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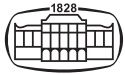Draps, Małgorzata

Kulesza, Maria

Glica, Agnieszka

et al.

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Emotional interference and attentional bias in compulsive sexual behaviors disorder – An fMRI study on heterosexual males

MAŁGORZATA DRAPS[1*] , MARIA KULESZA[2] ,
AGNIESZKA GLICA[3] , JULIA SZYMANOWSKA[4],
KATARZYNA LEWIŃSKA[4], WERONIKA ŻUKROWSKA[1] and
MATEUSZ GOLA[1,5]

[1] Institute of Psychology, Polish Academy of Sciences, Warsaw, Poland

[2] Laboratory of Brain Imaging, Neurobiology Center, Nencki Institute of Experimental Biology, Polish Academy of Sciences, Warsaw, Poland

[3] Laboratory of Language Neurobiology, Nencki Institute of Experimental Biology, Polish Academy of Sciences, Warsaw, Poland

[4] Department of Psychology, University of Social Sciences and Humanities, Warsaw, Poland

[5] Swartz Center for Computational Neuroscience, Institute for Neural Computations, University of California San Diego, San Diego, USA

ABSTRACT

Background and aims: Despite the inclusion of the Compulsive Sexual Behavior Disorder (CSBD) in the 11th edition of the International Classification of Diseases, emotional and cognitive impairments related to CSBD remains unclear. This study aimed to investigate the behavioral and neuronal effects of emotional interference on cognition among CSBD patients. *Methods:* Thirty heterosexual males with CSBD and matched healthy controls (HC) were studied with the Emotional Stroop Task using 5 categories of emotionally arousing words (sex-related, positive, fear-related, negative, neutral) during functional magnetic imaging. *Results:* At the behavioral level, we found the main effect of the condition: sex-related words evoked a stronger Stroop effect than other conditions. At the neural level, we found a significant group effect. Among CSBD patients processing of sex-related words was related to increased activity in the right putamen, right thalamus, hippocampi, and left pulvinar, when compared to HC. We also found a negative correlation between neuronal activation and time spent on sexual activity during the week preceding study and numerous group differences in brain regions connected to the emotional and motivational processing of sexually explicit material, correlating with CSBD symptoms. *Conclusions:* Behavioral results indicate a specific attentional bias toward sex-related stimuli in both groups, while neural data uncovered stronger reactivity to sex-related words in CSBD compared to HC. This reactivity is related to CSBD symptoms and provides evidence for the interference of sex-related stimuli with cognition. Such results are firmly in line with the Incentive Salience Theory and conceptualizing CSBD as a behavioral addiction.

*Corresponding author.
E-mail: mdraps@psych.pan.pl

INTRODUCTION

Compulsive Sexual Behavior Disorder (CSBD), recently included in the 11th edition of the International Classification of Diseases (ICD-11), has been increasingly studied during the last 10 years (Gola & Potenza, 2018; Kraus, Voon, & Potenza, 2016; Kühn & Gallinat, 2016).

CSBD is characterized by a pattern of repeated failure to resist an impulse or urge to engage in different kinds of sexual behaviors (e.g. pornography watching, compulsive masturbation, engaging in sexual behaviors with others etc.), which turn into harmful symptoms impairing essential areas of life. To fulfill CSBD criteria patient for at least 6 months needs to meet following criteria: (a) failure to control repetitive, intrusive, strong sexual impulses or urges; (b) these impulses lead to different forms of compulsive sexual behavior; (c) engaging into those behaviors has become a central focus of the patient's life causing the neglect of health/personal care or other interests (d) these sexual behaviors are associated with personal distress or difficulties in patient's important areas of life; (e) subject continues repetitive sexual behavior despite adverse consequences or (f) deriving little or no satisfaction from it. The pattern of failure to control repetitive sexual urges could not be better accounted for by another mental disorder (e.g., manic episode) or other medical condition and is not due to the effects of a substance abuse or medication. Also, if distress connected to sexual behaviors is entirely related to moral judgments/religious beliefs and disapproval, CSBD should not be diagnosed (WHO, 2023). Unfortunately, current research does not provide a transparent model explaining the mechanism underlying CSBD symptoms, taking into consideration both cognitive impairments (Chatzittofis et al., 2016; Kor, Fogel, Reid, & Potenza, 2013; Kowalewska et al., 2018; Liberg et al., 2022; Mechelmans et al., 2014) and processing of emotional events/stimuli (Bőthe et al., 2019; Draps et al., 2021; Gola & Draps, 2018; Miner, Dickenson, & Coleman, 2019; Sinke et al., 2020).

Regarding cognitive impairments, there is evidence for attentional bias toward sexual stimuli (Mechelmans et al., 2014), impairment in general attentional abilities (Draps et al., 2021), higher sensitivity to novelty and cue-reactivity (Banca, Morris, et al., 2016; Brand, Snagowski, Laier, & Maderwald, 2016; Draps et al., 2021; Gola et al., 2017). All these impairments correlate with CSBD symptoms, similar to other findings related to the cognitive domain, such as inhibition capacities (Antons & Brand, 2018; Draps, et al., 2021), impulsivity (Antons et al., 2019; Banca, Harrison, & Voon, 2016; Bothe et al., 2019; Draps, et al., 2021; Miner et al., 2016; Reid, Garos, Carpenter, & Coleman, 2011; Wetterneck, Burgess, Short, Smith, & Cervantes, 2012), and impaired executive control (Seok & Sohn, 2018).

The second important aspect is processing of emotional events/stimuli, especially strategies for coping with negative emotions. It is known that individuals with CSBD experience increased level of shame, low self-esteem, and loneliness and that CSBD symptoms are often accompanied by stress (Odlaug et al., 2013; Reid, Temko, Moghaddam, & Fong, 2014; Schreiber, Grant, & Odlaug, 2012; Spenhoff, Kruger, Hartmann & Kobs, 2013) and severe anxiety (Gola, Miyakoshi, & Sescousse, 2015; Wordecha et al., 2018). There is a hypothesis that CSBD symptoms serve as a coping mechanism to self-regulate negative emotional states (Lew-Starowicz, Lewczuk, Nowakowska, Kraus, & Gola, 2020; Miner et al., 2019; Wordecha et al., 2018). Therefore

impaired emotion regulation was not included in the CSBD criteria as potentially not specific symptom, yet it is important to understand its functional role (Gola & Kraus, 2021). Unfortunately, the amount of scientific studies in this domain is limited. Farthermost previous studies investigated either cognitive processes or emotional processing in CSBD, and there are very few attempts (e.g. our previous work: Draps et al., 2021) to examine both and look into the potential interference between them. Understanding such interference could shed new light on the nature of CSBD and its underlying mechanisms.

One of the measures of interaction between cognitive and emotional processing is cognitive conflict, occurring when the processing of task-relevant information is coalbed by a distractor (Nee, Wager, & Jonides, 2007). A proper example of a daily distractor is emotionally salient stimuli of danger or any other important negative emotion (LeDoux, 2000). In this situation, cognitive conflict can arise from this emotional interference caused by danger and compromise the ability to complete tasks requiring cognitive control (Etkin, Egner, Peraza, Kandel, & Hirsch, 2006). So, the ability to efficiently resolve emotional interference seems to be a relevant human skill. Lastly, researchers started to view emotional processing and cognitive control skills as brain functions that do not operate independently. Conversely, numerous studies suggest that both functions share the same neural circuitry (Mueller, 2011; Pessoa, 2008; Shackman et al., 2011). For example, there is compelling evidence that brain regions commonly associated with cognitive control, such as the dorsolateral prefrontal cortex (DLPFC), also play an important role in emotion processing (Okon-Singer, Hendler, Pessoa, & Shackman, 2015). The meta-analysis of 43 studies with different emotional tasks intermixed with a variety of cognitive control tasks (e.g., Stroop, n-back, stop signal, or the go/no-go task), showed consistent brain activation in both cognitive control (e.g., dorsolateral prefrontal cortex (DLPFC), and inferior frontal gyrus (IFG)) and emotion processing structures (e.g., subgenual anterior cingulate cortex (ACC) and amygdala regions) (Cromheeke & Mueller, 2014).

The Emotional Stroop Task (EST) is particularly efficient for studies of emotion and cognition interactions (Etkin et al., 2006; Melcher, Born, & Gruber, 2011). In this task, emotional words are displayed in various colors, and the subject is asked to indicate the color. The assumption is that the reaction times will be significantly different if the words are emotionally charged as opposed to neutral words (Draps et al., 2021). In 2017, Albery and colleagues showed on healthy controls that there is a negative relationship between sexual experience and bias towards sex-related stimuli in modified EST, suggesting that attentional preference for sexual stimuli varies as a function of the interaction between how long a person has been active sexually and how compulsive their sexual behavior is (Albery et al., 2017). But there is almost no data on EST collected with a CSBD group. Our recent study (Draps et al., 2021) showed a difference between CSBD patients and healthy controls in the processing of positive (also sexually related) and negative

stimuli, concluding that the sexual stimuli could play a more distractive role during cognitive processing (causing more attentional biases) in CSBD patients. Unfortunately, this did not involve collecting any neuronal measures. Wang & Zhang (2021) using electroencephalographic data collected from a non-clinical group with CSBD symptoms, demonstrated that sexual stimuli induce greater amplitudes of P200 and LPP (late positive potential) evoked response potentials related to the salience of stimuli, than neutral stimuli, especially at the frontal, frontocentral, and central regions. This result suggests that individuals with CSBD symptoms tend to automatically allocate more attention to sexually explicit images than neutral ones (Wang & Zhang, 2021).

Taking into consideration all matters described above we decided to conduct the study aiming to examine interference between emotional stimuli (including sexual stimuli) and cognitive processing using EST during functional magnetic resonance imagining (fMRI) among CSBD patients and healthy controls. We hypothesized that the CSBD group would show higher levels of interference on task performance for sex-related and negative stimuli apparent in both measures of reaction time and altered pattern of neural reactivity. More precisely, we hypothesized that positive emotional stimuli and sex-related stimuli would be connected to bigger motivation to correct and quit response (Draps et al., 2021; Gola et al., 2017) seemed as the shortening of behavioral results in both groups, but the difference between neutral and sex-related trials would be more prominent among CSBD patients what would be in line with specific sensitization hypothesis (Berridge, 2012). If the hypothesis of generally impaired processing of emotional stimuli (Lew-Starowicz et al., 2020; Miner et al., 2019; Wordecha et al., 2018) is correct, negative and fearful emotional stimuli would be connected with bigger cognitive interference, causing an increase in reaction times (RTs) in CSBD. Regarding previous findings (Wang & Zhang, 2021) on the neuronal level, we expected increased neuronal activation in the CSBD group, compared to healthy controls, during the processing of sex-related stimuli, especially in areas connected to the processing of sexually arousing material. We also expected an increased activation in the CSBD group, compared to healthy controls, during processing of negative stimuli (general category and specific fearful words) in areas related to emotional processing.

METHODS

Recruitment

Individuals with CSBD ($N = 30$) were recruited by a psychologist, based on clinical interviews (CSBD criterion-ICD-11 World Health Organization, 2023), and scores in Sexual Addiction Screening Test >8 (SASTR; Gola et al., 2016, the scale is created by Patrick Carnes to assist in the assessment of sexually compulsive behavior, Polish version consisted with 20 items measuring different kinds of sexual behaviors with restriction that more than 5 points can indicate the

need for additional clinical interviews for CSBD), scores >4 in Brief Pornography Screening Test (BPS; Kraus et al., 2020, 5-items scale created by Shane Kraus to assist in the assessment of problematic pornography use- PPU, scores equal or more than 4 is considered a positive screen for possible PPU), Hypersexual Behavior Inventory with no cut-off score (HBI; Reid et al., 2011, 19-item scale created by Rory Reid to assesses different aspects of hypersexuality through three factors: control, coping, and consequences of sexual behaviors). All participants were screened for co-morbid addictions ((included if scores <14 on Alcohol Use Disorder Identification Test (AUDIT; Babor, de la Fuente, Saunders, & Grant, 1992, 10-item screening tool developed by the World Health Organization (WHO) to assess alcohol consumption, drinking behaviors, and alcohol-related problems) and included if scores <5 on the South Oaks Gambling Screen (SOGS; Stinchfield, 2002, 20-item questionnaire tool based on DSM criteria to screening for pathological gambling)), as well as identifying as exclusively or predominantly heterosexual on the Kinsey Scale (included if scores <14; Polish adaptation: Wierzba et al., 2015, the scale is a tool to describe a person's sexual orientation based on one's experience). Thirty age, and income-matched Healthy Controls (HC) without psychopathological symptoms (including CSBD symptoms) were also recruited from a community sample. Additional exclusion criteria for both groups were: history of other psychiatric disorders, neurological or medical serious issues, contraindications for magnetic resonance imaging procedures, and color blindness (Ishihara's Test (1987)). One CSBD patient was excluded from the analysis due to the lack of data.

Procedure

CSBD patients were recruited from treatment clinics in Warsaw, Poland while HC were recruited through online announcements. After the positive enrollment, participants were invited to the Laboratory of Brain Imaging of Nencki Institute, PAS (Warsaw, Poland) for the experimental examination. After receiving detailed information about the study's aims and confirmation of anonymity and confidentiality participants signed informed consent. For anonymity reasons, we applied a double-blind procedure, so the research team, during data acquisition, had no access to the data from recruitment. The procedure took approximately 1.5 h to complete training in mock scanner and to complete structural and functional magnetic resonance imaging. Addition of training in the mock scanner was related to need of ensure that all participant understood the procedure and the task and mainly involved learning which button (in the left or right thumb or index finger) corresponds to which color. It took between 10 and 15 trials for each subject. Participants received a financial compensation of 150 PLN (~34 EUR).

Task

We used a modified version of Dresler's Emotional Stroop Task (Dresler, Mériau, Heekeren, & Van Der Meer, 2009). In our version, instead of 3, we had 5 categories of emotionally

arousing words (sex-related, positive, fear-related, negative, and neutral), details information is provided in Draps et al., 2021 and in Fig. 1.

Data acquisition

Data acquisition took place at the Laboratory of Brain Imaging of Nencki Institute, PAS (Warsaw, Poland) on a 3-Tesla MRI scanner (Siemens Magnetom Trio TIM, Erlangen, Germany) equipped with a 32-channel phased array head coil. All information about data acquisition is provided in Table 1.

Statistical analyses of behavioral data

To investigate the magnitude of the emotional Stroop effect measured with reaction times (RTs), we calculated an emotional interference value, defined as the difference between mean RTs in the neutral category and mean RTs in emotional categories (e.g. neutral minus sex-related). The reason for such calculation was an assumption that (a) the positive emotional category and sex-related category would be connected with the shortening of RTs and differences would be over 0 and (b) both negative emotional categories would be connected with cognitive load interference causing an increase in RTs and differences will be under the 0. To test
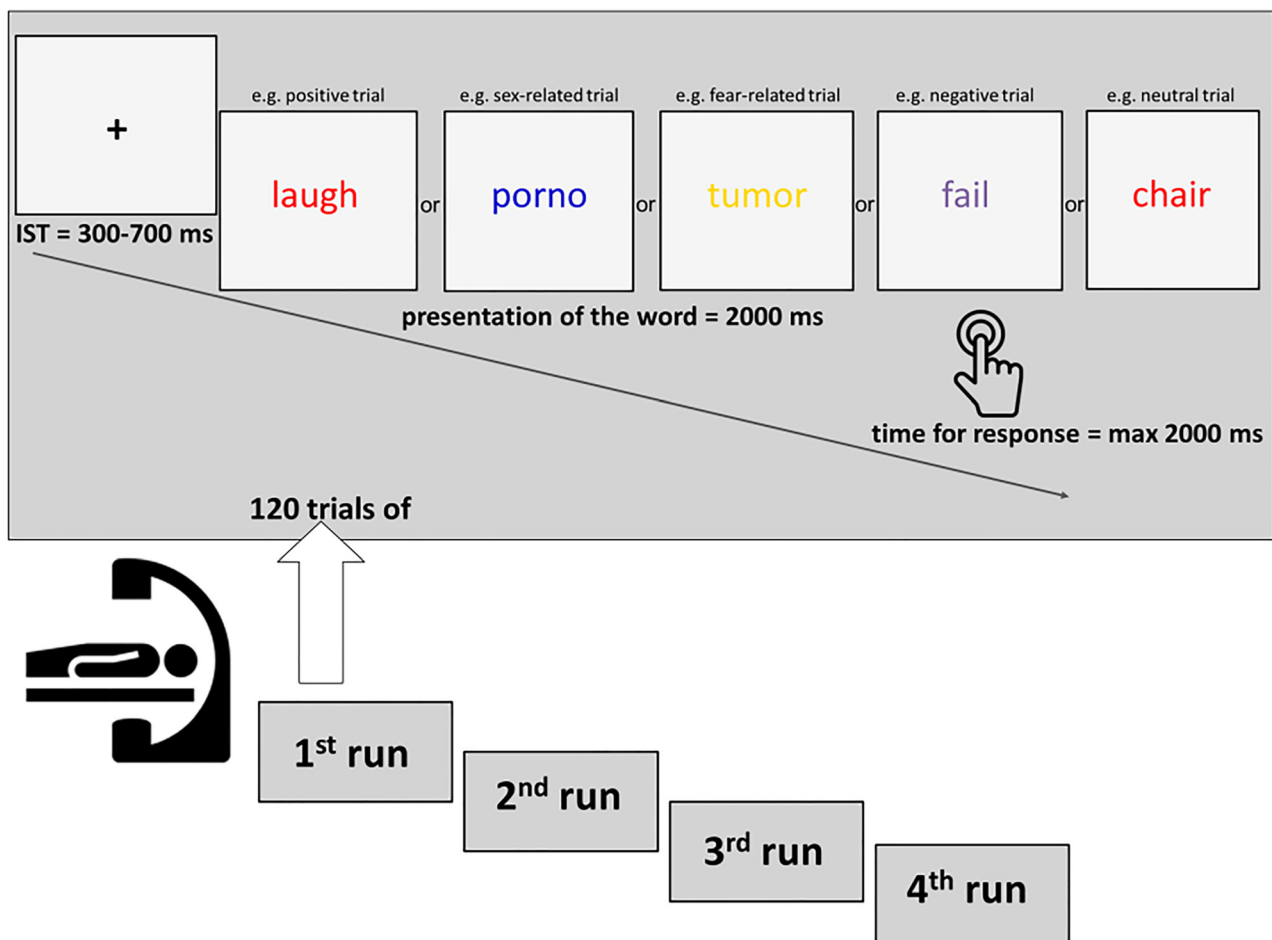

Fig. 1. Experimental procedure

We used a modified version of Dresler's Emotional Stroop Task (Dresler et al., 2009). In our version, instead of 3 categories of emotionally arousing words (positive, negative and neutral) we used 5 (sex-related, positive, fear-related, negative, and neutral) with 4–8 letters long words (the mean number in each category was about 6 letters). We used sex-related words despite not being a typical emotional category, based on our clinical observations, that patients often report processing of sexual stimuli as inseparably linked with emotional states, such as e.g. pleasure, sadness, or anger (Wordecha et al., 2018). All words were taken from Nencki Affective Word List – NAWL (Riegel et al., 2015) and displayed in four different colors (yellow, red, blue, and purple on a screen that could be seen through a tilted mirror attached to the fMRI's head coil. Participants had to indicate the color of the word by pressing one of the 4 corresponding buttons with the left or right thumb or index finger (the same configuration for all participants). Trials were presented in event-related design in a semi-randomized order counterbalances across conditions in 4 separate scanning sessions. Functional MRI scanning consisted of 4 runs with 20 words in each sex-related, positive, fear-related, and negative category and 40 words in the neutral category. All the words we presented twice in different runs. All 4 runs of the task were counterbalanced across participants in both groups. Each word was presented on a gray screen until a response was given with a maximum duration of 2,000 ms, with intertrial intervals (ITI) ranging between 300 and 700 ms

Table 1. Information about data acquisition. * Field mapping was done based on a method outlined in Jezzard and Balaban (1995)

Type of data	Sequence	Parameters
Anatomical data of the brains	T1-weighted sequence	time repetition = 2,530 ms, time echo = 3.32 ms, flip angle = 7°, field of view = 256 mm, and 176 axial slices with 1 mm slice thickness
Functional data from the Emotional Stroop Task	T2*-weighted gradient echo planar imaging sequence	time repetition = 2500 ms, time echo = 28 ms, flip angle = 90°, in plane resolution = 64 × 64 mm, the field of view = 192 mm, and 38 axial slices with 3 mm slice thickness with no gap between slices
Field mapping	double echo FLASH	echo time 1 = 4.92, echo time 2 = 7.38, time repetition = 600 ms with the same spatial properties as functional scans

differences between 4 different emotional categories and between 2 groups (CSBD vs. HC), repeated measures ANOVA (4 × 2) with RTs (in ms) as a dependent variable was conducted. Post hoc comparisons between emotional categories were calculated with Bonferroni correction ($p < 0.05$). In addition to examining evidence for the null hypothesis stating a lack of between-group differences in certain conditions we have conducted Bayesian Repeated Measures ANOVA and t-tests using JASP software (JASP Team, 2019).

Data preprocessing and statistical analyses of neuronal data

We used Statistical Parametric Mapping (SPM12) for data preprocessing and statistical analyses. Functional data were corrected for the head motion with field map realignment option (FieldMap Toolbox; Jezzard, Balaban, 1995), then coregister to T1w image, normalized and smooth in 6 mm full-width at half-maximum isotropic Gaussian kernel. Structural scans were automatically classified into types of brain matter with the „New Segmentation" tool (Ashburner, Friston, 2005). Then a two-step random-effects approach was used for all analyses. Firstly, all activation during the conditions of interest (5 categories of events: sex-related, positive, fear-related, negative and neutral trials) were fitted using the general linear model (GLM) as a 2 s box-car events for each participant individually with 6 regressors of head motions. We modeled 4 runs separately as blocks in the same order for all participants. All models were masked on threshold 0.2. and a high-pass filter with a cut-off of 128 s was applied to the time series. Secondly, to investigate group differences, the contrasts of interest (each emotion minus neutral contrasts) were entered as the dependent variables with the group variable as the independent variable in simple two-sample t-tests. The reason for that was the assumption that all emotional categories will be connected with more neuronal activation than processing words in neutral trials. The last step of analysis included region-of-interests (ROI) analysis. We selected a list of ROIs (from Automated Anatomical Labelling atlas

(https://www.gin.cnrs.fr/en/tools/aal/) to identify amygdala, anterior cingulate cortex (ACC), caudate, pallidum, putamen, nucleus accumbens, (NAcc), insula, thalamus and ventral tegmental area (VTA), posterior orbitofrontal cortex (pOFC), anterior orbitofrontal cortex (aOFC) and we created the two spheres left and right ventral striatum (ROI defined a priori based on a previous meta-analysis of reward anticipation (Liu, Hairston, Schrier, & Fan, 2011); as a 8 mm sphere centered around: Left: x = −12, y = 10 z = −6; Right: x = 12, y = 10, z = −4) based on meta-analysis on emotional and motivational processing of sexually explicit material described by Stark et al. (2019) and extracted the percentage of BOLD signal change in these ROIs during processing sex-related words by the usage of the MarsBaR toolbox (http://marsbar.sourceforge.net/). We also did exploratory correlation analysis between severity of CSBD symptoms' and percentage of BOLD signal change (extracted by MarsBaR) in clusters that statistically significantly differentiated the studied groups (in CSBD minus HC comparison) in previous contrasts of interest i.e. sex-related trials minus neutral trials and with selected ROIs. The last exploratory correlation analysis was done only in the CSBD group, because we were interested in showing how the clinical severity of the symptoms translates into increased neural activity during the task processing and in the HC group there had no clinical symptoms to explore.
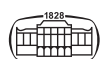
Ethics

All the procedures were carried out in accordance with the Declaration of Helsinki. The study was approved by the local ethics committee of the Institute of Psychology Polish Academy of Sciences.

RESULTS

Participant's characteristics

There was no between-group difference in the mean age (t (57) = 0.159 p = 0.874). CSBD patients obtained

significantly higher scores of CSBD severity across all used scales (SASTR: t (57) = 19.687 $p < 0.001$; BPS: t (57) = 19.107 $p < 0.001$; HBI: t (57) = −11.890, $p < 0.001$). For all participants, the scores measuring comorbid addiction symptoms were below the threshold (AUDIT: t (57) = −0.496 $p = 0.622$; SOGS: t (57) = 0.526 $p = 0.601$). Groups did differ at the: Obsessive-Compulsive Inventory-Revised (t (57) = −4.357, $p < 0.001$; OCI-R, Foa et al., 2002), Hospital Anxiety and Depression Scale (anxiety sub-scale: t (57) = −4.897, $p < 0.001$; depression sub-scale: t (57) = −3.609, $p < 0.001$; Zigmond & Snaith, 1983), State-Trait Anxiety Inventory (state sub-scale: t (57) = −3.831, $p < 0.001$; Spielberger, 1989), Barratt Impulsiveness Scale (attentional impulsiveness sub-scale: t (57) = −5.265, $p < 0.001$; motor impulsiveness sub-scale: t (57) = −3.140, $p = 0.003$; non-planning impulsiveness sub-scale; t (57) = −2.197, $p = 0.032$; Stanford et al., 2009), UPPS-P Impulsive Behavior Scale (positive urgency sub-scale: t (57) = −3.050, $p = 0.003$; negative urgency sub-scale: t (57) = −6.642, $p < 0.001$; lack of perseverance sub-scale t (57) = −2.377, $p = 0.021$; Lynam, Smith, Whiteside, & Cyders, 2006), Sensitivity to Punishment and Reward Questionnaire (punishment sub-scale: t (57) = −3.402, $p < 0.001$; Cooper & Gomez, 2008). There were no significant group differences in certain sub-scales of State-Trait Anxiety Inventory (trait sub-scale: t (57) = 0.833, $p = 0.408$), UPPS-P Impulsive Behavior Scale (lack of premedation sub-scale: t (57) = −0.361, $p = 0.720$ and sensation seeking sub-scale: t (57) = −0.089, $p = 0.929$; Lynam et al., 2006), and in Monetary Choice Questionnaire (overall K value: t (57) = 1.784, $p = 0.080$; MCQ, Kirby & Maraković, 1996) and Sensitivity to Punishment and Reward Questionnaire (reward scale: t (57) = −0.590, $p = 0.558$; Cooper & Gomez, 2008) (Table 2).

Table 2. Participants' characteristics – comparison of the questionnaire statistics obtained for CSBD and HC groups (significance value of < 0.05)

	CSBD (N = 29) mean (SD)	HC (N = 30) mean (SD)	p value	Cohen's d	SE Cohen's d
Age	33.93 (6.573)	33.43 (6.399)	0.769	−0.077	0.261
Brief Pornography Screening Test	7.79 (2.059)	1 (1.050)	**<0.001**	**−4.177**	**0.599**
Sexual Addiction Screening Test-Revised	12.93 (2.927)	1.37 (1.273)	**<0.001**	**−5.155**	**0.715**
Hypersexual Behavior Inventory	59.069 (14.709)	24.63 (6.494)	**<0.001**	**−3.047**	**0.472**
Alcohol Use Disorder Identification Test	6.24 (2.773)	6.53 (2.968)	0.698	0.102	0.261
South Oaks Gambling Screen	0.76 (1.480)	0.57 (0.935)	0.552	−0.156	0.261
Obsessive Compulsive Inventory-Revised	20.14 (9.775)	10.31 (6.448)	**<0.001**	**−1.187**	**0.305**
Hospital Anxiety and Depression Scale anxiety scale	8.72 (3.575)	4.59 (2.732)	**<0.001**	**−1.301**	**0.313**
Hospital Anxiety and Depression Scale depression scale	5.93 (3.605)	2.93 (2.789)	**<0.001**	**−0.931**	**0.290**
State-Trait Anxiety Inventory state scale	44.07 (12.218)	33.23 (8.443)	**<0.001**	**−1.035**	**0.293**
State-Trait Anxiety Inventory trait scale	48.14 (2.489)	48.57 (2.161)	0.482	0.184	0.261
Barratt Impulsiveness Scale attentional impulsiveness scale	12.72 (2.389)	9.03 (2.580)	**<0.001**	**−1.484**	**0.323**
Barratt Impulsiveness Scale motor impulsiveness scale	18.62 (3.736)	15.83 (3.130)	**0.003**	**−0.810**	**0.281**
Barratt Impulsiveness Scale non-planning impulsiveness scale	23.207 (4.799)	20.30 (4.669)	**0.022**	**−0.614**	**0.272**
UPPS-P Impulsive Behavior Scale positive urgency scale	32.69 (6.872)	28.03 (4.313)	**0.003**	**−0.811**	**0.283**
UPPS-P Impulsive Behavior Scale negative urgency scale	32.24 (5.396)	23.45 (4.339)	**<0.001**	**−1.796**	**0.353**
UPPS-P Impulsive Behavior Scale lack of premeditation scale	24.55 (2.515)	24.17 (2.989)	0.603	−0.137	0.263
UPPS-P Impulsive Behavior Scale lack of perseverance scale	23.17 (4.343)	20.34 (4.490)	**0.018**	**−0.640**	**0.276**
UPPS-P Impulsive Behavior Scale sensation seeking scale	32.80 (6.15)	32.65 (6.32)	0.983	0.006	0.263
Monetary Choice Questionnaire overall K value	0.01 (0.019)	0.03 (0.055)	0.088	0.456	0.269
Sensitivity to Punishment and Reward Questionnaire punishment scale	5.41 (3.459)	2.47 (3.277)	**<0.001**	**−0.875**	**0.284**
Sensitivity to Punishment and Reward Questionnaire reward scale	5.17 (2.189)	4.90 (2.203)	0.636	−0.124	0.261

Behavioral results

Reaction times were influenced by the experimental condition (type of emotion) $F (3,232) = 10.608$; $p = 0.001$ with strong effect size (eta2 = 0.109; interpretation based on Cohen, 1988). To examine between-group differences within each emotional category, we have conducted Bonferroni-corrected post hoc comparisons. Results of this analysis revealed a significantly higher difference in RTs (neutral minus sex-related) trials (more precisely there was a bigger emotional Stroop effect in sex-related trials) than in positive trials (neutral minus positive trials) ($p = 0.002$), negative trials (neutral minus negative trials) ($p = 0.002$), and fear-related trials (neutral minus fear-related trials) ($p = 0.001$). RTs did not differ significantly between positive and negative words, positive and fear-related, and between negative and fear-related. Interaction between the emotional category and the group was insignificant ($F (3,232) = 1.385$; $p = 0.249$; eta2 = 0.014) and we did not find any significant group effect ($F (1,116) = 3.547$; $p = 0.065$; eta2 = 0.017; for details see Fig. 2) Mean RTs are listed in Table 3 as a difference (neutral minus each category) and as an absolute value, worth to mention is the fact that our assumption about shortening RTs in sex-related category seems to be opposite.

Therefore we have conducted additional Bayesian analysis focused on the Bayesian Factor 01 (BF_{01}) indicating the level of evidence in favor of the null hypothesis on the lack of differences. Obtained results were at anecdotal levels for between-group differences in sex-related category ($BF_{01} = 0.964$) and positive category ($BF_{01} = 1.507$), so we cannot say that groups do not differ in this matter. In negative category and fear-related category BF_{01} were on the moderate level (negative: $BF_{01} = 3.033$, fear-related:

$BF_{01} = 3.728$), therefore is it hard to tell that both groups definitively do not differ in these two conditions.

Table 3. Mean reaction times

	CSBD ($N = 29$) mean (SD)	HC ($N = 30$) mean (SD)
RTs in neutral minus sex-related category	−28.23 ms (52.22)	−8.81 ms (25.99)
RTs in neutral minus positive emotional category	2.19 ms (25.29)	11.84 ms (24.55)
RTs in neutral minus negative emotional category	−0.67 ms (23.52)	4.37 ms (29.25)
RTs in neutral minus fear-related category	6.70 ms (23.70)	5.59 ms (21.63)
RTs in neutral category	823.63 ms (158.03)	794.90 ms (118.35)
RTs in sex-related category	851.86 ms (182.76)	803.72 ms (120.25)
RTs in positive emotional category	821.43 ms (156.04)	783.06 ms (109.96)
RTs in negative emotional category	824.29 ms (159.50)	790.53 ms (121.10)
RTs in fear-related category	816.92 ms (159.41)	789.31 ms (116.99)

Neuronal results

Neuronal analyses were limited to comparisons between CSBD and HC. On the whole-brain level of analyses we found a significant difference between CSBD and HC in contrast sex-related words minus neutral words in two
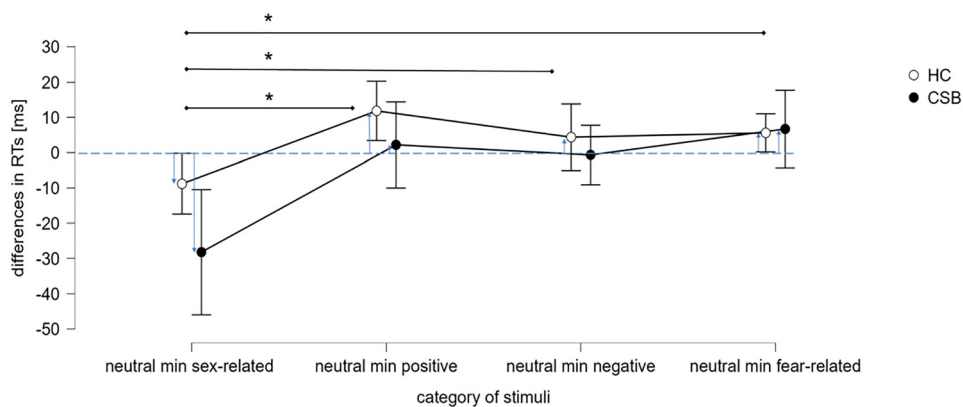

Fig. 2. Differences of mean reaction times in 4 categories of trials. In the CSBD group in the neutral minus sex-related category $M = -28.23$ ms (SD = 52.22), in neutral minus positive emotional category $M = 2.19$ ms (SD = 25.29), in neutral minus negative emotional category $M = -0.67$ ms (SD = 23.52) and in neutral minus fear-related category $M = 6.70$ ms (SD = 23.70). Among healthy controls (HC) in neutral minus sex-related category $M = -8.81$ ms (SD = 25.99), in neutral minus positive emotional category $M = 11.84$ ms (SD = 24.55), in neutral minus negative emotional category $M = 4.37$ ms (SD = 29.25) and in neutral minus fear-related category $M = 5.59$ ms (SD = 21.63). There was a significant main effect of emotion type on differences of mean reaction times $F (3,232) = 10.608$; $p = 0.001$ with strong effect size (eta2 = 0.109). Interaction between emotional category and the group ($F (3,232) = 1.385$; $p = 0.249$; eta2 = 0.014) and main group effect ($F (1,116) = 3.547$; $p = 0.065$; eta2 = 0.017) were insignificant. The blue lines represents if the differences are in over or under 0, to test if right is an assumption that (a) the positive emotional category and sex-related category would be connected with the shortening of RTs and differences would be over 0 and (b) both negative emotional categories will be connected with cognitive load interference causing an increase in RTs and differences will be under the 0
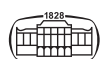
clusters located in the right and left hemispheres (Fig. 3) located respectively within the right hippocampus, right putamen, and right thalamus (peak in MNI: x = 28, y = −14, z = −8; FWEc = 181; t = 4.53; p < 0.001) and left pulvinar (posterior part of the thalamus) and left hippocampus (peak in MNI: x = −14, y = −32, z = 14; FWEc = 181; t = 5.07; p < 0.001). By examining the contrast between positive and neutral trials, we found a significant difference between HC and CSBD in the left middle frontal gyrus (peak in MNI: x = −52, y = 16, z = 46; FWEc = 91; t = 4.70; p = 0.006; see Fig. 3). Two remaining contrasts (fear vs. neutral and negative vs. neutral) were insignificant.

To examine the relation between the above-described neural activations (see Figs 3 and 4) and CSBD symptoms, we have conducted an exploratory correlation analysis of the percent of BOLD signal change within each of the described above clusters (as a regions of interest – ROIs) and CSBD symptoms measured with questionnaires and self-reported frequency of sexual behavior (only in CSBD patients). Neural activation in the left cluster (peak in MNI: x = −14, y = −32, z = 14; FWEc = 181; t = 5.07; p < 0.001) was significantly negatively correlated with time spent on sexual activity during the week preceding fMRI recording (r = −0.556; p < 0.05; see Table 4).
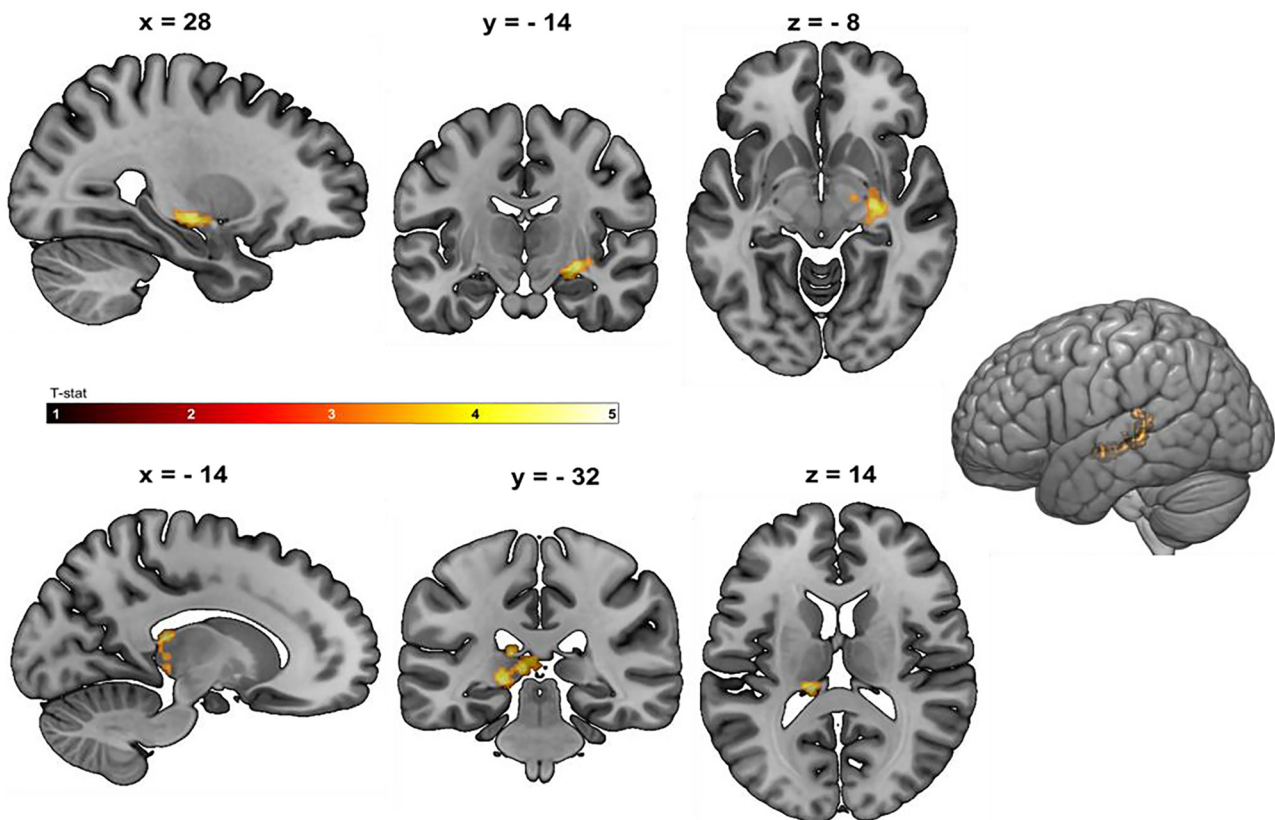

Fig. 3. Neuronal activations during sex-related words processing (contrast sex-related words minus neutral words): We found a significant difference between CSBD vs. HC in two clusters located in the right and left hemispheres located respectively within right hippocampus, right putamen, and right thalamus (peak in MNI: x = 28, y = −14, z = −8; FWEc = 181; t = 4.53; p < 0.001) and left pulvinar (posterior part of the thalamus) and left hippocampus (peak in MNI: x = −14, y = −32, z = 14; FWEc = 181; t = 5.07; p < 0.001)
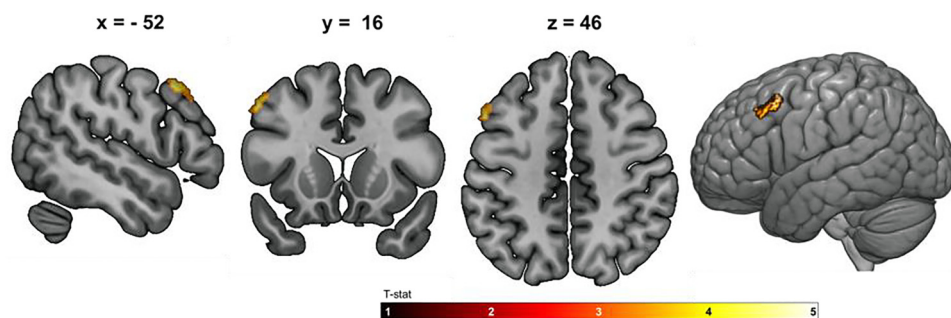

Fig. 4. Neuronal activations during positive words processing (contrast positive words minus neutral words): We found a significant difference between HC vs. CSBD in the left middle frontal gyrus (peak in MNI: x = −52, y = 16, z = 46; FWEc = 91; t = 4.70; p = 0.006)

Table 4. Correlation analysis of neuronal activation and CSBD symptoms (Pearson's r or Spearman's rho statistics based on normality of distribution measured with Shapiro-Wilk test) among CSBD group (significance value $^*p < 0.05$; $^{**}p < 0.01$)

BOLD signal changed during processing of sex-related words	The sum of all subscales in Hypersexual Behavior Inventory	Coping Subscale in Hypersexual Behavior Inventor	Consequences Subscales in Hypersexual Behavior Inventory	Control Subscale in Hypersexual Behavior Inventory	Sexual Addiction Screening Test-Revised version	Brief Pornography Screening Test	Onset of pornography watched the first time	Time of pornography watching during the week proceeding study	Numbers of masturbation during the week proceeding study	Numbers of intercourse during the week proceeding study	mean reaction times in sex-related trials	mean reaction times in neutral vs sex-related trials
left cluster (peak in MNI: x = -14, y = -32, z = 14)	0.201	0.111	0.288	0.148	0.114	−0.015	−0.227	0.095	0.142	**−0.556***	−0.219	0.01
right cluster (peak in MNI: x = 28, y = -14, z = -8)	−0.011	−0.043	−0.124	0.085	−0.131	−0.184	0.199	0.139	0.022	0.008	−0.091	0.08
left Anterior Cingulate Cortex	0.112	0.161	0.091	0.028	0.019	0.105	−0.063	0.273	0.289	−0.226	0.049	−0.23
right Anterior Cingulate Cortex	0.003	0.031	0.001	−0.022	−0.083	0.045	−0.064	0.191	0.125	−0.145	0.040	−0.19
left amygdala	−0.059	0.022	−0.080	−0.097	−0.307	−0.218	−0.110	−0.247	0.017	−0.321	−0.068	0.04
right amygdala	0.073	0.033	0.060	0.085	−0.122	0.066	0.054	−0.060	−0.130	−0.092	−0.065	−0.02
left caudate	0.010	−0.113	0.022	0.113	−0.156	−0.011	−0.031	0.086	0.098	−0.316	−0.108	−0.11
right caudate	0.019	−0.043	0.012	0.071	−0.157	−0.090	−0.033	0.121	0.145	−0.355	−0.006	−0.14
left insula	0.289	**0.368***	0.173	0.153	0.031	0.036	0.000	0.085	0.173	−0.039	−0.048	−0.19
right insula	0.309	**0.378***	0.192	0.174	0.013	0.081	0.010	0.075	0.079	0.120	0.016	−0.16
left Nucleus accumbens	0.023	−0.058	−0.038	0.120	−0.179	−0.029	−0.060	−0.007	0.050	0.235	0.081	−0.18
right Nucleus accumbens	0.040	−0.003	0.029	0.068	−0.108	−0.168	−0.254	0.162	0.255	0.059	0.211	−0.32
left Anterior Orbitofrontal Cortex	0.144	0.037	0.109	0.198	0.122	0.236	−0.107	0.114	0.092	0.226	0.300	**−0.519****
right Anterior Orbitofrontal Cortex	0.208	0.156	0.181	0.179	0.144	0.248	−0.261	0.062	0.042	0.201	0.257	**−0.437***
left Posterior Orbitofrontal Cortex	0.230	0.142	0.213	0.218	0.114	0.174	−0.089	0.235	0.207	−0.117	0.167	**−0.382***
right Posterior Orbitofrontal Cortex	0.167	0.113	0.165	0.145	−0.003	0.254	−0.053	−0.003	−0.069	−0.039	0.199	**−0.394***
left pallidum	−0.019	0.121	−0.124	−0.081	−0.263	−0.268	−0.037	0.038	0.169	−0.039	−0.046	−0.04
right pallidum	−0.178	0.017	−0.228	−0.252	−0.211	**−0.383***	−0.047	−0.216	0.077	−0.405	−0.137	0.03
left putamen	−0.121	0.054	−0.244	−0.162	**−0.378***	−0.219	−0.078	−0.034	0.032	0.014	−0.158	−0.03

(continued)

Table 4. Continued

BOLD signal changed during processing of sex-related words	The sum of all subscales in Hypersexual Behavior Inventory	Coping Subscale in Hypersexual Behavior Inventor	Consequences Subscales in Hypersexual Behavior Inventory	Control Subscale in Hypersexual Behavior Inventory	Sexual Addiction Screening Test-Revised version	Brief Pornography Screening Test	Onset of pornography watched the first time	Time of pornography watching during the week proceeding study	Numbers of masturbation during the week proceeding study	Numbers of intercourse during the week proceeding study	mean reaction times in sex-related trials	mean reaction times in neutral vs sex-related trials
right putamen	−0.104	0.071	−0.234	−0.147	−0.363	−0.156	−0.048	0.022	0.069	−0.042	−0.101	−0.06
left Ventral Striatum	0.216	0.047	0.298	0.232	0.175	0.120	−0.148	−0.024	0.132	−0.123	0.132	0.01
right Ventral Striatum	0.267	0.261	0.249	0.165	−0.028	0.028	−0.139	0.211	0.140	−0.263	0.082	−0.23
left Ventral Tegmental Area	0.009	0.015	−0.036	0.025	−0.141	−0.163	−0.079	−0.033	0.093	0.070	0.001	−0.14
right Ventral Tegmental Area	0.110	0.140	0.046	0.070	−0.103	−0.086	−0.027	−0.006	0.132	−0.045	0.129	−0.22

$^*p < 0.05;$ $^{**}p < 0.01.$

ROI analysis across brain regions related with emotional and motivational processing of sexually explicit material justified by review of literature and described previously by Stark et al. (2019) and listed in Table 5, showed group differences (differences between CSBD vs. HC without correction for multiple comparisons) in: left caudate (t (57) $= −2.055$ $p = 0.044$), right caudate (t (57) $= −2.167$ $p = 0.034$), right insula (t (57) $= −1.976$ $p = 0.053$), left pallidum (t (57) $= −2.368$ $p = 0.021$), left putamen (t (57) $= −2.012$ $p = 0.049$), left thalamus (t (57) $= −2.688$ $p = 0.009$), right thalamus (t (57) $= −2.451$ $p = 0.017$) and right ventral striatum (t (57) $= −2.1$ $p = 0.040$). In some of these ROIs BOLD signal correlated with CSBD symptoms (calculated only in CSBD group). We found positive trends (correlation without correction for multiple comparisons) between the signal from the left and right insula and scores in the HBI coping subscale, a negative trend between activation in right pallidum and BPS score, a negative correlation between activation of left putamen and SASTR score and negative trend between activation in bilateral aOFC and pOFC and mean RT in neutral vs sex-related trials and also significant negative trend between numbers of intercourse during the week proceeding study and activation in left cluster (peak in MNI: x $= −14$, y $= −32$, z $= 14$) (see Table 4). Unfortunately, none of the results survived Bonferroni-Holm's (1979) correction for multiple comparisons.

DISCUSSION

In our study, we did not find any evidence on behavioral and/or neuronal levels supporting the hypothesis of generally impaired emotional processing in CSBD, which was to be seen through increased cognitive conflict (EST interference) both in generally negative trials and in fearful trials (based on results from frequent and Bayesian statistics). There was also no evidence for bigger cognitive interference in positive trials in results from frequent statistics, but the BF stats provided only anecdotal evidence supporting the null hypothesis in the positive condition, so the groups probably differ in this matter. Instead, our study revealed that there is an increased EST effect (conclusion based on results from frequent and Bayesian statistics) increasing cognitive load visible in increased RTs) in sex-related trials, especially in the CSBD group. Taking into consideration all of this results contrary to hypothesis, CSBD could be connected to the cognitive conflict during processing of positive and symptom's related stimuli. What is more, our results can be understood as evidence of impaired cognitive coping strategies during exposure to a stimulus associated with problematic sexual behavior. It is well established that CSBD symptoms are correlated with increased biases during attentional processing of sex-related stimuli. For example Pekal et al. study (2018) showed that problematic pornography use was associated with attentional bias toward sexual stimuli. A similar effect was found in Mechelmans et al. study (2014). Other studies using the Stroop task and emotional Stroop task

Table 5. Between-group comparison of neural activations across all regions of interest (ROI) (significance value of <0.05)

	CSBD (N = 29) mean (SD)	HC (N = 30) mean (SD)	*p* value	Cohen's d	SE Cohen's d
Left Anterior Cingulate Cortex (ACC)	0.829 (1.251)	0.273 (1.134)	0.079	−0.466	0.267
Right Anterior Cingulate Cortex (ACC)	0.445 (0.921)	0.143 (0.779)	0.179	−0.354	0.264
Left Amygdala	0.360 (0.683)	0.286 (0.645)	0.670	−0.111	0.261
Right Amygdala	0.428 (0.581)	0.199 (0.563)	0.129	−0.401	0.266
Left Caudate	0.391 (0.771)	0.038 (0.530)	**0.044**	**−0.535**	**0.269**
Right Caudate	0.383 (0.690)	0.032 (0.551)	**0.034**	**−0.564**	**0.270**
Left Insula	0.402 (0.655)	0.141 (0.561)	0.106	−0.428	0.266
Right Insula	0.458 (0.733)	0.078 (0.745)	**0.053**	**−0.515**	**0.269**
Left Nucleus accumbens (NAcc)	0.316 (0.843)	0.107 (0.750)	0.318	−0.262	0.263
Right Nucleus accumbens (NAcc)	0.176 (0.759)	0.008 (0.699)	0.380	−0.231	0.262
Left Anterior Orbitofrontal Cortex (aOFC)	0.384 (0.928)	0.295 (0.865)	0.706	−0.099	0.261
Right Anterior Orbitofrontal Cortex (aOFC)	0.263 (0.907)	0.145 (0.964)	0.629	−0.127	0.261
Left Posterior Orbitofrontal Cortex (pOFC)	1.099 (1.232)	0.787 (0.823)	0.256	−0.299	0.263
Right Posterior Orbitofrontal Cortex (pOFC)	1.028 (1.088)	0.586 (0.959)	0.103	−0.432	0.266
Left Pallidum	0.134 (0.332)	−0.061 (0.299)	**0.021**	**−0.617**	**0.272**
Right Pallidum	0.092 (0.357)	−0.068 (0.351)	0.088	−0.453	0.267
Left Putamen	0.151 (0.556)	−0.108 (0.427)	**0.049**	**−0.524**	**0.269**
Right Putamen	0.109 (0.483)	−0.117 (0.434)	0.063	−0.493	0.268
Left Thalamus	0.291 (0.466)	−0.023 (0.431)	**0.009**	**−0.700**	**0.276**
Right Thalamus	0.228 (0.439)	−0.047 (0.422)	**0.017**	**−0.638**	**0.273**
Left Ventral Striatum (VStr)	0.111 (0.633)	0.004 (0.589)	0.505	−0.175	0.261
Right Ventral Striatum (VStr)	0.338 (0.539)	0.032 (0.578)	**0.040**	**−0.547**	**0.270**
Left Ventral Tegmental Area (VTG)	0.318 (0.655)	0.001 (0.600)	0.057	−0.506	0.268
Right Ventral Tegmental Area (VTG)	0.359 (0.637)	0.049 (0.682)	0.077	−0.470	0.267

with word-related emotional and sexual words also showed behavioral markers of attentional biases toward sex-related words among CSBD patients and correlation of the magnitude of these biases with severity of CSBD symptoms (Albery et al., 2017; Draps et al., 2021; Wang, Chen, & Zhang, 2021).

This pattern of behavioral reaction could be discussed in reference to Incentive Salience Theory (IST). The Incentive Salience Theory framework was developed in the field of addiction studies and proposed by Robinson and Berridge (1993) to distinguish between two primary components of motivated behavior: "liking" and "wanting." "Liking" is linked to the experienced value of the reward, usually carried by an unconditional stimulus such as alcohol consumption or pornography watching. "Wanting" is related to the expected value of the reward, often carried by conditional stimulus (e.g. presence of people with whom the patient used to drink alcohol, or conditions indicating an opportunity to watch pornography). The IST assumes that during the repetitive engagement in certain stimuli, they gain salience due to the neural sensitization, and become powerful triggers of problematic behavior evoking an urge in response to substance-related cues which manifests itself in shortening of reaction times among addicted individuals (Berridge, 2012). While many previous studies shows shortening of reaction times among CSBD individuals for sex-related cues (review in Gola & Draps, 2018), they don't examine cognitive conflict during salient stimuli processing. Franken (2003) argued that after repeated experience with a substance

learned problematic cues become salient and are more likely to interfere with attention due to dopamine release in the corticostriatal circuit they evoke. This line of reasoning was confirmed in Albery et al. (2017) results. So it could be that cognitive processing during emotionally arousing conditions, salient stimuli (in CSBD it would be for example sex-related words) affect RTs more than any other emotional stimuli (e.g. positive or negative words) and our results observed among CSBD patients are in line with these IST assumptions.

Moreover, the processing of salient stimuli is associated with the increased dopaminergic activity of the reward system and structures essential for the motivational system (Robinson & Berridge, 1993). We assessed neuronal activity in regions that have been previously linked to the emotional and motivational processing of sexually explicit material. We found significant group differences in the left and right caudate, the right insula, the left pallidum, the left putamen, the left and right thalamus, and the right ventral striatum. In our previous datasets, we revealed that men with and without CSBD symptoms differed in their right ventral striatal responses to cues predicting erotic outcomes (Gola et al., 2017; Golec, Draps, Stark, Pluta, & Gola, 2021). A literature review on this topic found that neuronal hyperactivity in the ventral striatum during the processing of sex-related stimuli among CSBD patients seems to be a crucial mechanism underlying the CSBD symptoms (Gola & Draps, 2018). Ventral striatal activations in CSBD were reported not only in the response to cues predicting erotic outcomes

but also for watching sexually explicit pictures and videos (Brand et al., 2016; Voon et al., 2014). Banca et al. (2016) showed also decreased ventral striatal activations among CSBD patients as a response to a lack of erotic or monetary reward in a conditioning task, while Klucken, Wehrum-Osinsky, Schweckendiek, Kruse, and Stark (2016) showed decreased coupling between the ventral striatum and pre-frontal cortex in the CSBD during appetitive conditioning.

Unlike ventral, the dorsal part of the striatum was not as often reported in CSBD studies. The dorsal striatum consists of the caudate nucleus and the putamen. In 2014 Kühn & Gallinat found that there is a negative correlation between the amount of pornography consumption per week and gray matter values extracted from the cluster in the right caudate, and this lowered density of the right caudate is associated with negative correlation between the amount of pornography consumption per week and functional reactivity during a sexual cue–reactivity paradigm of the left putamen during sexual stimuli. However, those data were collected from non-clinical sample. In 2015, Seok & Sohn showed higher activation of the left caudate nucleus in response to erotic pictures in the CSBD group when compared to controls and lower activation for neutral pictures in the left caudate nucleus, the inferior parietal lobe, the dorsal anterior cingulate gyrus, the thalamus, and the dorsolateral prefrontal cortex which is more in line with our results.

Other interesting results are related to the group differences in the right insular cortex and the left and right thalamus, as the reactivity of those regions was shown in the context of motivation towards obtaining a reward (insula; Kühn & Gallinat, 2011; Stark et al., 2019) and suggested as encoding expected reward salience (thalamus; Sescousse, Caldú, Segura, & Dreher, 2013). All those results align with the IST assumption of increased dopaminergic activity in reward circuits during the processing of salient stimuli related to the problematic behavior.

Moreover, our whole-brain analysis, showed that sex-related trials were related to neuronal differences between CSBD and HC groups. These differences were visible in two clusters located respectively in the right and left hemi-spheres. The first contains the right hippocampus, the right putamen, and the right thalamus, while the second contains the left pulvinar and the left hippocampus. Interestingly there was a significant negative correlation between neuronal activation in the left cluster and time spent on sexual activity during the week preceding data collection. Considering the functional role of mentioned brain regions, such a pattern of neuronal activations sheds new light on the mechanism of CSBD. The hippocampus is a crucial part of the limbic system (Martin, 2012), plays an important role in the consolidation of information from short-term memory to long-term memory and in spatial memory (Bachevalier, 2019; Kovács, 2020; Squire, 2009) and has a functional role in approach-avoidance conflict and learning reaction to negative (related to anxiety) stimuli (Chan, Morell, Jarrard, & Davidson, 2001; Etkin & Wager, 2007; Ito & Lee, 2016; Satpute, Mumford, Naliboff, & Poldrack, 2012). The

putamen with caudate nucleus (parts of the basal ganglia system) form the dorsal striatum (Martin, 2012). A primary function of the putamen is to regulate different stages of movement (e.g. preparation and execution) (Marchand et al., 2008; Shirinbayan, Dreyer, & Rieger, 2019). It also affects reinforcement learning and implicit learning (Packard & Knowlton, 2002). Both learning processes are enforced to maximize the outcome and to perceive knowledge from repetitive exposure to a particular type of stimulus, e.g., pornographic or any other sex-related stimulus. The pulvi-nar is a part of the thalamus, and its function is related to attentional deficits (Arend, Rafal, & Ward, 2008). The thalamus is a larger structure of the brain and obviously has multiple functions, mainly as a hub, relaying information between different subcortical areas and the cerebral cortex (Gazzaniga, Ivry, & Mangun, 2006). These reveal the involvement of a whole network of brain structures, which has not been previously investigated in the context of CSBD symptoms and is worth attention in future studies.

Limitation

Despite the importance of revealed results, our study does have some limitations. Only heterosexual males aged be-tween 21 and 47 years resident in the capital city of WEIRD (Western, Educated, Industrialized, Rich, Democratic) type country were recruited. In future research, greater diversity (e.g. female or gay and/or lesbian participants) would be needed. There is also a methodological limitation to the study. Namely, different types of the Emotional Stroop Task have been used in neuroimaging studies, which results with various levels of induced cognitive interference (compare to Song et al., 2017) and difficulty with direct comparison of the results. The one used here seems to result in only mild emotional interference as the emotional words stimuli are not semantically-relevant to the task in-structions (Etkin et al., 2006), as previously shown in healthy subjects (reviews in: Song et al., 2017; Williams, Mathews, & MacLeod, 1996), so the usage of other types of task is needed e.g. task with sexually arousing pictures or videos.

CONCLUSION

Our findings suggest that in accordance with IST (Robinson & Berridge, 1993) and similar to what is observed in sub-stance and gambling addictions (Berridge, 2012), the neuronal and behavioral mechanisms associated with the processing of sex-related words could be understood as evidence of attentional biases toward those stimuli. This behavioral and neuronal bias is more robust among CSBD patients than healthy controls and is related to clinically relevant features of CSBD. Moreover, the bias is a source of cognitive conflict, which results in the decreased level of cognitive processing among CSBD patients when exposed to sex-related conditions, but not during the processing of other negative stimuli. There is also a possible influence of positive

stimuli when CSBD patients are exposed to positive stimuli. These results need further investigation and replications.

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REFERENCES

Albery, I. P., Lowry, J., Frings, D., Johnson, H. L., Hogan, C., & Moss, A. C. (2017). Exploring the relationship between sexual compulsivity and attentional bias to sex-related words in a cohort of sexually active individuals. *European Addiction Research*, 23(1), 1–6. https://doi.org/10.1159/000448732.

Antons, S., & Brand, M. (2018). Trait and state impulsivity in males with tendency towards internet-pornography-use disorder. *Addictive Behaviors*, 79, 171–177. https://doi.org/10.1016/j.addbeh.2017.12.029.

Antons, S., Mueller, S. M., Wegmann, E., Trotzke, P., Schulte, M., & Brand, M. (2019). Facets of impulsivity and related aspects differentiate among recreational and unregulated use of internet pornography. *Journal of Behavioral Addictions*, 1–11. https://doi.org/10.1556/2006.8.2019.22.

Arend, I., Rafal, R., & Ward, R. (2008). Spatial and temporal deficits are regionally dissociable in patients with pulvinar lesions. *Brain*, 131(8), 2140–2152. https://doi.org/10.1093/brain/awn135.

Ashburner, J., & Friston, K. J. (2005). Unified segmentation. *Neuroimage*, 26(3), 839–851. https://doi.org/10.1016/j.neuroimage.2005.02.018.

Babor, T. F., de la Fuente, J. R., Saunders, J., & Grant, M. (1992). *AUDIT. The alcohol use disorders identification test. Guidelines for use in primary health care*. Geneva, Switzerland: World Health Organization.

Bachevalier, J. (2019). Nonhuman primate models of hippocampal development and dysfunction. *Proceedings of the National Academy of Sciences*, 116(52), 26210–26216. https://doi.org/10.1073/pnas.1902278116.

Banca, P., Harrison, N. A., & Voon, V. (2016). Compulsivity across the pathological misuse of drug and non-drug rewards. *Frontiers in Behavioral Neuroscience*, 10(8), 154. https://doi.org/10.3389/fnbeh.2016.00154.

Banca, P., Morris, L. S., Mitchell, S., Harrison, N. A., Potenza, M. N., & Voon, V. (2016). Novelty, conditioning and attentional bias to sexual rewards. *Journal of Psychiatric Research*, 72(11), 91–101. https://doi.org/10.1016/j.jpsychires.2015.10.017.

Berridge, K. C. (2012). From prediction error to incentive salience: Mesolimbic computation of reward motivation. *European Journal of Neuroscience*, 35(7), 1124–1143. https://doi.org/10.1111/j.1460-9568.2012.07990.x.

Bőthe, B., Tóth-Király, I., Potenza, M. N., Griffiths, M. D., Orosz, G., & Demetrovics, Z. (2019). Revisiting the role of impulsivity and compulsivity in problematic sexual behaviors. *The Journal of Sex Research*, 56(2), 166–179. https://doi.org/10.1080/00224499.2018.1480744.

Brand, M., Snagowski, J., Laier, C., & Maderwald, S. (2016). Ventral striatum activity when watching preferred pornographic pictures is correlated with symptoms of internet pornography addiction. *Neuroimage*, 129, 224–232. https://doi.org/10.1016/j.neuroimage.2016.01.033.

Chan, K. H., Morell, J. R., Jarrard, L. E., & Davidson, T. L. (2001). Reconsideration of the role of the hippocampus in learned inhibition. *Behavioural Brain Research*, 119(2), 111–130. https://doi.org/10.1016/s0166-4328(00)00363-6.

Chatzittofis, A., Arver, S., Öberg, K., Hallberg, J., Nordström, P., & Jokinen, J. (2016). HPA axis dysregulation in men with hypersexual disorder. *Psychoneuroendocrinology*, 63, 247–253. https://doi.org/10.1016/j.psyneuen.2015.10.002.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. New York, NY: Routledge Academic.

Cooper, A. J., & Gomez, R. (2008). The development of a short form of the sensitivity to punishment and sensitivity to reward questionnaire. *Journal of Individual Differences*, 29, 90–104. https://doi.org/10.1027/1614-0001.29.2.90.

Cromheeke, S., & Mueller, S. C. (2014). Probing emotional influences on cognitive control: An ALE meta-analysis of cognition emotion interactions. *Brain Structure and Function*, 219, 995–1008. https://doi.org/10.1007/s00429-013-0549-z.

Draps, M., Sescousse, G., Wilk, M., Obarska, K., Szumska, I., Żukrowska, W., … Gola, M. (2021). An empirical study of affective and cognitive functions in Compulsive Sexual Behavior Disorder. *Journal of Behavioral Addictions*, 10(3), 657–674. https://doi.org/10.1556/2006.2021.00056.

Dresler, T., Mériau, K., Heekeren, H. R., & Van Der Meer, E. (2009). Emotional Stroop task: Effect of word arousal and subject anxiety on emotional interference. *Psychological Research*, 73(3), 364–371. https://doi.org/10.1007/s00426-008-0154-6.

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. https://doi.org/10.1016/j.neuron.2006.07.029.

Etkin, A., & Wager, T. D. (2007). Functional neuroimaging of anxiety: A meta-analysis of emotional processing in PTSD, social anxiety disorder, and specific phobia. *American Journal of Psychiatry*, 164(10), 1476–1488. https://doi.org/10.1176/appi.ajp.2007.07030504.

Foa, E. B., Huppert, J. D., Leiberg, S., Hajcak, G., Langner, R., Kichic Hajcak, G., & Salkovskis, P. M. (2002). The obsessive compulsive inventory: Development and validation of a short version. *Psychological Assessment*, 14, 485–496. https://doi.org/10.1037/1040-3590.14.4.485.

Franken, I. H. (2003). Drug craving and addiction: Integrating psychological and neuropsychopharmacological approaches. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, 27(4), 563–579. https://doi.org/10.1016/S0278-5846(03)00081-2.

Gazzaniga, M. S., Ivry, R. B., & Mangun, G. R. (2006). *Cognitive Neuroscience. The biology of the mind.* (2014). London: Norton Press.

Gola, M., & Draps, M. (2018). Ventral striatal reactivity in compulsive sexual behaviors. *Frontiers in Psychiatry*, 9, 546. https://doi.org/10.3389/fpsyt.2018.00546.

Gola, M., & Kraus, S. (2021). Sexual addiction vs. CSBD. compulsive sexual behavior disorder: Understanding, assessment, and treatment. *American Psychiatric Assotiation*, (Chapter 7).

Gola, M., Miyakoshi, M., & Sescousse, G. (2015). Sex, impulsivity and anxiety: Interplay between ventral striatum and amygdala reactivity in problematic sexual behaviors. *Journal of Neuroscience*, 35(46), 15227–15229. https://doi.org/10.1523/JNEUROSCI.3273-15.2015.

Gola, M., & Potenza, M. N. (2018). The proof of the pudding is in the tasting: Data are needed to test models and hypotheses related to compulsive sexual behaviors. *Archives of Sexual Behavior*, 47(5), 1323–1325. https://doi.org/10.1007/s10508-018-1167-x.

Gola, M., Skorko, M., Kowalewska, E., Kołodziej, A., Sikora, M., Wodyk, M., … Dobrowolski, P. (2016). Polska adaptacja testu przesiewowego na uzależnienie od zachowań seksualnych (Sexual Addiction Screening Test - Revised) SAST-PL-M. *Psychiatria Polska*. https://doi.org/10.12740/PP/OnlineFirst/61414.

Gola, M., Wordecha, M., Sescousse, G., Lew-Starowicz, M., Kossowski, B., Wypych, M., … Marchewka, A. (2017). Can pornography be addictive? An fMRI study of men seeking treatment for problematic pornography use. *Neuropsychopharmacology*, 42(10), 2021–2031. https://doi.org/10.1038/npp.2017.78.

Golec, K., Draps, M., Stark, R., Pluta, A., & Gola, M. (2021). Aberrant orbitofrontal cortex reactivity to erotic cues in Compulsive Sexual Behavior Disorder. *Journal of Behavioral Addictions*, 10(3), 646–656. https://doi.org/10.1556/2006.2021.00051.

Holm, S. (1979). A simple sequentially rejective multiple test procedure. *Scandinavian Journal of Statistics*, 6, 65–70.

Ishihara, S. (1987). *Test for colour-blindness*. Tokyo, Japan: Kanehara.

Ito, R., & Lee, A. C. (2016). The role of the hippocampus in approach-avoidance conflict decision-making: Evidence from rodent and human studies. *Behavioural Brain Research*, 313, 345–357. https://doi.org/10.1016/j.bbr.2016.07.039.

JASP Team (2019). JASP. Version 0.11.1. (Computer software).

Jezzard, P., & Balaban, R. S. (1995). Correction for geometric distortion in echo planar images from B0 field variations.

Magnetic Resonance in Medicine, 34(1), 65–73. https://doi.org/10.1002/mrm.1910340111.

Kirby, K. N., & Maraković, N. N. (1996). Delay-discounting probabilistic rewards: Rates decrease as amounts increase. *Psychonomic Bulletin & Review*, 3(1), 100–104. https://doi.org/10.3758/BF03210748.

Klucken, T., Wehrum-Osinsky, S., Schweckendiek, J., Kruse, O., & Stark, R. (2016). Altered appetitive conditioning and neural connectivity in subjects with compulsive sexual behavior. *The Journal of Sexual Medicine*, 13, 627–636. https://doi.org/10.1016/j.jsxm.2016.01.013.

Kor, A., Fogel, Y., Reid, R. C., & Potenza, M. N. (2013). Should hypersexual disorder be classified as an addiction? *Sexual Health & Compulsivity*, 20(1–2), 27–47. https://doi.org/10.1080/10720162.2013.768132.

Kovács, K. A. (2020). Episodic memories: How do the hippocampus and the entorhinal ring attractors cooperate to create them? *Frontiers in Systems Neuroscience*, 14, 559168. https://doi.org/10.3389/fnsys.2020.559186.

Kowalewska, E., Grubbs, J. B., Potenza, M. N., Gola, M., Draps, M., & Kraus, S. W. (2018). Neurocognitive mechanisms in compulsive sexual behavior disorder. *Current Sexual Health Reports*, 10, 255–264.

Kraus, S., Gola, M., Grubbs, J., Kowalewska, E., Hoff, R. A., Lew-Starowicz, M., … Potenza, M. N. (2020). Validation of a brief pornography screen across multiple samples. *Journal of Behavioral Addictions*, 9(2), 259–271. https://doi.org/10.1556/2006.2020.00038.

Kraus, S. W., Voon, V., & Potenza, M. N. (2016). Should compulsive sexual behavior be considered an addiction? *Addiction*, 111(12), 2097–2106. https://doi.org/10.1111/add.13297.

Kühn, S., & Gallinat, J. (2011). A quantitative meta-analysis on cue-induced male sexual arousal. *The Journal of Sexual Medicine*, 8(8), 2269–2275. https://doi.org/10.1111/j.1743-6109.2011.02322.x.

Kühn, S., & Gallinat, J. (2014). Brain structure and functional connectivity associated with pornography consumption: The brain on porn. *JAMA Psychiatry*, 71(7), 827–834. https://doi.org/10.1001/jamapsychiatry.2014.93.

Kühn, S., & Gallinat, J. (2016). Neurobiological basis of hypersexuality. *International Review of Neurobiology*, 129, 67–83. https://doi.org/10.1016/bs.irn.2016.04.002.

LeDoux, J. E. (2000). Emotion circuits in the brain. *Annual Review of Neuroscience*, 23(1), 155–184. https://doi.org/10.1146/annurev.neuro.23.1.155.

Lew-Starowicz, M., Lewczuk, K., Nowakowska, I., Kraus, S., & Gola, M. (2020). Compulsive sexual behavior and dysregulation of emotion. *Sexual Medicine Reviews*, 8(2), 191–205. https://doi.org/10.1016/j.sxmr.2019.10.003.

Liberg, B., Görts-Öberg, K., Jokinen, J., Savard, J., Dhejne, C., Arver, S., … Abé, C. (2022). Neural and behavioral correlates of sexual stimuli anticipation point to addiction-like mechanisms in compulsive sexual behavior disorder. *Journal of Behavioral Addictions*, 11(2), 520–532. https://doi.org/10.1556/2006.2022.00035.

Liu, X., Hairston, J., Schrier, M., & Fan, J. (2011). Common and distinct networks underlying reward valence and processing

stages: A meta-analysis of functional neuroimaging studies. *Neuroscience and Biobehavioral Reviews*, *35*, 1219–1236. https://doi.org/10.1016/j.neubiorev.2010.12.012.

Lynam, D. R., Smith, G. T., Whiteside, S. P., & Cyders, M. A. (2006). *The UPPS-P: Assessing five personality pathways to impulsive behavior*. West Lafayette, IN: Purdue University, 10.

Marchand, W. R., Lee, J. N., Thatcher, J. W., Hsu, E. W., Rashkin, E., Suchy, Y., … Barbera, S. S. (2008). Putamen coactivation during motor task execution. *NeuroReport: For Rapid Communication of Neuroscience Research*, *19*(9), 957–960. https://doi.org/10.1097/WNR.0b013e328302c873.

Martin, J. H. (2012). *Neuroanatomy text and atlas*. McGraw-Hill.

Mechelmans, D. J., Irvine, M., Banca, P., Porter, L., Mitchell, S., Mole, T. B., & Voon, V. (2014). Enhanced attentional bias towards sexually explicit cues in individuals with and without compulsive sexual behaviours. *PloS One*, *9*(8). https://doi.org/10.1371/journal.pone.0105476.

Melcher, T., Born, C., & Gruber, O. (2011). How negative affect influences neural control processes underlying the resolution of cognitive interference: An event-related fMRI study. *Neuroscience Research*, *70*(4), 415–427. https://doi.org/10.1016/j.neures.2011.05.007.

Miner, M. H., Dickenson, J., & Coleman, E. (2019). Effects of emotions on sexual behavior in men with and without hypersexuality. *Sexual Addiction Compulsivity*, *26*(1–2), 24–41. https://doi.org/10.1080/10720162.2018.1564408.

Miner, M. H., Romine, R. S., Raymond, N., Janssen, E., MacDonald, A., & Coleman, E. (2016). Understanding the personality and behavioral mechanisms defining hypersexuality in men who have sex with men. *Journal of Sexual Medicine*, *13*, 1323–1331. https://doi.org/10.1016/j.jsxm.2016.06.015.

Mueller, S. C. (2011). The influence of emotion on cognitive control: Relevance for development and adolescent psychopathology. *Frontiers in Psychology*, *2*, 327. https://doi.org/10.3389/fpsyg.2011.00327.

Nee, D. E., Wager, T. D., & Jonides, J. (2007). Interference resolution: Insights from a meta-analysis of neuroimaging tasks. *Cognitive, Affective & Behavioral Neuroscience*, *7*(1), 1–17. https://doi.org/10.3758/cabn.7.1.1.

Odlaug, B. L., Lust, K., Schreiber, L. R., Christenson, G., Derbyshire, K., Harvanko, A., & Grant, J. E. (2013). Compulsive sexual behavior in young adults. *Annals of Clinical Psychiatry: Official Journal of the American Academy of Clinical Psychiatrists*, *25*(3), 193–200.

Okon-Singer, H., Hendler, T., Pessoa, L., & Shackman, A. J. (2015). The neurobiology of emotion–cognition interactions: Fundamental questions and strategies for future research. *Frontiers in Human Neuroscience*, *9*, 58. https://doi.org/10.3389/fnhum.2015.00058.

Packard, M. G., & Knowlton, B. J. (2002). Learning and memory functions of the basal ganglia. *Annual Review of Neuroscience*, *25*(1), 563–593. https://doi.org/10.1146/annurev.neuro.25.112701.142937.

Pekal, J., Laier, C., Snagowski, J., Stark, R., & Brand, M. (2018). Tendencies toward Internet-pornography-use disorder: Differences in men and women regarding attentional biases to pornographic stimuli. *Journal of Behavioral Addictions*, *7*(3), 574–583. https://doi.org/10.1556/2006.7.2018.70.

Pessoa, L. (2008). On the relationship between emotion and cognition. *Nature reviews Neuroscience*, *9*(2), 148–158. https://doi.org/10.1038/nrn2317.

Reid, R., Temko, J., Moghaddam, J. F., & Fong, T. W. (2014). Shame, rumination, and self-compassion in men assessed for hypersexual disorder. *Journal of Psychiatric Practice*, *20*(4), 260–268. https://doi.org/10.1097/01.pra.0000452562.98286.c5.

Reid, R. C., Garos, S., Carpenter, B. N., & Coleman, E. (2011). A surprising finding related to executive control in a patient sample of hypersexual men. *Journal of Sexual Medicine*, *8*(8), 2227–2236. https://doi.org/10.1111/j.1743-6109.2011.02314.x.

Riegel, M., Wypych, M., Żurawski, Ł., Jednoróg, K., Grabowska, A., & Marchewka, A. (2015). Nencki affective word list (NAWL): The cultural adaptation of the Berlin affective word list – reloaded (BAWL-R) for Polish, 1222–1236. https://doi.org/10.3758/s13428-014-0552-1.

Robinson, T. E., & Berridge, K. C. (1993). The neural basis of drug craving: An incentive-sensitization theory of addiction. *Brain Research Reviews*, *18*(3), 247–291. https://doi.org/10.1016/0165-0173(93)90013-p.

Satpute, A. B., Mumford, J. A., Naliboff, B. D., & Poldrack, R. A. (2012). Human anterior and posterior hippocampus respond distinctly to state and trait anxiety. *Emotion*, *12*(1), 58. https://doi.org/10.1037/a0026517.

Schreiber, L. R., Grant, J. E., & Odlaug,, B. L. (2012). Emotion regulation and impulsivity in young adults. *Journal of Psychiatric Research*, *46*, 651–658. https://doi.org/10.1016/j.jpsychires.2012.02.005.

Seok, J. W., & Sohn, J. H. (2015). Neural substrates of sexual desire in individuals with problematic hypersexual behavior. *Frontiers in Behavioral Neuroscience*, *9*, 321. https://doi.org/10.3389/fnbeh.2015.00321.

Seok, J. W., & Sohn, J. H. (2018). Altered prefrontal and inferior parietal activity during a stroop task in individuals with problematic hypersexual behavior. *Frontiers in Psychiatry*, *9*, 460. https://doi.org/10.3389/fpsyt.2018.00460.

Sescousse, G., Caldú, X., Segura, B., & Dreher, J. C. (2013). Processing of primary and secondary rewards: A quantitative meta-analysis and review of human functional neuroimaging studies. *Neuroscience and Biobehavioral Reviews*, *37*(4), 681–696. https://doi.org/10.1016/j.neubiorev.2013.02.002.

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. *Nature Reviews Neuroscience*, *12*(3), 154–167. https://doi.org/10.1038/nrn2994.

Shirinbayan, S. I., Dreyer, A. M., & Rieger, J. W. (2019). Cortical and subcortical areas involved in the regulation of reach movement speed in the human brain: An fMRI study. *Human Brain Mapping*, *40*(1), 151–162. https://doi.org/10.1002/hbm.24361.

Sinke, C., Engel, J., Veit, M., Hartmann, U., Hillemacher, T., Kneer, J., & Kruger, T. H. C. (2020). Sexual cues alter working memory performance and brain processing in men with compulsive sexual behavior. *NeuroImage: Clinical*, *27*, 102308. https://doi.org/10.1016/j.nicl.2020.102308.

Song, S., Zilverstand, A., Song, H., d'Oleire Uquillas, F., Wang, Y., Xie, C., … Zou, Z. (2017). The influence of emotional

interference on cognitive control: A meta-analysis of neuro-imaging studies using the emotional stroop task. *Scientific Reports*, 7(1), 2088. https://doi.org/10.1038/s41598-017-02266-2.

Spenhoff, M., Kruger, T. H., Hartmann, U., & Kobs, J. (2013). Hypersexual behavior in an online sample of males: Associations with personal distress and functional impairment. *The Journal of Sexual Medicine*, 10, 2996–3005. https://doi.org/10.1111/jsm.12160.

Spielberger, C., D. (1989). *State-trait anxiety inventory: Bibliography*. Consulting Psychologists Press.

Squire, L. R. (2009). The legacy of patient H.M. for neuroscience. *Neuron*, 61, 6–9. https://doi.org/10.1016/j.neuron.2008.12.023.

Stanford, M. S., Mathias, C. W., Dougherty, D. M., Lake, S. L., Anderson, N. E., & Patton, J. H. (2009). Fifty years of the Barratt impulsiveness scale: An update and review. *Personality and Individual Differences*, 47, 385–395. https://doi.org/10.1016/j.paid.2009.04.008.

Stark, R., Klein, S., Kruse, O., Weygandt, M., Leufgens, L. K., Schweckendiek, J., & Strahler, J. (2019). No sex difference found: Cues of sexual stimuli activate the reward system in both sexes. *Neuroscience*, 416, 63–73. https://doi.org/10.1016/j.neuroscience.2019.07.049.

Stinchfield, R. (2002). Reliability, validity, and classification accuracy of the South Oaks Gambling Screen (SOGS). *Addictive behaviors*, 27(1), 1–19. https://doi.org/10.1016/s0306-4603(00)00158-1.

Voon, V., Mole, T. B., Banca, P., Porter, L., Morris, L., Mitchell, S., … Irvine, M. (2014). Neural correlates of sexual cue reactivity in individuals with and without compulsive sexual behaviours. *PLoS One*, 9, e102419. https://doi.org/10.1371/journal.pone.0102419.

Wang, J., Chen, Y., & Zhang, H. (2021). Electrophysiological evidence of enhanced early attentional bias toward sexual images in individuals with tendencies toward cybersex addiction. *Journal of Behavioral Addictions*, 10(4), 1036–1047. https://doi.org/10.1556/2006.2021.00082.

Wetterneck, C. T., Burgess, A. J., Short, M. B., Smith, A. H., & Cervantes, M. E. (2012). The role of sexual compulsivity, impulsivity, and experiential avoidance in internet pornography use. *Psychological Record*, 62, 3–18. https://doi.org/10.1007/BF03395783.

Wierzba, M., Riegel, M., Pucz, A., Leśniewska, Z., Dragan, W. Ł., & Gola, M. (2015). Erotic subset for the Nencki affective picture system (NAPS ERO): Cross-sexual comparison study. *Frontiers in Psychology*, 6, 1336. https://doi.org/10.3389/fpsyg.2015.01336.

Williams, J. M. G., Mathews, A., & MacLeod, C. (1996). The emotional Stroop task and psychopathology. *Psychological Bulletin*, 120(1), 3. https://doi.org/10.1037/0033-2909.120.1.3.

Wordecha, M., Wilk, M., Kowalewska, E., Skorko, M., Łapiński, A., & Gola, M. (2018). "Pornographic binges" as a key characteristic of males seeking treatment for compulsive sexual behaviors: Qualitative and quantitative 10-week-long diary assessment. *Journal of Behavioral Addictions*, 7(2), 433–444. https://doi.org/10.1556/2006.7.2018.33.

World Health Organization (2023). ICD-11 for mortality and morbidity statistics. https://icd.who.int/browse11/l-m/en#/http://id.who.int/icd/entity/1630268048.

Zigmond, A. S., & Snaith, R. P. (1983). The hospital anxiety and depression scale. *Acta Psychiatrica Scandinavica*, 67, 361–370.