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Altered Appetitive Conditioning and Neural Connectivity in Subjects With Compulsive Sexual Behavior

Tim Klucken, PhD,[1,2] Sina Wehrum-Osinsky, Dipl-Psych,[1,2] Jan Schweckendiek, PhD,[1,2] Onno Kruse, MSc,[1,2] and Rudolf Stark, PhD[1,2]

ABSTRACT

Introduction: There has been growing interest in a better understanding of the etiology of compulsive sexual behavior (CSB). It is assumed that facilitated appetitive conditioning might be an important mechanism for the development and maintenance of CSB, but no study thus far has investigated these processes.

Aim: To explore group differences in neural activity associated with appetitive conditioning and connectivity in subjects with CSB and a healthy control group.

Methods: Two groups (20 subjects with CSB and 20 controls) were exposed to an appetitive conditioning paradigm during a functional magnetic resonance imaging experiment, in which a neutral stimulus (CS+) predicted visual sexual stimuli and a second stimulus (CS-) did not.

Main Outcome Measures: Blood oxygen level-dependent responses and psychophysiologic interaction.

Results: As a main result, we found increased amygdala activity during appetitive conditioning for the CS+ vs the CS- and decreased coupling between the ventral striatum and prefrontal cortex in the CSB vs control group.

Conclusion: The findings show that neural correlates of appetitive conditioning and neural connectivity are altered in patients with CSB. The increased amygdala activation might reflect facilitated conditioning processes in patients with CSB. In addition, the observed decreased coupling could be interpreted as a marker for impaired emotion regulation success in this group.

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Key Words: Amygdala; Conditioning; Emotion; Positive; Reward; Sexual Arousal

INTRODUCTION

The development in Internet and streaming services (eg, by smartphones) has provided new, fast, and anonymous ways to access sexually explicit material (SEM). Exposure to SEM is accompanied by specific subjective, autonomous, behavioral, and neural responses.[1–7] Analyses in Britain in 2013 showed that approximately 10% of the Internet traffic were on adult sites that exceeded traffic across all social networks.[8] An online questionnaire study investigating the motivation for Internet pornography identified four factors—relationship, mood management, habitual use, and fantasy.[9] Although most of the predominantly male users have no problems with their SEM consumption, some men describe their behavior as a compulsive sexual behavior (CSB) characterized by excessive use, loss of control, and inability to decrease or stop the problematic behavior, resulting in considerable economically, physically, or emotionally negative consequences to self or others. Although these men often describe themselves as "sex or porn addicts," there are competing theories regarding the nature and conceptualization of CSB. Some investigators have interpreted this behavior as an impulse control disorder,[10] mood regulation deficit, obsessive-compulsive disorder,[11] or behavioral addiction disorder,[12] whereas others have avoided etiologic associations by using the term *non-paraphilic hypersexuality disorder*.[13] Other investigators have challenged the need for a distinct diagnosis in general.[14,15] Therefore, neurobiological experiments investigating the neural correlates of CSB are important to gain more insight into the underlying mechanisms.

It has been proposed that facilitated appetitive conditioning might be a crucial mechanism for the development and maintenance of addictions and further psychiatric disorders.[16,17] In appetitive conditioning paradigms, a neutral stimulus (CS+)

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[1]Department of Psychotherapy and Systems Neuroscience, Justus Liebig University Giessen, Germany;

[2]Bender Institute of Neuroimaging, Justus Liebig University Giessen, Germany

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is paired with an appetitive stimuli (UCS), while a second neutral stimulus (CS−) predicts the absence of the UCS. After a few trials, the CS+ elicits conditioned responses (CRs) such as increased skin conductance responses (SCRs), changes in preference ratings, and altered neural activity.[16,18,19] Regarding the neural correlates of appetitive conditioning, a network has been identified that includes the ventral striatum, amygdala, orbitofrontal cortex (OFC), insula, anterior cingulate cortex (ACC), and occipital cortex.[20–24] Hence, the ventral striatum is involved in appetitive conditioning because of its central role in anticipation, reward processing, and learning.[25,26] However, in contrast to the ventral striatum, the role of the amygdala for appetitive conditioning is less clear. Although many animal and human studies have repeatedly confirmed the amygdala as the central region for fear conditioning,[27] its involvement in appetitive conditioning has been investigated only rarely. Recently, animal and human studies have demonstrated that the amygdala is involved in the processing of appetitive stimuli, appetitive conditioning, and processing of CSB using various stimuli and designs.[28–36] For instance, Gottfried et al[29] found increased amygdala activation to the CS+ vs the CS− during human appetitive conditioning using pleasant odors as the UCS. Activations in the OFC, insula, ACC, and occipital cortex are often interpreted as conscious and/or in-depth evaluation processes of the stimuli.[16]

To date, only two functional magnetic resonance imaging (fMRI) studies have investigated the neural correlates of CSB and found increased activations in the amygdala and ventral striatum as well as altered neural connectivity in subjects with CSB during the presentation of related (sexual) cues.[35,36] These structures are in line with other studies investigating the neural correlates of addiction disorders and impulse control deficits.[37,38] For instance, meta-analytical findings have shown a significant correlation between amygdala activation and the intensity of craving.[37] Another study that used diffusion tensor imaging found increased white matter microstructure integrity in prefrontal areas in subjects with CSB and a negative correlation between CSB and structural connectivity in the frontal lobe.[39]

In addition to the importance of appetitive conditioning processes, impairments in the inhibition of impulsive behavior are crucial for the development and maintenance of many psychiatric disorders and dysfunctional behaviors.[40,41] These difficulties with inhibition can explain the loss of control of subjects with CSB when confronted with related cues. Regarding the neural correlates of impulsive behavior and its regulation, the ventral striatum and ventromedial prefrontal cortex (vmPFC) seem to be important antagonists: the ventral striatum is assumed to be relevant for initiating impulsive behavior, whereas its downregulation is driven by the vmPFC through reciprocal connections.[42] For instance, previous results have linked impaired ventral striatal and prefrontal connectivity to trait impulsivity and to impulsive behavior.[42,43]

However, no study thus far has investigated the neural correlates of appetitive learning mechanisms or the loss of control in subjects with CSB compared with healthy controls. Based on the literature cited earlier, the first aim of the present study was to explore the hemodynamic responses of appetitive conditioning in these subjects compared with a matched control group. We hypothesized increased activation in the amygdala and ventral striatum in subjects with CSB compared with the control group. The second aim was to explore connectivity differences between the two groups. Identifying the neural substrate of altered appetitive conditioning and connectivity in these subjects would have implications not only for the understanding of the development and maintenance of this behavior but also for treatment strategies, which typically focus on behavioral modification through altered learning experiences (eg, cognitive behavioral therapy).[44]

METHODS

Participants

Twenty men with CSB and 20 matched controls were recruited by self-referral after an advertisement and referrals of a local outpatient clinic for cognitive behavioral therapy (Table 1). All participants had normal or corrected-to-normal vision and signed an informed consent. The study was conducted in accordance with the Declaration of Helsinki. All participants underwent structural clinical interviews to diagnose Axis I and/or Axis II diagnoses. Participants classified as

Table 1. Demographic and Psychometric Measurements for CSB and Control Groups*

	CSB group	Control group	Statistics
Age	34.2 (8.6)	34.9 (9.7)	t = 0.23, P = .825
BDI-II	12.3 (9.1)	7.8 (9.9)	t = 1.52, P = .136
Time spent watching time SEM, min/wk	1,187 (806)	29 (26)	t = 5.53, P < .001
Axis I disorder			
MD episode	4	1	
Recurrent MD disorder	4		
Social phobia	1		
Adjustment disorder	1		
Specific phobia	1	1	
Orgasmic-erection disorder	3		
Somatoform disorder	1		
Axis II disorder			
Narcissistic personality disorder	1		
Psychiatric medication			
Amitriptyline	1		

BDI = Beck Depression Inventory II; CSB = compulsive sexual behavior; MD = major depressive; SEM = sexual explicit material.
*Data are presented as mean (SD).