

Late positive potential to explicit sexual images associated with the number of sexual intercourse partners

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Risky sexual behaviors typically occur when a person is sexually motivated by potent, sexual reward cues. Yet, individual differences in sensitivity to sexual cues have not been examined with respect to sexual risk behaviors. A greater responsiveness to sexual cues might provide greater motivation for a person to act sexually; a lower responsiveness to sexual cues might lead a person to seek more intense, novel, possibly risky, sexual acts. In this study, event-related potentials were recorded in 64 men and women while they viewed a series of emotional, including explicit sexual, photographs. The motivational salience of the sexual cues was varied by including more and less explicit sexual images. Indeed, the more explicit sexual stimuli resulted in enhanced late positive potentials (LPP) relative to the less explicit sexual images. Participants with fewer sexual intercourse partners in the last year had reduced LPP amplitude to the less explicit sexual images than the more explicit sexual images, whereas participants with more partners responded similarly to the more and less explicit sexual images. This pattern of results is consistent with a greater responsivity model. Those who engage in more sexual behaviors consistent with risk are also more responsive to less explicit sexual cues.

Keywords: HIV; sexual risk behavior; sexual response; late positive potential; sexual motivation

INTRODUCTION

Despite the necessity of sexual motivation preceding consensual sexual behaviors, surprisingly little is known about the impact of sexual motivation on sexual risk behaviors. Sexual motivation level predicts greater sexual risk intentions (Ariely and Loewenstein, 2006). In fact, sexual motivation levels predict people's intentions to engage in risky sexual behaviors better than the amount of alcohol consumed in replicated laboratory studies (George *et al.*, 2009; Prause *et al.*, 2011) and has been suggested to be the primary mechanism by which drugs promote sexual risk behaviors (Volkow *et al.*, 2007).

Approach motivation has been expanded from the mere pursuit of pleasure (e.g. Lewin, 1935) to describe any movement toward goals (Carver and White, 1994) usually pursuing a reward or avoiding punishment (Gray, 1987). Relatedly, reward sensitivity could be described as both how easily reward systems become active and how rapidly reward increases to higher levels. Reward sensitivity may be thought of as a particular aspect of personality especially relevant for motivated behavior (Matthews and Gilliland, 1999). Approach motivation, however, does not only refer to a pursuit of rewards. For example, 'anger' clearly involves the activation of behavior (Yan and Dillard, 2010), but it is difficult to conceptualize the emotion, behavior, or outcome associated with anger as simple rewards. Reward sensitivity and approach motivation tend to be positively related. For example, the activity in brain areas associated with rewards is greater in those who score higher on measures of behavioral approach (Simon *et al.*, 2010). Approach motivation may promote behaviors by increasing the salience of the eliciting stimulus (Ode *et al.*, 2012). This salience change could occur by the attention narrowing effects of approach motivation (Gable and Harmon-Jones, 2008, 2011b).

Sexual arousability might be thought of as a specific case of reward sensitivity that motivates sexual approach behaviors. Sexual arousability has been described as an individual's 'characteristic rate of approach to orgasm as a result of sexual stimulation' (Whalen, 1966). The ease with which a person becomes sexually aroused has been related, in questionnaire studies, to self-reported sexual risk behaviors and the frequency of sexual behaviors (Hoon *et al.*, 1976). More recently, 'sexual excitation proneness' was proposed as a concept to parallel behavioral activation in the sexual domain (Janssen *et al.*, 2002b). Sexual excitation proneness also has been related to the rate of physiological sexual arousal in the laboratory (Janssen *et al.*, 2002a) as well as self-reported sexual risk behaviors (Bancroft *et al.*, 2003). One model suggests that sexual excitation proneness should play an important, if not primary, role in regulating sexual risk behaviors (Nagoski *et al.*, 2012).

Concepts like sexual desire and sexual motivation fall within this nomological network. Sexual motivation has been described as the expectation of sexual response induced by a learned cue (Hardy, 1964) that is characterized at one particular point in time as a state (Whalen, 1966). Sexual motivation is thought to manifest, in part, as felt sexual desire and sexual arousal (Singer and Toates, 1987), thus sexual motivation has long been measured by subjective reports in humans (Whalen, 1966). Together, these have been characterized as the 'push' of sexual behavior, whereas the incentive salience in a sexual cue has been described as the 'pull' of sexual behavior (Singer and Toates, 1987). Measures of sexual desire and motivation also have been positively associated with sexual risk behaviors (Turchik and Garske, 2009; Zea *et al.*, 2009). The relationship of reward responsiveness, measured centrally and sexual risk behaviors remains unknown.

A few studies of central reward responsiveness have attempted to predict real-world sexual behaviors. In one strong protocol, researchers attempted to use the activation of reward-related brain structures to prospectively predict the participants' future number of sexual partners (Demos *et al.*, 2012). Unfortunately, insufficient variance in the number of new sexual partners left the investigators unable to conduct the intended analysis. Also, the study was restricted to women and

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used non-explicit sexual images that may be better characterized as ‘romantic’. A long viewing time also might have allowed participants to engage in up- or down-regulation strategies (cp. [Beauregard et al., 2001](#)), which could make interpretation difficult. Only one other study has used fast, event-related potentials (ERPs) to predict sexual risk behaviors ([Iacono and McGue, 2006](#)). This large study of male and female 17-year-old twins predicted a general risk index that included tobacco use, alcohol use, illicit drug use, police interactions and the age of sexual debut, making it difficult to know the specific relationship with sexual risk. The peak amplitude in the 200–800 ms window after the onset of a visual oddball was quantified. P300 was negatively related to the risk index, especially in boys. The authors speculate that this pattern could serve as a useful endophenotype for predicting externalizing disorders. In a separate investigation, researchers found that the P300 to condoms presented as novel oddballs were much higher when contrasted with more frequent positive than more frequent negative image contexts ([Lust and Bartholow, 2009](#)). The authors interpret this as indicative of perceiving condoms as less novel when presented with other negative images, hence evidence that the condom images are perceived as negative. This pattern occurred despite participants rating condoms as positive. These studies suggest the likely predictive value of early neural responsiveness to sexual cues for later sexual feelings or behaviors. The current research examines whether early, motivation-sensitive neural responses to explicit, sexual images are related to a common measure of sexual risk behaviors.

Quantifying sexual risk behaviors is fraught with psychometric and interpretive challenges. Consider a male engaging in a single episode of penetrative intercourse with a new partner. This may be a very low risk activity for the male if the partner is female, recently tested as negative for infections, and condoms are used consistently. Risk may be considerably different if the partner for this male is an HIV-positive penetrating male with whom no condom is used during anal intercourse. Approaches that predict single, particular sexual risk behaviors have been referred to as ‘count’ approaches as contrasted with ‘composite’ approaches. Composite approaches try to account for the complexity of sexual risk behaviors by combining several sexual behaviors into a single risk score (e.g. [Zuckerman and Kuhlman, 2000](#)). However, there is evidence that composite approaches create new problems, such as non-linearity ([Catania et al., 2005](#); [Schroder et al., 2005](#)). Researchers primarily use single count data. Unprotected anal sex is the most common primary outcome in studies of men who have sex with men (e.g. [Gillmore et al., 2002](#)). Participants such as ours tend to make many errors in their use of condoms, making reported condom use less convincing as an indicator of sex risk (e.g. applying a condom only before ejaculation; [Crosby et al., 2003](#)). New partner counts are the most common sexual behavior assessed relevant to risk in large, national studies ([Binson and Catania, 1998](#); [Laumann et al., 1999](#); [Johnson et al., 2001](#)). As such, the relationship between new partner counts and actual infections from sexual behavior is well known (see ‘Data analysis’ section below). This study used a count approach. Specifically, the number of new intercourse partners in the last year was used to index sexual risk.

Risky sexual behaviors have been described as positively related to greater responsiveness to sexual cues. The assumption is that greater responsiveness to sexual cues is indicative of higher sexual arousability, which, in turn, motivates seeking new sexual partners even with relatively low-intensity sexual cues. However, the reverse also is possible. Lower early responsiveness to sexual cues might be negatively related to risky sexual behaviors. For example, anhedonia is characterized by low reactivity sexual reward cues ([Larson et al., 2007](#)). Low responsiveness may drive risky sexual behaviors as a means to overcome an under-reactive reward system ([Franken and Muris, 2006](#)). Some reports have identified a subset of individuals who specifically seek out sexual partners to ameliorate low mood states ([Bancroft et al., 2005](#)).

Based on studies to date, it is therefore unclear whether those who engage in more sexual risk behaviors are either over-reactive or under-reactive to sexually motivating reward stimuli.

Electroencephalography (EEG) has been useful in characterizing how general reward responsiveness relates to non-sexual approach behaviors. Theta-band (4–7 Hz) EEG power to rewarding stimuli has been associated with higher activity of the behavioral approach system (BAS; [Knyazev and Slobodskoj-Plusnin, 2007](#)). Greater impulsivity (questionnaire and behavioral measures [Moeller et al., 2004](#)) and sensation seeking ([Ratsma et al., 2001](#); [Wang and Wang, 2001](#)) have been associated with lower P300 amplitudes to novel oddball stimuli. Also, behavioral activation scores were related to larger P300 amplitudes ([Nijs et al., 2007](#); [Peterson et al., 2008](#)) to infrequent targets in a visual oddball task. BAS also predicts very early increases at N100 specifically to reward stimuli ([Gable and Harmon-Jones, 2013](#)) as well as the late positive potential (LPP; [Balconi et al., 2012](#)). However, others suggested, and found, that BAS was related to EEG band measures of approach motivation only ([Amodio et al., 2008](#)).

Although sexual stimuli are often used with ERPs to characterize affective brain responses, ERPs are rarely used to study sexual responsiveness specifically. [Vardi et al. \(2009\)](#) examined P300 auditory potentials evoked during either a low-intensity or high-intensity sexual film in women with and without hypoactive sexual desire disorder. Women with hypoactive sexual desire disorder had lower P300 during the ‘low-intensity’ sexual film as compared with the high intensity sexual film, whereas the control women’s P300 did not differ between film conditions. Similarly, they found that the more sexual arousal reported during a sexual film, the lower the amplitude of the P300 to auditory oddball ([Vardi et al., 2006](#)). These results mirror those in another ERP study during auditory sexual stimuli ([Zhen et al., 2011](#)). A recent investigation clarified that this decreased amplitude occurred to any high-intensity film, so the effect was not specific to sexual stimuli ([Carvalho et al., 2011](#)). Higher amplitude LPP to sexual stimuli has been interpreted as indicative of more motivated states during the ovulatory phase of the menstrual cycle ([Krug et al., 2000](#)).

The ERP in response to sexual stimuli also appears sensitive to sexual preferences and feelings. ERP components are sensitive to safe/unsafe judgments of potential sexual targets with respect to their HIV status ([Schmalzle et al., 2011](#); [Renner et al., 2012](#)). Preferred sexual stimuli in paraphilic men, as compared with controls, provoked larger P600 responses ([Waismann et al., 2003](#)), although an exception exists for women ([Johnston and Wang, 1991](#)). P2 is greater to target stimuli regardless of their attractiveness, whereas LPP is enhanced (in men, not women) specifically to attractive sexual target stimuli ([van Hooff et al., 2011](#)).

Although much research on ERPs and reward responsiveness has focused on the P300, the later and more extended LPP appears more strongly linked to motivation. This later ERP component appears more sensitive to motivational processes ([Schupp et al., 2000](#); [Bradley et al., 2007](#)), and, unlike earlier components, is correlated with cortical and subcortical structures involved in emotional picture perception ([Sabatinelli et al., 2007, 2013](#)). The LPP is enhanced during the presentation of both pleasant and unpleasant images relative to neutral images ([De Cesarei and Codispoti, 2006](#)). Sexual images produce remarkable increases in ERP amplitude, but especially in late (500–750 ms) windows, as compared with high arousal sports photographs in both men and women ([van Lankveld and Smulders, 2008](#)).

This study tests whether, and in what direction, a neural index of responsiveness to sexual reward cues is related to sexual risk behaviors. As the LPP has been linked to motivational salience, LPPs to photographs of varying sexual salience were recorded. Sexual salience was manipulated by selecting photographs that varied in their sexual explicitness (see ‘Image explicitness’ section below). Consistent with

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previous research in reward sensitivity, we hypothesized that the LPP would be higher to cues of higher sexual salience, because these are thought to be more motivating than cues of lower sexual salience. Relatedly, and most consistent with previous publications, we predicted that those who engage in more sexual risk behaviors would exhibit higher LPP to the cues of higher sexual salience. Images of non-sexual pleasant, unpleasant, or neutral images were included to ensure that affective responses were otherwise typical.

Sexual stimuli in research

Image explicitness

The sexual image stimuli most commonly used in emotion research may be of somewhat low intensity compared with what is now easily accessed by those with internet connections. The commonly used sexual images portray nude individuals alone not behaving sexually (e.g. not touching genitalia), or couples not engaged in any penetrative act. The majority of adults has viewed sexual images intentionally, used them for sexual pleasure, and report preferring images of penetrative intercourse (Hald, 2006). Using the common, less intense sexual images for sexual motivation research may be problematic because romantic vs sexual stimuli have been shown to exert different effects in men and women (e.g. Geer and Bellard, 1996). The weaker sexual images have been shown to be processed as 'romantic', and not 'sexual' (Spiering et al., 2004). Thus, although consistency has been reported across romantic and non-explicit sexual stimuli in functional MRI (fMRI) work (Sabatinelli et al., 2007) the focus on sexual feelings and behaviors in this study warranted including stimuli that were powerfully sexually motivating (henceforth 'explicit sexual'). In fact, these two stimulus categories (sexual, explicit sexual) provided an ideal contrast in that they differed mainly in sexual explicitness. For example, the explicit sexual stimuli displayed erect penises, whereas no erections are shown in the sexual photographs.

Exposure history to visual sexual stimuli

Although the LPP is robust to habituation (Schupp et al., 2000; De Cesarei and Codispoti, 2011; Ferrari et al., 2011), late components of the ERP may be sensitive to novelty, which introduces a complication when employing sexual images as experimental stimuli. Both male and female children who use the internet have overwhelmingly been exposed to sexual images by age 11 (Stulhofer et al., 2008). However, adults vary widely in their consumption of visual sexual stimuli. This variability may emerge from a shift toward intentional viewing these images for sexual pleasure (Hald, 2006; Carroll et al., 2008). This means sexual images will be more novel for some participants than others. Given that novelty is a strong modulator of many ERP components, tests include self-reported frequency of viewing visual sexual stimulus (VSS) as an index of stimulus novelty.

METHODS

Participants

Participants were recruited from psychology classes using a private online system. Volunteers provided informed consent before participating. Participants had to be right-handed (Oldfield, 1971) and have normal or corrected-to-normal vision and hearing. They received course credit. The 62 participants included men ($N=40$) and women ranging in age from 18 to 40, M (s.d.) = 24.0 (6.5). Most reported being heterosexual and single (Table 1). The majority had sexual intercourse at least once per month in the last year and more than one lifetime sexual intercourse partner. Most reported not viewing any visual erotica in the past year. This study was approved by Idaho State University's institutional review board.

Table 1 Demographic characteristics of sample

Demographic	Mean (s.d.)
Age	24.1 (5.78)
Porn hours per week last month	0.6 (1.5)
Sex partners last year	2.0 (2.5)
Sexual Desire Inventory	
Dyadic	46.0 (11.2)
Solitary	9.4 (5.5)
BIS BAS	
Behavioral Inhibition Scale	15.3 (1.8)
Behavioral Activation Scale	26.6 (3.7)
Reward responsiveness	26.6 (3.7)
SISSES	
Sexual Excitation Scale ^a	51.1 (7.0)
Sexual Inhibition Scale I ^b	29.8 (5.1)
Sexual Inhibition Scale II ^c	31.1 (4.5)
Group	Frequency (%)
Relationship status	
Monogamous	35 (56.5)
Non-monogamous	2 (3.2)
Not in sexual relationship	25 (40.3)
Sexual activity frequency typical month	
None	12 (19.7)
1–3 times per month	11 (18)
4–16 times per month	29 (47.6)
17 times per month or more	9 (14.8)

^aScale range = 30–80. ^bScale range = 14–50. ^cScale range = 11–42.

Stimuli

Two hundred and twenty-five pictures were selected from two standardized sets of stimuli commonly used in psychological research (Lang et al., 1999; Spiering et al., 2002) to represent pleasant ($N=75$; e.g. skydiving), neutral ($N=75$; e.g. portrait) and unpleasant ($N=75$; e.g. mutilated body) categories. Pictures were sized to fill the screen without distortion.¹

The pleasant stimuli from the International Affective Picture System were matched on their level of general arousal with the most arousing unpleasant stimuli (the neutral stimuli will evoke lower levels of arousal).² Every stimulus included a person. Half of the pleasant stimuli ($N=38$) were sexual. Half of the sexual images were from the International Affective Picture System (Lang et al., 1999) in which they were described as sexual or erotic. The other half of the sexual images depicted one man and one woman engaged in penetrative sexual behaviors (Spiering et al., 2004). Men and women were shown the same sexual images. This avoids a confound that is usually overlooked when men and women are shown sexual images of the opposite gender. Heterosexual women report lower sexual motivation in response to photographs of nude males than nude females (Chivers et al., 2007). Showing participants opposite-sex nudes results in unbalanced stimuli

¹ 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, 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, 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.

² Arousal M (s.d.): unpleasant = 5.5 (0.5), neutral = 3.6 (0.5), pleasant non-sexual = 5.6 (0.7), sexual IAPS = 6.5 (0.6); valence M (s.d.): unpleasant = 2.4 (0.4), neutral = 5.1 (0.5), pleasant non-sexual = 7.5 (0.3), sexual IAPS = 7.4 (0.4).

for men, who are more likely to experience female nudes as pleasant and motivating, and women, who are less likely to experience male nudes as pleasant or motivating. These stimuli still could be more appealing to one gender or the other, although research on films documented surprising overlap in men and women's reported preferences for the same sexual films (Janssen et al., 2003).

Questionnaires

Each participant completed a number of questionnaires. The sexual history form included questions about demographic information, sexual history questions from the National AIDS Behavior Survey (Binson and Catania, 1998) and the amount of visual sexual stimuli use in the last week. The specific question of interest for this study was 'With how many partners have you had sexual intercourse in the last 12 months?' Sexual intercourse was defined as having a penis in the vagina or butt to ensure participant understanding.

Procedure

After giving informed consent, participants first completed questionnaires (see above). Participants were informed before completing the questionnaires that they should feel free to ask questions about anything that was not clear. Also, they were told that the experimenter could not view their responses while they were answering the questionnaires to maintain their sense of privacy. After completing the questionnaires, participants were seated for electroencephalographic recordings (described below). Participants then were randomly assigned to view either a series of color photographs or films first. Data from the films are presented elsewhere.

Photographs were presented on a CRT monitor using DMDX (Forster and Forster, 2003) on a 1280 × 1024 CRT monitor with 75 Hz refresh and 32 bit color depth. Images were presented in color at the maximum size for the screen. Participants were seated approximately 160 cm from the screen. These were pseudorandomized such that no more than three images of the same class were presented in a row. No image was repeated. Participants were instructed to view the photographs the entire time that they were on the screen. They received one break halfway through the task. Photographs were presented briefly (1000 ms) one at a time, followed by presentation of a fixation cross for variable duration (1000, 1500 and 2000 ms) and a blank screen (1000 ms). A break occurred after the first half of the trials (113 trials), or about 4 min. Not including the time participants took at this break, the entire task took about 8 min to complete.

Electroencephalographic recordings

Continuous electrophysiological data were recorded with Neuroscan Acquire software 4.4 in conjunction with a 40-channel Neuroscan NuAmps amplifier (Neuroscan, Inc., El Paso). 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 et al., 1999). All signals were digitized at 1000 Hz during data collection. EEG activity was recorded using linked ear lobes as reference. Horizontal electrooculogram (EOG) was measured with electrodes placed infra-orbital (about 1 cm) and supra-orbital (about 1 cm) to the middle of the right eye and vertical EOG was measured with electrodes placed at the outer canthus (about 1 cm) of each eye. All impedances were kept below 10 k ω using light abrasion as comfortable for the participant.

ERP data reduction

Pre-processing included bandpass filtering between 0.1 and 55 Hz, downsampling to 256 Hz and eye-blink removal. Bad channels were

identified as having activity four standard deviations away from the mean (on average, <1 electrode per participant met this criteria, 0.71 electrodes per participant). These channels were replaced using spline interpolation. Eye-blink removal was accomplished using an independent component analysis (ICA) technique. The ICA utility in the EEGLab software (Makeig et al., 2004) was used to derive components then, using an in-house template matching algorithm (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 -1000 ms pre-stimulus to 2000 ms post-stimulus with a baseline correction of 110 ms preceding the stimulus. An ERP was averaged for each stimulus type (unpleasant, neutral, pleasant non-sexual, pleasant sexual, pleasant sexual explicit). Within each trial, individual electrodes in which activity exceeded $\pm 100 \mu V$ were omitted from analysis. Applying these criteria, 8.67% of trials were excluded. The LPP component was defined by the positive deflection between 350 and 850 ms post-stimulus onset. This window was selected on the basis of visual inspection and consistent with previous research investigating LPP response (e.g. Hajcak et al., 2010). Topographical plots were extracted to permit examination of the source of the LPP.

The window and electrodes averaged in previous studies of the LPP have varied. The LPP raw average amplitude in this study was calculated between 350 and 850 ms. The LPP often is averaged across the electrode sites that contribute to it to reduce variability due to electrode selection. To ensure that the correct electrodes were being averaged in the LPP for this study, the activity in the 350–850 window was plotted topographically across all stimuli types (Figure 1). The activity during LPP generation appeared to include C3, Cz, C4, CP3, CPz, CP4, P3, Pz and P4. This was consistent with the electrodes averaged for the LPP in other studies (e.g. De Cesarei and Codispoti, 2011). The LPP was averaged across these electrode sites for analysis.

Data analysis

LPP voltage first was tested to replicate affective modulation and extend this to the more explicit sexual stimuli. As difference scores could mask the nature of effects, categorical analyses were used. A mixed analysis was calculated in R (v. 2.15.1) using libraries lme4 (Bates et al., 2012) for mixed and languageR (Baayen, 2007) for *P*-values. REML was used with participant specified as random, category as fixed, and 10 000 Markov chain Monte Carlo samples estimated the distribution for a *P*-value. Mixed approaches can offer several advantages over analysis of variance approaches. Of particular interest for psychophysiological research, mixed approaches handle missing data more efficiently and allow the specification of variance structures that can include time-varying structure (Bagiella et al., 2000).

Sexual risk variables are consistently, strongly positively skewed, making transformations to meet common test assumptions difficult or impossible (Catania et al., 2005, for review, see). One common approach has been to define HIV risk according to the number of new intercourse partners in the last year, where 1 or 0 partner classifies a person as low risk and two or more partners classify a person as high risk (e.g. Gerver et al., 2011; Hall et al., 2012). This cut-off is clinically meaningful. Having two or more intercourse partners in the last year has been related to marked increases in sexually transmitted infections (e.g. Johnson et al., 2012), related to other sexually risky behaviors (Stuart and Hinde, 2010), and discriminates those reporting more sexual compulsivity (Storholm et al., 2011). To accommodate the positive skew for the number of intercourse partners reported in the last year, the same approach of classifying participants as high risk (two or

³ For comparison with more common statistical approaches, this main effect of stimulus category also was significant in an analysis of variance [$F(1,288) = 74.92, R^2_{adj} = .21, p < .0001$].

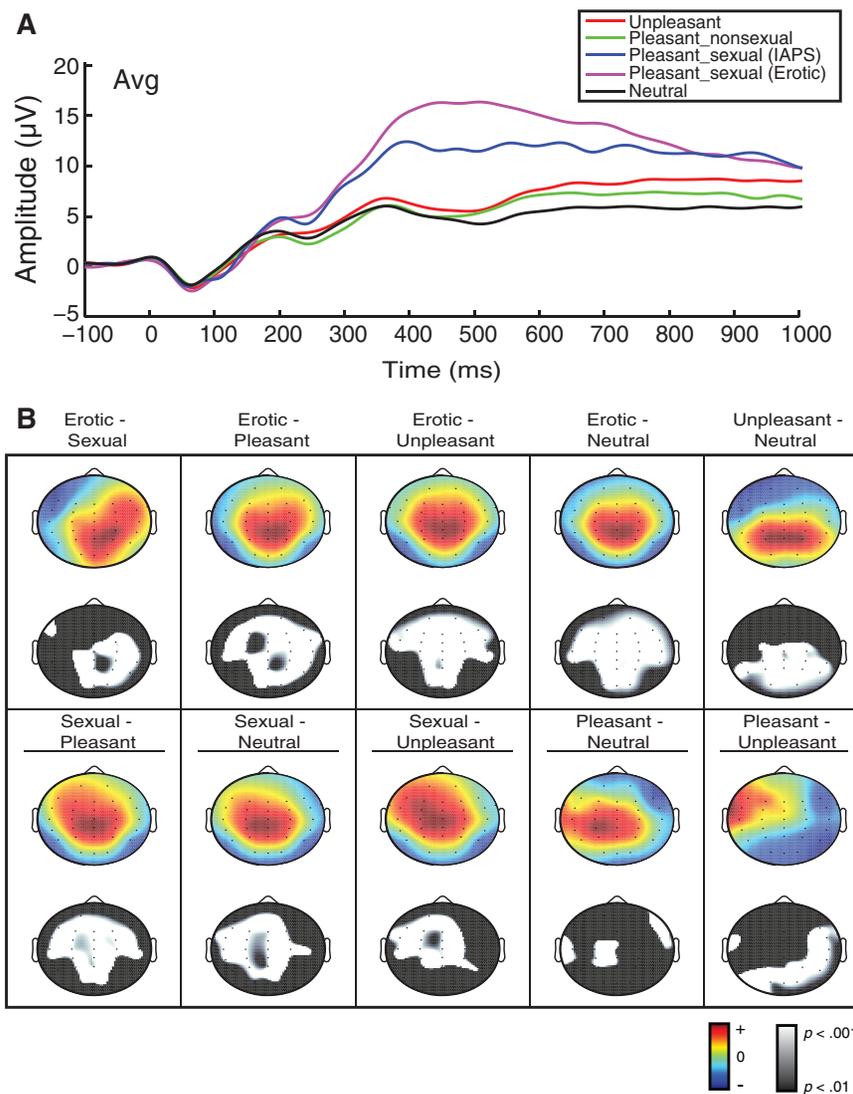


Fig. 1 ERP time course by picture category. (A) ERP time course by picture category; (B) Topographic plots of category contrasts showing activity differences (top) and significance of differences (bottom).

more sexual intercourse partners in the last year) or low risk (zero or one sexual intercourse partner in the last year) is taken here.

effects with emotional stimuli, the other planned analyses were conducted.

RESULTS

Explicit sexual images in LPP

5 The main effect of stimulus category significantly predicted the LPP amplitude. A mixed approach yielded similar results (AIC = 1836, $P < 0.0001$).³ Given that the more explicit sexual stimuli represented an addition to the classes of stimuli most commonly included, one contrast specifically tested whether these more explicit sexual images differed from the less explicit sexual images. Indeed, the LPP amplitude to the more explicit sexual stimuli was higher than the LPP amplitude to the less explicit sexual stimuli ($t = 2.02, P = 0.04$). Additional contrasts were conducted to ensure that the commonly used International Affective Picture System (IAPS) sexual images replicated previously identified patterns. The IAPS sexual images evoked a higher LPP relative to unpleasant ($t = -3.8, P < 0.0001$), neutral ($t = -5.6, P < 0.0001$) and pleasant-non-sexual ($t = -4.7, P < 0.0001$) images. The unpleasant and pleasant-non-sexual images did not provoke significantly different LPP amplitudes, consistent with their selection to match on arousal level. Based on this basic replication of LPP

Relationship of LPP to recent sexual partner count

Of the participants who reported their number of sexual intercourse partners in the last year, 37 reported 0 or one sexual partner and 24 reported two or more sexual partners. The total mixed model fit well (AIC=758.7) with significant main effects of category ($t = -2.97, CI = 1.4-14.3, P = 0.0006$), sexual partner number ($t = 3.5, CI = 4.64-81.96, P = 0.02$), and a significant interaction of stimulus category and sexual partner number ($t = -2.4, CI = -8.6 to -0.4, P = 0.02$). Specifically, participants reporting fewer sexual partners in the last year had LPP amplitudes that were lower to the less explicit sexual stimuli and higher to the more explicit sexual stimuli, whereas participants reporting more sexual partners in the last year had LPP amplitudes that were more similar between the more and less explicit sexual stimuli (Figure 2).

DISCUSSION

Participants who reported more sexual intercourse partners in the last year exhibited similar amplitudes in their LPP to more and less explicit

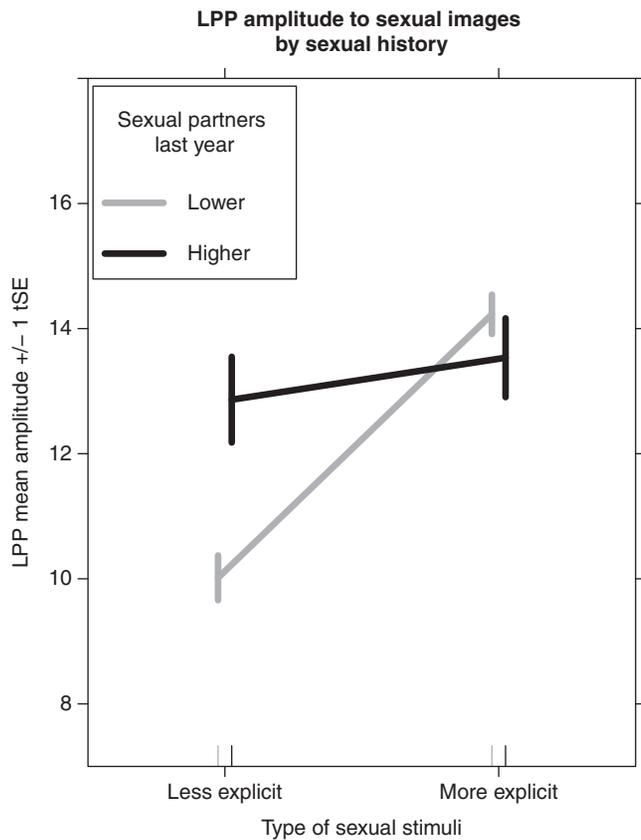


Fig. 2 LPP amplitude to sexual stimuli association with sexual intercourse partners in the last year.

sexual images, whereas those reporting fewer intercourse partners in the last year showed reduced LPP amplitudes to the less explicit sexual images. This pattern is consistent with sexual risk-takers having a highly responsive, sensation seeking hedonic drive, rather than 'chasing' risks to overcome an under-responsive drive. However, reward responsiveness also interacted with sexual partner history in predicting LPP amplitude. Specifically, high reward responsiveness did not increase, and actually partially reversed the effect observed when sexual partner history was the sole predictor. This suggests that the high responsiveness to sexually motivating stimuli in participants with more sexual partners was not due to differences in reward responsiveness.

Predictors of sexual risk behaviors commonly examined, such as sexual attitudes and condom knowledge, emerge from later, elaborated processes. This may have implications for interventions to reduce high risk sexual behaviors. More effective sexual risk reduction programs generally focus on sexual education for adolescents (Chin et al., 2012) and increasing motivation to use (Yap and Traynor, 2012), and decreasing barriers to using (Goodall et al., 2012), condoms for adults. If early reactivity to sexual stimuli predicts later sexual risk behaviors, a focus on the state at the time sexual decisions are made may be beneficial. Similar suggestions to manage sexual motivation that leads to sexual risk behaviors in-the-moment (e.g. Elders, 2010) have, unfortunately, been met with political resistance (for review, see Money, 1995; Barroso and La Rosa, 2007; van Lunsen et al., 2013). As evidence of need for science in this area continues to emerge, perhaps these social constraints will support such investigations.

As the effects identified compared more and less explicit sexual stimuli, the importance of distinguishing this aspect of sexual stimuli appears important. Typically, only the sexual target match is considered: women are shown nude male, and men are shown nude

female, stimuli. In fact, similar graded approach is taken already in research on hunger and sleep drives. For example, fMRI studies distinguish pleasant from highly palatable tastes (e.g. Szalay et al., 2012) and stress reactivity results distinguish better from worse quality sleep as predictors (e.g. Goodin et al., 2012). Also, it is worth considering whether stimulus explicitness may covary with some other important construct. Participants may feel more embarrassed or guilty when viewing more explicit, as compared with less explicit, sexual images in the laboratory. Visual sexual stimuli are unique in their ability to induce high coactivation of negative and positive emotions (Peterson and Janssen, 2007; Prause et al., 2013). Participants in this study were aware before volunteering that they would be asked to view visual sexual stimuli from the advertisements, which reduces the risk that results are attributable merely to negative affect to the more explicit sexual stimuli. However, this possibility will be important to test in future studies.

As with any non-specific ERP component, the LPP is a reasonable, but not veridical, measure of motivation (Schupp et al., 2000). Many processes appear to underlie the generation of this component, and the contribution of each process varies within the component window (Moratti et al., 2011). Although greater emotional arousal has been reliably shown to increase the amplitude of the LPP (e.g. Hajcak et al., 2009), the LPP reflects more than stimulus novelty, mere perceptual differences, or violations of expectation characteristic of the P300 or very early components (Hajcak et al., 2010). In fact, the LPP correlates well with activity in amygdala and ventral striatum during emotional picture perception, as well as corticolimbic and visual cortical structures (Sabatinelli et al., 2013). Nevertheless, given the infrequent use of explicit sexual stimuli in affective studies, additional evidence supporting a motivation interpretation of the LPP in response to sexual stimuli would be reassuring.

These data begin to improve the utility of sexual stimuli for studies of approach motivation. Approach motivation is perhaps no stronger than in response to sexual cues, so it is surprising that studies of approach motivation generally limit stimuli to monetary rewards (Gable and Harmon-Jones, 2011a) and desserts (Harmon-Jones et al., 2011). Sexual stimuli are the strongest modulators of physiological responses amongst pleasant stimuli (Bradley et al., 2001a) for both men and women (Bradley et al., 2001b). Sexual motivation level also appears to be very stable, at least insofar as it is difficult to change in clinical treatment. This is true both for hypoactive sexual desire disorder (Heiman, 2002), the most common sexual difficulty that women report, and hypersexuality (Kaplan and Krueger, 2010). For those interested in reward sensitivity, these are encouraging features that could support further investigation into sexual reward processing.

This novel investigation faced a number of design challenges for which other choices could have been made. While more clearly sexual, the stimuli used do not account for possible individual sexual preferences. Many report seeking more specialized sexual content, such as domination or anal intercourse (Paul, 2009). Although most of the stimuli used were from a well-characterized picture set with published ratings in a large sample similar to this study, it was not verified that these images provoke the same emotional responses in the current sample. Also, negative approach motivating stimuli such as those invoking anger (Harmon-Jones and Allen, 1998) were not included. It may be that differences in motivation or emotional reactivity broadly, not specifically sexual reactivity, would result in the same pattern of effects. Finally, the control offered by the laboratory environment reduces the external validity of the results, which might be particularly acute in the typically very private activity of viewing visual erotica.

This study suggests processing differences that lead to sexual risk behaviors may occur very early. Those reporting more novel sexual

partners in the last year had higher LPP amplitudes even to less explicit sexual stimuli than those who reported fewer sexual partners. Dividing the sample into higher and lower reward sensitivity showed those with higher reward sensitivity reporting more sexual partners actually had lower LPP to more explicit sexual stimuli as compared with those with fewer sexual partners. LPP amplitude to sexual stimuli may be sensitive to sexual deprivation or low sexual novelty, where those who did not access new partners may be more motivated by explicit sexual stimuli. Interventions to reduce sexual risk behaviors could be improved by further studies concerning how early reactions to sexual stimuli might be influencing decision making.

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