

# Appetitive Responses to Sexual Stimuli Are Attenuated in Individuals with Low Levels of Sexual Desire

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Despite the high prevalence of sexual desire disorders, little is known about their biological underpinnings in humans. Animal studies suggest that dopamine is involved in appetitive sexual behavior; thus, one aim of this study was to elucidate that relationship in humans. This study used measurement of the acoustic startle response (ASR) and prepulse inhibition of the startle response (PPI) as psychophysiological indicators of changes in motivational states to assess the potential relation between sexual desire and appetitive motivation in humans. Responses to sexually provocative stimuli consisting of single nude men and single nude women in a sample of 153 participants (77 men, 76 women) were assessed. The results indicated that ASR was attenuated after exposure to appetitive stimuli (i.e., sexually provocative pictures of attractive individuals) to a greater extent among participants with higher levels of sexual desire, as measured by the Sexual Desire Inventory-2 (Spector, I. P., Carey, M. P., & Steinberg, L. (1996). *Journal of Sex & Marital Therapy*, 22, 175–190). In addition, PPI was inversely associated with subjective ratings across stimuli such that greater subjective levels of desire were correlated with lower levels of PPI. In general, these results suggest that individuals with lower levels of sexual desire may have a diminished physiological response to appetitive sexual stimuli.

**KEY WORDS:** sexual desire; hypoactive sexual desire disorder; acoustic startle response; prepulse inhibition; sex differences.

## INTRODUCTION

Sexual desire is commonly defined as a wish, need, or drive to seek out and/or respond to sexual activities or the pleasurable anticipation of such activities. It is an appetitive state (i.e., characterized by craving) and is considered by some to be distinct from physiological genital arousal and sexual activity (Brezsnyak & Whisman, 2004). Dysfunctional deficits in sexual desire were first introduced to the psychiatric nomenclature in the DSM-III (American Psychiatric Association, 1980) as Inhibited Sexual Desire and are currently diagnosed in the DSM-IV

as Hypoactive Sexual Desire Disorder (HSDD). HSDD is defined as persistently or recurrently deficient (or absent) sexual fantasies and desire for sexual activity (American Psychiatric Association, 2000).

Current annual prevalence estimates of disorders of desire are approximately 32% among American women and 15% among American men (Laumann, Paik, & Rosen, 1999). Some studies suggest, however, that the actual rate may be much higher (Beck, 1995) and that the rate of occurrence may be increasing (Kaplan, 1995; LoPiccolo & Friedman, 1988; Spector & Carey, 1990). At sex therapy clinics, dysfunctions of sexual desire are the most common presenting problems (Beck, 1995; Hawton, Catalan, & Fagg, 1991; Leiblum & Rosen, 1988), occurring in over 50% of couples seeking sex therapy (Schover & LoPiccolo, 1982). HSDD responds less favorably to treatment than dysfunctions of arousal or orgasm (Kaplan, 1977; Hawton et al., 1991) and it requires more treatment sessions to achieve positive results (Rosen

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& Leiblum, 1995). In addition, treatment of dysfunctions of desire is often complicated by the high prevalence (41%) of co-morbid sexual dysfunctions in patients with HSDD (Segraves & Segraves, 1991). In many recurring cases of orgasm or arousal dysfunction, it is believed that relapse may be due to an underlying desire disorder that was not successfully treated (Kaplan, 1995; LoPiccolo & Friedman, 1988). The absence of knowledge about what constitutes "normal" desire and/or what biological factors may play a role in enhancement or disruption of human sexual desire has limited the development of more effective treatments for HSDD. New approaches to the study of sexual desire in humans are necessary in order to advance the knowledge base and improve treatment outcomes.

Although there has been little evaluation of the biochemical underpinnings of sexual desire in humans, more is known about the role of biological factors in the expression of sexual motivation in animals. Numerous studies have shown that dopamine agonists consistently facilitate male sexual motivation across species; in contrast, dopamine antagonists consistently interfere with these behaviors (e.g., Gessa & Tagliamonte, 1974; Moses, Loucks, Watson, Matuszewich, & Hull, 1995). Furthermore, exposure of male rats to a receptive female significantly increases dopamine release in the nucleus accumbens (NA; Pfaus, Mendelson, & Phillips, 1990; Robinson et al., 2001) and increased dopamine in the NA is correlated with increased sexual motivation (van Furth, Wolterink, & van Rhee, 1995).

The effect of dopamine on sexual motivation in female animals has been studied far less extensively, but it appears that dopamine plays a facilitating role similar to that in males. Research has consistently found that dopamine agonism increases proceptive or soliciting behaviors (e.g., hopping and darting; Melis & Argiolas, 1995; Wilson, 1993), which are presumed to be somewhat analogous to human desire. Similar to the findings in males, dopamine levels rise in the NA of hormonally-primed female hamsters exposed to males (Kohlert & Meisel, 1999) and it has been shown that D<sub>2</sub> receptors are involved in the appetitive process of sexual behavior in female hamsters (Meisel, Joppa, & Rowe, 1996). Also, as found in male rats, sexual anticipation increases dopamine transmission in the NA in female rats (Pfau, Damsma, Wenkstern, & Fidiger, 1995). Further, researchers have linked dopaminergic activity to sexual functioning in human females. Due to evidence that dopaminergic activity modulates the desire phase of the sexual response cycle (Segraves, 1996), Segraves et al. (2001) studied the use of a dopamine reuptake inhibitor (bupropion) in HSDD patients. Results of this study showed that bupropion,

by increasing dopaminergic activity, markedly increased sexual desire in nearly one third of those with HSDD.

One reason for a lack of studies on physiological mechanisms that underlie hypoactive sexual desire in humans has been the lack of a clearly agreed-upon definition of desire and disordered desire. Another reason has been the lack of a methodological paradigm that is non-invasive, but yet well suited for studying appetitive motivation. Recent evidence has shown support for the use of psychophysiological measures in the study of HSDD (Stoleru, Redoute, & Costes, 2003). In recent years, two non-invasive methodologies have shown promise with respect to testing the biological mechanisms that underlie appetitive motivation. The first of these methodological paradigms is the modification of the acoustic startle response (ASR). The ASR is a well-documented physiological phenomenon that consists of a defensive response (e.g., an eyeblink or body jerk) to a startling stimulus, such as a loud noise. This paradigm may be of use in evaluating human sexual desire, as it has been well documented that the magnitude of the ASR is influenced by acute exposure to appetitive stimuli (e.g., nude pictures; Bradley & Lang, 2000; Lang, 1995; Filion, Dawson, & Schell, 1998; Lang, Bradley, & Cuthbert, 1990). Specifically, the magnitude of the startle response decreases in the presence of positively-valenced, appetitive stimuli and increases in the presence of negatively-valenced stimuli. Furthermore, the influence of appetitive stimuli on ASR in the rat appears to be controlled, at least in part, by dopamine activity in the NA (Koch, Schmid, & Schnitzler, 1996).

Only two studies have examined the startle response in the context of sexually provocative stimuli in humans (Koukounas & McCabe, 2001; Koukounas & Over, 2000). One of these reports indicated that erotic stimuli attenuated the startle response and there was a very strong, inverse correlation between the startle response and physiological and subjective sexual arousal as well as positive feelings about the stimuli ( $r = -.64, -.68$ , and  $-.67$ ; Koukounas & McCabe, 2001). In the other study, repeated presentation of a sexual stimulus resulted in a reduction of arousal (habituation) and an increase in the startle response while the introduction of a novel sexual stimulus increased arousal and decreased the startle response (Koukounas & Over, 2000). These results are noteworthy because the startle response shows marked habituation over trials. Thus, an increase in the startle response in later trials suggests that the sexual stimulus was decreasing startle in the earlier trials. In sum, these two studies suggest that exposure to sexual stimuli decreases the startle response in humans.

The second non-invasive method is prepulse inhibition (PPI) of the acoustic startle reflex (ASR), which may

reflect dopamine activity in mesolimbic brain structures (e.g., Zhang, Forkstam, Engel, & Svensson, 2000). PPI refers to the suppression of the startle reflex that is caused by a non-startling stimulus (i.e., the prepulse) that precedes the startle-eliciting stimulus; the prepulse is typically presented 30 to 500 ms prior to the startle-eliciting stimulus. This inhibition is also known as “sensory gating” and is hypothesized to reflect a protection of the processing of the prepulse, thereby reducing the magnitude of the startle response (Norris & Blumenthal, 1996). Mesolimbic dopamine activity potently disrupts the expression of PPI, particularly activity in the NA; higher levels of dopamine activity in the NA are associated with a reduction in PPI (Geyer, Krebs-Thomson, Braff, & Swerdlow, 2001; Swerdlow, Caine, & Geyer, 1992; Swerdlow et al. 2000). Thus, differential levels of PPI may reflect the level of dopamine activity in the NA.

In an effort to expand the base of knowledge regarding the potential role of appetitive motivation and/or dopamine in the experience of human sexual desire, this study assessed the relationship between ASR, PPI, and sexual desire. The primary objectives of this study were: to assess the relation between acute (e.g., within 4 sec) psychophysiological responses to appetitive stimuli (i.e., sexually-provocative pictures) and trait levels of sexual desire in a human sample. A secondary aim was to examine the relation between PPI and trait levels of sexual desire. It was hypothesized that higher levels of sexual desire would be associated with (1) an attenuated ASR after exposure to the appetitive stimuli and (2) lower levels of PPI. Smaller mean ASR responses were expected while participants viewed opposite-sex stimuli as compared to neutral stimuli; it was further hypothesized that this difference would be larger in participants with higher levels of sexual desire. Additional objectives included examining potential sex differences in both ASR and PPI responses to a variety of sexual stimuli (i.e., same-sex as well as opposite sex) and evaluating potential moderators (e.g., religiosity, political orientation) of the relationship between ASR/PPI and sexual desire.

## METHOD

### Participants

Participants were undergraduate students recruited from introductory psychology classes. Participants received credit toward a course research requirement for participating in the study. Participants were excluded if they were taking any medications known to affect either dopamine or sexual desire (e.g., antidepressants, beta blockers, stimulants, thyroid medications), had a history

of hearing loss that could interfere with responses to the acoustic startle stimuli, or smoked an average of greater than 5 cigarettes per day. This study was approved by the university-level internal review board; all participants gave written, informed consent prior to participation.

Of the 205 participants (99 men, 106 women) who signed up for this experiment and arrived for their scheduled experimental session, 6 (2.9%; 2 men, 4 women) declined to participate in the study. Based on the a priori criteria for inclusion in the analyses noted above, 29 participants (14.6%; 14 men, 15 women) were excluded from the study due to use of prohibited concomitant medications ( $n = 13$ ; 6.5%), history of hearing loss ( $n = 3$ ; 1.5%), or smoking more than 5 cigarettes per day ( $n = 13$ ; 6.5%); these exclusions resulted in a sample size of 170 (83 men, 87 women). Of these 170, an additional 14 participants (8.2%; 5 men, 9 women) had insufficient startle response for one or more of the stimulus types (see data reduction), and 3 participants (1.8%; 2 men, 1 woman) had no usable psychophysiological data due to experimenter/equipment error; these 17 participants were excluded from all analyses. Thus, the final sample included 153 participants (76 men, 77 women). Eighty-four percent of the participants were Caucasian, 7% were Latino, 7% were Asian, and 2% were African-American. The average participant was 19.2 years old (range, 18 to 33;  $SD = 1.6$ ). All participants reported a heterosexual orientation; no participants self-identified as either bisexual or homosexual, and participants had a mean of 2.28 years of sexual experience (range, 0 to 8;  $SD = 1.59$ ).

### Self-Report Measures

#### *Baseline Questionnaires*

*Demographic Questionnaire.* This questionnaire collected demographic and background information in order to account for any extraneous sources of variance. This questionnaire included the following single-item assessments: age, race, marital/relationship status, educational level, and religious affiliation, and sexual orientation. We assessed sexual orientation using the Kinsey scale, a single-item, 7-point Likert-type scale assessing sexual orientation with “entirely heterosexual” at one end of the continuum and “entirely homosexual” at the other (Kinsey, Pomeroy, & Martin, 1948). In addition, the questionnaire included two short multi-item assessments- Religiosity and Political Conservatism. The first was aimed at assessing degree of religiosity or the extent to which one is religious. This scale consisted of four items (e.g., “religion is a guiding force in my life”) and participants responded

on a 5-point Likert-type scale (Mahaffey & Judd, 2001). The second was aimed at assessing the extent to which one is politically conservative. This scale consisted of five items (e.g., "I believe a woman should have the right to a safe and affordable abortion") and participants responded on a 5-point Likert-type scale. (Bryan & Smith, 1996).

*Sexual Desire Inventory-2 (SDI-2)*. This 14-item measure assessed sexual desire in a dyadic context. Four items were answered using an 8-point response scale (0 = "Not at all" to 7 = "More than once a day") regarding frequency of desire (e.g., "During the last month, how often have you had sexual thoughts involving a partner?"); the remainder of items utilized a 9-point Likert scale ranging from 0 = no desire to 8 = strong desire. Possible scores ranged from 0 to 112. Internal consistency analyses for this scale yielded a Cronbach's alpha of 0.86 (Spector, Carey, & Steinberg, 1996).

*Social Desirability Scale (SDS)*. This scale measured an individual's tendency to present him/herself in a socially desirable manner, and provided an indicator of the degree to which an individual may have biased or defensive responding. This study used Reynolds' (1982) Form C of the original Crowne and Marlowe (1960) scale consisting of 13 forced-choice (i.e., yes/no) items (e.g., "I am always courteous, even to people who are disagreeable.").

#### *Subjective Valence Ratings*

This scale was presented after each photographic stimulus. The single item measure assessed the emotional valence of the participant's reaction to each stimulus using a modified version of the Self-Assessment Mannequin (SAM; Bradley & Lang, 1994). The scale required each participant to indicate their emotional reaction on a 9-point scale that is represented as nine different images on a dimension of happiness/unhappiness.

#### **Psychophysiological Measures**

The pulse-alone probe consisted of a burst of white noise (intensity = 100 dB, duration = 50 ms); the pre-pulse consisted of a non-startling white noise (intensity = 68 dB [6 dB above background noise], duration = 30 ms, rise time = 3 ms) presented 120 ms prior to the startle-eliciting stimulus (identical to the pulse-alone probe). Pulse-alone and pre-pulse stimuli were administered to the participants via headphones and generated by the same iMac computer (Apple Computer, Inc., Cupertino, CA) used to present the photographic stimuli. All startle responses were recorded by the Biopac Systems Model MP-100 (Biopac Systems, Inc., Santa Barbara, CA).

Participants were monitored for startle response via two 4 mm EMG electrodes placed under the right lower eyelid, 20 mm apart, over the orbicularis oculi. In addition, a ground electrode was placed on the center of the forehead. The skin beneath the electrodes was cleaned with an alcohol-saturated cotton swab immediately prior to electrode placement. The EMG reading for the orbicularis oculi was sampled continuously at 1000 Hz from the beginning of the baseline period until the completion of the photographic presentation.

After completion of the experimental session, each participant's psychophysiological data were filtered off-line with a bandwidth of 28–500 Hz. No integration of the signal was performed because the integrated and raw signal are highly correlated (Blumenthal, 1996), and integration can result in attenuation of the raw signal.

Peak EMG magnitude within 120 ms of the presentation of each startle-eliciting response was recorded for each participant. Peak startle responses less than background noise were treated as missing values. Average peak EMG magnitude (i.e., ASR) and percentage PPI were calculated for each of the different types of photographic stimuli (i.e., neutral, same-sex, and opposite-sex). The percentage of PPI was calculated as the difference between the average peak startle response of the pulse alone trials minus the average peak startle response from the prepulse trials, divided by the average startle response for the pulse alone trials ( $\% \text{ PPI} = [(\text{pulse} - \text{prepulse})/\text{pulse}] \times 100$ ). These parameters are identical to the parameters used in our previous studies (Hutchison, Niaura, & Swift, 2000; Hutchison & Swift, 1999).

#### **Photographic Stimuli**

The photographic stimuli consisted of 36 photographic images; 12 of these were affectively neutral images taken from the International Affective Picture System (IAPS, Lang, Öhman, & Vaitl, 1988) and 24 were images with sexual content (12 each depicting erotically-suggestive male nudes and female nudes) taken from the public domain. Images from the IAPS were selected from the slides comprising sets 1–8 of the IAPS according to the following criteria:

1. Valence: Slides selected for the neutral category were rated between 4.25 and 5.75 on a 9-point scale (with 1 being most negative and 9 most positive) by a large sample of college students (Ito, Cacioppo, & Lang, 1998).
2. Content: Slides were excluded if they depicted violence, bodily harm, or images of reproductive significance (e.g., babies).

3. Arousal: Among the slides meeting the above criteria, those with the highest arousal/excitement rating (Ito et al., 1998) were selected in an effort to minimize the difference between the sexual and neutral slides with respect to arousal.

## Procedure

Sign-ups for this study were conducted via an online system administered by the introductory psychology course personnel; in an effort to avoid the selection bias that tends to plague sex research (e.g., Plaud, Gaither, Hegstad, Rowan, & Devitt, 1999), no information about the nature of the study was given prior to arrival at the laboratory. All data were collected during a single experimental session.

Informed consent was obtained from each participant prior to the completion of any study-related assessments. Participants were made aware that the study would entail viewing photographs with explicit images of male and female nudes, and sample items from the questionnaires were reviewed. Any participant who was uncomfortable with the study procedures was allowed to leave after reviewing the informed consent form (of 205 potential participants, 6 chose not to participate after reviewing the informed consent form). After giving informed consent, participants completed the baseline packet of written questionnaires. They were then seated in front of a computer, which was used to present the photographic stimuli. Baseline ASR and PPI were measured by eight pulse-alone probes and eight pre-pulse probes administered during a period of approximately 6 min; the computer screen remained blank during the baseline block of probes. The order of the pulse and prepulse trials was randomly generated for each participant so that no more than three of the same trial type were presented consecutively. The time elapsed between each trial was also randomly generated and varied between 18 and 25 s.

After collection of the baseline ASR and PPI data, participants were instructed to observe the computer screen for the presentation of the photographic stimuli, which were presented on an iMac computer screen using REALBasic software (REAL Software, Inc., Austin, TX). ASR and PPI were measured during the photo presentations by 18 prepulse and 18 pulse-alone probes (one probe presented during each photograph). Participants viewed each of the 36 stimuli for 6 s and then completed the valence rating for the stimulus. The order of the prepulse and pulse-alone trials, as well as the order of the picture presentation, were randomly generated for each participant so that each picture category (same-

sex, opposite-sex, or neutral) had equal numbers of prepulse and pulse-alone trials, and no more than three of the same type of probes (pulse or prepulse) or picture were presented consecutively. After completion of the subjective valence rating, the computer screen remained blank for a randomly-generated interval ranging from 18 to 25 s. Prepulse and pulse-alone startle probes occurred at a randomly-determined time between 3 and 5.5 s after presentation of each photograph.

## Statistical Analysis

Descriptive statistics were generated for all assessments used in the study, and all dependent variables were assessed for normal distribution.<sup>4</sup> Examination of the data for potential outliers included consideration of leverage values, studentized residuals, and Cook's distances as described by Judd and McClelland (1989). No participants were excluded from the analyses based on these assessments. The relationships between sexual desire and demographic characteristics and between sexual desire and measurements of social desirability, religiosity, and political liberalism were assessed.

## RESULTS

On average, men reported significantly higher levels of sexual desire than women,  $t(1, 151) = 3.95$ ,  $p < .0001$ . Sexual desire was not significantly related to race, age, relationship status, or religious affiliation, but was marginally related to social desirability ( $r = -.15$ ;  $p = .07$ ) and political conservatism ( $r = -.16$ ;  $p = .055$ ) and significantly related to degree of religiosity ( $r = -.17$ ;  $p < .05$ ). Higher levels of social desirability and religiosity and more conservative political attitudes were all associated with lower levels of sexual desire. In addition, the number of years a participant had been sexually active was positively correlated with sexual desire ( $r = .29$ ;  $p = .01$ ). The potential influence of these variables was consequently assessed during preliminary analyses. Inclusion of social desirability, religiosity, liberalism, or years of sexual activity as covariates in the analyses resulted in no differences in tests of significance for the primary hypotheses; they were, therefore, not included in the final analyses.

<sup>4</sup>Psychophysiological dependent variables (i.e., PPI and ASR) were slightly skewed. Following correction of the skewness by power transformations, it was found that the analytical results were not materially different from those generated by analyses conducted on the untransformed variables. Therefore, all analyses reported here are based on untransformed variables.

**Table I.** Acoustic Startle Response, Prepulse Inhibition, and Valence Ratings as a Function of Sex and Stimulus Type

	Baseline		Opposite Sex		Same Sex		Neutral	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
ASR ( $\mu$ V)								
Men	145.2	106.6	97.2	98.7	101.0	92.8	107.9	90.2
Women	174.4	129.4	100.2	100.9	101.2	98.2	107.1	98.7
Combined	159.9	119.2	98.7	99.5	101.1	95.2	107.5	94.2
PPI (%)								
Men	63.18	21.11	62.06	21.66	62.04	21.31	60.45	24.00
Women	65.64	22.48	62.92	20.06	64.13	23.91	62.08	22.91
Combined	64.61	21.77	62.49	20.80	63.09	22.06	61.72	23.93
Valence <sup>a</sup>								
Men	—	—	66.16	9.51	31.85	13.98	50.90	6.91
Women	—	—	56.57	12.17	41.58	14.36	45.77	9.75
Combined	—	—	61.33	11.90	36.75	14.95	48.32	8.82

<sup>a</sup>Absolute range, 0–100.

### Acoustic Startle Response

One-way, repeated measures ANOVA were used to evaluate the main effects of stimulus type (i.e., neutral, same-sex, and opposite-sex) within-subjects on ASR and PPI. When an ANOVA revealed a main effect for stimulus type, planned contrasts were conducted comparing opposite-sex versus same-sex stimuli, opposite-sex versus neutral stimuli, and same-sex versus neutral stimuli. Sexual desire was examined as a moderator of within-subjects effects of stimulus type on ASR and PPI by conducting regression analyses using sexual desire (as measured by the SDI-2) as a continuous predictor and a difference score between neutral and opposite-sex stimuli as the dependent variable.

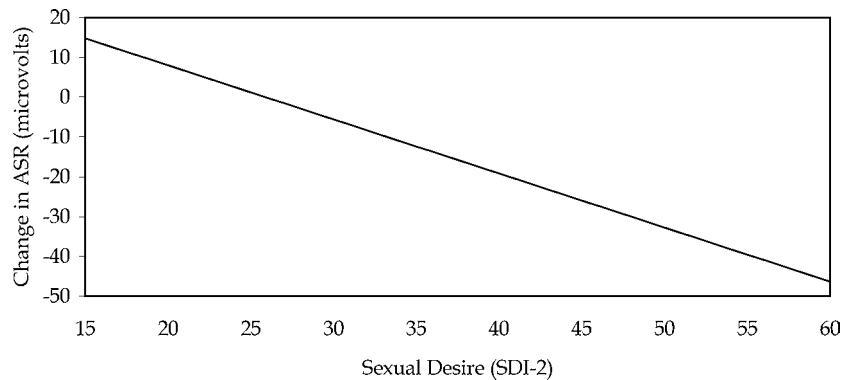
Table I shows the means and SDs for the ASR as a function of sex and stimulus type. A 2 (sex)  $\times$  3 (stimulus type) ANOVA on ASR revealed a significant main effect of stimulus type,  $F(2, 302) = 7.33, p = .001$ . There was no significant main effect of sex or a significant sex by stimulus type interaction. Consistent with our hypothesis, startle magnitude was significantly lower while viewing opposite-sex stimuli compared to neutral stimuli,  $F(1, 151) = 17.98; p < .0001$ . This contrast yielded a moderate effect size ( $PRE = .11$ ). Consistent with two previous reports (Mahaffey, Bryan, & Hutchison, 2005a, 2005b), startle magnitude was also significantly lower when viewing same-sex stimuli as compared to neutral stimuli,  $F(1, 151) = 6.20, p < .05$ , showing a smaller effect ( $PRE = .04$ ). The difference between opposite-sex and same-sex stimuli was not statistically significant ( $p > .05$ ).

There was no main effect of sexual desire on startle magnitude ( $p > .05$ ). Consistent with our hypothesis, a significant interaction indicated that sexual desire mod-

erated the effect of stimulus type on ASR. Fig. 1 shows that participants with higher sexual desire showed greater decreases in ASR while viewing opposite-sex stimuli as compared to neutral stimuli than did participants with lower sexual desire,  $B = -.21, p < .01$ . At lower levels of sexual desire, differences in ASR between opposite-sex and neutral stimuli approached zero, which suggested that opposite-sex stimuli did not induce an appetitive state in participants with lower sexual desire. This relationship remained significant even when controlling for subjective ratings of affective valence during opposite-sex and neutral stimuli,  $B = -.23, p < .01$ . This finding suggests that opposite-sex stimuli may have evoked an appetitive state beyond that which is associated with affective valence. It is important to note that there was no association between sexual desire and changes in ASR while viewing same-sex stimuli,  $B = -.10, p > .05$ . There were also no significant sex differences in the relationship between sexual desire and ASR.

### Prepulse Inhibition

Table I also shows the means and SDs for the PPI as a function of sex and stimulus type. A 2 (sex)  $\times$  3 (stimulus type) ANOVA on PPI did not reveal a significant main effect of stimulus type on PPI or a significant interaction between sex and stimulus type. An analysis of sexual desire did not reveal interaction between stimulus type and sexual desire ( $p > .05$ ). There was, however, a significant association between sexual desire and PPI in general. Examination of the correlations between sexual desire and PPI for each of the stimulus types revealed a significant correlation between sexual desire and PPI during both of the sexual stimulus types (opposite-sex



**Fig. 1.** Change in ASR (ASR after exposure to opposite-sex stimuli minus ASR after exposure to neutral stimuli) as a function of sexual desire. Analyses indicated a significant association such that individuals with greater sexual desire demonstrate an attenuated ASR after exposure to opposite-sex stimuli.

stimuli  $r = -.18$ ,  $p < .05$ ; same-sex stimuli  $r = -.17$ ,  $p < .05$ ); the correlation between sexual desire and PPI during the presentation of neutral stimuli approached significance ( $r = -.14$ ;  $p = .08$ ). Sexual desire was not predictive of within-subject differences in PPI between stimulus types,  $F(2, 302) < 1$ .

### Valence

As secondary analyses, one-way, repeated measures ANOVAs were used to evaluate the main effects of stimulus type (neutral, same-sex, and opposite-sex) within-subjects on the subjective rating of emotional valence. As above, when an ANOVA revealed a main effect for stimulus type, planned contrasts for each of the pair-group combinations were tested individually. The potential influence of sex of participant was evaluated as described above. To assess the relationship between ASR and valence, ASR was regressed on valence ratings. To adjust for multiple comparisons, all secondary analyses utilized a significance level of  $\alpha = .01$ .

Table I shows the means and SDs for the valence ratings as a function of sex and stimulus type. A 2 (sex)  $\times$  3 (stimulus type) ANOVA on valence ratings revealed a significant sex by stimulus type interaction ( $F(2, 302) = 31.70$ ,  $p < .0001$ ). Male participants gave significantly more positive valence ratings to opposite-sex stimuli relative to same-sex stimuli than did women ( $F(1, 151) = 48.70$ ,  $p < .0001$ ). Compared to women, men also showed a trend toward more positive ratings of opposite-sex stimuli relative to neutral stimuli ( $F(1, 151) = 4.32$ ,  $p < .05$ ). In addition, men gave less positive ratings to same-sex stimuli relative to neutral stimuli than did women ( $F(1, 151) = 31.08$ ,  $p < .01$ ).

Ratings of valence while viewing stimuli were significantly correlated with startle magnitude in this sample ( $p < .05$ ). Stimuli with higher valence ratings were associated with lower startle magnitudes, thus showing a concordance between subjective and objective responses.

### DISCUSSION

These findings demonstrate that sexual stimuli, especially opposite-sex stimuli, significantly decrease ASR and, more importantly, demonstrate that levels of sexual desire have a marked influence on ASR after exposure to sexual stimuli. Specifically, participants with higher levels of sexual desire showed greater decreases in ASR while viewing opposite-sex stimuli as compared to neutral stimuli. In fact, participants with lower levels of sexual desire showed no difference in startle response between opposite-sex and neutral stimuli. This finding is novel as it suggests that sexual cues may fail to engage an appetitive, physiological response among individuals with hypoactive sexual desire. The implication of these findings is that this experimental paradigm may be used to examine the biological underpinnings of hypoactive desire as well as medications or other interventions that may restore an appetitive physiological response to sexual cues. In general, these findings extend a previous report that sexually provocative stimuli decrease ASR and that ASR after exposure to these stimuli are inversely correlated with sexual arousal and mood state (Koukounas & McCabe, 2001).

Prior research clearly implicates dopamine activity in the NA in the experience of appetitive states in general (DiChiara, 1999; Robinson & Berridge, 2000). Furthermore, it appears that the brain circuitry underlying

responsivity to drug-related stimuli is largely similar to that underlying responsiveness to other appetitive stimuli (Garavan et al., 2000; Robinson & Berridge, 2000; Schultz, 1997). Given the overall support for the role of dopamine in appetitive behavior and the study by Koch et al. (1996) that specifically evaluated the role of dopamine in the modification of startle response by appetitive stimuli, it is reasonable to suggest that the results of the current study are consistent with the notion that these mechanisms play an important role in appetitive responses to sexual stimuli among humans as well as animals.

In addition to the differences in ASR, these findings indicate that lower levels of sexual desire are generally associated with greater basal levels of PPI. This finding is consistent with studies suggesting that traits associated with long term changes in dopamine activity may also produce changes in PPI. For example, others have noted that disorders or personality traits associated with changes in dopamine function (e.g., schizophrenia) are also associated with differences in PPI (e.g., Braff, Geyer, & Swerdlow, 2001). Thus, lower levels of trait sexual desire may also be related to both lower overall dopamine function and greater PPI. However, it should be noted that the effect size for the association between sexual desire and PPI was small. In addition, it is difficult to compare the current results to those from the animal literature because of the different methodologies employed when evaluating the biological mechanisms that underlie sexual motivation in humans and in animals. Finally, the results suggest that ASR is more responsive to momentary changes in brain structures that process appetitive and emotional stimuli than is PPI. PPI may therefore be more relevant for the assessment of trait differences (as suggested by Cadenhead, Carasso, Swerdlow, Geyer, & Braff, 1999) or for the assessment of within-subjects differences after longer periods of exposure.

There are some limitations that must be considered when interpreting these results. Perhaps most obviously, the sample was limited to undergraduate introductory psychology students. Although this sample allowed for greater freedom from volunteer selection bias, it also constrained the variability of participant characteristics, including age and education level. As found by Laumann et al. (1999), rates of problems with sexual desire vary across both of these characteristics. As such, these findings may not be generalizable to a wider population, and further study is required to assess the relationship between ASR, PPI and sexual desire across both the life span and the full range of educational backgrounds. In addition, the sample consisted only of individuals who identified themselves as heterosexual. An important direction for future research is to examine how responses

may vary as a result of sexual orientation, especially given recent findings suggesting an effect for sexual orientation on PPI (Rahman, Kumari, & Wilson, 2003).

Additionally, although PPI is reliably related to dopamine, it is also affected by the activity of other neurotransmitters (e.g., GABA, 5-HT, glutamate) and, as such, the role of other neurotransmitters in these results cannot be ruled out. Similarly, it is difficult to speculate about the role of dopamine and appetitive motivation with respect to the effect of sexual stimuli on ASR. Studies employing pharmacological enhancement or blockade of dopamine activity would increase confidence that these differences are not due to factors other than variation in dopamine activity. For example, future studies might examine whether dopamine antagonism inhibits the attenuation of startle after exposure to opposite-sex stimuli among individuals with greater levels of sexual desire.

One final potential limitation is that, in the current paradigm, we did not measure sexual arousal and thus, cannot distinguish between the effects of desire and arousal. It is therefore possible that our findings are related to arousal as much as they are to desire. There is controversy in the literature such that it is commonly considered difficult to impossible to separate desire from arousal. What is important in this particular paradigm is that, as hypothesized, our data showed a clear connection between sexual desire and reduced startle magnitude. An attempt to use a similar paradigm to tease out the effects of sexual desire versus sexual arousal would be an important direction for future studies.

In conclusion, the results from this study indicate that sexual stimuli decrease ASR consistent with an appetitive response and indicate that this decrease is moderated by trait levels of sexual desire. Among participants with lower levels of sexual desire, there was no difference in startle response magnitude between sexual stimuli and neutral stimuli, suggesting a lack of appetitive response during exposure to the opposite-sex stimuli. These preliminary findings pave the way for future studies that may include pharmacological manipulations of dopamine activity to assess the role of dopamine in physiological indicators of trait levels of human sexual desire (e.g., PPI) and indicators of cue-elicited desire (e.g., ASR after exposure to sexual stimuli).

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