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A Current Understanding of the Behavioral Neuroscience of Compulsive Sexual Behavior Disorder and Problematic Pornography Use

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Abstract

Purpose of Review In the recently released eleventh edition of the International Classification of Diseases (ICD-11), compulsive sexual behavior disorder (CSBD) was for the first time included and classified as an impulse control disorder. The present report aims at summarizing the empirical results concerning the neurobiological underpinnings of CSBD, including problematic pornography use. Insight into mechanistic factors underlying CSBD may promote the development of more effective therapeutic interventions for people affected.

Recent Findings Recent neurobiological studies have revealed that compulsive sexual behaviors are associated with altered processing of sexual material and differences in brain structure and function.

Summary Although few neurobiological studies of CSBD have been conducted to date, existing data suggest neurobiological abnormalities share communalities with other additions such as substance use and gambling disorders. Thus, existing data suggest that its classification may be better suited as a behavioral addiction rather than an impulse-control disorder.

Keywords Compulsive sexual behavior disorder · Problematic pornography use · fMRI · Hypersexuality · Sexual addiction

Introduction

What Is Compulsive Sexual Behavior Disorder?

Already by the end of the nineteenth century, v. Krafft Ebing [1] described satyriasis and nymphomania as the male and female forms, respectively, of abnormal sexual drives resulting in compulsive sexual behavior (CSB). Indeed, satyriasis and nymphomania are specifically mentioned in the tenth edition of the International Classification of Diseases (ICD-10) under the F52.8 coded 'other sexual dysfunction not due to substance or known physiological condition' [2]. It may be argued that CSB gained more scientific attention in the 1970s and 1980s [3, 4]. With the growing availability of high-speed Internet access, academic interest further increased, and research suggested that the Internet may promote the different aspects of CSB. In their sample of people with CSB, Reid and colleagues [5] found excessive masturbation (78%), watching pornography (81%), using phone sex (8%) and cybersex (18%), visiting strip clubs (9%), and having sex

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with consenting adults (45%) as the most prevalent forms of CSB. In an exclusively male sample of self-identified "sex addicts", Spenhoff et al. [6] found comparable numbers with the exception that casual sex was found in only 20%.

There has been considerable debate regarding whether non-paraphilic CSB may be defined as a disorder and, if so, what might be the most appropriate classification [7, 8]. Several leading views consider CSBD as a behavioral addiction [4, 7], an impulse-control disorder [9], sexual compulsivity [10], or hypersexuality [11]. These debates may have found their provisional end with the introduction of the ICD-11 in 2018. Here, the diagnosis *compulsive sexual behavior disorder* (CSBD) was incorporated in the chapter of impulse-control disorder (code 6C72). Despite academic discussion regarding which criteria should be used to define CSBD and how to differentiate CSBD from non-disordered sexual behavior, there is some agreement on the core features: impaired control, the use of sexual behavior for emotion regulation purposes, and the continued engagement in CSB despite significant impairments in personal, family, social, educational, occupational, or other important areas of functioning.

As described earlier, people may suffer from different forms of CSB. Arguably, the most prominent behavior—especially in men—is watching pornography with accompanied masturbation [5]. Therefore, behavioral neuroscience research using functional magnetic resonance imaging (fMRI) has mainly focused on male subjects suffering from problematic pornography use (PPU). Thus, the present review will focus predominantly on PPU when summarizing neuroimaging data, and findings from pharmacological and other neurobiological research of CSB will be also reported (see also e.g., [12]).

Sexual Stimuli Are Per Se Rewarding

When asking people about their feelings when watching sexual material, they rate their feelings high on valence and arousal (e.g., [13]). The last 20 years of brain imaging research has produced important insights into neural responses to sexual material. Several meta-analyses and reviews [14–17] present a relatively consistent picture of the involvement of specific brain structures in the processing of sexual material. One model [15] posits that four components (cognitive, emotional, motivational, and autonomic and endocrine) are linked to specific brain structures. Within the motivational domain, brain structures associated with key structures of the human "reward system," like the ventral striatum (including the nucleus accumbens not used afterwards) and the anterior cingulate cortex (ACC), have been a focus of study. Involvement of these brain structures may underlie rewarding and reinforcing characteristics of sexual material. Such involvement fits with evolutionary models given that sexual stimuli should motivate approach behavior to ensure survival of the species.

Neurobiological Markers of CSBD

Altered Processing of Sexual Material in CSBD

The processing of sexually explicit material (SEM) in pornography-related CSBD has been investigated in cue-reactivity studies. The cue-reactivity concept has long been investigated in classical conditioning research of drug addictions [18]. Cues are conditioned stimuli, which could be moods, contexts, or other stimuli, that are repeatedly associated with drug intake (unconditioned stimuli). Cues then become predictors and triggers of drug intake. In the development and maintenance of an addiction, cues induce craving which is closely linked to wanting within the framework of the incentive-sensitization theory of addiction [19]. A main thesis of this framework is to separate liking from wanting. The theory posits that at the beginning of the development of an addiction, the hedonistic pleasure (=liking) dominates the experience; later, the addicted person experiences a need for drug use (=wanting) that is more independent of pleasure. Data suggest that while wanting may be closely linked to mesolimbic dopamine pathways, liking is not.

In the context of pornography-related CSBD, it is a justifiable question whether sexual stimuli are cues or unconditioned stimuli. They are often interpreted as cues although this material presumably also has unconditioned features (for further discussion of this topic, see [20]).

Over the last decade, the first functional brain imaging studies have been conducted. These studies show altered processing of sexual material in CSBD (Table 1).

In their seminal fMRI study, Voon et al. [22] compared responses to SEM film clips and film clips with exciting but non-sexual content in male subjects with and without CSBD. The results revealed that men with CSBD demonstrated greater blood oxygenation level-dependent (BOLD) responses in the reward system (ventral striatum, dorsal ACC) and the amygdala than did healthy control men to SEM. Further, SEM induced higher subjective sexual desire in men with CSBD than in men without CSBD. In a similar study by Seok and Sohn [24], men with and without CSBD viewed pictures of SEM and pictures of positive-arousing non-sexual content. Again, men suffering from CSBD compared to those without showed greater BOLD responses towards SEM in contrast to non-sexual stimuli in multiple brain regions including the thalamus, dorsolateral prefrontal cortex, right supramaginal gyrus, dorsal ACC, and caudate. Subjective responses also indicated higher SEM-induced sexual desire ratings in men with CSBD than in men without CSBD. The results of the fMRI study of Brand et al. [31•] pointed in the same direction: the extent of self-reported symptoms of Internet pornography addiction (subclinical male sample) correlated with neural responses towards preferred SEM (in contrast to non-preferred SEM) in the ventral striatum.

Table 1 Chronological overview of fMRI studies contrasting neural responses measured by blood oxygenation level depend (BOLD) signal in individuals with compulsive sexual behavior disorder (CSBD) and subjects without CSBD (clinical studies). Additionally, fMRI studies investigating in samples at risk of CSBD (subclinical studies) are included. In most studies, only men were included

Study	Topic	Experiment	Sample	Main results
fMRI studies—clinical samples				
Politis et al. [21]	cue reactivity	passive viewing task • blocks of pictures of – drug – food – money and gambling – sexual – neutral content • two sessions: ON or OFF L-Dopa medication	*n* = 12 (1 woman) patients with Parkinson disease and CSBD *n* = 12 (2 women) patients with Parkinson disease but without CSBD CSBD diagnosed with • checklist for hypersexuality • clinical interview *note: patients with CSBD were taking significantly more dopamine agonists and significant less L-DOPA than the patients without CSBD*	independent of ON or OFF L-Dopa medication: • greater neural responses towards sexual pictures in contrasts to neutral pictures in patients with CSBD in: – bilateral OFC, bilateral ACC, bilateral PCC, left amygdala, bilateral ventral striatum, bilateral Hypothalamus (ROI analyses) – bilateral anterior PFC, bilateral SPL, right IPL (whole brain analyses) • lower neural responses towards sexual pictures in contrasts to neutral pictures in patients with CSBD in: – bilateral insula, right claustrum (whole brain analyses)
Voon et al. [22]	cue reactivity	passive viewing task • 9 s film clips: SEM, erotic, non-sexual exiting, money, neutral • main contrast of interest: 'SEM minus exiting videos'	*n* = 19 heterosexual men with CSBD (focus on online pornography) *n* = 19 heterosexual men without CSBD CSBD diagnosed with • Internet Sex Screening Test [23] • clinical interview based on Kafka's criteria [11] and the measures described by Reid [5]	• greater sexual desire in response to SEM in men with CSBD in comparison with men without CSBD • greater neural responses to SEM in men with CSBD in comparison with men without CSBD in – dACC, right ventral striatum, right amygdala, right substantia nigra (exploratory analysis) • higher correlation between sexual desire and functional connectivity between dACC/right ventral striatum and dACC/right amygdala, and dACC/left substantia nigra (exploratory analysis) in men with CSBD in comparison to men without CSBD
Seok & Sohn [24]	cue reactivity	passive viewing task • SEM and non-SEM pleasant photos	*n* = 23 heterosexual men with CSBD *n* = 22 heterosexual men without CSBD CSBD diagnosed with • Sexual Addiction Screening Test-R (SAST-R [25]), • Hypersexual Behavior Inventory (HBI [26]) • clinical interview	• greater sexual desire in response to SEM in men with CSBD in comparison with men without CSBD • greater neural responses to SEM in men with CSBD in comparison with men without CSBD in – right dACC, left and right thalamus, left caudate nucleus, right supramaginal gyrus, right dorsolateral prefrontal cortex • The extent of CSBD (measured by SAST-R [25], HBI [26]) was positively correlated with neural activation in the right thalamus and the right dorsolateral prefrontal cortex *Note: quite liberal testing of statistical significance, i. e. no FWE correction*

Table 1 (continued)

Study	Topic	Experiment	Sample	Main results
Klucken et al. [27]	appetitive conditioning	differential appetitive conditioning paradigm • colored squares as CS+ and CS- • UCS: SEM pictures • 100% reinforcement	*n* = 20 men with CSBD *n* = 20 men without CSBD CSBD diagnosed with • Kafka's criteria [11] • clinical interview	• higher learned responses to the CS+ in contrast to the CS- in men with CSBD in comparison to men without CSBD in the right amygdala • lower functional connectivity between ventral striatum and prefrontal cortex in subjects with CSBD in comparison to men without CSBD
Banca et al. [28]	appetitive learning	differential appetitive conditioning paradigm • 6 colored patterns served as 2 × CS + sex, 2 × CS + money, and 2 × CS- • after CS + sex a picture of a naked women appeared; after CS + money a 1 pound symbol was presented, after CS- a gray box was shown • extinction phase after acquisition: no rewards or control picture after the different CSs	*n* = 20 men with CSBD *n* = 20 men without CSBD CSBD diagnosed with • Internet Sex Screening Test [23] • clinical interview based on Kafka's criteria [11] and the measures described by Reid [5]	• there was no group effect regarding the neural responses towards the different CSs • the reaction towards the sexual pictures (after CS + sex) decreased faster in men with CSBD than in men without CSBD in the dACC • men with CSBD in comparison with men without CSBD showed greater functional connectivity between the dACC and the right ventral striatum and the left and the right hippocampus for the contrast last trials minus first trials of exposure to sexual pictures
Gola et al. [29]	cue reactivity	incentive delay task: • cues (control cue: symbol of a circle, monetary cue: dollar sign, erotic cue: pictogram of a women) served as signals to receive either nothing (scrambled picture) or monetary (picture of amount of money they won) or erotic rewards (SEM picture). Immediate outcome delivery in case of solving a target discrimination task	*n* = 28 heterosexual men with CSBD *n* = 24 heterosexual men without CSBD CSBD diagnosed with • Kafka's criteria of hypersexuality [11] • clinical interview • treatment seeking of all men with CSBD	• shorter reaction times in men with CSBD than in men without CSBD in erotic trials but not in monetary trials • greater neural responses to the erotic cues in men with CSBD than in men without CSBD in the left and the right ventral striatum • no group differences in behavioral and neural responses towards the monetary cue • no group differences in reaction towards the SEM pictures (reward delivery) *Note: Only reactions of the right and left ventral striatum were analyzed (*a priori *regions of interest)*
fMRI – subclinical samples				
Kühn & Gallinat [30]	cue reactivity	passive viewing task • sexual and non-sexual arousing pictures • block design -presentation blocks: − sexual pictures − non-sexual pictures − fixation	*n* = 64 heterosexual men with a wide range of pornography consumption independent variable: reported hours of pornography consumption per week	• negative correlation between reported hours of pornography consumption per week and neural responses towards sexual stimuli in the left putamen
Brand et al. [31]	cue reactivity	passive viewing task SEM with • male/male actors • male/female actors	*n* = 19 heterosexual men sample with varying severity of Internet addiction	• severity of Internet addiction was correlated with effect sizes of the contrast 'preferred material (female/male) minus

Table 1 (continued)

Study	Topic	Experiment	Sample	Main results
		• female/female actors • event-related design • ratings after each picture presentation on the dimensions sexual arousal, unpleasantness, closeness to 'ideal' picture	Internet addiction measured by the Short Internet Addiction Test modified for cybersex (s-IATsex) [32]	unpreferred material (male/male)' in the ventral striatum

FWE family-wise error, *SEM* sexually explicit material, brain regions: *dACC* dorsal anterior cingulate cortex, *PCC* posterior cingulate cortex, *OFC* orbitofrontal cortex, *IPL* inferior parietal lobule, *SPL* superior parietal lobule

In contrast to these reports, Kuehn and Gallinat [30] found a negative correlation between neural responses to SEM in the striatum (left putamen) and the amount of hours spent watching pornography in their subclinical male sample. The authors interpreted this counterintuitive finding as being possibly linked to a habituation process related to frequent exposure to pornographic stimuli. In an informative fMRI study, which disentangled neural regions associated with anticipatory versus consummatory phases, Gola et al. [29••] found comparable neural responses in men seeking treatment for PPU and men without PPU when they viewed sexual pictures. However, viewing of stimuli (=cues) predicting the presentation of SEM (as compared to cues predicting monetary rewards) in the incentive delay task resulted in higher BOLD responses in men with PPU than in men without PPU in the left and the right ventral striatum. Politis et al. [21] studied two groups of individuals with Parkinson disease, one with symptoms of CSB and another with comparable severity of Parkinson disease but without symptoms of CSB. As discussed below, CSB and other impulse-control behaviors and disorders (relating to gambling, buying, and eating) have been linked to aspects of Parkinson's disease including its treatment [37–39]. The results of their fMRI study showed that the BOLD responses towards SEM were higher in Parkinson patients with CSB than in patients without CSB in numerous brain regions including the orbitofrontal cortex, ACC, posterior cingulate cortex, amygdala, ventral striatum, and hypothalamus [21]. The two regions in which patients with CSB showed relatively less activation were the insula and claustrum.

To summarize, most fMRI studies examining cue reactivity in CSBD revealed that BOLD responses towards SEM are relatively higher in the reward system in the affected group [21, 22, 24, 29, 31]. Only one study [30] showed an inverse relationship between SEM-related BOLD response in the left putamen and pornography consumption, and this was not in a sample with CSBD.

Since conditioning processes may be important in the development of CSBD, we also consider here two fMRI studies investigating altered conditioning processes in CSBD.

Banca et al. [28•] reported that men with CSBD preferred novel SEM and cues conditioned to SEM to a larger extent than men without CSBD. This study also included an fMRI experiment on differential appetitive conditioning. While no group effects concerning the conditioned BOLD responses were found, the BOLD response in the dorsal ACC to unconditioned SEM habituated more rapidly in CSBD group than in the comparison group. The findings suggest that ACC function contributes to habituation associated with problematic pornography consumption. In another appetitive conditioning fMRI experiment with sexual pictures as unconditioned stimuli, Klucken et al. [27] found a significant difference in the conditioned BOLD responses in the amygdala between men with and without CSBD. Further, they observed decreased functional connectivity between the prefrontal cortex and ventral striatum in the CSBD group; these findings raise the possibility that prefrontal-striatal circuits may be involved in cognitive control over motivational brain circuitry in CSBD as has been reported in drug addictions [40].

Additional larger and longitudinal studies are needed to replicate and extend the understanding of conditioning processes in CSBD and how other phenomena (e.g., prefrontal control over subcortical responsivity during regulation of craving) may be important to consider in CSBD and its treatment.

In contrast to the fMRI studies demonstrating increased SEM-elicited neural responses in CSBD, Prause et al. [41] reported reduced cue reactivity as indicated by decreased late positive potentials during electroencephalogram (EEG). This study used a passive viewing task with emotional pictures including SEM. Although debate exists regarding how best to interpret the findings [20], future studies should explain possible differences between previous fMRI studies and this EEG study.

In addition to the fMRI and EEG studies described above, several behavioral studies have examined neuropsychological aspects of CSBD, which may provide additional insight into the underpinnings of mechanisms involved in CSBD. Miner et al. [33] reported that 8 men with CSBD showed higher self-reported impulsivity and response impulsivity on a Go/No-Go task than 8 men without CSBD. The results of a behavioral dot-probe study of Mechelmans et al. [42] indicated that men with CSBD had a higher attentional bias towards SEM but not towards erotic stimuli than men without CSBD. However, this

difference was observed during a response window close to the picture presentation, prior to complete or consciously aware cognitive processing. Messina et al. [43] compared executive functions (e.g., decision-making on the Iowa Gambling Task, cognitive flexibility on the Wisconsin Card Sorting Test) in men with and without CSBD before and after watching SEM. Men with CSBD as compared to those made more disadvantageous decisions early in the Iowa Gambling Task and demonstrated less cognitive flexibility following viewing of SEM. Schiebener et al. [44] observed that among a sample of 104 men performing a classification task with sexual or non-sexual pictures, the men with CSBD tendencies had less balanced performance across the sexual and non-sexual pictures, with findings suggesting either avoidance of or approach towards SEM in association with CSBD tendencies. In another study using an Approach-Avoidance Task, individuals with tendencies towards cybersex addiction tended to either avoid or approach SEM [45]. These findings suggest heterogeneity with respect to expression of behaviors in relation to CSBD in men.

Structural Brain Differences in CSBD

Miner and colleagues [33] conducted a diffusion tensor imaging (DTI) analysis comparing the mean diffusivity and fractional anisotropy in the inferior and superior frontal area in 8 men with and 8 men without CSBD (Table 2). In contrast to expectations based on lower mean diffusivity in inferior frontal

Table 2 Studies on structural differences between men with CSBD and men without CSBD (clinical studies) and related studies (subclinical studies). The studies exclusively investigated male subjects

Study	Topic and method	Sample	Main results
Clinical studies			
Miner et al. [33]	Structural connectivity: DTI	$n = 8$ men with CSBD $n = 8$ men without CSBD CSBD diagnosed with • the presence of recurrent and intense sexually arousing fantasies, sexual urges, or behaviors over a period of at least 6 months that cause distress or impairment • treatment seeking of all men with CSBD	• men with CSBD were more impulsive than men without CSBD as measured by questionnaires and a Go/No-Go paradigm • mean diffusivity was lower in men with CSBD than in men without CSBD in superior frontal regions *Note: the diffusion result was contrary to the hypothesis expecting higher mean diffusivity in inferior frontal region*
Schmidt et al. [34]	• gray-matter volume: VBM • connectivity: resting state functional connectivity	$n = 23$ men with CSBD (focus on online pornography use) $n = 69$ men without CSBD ($n = 45$ for the resting state analyses) CSBD diagnosed with: • Kafka criteria of hypersexuality [11] and Carnes criteria of sexual addiction [35] • clinical interview	• greater left amygdala gray-matter volume in men with CSBD than men without CSBD • reduced resting state functional connectivity between the left amygdala seed and bilateral PFC (follow-up analysis of VBM analysis) in CSBD
Seok & Sohn [36]	• gray-matter volume: VBM • connectivity: resting state functional connectivity	$n = 17$ with CSBD $n = 17$ without CSBD CSBD diagnosed with: • Kafka criteria of hypersexuality [11] and Carnes criteria of sexual addiction [25] • HBI [26] • clinical interview	• significantly lower gray-matter volume in men with CSBD in comparison to men without CSBD in the left STG and the right MTG • significantly lower resting-state functional connectivity in men with CSBD than in men without CSBD between left STG (seed) and left precuneus and right caudate
Subclinical studies			
Kühn & Gallinat [30]	• gray-matter volume: VBM • connectivity: resting-state functional connectivity	$n = 64$ heterosexual men with a wide range of pornography consumption independent variable: reported hours of pornography consumption per week	• significant negative correlation between reported hours of pornography consumption per week and the right caudate nucleus volume • negative correlation between reported hours of pornography consumption and the resting-state functional connectivity between the right striatum and the left dorsolateral PFC during resting state fMRI

DTI diffusion tensor imaging, *VBM* voxel-based morphometry, brain regions: *PFC* prefrontal cortex, *MTG* medial temporal gyrus, *STG* superior temporal gyrus

areas in impulse-control disorders (e.g., [46]), they found lower mean diffusivity in superior frontal areas. Schmidt et al. [34] found greater left amygdala gray matter volume as measured by voxel-based morphometry (VBM) in men with CSBD as compared to men without. Further, there was reduced resting-state functional connectivity between the left amygdala and the bilateral dorsolateral prefrontal cortex in the group with CSBD as compared to the group without. This result suggests that prefrontal regulatory influences on emotional and motivational circuits may be diminished in men with CSBD, although this possibility warrants direct investigation. In a more recent study by Seok and Sohn [36], the volumes of the left superior temporal gyrus and the right middle temporal gyrus were reduced in men with CSBD as compared to men without. Further, lower resting-state functional connectivity was observed in CSBD between the left superior temporal gyrus and both the left precuneus and right caudate. Since the gray matter volume of the left superior temporal gyrus and the functional connectivity between the left superior temporal gyrus and the right caudate was negatively correlated with the severity of CSBD, the authors proposed that abnormalities in the left superior temporal gyrus may be crucial in CSBD. In their subclinical male sample, Kuehn and Gallinat [30] correlated the reported pornography hours per week with the gray matter volume and found a negative correlation in the right caudate. Further, they found that the resting-state functional connectivity between the right caudate (seed region) and the left dorsolateral prefrontal cortex negatively correlated with the reported hours of pornography consumption. The authors interpreted these negative associations as a possible consequence of the intense stimulation of the reward system, although longitudinal studies are needed to examine directly this possibility.

Taken together, initial findings indicate that CSBD in men is accompanied by structural changes in some brain regions. Further studies should examine whether the observed differences may reflect causes or consequences of the development of CSBD.

Stress Hormones and CSBD

In a Swedish CSBD sample, Chatzittofis et al. [47] reported on a dysfunction of the hypothalamic pituitary adrenal (HPA) axis in men with CSBD. Baseline cortisol and adrenocorticotropic hormone (ACTH) did not differ between men with and without CSBD. However, after a dexamethasone suppression test, the CSBD group was more likely to show non-suppression and higher ACTH levels than the group without CSBD. Within the same sample, the researchers found a reduced level of methylation of the *CRH* gene in the CSBD group [48]. These results suggest implicate stress regulation processed in CSBD in manners consistent with other psychiatric conditions and behaviors including depression, alcoholism, and suicidality (see, e.g., [49]).

Personality Traits and CSBD

Several sexuality-related tendencies have been reported to be higher in CSBD, including sexual compulsivity [50, 51], sexual motivation [27], and sexual excitation [52, 53]. Future studies will have to examine the moderating role of these characteristics in CSBD. Several general tendencies found to be elevated in CSBD include impulsivity [28, 42, 52, 54, 55], novelty seeking [56], and difficulties in emotion regulation [54, 57, 58], to name only several prominent domains. Additionally, adverse childhood experiences, especially interpersonal violence and sexual abuse, also seem more prevalent in people with CSBD [59–61], and these should be considered in the treatment of CSBD.

Genetics

The research on genetics of CSBD is still in its infancy, with studies to date largely focusing on candidate genes, employing small samples and not including individuals with CSBD (rather assessing different sexual behaviors). Several studies have examined polymorphisms that may relate to dopamine function in relation to sexual behaviors. For instance, a study by Miller et al. [62] showed that age of first intercourse was associated with alleles of the dopamine receptor genes *DRD2* and with the interaction between *DRD1* and *DRD2* alleles. Of note, the extent to which *DRD2* findings relate to the gene coding for the D2 dopamine receptor per se has been debated given, for example, linkage disequilibrium with *ANKK1*. Age of first sexual intercourse was also linked to a dopamine D4 receptor gene (*DRD4*) polymorphism [63]. Further, Ben-Zion et al. [64] found an association of a *DRD4* polymorphism and questionnaire data concerning sexual desire, arousal, and function. Similarly, Garcia et al. [65] have reported that the *DRD4* polymorphism was associated with promiscuous sexual behavior and sexual infidelity. Beaver et al. [66] reported that a polymorphism of the dopamine transporter gene (*DAT1*) was associated with the number of sexual partners. In sum, preliminary candidate gene studies focusing on potentially dopamine-related allelic polymorphisms suggest a possible role for these genes in some sexual behaviors. However, caution is warranted in that larger genetic studies (e.g., genome-wide association studies (GWAS)) often do not find as strong support for allelic variants implicated in candidate gene studies. One such GWAS recently generated findings that suggested that genes involved in risky sexual behavior related to alcohol dependence may overlap with those implicated in personality disorders and other psychopathologies and that these may be sensitive to gender/sex [67]. More studies of this sort that directly investigate CSBD using GWAS and other methodologies (e.g., polygenic risk scores) are needed.

Insights into the Neurobiological Underpinnings of CSB from Related Research Fields

Drug-Induced CSB

Dopaminergic and other (e.g., serotonergic) transmitter systems may contribute to CSBD. Dopamine agonists have been associated with CSB and other impulse-control behaviors [68–74]. However, given that other features appear linked to CSB and other impulse-control behaviors in Parkinson's disease, including geographic location and marital status among other factors, the etiology of CSB in Parkinson's disease is likely complex and multifactorial [75]. Furthermore, one should be cautious in extrapolating from a disease like Parkinson's (that is associated with significant dopamine degeneration) to non-Parkinson populations. Dopamine agonists are also used in the treatment of tumors of the pituitary gland and restless legs, and case reports suggest that these medications (or the conditions being treated) may occasionally be associated with CSB (tumors of the pituitary gland: [76–79]; treatment of restless legs syndrome: [80, 81]). Additionally, case reports of monoamine oxidase inhibitors (safinamide [82] and rasagiline [83, 84]) used in the treatment of Parkinson's disease exist for hypersexuality. Importantly, one should be cautious in interpreting data from case reports and large databases based on case reports as multiple factors (e.g., publicity) may bias such reporting [85]. As such, carefully conducted large-scale clinical epidemiological studies are warranted in investigating such matters.

Case reports also exist for CSB related to the use of psychostimulants (ampethamine [86], methylphenidate [87], and modafinil [88]), antiepileptic drugs [89], and antidepressants (duloxetine [90] and venlafaxine [91]). Reports of CSB with antidepressants may be surprising as this class of drugs is associated with hyposexual dysfunction. There are also case reports linking atypical antipsychotic drugs (risperidone [92], paliperidone [93], and aripiprazole [94–96]) to CSB. While the above cited cases suggest that clinicians should monitor for CSB in multiple patient populations treated with a variety of drugs, caution is warranted in extending case reports to mechanistic interpretations in the absence of larger-scale and more direct studies.

Pharmacological Treatment of CSBD

Studies on pharmacological treatment of CSBs may suggest possible neurotransmitter systems underlying CSBD. Data suggest that three different classes of drugs may reduce CSBs (overview [97]): (1) antidepressant drugs affecting dopaminergic, noradrenergic, and serotonergic transmission; (2) antiandrogens; and (3) gonadotropin-releasing hormone agonists. The latter two are primarily used in forensic contexts due to the high costs and possible considerable adverse effects of these drugs. However, Safarinejad [98] reported positive effects in an open-label trial of a gonadotropin-releasing hormone (i.e., triptorelin) in men with nonparaphilic hypersexuality. Additional controlled studies in CSBD appear warranted.

The beneficial effects of selective serotonin reuptake inhibitors (SSRIs)—often used in the treatment of depressive, anxiety, and obsessive-compulsive disorders—on CSBs have been suggested in initial studies of citalopram [99, 100], fluoxetine [101], and paroxetine [102]. However, randomized clinical trials are needed to evaluate both short- and longer-term efficacy and tolerability. In this regard, the study by Gola and Potenza [102] raises doubts about sustained effects with the theory that the medication studied (paroxetine) may only target a subset of features (e.g., anxiety or depression) related to engagement in CSBs.

There exist additional case reports regarding possible positive effects of the opioid antagonist naltrexone [103–105], beta blockers (in an autistic male adolescent [106]), atypical antipsychotic drugs (clozapine [107]), cholinesterase inhibitors (in Alzheimer disease [108]), and anticonvulsant/antimanic drugs (topiramate [109]) in treating CSBs.

Case reports suggest the possible involvement of multiple neurotransmitters in CSBD. However, placebo-controlled randomized clinical trials are needed to examine efficacy and tolerability. This is important as currently there exist no medications with an indication (e.g., by the US food and Drug Administration) for CSBD.

CSBD and Co-occurring Disorders

Co-occurring disorders may provide insight into the neurobiological underpinnings of CSBD. Co-occurring disorders are prevalent in CSBD and may impact well-being and guide treatment. In a recent online study, Wery et al. [110] found that 90% of participants with CSBD reported co-occurring psychiatric diagnoses. The most prominent co-occurring conditions may include mood, anxiety, substance-use, and impulse-control disorders [111, 112]. Personality disorders [113, 114], in a gender-sensitive fashion [54], may also frequently co-occur with CSBD.

CSB in Neurological Diseases

CSB is a clinical consideration in multiple neurological conditions. CSB has been observed, for example, in dementia [115–117]. In a comparison between frontotemporal dementia and Alzheimer's disease, Mendez and Shapira [118] found CSB in 13% of patients with frontotemporal dementia but in none of the patients with Alzheimer's disease. Further, there are case reports of CSB in individuals with traumatic brain injuries [119], Huntington's disease [120], bipolar disorder (in women) [121], multiple sclerosis [122], and Kluver Bucy syndrome [123, 124]. Reports in Kluver Bucy syndrome suggest

the involvement of the temporal lobe in CSB as Kluver Bucy syndrome involves bilateral temporal lobe lesions. A role for the temporal lobe in CSB is also suggested by findings that tumors in the temporal lobe [125] and temporal lobe strokes may result in CSB. In this regard, Korpelainen et al. [126] found an increased sexual libido in 10% of stroke patients.

Data from individuals with neurological diseases suggest involvement of the prefrontal cortex and temporal lobe in CSB. These findings resonate with functions of these brain regions in emotional/motivational processing and emotion regulation.

Conclusion

The inclusion of CSBD in ICD-11 improves the likelihood that problems experienced by individuals with CSBD will be identified and receive appropriate clinical attention. Having generally accepted diagnostic criteria for this disorder should aid in the development of effective psychological and medical treatments for CSBD. The development of effective treatments will be facilitated by an understanding of the psychological and physiological mechanisms that underlie CSB. Behavioral neuroscience studies are important for improving our understanding of the processes underlying the development, perpetuation, exacerbation of CSBD, and the recovery from CSBD. In part due to debates whether or not to classify CSBD as a disorder and a lack of generally accepted diagnostic criteria, neurobiological research efforts have been limited to date.

Although relatively few behavioral neuroscience studies have been conducted in CSBD, some conclusions may be drawn. First, fMRI studies show differences in men with and without CSBD in the processing of sexual stimuli as indicated by altered BOLD responses in the "reward system." Of note, most studies have focused on PPU in heterosexual men, thereby limiting generalizability to the broader spectrum of CSBs in more diverse populations. The involvement of the reward system observed in the brain imaging studies to date fits well with studies from the addiction field.

The findings summarized in our overview suggest relevant similarities with behavioral and substance-related addictions, which share many abnormalities found for CSBD (as reviewed in [127]). Although beyond the scope of the present report, substance and behavioral addictions are characterized by altered cue reactivity indexed by subjective, behavioral, and neurobiological measures (overviews and reviews: [128–133]; alcohol: [134, 135]; cocaine: [136, 137]; tobacco: [138, 139]; gambling: [140, 141]; gaming: [142, 143]). Results concerning resting-state functional connectivity show similarities between CSBD and other addictions [144, 145]. Therefore, future research should determine the most appropriate classification of CSBD. That is, whether it should be classified as an impulse-control disorder, as in the current ICD-11, or more appropriately as a behavioral addiction. Such a reclassification (from impulse-control to addictive disorders) occurred with gambling disorder in DSM-5 and ICD-11 based on existing data. As more data are collected on CSBD, its classification may be revisited.

While significant progress has been made in understanding CSB and CSBD, important questions remain to be addressed. For example, it is an open question whether the same neurobiological processes are involved in PPU as compared to other CSBs (e.g., problematic sexual behaviors involving casual partners). Further, most research has focused on young, heterosexual, white men. It remains an open question whether the same pathological mechanisms are also present in other groups (e.g., older adults, women, homosexual, bisexual, transsexual or other groups, or non-white individuals with CSBD). Finally, due to the absence of internationally accepted diagnostic criteria for CSBD in the last years (which has now changed with ICD-11), there are no reliable and valid assessments of the prevalence of CSBD, so far. As these data are collected, advancements in the prevention and treatment of CSBD, as well as policies related to CSBD, should be made.

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Compliance with Ethical Standards

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- •• Of major importance

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