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Distinct Emotional and Cardiac Responses to Audio Erotica between Genders

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Abstract: Emotional and cardiac responses to audio erotica and its gender differences are relatively unclear in human sexual response. The current study was designed to investigate gender differences in positive and negative emotions to erotica as well as its association with cardiac response. Forty healthy participants (20 women) were exposed to erotic, neutral, and happy audio segments during which emotions and heart rate changes were evaluated. Our data showed distinct emotions to erotica between genders in which women reported a higher level of shame than men and rated erotic audios as less pleasant than happy ones. Meanwhile, men reported erotic and happy audios as equally pleasant. These results were independent on cardiac changes as both sexes demonstrated comparable heart rate deceleration when exposed to erotica relative to neutral and happy stimuli. Our results highlight the role of sociocultural modulation in emotional response to erotica.

Keywords: gender difference; erotica; emotions; heart rate

1. Introduction

Sexual arousal is a key component of the human sexual response which has been extensively investigated in decades (Chivers, Seto, and Blanchard 2007; Dekker and Everaerd 1988; Wincze and Qualls 1984; Van Lankveld and Van Den Hout 2004). It is generally accepted that men demonstrate higher sexual arousal and show higher concordance between physiological and subjective arousal than do women (Steinman et al. 1981; Chivers et al. 2010). However, the human sexual response is a dynamic combination of physiological, cognitive, and emotional processes, of which emotional responses to erotica and its gender differences are relatively unclear.

Erotica (or erotic stimulus) is usually known as a quality (or material) that can cause sexual desire or arousal. Exposed to erotica is associated with a range of positive and negative emotional experiences, ranging from pleasant, passionate to ashamed/embarrassed and disgusted/aversion (Peterson and Janssen 2007). Among these positive emotions, pleasure has been identified as the principle variance in emotional meaning (Mehrabian and Russell 1974; Osgood, Suci, and Tannenbaum 1957), as well as been most widely used in the study of emotional responses to erotica (Bradley, Codispoti, Cuthbert, et al. 2001; Peterson and Janssen 2007). Indeed, erotica is believed to be associated with increased pleasure as it is characterised by high level of appetitive motivation and arousal (Bradley, Codispoti, Cuthbert, et al. 2001; Peterson and Janssen 2007; Koukounas and McCabe 2001). Moreover, men tend to rate erotic stimuli as more pleasant than do women (Bradley, Codispoti, Sabatinelli, et al. 2001; Costa, Braun, and Birbaumer 2003). Interestingly, erotic

stimuli can also provoke unique negative emotions especially in women, with shame or embarrassment being most commonly evaluated (Laan and Everaerd 1995; Laan et al. 1993; Bradley, Codispoti, Sabatinelli, et al. 2001). This set of negative emotions is suggested to reflect normative expectations that women tend to report altered sex behaviours or experiences to meet these expectations (Alexander and Fisher 2003). Overall, there seems to be a gender difference in emotional patterns in the context of erotica. To date, there is no evidence to directly compare the emotional properties induced by erotic stimuli in men and women. One study demonstrated that a higher proportion of women endorsed embarrassed while men reported excited to erotic pictures (Bradley, Codispoti, Sabatinelli, et al. 2001).

It is noted that previous studies have predominantly presented visual erotic stimuli in the studies of sexual response (Costa, Braun, and Birbaumer 2003; Bradley, Codispoti, Sabatinelli, et al. 2001). Audio erotica has been barely evaluated in the context of sexual arousal or erotic emotions. Only one study presented audio narrative erotica and demonstrated similar genital responses to those induced by visual or visual-audio stimuli depicting couples engaged in sexual activities (Chivers and Timmers 2012). Specifically, both sexes demonstrated significant increases in genital response to audio erotica, with men being more selective to preferred materials (Chivers and Timmers 2012). Audio erotica is a critical component of sexual arousal and sex experience. However, our understanding of sexual arousal and emotional responses to audio erotica is highly limited.

It is also interesting to know whether different emotional response to erotica between gender is characterised by physiological changes. It is well established that exposed to erotica is associated with cardiac deceleration in the early stage indicative of orienting and sensory intake, followed by cardiac acceleration supporting defensive action (Bradley, Codispoti, Cuthbert, et al. 2001; Bradley, Codispoti, Sabatinelli, et al. 2001). One study also examined gender differences in cardiac response to erotica, with results depending on the type of stimuli. Specifically, both sexes were comparable in cardiac deceleration as well as acceleration when exposed to pictures of erotic couples, but opposite-sex erotica was associated with larger cardiac deceleration in women (Bradley, Codispoti, Sabatinelli, et al. 2001). However, it is noted that these studies employed visual erotic stimuli (Bradley, Codispoti, Cuthbert, et al. 2001; Bradley, Codispoti, Sabatinelli, et al. 2001), cardiac response to audio erotica has not been reported nor the gender differences. Compared to visual stimuli, erotic audios such as moaning and thrusting represent dynamic content of sexual experiences and may grasp at least comparable or even much more attention to visual stimuli. Exposed to erotic audios is therefore expected to be associated with cardiac deceleration to support attention orientation (Bradley, Codispoti, Cuthbert, et al. 2001).

The current study was designed to investigate gender differences in positive and negative emotions to erotica as well as the association with cardiac response. Previous studies have extensively investigated physiological arousal to erotica (Karama et al. 2002; Parada et al. 2018). Meanwhile, the current study focused on the emotional properties to erotica as well as its gender differences, which would enrich our understanding of the human sexual response. Moreover, visual erotica has been predominantly evaluated in the literature, this study uniquely presented audio erotica as it is a critical component of sexual arousal and sexual experience. It is noted that participants from Western cultures were consistently recruited in previous studies. This study recruited participants from an Eastern culture, results of which would add to the understanding of emotional response to sexual arousal across cultures. In addition, we assessed heart rate changes to evaluate physiological sexual arousal, findings from which would shed light on the possible reasons of distinct emotions to erotica between genders.

In the current investigation, healthy male and female participants were exposed to erotic, neutral, and happy audio segments while they reported the level of pleasure and shame. Happy stimuli were included as an active control condition. Electrocardiogram (ECG) was used to measure heart rate changes to the audio stimuli. We hypothesized that male and female participants would be associated with higher pleasure and shame

respectively. It is also assumed that both genders would demonstrate comparable heart rate changes as we used stimuli of erotic couples (see Bradley, Codispoti, Sabatinelli, et al. 2001).

2. Methods

2.1. Participants

Sample size calculation was performed to determine the minimum sample size needed to power a mixed ANOVA design (Faul et al. 2007). Specifically, the significant level (alpha) and power were set to 0.05 and 0.8 respectively. In order to achieve a medium effect size (Cohen's d= 0.5), a total sample of 32 was needed which determined a critical F and η_p^2 value of 4.15 and 0.2 respectively. A group of forty adults were therefore recruited in this study (age range: 18-27 years, Mean ± SD = 19.25 ± 1.81, all Han Chinese, 20 women). The determined F and η_p^2 values were comparable to those reported in the main findings.

Potential participants were recruited through flyers posted in libraries in the China West Normal University. All the participants were heterosexual by means of self-report ('heterosexual', 'homosexual', 'bisexual', 'gender non-conforming', 'transgender', 'prefer not to indicate'). In order to reduce expectancy effects, participants were told that the aim of the study was to examine heartbeat response to audio fragments. Exclusion criteria included use of psychoactive medication or a history or current diagnosis of a psychiatric disorder, as assessed by the Mini International Neuropsychiatric Interview (MINI) (Sheehan and Lecrubier 2001). Being pregnant or during menstrual bleeding were also exclusion criteria as pregnancy tends to alter sexual desire (Fernández-Carrasco et al. 2020) and menstrual phases can modulate sexual responses to erotica (Gizewski et al. 2006). All study participants provided informed consent and the experiment was approved by the Ethics Committee in the China West Normal University. This study was conducted in Sichuan, China in accordance with the Declaration of Helsinki.

2.2. Experimental Design and Procedure

A single-session, mixed design protocol was used in this study. Gender was the between-subject variable while the within-subject variable was stimuli that included erotic, neutral and happy audio fragments.

Following consent, participants were set up with the ECG recording system (see below in *ECG recordings*) and asked to adjust the volume on the earphones. Participants then underwent the audio tasks (see below in *Experimental Protocol*) in which they rated the level of pleasure and shame of the audio fragments.

2.3. Experimental Protocol

Participants underwent 3 blocks of audio task each including 6 trials. Each block started with a fixation cross for 2 seconds, which was followed by the presentation of a 5-second audio fragment (2 in each category, 6 in total). Participants were then asked to rate the level of "pleasure" ('How much do you feel pleased by the audio' as used in Bradley, Codispoti, Cuthbert, et al. (2001)) and "shame" ('How much do you feel ashamed by the audio' as used in Laan et al. (1993)) in 4 seconds of each on a scale of 0 to 10 (0-10: not at all to extremely intensive). The ratings were provided on a piece of paper that could not be seen by the experimenter. Each trial ended with a white noise lasting for 3 seconds to control carryover effects. The 6 trials included in a certain block were randomized in a way that 2 trials of the same category (e.g. erotic) were not presented consecutively. Participants took a break for 5 minutes between blocks. The experimenter was outside of the lab during the audio task to control social judgements.

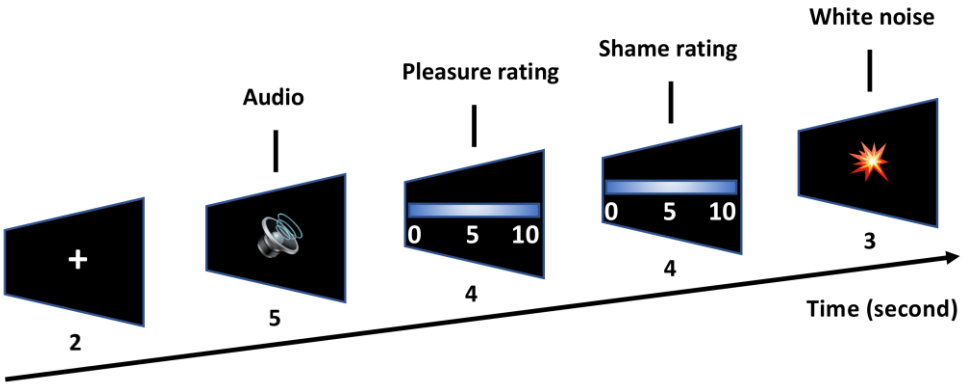


Figure 1. Experimental protocol. A single block is presented here for illustration purpose. Each block consisted of six trials with two in each stimulus category. A total of three blocks were performed.

2.4. Experimental Stimuli

Another group of nineteen participants were initially recruited to evaluate the experimental stimuli used in this study (age range: 18-33 years, Mean ± SD = 19.64 ± 2.32, all Han Chinese, 9 women). Same inclusion and exclusion criteria were used as above (see *Participants*). The experimental protocol was same to the audio tasks except that the participants were asked to rate the "valence" and "arousal" of the audio fragments. Valence describes the extent to which an emotion is positive or negative (0-10: extremely negative to extremely positive, 'Please indicate the valence of the audio'), whereas arousal refers to the strength of the associated emotional state (0-10: no arousal to extremely arousal, 'Please indicate the level of arousal of the audio') (Lang, Bradley, and Cuthbert 1997). A total of 30 audio fragments (5 blocks, 10 in each category) were extracted from the Internet. The erotic, neutral, and happy audio fragments were extracted from the free sites respectively (https://www.pornhub.com/; https://www.ximalaya.com/jiaoyupeixun/2808888/; https://sc.chinaz.com/tag_yinxiao/XiaoSheng.html). Specifically, the erotic audios were extracted which included sounds of having sex, such as moaning (mainly from women), thrusting and sounds of water. The neutral audios were extracted from sounds of Mandarin reading, such as introduction of stones, technical reports, and weather forecast. Meanwhile, the happy audios were laughter.

Chi-square tests based on the arousal data were used to select the experimental stimuli (see *Supplementary Material S1*). Specifically, P values of Chi-square tests were ranked for each stimulus. Six stimuli in each category were selected which showed the largest P values between genders. As a result, male and female participants were matched on both arousal and valence for a certain stimulus. We also compared the selected stimuli between the categories. Specifically, two-way mixed ANOVAs (gender X stimuli) and post-hoc pairwise comparisons revealed that the selected erotic and happy stimuli were comparable in arousal (P_{Bonf} = 0.99) and valence (P_{Bonf} = 0.99). As expected, both the erotic (P_{Bonf} = 0.013, M = 5.60, SD = 1.95) and happy stimuli (P_{Bonf} = 0.014, M = 5.31, SD = 2.29) showed higher arousal than the neutral stimuli (M = 3.96, SD = 2.28). The selected stimuli were also comparable in valence (P_{Bonf} = 0.99). We also tested the correlation between the valence and arousal in the selected stimuli and the results showed a significant positive correlation across stimulus categories (r = 0.43, p = 0.001).

2.5. ECG recordings

ECG was recorded using a BITalino (r)evolution Board Kit BT (BITalino, Portugal) (http://bitalino.com/en/). Three Ag/AgCl electrodes were used, with two being attached to the bilateral clavicle area within the rib cage respectively and one electrode to the lower

edge of left rib cage. Data were recorded with OpenSignals (r)evolution software (v.2017, BITalino, Portugal) in the sampling rate of 1,000 Hz.

2.6. Data Analysis

For ratings of pleasure and shame, data were averaged across trials for each participant. For the ECG data, inter-beat-interval (IBI) series were derived by Pan-Tompkins algorithm that identifies the peak of the R wave as the fiducial point (Pan and Tompkins 1985; Tian et al. 2020; Luo, Liu, and Che 2020). Artefacts were visually checked and edited if necessary, according to published guidelines (Berntson et al. 1997). IBI series were then transformed to beat-per-minute (BPM) series and baseline corrected for each trial (-2-0 second, where time 0 represents the onset of the audio clip). This method is believed to control for individual differences in baseline heart rate and to capture the dynamics of event-related heart rate change in a short period (Bradley, Codispoti, Cuthbert, et al. 2001; Che, Cash, Fitzgerald, et al. 2018). Heart rate data were then averaged across trials for each participant, and area under the curve (AUC) was calculated with the linear trapezoidal rule to measure event-related heart rate change during the presentation and evaluation of audio segments. For two female and one male participant, heart rate recordings were unavailable due to technical issues.

2.7. Statistical Analyses

Using SPSS (version 23; IBM Corp, Armonk, NY), mixed two-way ANOVAs were performed to examine the main and interaction effects of gender (men, women) and stimuli (erotic, neutral and happy) on ratings of pleasure and shame as well as on AUC of heart rate changes. Post-hoc pairwise comparisons were then conducted to explore the significant main and interaction effects, with a Bonferroni correction and α-level set to 0.05. It is noted that we divided the original alpha level (0.05) by the number of comparisons in Bonferroni corrections (e.g. 0.05/3 in the comparisons of a 3-level stimuli). We also performed a series of bivariate correlation analyses between cardiac changes and pleasure as well as shame, both across genders and in each gender group.

2.8. Supplementary Analysis

As both genders appeared to demonstrate different dynamics in heart rate changes when exposed to erotic segments, we further performed a mixed two-way ANOVA on heart rate changes. Specifically, gender (men, women) and time (baseline, image presentation, during pleasure rating, during shame rating) were specified as the between-group and within-group factor respectively. The same method was also applied to the neutral and happy stimuli.

3. Results

3.1. Pleasure Ratings

As shown in Fig. 2A and Table 1, the two-way ANOVA revealed a significant gender × stimuli interaction effect on pleasure ratings ($F_{2,76} = 4.13$, $P = 0.026$, $\eta_p^2 = 0.098$). Post-hoc pairwise comparisons indicated that women reported higher pleasure to happy stimuli ($M = 5.55$, $SD = 2.57$) compared to erotic ($P_{Bonf} = 0.007$, $M = 2.86$, $SD = 2.67$) and neutral stimuli ($P_{Bonf} = 0.013$, $M = 3.29$, $SD = 2.58$). Meanwhile, male participants reported higher pleasure to happy ($P_{Bonf} = 0.016$, $M = 4.47$, $SD = 2.13$) and erotic ($P_{Bonf} = 0.016$, $M = 4.43$, $SD = 1.73$) stimuli compared to neutral stimuli ($M = 2.43$, $SD = 2.05$).

Table 1. Summaries of ANOVA results.

Source	*df*	Mean square	*F*	*p*	η_p^2
(Pleasure ratings)					
Gender	1	0.47	0.09	0.770	0.00
Stimuli	2	47.33	8.98	0.000***	0.19
Gender x Stimuli	2	21.79	4.13	0.026*	0.10
(Shame ratings)					
Gender	1	7.33	2.38	0.130	0.06
Stimuli	2	371.59	180.83	0.000***	0.83
Gender x Stimuli	2	18.66	9.08	0.003**	0.19
(Heart Rate-during image presentation)					
Gender	1	2.84	0.58	0.450	0.02
Stimuli	2	30.99	7.66	0.002**	0.18
Gender x Stimuli	2	0.02	0.01	0.990	0.00
(Heart Rate-during pleasure rating)					
Gender	1	23.98	2.26	0.142	0.06
Stimuli	2	157.09	18.43	0.000***	0.35
Gender x Stimuli	2	1.88	0.22	0.784	0.01
(Heart Rate-during shame rating)					
Gender	1	1.29	0.15	0.698	0.00
Stimuli	2	129.05	18.10	0.000***	0.34
Gender x Stimuli	2	5.86	0.82	0.442	0.02

* denotes $P < 0.05$; ** denotes $P < 0.01$; *** denotes $P < 0.001$

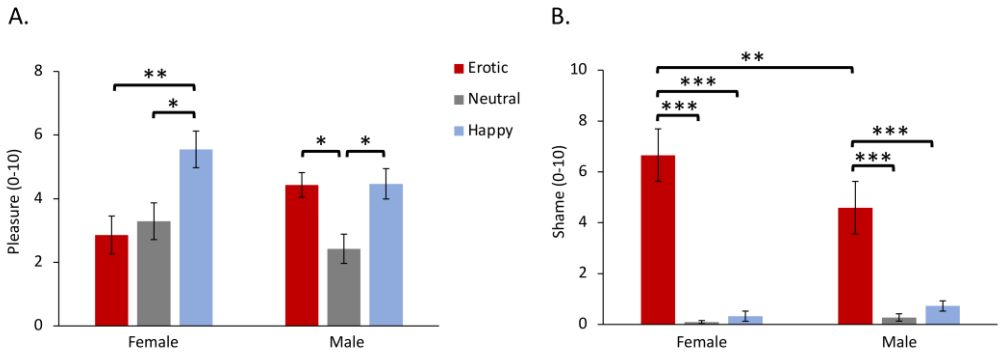


Figure 2. Self-reported pleasure (A) and shame (B) as a function of gender and stimuli. *$P \leq 0.05$, **$P \leq 0.01$, ***$P \leq 0.001$.

3.2. Shame Ratings

The two-way ANOVA revealed a significant gender × stimuli interaction effect on shame ratings ($F_{2,76} = 9.08$, $P = 0.003$, $\eta_p^2 = 0.19$) (Fig. 2B and Table 1). Post-hoc pairwise comparisons showed that erotic stimuli (women: $M = 6.66$, $SD = 2.27$, men: $M = 4.59$, $SD = 2.44$) induced higher shame compared to neutral (women: $P_{Bonf} = 0.001$, $M = 0.09$, $SD = 0.27$, men: $P_{Bonf} = 0.001$, $M = 0.27$, $SD = 0.65$) and happy (women: $P_{Bonf} = 0.001$, $M = 0.32$, $SD = 0.78$, men: $P_{Bonf} = 0.001$, $M = 0.73$, $SD = 1.48$) stimuli in both genders. Moreover, women ($M = 6.66$, $SD = 2.27$) reported higher shame compared to men ($M = 4.59$, $SD = 2.44$) in response to erotic stimuli ($P_{Bonf} = 0.01$).

3.3. Heart Rate Changes

Fig. 3A demonstrated the dynamic heart rate deceleration induced by different stimuli. For the image presentation stage, a two-way ANOVA revealed a main effect of stimuli on heart rate change ($F_{2,70} = 7.66$, $P = 0.002$, $\eta_p^2 = 0.18$) (Fig. 3B and Table 1). Post-hoc pairwise comparisons indicated that erotic stimuli ($M = -2.13$, $SD = 2.31$) induced a larger heart rate deceleration compared to neutral ($P_{Bonf} = 0.016$, $M = -0.93$, $SD = 1.89$) and happy stimuli ($P_{Bonf} = 0.007$, $M = -0.44$, $SD = 1.76$) regardless of gender. Heart rate changes were not associated with the level of pleasure or shame (all $P > 0.05$).

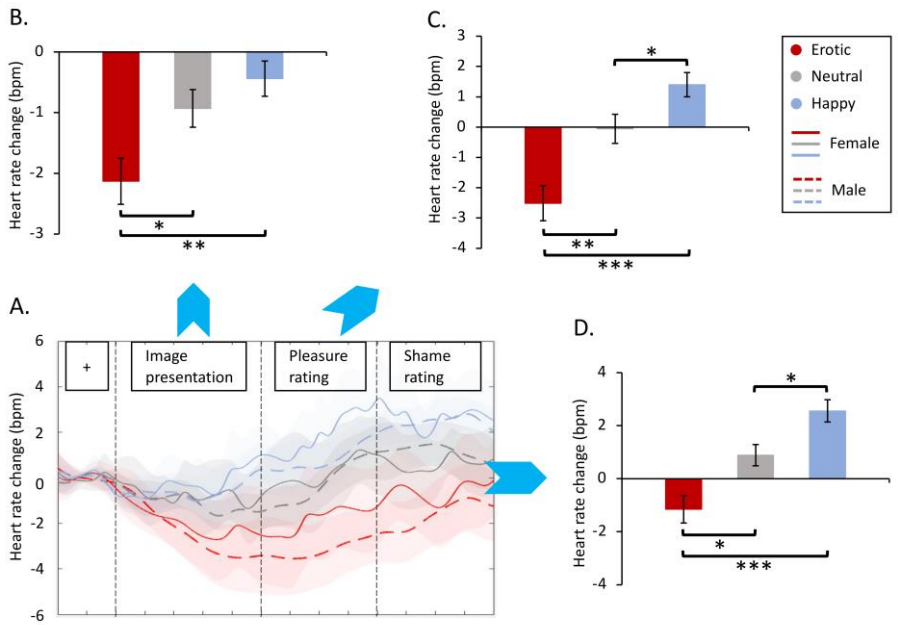


Figure 3. Heart rate results. (A) Heart rate dynamics across gender groups and stimuli. (B-D) indicated heart rate statistics in the image presentation, pleasure rating, as well as shame rating phases respectively. Dashed lines outline these phases. bpm denotes beat-per-minute, *$P \leq 0.05$, **$P \leq 0.01$, ***$P \leq 0.001$.

During pleasure rating, a two-way ANOVA revealed a main effect of stimuli on heart rate change ($F_{2,70} = 18.43$, $P = 0.000$, $\eta_p^2 = 0.35$) (Fig. 3C and Table 1). Post-hoc pairwise comparisons indicated that erotic stimuli ($M = -2.51$, $SD = 3.53$) induced a larger heart rate deceleration compared to neutral ($P_{Bonf} = 0.003$, $M = -0.06$, $SD = 2.92$) and happy stimuli ($P_{Bonf} = 0.000$, $M = 1.40$, $SD = 2.31$) regardless of gender. Happy stimuli ($M = 1.40$, $SD = 2.31$) also induced increased heart rate compared to neutral stimuli ($P_{Bonf} = 0.035$, $M = -0.06$, $SD = 2.92$).

During shame rating, a two-way ANOVA also revealed a main effect of stimuli on heart rate change ($F_{2,70} = 18.10$, $P = 0.000$, $\eta_p^2 = 0.34$) (Fig. 3D and Table 1). Post-hoc pairwise comparisons indicated that erotic stimuli ($M = -1.15$, $SD = 3.16$) induced a larger heart rate deceleration compared to neutral ($P_{Bonf} = 0.011$, $M = 0.89$, $SD = 2.43$) and happy stimuli ($P_{Bonf} = 0.000$, $M = 2.56$, $SD = 2.55$) regardless of gender. Happy stimuli ($M = 2.56$, $SD = 2.55$) also induced increased heart rate compared to neutral stimuli ($P_{Bonf} = 0.024$, $M = 0.89$, $SD = 2.43$).

3.4. Supplementary Results

A mixed ANOVA revealed no gender × time interaction effect on the erotic data ($F_{3,105} = 0.94$, $P = 0.398$, $\eta_p^2 = 0.03$), suggesting that both genders were comparable in heart rate deceleration when exposed to erotic stimuli. There was only a time effect ($F_{3,105} = 9$, 12,95, $P = 0.000$, $\eta_p^2 = 0.27$), which indicated that heart rate was decelerating across genders.

4. Discussion

The current study was designed to investigate gender differences in emotional response to erotica. Audio erotica was uniquely presented which is a key component of human sexual arousal and sexual experience. Our results demonstrated distinct emotions to erotica between genders, with women reporting a higher level of shame compared to men and rated erotic stimuli as neutral. Meanwhile, men tended to feel more pleasant when exposed to erotic relative to neutral stimuli. Cardiac data indicated that both genders showed comparable heart rate deceleration to erotica compared to neutral and happy stimuli.

Compared to men, women reported higher level of shame in the context of erotica (Fig. 2B). Previous studies indicated that women tend to experience unique negative emotions to erotic stimuli, such as shame and embarrassment (Bradley, Codispoti, Sabatinelli, et al. 2001; Laan et al. 1993; Laan and Everaerd 1995). Our findings extended these results by demonstrating that both sexes could be ashamed of erotica, and more interestingly, that women tend to feel more ashamed than men. Possible reasons for this distinction are discussed later.

In terms of pleasure, women reported erotic stimuli as equally pleasant as neutral ones (Fig. 1A). This is consistent with the finding that women tended to rate erotic pictures as neutral (Costa, Braun, and Birbaumer 2003). However, contrary to our hypothesis, men did not report higher pleasure to erotic stimuli than women in our data. The literature indicated that men felt more pleasant when exposed to erotica compared to women (Costa, Braun, and Birbaumer 2003; Bradley, Codispoti, Sabatinelli, et al. 2001). Although our result suggested that both sexes were different in reported pleasure to some extent ($M_{men} = 4.43$, $M_{women} = 2.86$), it did not reach significance. It is possible that male participants did not favour the erotic audios used in this study that much and therefore reported medium pleasure. Indeed, the selection of stimuli could modulate sexual response in men (Huberman and Chivers 2015; Chivers and Timmers 2012).

More interestingly, men reported erotic stimuli to be equally pleasant as happy ones, while women rated happy stimuli to be more pleasant than erotic stimuli. It is widely accepted that men have higher sexual desire (Baumeister, Catanese, and Vohs 2001; Peplau 2003), sexual arousal (Janssen, Carpenter, and Graham 2003; Parada et al. 2018), and thus report erotica as more pleasant (Costa, Braun, and Birbaumer 2003). However, women's sexual response is shaped by contextual (e.g. commitment) and social (culture, beliefs) factors to a larger extent (Peplau 2003; Dewitte 2015). Our data of the cardiac response may provide further evidence on this argument. Specifically, two sexes showed comparable heart rate deceleration to erotica compared to the control stimuli (Fig. 3). Heart rate deceleration is believed to support orienting and sensory intake to external stimuli (Bradley, Codispoti, Cuthbert, et al. 2001; Lang 1995; Lang, Bradley, and Cuthbert 1997). Moreover, heart rate changes were not associated with either pleasure or shame whatsoever. Therefore, both genders may demonstrate equal bodily involvement in the erotic stimuli, suggesting that the distinct emotional patterns between sexes may be a result of other processes.

One possibility is that women's sexual response is influenced by social desirability and social expectation. Women tend to show lower concordance between increased genital arousal and self-reported sexual arousal (Steinman et al. 1981; Chivers et al. 2010). Furthermore, gender difference in self-reported sexual behaviours were most prominent in a threat context whereby the experimenter could potentially view participant's response, especially for behaviours considered less acceptable for women than men (e.g. masturbation) (Alexander and Fisher 2003). Our data indicated that both sexes were equally engaged in the erotic stimuli, but women reported higher level of shame than men and preferred happy audios more than erotic ones. These findings together highlight the significance of sociocultural factors in shaping women's sexual response. Indeed, it is proposed that gender differences in sexuality may mirror sex roles and individuals may alter their self-presentations to meet these roles (Alexander and Fisher 2003; Eagly 2013).

Men and women also differ in neural responses to erotica which may be associated with distinct emotional responses. Although both sexes showed similar patterns in brain activation to erotica (Parada et al. 2018; Karama et al. 2002), men demonstrated increased brain activation in the amygdala than women (Hamann et al. 2004). Meanwhile, women showed increased brain activity mainly in the cingulate and insular cortex (Parada et al. 2018). These findings indicated that men may attribute a greater appetitive incentive value to erotica, while exposed to erotica may be associated with more interoceptive awareness in women.

It is noted that distinct emotional patterns to erotica between sexes may result from a combination of both sociocultural and neural modulation. Emotions are believed to be products of neuronal firing which is also shaped by social and environmental contexts. It is also important to consider the role of hormones in the association between physiological and emotional responses to erotica in our data. Kisspeptin, a family of peptide hormones cleaved from the product of the Kiss1 gene, is believed to be potential in fulfilling this role. Human studies indicated that kisspeptin signaling may be able to integrate sensory processing with limbic pathways involved in sexual arousal and mood (Comninos et al. 2017; Comninos and Dhillo 2018). Besides, other endocrine mediators including oxytocin, cortisol, and vasopressin are of great importance in integrating physiological reproductive processed with essential emotions (Yang, Comninos, and Dhillo 2018).

We also presented interesting cardiac response in the phase of emotional evaluation (Fig. 3C-D). Previous studies generally demonstrated cardiac response during the presentation of erotic stimuli (Bradley, Codispoti, Cuthbert, et al. 2001; Bradley, Codispoti, Sabatinelli, et al. 2001). Our study extended the time window and showed heart rate acceleration especially in the evaluation of positive stimuli. This finding may not be associated with movement as it was unique to positive stimuli. Cardiac acceleration in the rating of positive stimuli is potentially indicative of positive emotions.

There are some limitations in the study. Sexual experience is suggested to affect sexual responses (Hally and Pollack 1993), but we were not able to examine the influence of sexual experience on our findings as there were only a few participants (2 women and 3 men) who reported having sexual experience. Other factors such as religions and beliefs may also have an impact on emotional responses to erotica which needs to be evaluated in this context. It also indicates that erotic audios and images may not employ the exact same pathways for sexual arousal. Moreover, the experimental materials were slightly different in terms of verbal content (e.g. sounds of having sex vs. sounds of Mandarin reading vs. laughter), which might be a potential confound of the findings. Nonetheless, our statistics indicated that the erotic and happy stimuli were comparable in arousal and valence and that all three types of stimulus were matched in valence. Although the experimenter was outside of the lab in order to control social desirability, we did not provide an objective measure of social desirability (e.g. Marlowe-Crowne Social Desirability Scale) (Crowne and Marlowe 1960). This could be a potential confound as the mere presence of another person could modulate participants' response (Cottrell et al. 1968; Che, Cash, Chung, et al. 2018). In consistent with previous studies (Laan et al. 1993; Bradley, Codispoti, Cuthbert, et al. 2001), self-reported pleasure and shame were evaluated in the current study. Although we have demonstrated consistent findings as these studies, it is acknowledged that self-reported pleasure and shame were based on single item respectively, which did not allow to evaluate the reliability using Cronbach's alpha.

Findings from this study may have implications for future investigations. There is evidence that women demonstrated genital arousal to both preferred and nonpreferred gender, while men reported higher sexual arousal to female stimuli (Peterson, Janssen, and Laan 2010; Chivers et al. 2004). Erotic audios used in this study were composed of moaning of women mostly, followed by men's moaning and sounds of thrusting and water. We present unique emotions to erotica in men and women, characterised by more pleasure and shame respectively. Future studies may wish to further characterise this pattern of emotions in exact contents of erotica, e.g. erotic couples, same- and opposite-sex erotic stimuli. We evaluated the two most often used emotions (e.g. pleasure and shame), leaving other related emotional experiences to be assessed in future studies, such as passionate, interested, aversion/disgust. Findings on a range of emotions would provide a more overall picture of human emotional response to sexual arousal. It is noted that our participants had an Eastern background which may be more conservative on the expression of sexual emotions. It would be interesting for future studies to directly compare the expression of sexual emotions between cultures.

To conclude, we demonstrate distinct patterns of emotional response to audio erotica between genders. Moreover, this effect is independent on cardiac deceleration indicating the level of engagement in erotica. Our findings may add to our understanding on sexual response as well as its gender differences by highlighting distinct emotions to audio erotica.

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