Modulation of late positive potentials by sexual images in problem users and controls inconsistent with "porn addiction"

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ABSTRACT

"Excessive" viewing of visual sexual stimuli (VSS) is the most commonly reported hypersexual behavior problem and is especially amenable to laboratory study. A pattern of enhanced sexual cue responsiveness is expected in this sample if hypersexuality shares features of other addiction models. Participants ($N = 122$) who either reported or denied problematic VSS use were presented with emotional, including explicit sexual, images while their evoked response potentials were recorded. An interaction of hypersexual problem group and the level of desire for sex with a partner predicted LPP amplitude. Specifically, those reporting problems regulating their VSS use who also reported higher sexual desire had lower LPP in response to VSS. This pattern appears different from substance addiction models. These are the first functional physiological data of persons reporting VSS regulation problems.

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1. Introduction

"Addiction" is used to refer to high frequency sexual behaviors in about 37% of research articles (Mudry et al., 2011). Yet, theoretical models of visual sexual stimulus (VSS) problems have been poorly specified (Ley, Prause, & Finn, 2014). For example, Coleman (1987) suggested a compulsivity model, but specific predictions have not been tested. VSS use problems are amenable to study and remain the most common high frequency sexual problem reported (Reid et al., 2012b). Substance addiction research suggested that addicts are especially motivated by cues of their substance. Thus, in the current study, we investigated whether neural responses to sexual cues also were greater to sex cues in those who report problems controlling their VSS use.

Although "addicts" are thought to have high sexual desire as a core feature of their difficulties, this actually is not established. Problem online erotica use was modestly related ($r = .25$) to the level of sexual arousal reported to sexual images (Brand et al., 2011). A study of 50 males identified those classified as hypersexual as reporting higher sexual arousal and desire to masturbate to sexual images than controls (Laier, Pawlikowski, Pekal, Schulte, & Brand, 2013). Those who engaged in the highest levels of "impersonal" sex (e.g., masturbation, one-time partner) in that study, reported feeling very easily sexually aroused. Contrary evidence suggests that hypersexuals may not exhibit more sexual desire. No relationship between neural (P300) responses to sexual images and three measures of hypersexuality could be identified in a study sufficiently powered to detect small effect sizes (Steele, Prause, Staley, & Fong, 2013). Another study of 120 men and women did not identify any differences in the level of sexual arousal reported to sexual films between those reporting problem use of VSS and controls (Prause, Staley, & Fong, 2013). Finally, sexual desire was related to individuals' ability to regulate their sexual arousal, whereas the level of hypersexuality was unrelated (Winters, Christoff, & Gorzalka, 2010). Thus, both VSS problems and sexual desire levels were included as predictors of neural response in the present study.

Cue-reactivity characterizes how individuals respond to cues of their substance or behavior (Drummond, 2000). Event-related potentials (ERPs) have often been used as a physiological measure of cue reactivity. ERP differences to VSS predict genital responses (Ponseti, Kropp, & Bosinski, 2009) and the number of sexual partners (Prause, Steele, Staley, & Sabatinelli, 2014).

The late positive potential (LPP) component of the ERP has been used as an index of emotional responses (Schupp, Flaisch, Stockburger, & Junghöfer, 2006). The LPP is a late component of the ERP with central, parietal, and occipital sources when localized in EEG (Foti, Hajcak, & Dien, 2009) sensitive to motivational processes (Bradley, Hamby, Löw, & Lang, 2007; Hajcak, MacNamara, & Olvet, 2010; Schupp et al., 2000). LPP amplitude is enhanced during the presentation of both pleasant and unpleasant images relative to neutral images (Cesarei, Codispoti, Schupp, & Stegagno, 2006) and is associated with motivated and sustained attention (Hajcak, Dunning, & Foti, 2009; Schupp et al., 2000). It is correlated with activity in cortical and subcortical structures involved in emotional picture perception (Sabatinelli, Keil, Frank, & Lang, 2013; Sabatinelli, Lang, Keil, & Bradley, 2007). Also, the subcortical structures involved in LPP modulation differ for unpleasant, as compared to pleasant, stimuli (Liu, Huang, McGinnis-Deweese, Keil, & Ding, 2012). LPP amplitude to pleasant stimuli is specifically related to higher approach motivation (Wacker, Mueller, Pizzagalli, Hennig, & Stemmler, 2013), which is not due merely to general arousal (Gable & Harmon-Jones, 2013).

The enhancement of the LPP to cues relevant to the addiction under study is well replicated. Problem gamblers show an enhanced LPP to gambling cues (Wölfling et al., 2011); problem gamers show an enhanced LPP to gaming cues (Thalemann, Wölfling, & Grüsser, 2007). This LPP pattern has also been observed in problem users of heroin (Franken, Stam, Hendriks, & van den Brink, 2003), nicotine (Littel & Franken, 2007), and cocaine users show enhanced LPP to images of cocaine (Dunning et al., 2011) and enhances during higher cocaine craving (Franken & Muris, 2006). This pattern is so well-replicated that some consider it a biomarker for disadvantageous substance choices (Moeller et al., 2012a).

Hypersensitivity to sexual reward stimuli has been proposed to underlie VSS addiction. For example, an "unrestrained dopamine crescendo" in nucleus accumbens was cited as a key target for treating internet sex addiction (p. 229, Bostwick & Bucci, 2008). Further, impulsivity is thought to be a key feature of hypersexual behaviors (Miner, Raymond, Mueller, Lloyd, & Lim, 2009; Reid, Cooper, Prause, Li, & Fong, 2012), and impulsivity is positively related to reward sensitivity (Torrubia, Ávila, Moltó, & Casera, 2001). Finally, those with more sexual intercourse partners exhibit greater LPP responses to sexually explicit images (Prause et al., 2014). However, the only study of neural sensitivity to sexual cues in those with problems regulating their viewing of VSS failed to find a relationship (Steele et al., 2013).

Sensitivity to sexual rewards has been better characterized with respect to sexual desire levels than VSS viewing problems. Responsivity to VSS was greater in reward-related brain areas in those with higher sexual motivation (Arnow et al., 2009; Demos, Heatherton, & Kelley, 2012; Fonteille & Stoléru, 2011), although the P300 to VSS was inversely related to sexual motivation in a different sample (Steele et al., 2013). Dopamine agonists further increase neural responses to sexual stimuli, even when sexual stimuli are presented subliminally (Oei, Rombouts, Soeter, van Gerven, & Both, 2012). The specificity of cue reactivity activation to VSS for hypersexuality is unclear. For example, rodents bred for greater reward sensitization exhibit more frequent sexual behaviors (Cummings, Clinton, Perry, Akil, & Becker, 2013). Thus, studies suggest that sexual motivation increase responses to VSS, but VSS response in a control and hypersexual sample have not been published.

The current study examined the LPP in response to sexually motivating images as a neural index of sexual responsivity in those reporting VSS viewing problems. Whereas the only previous ERP study of high frequency VSS viewing (Steele et al., 2013) characterized hypersexuality dimensionally (cp., Walters, Knight, & Långström, 2011) using a within-subject control, the current study used a separate control group. Specifically, we test whether (1) a

group that self-identified as having problems regulating their viewing of sexual images differs in their LPP amplitude to explicit sexual images from a control group and (2) whether differences between groups are attributable to sexual desire (dyadic or solitary) levels. Ethical approval for the study was obtained from the Idaho State University Institutional Review Board and all participants provided informed consent to participate.

2. Materials and methods

2.1. Participants

Both women ($n = 36$) and men from the community participated. All ($N = 122$) reported attraction to the opposite sex (see Table 2). The VSS problem group was recruited using advertisements requesting volunteers who were experiencing "problems regulating your viewing of sexual images". Volunteers were screened ($N = 142$) in the laboratory. They answered questions about their problems with VSS on a computer. After approximately ten volunteers completed these measures, the experimenter began reviewing the scores of the volunteers on each measure. As hypersexuality is not a codified diagnosis and we were expressly prohibited from recruiting patients, no thresholds could be used to empirically identify problem users. Those who volunteered due to feeling distressed about their use by virtue of the recruitment materials, also were required to endorse problems with VSS viewing on these empirical measures as determined by review of the experimenter. This continuous, non-threshold approach appears consistent with the dimensional nature of hypersexuality (Walters et al., 2011) and NIH working group (Insel et al., 2010). It also is supported by the largest study of a hypersexual disorder diagnosis to date: those who self-identified as having hypersexual problems were diagnosed as having hypersexual disorder by clinicians in 88% (134 of 152 referred) of cases (Reid et al., 2012b).

A comparison group of 67 men and women was recruited using advertisements for a study of "emotional response". On arrival, control participants were asked to answer a questionnaire that included "If you use pornography, how do you feel about this? Please check all that apply". They were required to select either or both of the options "I am fine with my porn use" or "I am fine with [my porn use], but my partner does not (or would not) like me using porn" to be included. Control group participants did not differ significantly from the VSS problem group in gender or age, but endorsed less VSS use, fewer sexual partners, and lower sexual desire (see Table 1) supporting the differentiation of these groups. See Section 3 below for a description of the outcome of the selection process.

2.1.1. Stimuli

Pictures ($N = 225$) were selected (Lang, Bradley, & Cuthbert, 2008; Spiering, Everaerd, & Elzinga, 2002) to represent pleasant ($N = 75$; e.g., skydiving), neutral ($N = 75$; e.g., portrait), and unpleasant ($N = 75$; e.g., mutilated body), categories.[2] Pleasant stimuli were matched on their level of general arousal with the most arousing

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[2] Unpleasant: 2053, 2095, 2141, 2205, 2276, 2455, 2683, 2703, 2710, 2750, 2799, 2800, 2900, 2900.1, 3016, 3017, 3051, 3061, 3062, 3101, 3160, 3168, 3180, 3181, 3215, 3220, 3225, 3230, 3300, 3301, 3350, 3550, 6021, 6022, 6212, 6213, 6242, 6243, 6311, 6415, 6530, 6571, 6825, 6830, 6831, 6838, 8230, 9007, 9040, 9041, 9220, 9254, 9265, 9331, 9400, 9415, 9419, 9420, 9421, 9423, 9424, 9425, 9427, 9428, 9429, 9430, 9433, 9435, 9520, 9530, 9800, 9900, 9903, 9910, 9920; Neutral: 2005, 2020, 2038, 2102, 2104, 2190, 2200, 2210, 2214, 2215, 2221, 2230, 2235, 2271, 2272, 2280, 2305, 2372, 2381, 2383, 2385, 2393, 2394, 2396, 2397, 2435, 2440, 2441, 2485, 2487, 2491, 2493, 2495, 2499, 2506, 2512, 2513, 2514, 2516, 2518, 2520, 2570, 2575, 2579, 2580, 2593, 2595, 2597, 2600, 2620, 2635, 2690, 2695, 2702, 2749, 2752, 2810, 2830, 2840, 2850, 2870, 2890, 4000, 4571, 4605, 7493, 7496, 7506, 7550, 8010, 8241, 8311, 9070, 9700; Pleasant non-sexual: 1340, 1999, 2040, 2058, 2071, 2080, 2150, 2160,

Table 1
Demographic characteristics of sample.

Variable	Controls (N = 67)		Hypersexual (N = 55)	
	M	(SD)	M	(SD)
Age	24.0	(6.5)	24.4	(4.9)
Porn hours per week last month[*]	.6	(1.5)	3.8	(1.3)
Sex partners last year[*]	2.0	(2.5)	3.3	(3.6)
Sexual Desire Inventory				
Dyadic[a,*]	45.9	(11.1)	52.1	(6.9)
Solitary[b,*]	9.6	(5.6)	13.6	(5.0)
CBOSB[c]				
Behavioral[d]			4.0	(2.6)
Cognitive[e]			1.7	(0.4)
Behavioral Inhibition-Activation Scales				
Behavioral Inhibition Scale[f]	15.4	(1.8)	15.4	(1.7)
Behavioral Activation Scale[g]	26.5	(3.7)	25.6	(4.0)

[a] Range 8–70.
[b] Range 3–26.
[c] Only hypersexuals completed this measure (see text).
[d] Range 0–16.
[e] Range 1–4.
[f] Range 7–49.
[g] Range 13–52.
[*] p < .01.

Table 2
Demographic characteristics of sample split by group membership.

Variable[a]	Controls (N = 67)		Hypersexual (N = 55)	
	N	(%)	N	(%)
Women	23	(35.4)	13	(25)
Ethnicity				
White	51	(78.5)	45	(86.5)
Asian	1	(1.5)	1	(1.9)
Black	3	(3.1)	0	(0)
Hispanic	10	(15.4)	4	(7.7)
Native American	0	(0)	2	(3.8)
Other ethnicity	2	(3.1)	0	(0)
Relationship status				
Exclusive	38	(58.5)	28	(53.8)
Not exclusive	2	(3.1)	12	(23.1)
Not in sexual relationship	26	(38.5)	11	(21.2)
Typical frequency of partnered sexual activity				
None	15	(23.1)	5	(9.6)
Once per month	4	(6.2)	2	(3.8)
Several times per month	8	(12.3)	6	(11.5)
Once or twice per week	13	(20)	11	(21.2)
Several times per week	20	(30.8)	22	(42.3)
Once a day or more	3	(4.6)	6	(11.5)

[a] Not all sum to total due to non-responders.

unpleasant stimuli. Every stimulus included a person. Half of the pleasant stimuli (N = 38) were sexual.

The sexual images were selected carefully. Most adults have viewed sexual images intentionally, used them for pleasure, and report preferring images of penetrative intercourse (Hald, 2006). Sexual images from the IAPS have been shown to be processed as "romantic", not "sexual" (Spiering, Everaerd, & Laan, 2004). Romantic stimuli exert different effects in men and women (e.g., Geer & Bellard, 1996). Thus, half of the sexual images were IAPS, the other half depicted one man and one woman engaged in penetrative sexual behaviors (Spiering et al., 2004).

2216, 2340, 2345, 2346, 2352.1, 2391, 2398, 7502, 8034, 8090, 8120, 8180, 8185, 8186, 8200, 8210, 8300, 8350, 8370, 8380, 8400, 8420, 8461, 8470, 8490, 8496, 8499, 8540; Sexual: 4220, 4290, 4607, 4608, 4623, 4660, 4680, supplemental sex photographs have no associated picture codes

Men and women were shown the same sexual images. Heterosexual women report lower sexual motivation to photographs of nude males than nude females (Chivers, Seto, & Blanchard, 2007). Also, men and women prefer similar sexual films (Janssen, Carpenter, & Graham, 2003) and process them similarly (Wehrum et al., 2013). Sexual desire level is the most reliable difference in sexual processing between men and women (Baumeister, Catanese, & Vohs, 2001), so it is included as a covariate rather than gender.

2.1.2. Questionnaires

A sexual history form acquired information about demographics and sexual behaviors (from the National AIDS Behavior Survey, Binson & Catania, 1998).

2.1.2.1. Problem use screening. Volunteers for the problem group completed three questionnaires to ensure that they were experiencing problems related to their use (described above). These included the Sexual Compulsivity Scale (Kalichman & Rompa, 1995) and the negative effects subscale of the Pornography Consumption Effects Scale (Hald & Malamuth, 2008). The third scale offered psychometric and interpretive advantages over these scales (presented next), so these two scales are reported for completeness.

2.1.2.2. Cognitive and Behavioral Outcomes of Sexual Behavior Scale. (CBOSB, McBride, Reece, & Sanders, 2007). The CBOSB assesses both the concerns and actual consequences resulting from individuals' sexual behaviors. "Cognitive" and "behavioral" scales separate the participant's extent of worry from consequences experienced. Rated on a 4-point scale ranging from "never" to "always," the cognitive outcomes scale consists of 20 items measuring how much the participant worried about his/her sexual activities in the past year resulting in negative outcomes. Rated on a binary scale of "yes" or "no," the behavioral outcomes scale consists of 16 items concerning the extent the participant experienced actual negative outcomes as a result of his/her sexual activities in the past year. The CBOSB was selected over other questionnaires (e.g., Kalichman, Johnson, Adair, Rompa, Multhauf, & Kelly, 1994) specifically to reduce the possibility that confounds, such as religiosity (Grubbs, Exline, Pargament, Hook, & Carlisle, 2014), known to inflate perceptions of VSS problems would be minimized.

2.1.2.3. Sexual Desire Inventory (SDI, Spector, Carey, & Steinberg, 1996). The SDI is a 14-item, Likert-style questionnaire that measures levels of trait sexual desire. One-month test-retest reliability was r = 0.76 (Spector et al., 1996). SDI scores also have been related to activity in areas of the brain associated with rewards in general (Demos et al., 2012). The SDI is typically calculated as two subscales (Spector et al., 1996; Winters, 2010). The 3-item Solitary Sexual Desire scale measures an individual's desire for autoerotic sexual activity. The 8-item Dyadic Desire scale measures an individual's desire for sex with a partner and is commonly used as an index of trait sexual desire level (Giargiari, Mahaffey, Craighead, & Hutchison, 2005; Goldey & van Anders, 2012; Prause, Janssen, & Hetrick, 2008). Both subscales are related to impulsive sexual behaviors, intentions to engage in risky sexual behaviors, including anal intercourse, but only the dyadic scale was related to actual risky sex acts, including with uncommitted partners (Turchik & Garske, 2009). The scales were analyzed separately as recommended to identify the separate influences of desire for solo or partnered sex.

2.2. Procedure

Following phone screening, participants attended one private laboratory session. After providing informed consent, participants completed questionnaires. Next, electroencephalographic
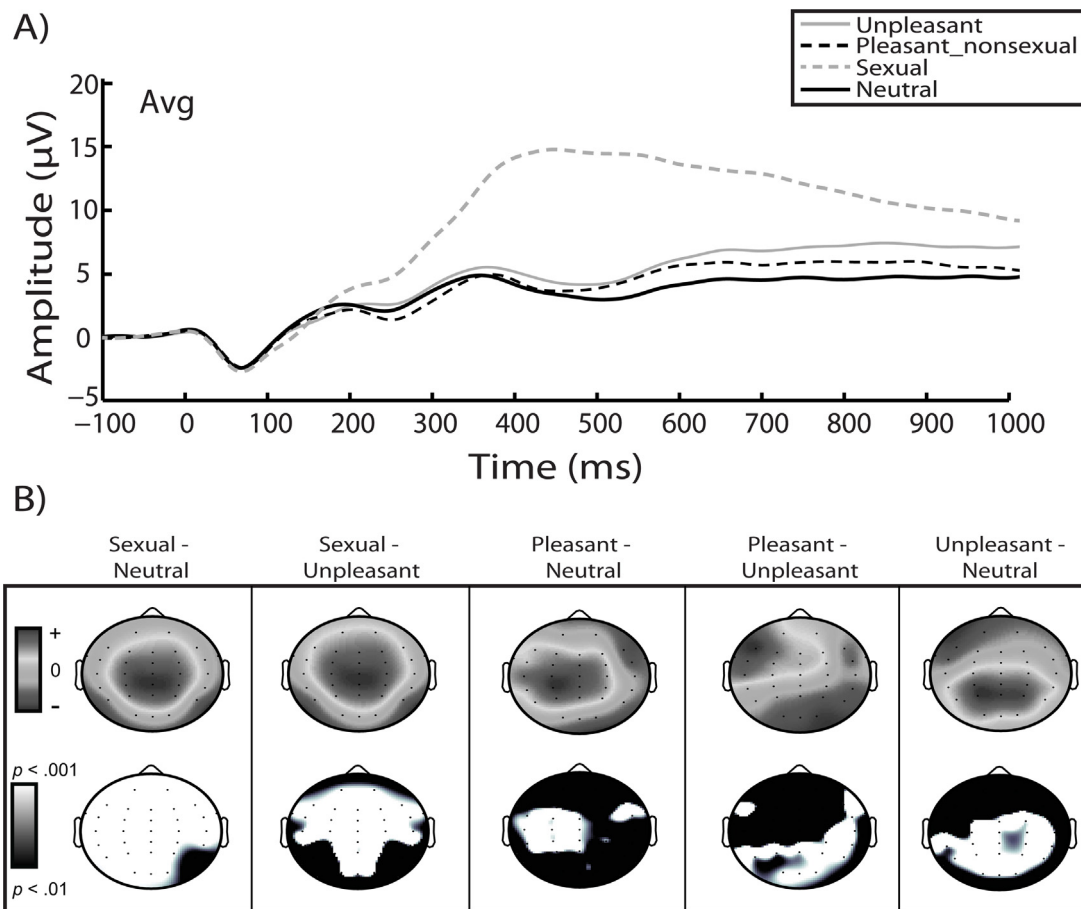
Fig. 1. Evoked response potential by stimulus category for all participants.
Note: (A) Time course of the ERP showing the highest LPP to the sexual images; (B) topographical maps contrasting LPP activity and significant differences by major stimulus categories.

caps were applied. Photographs were presented using the stimulus presentation software DMDX (Forster & Forster, 2003) on a 1280 × 1024CRT monitor with 75 Hz refresh and 32-bit color depth lasting 8 minutes. Photographs were pseudorandomized. No more than three images of the same class were presented consecutively. Each trial consisted of a fixation cross (120 ms), a photograph (1000 ms), then an asterisk "*" (1000 ms). One break was provided.

2.2.1. Electroencephalographic recordings

Electrophysiological data were recorded with Neuroscan Acquire software 4.4. A 40-channel cap (NuAmp QuickCap, Compumedics) collected EEG activity using sintered Ag–AgCl electrodes placed in accordance with the 10–20 International System (Klem, Luders, Jasper, & Elger, 1999) at 1000 Hz. Reference was digitally-linked ears. Horizontal electrooculogram was measured with electrodes infraorbital and supra-orbital to the middle of the right eye; vertical electrooculogram was measured with electrodes placed at the outer canthis of each eye. All impedances were kept below 10 kΩ using light abrasion as comfortable for the participant.

2.3. Event-Related Potential (ERP) data reduction

Pre-processing of electrocortical data included bandpass filtering between 0.1 Hz and 55 Hz, downsampling to 256 Hz, and eye-blink removal. Bad channels were identified as having activity four standard deviations from the mean (on average, 0.71 electrodes per participant). These bad channels were replaced using spherical spline interpolation. Independent component analysis

(ICA) in EEGLab (Makeig, Debener, Onton, & Delorme, 2004) was used to remove eyeblinks. Specifically, components were derived, then, using a template matching algorithm (cp., Jung et al., 2000), blink components were identified and removed from the data. ERP epochs were defined in relation to onset of each picture slide from −110 ms pre- to 1000 ms post-stimulus with a baseline correction of 110 ms preceding the stimulus. An ERP was averaged across each stimulus type (unpleasant, neutral, pleasant non-sexual, pleasant sexual, and pleasant explicit-sexual). Within each trial, individual electrodes in which activity exceeded ±100 μV were omitted. 8.67% of trials were excluded. LPP was defined as the average positive deflection 350 ms to 850 ms post-stimulus onset. This was most consistent with previous research (e.g., Hajcak et al., 2010), modulated by sexual stimuli (Weinberg & Hajcak, 2010), and supported by visual inspection (see Fig. 1). LPP activity is maximal at C3, Cz, C4, CP3, CPz, CP4, P3, Pz, and P4, so the LPP average across sites was used consistent with other studies (e.g., De Cesarei & Codispoti, 2011) to avoid biased electrode selection. Analyses (see below) were performed on this average. LPP modulation to images appears stable (Moran, Jendrusina, & Moser, 2013).

At the suggestion of reviewers, we also examined the early posterior negativity (EPN) re-referenced to average and in the 200–300 ms window. Electrodes included were O1, O2, and Oz, which did not include some anterior sites common in EPN studies due to the cap density used (cp., Schupp, Markus, Weike, & Hamm, 2003). The EPN did replicate previous studies with its main effect of stimulus type (AIC = 8858, coefficient = −0.3, CI+/− = −0.37 to −0.3, $t = -18.4$, $p < .0001$). Contrasts confirmed that sexual images

resulted in a more negative EPN that the pleasant, CI+/− = 0.8–1.6, $p < .0001$, and unpleasant, CI+/− = 1.3–1.9, $p < .0001$, photographs. Pleasant and unpleasant photographs also evoked lower EPN than neutral photographs, CI+/− = 2.7–3.4, $p < .0001$. More explicit sexual stimuli provoked a lower EPN than less explicit sexual stimuli CI+/− = 0.4–0.9, $p < .0001$. However, stimulus type did not interact with either group or sexual desire level. The EPN is less consistently related to emotion processing (de Rover et al., 2012 Sabatinelli et al., 2013), including in addictions (Moeller et al., 2012b), than the LPP. Given that no interaction was present and some of the common inferior occipital EEG sites could not be included, these results are considered preliminary and not pursued further here.

2.4. Data analysis

First, a replication of the LPP modulation to emotional images was attempted, adding a subtype for sexual stimuli. A mixed analysis was calculated in R (v. 2.15.1) using R statistical libraries lme4 (Bates, Maechler, & Bolker, 2012) for mixed and languageR (Baayen, 2011) for p values. REML was used with participant specified random, Category (Unpleasant, Neutral, Pleasant, Sexual) as fixed, within-subject, and 10,000 Markov chain Monte Carlo samples estimating the p value distribution.

Unlike cocaine or gambling cues, sexual cues potentiate LPP relative to neutral stimuli in those without any sexual problems. As these represent the first neural responsiveness data in this population, "non-sexual" (emotional and neutral) cues were contrasted with sex cues. This controls for any non-sexual, affective response differences. To support addiction, LPP amplitude should interact with Category (Sexual, Non-sexual) and Group (VSS problems, no VSS problems). Desire for sex with a partner was included as a continuous covariate.

3. Results

3.1. Recruitment of problem users

Of those who reported problems regulating their viewing, 68 were contacted to enroll and 74 were not contacted to enroll. Those who were invited to enroll differed significantly on all problem use measures from those who were not invited to enroll. Specifically, those invited to enroll reported many more negative effects from viewing erotica on the Pornography Consumption Effects Scale – Negative effects subscale ($M = 2.41$ v. 1.38, $t(115) = 9.4$, $p < .0001$, $d = 1.6$), Sexual Compulsivity Scale ($M = 2.06$ v. 1.35, $t(124) = 7.8$, $p < .0001$, $d = 1.3$), and both the Cognitive ($M = 1.7$ v. 1.3, $t(120) = 6.6$, $p < .0001$, $d = 1.1$) and Behavioral ($M = 3.8$ v. 1.4, $t(125) = 6.4$, $p < .0001$, $d = 1.1$) subscales of the Cognitive and Behavioral Outcomes of Sexual Behavior Scale. Of the 68 who were contacted to enroll, 55 ultimately participated. These volunteers reached suggested criteria for problem use according to the Cognitive and Behavioral Outcomes of Sexual Behaviors (CBOSB, McBride et al., 2007). They were meaningfully different from controls on all expected variables (see below).[1] Thus, this recruitment method appears to have been very successful at identifying individuals with major problems in their sex film viewing habits.

3.2. Manipulation check

The main effect of stimulus category was significant Akaike information criterion (AIC = 3291, coefficient = .93, CI+/− = 0.85–1.02, $t = 24.2$, $p < .0001$). Contrasts confirmed that sexual images evoked a higher LPP than the pleasant, CI+/− = −5.4 to −4.0, $p = .0001$, and unpleasant, CI+/− = −5.0 to −3.5, $p = .0001$, photographs (see Fig. 1). Pleasant and unpleasant photographs also evoked higher LPP than neutral photographs, CI+/− = −1.77 to −0.10, $p = .03$. More explicit sexual stimuli provoked a higher LPP than less explicit sexual stimuli CI+/− = −2.02 to −.55, $p = .0002$. Based on this replication and extension, planned analyses were conducted.

3.3. LPP average amplitude predicted by group and sexual desire level

The interaction of group (VSS viewing problems, no viewing problems) X stimulus type (non-sexual, sexual) was significant, coefficient = −6.8, $t = −2.5$, $p = .01$. This was superseded by a group X stimulus type X SDI score[3] interaction, coefficient = .11, $t = 2.17$, $p = .03$ (see Fig. 2). The figure uses a median split within each group to aid interpretation, although the SDI score was a continuous covariate. The LPP was lower in participants reporting problems with VSS, but LPP was particularly lower to the sexual images in those who also had higher SDI scores. No other main or interaction effects were significant. At the suggestion of a reviewer, we also restricted the sample to men alone. We found the same pattern of results in this smaller sample as when women were included.

4. Discussion

Women and men ($N = 122$) who reported ($n = 55$) or denied problems regulating their viewing of visual sexual stimuli (VSS) viewed photographs while electroencephalography was recorded. Those reporting VSS problems and higher sexual desire exhibited lower LPP to sexual images as compared to non-sexual images. Restated, VSS users with problems and higher sexual desire had a smaller difference between sexual and non-sexual LPP, rather than a larger difference. This pattern of results appears inconsistent with some predictions made by addiction models.

Habituation offers one explanation for the LPP pattern. Those reporting VSS overuse problems reported significantly more hours of current VSS viewing per week (see Table 1). Those who view more VSS during the week also show lesser brain response to VSS relative to neutral cues (Kühn & Gallinat, 2014). This difference was even larger when just those with higher sexual desire are analyzed between groups ($t(58.8) = 3.7$, $p = .0005$, $d = 1.02$). Other addiction studies show evidence of potentiation, not habituation, to visual cues of addiction.

The problem group reported significantly more hours per week of VSS consumption, but still endorsed only 3.8 hours per week. This appears low relative to some of samples of such groups (Spenhoff, Kruger, Hartmann, & Kobs, 2013). This could reflect that these individuals already were attempting to reduce their use, or that the participants had less intense problems since the recruitment of patients was prohibited by the Institutional Review Board. While self-identification as a sex addict tends to be supported by clinical interviews (see review above), it is possible that the participants in this sample ultimately experienced fewer problems, or a less severe problem, than a treatment-seeking sample. Guidelines allow the

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[1] Initial plans called for patients in sex addiction treatment to be recruited. The local Institutional Review Board prohibited this approach out of concern for causing these individuals to "relapse" by showing them sexual images. The protocol was likened to administering alcohol to alcoholics.

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[3] Solitary sexual desire had been included as a predictor as planned, but was not significant. SDI here refers to Dyadic Sexual desire as measured by the SDI.
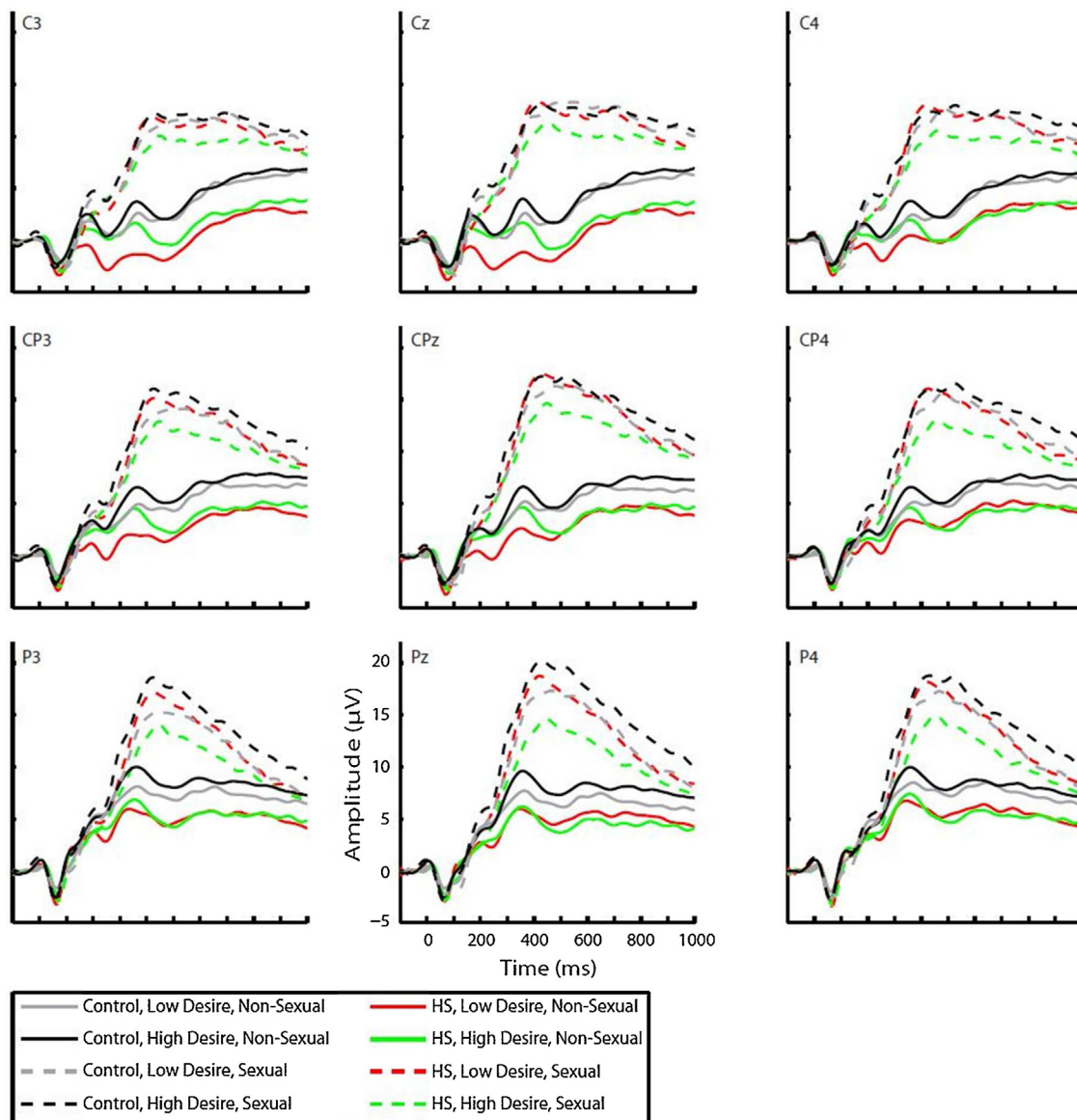
Fig. 2. Evoked response potential by stimulus type, problem group, and sexual desire level.

administration of the substances to those with substance problems (National Advisory Council on Alcohol Abuse and Alcoholism, 2005). It would be useful if similar standards allowed testing in treatment-seeking individuals. Another possibility is that other studies framing their research as "sex addiction" may promote reporting bias. This study recruited those with problems regulating their use, never using addiction terminology, and this may have reduced the reporting bias compared to other studies.

Those complaining of uncontrollable motivation for VSS exhibited evidence of weaker approach motivation (lower LPP) towards VSS, particularly when their reported sexual desire was higher. This study appears to add to a list of studies that have not been able to identify pathology consistent with substance addiction models. First, hypersexuals report neuropsychological problems (Reid, Karim, McCrory, & Carpenter, 2010), but neuropsychological testing does not suggest problems (Reid, Garos, Carpenter, & Coleman, 2011). Second, hypersexuals report using VSS to regulate negative mood, but show few, small differences in positive or negative emotions when viewing VSS relative to controls (Prause et al., 2013). Finally, those with higher hypersexuality scores do not appear impaired in their ability to regulate their sexual arousal

(Winters, Christoff, & Gorzalka, 2009), which recently was replicated (Moholy, Prause, Proudfit, Rahman, & Fong, 2015).

Another explanation is that higher sexual desire hypersexuals are engaging in more effort to downregulate their sexual responses to VSS during the study. Viewing VSS is usually accompanied by masturbation (Hald, 2006), but participants in this study were instructed not to masturbate during the task. LPP amplitude can be decreased by effortful downregulation (Hajcak et al., 2010). For example, problem gamers rapidly inhibited their high brain reactivity to gaming cues in an fMRI study (Lorenz et al., 2013). These data might reflect successful efforts to downregulate sexual response in the higher desire hypersexuals. This raises broader questions about the defining features of high frequency sexual problems. For example, suppressed late ERP components have been related to lower intelligence (Jaušovec & Jaušovec, 2000; Russo, De Pascalis, Varriale, & Barratt, 2008) and greater impulsivity (Nijs, Franken, & Smulders, 2007; Stenberg, 1992). Lower intelligence in childhood has been linked to sexual behaviors as an adult, but problems with impulsiveness as a child appeared to largely explain that relationship (Fergusson, John Horwood, & Ridder, 2005). However, "hypersexual" men have demonstrated impulsive choice in a gambling task

(Mulhauser et al., 2014). Perhaps those effects are driven by men with higher sexual drive. Impulsivity of sexual behaviors would provide a useful, testable theory to test for future studies. At least, these data suggest models of high drive worth additional exploration.

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