to the cognitive-behavioral model of problematic internet gaming of Haagsma et al. (2013) suggests that these constructs might be interlinked with POSI and together with it contribute to the negative consequences associated with IGD by influencing mood and self-regulation (see Figure 3).

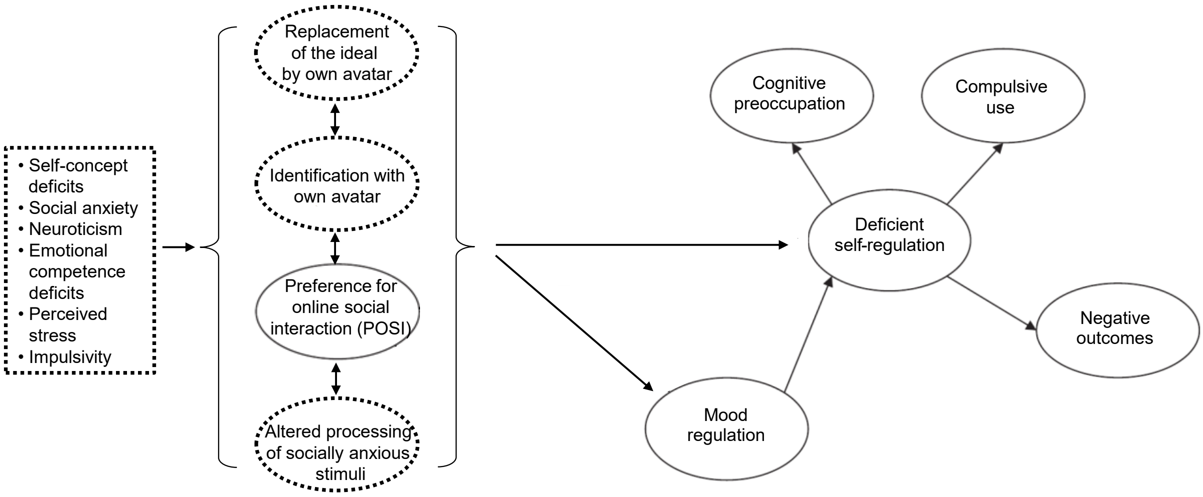

Figure 3: Extension of Haagsma's cognitive-behavioral model of problematic internet gaming to IGD
The components of the original model of Haagsma et al. (2013) are depicted in continuous circles. Added components are designated by dotted lines and include self-concept deficits, increased identification with the own avatar and the replacement of the ideal by the own avatar (study 1) as well as increased social anxiety, impulsivity, neuroticism, emotional competence deficits, perceived stress and an altered processing of socially anxious stimuli (study 2) as potential additional factors that, together with POSI, might influence mood and self-regulation and thereby contribute to the negative outcomes associated with IGD.

The detailed mechanisms in the proposed extended model (see Figure 3) might be delineated as follows.

In accordance with previous findings (Dong & Potenza, 2014; Lehenbauer-Baum et al., 2015; Leménager et al., 2013; Mehroof & Griffiths, 2010), the psychometric results of studies 1 and 2 suggest self-concept and emotional competence deficits as well as increased neuroticism, impulsivity, social anxiety and perceived stress in internet gaming addicts. Individuals with such traits might especially be attracted by the internet, as it depicts a way of coping with emotions such as stress or loneliness (Wan & Chiou, 2006). Furthermore, as suggested by substance addictions (Koob & Volkow, 2010) and their similarities to IGD (Dong & Potenza, 2014), an increased level of impulsivity might promote rapid, unplanned reactions to internet game-related stimuli and render internet gaming addicts unable to inhibit their gaming behavior once it is initiated. In addition, the internet seems to offer greater anonymity and control over self-presentation as well as reduced responsibility and social risk (i.e. less personal costs if interactions or relationships fail) than face-to-face communication in real life (among other factors; Caplan, 2003; Shaw & Black, 2008; Turkle, 1995). This seeming security might allow individuals to express themselves more on the internet, possibly leading to perceptions such as to feel better about themselves or to be treated better by others in the virtual game world than offline in real life (Haagsma et al., 2013; M. Liu & Peng, 2009). Such perceptions could in turn entail alterations in the processing of socially anxious stimuli as well as an increased identification with the own avatar as compensational measures for real life problems, self-concept deficits and early factors for POSI in IGD development. Hereby, the avatar seems to play a central role. The neurobiology-based suggestions that gamers' ideal might be replaced by their avatar and that the latter might be included in the self-concept (as results of study 1) are supported by previous psychometric study findings and descriptions of feelings of embodiment as well as "proprioception" related to the own avatar in internet game users (Ganesh et al., 2011; Pearce, 2006, 2007; Taylor, 2002). Besides this direct value of the avatar to internet gamers, it is likely to play a central role in other central gaming motivations such as relieving negative mood or stress, enabling feelings of power and superiority (Hussain & Griffiths, 2009; Kuss, 2013b; Wan & Chiou, 2006), increasing one's reputation and the admiration from the gaming community for gaming achievements (Kuss, 2013b) as well as socializing (Kuss, 2013b; Wan & Chiou, 2006). All these aspects are either associated with the tendency to escape from negative feelings related to the offline world or with the striving towards the internet game that is (at least in the beginning) linked to positive aspects, thereby closely interrelating the role of the avatar with mood regulation. These processes might in turn reduce self-regulation, i.e. the ability to control and adapt one's own responses in order to achieve long-term goals (Diekhof & Gruber, 2010): The control loss in IGD development might be characterized by the preference of immediate positive feelings associated with internet gaming to the prevention of long-term negative consequences such as a lack of real-life relationships, low well-being, high loneliness or worse academic achievement (among others; Kuss & Griffiths, 2012a). As suggested based on substance addictions, this learned association might be fortified with the ongoing use of internet games and entail compulsive gaming behavior (reflected in the urge for gaming despite negative consequences; Lubman, Yucel, & Pantelis, 2004) and cognitive preoccupation (i.e. obsessive thought patterns regarding internet gaming; Caplan & High, 2011) as two facets of impaired self-regulation (Caplan, 2010; Haagsma et al., 2013). Taken together, these mechanisms might culminate in a vicious circle, leading to IGD development (see Figure 3).

5.4 Limitations

When considering the results presented in this thesis, it has to be kept in mind that the sample sizes of both studies were relatively low. This was mainly owed to the division of internet addicts into subgroups in order to do justice to the assumption that divergent mechanisms might underlie the addiction to different internet applications. Therefore, the presented interpretations should be considered with caution and confirmed by future investigations.

Furthermore, it has to be noted that in both studies, the group of internet gaming addicts was not subdivided according to the preferred or mostly used internet game genre. In study 1, the majority of internet gaming addicts played WoW, while a minority played LoL. Both games are classified as MMORPGs (Poels, Ijsselsteijn, & Kort, 2014; Schwartz, 2013). In study 2, internet gaming addicts mainly played LoL, WoW, Diablo and Star Wars (with the latter two classified as action/role-playing games; Apperley, 2006; Dickey, 2006; Loguidice & Barton, 2009), while a minority was involved in Battlefield (an action game; Gackenbach & Bown, 2011), Counterstrike [a first-person shooter (FPS) game; Claypool, 2002], Call of Duty (an action game; Gackenbach & Bown, 2011), Guild Wars (combat/FPS; Meredith, Hussain, & Griffiths, 2009), Dota [a real-time strategy (RTS) game; Guo, Shen, Visser, & Iosup, 2012] or StarCraft (RTS; Claypool, 2002). These types of internet games played by the internet gaming addicts of studies 1 and 2, i.e. role-playing (LoL, WoW, Diablo and Star Wars), action, RTS and FPS games (Battlefield, Counterstrike, Call of Duty, Guild Wars, Dota or StarCraft), seem to be among the most frequently played ones (Nagygyörgy et al., 2013), which might suggest increased addiction potentials to be inherent in these games (especially in online role-playing games and online shooters; Lemmens & Hendriks, 2016). Although they differ in their core characteristics (e.g. MMORPGs: Avatar advancement, social interactions and explorations of the virtual environment; FPS: Combat and killing of opponents; RTS: Resource collection, unit construction, and battles in real-time; Claypool, 2002), they all seem to address personal needs in internet gaming addicts such as the potential compensation of self-concept deficits by the identification with the own avatar (MMORPGs; Leménager et al., 2014), achievement (FPS; Ghuman & Griffiths, 2012; as the achievement of goals seems to be easier in the game than in real life) or immersion in the game (RTS; Ghuman & Griffiths, 2012; perhaps to divert from the dissatisfaction with the own self). As another commonality, it is emphasized that all these processes are mediated by avatars. Therefore, it might be suggested that similar mechanisms contribute to the development of an addiction to these games and that a subdivision of internet gaming addicts according to detailed game genre neither seems to be necessary nor feasible (due to sample size reductions).

Lastly, it has to be taken into account that no verified causality statements can be made by the presented extended model and that its completeness cannot be guaranteed. However, based on a thorough examination of IGD-specific literature, it might be suggested that the proposed model contains the major IGD-characterizing components which are currently discussed. This is also emphasized by a comparison with another cognitive-behavioral model of IGD developed by Dong & Potenza (2014), which includes executive control, decision making as well as reward-seeking as its major components (Dong & Potenza, 2014). As denoted above and in concordance with Dong & Potenza (2014), the feeling of control during internet gaming, e.g. regarding social interactions and fast achievements in the game, might be rewarding for internet gamers (Leung, 2004), so that internet gaming addicts' reduced self-regulation capabilities related to internet gaming lead to impaired decision-making between "gaming now" and "negative consequences later" in favor of internet gaming, further promoting the development of IGD.

6 SUMMARY AND CONCLUSION

Study 1 aimed at the neurobiological exploration of the relation between internet gaming addicts' concepts of self, ideal and avatar as well as the comparison of these aspects to healthy controls as a further step towards the understanding of internet gaming disorder. It was focused on the brain region of the left angular gyrus due its previous association with self-identification from a third-person perspective in healthy controls as well as with increased identification with the avatar in long-term and addicted internet gamers as deduced from left angular gyrus hyperactivity during the reflection on the avatar and avatar perception, respectively.

In concordance with these previous results, internet gaming addicts of study 1 showed significantly higher left angular gyrus activation during the reflection on their avatar relative to self-reflection within their group. This finding also persisted compared to healthy controls as revealed by a region of interest analysis, altogether supporting the suggestion of internet gaming addicts' higher identification with their own avatar than with their real self.

Given that within the group of internet gaming addicts as well as compared to healthy controls the reflection on the own avatar recruited significantly higher left angular gyrus activation than the reflection on the ideal and considering the hint that the avatar is possibly constructed according to gamers' ideal, it might be suggested that in internet gaming disorder the concrete avatar increasingly replaces the rather abstract ideal as a construct to identify with. The need for such an external construct might arise from the urge to compensate dissatisfaction with the own person as a facet of self-concept deficits. These considerations may contribute to the development of internet gaming disorder-specific psychotherapeutic interventions.

Study 2 aimed to assess the neuropsychological and dorsal anterior cingulate cortex-related neurobiological basis of emotional inhibitory control, i.e. the control of cognitive processes that regulate information processing and behavior in relation to anxious and specifically socially anxious contexts in internet gaming addicts and controls, as well as compared to social network addicts. This aim was derived from the dorsal anterior cingulate cortex' role in anxiety-related affect (such as social exclusion) and cognitive control as well as from observations of increased impulsivity, reduced inhibitory control, impairments in emotional competencies and increased levels of social anxiety in internet gaming disorder.

Neuropsychologically, internet gaming addicts did not significantly differ from healthy controls in emotional inhibitory control, as reflected by non-significant differences in the outcome measures of the affective Go/No-Go task (i.e. amount of commission errors) and the emotional Stroop task (reaction time). However, significant correlations were observed

between reduced emotional response inhibition ability in anxiety blocks (i.e. more commission errors in the affective Go/No-Go task) and addiction severity in the overall sample as well as between increased interference in socially anxious blocks (i.e. longer reaction time in the emotional Stroop task) and lifetime addiction severity in internet gaming addicts. This might indicate that impaired emotional inhibitory control, especially related to anxious as well as socially anxious contexts and addiction severity are interlinked and might even mutually influence each other.
From the neurobiological approach, internet gaming addicts did not show altered dorsal anterior cingulate cortex activation during socially anxious (relative to positive, negative and neutral) word blocks in the emotional Stroop task relative to controls, but exhibited decreased left middle and superior temporal gyrus activation during these blocks relative to social network addicts. Given the assumed role of the middle and superior temporal gyrus in the successful retrieval of words or expressions during communication, social perception and emotion regulation and considering the association of internet gaming disorder with increased social anxiety as well as emotional competence deficits, it might be deduced based on the obtained results that 1) social words are less retrievable from the semantic storage of internet gaming addicts than positive, negative or neutral words, 2) in internet gaming disorder, social anxiety-related emotional inhibitory control is possibly represented by brain regions that are implicated in the processing of social information (such as the middle and superior temporal gyrus) and that 3) internet gaming addicts may have deficiencies in the cognitive regulation of emotions as well as in the processing of social information and that the observed middle and superior temporal gyrus hypoactivation during social anxiety word blocks depicts a neurobiological correlate of internet gaming disorder-associated social and emotional competence deficits as facets of self-concept impairments.

The pre-existing cognitive-behavioral model of problematic internet use, developed to increase the understanding of the condition and its negative consequences, was now referred to internet gaming disorder and extended by self-concept deficits, increased identification with the own avatar, replacement of the ideal by the own avatar, increased social anxiety, impulsivity and neuroticism, emotional competence deficits and an altered processing of socially anxious stimuli as the results from studies 1 and 2 (involving psychological, neuropsychological and neurobiological approaches). The proposed extended model of this thesis might contribute to the understanding of internet gaming disorder as a prerequisite for the development of more specific therapy approaches and prevention strategies.

7 BIBLIOGRAPHY (EXCEPT STUDIES 1 AND 2)

Albert, J., Lopez-Martin, S., Tapia, M., Montoya, D., & Carretie, L. (2012). The role of the anterior cingulate cortex in emotional response inhibition. *Hum Brain Mapp, 33*(9), 2147-2160. doi:10.1002/hbm.21347

Allison, S. E., von Wahlde, L., Shockley, T., & Gabbard, G. O. (2006). The development of the self in the era of the internet and role-playing fantasy games. *Am J Psychiatry, 163*(3), 381-385. doi:10.1176/appi.ajp.163.3.381

Allison, T., Puce, A., & McCarthy, G. (2000). Social perception from visual cues: role of the STS region. *Trends Cogn Sci, 4*(7), 267-278.

APA. (2013). *Diagnostic and Statistical Manual of Mental Disorders* (Fifth Edition (DSM-5™) ed.).

Apperley, T. H. (2006). Genre and game studies: Toward a critical approach to video game genres. *Simulation & Gaming, 37*(1), 6-23. doi:10.1177/1046878105282278

Arnett, J. J. (2000). Emerging adulthood. A theory of development from the late teens through the twenties. *Am Psychol, 55*(5), 469-480.

Aron, A. R., Robbins, T. W., & Poldrack, R. A. (2004). Inhibition and the right inferior frontal cortex. *Trends Cogn Sci, 8*(4), 170-177. doi:10.1016/j.tics.2004.02.010

Ashby, F. G. (2011). *Statistical Analysis of fMRI Data*: MIT Press.

Batthyány, D., Müller, K. W., Benker, F., & Wölfling, K. (2009). [Computer game playing: clinical characteristics of dependence and abuse among adolescents]. *Wien Klin Wochenschr, 121*(15-16), 502-509. doi:10.1007/s00508-009-1198-3

Beckmann, D., Brähler, E., & Richter, H. E. (1990). *Der Gießen-Test (GT)* (4 ed.). Bern: Huber.

Bénar, C.-G., Bagshaw, A. P., & Lemieux, L. (2010). Experimental Design and Data Analysis Strategies. In C. Mulert & L. Lemieux (Eds.), *EEG - fMRI: Physiological Basis, Technique, and Applications* (pp. 221-258): Springer-Verlag Berlin Heidelberg

Bernardi, S., & Pallanti, S. (2009). Internet addiction: a descriptive clinical study focusing on comorbidities and dissociative symptoms. *Compr Psychiatry, 50*(6), 510-516. doi:10.1016/j.comppsych.2008.11.011

Bessière, K., Seay, A. F., & Kiesler, S. (2007). The ideal elf: identity exploration in World of Warcraft. *Cyberpsychol.Behav, 10*(4), 530-535.

Binder, J. R., Desai, R. H., Graves, W. W., & Conant, L. L. (2009). Where is the semantic system? A critical review and meta-analysis of 120 functional neuroimaging studies. *Cereb Cortex, 19*(12), 2767-2796. doi:10.1093/cercor/bhp055

Bischof, G., Bischof, A., Meyer, C., John, U. & Rumpf, H.J. . (2013). *Prävalenz der Internetabhängigkeit – Diagnostik und Risikoprofile (PINTA-DIARI), Kompaktbericht an das Bundesministerium für Gesundheit*.

Boddaert, N., Chabane, N., Gervais, H., Good, C. D., Bourgeois, M., Plumet, M. H., . . . Zilbovicius, M. (2004). Superior temporal sulcus anatomical abnormalities in childhood autism: a voxel-based morphometry MRI study. *Neuroimage, 23*(1), 364-369. doi:10.1016/j.neuroimage.2004.06.016

Borkenau, P., & Ostendorf, F. (1993). *NEO-Fünf-Faktoren-Inventar (NEO-FFI) nach Costa und McCrae*. Göttingen: Hogrefe.

Borkenau, P., & Ostendorf, F. (2008). *NEO-Fünf-Faktoren-Inventar (NEO-FFI) nach Costa und McCrae*. Göttingen: Hogrefe.

Brett, M., Johnsrude, I. S., & Owen, A. M. (2002). The problem of functional localization in the human brain. *Nat Rev Neurosci, 3*(3), 243-249. doi:10.1038/nrn756

Brett, M., Penny, W., & Kiebel, S. (2004). Introduction to Random Field Theory. In R. S. J. Frackowiak (Ed.), *Human Brain Function* (2 ed., pp. 867-880): Elsevier Science (USA).

Buckner, J. D., Schmidt, N. B., Lang, A. R., Small, J. W., Schlauch, R. C., & Lewinsohn, P. M. (2008). Specificity of social anxiety disorder as a risk factor for alcohol and cannabis dependence. *J Psychiatr Res, 42*(3), 230-239. doi:10.1016/j.jpsychires.2007.01.002

Buehler, M., Oberthuer, C., & Flor, H. (2008). Standard Operating Procedure for IMAGEN, SOP-25/02/2008 version 2.2, WP2: Neuropsychological Testing. Retrieved from http://www.imageneurope.com/media/WP2_SOP_Neuropsychological_testing_250208.pdf, April 19, 2011

Bush, G., Luu, P., & Posner, M. I. (2000). Cognitive and emotional influences in anterior cingulate cortex. *Trends Cogn Sci, 4*(6), 215-222.

Buxton, R. B. (2002). *Introduction to Functional Magnetic Resonance Imaging: Principles and Techniques*: Cambridge University Press.

Calhoun, V. D., Stevens, M. C., Pearlson, G. D., & Kiehl, K. A. (2004). fMRI analysis with the general linear model: removal of latency-induced amplitude bias by incorporation of hemodynamic derivative terms. *Neuroimage, 22*(1), 252-257. doi:10.1016/j.neuroimage.2003.12.029

Calvert, G. A., Bullmore, E. T., Brammer, M. J., Campbell, R., Williams, S. C., McGuire, P. K., . . . David, A. S. (1997). Activation of auditory cortex during silent lipreading. *Science, 276*(5312), 593-596.

Campbell-Sills, L., & Barlow, D. H. (2007). Incorporating Emotion Regulation into Conceptualizations and Treatments of Anxiety and Mood Disorders. In J. J. Gross (Ed.), *Handbook of emotion regulation* (pp. 542-559). New York, NY, US: Guilford Press.

Campbell, J. D., Trapnell, P. D., Heine, S. J., Katz, I. M., Lavallee, L. F., & Lehmann, D. R. (1996). Self-Concept Clarity: Measurement, Personality Correlates, and Cultural Boundaries. *Journal of Personality and Social Psychology, 70*(1), 141-156.

Caplan, S. E. (2002). Problematic Internet use and psychosocial well-being: Development of a theory-based cognitive-behavioral measure. *Computers in Human Behavior, 18*, 533-575.

Caplan, S. E. (2003). Preference for Online Social Interaction: A Theory of Problematic Internet Use and Psychosocial Well-Being. *Communication Research, Sage Publications, 30*(6), 625-648. doi:10.1177/0093650203257842

Caplan, S. E. (2005). A Social Skill Account of Problematic Internet Use. *Journal of Communication, 55*(4), 721-736. doi:10.1111/j.1460-2466.2005.tb03019.x

Caplan, S. E. (2007). Relations among loneliness, social anxiety, and problematic Internet use. *Cyberpsychol Behav, 10*(2), 234-242. doi:10.1089/cpb.2006.9963

Caplan, S. E. (2010). Theory and measurement of generalized problematic Internet use: A two-step approach. *Computers in Human Behavior, 26*(5), 1089-1097. doi:10.1016/j.chb.2010.03.012

Caplan, S. E., & High, A. C. (2011). Online Social Interaction, Psychosocial Well-Being, and Problematic Internet Use. In K. S. Young & C. N. de Abreu (Eds.), *Internet Addiction: A Handbook and Guide to Evaluation and Treatment* (pp. 35-54): John Wiley & Sons, Inc.

Caplan, S. E., Williams, D., & Yee, N. (2009). Problematic Internet use and psychosocial well-being among MMO players. *Computers in Human Behavior, 25*(6), 1312–1319. doi:10.1016/j.chb.2009.06.006

Carlson, S., & Wang, T. S. (2007). Inhibitory control and emotion regulation in preschool children. *Cognitive Development, 22*(4), 489-510. doi:10.1016/j.cogdev.2007.08.002

Chakraborty, K., Basu, D., & Vijaya Kumar, K. G. (2010). Internet addiction: consensus, controversies, and the way ahead. *East Asian Arch Psychiatry, 20*(3), 123-132.

Chambers, R. A., Taylor, J. R., & Potenza, M. N. (2003). Developmental neurocircuitry of motivation in adolescence: a critical period of addiction vulnerability. *Am J Psychiatry, 160*(6), 1041-1052. doi:10.1176/appi.ajp.160.6.1041

Charlton, J. P., & Danforth, I. D. W. (2010). Validating the distinction between computer addiction and engagement: online game playing and personality. *Behaviour & Information Technology, 29*(6), 601–613. doi:10.1080/01449290903401978

Choi, J. S., & Han, Y.-S. (2013). Representative reviewers for Internet social media. *Elsevier, 40*, 1274–1282.

Claypool, M. (2002). *Network analysis of Counter-strike and Starcraft.* Paper presented at the Performance, Computing, and Communications Conference, 2003. Conference Proceedings of the 2003 IEEE International, September 14, 2016

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *J Health Soc Behav, 24*(4), 385-396.

Costa, P. T., Jr., & McCrae, R. R. (1980). Influence of extraversion and neuroticism on subjective well-being: happy and unhappy people. *J Pers Soc Psychol, 38*(4), 668-678.

Costa, P. T., Jr., & McCrae, R. R. (1985). The NEO Personality Inventory manual. *Psychological Assessment Resources, Inc.; Odessa, FL*.

Costa, P. T., Jr., & McCrae, R. R. (1989). The NEO-PI/FFI manual supplement. *Psychological Assessment Resources, Inc.; Odessa, FL*.

Costa, P. T., & McCrae, R. R. (1992). Normal Personality Assessment in Clinical Practice: The NEO Personality Inventory. *Psychological Assessment, 4*(1), 5-13. doi:10.1037/1040-3590.4.1.5

Costantini, A. F., & Hoving, K. L. (1973). The relationship of cognitive and motor response inhibition to age and IQ. *Journal of Genetic Psychology, 123*, 309-319.

Craik, F. I. M., Moroz, T. M., Moscovitch, M., Stuss, D. T.,, & Winocur, G., Tulving, E., & Kapur, S. . (1999). In search of the self: A positron emission tomography study. *Psychological Science, 10*, 26 –34.

Critchley, H., Daly, E., Phillips, M., Brammer, M., Bullmore, E., Williams, S., . . . Murphy, D. (2000). Explicit and implicit neural mechanisms for processing of social information from facial expressions: a functional magnetic resonance imaging study. *Hum Brain Mapp, 9*(2), 93-105.

D'Argembeau, A., Cassol, H., Phillips, C., Balteau, E., Salmon, E., & Van der Linden, M. (2013). Brains creating stories of selves: the neural basis of autobiographical reasoning. *Soc Cogn Affect Neurosci*. doi:10.1093/scan/nst028

D'Argembeau, A., Collette, F., Van der, L. M., Laureys, S., Del Fiore, G., Degueldre, C., . . . Salmon, E. (2005). Self-referential reflective activity and its relationship with rest: a PET study. *Neuroimage, 25*(2), 616-624.

D'Argembeau, A., Jedidi, H., Balteau, E., Bahri, M., Phillips, C., & Salmon, E. (2012). Valuing one's self: medial prefrontal involvement in epistemic and emotive investments in self-views. *Cereb Cortex, 22*(3), 659-667. doi:10.1093/cercor/bhr144

D'Argembeau, A., Ruby, P., Collette, F., Degueldre, C., Balteau, E., Luxen, A., . . . Salmon, E. (2007). Distinct regions of the medial prefrontal cortex are associated with self-referential processing and perspective taking. *J Cogn Neurosci, 19*(6), 935-944. doi:10.1162/jocn.2007.19.6.935

D'Esposito, M. (2006). *Functional MRI: Applications in Clinical Neurology and Psychiatry* (M. D'Esposito Ed.): Taylor & Francis Group, LLC.

David, N., Bewernick, B. H., Cohen, M. X., Newen, A., Lux, S., Fink, G. R., . . . Vogeley, K. (2006). Neural representations of self versus other: visual-spatial perspective taking and agency in a virtual ball-tossing game. *J Cogn Neurosci, 18*(6), 898-910. doi:10.1162/jocn.2006.18.6.898

Davis, R. A. (2001). A Cognitive-Behavioral Model of Pathological Internet Use. *Computers in Human Behavior, 17*(2), 187-195.

Decety, J., & Chaminade, T. (2003). When the self represents the other: a new cognitive neuroscience view on psychological identification. *Conscious Cogn, 12*(4), 577-596.

Decety, J., & Grezes, J. (2006). The power of simulation: imagining one's own and other's behavior. *Brain Res, 1079*(1), 4-14.

Derrfuss, J., Brass, M., & von Cramon, D. Y. (2004). Cognitive control in the posterior frontolateral cortex: evidence from common activations in task coordination, interference control, and working memory. *Neuroimage, 23*(2), 604-612. doi:10.1016/j.neuroimage.2004.06.007

Deusinger, I. M. (1996). "Locus of control" - ein Selbstkonzept. In I.M.Deusinger (Ed.), *Kognitionsforschung; Festschrift zum 65. Geburtstag von Fritz Süllwold* (pp. 86-110). Göttingen: Hogrefe. (Reprinted from: Not in File).

Deusinger, I. M. (1998). *Die Frankfurter Körperkonzeptskalen: (FKKS) ; Handanweisung ; mit Bericht über vielfältige Validierungsstudien*: Hogrefe, Verlag für Psychologie.

Dickey, M. D. (2006). Game Design Narrative for Learning: Appropriating Adventure Game Design Narrative Devices and Techniques for the Design of Interactive Learning Environments. *Educational Technology Research and Development, 54*(3), 245-263.

Diekhof, E. K., & Gruber, O. (2010). When desire collides with reason: functional interactions between anteroventral prefrontal cortex and nucleus accumbens underlie the human ability to resist impulsive desires. *J Neurosci, 30*(4), 1488-1493. doi:10.1523/jneurosci.4690-09.2010

Dieter, J., Hill, H., Sell, M., Reinhard, I., Vollstadt-Klein, S., Kiefer, F., . . . Lemenager, T. (2014). Avatar's Neurobiological Traces in the Self-Concept of Massively Multiplayer Online Role-Playing Game (MMORPG) Addicts. *Behav Neurosci*. doi:10.1037/bne0000025

Ding, W. N., Sun, J. H., Sun, Y. W., Chen, X., Zhou, Y., Zhuang, Z. G., . . . Du, Y. S. (2014). Trait impulsivity and impaired prefrontal impulse inhibition function in adolescents with internet gaming addiction revealed by a Go/No-Go fMRI study. *Behav Brain Funct, 10*, 20. doi:10.1186/1744-9081-10-20

Dong, G., Devito, E. E., Du, X., & Cui, Z. (2012). Impaired inhibitory control in 'internet addiction disorder': a functional magnetic resonance imaging study. *Psychiatry Res, 203*(2-3), 153-158.

Dong, G., Huang, J., & Du, X. (2011). Enhanced reward sensitivity and decreased loss sensitivity in Internet addicts: an fMRI study during a guessing task. *J Psychiatr Res, 45*(11), 1525-1529. doi:10.1016/j.jpsychires.2011.06.017

Dong, G., Lin, X., & Potenza, M. N. (2015). Decreased functional connectivity in an executive control network is related to impaired executive function in Internet gaming disorder. *Prog Neuropsychopharmacol Biol Psychiatry, 57*, 76-85. doi:10.1016/j.pnpbp.2014.10.012

Dong, G., & Potenza, M. N. (2014). A cognitive-behavioral model of Internet gaming disorder: theoretical underpinnings and clinical implications. *J Psychiatr Res, 58*, 7-11. doi:10.1016/j.jpsychires.2014.07.005

Dong, G., Zhou, H., & Zhao, X. (2010). Impulse inhibition in people with Internet addiction disorder: electrophysiological evidence from a Go/NoGo study. *Neurosci Lett, 485*(2), 138-142. doi:10.1016/j.neulet.2010.09.002

Egner, T., Etkin, A., Gale, S., & Hirsch, J. (2008). Dissociable neural systems resolve conflict from emotional versus nonemotional distracters. *Cereb Cortex, 18*(6), 1475-1484. doi:10.1093/cercor/bhm179

Eickhoff, S. B., & Bzdok, D. (2013). Meta-Analyses in Basic and Clinical Neuroscience: State of the Art and Perspective. In S. Ulmer & O. Jansen (Eds.), *fMRI: Basics and Clinical Applications* (pp. 77-90): Springer-Verlag Berlin Heidelberg.

Eisenberger, N. I., & Lieberman, M. D. (2004). Why rejection hurts: a common neural alarm system for physical and social pain. *Trends Cogn Sci, 8*(7), 294-300. doi:10.1016/j.tics.2004.05.010

Elliott, R., Ogilvie, A., Rubinsztein, J. S., Calderon, G., Dolan, R. J., & Sahakian, B. J. (2004). Abnormal ventral frontal response during performance of an affective go/no go task in patients with mania. *Biol Psychiatry, 55*(12), 1163-1170. doi:10.1016/j.biopsych.2004.03.007

Elliott, R., Rubinsztein, J. S., Sahakian, B. J., & Dolan, R. J. (2000). Selective attention to emotional stimuli in a verbal go/no-go task: an fMRI study. *Neuroreport, 11*(8), 1739-1744.

Etkin, A., Egner, T., Peraza, D. M., Kandel, E. R., & Hirsch, J. (2006). Resolving emotional conflict: a role for the rostral anterior cingulate cortex in modulating activity in the amygdala. *Neuron, 51*(6), 871-882. doi:10.1016/j.neuron.2006.07.029

Falquez, R., Dinu-Biringer, R., Stopsack, M., Arens, E. A., Wick, W., & Barnow, S. (2015). Examining cognitive emotion regulation in frontal lobe patients: The mediating role of response inhibition. *NeuroRehabilitation, 37*(1), 89-98. doi:10.3233/nre-151242

Festl, R., Scharkow, M., & Quandt, T. (2013). Problematic computer game use among adolescents, younger and older adults. *Addiction, 108*(3), 592-599. doi:10.1111/add.12016

Flandin, G., & Novak, M. J. U. (2013). fMRI Data Analysis Using SPM. In S. Ulmer & O. Jansen (Eds.), *fMRI: Basics and Clinical Applications* (2 ed., pp. 51-76): Springer-Verlag.

Fossati, P., Hevenor, S. J., Graham, S. J., Grady, C., Keightley, M. L., Craik, F., & Mayberg, H. (2003). In search of the emotional self: an fMRI study using positive and negative emotional words. *Am J Psychiatry, 160*(11), 1938-1945.

Friese, M., Binder, J., Luechinger, R., Boesiger, P., & Rasch, B. (2013). Suppressing emotions impairs subsequent stroop performance and reduces prefrontal brain activation. *PLoS One, 8*(4), e60385. doi:10.1371/journal.pone.0060385

Friston, K. J. (2002). Statistics I: Experimental Design and Statistical Parametric Mapping. In T. A.W. & M. J.C. (Eds.), *Brain Mapping: The Methods* (2 ed., pp. 605-633): Academic Press.

Friston, K. J., Holmes, A. P., Poline, J. B., Grasby, P. J., Williams, S. C., Frackowiak, R. S., & Turner, R. (1995). Analysis of fMRI time-series revisited. *Neuroimage, 2*(1), 45-53. doi:10.1006/nimg.1995.1007

Friston, K. J., Holmes, A. P., Worsley, K. J., Poline, J.-P., Frith, C. D., & Frackowiak, R. S. J. (1994). Statistical parametric maps in functional imaging: A general linear approach. *Hum Brain Mapp, 2*(4), 189-210. doi:DOI: 10.1002/hbm.460020402

Friston, K. J., Jezzard, P., & Turner, R. (1994). Analysis of functional MRI time-series. *Hum Brain Mapp, 1*(2), 153-171. doi:10.1002/hbm.460010207

Gackenbach, J., & Bown, J. (2011). Video Game Presence as a Function of Genre. *Loading... The Journal of the Canadian Game Studies Association, 5*(8), 4-28.

Gamer, M. (2011). Detecting of deception and concealed information using neuroimaging techniques. In B. Verschuere, G. Ben-Shakhar, & E. Meijer (Eds.), *Memory Detection: Theory and Application of the Concealed Information Test* (pp. 90-113). United States of America, New York: Cambridge University Press.

Ganesh, S., van Schie, H. T., de Lange, F. P., Thompson, E., & Wigboldus, D. H. (2011). How the human brain goes virtual: distinct cortical regions of the person-processing network are involved in self-identification with virtual agents. *Cereb Cortex, 22*(7), 1577-1585. doi:10.1093/cercor/bhr227

Gazzaniga, M. S. (2008). *Human: The science behind what makes us unique*. New York: Harper Collins.

Gefter, W. B. (2009). Magnetic Resonance Imaging of the Thorax. In T. W. Shields, J. LoCicero, C. E. Reed, & R. H. Feins (Eds.), *General Thoracic Surgery* (7 ed., pp. 167-198): Lippincott Williams & Wilkings.

Ghuman, D., & Griffiths, M. (2012). A Cross-Genre Study of Online Gaming: Player Demographics, Motivation for Play, and Social Interactions Among Players. *International Journal of Cyber Behavior, Psychology and Learning (IJCBPL), 2*(1), 13-29. doi:10.4018/ijcbpl.2012010102

Glowniak, J. (1998). History, structure, and function of the Internet. *Semin Nucl Med, 28*(2), 135-144.

Goebel, R. (2015). Revealing Brain Activity and White Matter Structure Using Functional and Diffusion-Weighted Magnetic Resonance Imaging. In C. Stippich (Ed.), *Clinical Functional MRI: Presurgical Functional Neuroimaging: Presurgical Functional Neuroimaging* (2 ed., pp. 13-61): Springer-Verlag Berlin Heidelberg.

Goldin, P. R., Manber, T., Hakimi, S., Canli, T., & Gross, J. J. (2009). Neural bases of social anxiety disorder: emotional reactivity and cognitive regulation during social and physical threat. *Arch Gen Psychiatry, 66*(2), 170-180. doi:10.1001/archgenpsychiatry.2008.525

Griffiths, M., & Wood, R. T. (2000). Risk factors in adolescence: the case of gambling, videogame playing, and the internet. *J Gambl Stud, 16*(2-3), 199-225.

Griffiths, M. D., Davies, M. N., & Chappell, D. (2004). Online computer gaming: a comparison of adolescent and adult gamers. *J Adolesc, 27*(1), 87-96. doi:10.1016/j.adolescence.2003.10.007

Griffiths, M. D., & Szabo, A. (2014). Is excessive online usage a function of medium or activity? An empirical pilot study. *J Behav Addict, 3*(1), 74-77. doi:10.1556/jba.2.2013.016

Gross, J. J., & Munoz, R. F. (1995). Emotion Regulation and Mental Health. *Clin Psychol Sci Prac*, 151-164.

Grüsser, S. M., Thalemann, R., & Griffiths, M. D. (2007). Excessive computer game playing: evidence for addiction and aggression? *Cyberpsychol Behav, 10*(2), 290-292. doi:10.1089/cpb.2006.9956

Grüsser, S. M., Wrase, J., Klein, S., Hermann, D., Smolka, M. N., Ruf, M., . . . Heinz, A. (2004). Cue-induced activation of the striatum and medial prefrontal cortex is associated with subsequent relapse in abstinent alcoholics. *Psychopharmacology (Berl), 175*(3), 296-302.

Guo, Y., Shen, S., Visser, O., & Iosup, A. (2012). *An analysis of online match-based games.* Paper presented at the IEEE, Munich

Ha, J. H., Kim, S. Y., Bae, S. C., Bae, S., Kim, H., Sim, M., . . . Cho, S. C. (2007). Depression and Internet addiction in adolescents. *Psychopathology, 40*(6), 424-430. doi:10.1159/000107426

Haagsma, M. C., Caplan, S. E., Peters, O., & Pieterse, M. E. (2013). A cognitive-behavioral model of problematic online gaming in adolescents aged 12–22 years. *Computers in Human Behavior, 29*(1), 202–209. doi:10.1016/j.chb.2012.08.006

Haase, R. F. (2011). Introduction and Review of Univariate General Linear Models *Multivariate General Linear Models* (pp. 1-26): SAGE Publications.

Hall, A. S., & Parsons, J. (2001). Internet addiction: college student case study using best practices in cognitive behavior therapy. *Journal of Mental Health Counseling, 23*(4).

Heatherton, T. F., Wyland, C. L., Macrae, C. N., Demos, K. E., Denny, B. T., & Kelley, W. M. (2006). Medial prefrontal activity differentiates self from close others. *Soc Cogn Affect Neurosci, 1*(1), 18-25. doi:10.1093/scan/nsl001

Heiss, W.-D., & Drzezga, A. (2014). PET/MR in Brain Imaging. In I. Carrio & P. Ros (Eds.), *PET/MRI: Methodology and Clinical Applications* (pp. 109-126): Springer-Verlag Berlin Heidelberg.

Hendrick, R. E. (2008). Contrast Agents in Breast Magnetic Resonance Imaging *Breast MRI: Fundamentals and Technical Aspects* (pp. 113-134): Springer Science+Business Media, LLC.

Herbert, C. (2006). *Emotional words obtain priority in processing: Evidence from event-related brain potential and functional magnetic resonance imaging studies.* (Dr. rer. nat.), Konstanz. Retrieved from http://nbn-resolving.de/urn:nbn:de:bsz:352-opus-24455, September 15, 2016

Herring, W. (2016). *Learning Radiology: Recognizing the Basics* (3 ed.): Elsevier.

Hickok, G., & Poeppel, D. (2004). Dorsal and ventral streams: a framework for understanding aspects of the functional anatomy of language. *Cognition, 92*(1-2), 67-99. doi:10.1016/j.cognition.2003.10.011

Hormes, J. M., Kearns, B., & Timko, C. A. (2014). Craving Facebook? Behavioral addiction to online social networking and its association with emotion regulation deficits. *Addiction, 109*(12), 2079-2088. doi:10.1111/add.12713

Hsu, S. H., Wen, M.-H., & Wu, M.-C. (2009). Exploring user experiences as predictors of MMORPG addiction *Computers & Education, 53*(3), 990-999. doi:10.1016/j.compedu.2009.05.016

Hussain, Z., & Griffiths, M. D. (2009). The attitudes, feelings, and experiences of online gamers: a qualitative analysis. *Cyberpsychol Behav, 12*(6), 747-753. doi:10.1089/cpb.2009.0059

Indefrey, P., & Levelt, W. J. (2004). The spatial and temporal signatures of word production components. *Cognition, 92*(1-2), 101-144. doi:10.1016/j.cognition.2002.06.001

Jenkins, A. C., & Mitchell, J. P. (2011). Medial prefrontal cortex subserves diverse forms of self-reflection. *Soc Neurosci, 6*(3), 211-218. doi:10.1080/17470919.2010.507948

Jeong, H., Sugiura, M., Suzuki, W., Sassa, Y., Hashizume, H., & Kawashima, R. (2015). Neural correlates of second-language communication and the effect of language anxiety. *Neuropsychologia, 66*, 182-192. doi:10.1016/j.neuropsychologia.2014.11.013

Jin, C., Zhang, T., Cai, C., Bi, Y., Li, Y., Yu, D., . . . Yuan, K. (2015). Abnormal prefrontal cortex resting state functional connectivity and severity of internet gaming disorder. *Brain Imaging Behav*. doi:10.1007/s11682-015-9439-8

Johnson, M. K., Raye, C. L., Mitchell, K. J., Touryan, S. R., Greene, E. J., & Nolen-Hoeksema, S. (2006). Dissociating medial frontal and posterior cingulate activity during self-reflection. *Soc Cogn Affect.Neurosci, 1*(1), 56-64.

Kaltiala, -. H., R., Lintonen, T., & Rimpela, A. (2004). Intemet addiction? Potentially problematic use of the intemet in a population of 12-18 year old adolescents. *Addict Res Theory, 12*, 89-96.

Kelley, W. M., Macrae, C. N., Wyland, C. L., Caglar, S., Inati, S., & Heatherton, T. F. (2002). Finding the self? An event-related fMRI study. *J Cogn Neurosci, 14*(5), 785-794. doi:10.1162/08989290260138672

Kim, K., Ryu, E., Chon, M. Y., Yeun, E. J., Choi, S. Y., Seo, J. S., & Nam, B. W. (2006). Internet addiction in Korean adolescents and its relation to depression and suicidal ideation: a questionnaire survey. *Int J Nurs Stud, 43*(2), 185-192. doi:10.1016/j.ijnurstu.2005.02.005

Kim, N., Hughes, T. L., Park, C. G., Quinn, L., & Kong, I. D. (2016). Resting-State Peripheral Catecholamine and Anxiety Levels in Korean Male Adolescents with Internet Game Addiction. *Cyberpsychol Behav Soc Netw*. doi:10.1089/cyber.2015.0411

Kjaer, T. W., Nowak, M., & Lou, H. C. (2002). Reflective self-awareness and conscious states: PET evidence for a common midline parietofrontal core. *Neuroimage, 17*(2), 1080-1086.

Klaiberg, A. (2002). GT. Gießen-Test. In E. Brähler, J. Schumacher, & B. Strauß (Eds.), *In Diagnostische Verfahren in der Psychotherapie* (pp. 172-175). Göttingen: Hogrefe. (Reprinted from: Not in File).

Klein, T. (2003). *Selbstkonzept und Coping-Prozesse bei Patienten nach einer Amputation: Eine Längsschnittstudie zur Entwicklung des Selbstkonzepts und zum Prozess der Bewältigung bei Patienten nach einer Beinamputation.* (Dr. phil.), Universität Dortmund, Dortmund.

Knyazev, G. G. (2007). Motivation, emotion, and their inhibitory control mirrored in brain oscillations. *Neurosci Biobehav Rev, 31*(3), 377-395. doi:10.1016/j.neubiorev.2006.10.004

Ko, C. H., Hsieh, T. J., Chen, C. Y., Yen, C. F., Chen, C. S., Yen, J. Y., . . . Liu, G. C. (2014). Altered brain activation during response inhibition and error processing in subjects with Internet gaming disorder: a functional magnetic imaging study. *Eur Arch Psychiatry Clin Neurosci, 264*(8), 661-672. doi:10.1007/s00406-013-0483-3

Koc, M., & Gulyagci, S. (2013). Facebook addiction among Turkish college students: the role of psychological health, demographic, and usage characteristics. *Cyberpsychol Behav Soc Netw, 16*(4), 279-284. doi:10.1089/cyber.2012.0249

Kolbeck, S., & Maß, R. (2009). *Fragebogen zu sozialer Angst und sozialen Kompetenzdefiziten: SASKO*: Hogrefe.

Konrad, K., Firk, C., & Uhlhaas, P. J. (2013). Brain development during adolescence: neuroscientific insights into this developmental period. *Dtsch Arztebl Int, 110*(25), 425-431. doi:10.3238/arztebl.2013.0425

Kontos, D., Megalooikonomou, V., & Makedon, F. (2004). *Computationally Intelligent Methods for Mining 3D Medical Images.* Paper presented at the Third Hellenic Conference on AI, SETN, Samos, Greece

Koob, G. F., & Volkow, N. D. (2010). Neurocircuitry of addiction. *Neuropsychopharmacology, 35*(1), 217-238. doi:10.1038/npp.2009.110

Kriegeskorte, N., Goebel, R., & Bandettini, P. (2006). Information-based functional brain mapping. *Proc Natl Acad Sci U S A, 103*(10), 3863-3868. doi:10.1073/pnas.0600244103

Kuss, D. J. (2013a). *For the Horde! How Playing World of Warcraft Reflects our Participation in Popular Media Culture*. Saarbrücken, Germany: LAP, Lambert Academic Publishing.

Kuss, D. J. (2013b). Internet gaming addiction: current perspectives. *Psychol Res Behav Manag, 6*, 125-137. doi:10.2147/prbm.s39476

Kuss, D. J., & Griffiths, M. D. (2012a). Internet Gaming Addiction: A Systematic Review of Empirical Research. *International Journal of Mental Health and Addiction, 10*(2), 278-296.

Kuss, D. J., & Griffiths, M. D. (2012b). Online gaming addiction in children and adolescents: A review of empirical research. *J Behav Addict, 1*(1), 3-22. doi:10.1556/jba.1.2012.1.1

Lamm, C., Batson, C. D., & Decety, J. (2007). The neural substrate of human empathy: effects of perspective-taking and cognitive appraisal. *J Cogn Neurosci, 19*(1), 42-58. doi:10.1162/jocn.2007.19.1.42

Lee-Won, R. J., Herzog, L., & Park, S. G. (2015). Hooked on Facebook: The Role of Social Anxiety and Need for Social Assurance in Problematic Use of Facebook. *Cyberpsychol Behav Soc Netw, 18*(10), 567-574. doi:10.1089/cyber.2015.0002

Lee, J., Lee, S., Chun, J. W., Cho, H., Kim, D. J., & Jung, Y. C. (2015). Compromised Prefrontal Cognitive Control Over Emotional Interference in Adolescents with Internet Gaming Disorder. *Cyberpsychol Behav Soc Netw, 18*(11), 661-668. doi:10.1089/cyber.2015.0231

Lehenbauer-Baum, M., Klaps, A., Kovacovsky, Z., Witzmann, K., Zahlbruckner, R., & Stetina, B. U. (2015). Addiction and Engagement: An Explorative Study Toward Classification Criteria for Internet Gaming Disorder. *Cyberpsychol Behav Soc Netw, 18*(6), 343-349. doi:10.1089/cyber.2015.0063

Leiner, B. M., Cerf, V. G., Clark, D. D., Kahn, R. E., Kleinrock, L., Lynch, D. C., . . . Wolff, S. S. (1997). The Past and Future History of the Internet. *Communications of the ACM, 40*(2), 102-108.

Leménager, T., Dieter, J., Hill, H., Koopmann, A., Reinhard, I., Sell, M., . . . Mann, K. (2014). Neurobiological correlates of physical self-concept and self-identification with avatars in addicted players of Massively Multiplayer Online Role-Playing Games (MMORPGs). *Addict Behav, 39*(12), 1789-1797. doi:10.1016/j.addbeh.2014.07.017

Leménager, T., Gwodz, A., Richter, A., Reinhard, I., Kammerer, N., Sell, M., & Mann, K. (2013). Self-concept deficits in massively multiplayer online role-playing games addiction. *Eur Addict Res, 19*(5), 227-234. doi:10.1159/000345458

Lemmens, J. S., & Hendriks, S. J. F. (2016). Addictive Online Games: Examining the Relationship Between Game Genres and Internet Gaming Disorder *Cyberpsychology, Behavior, and Social Networking, 19*(4), 270-276. doi:10.1089/cyber.2015.0415

Leung, L. (2004). Net-generation attributes and seductive properties of the internet as predictors of online activities and internet addiction. *Cyberpsychol.Behav, 7*(3), 333-348.

Li, D., Liau, A., & Khoo, A. (2011). Examining the influence of actual-ideal self-discrepancies, depression, and escapism, on pathological gaming among massively multiplayer online adolescent gamers. *Cyberpsychol Behav Soc Netw, 14*(9), 535-539. doi:10.1089/cyber.2010.0463

Licklider, J. C. R., & Clark, W. E. (1962). *On-line man-computer communication.* Paper presented at the AIEE-IRE '62 (Spring) Proceedings of the May 1-3, 1962, spring joint computer conference

Lievaart, M., van der Veen, F. M., Huijding, J., Naeije, L., Hovens, J. E., & Franken, I. H. (2016). Trait anger in relation to neural and behavioral correlates of response inhibition and error-processing. *Int J Psychophysiol, 99*, 40-47. doi:10.1016/j.ijpsycho.2015.12.001

Liu, C. Y., & Kuo, F. Y. (2007). A study of Internet addiction through the lens of the interpersonal theory. *Cyberpsychol Behav, 10*(6), 799-804. doi:10.1089/cpb.2007.9951

Liu, G. C., Yen, J. Y., Chen, C. Y., Yen, C. F., Chen, C. S., Lin, W. C., & Ko, C. H. (2014). Brain activation for response inhibition under gaming cue distraction in internet gaming disorder. *Kaohsiung J Med Sci, 30*(1), 43-51. doi:10.1016/j.kjms.2013.08.005

Liu, M., & Peng, W. (2009). Cognitive and psychological predictors of the negative outcomes associated with playing MMOGs (massively multiplayer online games). *Computers in Human Behavior, 25*, 1306–1311. doi:10.1016/j.chb.2009.06.002

Lo, S. K., Wang, C. C., & Fang, W. (2005). Physical interpersonal relationships and social anxiety among online game players. *Cyberpsychol Behav, 8*(1), 15-20. doi:10.1089/cpb.2005.8.15

Loguidice, B., & Barton, M. (2009). *Vintage Games: An Insider Look at the History of Grand Theft Auto, Super Mario, and the Most Influential Games of All Time*: Elsevier.

Lubman, D. I., Yucel, M., & Pantelis, C. (2004). Addiction, a condition of compulsive behaviour? Neuroimaging and neuropsychological evidence of inhibitory dysregulation. *Addiction, 99*(12), 1491-1502. doi:10.1111/j.1360-0443.2004.00808.x

MacDonald, A. W., 3rd, Cohen, J. D., Stenger, V. A., & Carter, C. S. (2000). Dissociating the role of the dorsolateral prefrontal and anterior cingulate cortex in cognitive control. *Science, 288*(5472), 1835-1838.

Macrae, C. N., Moran, J. M., Heatherton, T. F., Banfield, J. F., & Kelley, W. M. (2004). Medial prefrontal activity predicts memory for self. *Cereb Cortex, 14*(6), 647-654. doi:10.1093/cercor/bhh025

Maldjian, J. A., Laurienti, P. J., & Burdette, J. H. (2004). Precentral gyrus discrepancy in electronic versions of the Talairach atlas. *Neuroimage, 21*(1), 450-455.

Maldjian, J. A., Laurienti, P. J., Kraft, R. A., & Burdette, J. H. (2003). An automated method for neuroanatomic and cytoarchitectonic atlas-based interrogation of fMRI data sets. *Neuroimage, 19*(3), 1233-1239.

McClernon, F. J., Kozink, R. V., Lutz, A. M., & Rose, J. E. (2009). 24-h smoking abstinence potentiates fMRI-BOLD activation to smoking cues in cerebral cortex and dorsal striatum. *Psychopharmacology (Berl), 204*(1), 25-35. doi:10.1007/s00213-008-1436-9

Mehroof, M., & Griffiths, M. D. (2010). Online gaming addiction: the role of sensation seeking, self-control, neuroticism, aggression, state anxiety, and trait anxiety. *Cyberpsychol.Behav Soc Netw., 13*(3), 313-316.

Meredith, A., Hussain, Z., & Griffiths, M. D. (2009). Online gaming: a scoping study of massively multi-player online role playing games. *Electronic Commerce Research, 9*(1), 3-26.

Milham, M. P., Banich, M. T., Claus, E. D., & Cohen, N. J. (2003). Practice-related effects demonstrate complementary roles of anterior cingulate and prefrontal cortices in attentional control. *Neuroimage, 18*(2), 483-493.

Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. *Annu Rev Neurosci, 24*, 167-202. doi:10.1146/annurev.neuro.24.1.167

Müller, H.-P., & Kassubek, J. (2008). *Multimodal Imaging in Neurology: Special Focus on MRI Applications and MEG*: Morgan & Claypool Publishers.

Mummendey, H. D. (1990). *Psychologie der Selbstdarstellung*. Göttingen: Hogrefe.

Nagygyörgy, K., Urbán, R., Farkas, J., Griffiths, M. D., Zilahy, D., Kökönyei, G., . . . Demetrovics, Z. (2013). Typology and Sociodemographic Characteristics of Massively Multiplayer Online Game Players. *International Journal of Human–Computer Interaction, 29*(3). doi:10.1080/10447318.2012.702636

Nichols, T., & Holmes, A. (2004). Nonparametric Permutation Tests for Functional Neuroimaging. In R. S. J. Frackowiak (Ed.), *Human Brain Function* (2 ed., pp. 887-910): Elsevier Science (USA).

Noordzij, M. L., Newman-Norlund, S. E., de Ruiter, J. P., Hagoort, P., Levinson, S. C., & Toni, I. (2010). Neural correlates of intentional communication. *Front Neurosci, 4*, 188. doi:10.3389/fnins.2010.00188

Northoff, G., Heinzel, A., de Greck, M., Bermpohl, F., Dobrowolny, H., & Panksepp, J. (2006). Self-referential processing in our brain--a meta-analysis of imaging studies on the self. *Neuroimage, 31*(1), 440-457. doi:10.1016/j.neuroimage.2005.12.002

Ochsner, K. N., Beer, J. S., Robertson, E. R., Cooper, J. C., Gabrieli, J. D., Kihsltrom, J. F., & D'Esposito, M. (2005). The neural correlates of direct and reflected self-knowledge. *Neuroimage, 28*(4), 797-814. doi:10.1016/j.neuroimage.2005.06.069

Ogawa, S., Lee, T. M., Kay, A. R., & Tank, D. W. (1990). Brain magnetic resonance imaging with contrast dependent on blood oxygenation. *Proc Natl Acad Sci U S A, 87*(24), 9868-9872.

Patton, J. H., Stanford, M. S., & Barratt, E. S. (1995). Factor structure of the Barratt impulsiveness scale. *J Clin Psychol, 51*(6), 768-774.

Pearce, C. (2006). *Seeing and Being Seen: Presence & Play in Online Virtual Worlds Position Paper*. Paper presented at the USC Institute for Creative Technologies Presence Workshop Online, Offline & The Concept of Presence When Games and VR Collide. http://homes.lmc.gatech.edu/~cpearce3/PearcePubs/PearcePosition.pdf; http://www.lcc.gatech.edu/~cpearce3/PearcePubs/PearcePosition.pdf, September 14, 2016

Pearce, C. (2007). Communities of Play: The Social Construction of Identity in Persistent Online Game Worlds. In P. Harrigan & N. Wardrip-Fruin (Eds.), *Second Person: Role-Playing and Story in Games and Playable Media* (pp. 311-317): MIT Press.

Penny, W., & Henson, R. (2007). Analysis of Variance. In K. J. Friston, J. T. Ashburner, S. J. Kiebel, T. E. Nichols, & W. D. Penny (Eds.), *Statistical Parametric Mapping: The Analysis of Functional Brain Images* (1 ed., pp. 166-177): Elsevier Ltd.

Petersen, K. U., Weymann, N., Schelb, Y., Thiel, R., & Thomasius, R. (2009). Pathological Internet use--epidemiology, diagnostics, co-occurring disorders and treatment. *Fortschr Neurol Psychiatr, 77*(5), 263-271. doi:10.1055/s-0028-1109361

Petry, N. M. (2007). Gambling and substance use disorders: current status and future directions. *Am J Addict, 16*(1), 1-9. doi:10.1080/10550490601077668

Pezoa-Jares, R. E., Espinoza-Luna, I. L., & Vasquez-Medina, J. A. (2012). Internet Addiction: A Review. *Addiction Research & Therapy*. doi:10.4172/2155-6105.S6-004

Pfeifer, J. H., Lieberman, M. D., & Dapretto, M. (2007). "I know you are but what am I?!": neural bases of. *J Cogn Neurosci, 19*(8), 1323-1337.

Pickering, M. J., & Garrod, S. (2013). An integrated theory of language production and comprehension. *Behav Brain Sci, 36*(4), 329-347. doi:10.1017/s0140525x12001495

Pinus, A. B., & Mohamed, F. B. (2006). fMRI Scanning Methodologies. In S. H. Faro & F. B. Mohamed (Eds.), *Functional MRI: Basic Principles and Clinical Applications* (pp. 24-58): Springer Science+Business Media New York.

Poels, K., Ijsselsteijn, W. A., & Kort, Y. (2014). World of Warcraft, the aftermath: How game elements transfer into perceptions, associations and (day)dreams in the everyday life of massively multiplayer online role-playing game players. *new media & society*, 1-17. doi:10.1177/1461444814521596

Poldrack, R. A. (2007). Region of interest analysis for fMRI. *Soc Cogn Affect Neurosci, 2*(1), 67-70. doi:10.1093/scan/nsm006

Poldrack, R. A., Mumford, J. A., & Nichols, T. E. (2011). *Handbook of Functional MRI Data Analysis*: Cambridge University Press.

Potenza, M. N. (2001). The neurobiology of pathological gambling. *Semin Clin Neuropsychiatry, 6*(3), 217-226.

Pulvermuller, F., Moseley, R. L., Egorova, N., Shebani, Z., & Boulenger, V. (2014). Motor cognition-motor semantics: action perception theory of cognition and communication. *Neuropsychologia, 55*, 71-84. doi:10.1016/j.neuropsychologia.2013.12.002

Raichle, M. E. (2010). The origins of functional brain imaging in humans. In S. Finger, F. Boller, & K. L. Tyler (Eds.), *History of Neurology* (Vol. 95, pp. 257-268): Elsevier.

Ramani, R. (2014). Neuroimaging Techniques. In K. J. Ruskin, S. H. Rosenbaum, & I. J. Rampil (Eds.), *Fundamentals of Neuroanesthesia: A Physiologic Approach to Clinical Practice* (pp. 77-89). New York, NY 10016: Oxford University Press.

Regenbogen, C., Habel, U., & Kellermann, T. (2013). Connecting multimodality in human communication. *Front Hum Neurosci, 7*, 754. doi:10.3389/fnhum.2013.00754

Regenbogen, C., Schneider, D. A., Gur, R. E., Schneider, F., Habel, U., & Kellermann, T. (2012). Multimodal human communication--targeting facial expressions, speech content and prosody. *Neuroimage, 60*(4), 2346-2356. doi:10.1016/j.neuroimage.2012.02.043

Rehbein, F., Kleimann, M., & Mössle, E. T. (2009). *Computerspielabhängigkeit im Kindes- und Jugendalter : Empirische Befunde zu Ursachen, Diagnostik und Komorbiditäten unter besonderer Berücksichtigung spielimmanenter Abhängigkeitsmerkmale (KFN-Forschungsbericht; Nr.: 108)*. Hannover: KFN.

Rehbein, F., & Mößle, T. (2012). Risikofaktoren für Computerspielabhängigkeit: Wer ist gefährdet? *Sucht, 58*(6), 391-400. doi:10.1024/0939-5911.a000216

Reynolds, D. M., & Jeeves, M. A. (1978). A developmental study of hemisphere specialization for recognition of faces in normal subjects. *Cortex, 14*, 511-520.

Ridderinkhof, K. R., van den Wildenberg, W. P., Segalowitz, S. J., & Carter, C. S. (2004). Neurocognitive mechanisms of cognitive control: the role of prefrontal cortex in action selection, response inhibition, performance monitoring, and reward-based learning. *Brain Cogn, 56*(2), 129-140. doi:10.1016/j.bandc.2004.09.016

Rindermann, H. (2009). *Emotionale-Kompetenz-Fragebogen*. Göttigen: Hogrefe.

Ritter, A., Franz, M., Dietrich, C., Miltner, W. H., & Weiss, T. (2013). Human brain stem structures respond differentially to noxious heat. *Front Hum Neurosci, 7*, 530. doi:10.3389/fnhum.2013.00530

Robins, R. W., Hendin, H. M., & Trzesniewski, K. H. (2001). Measuring Global Self-Esteem: Construct Validation of a Single-Item Measure and the Rosenberg Self-Esteem Scale. *Personality and Social Psychology Bulletin (PSPB), 27*(2), 151-161.

Robinson, T. E., & Berridge, K. C. (2003). Addiction. *Annu Rev Psychol, 54*, 25-53. doi:10.1146/annurev.psych.54.101601.145237

Roth, C. G., & Deshmukh, S. (2017). *Fundamentals of Body MRI* (2 ed.): Elsevier.

Roth, M., Körner, A., & Herzberg, P. Y. (2008). Typological and dimensional approach at comparing the Giessen Test (GT) with the NEO-Five-Factor-Inventory (NEO-FFI). *GMS Psychosoc Med, 5*(06), 1-5.

Ruby, P., & Decety, J. (2001). Effect of subjective perspective taking during simulation of action: a PET investigation of agency. *Nat Neurosci, 4*(5), 546-550.

Rumpf, H. J., Meyer, C., Kreuzer, A., & John, U. (2011). Prävalenz der Internetabhängigkeit (PINTA) Bericht an das Bundesministerium für Gesundheit. Retrieved from http://drogenbeauftragte.de/fileadmin/dateien-dba/DrogenundSucht/Computerspiele_Internetsucht/Downloads/PINTA-Bericht-Endfassung_280611.pdf, September 15, 2016

Sagan, P., & Leighton, T. (2010). The Internet & the future of news. *Daedalus, American Academy of Arts & Sciences; MIT Press, 139*(2), 119-125.

Sass, K., Habel, U., Sachs, O., Huber, W., Gauggel, S., & Kircher, T. (2012). The influence of emotional associations on the neural correlates of semantic priming. *Hum Brain Mapp, 33*(3), 676-694. doi:10.1002/hbm.21241

Sassa, Y., Sugiura, M., Jeong, H., Horie, K., Sato, S., & Kawashima, R. (2007). Cortical mechanism of communicative speech production. *Neuroimage, 37*(3), 985-992. doi:10.1016/j.neuroimage.2007.05.059

Schulz, K. P., Fan, J., Magidina, O., Marks, D. J., Hahn, B., & Halperin, J. M. (2007). Does the emotional go/no-go task really measure behavioral inhibition? Convergence with measures on a non-emotional analog. *Arch Clin Neuropsychol, 22*(2), 151-160. doi:10.1016/j.acn.2006.12.001

Schwartz, R. H. (2013). Excessive participation in on-line internet action games by two American teenagers: Case report, description of extent of overuse, and adverse consequences. *Open Journal of Pediatrics, 3*(3), 201-203. doi:10.4236/ojped.2013.33035

Sebastian, C., Burnett, S., & Blakemore, S. J. (2008a). Development of the self-concept during adolescence. *Trends Cogn Sci, 12*(11), 441-446. doi:10.1016/j.tics.2008.07.008

Seghier, M. L. (2013). The angular gyrus: multiple functions and multiple subdivisions. *Neuroscientist, 19*(1), 43-61. doi:10.1177/1073858412440596

Shackman, A. J., Salomons, T. V., Slagter, H. A., Fox, A. S., Winter, J. J., & Davidson, R. J. (2011). The integration of negative affect, pain and cognitive control in the cingulate cortex. *Nat Rev Neurosci, 12*(3), 154-167. doi:10.1038/nrn2994

Shapira, N. A., Goldsmith, T. D., Keck, P. E., Jr., Khosla, U. M., & McElroy, S. L. (2000). Psychiatric features of individuals with problematic internet use. *J Affect.Disord, 57*(1-3), 267-272.

Shaw, M., & Black, D. W. (2008). Internet addiction: definition, assessment, epidemiology and clinical management. *CNS Drugs, 22*(5), 353-365.

Shibata, M., Terasawa, Y., & Umeda, S. (2014). Integration of cognitive and affective networks in humor comprehension. *Neuropsychologia, 65*, 137-145. doi:10.1016/j.neuropsychologia.2014.10.025

Siemens-AG. (2001). *MR Glossary*: Siemens AG, Medical Solutions, Magnetic Resonance Division.

Smahel, D., Blinka, L., & Ledabyl, O. (2008a). Playing MMORPGs: connections between addiction and identifying with a character. *Cyberpsychol.Behav, 11*(6), 715-718.

Smahel, D., Blinka, L., & Ledabyl, O. (2008b). Playing MMORPGs: connections between addiction and identifying with a character. *Cyberpsychol Behav, 11*(6), 715-718. doi:10.1089/cpb.2007.0210

Smith, S. M. (2004). Overview of fMRI analysis. *Br J Radiol, 77 Spec No 2*, S167-175. doi:10.1259/bjr/33553595

Stippich, C. (2013). Preoperative Blood Oxygen Level-Dependent (BOLD) Functional Magnetic Resonance Imaging (fMRI) of Motor and Somatosensory Function. In S. Ulmer & O. Jansen (Eds.), *fMRI: Basics and Clinical Applications* (pp. 91-110): Springer-Verlag Berlin Heidelberg.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology,, 18*, 643-662.

Taylor, T. L. (2002). Living Digitally: Embodiment in Virtual Worlds. In R. Schroeder (Ed.), *The Social Life of Avatars: Presence and Interaction in Shared Virtual Environments* (pp. 40-62). London: Springer-Verlag.

Turkle, S. (1994). Constructions and reconstructions of self in virtual reality: Playing in the MUDs. *Mind, Culture, and Activity, 1*(3), 158-167. doi:10.1080/10749039409524667

Turkle, S. (1995). *Life on the Screen: Identity in the age of the internet*: Simon & Schuster Paperbacks.

Van Horn, J. D., & Poldrack, R. A. (2009). Functional MRI at the crossroads. *Int J Psychophysiol, 73*(1), 3-9. doi:10.1016/j.ijpsycho.2008.11.003

van Rooij, A. J., Schoenmakers, T. M., van de Eijnden, R. J., & van de Mheen, D. (2010). Compulsive Internet use: the role of online gaming and other internet applications. *J Adolesc Health, 47*(1), 51-57. doi:10.1016/j.jadohealth.2009.12.021

Vigneau, M., Beaucousin, V., Herve, P. Y., Duffau, H., Crivello, F., Houde, O., . . . Tzourio-Mazoyer, N. (2006). Meta-analyzing left hemisphere language areas: phonology, semantics, and sentence processing. *Neuroimage, 30*(4), 1414-1432. doi:10.1016/j.neuroimage.2005.11.002

Wallisch, P., Lusignan, M. E., Benayoun, M. D., Baker, T. I., Dickey, A. S., & Hatsopoulos, N. G. (2009). *MATLAB for Neuroscientists: An Introduction to Scientific Computing in MATLAB* (2 ed.): Elsevier.

Wan, C. S., & Chiou, W. B. (2006). Why are adolescents addicted to online gaming? An interview study in Taiwan. *Cyberpsychol.Behav, 9*(6), 762-766.

Wang, C. W., Chan, C. L., Mak, K. K., Ho, S. Y., Wong, P. W., & Ho, R. T. (2014). Prevalence and correlates of video and internet gaming addiction among Hong Kong adolescents: a pilot study. *ScientificWorldJournal, 2014*, 874648. doi:10.1155/2014/874648

Wang, H., Jin, C., Yuan, K., Shakir, T. M., Mao, C., Niu, X., . . . Zhang, M. (2015). The alteration of gray matter volume and cognitive control in adolescents with internet gaming disorder. *Front Behav Neurosci, 9*, 64. doi:10.3389/fnbeh.2015.00064

Wang, Y. M., Schultz, R. T., Constable, R. T., & Staib, L. H. (2003). Nonlinear Estimation and Modeling of fMRI Data Using Spatio-temporal Support Vector Regression. In C. Taylor & J. A. Noble (Eds.), *Information Processing in Medical Imaging 18th International Conference, IPMI 2003, Ambleside, UK, July 20-25, 2003. Proceedings* (pp. 647-659): Springer Berlin Heidelberg.

Weishaupt, D., Koechli, V. D., & Marincek, B. (2009). *Wie funktioniert MRI?* (6 ed.): Springer Medizin Verlag Heidelberg

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

White, M. J. (1981). Response selection and visual search. *Bulletin of the Psychonomic Society, 18*, 201-202.

Willems, R. M., de Boer, M., de Ruiter, J. P., Noordzij, M. L., Hagoort, P., & Toni, I. (2010). A dissociation between linguistic and communicative abilities in the human brain. *Psychol Sci, 21*(1), 8-14. doi:10.1177/0956797609355563

Williams, J. M., Mathews, A., & MacLeod, C. (1996). The emotional Stroop task and psychopathology. *Psychol Bull, 120*(1), 3-24.

Wischmann, T. (2002). Gießen-Test (GT). In E. Brähler, H. Holling, D. Leutner, & F. Petermann (Eds.), *Handbuch psychologischer und pädagogischer Test* (3 ed., pp. 661-662). Göttingen: Hogrefe. (Reprinted from: Not in File).

Wise, R., Chollet, F., Hadar, U., Friston, K., Hoffner, E., & Frackowiak, R. (1991). Distribution of cortical neural networks involved in word comprehension and word retrieval. *Brain, 114 (Pt 4)*, 1803-1817.

Wittchen, H. U., Zaudig, M., & Fydrich, T. (1997). *Strukturiertes klinisches Interview für DSMIV (SKID)*. Göttingen: Hogrefe.

Witthöft, M., Mier, D., Ofer, J., Müller, T., Rist, F., Kirsch, P., . . . Diener, C. (2013). Neuronal and behavioral correlates of health anxiety: Results of an illness related emotional Stroop task. *Neuropsychobiology submitted*.

Wölfling, K., Beutel, M. E., & Müller, K. W. (2012). Construction of a Standardized Clinical Interview to Assess Internet addiction: First Findings Regarding the Usefulness of AICA-C *Addiction Research & Therapy, S6:003*. doi:10.4172/2155-6105.S6-003

Wölfling, K., & Müller, K. W. (2008). Phänomenologie, Forschung und erste therapeutische Implikationen zum Störungsbild Computerspielsucht. *Psychotherapeutenjournal*(02/2008), 128-135. doi:www.rollenspielsucht.de, June 20, 2008

Wölfling, K., Müller, K. W., & Beutel, M. E. (2008). [Skala zum Onlinesuchtverhalten bei Erwachsenen (OSVe-S)].

Worsley, K. J., Evans, A. C., Marrett, S., & Neelin, P. (1992). A three-dimensional statistical analysis for CBF activation studies in human brain. *J Cereb Blood Flow Metab, 12*(6), 900-918. doi:10.1038/jcbfm.1992.127

Yao, Y. W., Wang, L. J., Yip, S. W., Chen, P. R., Li, S., Xu, J., . . . Fang, X. Y. (2015). Impaired decision-making under risk is associated with gaming-specific inhibition deficits among college students with Internet gaming disorder. *Psychiatry Res, 229*(1-2), 302-309. doi:10.1016/j.psychres.2015.07.004

Yee, N. (2002). *Ariadne – Understanding MMORPG Addiction*. http://www.nickyee.com/hub/addiction/addiction.pdf, September 14, 2016

Yee, N. (2006a). Motivations for play in online games. *Cyberpsychol Behav, 9*(6), 772-775. doi:10.1089/cpb.2006.9.772

Yee, N. (2006b). The Psychology of Massively Multi-User Online Role-Playing Games: Motivations, Emotional Investment, Relationships and Problematic Usage. In R. Schroeder & A.-S. Axelsson (Eds.), *Avatars at Work and Play* (Vol. 34, pp. 187-207): Springer Netherlands.

Yen, J. Y., Ko, C. H., Yen, C. F., Wu, H. Y., & Yang, M. J. (2007). The comorbid psychiatric symptoms of Internet addiction: attention deficit and hyperactivity disorder (ADHD), depression, social phobia, and hostility. *J Adolesc Health, 41*(1), 93-98. doi:10.1016/j.jadohealth.2007.02.002

Young, K. (2009). Understanding Online Gaming Addiction and Treatment Issues for Adolescents. *American Journal of Family and Therapy, 37*, 355-372. doi:10.1080/01926180902942191

Young, K. S. (1996). Psychology of computer use: XL. Addictive use of the Internet: a case that breaks the stereotype. *Psychol Rep, 79*(3 Pt 1), 899-902. doi:10.2466/pr0.1996.79.3.899

Young, K. S. (1998). Internet addiction: The emergence of a new clinical disorder. *CyberPsychology and Behavior, 1*(3), 237-244.

Young, K. S. (2004). Internet Addiction: A New Clinical Phenomenon and Its Consequences. *American Behavioral Scientist, 48*(4), 402-415. doi:10.1177/0002764204270278

Young, K. S., & Rogers, R. C. (1998). The Relationship Between Depression and Internet Addiction. *CyberPsychology & Behavior, 1*(1), 25-28. doi:10.1089/cpb.1998.1.25.

Yuan, K., Qin, W., Wang, G., Zeng, F., Zhao, L., Yang, X., . . . Tian, J. (2011). Microstructure abnormalities in adolescents with internet addiction disorder. *PLoS One, 6*(6), e20708. doi:10.1371/journal.pone.0020708

Yuan, K., Qin, W., Yu, D., Bi, Y., Xing, L., Jin, C., & Tian, J. (2015). Core brain networks interactions and cognitive control in internet gaming disorder individuals in late adolescence/early adulthood. *Brain Struct Funct*. doi:10.1007/s00429-014-0982-7

Yuan, K., Yu, D., Cai, C., Feng, D., Li, Y., Bi, Y., . . . Tian, J. (2016). Frontostriatal circuits, resting state functional connectivity and cognitive control in internet gaming disorder. *Addict Biol*. doi:10.1111/adb.12348

Zheng, X.-F. (2008). Cognitive Interference or Emotional Interference:Comparison of PIU College Students' Implicit Mental Characteristics. *Acta Psychologica Sinica*.

7.1 Own publications

Dieter, J., Hill, H., Sell, M., Reinhard, I., Vollstadt-Klein, S., Kiefer, F., . . . Lemenager, T. (2014). Avatar's Neurobiological Traces in the Self-Concept of Massively Multiplayer Online Role-Playing Game (MMORPG) Addicts. Behav Neurosci. doi:10.1037/bne0000025

Lemenager, T., Dieter, J., Hill, H., Hoffmann, S., Reinhard, I., Beutel, M., . . . Mann, K. (2016). Exploring the Neural Basis of Avatar Identification in Pathological Internet Gamers and of Self-Reflection in Pathological Social Network Users. J Behav Addict, 1-15. doi:10.1556/2006.5.2016.048

Leménager, T., Dieter, J., Hill, H., Koopmann, A., Reinhard, I., Sell, M., . . . Mann, K. (2014). Neurobiological correlates of physical self-concept and self-identification with avatars in addicted players of Massively Multiplayer Online Role-Playing Games (MMORPGs). Addict Behav, 39(12), 1789-1797. doi:10.1016/j.addbeh.2014.07.017

Dieter, J., Hoffmann, S., Mier, D., Reinhard, I., Beutel, M., Vollstädt-Klein, S., Kiefer, F., Mann, K., Leménager, T. (submitted). The role of emotional inhibitory control in internet addiction - an fMRI study.

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10 CURRICULUM VITAE

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SCHOOL CAREER

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