Chapter 7
Neuroscientific Approaches to (Online) Pornography Addiction

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Abstract The availability of pornographic material has substantially increased with the development of the Internet. As a result of this, men ask for treatment more often because their pornography consumption intensity is out of control; i.e., they are not able to stop or reduce their problematic behavior although they are faced with negative consequences. There is a long lasting debate whether these kinds of problems should be conceptualized as a behavior addiction. In the last two decades, several studies with neuroscientific approaches, especially functional magnetic resonance imaging (fMRI), were conducted to explore the neural correlates of watching pornography under experimental conditions and the neural correlates of excessive pornography use. Given previous results, excessive pornography consumption can be connected to already known neurobiological mechanisms underlying the development of substance-related addictions. In the introduction, phenomenological, epidemiological, and diagnostic aspects of a syndrome, which is here labeled pornography addiction, will be described knowing that the adequacy of this terminology has to be further validated. In the second section, after aetiological considerations, contemporary neurobiological models will be presented to offer reference points for the question whether excessive pornography consumption can result in an addiction. In the third section of the chapter, neurobiological findings concerning three topics will be summarized: Neural correlates of watching pornography, cue reactivity and appetitive conditioning, and finally neurobiological characteristics of men with pornography addiction. The present contribution will be rounded off with a short conclusion highlighting possible future research questions.

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7.1 Introduction

Pornography addiction describes a phenomenon by which people, especially men, are not able to control their excessive use of pornography although they are trying to stop or reduce their consumption due to pronounced negative consequences.

There is evidence that these clinically relevant problems have increased with the development of high-speed Internet access and smartphones. Already Cooper (1998) labeled the Internet as the triple A machine due to high accessibility, affordability, and anonymity. More than ten percent of the Internet traffic contains pornographic material (Buchuk 2013). A study by Meerkerk et al. (2006) suggests that watching pornography has the highest potential for addictive use among various Internet activities. Epidemiological studies estimate the prevalence of sexual addiction to range from 2 to 6% with a sex ratio of 4/1 men dominating (Kuzma and Black 2008; Ross et al. 2012; Odlaug et al. 2013). Thus, sexual addiction seems to be mainly a male problem and most of the studies on sexual addiction to date have been conducted with men.

Sexual addiction covers the addiction toward different online sexual behaviors (e.g., watching pornography, visiting sexual themed chat rooms) as well as offline sexual behaviors (e.g., excessive sexual dating, telephone sex). However, pornography addiction seems to be the most prominent form of sexual addiction (Reid et al. 2012).

Subjects with addictive consumption use of pornography often report to watch pornography on a daily basis for several hours. Usually, the use of pornography is accompanied by masturbation. There is an ongoing debate whether masturbation and/or orgasm is the actual drug (pornographic material would then merely be a cue) or whether sexual material is rewarding per se. Most likely, sexual material is both a reward and a cue. Due to the time spent on the use of pornography, other areas of life are neglected. Problems at work or in relationships—if existing—are the consequences. Facing these negative consequences, people affected try to reduce their behaviors but usually fail in their attempt to do so. The experience of loss of control is often a reason to search for treatment.

There is an ongoing scientific and sometimes political debate whether the symptomatology—excessive sexual behaviors, loss of control, negative consequences—should be conceptualized as addiction (Carnes et al. 1983), compulsion (Coleman 1991), impulse control disorder (Barth and Kinder 1987), or as hypersexuality (Kafka 2010). However, as shown in this article, there is growing evidence that the syndrome shares many similarities with other behavioral and substance-related addictions. This is why we prefer the label sexual addiction or in case of an excessive use of pornography the label of (online) pornography addiction.

Beside millions of sites of pornography, the Internet also offers chat rooms with sexual content, cybersex, and sexual dating platforms which can also promote the development of a sexual addiction. While for men the excessive use of pornography is the most relevant addictive problem with regard to Internet misuse (Reid et al. 2012), sexual addicted women mostly excessively use dating platforms despite massive negative consequences. Whether the related behaviors in women are

indeed variants of sexual addiction or whether these behaviors can be diagnosed otherwise, for example as symptoms of a borderline personality disorder, must be clarified by further research.

There are several self-report questionnaires, which measure the extent of sexual addiction and pornography addiction, respectively. A prominent screening instrument is the *Sexual Addiction Screening Test—Revised* (SAST-R, Carnes 2010) which is freely available on the Internet. For the diagnosis of pornography addiction, one can also specifically ask for the presence of the criteria of hypersexuality as proposed by Kafka (2010). For clinical diagnosis, the *Hypersexual Behavior Inventory* by Reid et al. (2011a) is also available. Further helpful questionnaires for measuring the severity of the related problems are the *Sexual Compulsivity Scale* (SCS, Kalichman and Rompa 1995) and the short form of the *Internet Addiction Test*, modified for cybersex (s-IATsex; Laier et al. 2013). Different aspects related to pornography addiction are measured by the *Pornography Consumption Inventory* (PCI, Reid et al. 2011b), the *Sexual Sensation Seeking Scale* (SSSS, Kalichman and Rompa 1995), and the *Trait Sexual Motivation Questionnaire* (TSMQ, Stark et al. 2015).

Until now, neither the ICD 10 (World Health Organization 1992) nor the DSM 5 (American Psychiatric Association 2013) offers a specific diagnosis for pornography addiction. To date, the related symptoms are diagnosed in the ICD 10 as 'obsessive-compulsive disorder, unspecified' (F42.9), as 'excessive sexual drive' (F52.7), or as 'habit and impulse disorder, unspecified' (F63.9). Likewise, possible diagnoses in the DSM 5 are 'unspecified obsessive-compulsive and related disorder' (300.3), 'unspecified sexual dysfunction' (302.70), or 'unspecified disruptive, impulse-control, and conduct disorder' (312.9). Kafka (2010) proposed a definition of hypersexuality for the DSM 5 (American Psychiatric Association 2013), but the experts did not consent to the proposal due to a lack of research in this field. This all leads to a vicious circle because epidemiological data cannot be collected if a well-accepted definition of the syndrome is not available and therefore the research in this field is hindered.

7.2 Use of Pornography: What Are the Prerequisites for an Addiction Diagnosis?

Many people, especially men, get in contact with pornography in their adolescence, but only few of these develop an addictive consumption pattern. So the question arises what are the concomitants of the transition from sporadic to excessive, addictive use? Is this course comparable with the course of the development of a substance-related addiction?

According to a major Norwegian study by Traeen et al. (2006) 96% of men and 76% of women at the age of 18–49 years reported contact with pornography at least once. From a study with US college students, it is known that 87% of the young men and 31% of the young women have used pornography at college age (Carroll et al. 2008). Asking for the reasons of the use of pornography, several studies

revealed the motives for consumption of pornography: Paul and Shim (2008) identified four factors in an Internet online questionnaire study of motives which they called *Relationship*, *Mood Management*, *Habitual Use*, and *Fantasy*. The factor *Mood Management* (exemplary item: 'to relieve stress') and the factor *Habitual Use* (exemplary item: 'because you couldn't stop yourself') can be linked to aspects of addiction (negative reinforcement, loss of control). Reid et al. (2011b) also identified four factors of motives in a sample of men who described themselves as sex addicted and who were looking for treatment. These factors were labeled *Emotional Avoidance*, *Sexual Curiosity*, *Excitement Seeking*, and *Sexual Pleasure*. Again, the factors can be associated with positive and negative reinforcement, which are important aspects of explanatory behavioral learning theories for the development of addiction: The use of pornography results in positive feelings like pleasure and lust, which lead to a positive reinforcement, and also to a cessation of negative feelings such as loneliness, boredom, or depressive feelings which lead to a negative reinforcement. It can be assumed that at the beginning of a habitual pornography use, the consumption is mainly driven by positive reinforcement, whereas later in the course it is driven by negative reinforcement. This is comparable to the course of substance-related addictions where the drug intake is first positively and later on negatively reinforced.

According to the DSM 5, the eleven criteria of a substance use disorder can be clustered in criteria regarding impaired control, social impairment, risky use, and finally tolerance and withdrawal as pharmacological indicators (American Psychiatric Association 2013). The severity of a substance use disorder is classified as mild, moderate, or severe depending on whether 2–3, 4–5, or more than 5 criteria are fulfilled. The term addiction is used synonymously to a severe substance use disorder with substantial loss of self-control indicated by compulsive drug taking despite the intention to stop taking the substance. Modern neurobiological theories of addiction understand an addiction as a brain disease (Volkow et al. 2016). The transition from a sporadic use of the drug to a sustained, intensified, and escalated use to a full addictive use of the drug is accompanied by neurophysiological changes in the brain (Piazza and Deroche-Gamonet 2013). If addiction is manifest, an addicted person passes through three recurring phases, which are called the addiction circle: binge and intoxication phase, withdrawal and negative affect phase, and anticipation and craving phase (Koob and Volkow 2010).

During the binge and intoxication phase, the dopamine release within the reward system, with the nucleus accumbens as a core structure, is central. The repeated exposure to a reward leads to a cue responsivity toward stimuli over time, which predicts the intake of the substance. Hereby, classical conditioning is the prominent associative learning mechanism (Schultz et al. 1997). The increasing craving can be explained by the incentive sensitization theory of Robinson and Berridge (1993). According to this theory, the development of an addiction is accompanied by a sensitization of the mesolimbic dopamine system: stimuli associated with reward become cues in the course of the development of addiction. These cues trigger enhanced dopamine release signaling incentive salience and induce 'wanting', which is clinically described as craving. It is assumed that these processes are the

consequence of drug-induced changes on neural and molecular level especially in the reward system. This view is supported by animal studies which revealed that drugs induce neuroplasticity in many brain regions including the nucleus accumbens (reward), the dorsal striatum (encoding of habits), the amygdala (emotion), the hippocampus (memory), and the prefrontal cortex (regulation). For review see Kauer and Malenka (2007) and Kourrich et al. (2015). According to this neuroplasticity, the reward-related dopamine response decreases in the course of the development of an addiction resulting in tolerance.

Withdrawal symptoms and negative affect during the withdrawal phase are the consequences of the compensatory processes to maintain homeostasis, which are triggered by the continuous drug intake. These processes are also the reason why natural rewards (e.g., food, sex,…) are experienced less rewarding by addicted subjects than by healthy subjects. These negative aftereffects motivate an addicted subject to further drug taking because the administration of the drug efficiently stops the negative affect (negative reinforcement). The preoccupation and anticipation phase is characterized by thoughts centered on the procurement of the drug and craving. Drug-induced changes in the function of prefrontal regulatory circuits lead to impaired response inhibition and salience attribution (I-RISA, Goldstein and Volkow 2002). It needs to be mentioned, that not all people who are exposed to drugs develop an addiction. Genetic factors (e.g., mediated by personality traits such as impulsivity or novelty seeking) as well as social factors (e.g., poor social and familial support) influence the risk of addiction.

Postulating similar neurobiological mechanisms in behavioral addictions to substance-related addictions, pornography, and pornography addiction should feature at least the following properties:

1. Pornography should—comparable to a drug—activate the dopaminergic reward system in sporadic users.
2. Cue reactivity as a result of conditioning processes should be greater in pornography addicted subjects than in nonaddicted subjects.
3. Tolerance: With increasing consumption intensity, the response of the reward system toward pornography should decrease.
4. Impaired prefrontal control of the reward system: In the course of the development of pornography addiction, the person affected should have more and more problems to control their addictive behavior.
5. Withdrawal: Stopping the consumption of pornography should induce stress symptoms.

7.3 Neurobiological Results

In the following three subchapters, we will review the neurobiological results of three research domains, which are related to the pornography addiction concept. The first chapter summarizes the neural correlates of watching pornography. Here,

the question of interest is whether pornography is a potent reward stimulating the reward circuits of the brain. The next chapter is dedicated to cue reactivity and appetitive conditioning. If there is a similarity between pornography addiction and substance-related addictions, then pornographic stimuli should be regarded as unconditioned stimuli. Due to appetitive conditioning, formerly neutral stimuli should be become conditioned stimuli if these stimuli predict the occurrence of pornographic stimuli. In the third chapter, results regarding neurophysiological characteristics of men, who are either excessive pornography users or patients with the diagnosis sexual addiction, are summed up.

7.3.1 Neural Responses Toward Pornography

Pictures or movies containing visual sexual stimuli (VSS) capture attention, a fact that is widely used in the advertising industry. An attention bias toward sexual stimuli could for example be demonstrated by Schimmack (2005), Most et al. (2007), or Prause et al. (2008). A recent review presents several studies indicating that VSS can attract attention similar to threat-related stimuli (Sennwald et al. 2016). Further, among others, Kagerer et al. (2014) found the attentional bias toward sexual stimuli to be related to sexual motivation related traits such as sexual sensation seeking.

As mentioned before, there is an ongoing debate whether sexual stimuli are per se rewarding or whether they serve as conditioned stimuli of sexual activity for example tactile manipulation of the genitals as the de facto rewarding entity. Thus, it is unclear whether sexual stimuli result in *liking* or *wanting*—using the terminology of Robinson and Berridge (1993). Most likely, watching erotic stimuli induces both wanting and liking (Stoléru et al. 2012), and it may depend on the circumstances whether liking or wanting prevails. Before summarizing the studies on the neural correlates of watching pornography, one has to be aware that watching pornography in privacy is often combined with masturbation. Therefore, the rewarding aspect in the experimental situation might be quite different to that in the usual situation, e.g., at home. Despite these difficulties related to validity, several studies on the neural correlates of watching sexual stimuli or pornography were conducted. These used positron emission tomography (PET, e.g., Bocher et al. 2001; Redoute et al. 2000), but mainly functional magnetic resonance imaging (fMRI, e.g., Hamann et al. 2004; Karama et al. 2002; Mouras et al. 2003). Some of the studies used static pictures (Sabatinelli et al. 2007; Stark et al. 2005; Walter et al. 2008) others movie clips (Arnow et al. 2002; Ferretti et al. 2005; Redoute et al. 2000).

Meanwhile, there are first meta-analyses of studies on the neural correlates activated when watching pornography (Georgiadis and Kringelbach 2012; Stoléru et al. 2012). The extended review by Stoléru et al. (2012) included 58 studies (40 fMRI studies, 14 PET studies, 2 MEG studies, 1 SPECT study, and 1 near-infrared spectroscopy study), which were published between 1994 and 2010. In this review,

Table 7.1 Brain structures identified in the meta-analyses by Stoléru et al. (2012) as involved in the processing of visual sexual stimuli (VSS)

Lateral occipital and/or lateral temporal cortex	83.9%
Anterior cingulate cortex	67.6%
Parietal cortex	56.8%
Inferior temporal cortex	54.1%
Dorsal striatum	51.4%
Thalamus	51.4%
Premotor areas	48.6%
Cerebellum	37.8%
Hypothalamus	37.8%
Orbitofrontal cortex	37.8%
Amygdala	35.1%
Claustrum	27.0%
Midbrain	27.0%
Ventral striatum	27.0%
Medial prefrontal cortex	24.3%

The percentage indicates the proportion of studies, which reported a structure as activated during VSS processing

no difference was made between static pictures or film clips or between sexual material, erotic material, and pornographic material. Most of the studies used a passive viewing paradigm meaning that subjects just watch either the sexual pictures or clips or corresponding control stimuli. This meta-analysis therefore summarizes precisely the brain regions activated by the drug *pornography*. Table 7.1 lists the structures found to be activated in several studies.

Stoléru et al. (2012) developed a neurophenomenological model of sexual arousal. As shown in Fig. 7.1, cognitive processes entail motor imagery, appraisal, and attention. Appraisal is further divided into a motivational, emotional, and, autonomic as well as an endocrine component. Involved brain areas are assigned to these functional components. This model also includes inhibitory components, which are activated if sexual arousal must be suppressed. The activation of these structures diminishes with increasing sexual arousal.

Investigating which neural activities toward VSS are stable over time and which are influenced by state factors in one of our own studies, we could demonstrate that activities in nucleus accumbens, anterior cingulate cortex, occipital cortex, and parietal cortex showed the most robust results with respect to temporal stability if subjects are examined a second time one year after the first assessment (Wehrum-Osinsky et al. 2014). Also potential sex effects need to be taken into account: Most studies so far investigated men and because pornography addiction seems to be primarily a male problem, these studies are highly relevant regarding pornography addiction. But nevertheless, results of studies which compare the activation pattern during the processing of pornographic material in men and women should not be neglected: Most of the few studies including both men and women report slightly greater activation in men than in women in some brain areas (e.g., thalamus, hypothalamus, Karama et al. 2002; amygdala, OFC, insula, ACC, Gizewski

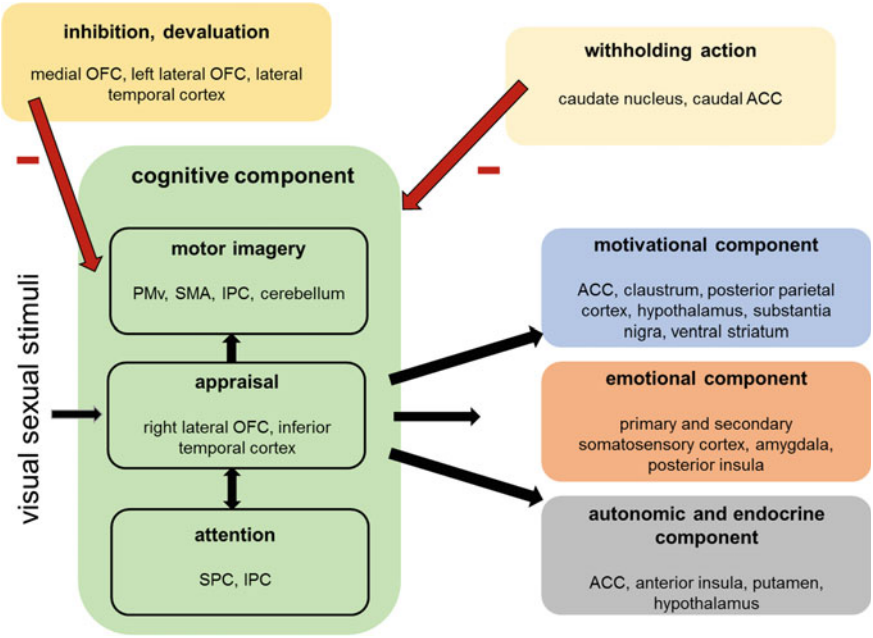

Fig. 7.1 Neurophenomenological model of sexual arousal by Stoléru et al. (2012). Abbreviations: *ACC* anterior cingulate cortex, *IPC/SPC* inferior/superior parietal cortex; *OFC* orbitofrontal cortex; *PMv* ventral premotor area; *SI/SII* primary/secondary somatosensory cortex; *SMA* supplementary motor area

et al. 2006; parital cortex, thalamus, Wehrum et al. 2013). However, often the fact that pornographic material is rated more pleasant and more sexually arousing by men than by women was not taken into account. Therefore, it is not entirely clear whether the observed sex differences are due to male biased stimulus material. A last note: Whereas in some studies there was no difference in subjective ratings, still a greater neural activation was observed in men than in women (e.g., Gizewski et al. 2006). If these results prove to be true by future research then this could be an explanatory factor why men are more prone to develop a pornography addiction.

7.3.2 Cue Reactivity and Appetitive Conditioning

In substance-related addictions, cue reactivity delineates the observation that formerly neutral stimuli which became associated with drug intake trigger craving by dopamine release in the ventral striatum even if the stimuli are backward masked (Childress et al. 2008). The underlying mechanism is appetitive conditioning, a form of classical conditioning (Martin-Soelch et al. 2007). It is assumed that appetitive conditioning is also involved in sexual behavior, e.g., the development of

sexual preferences (Akins 2004; Brom et al. 2014; Martin-Soelch et al. 2007; Pfaus et al. 2001) and also plays a major role in sexual addiction (Banca et al. 2016; Klucken et al. 2016). Interestingly, although appetitive conditioning is assumed to be a central mechanism of the development of addiction, only few studies to date have examined the neural correlates of appetitive conditioning, especially in context of sexual addiction.

In case of pornography addiction, one assumes that internal (e.g., arousal, negative mood) or external (e.g., the view of a computer or smartphone) stimuli which were associated with pornography use and masturbation in the past trigger the currently addictive behavior. This hypothesis requires that pornography can indeed serve as unconditioned stimuli in an appetitive conditioning paradigm resulting in a conditioned dopaminergic-driven neural response in the ventral striatum toward the conditioned stimuli.

In typical appetitive conditioning experiments, a neutral stimulus (later the conditioned stimulus, CS+) is paired with a reward (unconditioned stimulus, UCS) like money, pleasant odors, drug, or sexual stimuli, while a second neutral stimulus (CS−) is associated with the absence of the UCS (Martin-Soelch et al. 2007). By testing the differential responses toward CS+ and CS−, differential appetitive conditioning can be proven. There are several studies that have used this experimental design with sexual stimuli as unconditioned stimuli (Both et al. 2008, 2011; Klucken et al. 2009, 2013, 2015). These studies have repeatedly shown that the CS+, which is paired with sexual stimuli (e.g., sexual pictures or genital stimulation), elicits conditioned responses (i.e., increased responses to the CS+ in contrast to the CS−). For instance, increased preference and arousal ratings were found to the CS+ in contrast to the CS− after conditioning but not before (Klucken et al. 2009, 2013). However, while changes in preference ratings have repeatedly been found during appetitive conditioning, conditioned responses in other response systems like peripheral-physiological responses (e.g., skin conductance responses (SCRs) or genital responses) are less clear. For instance, Klucken et al. (2009) found increased subjective ratings and hemodynamic responses to the CS+ compared with the CS−, but no significant differences in SCRs. Moreover, the same subjects reliably differed in SCRs between the UCS (sexual pictures) and the non-UCS (neutral, nonsexual pictures), highlighting that SCRs are able to differ between salient and non-salient stimuli in general. However, other studies using a higher number of subjects could demonstrate increased conditioned SCRs toward the CS+ (Klucken et al. 2013). To interpret these diverging results, it is hypothesized that the conditioned effects in psychophysiological responses are smaller and may also depend more on individual differences (Klucken et al. 2009, 2013, 2015). In a review, Brom et al. (2014) also assume that peripheral-physiological responses may not be a strong marker for appetitive conditioning, especially in context of sexual stimuli.

With respect to the neural correlates of appetitive conditioning with sexual stimuli as UCS, studies have identified a subcortical and cortical network including the amygdala, the ventral striatum, the orbitofrontal cortex (OFC), the anterior cingulate cortex (ACC), and the insula (Martin-Soelch et al. 2007). One of the most important structures for appetitive conditioning is the amygdala, which is crucially involved in

the formation of the CS–UCS association (Martin-Soelch et al. 2007). Day and Carelli (2007) emphasize in their review the ventral striatum, or more specifically, the nucleus accumbens as key regions for appetitive conditioning. This important role of the ventral striatum in appetitive conditioning is also supported by findings, showing its involvement in the processing and the anticipation of positive events especially sexual arousal (Oei et al. 2012; Stark et al. 2005). OFC, insula, and ACC activations may reflect conscious evaluation processes of the current CS value and are also important for the awareness of bodily sensations, which seems to be irrespective of sexual stimuli, other emotions like fear and disgust, or other rewarding stimuli (Craig 2009; Domjan 1994; Klucken et al. 2009). Interestingly, studies investigating appetitive conditioning processes in subjects with sexual addiction found small differences to healthy control subjects only. In one of our own studies, Klucken et al. (2016) found increased amygdala activation in sex addicted subjects as well as decreased striatal/prefrontal connectivity during appetitive conditioning even after correcting for individual pleasantness ratings. One explanation for these group differences is the assumption that the increased amygdala activation mirrors facilitated conditioning and craving processes in men with sexual addiction. In addition, the decreased striatal/prefrontal connectivity may reflect impaired emotion-regulation processes like an impeded downregulation of craving in these patients.

In sum, knowledge about appetitive conditioning with sexual stimuli is limited. The few so far published studies showed the same neural network involved in other appetitive conditioning processes with nonsexual rewarding stimuli with the NAcc as one of the most important structures. However, one interesting perspective to explore is the time course of the dopamine activation, because there is some evidence that dopamine in the NAcc plays an important role in the beginning, but less in the sustained sexual behavior (Georgiadis et al. 2012).

7.3.3 Correlates of Pornography Addiction

While Gold and Heffner (1998) described the lack of empirical data on sexual addiction at the end of the last century pointedly in their paper entitled ‘Sexual addiction: many conceptions, minimal data’, the situation has changed significantly over the last 10 years. Now, there are first published studies focusing on the correlates of excessive consumption of pornography and on pornography addiction.

On a behavioral level, several studies have shown that sexual addiction is accompanied by specific characteristics. Mechelmans et al. (2014) demonstrated an enhanced attentional bias toward sexual cues in subjects with sexual addiction in comparison to subjects without sexual addiction. Banca et al. (2016) could demonstrate that men with pornography addiction showed greater novelty preference for sexual than for control images compared to healthy controls. In the same study, they could also show that men with pornography addiction more strongly prefer stimuli associated with sexual and monetary reward by a conditioning procedure than healthy controls.

In the meantime, several studies were published which address the structural and functional correlates of excessive use of pornography or pornography addiction. In a first neuroimaging study, Miner et al. (2009) expected deficits in structural connectivity in the inferior frontal area measured by diffusion tensor imaging (DTI) in subjects with sexual addiction, but they observed only a negative correlation between the fractional anisotropy (FA) within the inferior frontal area with the scores of questionnaires measuring impulsivity and negative emotionality. In the same paper, the authors reported higher impulsivity in men with sexual addiction in comparison with healthy controls measured by self-report and behavioral data (errors in a go-nogo task).

In a very interesting study, Kuehn and Gallinat (2014) investigated the neural correlates of the habitual use of pornography. They questioned their male participants about their hours of pornography consumption per week and correlated these consumption hours with neural structure, task-related activation, and functional resting-state connectivity. They found a negative correlation between reported pornography consumption hours and the gray matter volume in the right caudate. In an fMRI experiment, they presented blocks with sexual material and nonsexual material and interspersing fixation periods. The values of the contrast *sexual material minus fixation period* were negatively correlated with pornography consumption hours in the putamen. Finally, functional connectivity between the right caudate and the left dorsolateral prefrontal cortex was negatively correlated with pornography consumption hours. This could indicate that the higher the habitual consumption of pornography, the lower the cognitive control of the consumption behavior. However, from these correlative approaches one has to keep in mind that it remains unclear whether these neural correlates are the consequences or the causes for pornography consumption.

In a study by Voon et al. (2014), men with pornography addiction displayed enhanced neural activity toward explicit sexual film clips in the dorsal anterior cingulate cortex, ventral striatum, and amygdala compared to healthy controls. In a similar study, Seok and Sohn (2015) found that men with sexual addiction showed greater activation in caudate nucleus, inferior parietal lobe, dorsal ACC, thalamus, and dorsolateral prefrontal cortex toward explicit sexual pictures than control subjects. Recently, Brand et al. (2016) reported that preferred explicit sexual pictures in contrast to non-preferred sexual pictures resulted in greater ventral striatum activity. Further, this ventral striatum activity increased with increasing symptoms of Internet pornography addiction. Pornography addiction was measured by the short Internet Addiction Test, modified for cybersex (s-IATsex, Pawlikowski et al. 2013).

Summarizing the various studies, pornography addiction seems to be associated with functional and structural brain abnormalities. Interestingly, the results concerning cue reactivity are equivocal: While Voon et al. (2014), Seok and Sohn (2015), and Brand et al. (2016) reported greater neural activation toward sexual material in the reward circuitry in high pornography consuming men, Kuehn and Gallinat (2014) found a negative correlation between cue reactivity toward sexual material and weekly hours of pornography consumption. Since the studies however differ in many

aspects (high consumers vs. addicted consumers, pictures vs. films,…) future research must explore the relationship between habitual pornography consumption and cue reactivity in the reward circuits in more detail to explain this inconsistency.

7.4 Conclusions

In the last section, we have reviewed the studies regarding brain responses toward sexual material, cue reactivity, and appetitive conditioning and finally also the neurophysiological correlates of excessive pornography consumption. We could demonstrate that sexual stimuli induce neural activation in the reward circuit (e.g., ACC, ventral striatum, orbitofrontal cortex), probably due to the mesolimbic dopamine reward pathway. Thus, the hypothesis that the consumption of pornography might be appetitive for most men is confirmed. The appetitive value of pornographic material is further underlined by the fact that these stimuli can be used as unconditioned stimuli in appetitive conditioning experiments. Therefore—similar to other addictions—formally neutral stimuli become triggers of the addictive behavior. This is in accordance with reports of men with pornography addiction describing a strong urge/craving to consume pornography if confronted with certain situations, feelings, or stimuli which share similarities with situations, in which pornography is usually consumed. Especially stimuli with sexual aspects, for example a cover of a magazine, but also context information like being-alone-at-home might elicit the urge for addictive behavior.

Finally, we summarized the studies, which investigated the correlates of excessive pornography consumption on a neural level. Despite a lack of longitudinal studies, it is plausible that the observed characteristics in men with sexual addiction are the results not the causes of excessive pornography consumption. Most of the studies report stronger cue reactivity in the reward circuit toward sexual material in excessive pornography users than in control subjects, which mirrors the findings of substance-related addictions (see review by Chase et al. 2011; Garrison and Potenza 2014). The results concerning a reduced prefrontal-striatal-connectivity in subjects with pornography addiction can be interpreted as a sign of an impaired cognitive control over the addictive behavior.

Although all neurobiological insights from these studies support the concept of a pornography addiction, there are still many open questions. To name only a few: Is tolerance a necessary precondition of pornography addiction? Is a change in the preferred sexual material for example toward more deviant material a sign of development of tolerance? Is an increasing time spent on pornography an indicator of tolerance? Are symptoms of withdrawal observable in all subjects considered to be pornography addicted? Are therapeutic interventions known from substance-related addictions successfully transferable to pornography addiction? All these questions must be addressed in future research to further answer the question whether the conceptualization of pornography overuse as an addiction is appropriate or not.

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