

Uncovering category specificity of genital sexual arousal in women: The critical role of analytic technique

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Abstract

Based on analytic techniques that collapse data into a single average value, it has been reported that women lack category specificity and show genital sexual arousal to a large range of sexual stimuli including those that both match and do not match their self-reported sexual interests. These findings may be a methodological artifact of the way in which data are analyzed. This study examined whether using an analytic technique that models data over time would yield different results. Across two studies, heterosexual ($N = 19$) and lesbian ($N = 14$) women viewed erotic films featuring heterosexual, lesbian, and gay male couples, respectively, as their physiological sexual arousal was assessed with vaginal photoplethysmography. Data analysis with traditional methods comparing average genital arousal between films failed to detect specificity of genital arousal for either group. When data were analyzed with smoothing regression splines and a within-subjects approach, both heterosexual and lesbian women demonstrated different patterns of genital sexual arousal to the different types of erotic films, suggesting that sophisticated statistical techniques may be necessary to more fully understand women's genital sexual arousal response. Heterosexual women showed category-specific genital sexual arousal. Lesbian women showed higher arousal to the heterosexual film than the other films. However, within subjects, lesbian women showed significantly different arousal responses suggesting that lesbian women's genital arousal discriminates between different categories of stimuli at the individual level. Implications for the future use of vaginal photoplethysmography as a diagnostic tool of sexual preferences in clinical and forensic settings are discussed.

Descriptors: Sex/gender differences, Arousal, Analysis/statistical methods, Blood flow

Category specificity refers to showing genital sexual arousal to erotic stimuli that match one's sexual preferences, and failing to respond to stimuli that do not match one's sexual preferences. Sexual stimuli or cues that match sexual interests are referred to as *preferred cues*, and those that do not match are referred to as *nonpreferred cues*. Specificity of genital sexual arousal is typically assessed by comparing genital responses to a series of preferred versus nonpreferred sexual cues. In men, genital sexual arousal is typically measured with penile plethysmography using a mercury-in-rubber strain gauge that tracks penile tumescence (erection). Penile plethysmography has been shown to be reliable and valid for the assessment of men's genital sexual arousal (Geer & Janssen, 2000; Rosen & Keefe, 1978). In women, genital sexual arousal is typically measured with vaginal photoplethysmography, which consists of a tampon-shaped device inserted into the vagina that measures vaginal blood volume and vaginal pulse amplitude (VPA), the latter of which has been shown to be a sensitive and reliable index of women's genital sexual arousal (Laan, Everaerd,

& Evers, 1995). In both sexes, the unaroused genitals contain a resting level of blood; therefore, baseline arousal to a neutral stimulus must be recorded prior to the presentation of each erotic stimulus in laboratory studies. Genital arousal response is defined as the change in arousal over time from the neutral to the erotic stimulus and is usually calculated by subtracting the average arousal to the neutral film from the average arousal to the erotic film.

In studies on the category specificity of genital sexual arousal, sets of neutral and erotic film clips are presented featuring couples of different sexual orientations (such as a heterosexual couple or a lesbian couple), and subjects self-report their sexual preferences (such as sexual orientation). Arousal to each type of erotic film is averaged and then compared between stimulus categories. Category specificity refers to showing significantly higher genital arousal to erotic cues that match one's self-reported sexual preferences than to cues that do not match one's sexual preferences. Lack of specificity refers to showing equivalent genital sexual arousal to all categories of erotic cues regardless of the match between the content of the cues and one's self-reported sexual preferences.

There are two statistical methods currently used for evaluating the specificity of genital sexual arousal: (1) change in mean or max genital arousal (Bossio, Spape, Lykins, & Chivers, 2014; Bossio, Suschinsky, Puts, & Chivers, 2014; Chivers & Bailey, 2005;

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Chivers, Seto, & Blanchard, 2007; Laan et al., 1995), and (2) category specificity index or contrast score (Chivers, Rieger, Latty, & Bailey, 2004; Peterson, Janssen, & Laan, 2010; Suschinsky, Lalumière, & Chivers, 2009). Data reduction for these methods involves the binning of the data by time, such as 5- or 10-s intervals, to reduce the total number of data points, or by using all of the raw data itself.

The most widely used method of assessing category specificity is to compare the change in mean penile circumference or VPA between stimulus categories. Comparison of the change in mean genital arousal can be completed with analysis of covariance (ANCOVA) tests on the standardized mean arousal to the erotic stimuli, using the standardized mean arousal to the neutral stimuli preceding the erotic stimuli as covariates (Chivers & Bailey, 2005; Laan et al., 1995). Alternatively, some researchers have calculated the change in mean penile circumference/VPA by subtracting the mean penile circumference/VPA to the neutral film (from either the entire neutral film or the end portion of the neutral film) from the mean penile circumference/VPA to the erotic film, for each set of films. Resulting values are then standardized within subjects and compared between stimulus categories. Many studies have used the change in mean penile circumference/VPA as their outcome variable (Bossio, Spape et al., 2014; Bossio, Suschinsky et al., 2014; Chivers et al., 2007). In a few studies, researchers have used maximum penile circumference/VPA (the single largest penile circumference/VPA peak from the erotic film section) rather than mean penile circumference/VPA to compute this statistic (Suschinsky & Lalumière, 2011a,b; Suschinsky et al., 2009).

An alternative method for evaluating category specificity is to create a category specificity index or contrast score, which has also been called a standardized penile circumference/VPA difference score. For this approach, change in average penile circumference/VPA (the statistic discussed above) is calculated by subtracting the mean arousal to the neutral film from the mean arousal to the erotic film for each film category, and the resulting values are standardized within subjects. The index is created by subtracting the standardized change in mean penile circumference/VPA for one category from the standardized change in mean penile circumference/VPA for another category, such that positive values indicate higher arousal to the first category and negative values indicate higher arousal to the second category. For example, when assessing genital sexual arousal to films featuring heterosexual and lesbian couples, change in mean penile circumference/VPA to the lesbian film is subtracted from the change in mean penile circumference/VPA to the heterosexual film, such that positive values indicate greater arousal to the heterosexual film and negative values indicate greater arousal to the lesbian film. The category specificity index can be created with any two categories of preferred and non-preferred erotic stimuli. A number of studies have used the category specificity index for data analysis (Chivers et al., 2004; Peterson et al., 2010; Suschinsky et al., 2009). Common to both change in mean penile circumference/VPA and the category specificity index is a reliance on the average genital arousal response to each type of stimulus category, which condenses the rich penile circumference/VPA data to a single value and fails to take into account the pattern of genital arousal over time.

Based on analytic approaches that rely on the average genital arousal to erotic cues, studies have provided evidence for category specificity in men. For example, men only show genital sexual arousal to erotic cues of their preferred sexual orientation; they do not respond genitally to nonpreferred cues (Chivers & Bailey, 2005; Chivers et al., 2004). Also, men with a history of committing

sexual assault show greater genital sexual arousal to sexual threat stimuli than consensual sexual stimuli (Harris, Lalumière, Seto, Rice, & Chaplin, 2012; Lalumière & Quinsey, 1994; Lohr, Adams, & Davis, 1997). Men with pedophilic disorder show greater genital sexual arousal to sexual stimuli featuring children than those featuring adults (Blanchard, Klassen, Dickey, Kuban, & Blak, 2001; Seto, 2004).

The same analytic techniques relying on the average genital response have demonstrated a lack of category specificity in women. Women show genital sexual arousal to both preferred and nonpreferred cues for sexual orientation (Chivers et al., 2004, 2007; Suschinsky, Lalumière, & Chivers, 2009), to nonhuman primates engaged in sexual activity (Chivers & Bailey, 2005; Chivers et al., 2007), and stimuli depicting sexual assault (Both, Everaerd, & Laan, 2003; Laan et al., 1995; Suschinsky & Lalumière, 2011b; Suschinsky et al., 2009). The apparent lack of specificity in women's genital sexual arousal has led to much discussion in the literature over the past decade on this purported sex difference. If women truly lack specificity of genital sexual arousal, it may suggest that women's sexual arousal is more flexible than men's, perhaps as a result of broader gender roles for women than for men (Baumeister, 2000; Suschinsky et al., 2009). Yet, to our knowledge, the flexibility explanation for the lack of specificity in women's genital sexual arousal has not been tested empirically.

The preparation hypothesis, which also attempts to account for the lack of specificity in women's genital sexual arousal, posits that women show an automatic genital sexual arousal response to the presentation of sexual stimuli as an evolutionary adaptation to protect their reproductive organs if any type of vaginal penetration (consensual or nonconsensual) is to occur (Suschinsky & Lalumière, 2011b). The characterization of women's genital arousal as an automatic response has been supported (Basson et al., 2003; Laan & Everaerd, 1995; Laan, Everaerd, Van Aanholt, & Rebel, 1993), with research indicating that women's genital sexual arousal begins within seconds of the presentation of a visual erotic stimulus (Laan & Janssen, 2007). Some women who have experienced sexual assault report genital sexual arousal during the attack (Levin & van Berlo, 2004), an experience that can be accounted for by the preparation hypothesis. Empirical research on the preparation hypothesis has been mixed, with some studies supporting this idea (Laan et al., 1995; Suschinsky & Lalumière, 2011b; Suschinsky et al., 2009), yet others failing to support its predictions (Dawson, Suschinsky, & Lalumière, 2013). Dawson and colleagues examined genital arousal to repeated presentations of a sexual stimulus and found that both men and women showed habituation of genital arousal, contrary to the predictions of the preparation hypothesis that women's arousal response would fail to habituate. The notion that women show a reflexive genital arousal response to erotic stimuli suggests that differences in women's genital arousal to preferred versus nonpreferred sexual cues might be more subtle than differences in men's genital arousal to erotic cues. Therefore, testing for category specificity in women's genital sexual arousal may require a more sensitive analytic approach. Although the preparation hypothesis posits an initial reflexive genital arousal response to erotic stimuli, it does not describe the maintenance of this response. It is possible that women show an automatic genital arousal response to a wide range of sexual stimuli, yet the maintenance of that response over time varies by women's sexual preferences. This question remains unanswered, as studies tend to focus on the average genital arousal response rather than the pattern of arousal response over time.

We propose that the reported lack of category specificity observed in women is an artifact of the analytic approaches used to evaluate this construct. To our knowledge, all previous studies testing category specificity in women have used some variant of average genital arousal for analyses. Average genital arousal is an oversimplification of vaginal photoplethysmograph data, which is typically recorded at 80 to 200 times per second, resulting in hundreds of thousands of data points per subject. Viewed in that context, the average is the most basic statistical index, is easily skewed by outliers, and fails to reflect variability in data. More sophisticated analytic approaches that take all data points into account and model data over time might shed new light on the specificity of women's genital sexual arousal. One such method uses smoothing regression splines, a nonparametric regression technique that models the trajectory of data over time. In this study, heterosexual women's genital sexual arousal was assessed in response to films featuring male-female (hereafter referred to as heterosexual), female-female (referred to as lesbian), and male-male (referred to as gay male) couples engaged in sexual activity and intercourse. Data were analyzed with traditional statistics (change in mean VPA and category specificity index) and smoothing regression splines. Smoothing splines isolate two independent components of the sexual arousal response: overall level of arousal and trajectory of arousal over time. We hypothesize that the traditional statistics will fail to reveal a difference in genital arousal between films, but that the smoothing spline analyses will show that women have an overall higher level and different trajectory of arousal to the heterosexual film than either the lesbian or gay male films.

Study 1

Method

Participants. Participants were adult women recruited from the local community. Recruitment materials described a research study on women's sexual arousal, and interested participants called the laboratory to complete a confidential phone screen. Inclusion criteria included a minimum of 18 years of age, exclusively or predominantly heterosexual, and sexually functional. Sexual function status was determined during the phone screening by asking participants if they were experiencing problems with sexual desire, arousal, orgasm, or pain. Only women who denied sexual dysfunction were included in the study. Exclusion criteria included currently experiencing menopause or perimenopause; history of sexually transmitted diseases or current pelvic, vaginal, or urinary tract infection; history of a psychotic disorder; and taking any prescription medication shown to have sexual side effects that could affect the genital arousal response, including antidepressants, benzodiazepines, and beta blockers (Rosen & Kostis, 1985; Serretti & Chiesa, 2009).

The current sample included 19 heterosexual women aged 18 to 28, with an average age of 21.21 ($SD = 2.64$). Fourteen women identified as exclusively heterosexual and five identified as predominantly heterosexual. The majority of women had completed some college (79%), 10.5% had completed college, and 10.5% held an advanced degree. The sample was approximately equally split between single women (47%) and women who were married or in a committed relationship (53%). Thirty-seven percent of the sample was Caucasian, 26% was Hispanic, 21% was African American/Black, 10% identified as biracial, and 5% was Pacific Islander.

Measures. Physiological data were collected with vaginal photoplethysmography and electrocardiography (ECG) equipment. During the stimulus presentation, VPA was sampled at a rate of 200 samples/second throughout the film, band-pass filtered (0.5–30 Hz), and recorded on an MP100 data acquisition unit using the AcqKnowledge 3.9.1 software (Biopac Systems, Inc., Santa Barbara, CA). VPA data were recorded in millivolts. Heart rate was assessed with a three-lead ECG with disposable electrodes positioned by the experimenter on the participant's upper right chest, lower left chest, and inner right ankle. ECG data were collected to identify peaks in the VPA data and to help with the identification of movement artifacts.

Subjective sexual arousal was assessed with an adapted version of the film scale (Heiman & Rowland, 1983). The adapted measure included three items (mental sexual arousal, sexually aroused, and sexually turned off) that measured subjective sexual arousal on a 7-point Likert scale indicating *not at all* to *intensely*.

Background characteristics were collected with a demographics questionnaire assessing age, education, relationship status and duration, and ethnicity/race.

Sexual orientation was assessed with the Kinsey Scale (Kinsey, Pomeroy, Martin, & Gebhard, 1953), a single-item self-report measure of sexual orientation. This Likert-type scale asks participants to rate their sexual orientation based on both their subjective reactions and overt sexual experiences from exclusively heterosexual to exclusively lesbian. For the purposes of this study, only women who identified as exclusively or predominantly heterosexual were eligible to participate.

Stimulus materials. Three 10-min audiovisual films were used as stimulus materials in this study. Each film included a neutral film clip and an erotic film clip. The erotic film clips featured a heterosexual, lesbian, and gay male couple, respectively. Each film included a 1-min presentation of the word "relax," a 3-min neutral film showing images of nature and landscapes accompanied by classical music, and a 6-min erotic film showing 2 min each of foreplay, oral sex (cunnilingus in the heterosexual and lesbian films, and fellatio in the gay male film), and penetrative sex (vaginal intercourse in the heterosexual and lesbian films, with a strap-on sex toy used in the lesbian film, and anal sex in the gay male film). The films featuring heterosexual and lesbian couples were selected from female-produced erotica, as erotic films produced by women have been shown to be more appealing to women (Laan, Everaerd, Bellen, & Hanewald, 1994). The film featuring a gay male couple was selected from commercially available erotic films to match the heterosexual and lesbian films as much as possible in terms of intensity and positions of sexual activity.

Procedure. Participants were tested individually by a female research administrator. The administrator explained the study procedures and obtained informed consent. Then, the administrator positioned the ECG pads on the participant and left the room. For the rest of the session, the administrator and participant communicated through an intercom system. The participant inserted the vaginal probe and attached the ECG leads to the electropads. Then, the participant watched the three erotic films in randomized counterbalanced order as physiological sexual arousal was assessed. After each film, the participant completed the self-report measure of subjective sexual arousal, and completed distractor tasks (i.e., math problems) for 5 min to allow arousal to return to baseline. After all three films, the participant completed the demographics questionnaires and then

removed the equipment. Participants were compensated monetarily for their time.

Data analysis.

Data reduction. VPA was measured by the amplitude from the peak to the trough of each waveform. VPA and ECG data were exported from AcqKnowledge 3.9.3 to Microsoft Excel for processing. Participant movement during the film, including contraction of the pelvic muscles, creates artifacts in the physiological data that must be removed prior to analyses (Laan et al., 1995). Movement artifacts were identified and removed by an automatic processing procedure developed in our laboratory and shown to process data more accurately than visual inspection (Pulverman, Meston, & Hixon, 2015). When the automated procedure was compared with the traditional approach of visual inspection of the data and manual removal of artifacts, typically utilized in studies on category specificity (e.g., Chivers et al., 2007), the automatic procedure was found to identify artifacts at a comparable rate to visual inspection and to retain more of the original data than the visual inspection method (Pulverman et al., 2015). The automatic procedure was programmed and executed in the open source R software environment (R Foundation, 2014).

Raw VPA and ECG data from Excel were loaded into the automatic processing procedure in the R software environment, which identifies the heart rate peaks in the ECG data. The procedure calculates the mean and standard deviation of heart rate peaks and conducts a Bonferroni adjusted (alpha of .05) outlier test on the time interval between peaks to identify movement artifacts in the ECG data (which also indicate artifacts in the VPA data). These spurious heart rate peaks and associated VPA values are removed from the data file. Then, the valid heart rate peaks are used to identify the highest VPA value between heart rate peaks (i.e., the VPA peaks). Next, the procedure uses a standard generalized cross-validated smoothing spline to create a smooth trajectory through all of the VPA data, and residuals between the data points and the smoothing spline are calculated. Residuals are used to compute z scores for each VPA peak, which are converted to probability values that each data point is an artifact. Data points with probability values less than $1/N$, with N being the total number of VPA peaks in the data file, are identified as artifact. Artifacts are removed from the data set and the data is modeled again, and this process continues until all of the significant artifacts have been removed. Data files for each subject were processed with the automated artifact detection procedure.

Traditional methods. Change in mean VPA from the neutral to the erotic film was calculated for each film by subtracting the mean VPA during the neutral film from the mean VPA during the erotic film. Resulting values were standardized within subjects and compared with repeated measures analysis of variance (ANOVA) tests.

Category specificity index was calculated according to the method used in previous research (Chivers et al., 2004; Suschinsky et al., 2009) by subtracting the change in mean arousal to one film category from the change in mean arousal to another film category. In order to compare arousal to the three films, three separate category specificity indices were computed: the heterosexual/lesbian contrast, the heterosexual/gay contrast, and the lesbian/gay contrast. For these statistics, positive values indicate higher arousal to the first film category and negative values indicate higher arousal to the second film category. For each category specificity index, the mean, standard deviation, and range are reported. The three

category specificity indices were compared with repeated measures ANOVA tests.

Smoothing regression splines. Smoothing regression splines are a nonparametric regression technique that models data over time by constructing a flexible trajectory through all data points. This trajectory balances the fit between data points with the number of bends in the trajectory to provide a highly accurate model of the data. We used a standard generalized cross-validated smoothing spline to create a smooth trajectory through all of the VPA data points using the *mgcv* package (Wood, 2006, 2011) in the open source R software environment (R Foundation, 2014). The degree of smoothing was selected via generalized cross validation, which (among other things) approximates the well-known Akaike Information Criterion (AIC; Akaike, 1974), used for optimal model selection.

Data were sampled at a rate of 200 Hz, or 200 readings per second, which resulted in a data file with approximately 120,000 VPA readings for each subject (200 readings per second for 10 min of film). The automatic data processing procedure identified the VPA peaks for each subject. After processing, each subject had approximately 600 VPA peaks (i.e., data points) per film. In order to make data files more manageable, VPA data were binned by 5-s intervals, resulting in 72 data points for each 6-min erotic film (216 data points total per subject). To allow for potential differences between both films and subjects to manifest, VPA mean and standard deviation were calculated across the three film categories together. Data were standardized within each subject using each subject's mean and standard deviation across all three films combined.

In order to test for main effects of film and subject, as well as the interaction of film and subject, coding terms were constructed to represent each of film type, subject, and their interaction (the unique combination of film and subject). VPA data are time oriented, and with time-oriented data, serial dependency is often an issue. Such serial dependency produces autocorrelated errors, which if unaccounted for will artificially reduce standard errors for model coefficients and overstate statistical significance. To account for serial dependency, we incorporated a lagged term whereby each outcome datum serves as an independent predictor of the next. Five models were created: (1) lagged term only; (2) lagged term and film type; (3) lagged term and subject; (4) lagged term, subject, and film type; and (5) lagged term, subject, film type, and their interaction (Film Type \times Subject). Standard likelihood ratio tests were used to assess the significance of model components. For example, to test for the subject level effect, the lagged term only model was compared to the lagged term and subject model, with the negative two log likelihood difference assessed against a chi-squared distribution, with degrees of freedom equal to the difference in the number of parameters.

Smoothing splines allow for the examination of two separate characteristics of the genital arousal data: (1) level of sexual arousal, and (2) trajectory of arousal over time. Level effects describe the overall size or magnitude of the genital sexual arousal response. Trajectory over time effects capture the relationship between genital arousal and time, independent of level of arousal effects.

Results

Traditional methods. Change in mean VPA from the neutral to erotic film sections was computed and standardized within subjects for the heterosexual ($M = -.002$, $SD = .98$), lesbian ($M = -.08$,

$SD = .80$), and gay male ($M = .08$, $SD = .71$) films. A repeated measures ANOVA test on change in mean VPA found no difference in genital sexual arousal to the three erotic films, $F(2,36) = .12$, $p = .88$. This finding replicated those of previous studies (Bossio, Suschinsky et al., 2014; Chivers & Bailey, 2005; Laan et al., 1995), which also failed to detect category specificity in women's genital sexual arousal with change in mean VPA analyses.

For the category specificity index analyses, higher scores indicate greater arousal to the first film category and negative scores greater arousal to the second film category. These indices were calculated with the standardized change in mean arousal values for the three films described in the previous paragraph. The heterosexual/lesbian contrast ranged from 1.98 to -2.00 , ($M = .08$, $SD = 1.64$). The heterosexual/gay contrast ranged from 2.00 to -2.00 ($M = -.09$, $SD = 1.51$). The lesbian/gay contrast ranged from 1.62 to -1.83 ($M = -.17$, $SD = 1.15$). A repeated measures ANOVA test found no difference between the category specificity indices for the three contrasts, $F(2,36) = .18$, $p = .84$. This finding replicated those of previous studies (Chivers et al., 2004; Peterson et al., 2010; Suschinsky et al., 2009), which also failed to detect category specificity of genital sexual arousal using category specificity index statistics.

Smoothing regression splines.

Level of sexual arousal. There was a significant main effect of film on the level of arousal, $\chi^2(2.00) = 11.12$, $p < .01$, with an effect size of $R^2 = .003$. Pairwise comparisons revealed that the level of arousal to the heterosexual film was significantly higher than the level to the lesbian film, $\chi^2(1.00) = 5.76$, $p < .052$, $R^2 = .002$, and to the gay male film, $\chi^2(1.00) = 8.84$, $p < .01$, $R^2 = .003$, indicating that heterosexual women showed greater genital arousal to the heterosexual film (preferred film) than either the lesbian or gay male films (nonpreferred films). There was no difference in women's level of arousal between the lesbian and gay male films, $\chi^2(1.00) = .91$, $p = .34$ (see Figure 1).

The main effect of subject on the level of arousal was not significant, $\chi^2(18.00) = 1.43$, $p = 1.00$, as would be expected due to standardization.

There was a significant level effect for the interaction of Subject \times Film, $\chi^2(36.00) = 401.46$, $p < .001$. The interaction indicates that the level of women's arousal differed significantly between films when examined within subjects. Notably, the interaction effect ($R^2 = .07$) was larger than the main effect of film ($R^2 = .003$) on level of arousal. This suggests that, although the films themselves affected arousal level, the effect of film on level of arousal was even stronger when compared within subjects. In other words, the variations in response from one film to another within individual subjects was substantially greater than the variation from one film to another in general across all subjects.

Trajectory of sexual arousal. Comparing the trajectories of genital arousal to the three films (independent of level), there was a significant main effect of film, $\chi^2(4.10) = 39.42$, $p < .001$, $R^2 = .01$. Pairwise comparisons revealed that the trajectory of arousal to the heterosexual film was significantly different from the trajectory to the lesbian film, $\chi^2(3.13) = 22.23$, $p < .001$, $R^2 = .008$, and to the gay male film, $\chi^2(2.00) = 22.28$, $p < .001$, $R^2 = .008$. The trajectory of arousal to the lesbian film was also significantly different from the trajectory to the gay male film, $\chi^2(3.24) = 35.18$, $p < .001$, $R^2 = .01$. This suggests that women showed different patterns of genital sexual arousal to all three of the erotic films. Although the trajectories of arousal to the heterosexual and gay

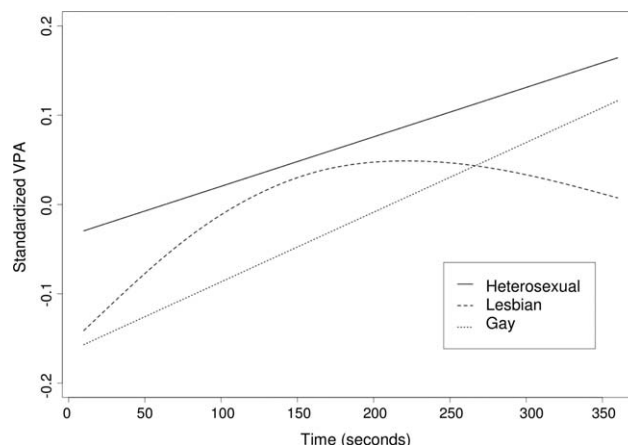


Figure 1. Smoothing regression splines showing the overall level and trajectory of standardized genital sexual arousal over time to the three erotic films for heterosexual women as a group. Women demonstrated a higher overall level of arousal to the heterosexual film than the other two films, and the trajectories of arousal were significantly different between all three films. VPA was recorded in millivolts and standardized within subjects. Residual standard deviation = 0.65.

male films both increased over time (see Figure 1), they were significantly different, indicating that they increased at different rates. By visual inspection of Figure 1, it appears that the trajectory of arousal to the lesbian film, in which arousal increased from baseline but then dropped off, demonstrates that arousal decreased as women were exposed to more of the film over time.

Additionally, there was a significant main effect of subject on trajectory of arousal, $\chi^2(21.17) = 61.13$, $p < .001$, $R^2 = .02$, suggesting that the trajectories of arousal were different from one woman to another.

There was also a significant interaction effect of Subject \times Film on trajectory of arousal, $\chi^2(135.93) = 1044.89$, $p < .001$, $R^2 = .22$, suggesting that the trajectories of women's arousal differed between films when examined within subjects. The interaction effect can be illustrated by comparing Figure 1, showing the arousal response of all women, to Figure 2, showing the arousal response of two individual women. Again the interaction effect ($R^2 = .22$) was larger than the effect of either film type ($R^2 = .01$) or subject ($R^2 = .02$) independently, suggesting that both individual subject characteristics as well as stimulus category should be considered when examining women's genital sexual arousal response. Women showed category-specific genital sexual arousal both in terms of their overall level of arousal and the trajectory of their arousal over time.

Subjective sexual arousal. Although not the focus of this study, subjective sexual arousal was assessed to ensure that women found the films subjectively sexually arousing. Subjective sexual arousal responses were scored from 0–18, with higher numbers indicating higher sexual arousal. Subjective sexual arousal was reported to the heterosexual film ($M = 12.00$, $SD = 3.20$), the lesbian film ($M = 6.22$, $SD = 4.20$), and the gay male film ($M = 5.72$, $SD = 3.59$). Subjective arousal scores were similar to scores reported by sexually functional heterosexual women in other studies in our laboratory, suggesting that the stimuli films were sufficiently psychologically sexually arousing to subjects. Subjective arousal scores were compared between films with repeated measures ANOVA tests. There was a significant difference in subjective sexual arousal between films, $F(2,34) = 26.83$, $p < .001$, effect size

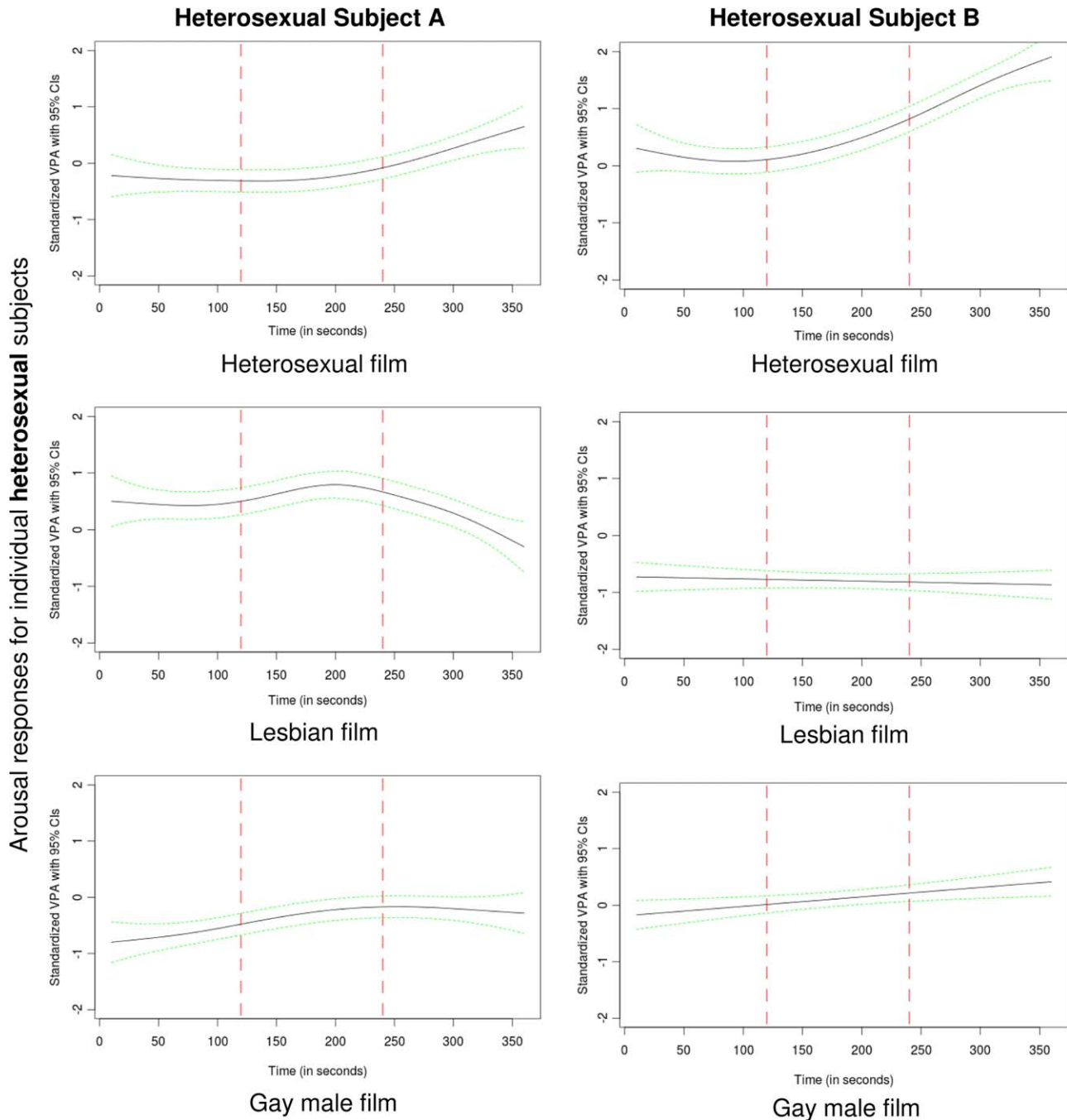


Figure 2. These sets of graphs show the genital arousal responses to the three films over time for two individual heterosexual subjects (heterosexual Subjects A and B). The vertical dashed red lines indicate a change in the content of the erotic films, which included 2 min of foreplay (0 to 120 s), 2 min of oral sex (120 to 240 s), and 2 min of penetrative sex (240 to 360 s). Graphs of individual responses illustrate the interaction effect: women showed even greater variability in their arousal responses when examined within subjects (i.e., each woman just compared to herself) than when examined together as a group (as in Figure 1). Smoothing splines reveal nuanced differences in genital response that are masked in the group analyses. There was a significant interaction between subject and film for both level of genital sexual arousal and trajectory of genital sexual arousal in the smoothing spline analyses. Green dashed lines represent 95% confidence intervals around the smoothing splines. VPA was recorded in millivolts and standardized within subjects. Residual standard deviation = 0.55.

$\eta^2 = .61$. Pairwise comparisons revealed a significant difference in subjective sexual arousal between the heterosexual film and the lesbian film, $F(1,17) = 32.01, p < .001$, and between the heterosexual film and the gay male film, $F(1,17) = 37.73, p < .001$. The sample reported significantly higher subjective sexual arousal to the heterosexual film than either of the other two films.

Discussion

The aim of this study was to examine category specificity in women using an advanced analytic technique: smoothing regression splines. We examined heterosexual women's genital arousal responses to preferred and nonpreferred erotic films with the

traditional change in mean VPA and category specificity index statistics and failed to find differences in average arousal between films. When we examined the same data with smoothing regression splines, we found that heterosexual women demonstrated a higher overall level of genital sexual arousal to the heterosexual erotic film than to the lesbian and gay male erotic films (see Figure 1). In terms of the trajectory or pattern of arousal, women showed significantly different trajectories of arousal to each film. As seen in Figure 1, arousal to the heterosexual and gay male films increased in a linear pattern across the film presentation (although at a higher level to the heterosexual film), but arousal to the lesbian film increased initially and then decreased. As the differences between these levels and trajectories of arousal were significantly different between the heterosexual film and the other two films, we concluded that heterosexual women have category-specific genital sexual arousal when measured with smoothing regression splines. These results suggest that it is necessary to examine both level and trajectory of arousal in order to evaluate this data accurately.

In addition to the influence of the content of erotic films (i.e., sexual orientation of couple presented) on women's genital arousal, we found that the individual subject was an even more important determinant of arousal response. For both the level and trajectory of genital sexual arousal, when each woman's arousal to each film was compared to her own arousal to the other two films, there were larger effects than when women's arousal responses were collapsed into a single group and compared between films. In other words, the arousal response depended upon the individual characteristics of each woman. The enhanced sensitivity of smoothing splines can reveal effects across all women as a group, as well as within each woman individually, ultimately allowing for more comprehensive data analysis.

In an effort to further examine this notable finding, we repeated the study with lesbian women. Testing for category specificity in a second group of women provides additional exploration of the efficacy of our new analytic approach. Lesbian women were selected as the second sample because, similar to heterosexual women, it is possible to clearly define categories of preferred and nonpreferred erotic cues for lesbian women. Previous studies on the category specificity of women's genital sexual arousal have included samples of both heterosexual and lesbian women (Chivers et al., 2007; Peterson et al., 2010). We hypothesized that, like the heterosexual women, lesbian women would show a higher overall level of arousal and different trajectory of arousal to their preferred erotic film (lesbian film) than to their nonpreferred films (heterosexual and gay male films).

Study 2

Method

Participants. Participants were lesbian adult women recruited from the local community. Recruitment materials described a research study on lesbian women's sexual arousal, and interested participants called the laboratory to complete a confidential phone screen. Recruitment materials were presented in the same venues as in Study 1, with the addition of locations known to attract lesbian women such as sexuality counseling centers and female-focused bookstores. Inclusion and exclusion criteria for Study 2 were identical to Study 1, except that heterosexual women were excluded and lesbian women included in the study. Women were required to identify as exclusively or predominantly lesbian on the

Kinsey Scale to qualify for this study. Bisexual-identified women were excluded from the study.

The sample for Study 2 included 14 lesbian women aged 18 to 47, with an average age of 26.07 ($SD = 8.38$). Seven women identified as exclusively lesbian and seven identified as predominantly lesbian. Forty-three percent of the sample had completed some college, 43% had completed college, and 14% held an advanced degree. There were slightly more single women in the sample (57%) than women married or in a committed relationship (43%). Fifty-seven percent of the sample was Caucasian, 21% was Hispanic, 14% was Asian, and 8% was African American/Black.

Measures, stimulus materials, procedure, data analysis. Self-report measures, erotic films, study procedure, and data analysis methods were identical to the procedures described in Study 1.

Results

Traditional methods. Change in mean VPA from the neutral to erotic film sections was computed and standardized within subjects for the lesbian ($M = -.40$, $SD = .77$), heterosexual ($M = -.008$, $SD = .75$), and gay male ($M = .41$, $SD = .80$) films. A repeated measures ANOVA test on change in mean VPA found no difference in genital sexual arousal between films, $F(2,26) = 2.58$, $p = .10$. Similar to previous studies (Chivers et al., 2007), we failed to detect category specificity of lesbian women's genital sexual arousal using change in mean VPA statistics.

In the category specificity index analyses, positive scores indicate greater arousal to the first film category and negative scores greater arousal to the second film category. For Study 2, category specificity indices were calculated in comparison to the lesbian film such that for both comparisons that included the lesbian film positive scores indicate greater arousal to the lesbian film. The lesbian/heterosexual contrast ranged from 1.73 to -1.95 , ($M = -.39$, $SD = 1.29$). The lesbian/gay contrast ranged from 1.86 to -2.00 ($M = -.81$, $SD = 1.38$). The heterosexual/gay contrast ranged from 1.88 to -1.92 ($M = -.42$, $SD = 1.35$). A repeated measures ANOVA test found no differences between the category specificity indices for the three contrasts, $F(2,26) = .54$, $p = .59$. This finding replicated those of previous studies (Chivers et al., 2004; Peterson et al., 2010), failing to detect differences in genital arousal to different types of erotic films for lesbian women using category specificity index analyses.

Smoothing regression splines.

Level of sexual arousal. There was a significant main effect of film on level of arousal, $\chi^2(2.00) = 6.21$, $p < .05$, with an effect size of $R^2 = .002$. Unexpectedly, pairwise comparisons revealed that the level of arousal to the lesbian film was significantly lower than the level of arousal to the heterosexual film, $\chi^2(1.00) = 5.56$, $p < .05$, $R^2 = .003$. There were no differences in level of arousal to the lesbian and gay male films, $\chi^2(1.00) = 1.96$, $p = .16$, or the heterosexual and gay male films, $\chi^2(1.00) = 1.37$, $p = .24$. Lesbian women showed a higher level of genital arousal to the heterosexual film than the lesbian film (see Figure 3). This unexpected finding will be examined in the Discussion.

The main effect of subject on the level of arousal was not significant $\chi^2(13.00) = 2.81$, $p = 1.00$, as would be expected due to standardization.

There was a significant level effect for the interaction of Subject \times Film, $\chi^2(26.00) = 258.25$, $p < .001$, $R^2 = .08$. When examined within subjects, the level of each woman's arousal

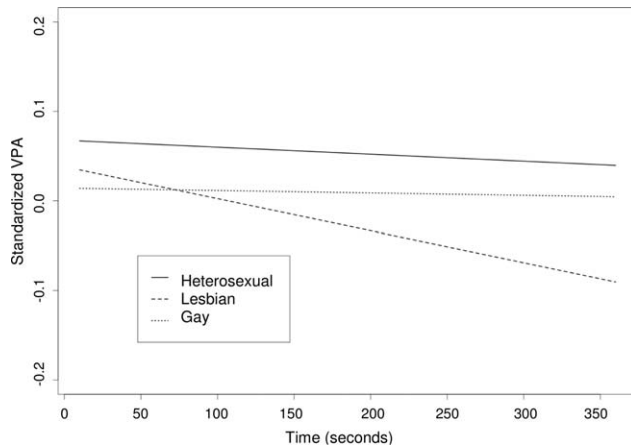


Figure 3. Smoothing regression splines showing the overall level and trajectory of standardized genital sexual arousal over time to the three erotic films for lesbian women as a group. Contrary to our hypotheses, lesbian women showed an overall lower level of arousal to the lesbian film than the heterosexual film. There were no differences in the trajectories of arousal to the three films for the lesbian women. VPA was recorded in millivolts and standardized within subjects. Residual standard deviation = 0.72.

response to the films differed. The interaction effect ($R^2 = .08$) was larger than the main effect of film ($R^2 = .002$) on level of arousal. The interaction suggests that the effect of film on level of arousal was larger when examined within subjects than when examined across all subjects together.

Trajectory of sexual arousal. Comparing the trajectories of genital arousal to the three films (independent of level), there was no main effect of film, $\chi^2(3.00) = 2.70, p = .44$. The trajectories of arousal to the three films did not differ significantly (see Figure 3).

There was no main effect of subject on trajectory of arousal, $\chi^2(14.00) = 13.96, p = .45$, indicating that when just comparing arousal within each woman there were no significant differences in the trajectories of her arousal.

There was a significant interaction effect of Subject \times Film for trajectory of arousal, $\chi^2(106.55) = 1446.23, p < .001, R^2 = .35$, suggesting that when examined within subjects the trajectories of lesbian women's arousal to the three films differed significantly. There was no main effect of film on trajectory of arousal, but the interaction of subject and film showed a large effect on trajectory of arousal, indicating that, within subjects, lesbian women showed different patterns of arousal to the three films. Lesbian women did not show a higher overall level or variable trajectory of arousal to the lesbian film as we had hypothesized, yet they still showed different levels and patterns of arousal to the three films. Although this finding does not fit with our current conceptualization of category specificity, it may be important for understanding lesbian women's genital arousal response.

Subjective sexual arousal. Subjective sexual arousal responses were scored from 0 to 18, with higher numbers indicating higher subjective sexual arousal. Lesbian women reported subjective sexual arousal to the lesbian film ($M = 12.11, SD = 4.39$), heterosexual film ($M = 10.54, SD = 2.31$), and gay male film ($M = 8.50, SD = 5.67$). These subjective arousal scores are similar to scores reported by sexually functional lesbian women in other studies in our laboratory, suggesting that the stimuli films were sufficiently sexually arousing to the subjects. There was a significant difference

in subjective sexual arousal between films, $F(2,26) = 3.47, p < .05$, effect size $\eta^2 = .21$. Pairwise comparisons revealed a significant difference in subjective sexual arousal between the lesbian and gay male erotic films, $F(1,13) = 6.40, p < .05$, but no difference in arousal between the lesbian and heterosexual erotic films, $F(1,13) = 1.30, p = .28$.

Discussion

Examination of lesbian women's arousal responses with traditional change in mean VPA and category specificity index statistics failed to find meaningful differences in average arousal between the three films. Smoothing regression splines revealed that lesbian women showed a higher overall level of genital sexual arousal to the heterosexual film than to the lesbian or gay male films. This contradicts our current conception of category specificity, that highest arousal will occur in response to films that match sexual preferences. Of course, these findings may indicate that lesbian women report a sexual preference for lesbian sexual activity, but are actually more genitally sexually aroused to visual depictions of heterosexual sexual activity. However, it is important to note that, when examined within subjects, lesbian women showed significantly different levels and patterns of arousal to the three films, indicating that, at an individual level, genital arousal discriminated between the different types of stimuli.

Examination of the trajectory of arousal within subjects helps to explain these nuanced differences in patterns of arousal for lesbian women. For example, the set of three graphs for Lesbian Subject A in Figure 4 shows the genital arousal response to the three films for one individual lesbian subject. As a reminder, each erotic film included 2 min each of foreplay, oral sex, and penetrative sex. Visual inspection of these graphs reveals that this subject's arousal to the heterosexual and gay male films decreased over time and arousal to the lesbian film increased over time. The increase in arousal across the lesbian film is consistent with previous research indicating that women show greater genital sexual arousal in response to erotic stimuli of higher intensity (i.e., higher to sexual intercourse than oral sex, foreplay, or solitary masturbation), an effect that has been termed *activity specificity* (Bossio, Suschinsky et al., 2014; Both, Boxtel, Stekelenburg, Everaerd, & Laan, 2005; Chivers et al., 2007; Suschinsky, Bossio, & Chivers, 2014). Yet, the smoothing spline analyses reveal that this subject's arousal response to the lesbian film was more complex than a simple linear increase across the course of the film as the sexual activity presented intensified. Her arousal increased slightly during the foreplay and oral sex portions of the film, increased more dramatically during the beginning of the vaginal penetration portion of the film, and then decreased toward the end of the vaginal penetration portion of the film. The application of smoothing splines to individual subjects' arousal data enables us to identify these nuanced differences in individual arousal response that are masked in the group analyses as the group analyses collapse across individual differences, which the current results indicate are meaningful and statistically significant. As this is the first opportunity scientists have had to examine individual arousal trajectories over time, our interpretations of the meaning of these results are speculative, and future research will be needed to clarify the relationship between individual differences in arousal response and sexual preferences. A variety of factors could have affected this woman's response, such as the sexual activities depicted in the erotic films (Chivers et al., 2007; Suschinsky et al., 2014), and characteristics of the actors such as their physical attractiveness, race and ethnicity, and

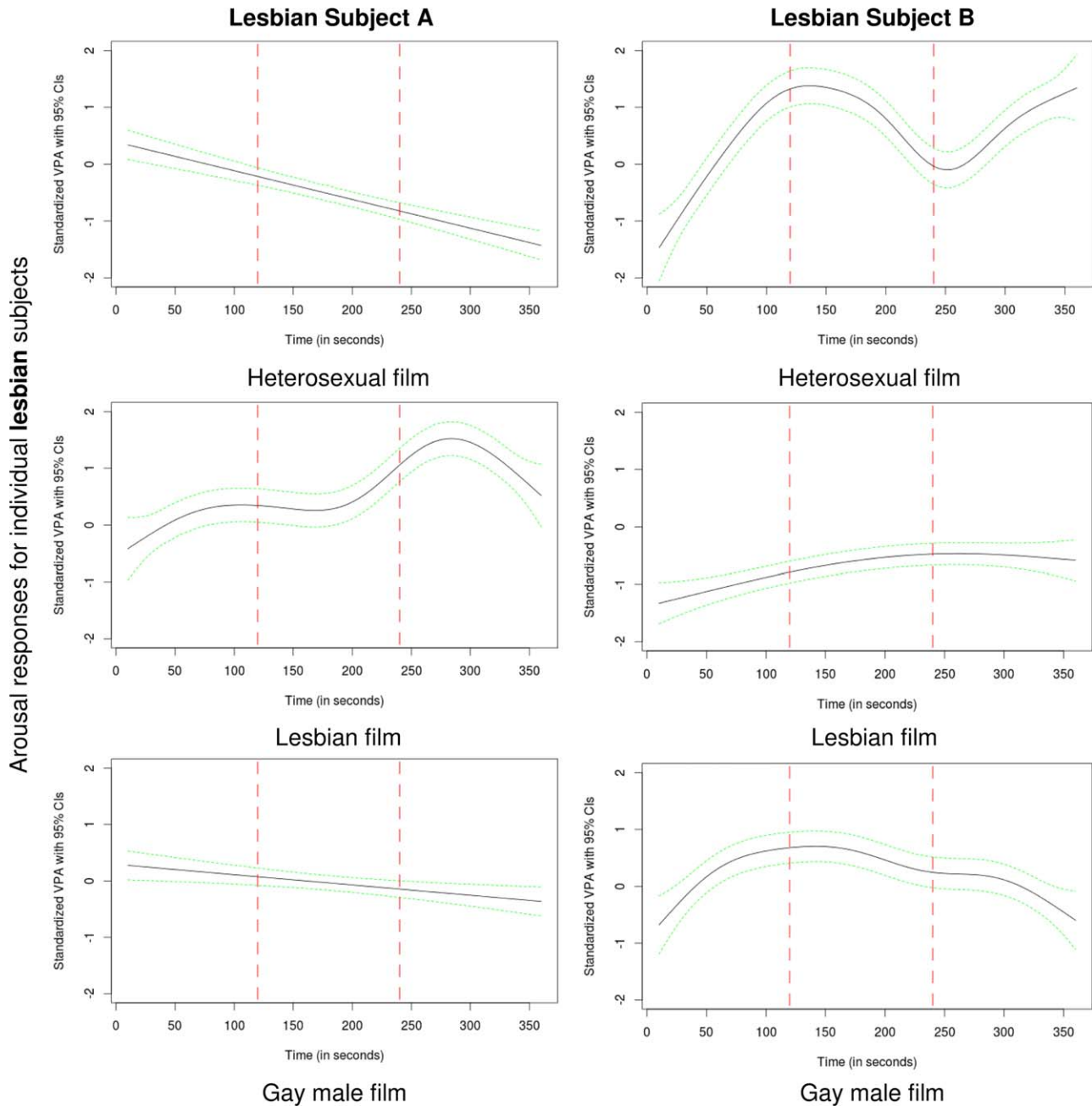


Figure 4. These graphs illustrate genital arousal responses to the three films over time for two individual lesbian subjects (lesbian Subjects A and B). The vertical dashed red lines indicate a change in the content of the erotic film, which included 2 min of foreplay (0 to 120 s), 2 min of oral sex (120 to 240 s), and 2 min of penetrative sex (240 to 360 s). Graphs of individual responses illustrate the interaction effect: lesbian women showed even greater variability in their arousal responses when examined within subjects (i.e., each woman just compared to herself) than when examined together as a group (as in Figure 3). Smoothing splines reveal nuanced differences in genital response that are masked in the group analyses. There was a significant interaction between subject and film for both level of genital sexual arousal and trajectory of genital sexual arousal in the smoothing spline analyses. Dashed lines represent 95% confidence intervals around the smoothing splines. VPA was recorded in millivolts and standardized within subjects. Residual standard deviation = 0.55.

similarity to the participant and/or her past sexual partners. It appears that, at an individual level, lesbian women's genital sexual arousal response discriminates between different elements of the erotic stimulus, such as content and actor characteristics, at a much more nuanced level than previously known. Although individual differences in the lesbian women's genital responses cannot explain the lack of category specificity observed in this group, these differences suggest that arousal is affected by a number of factors and

calls for future research on the influence of various elements of erotic stimuli on lesbian women's genital sexual arousal response.

General Discussion

The aim of these studies was to determine whether smoothing spline analyses would yield different results for the specificity of women's genital sexual arousal than the traditional analytic

method, which focuses on average arousal response. For both groups of women, our findings supported previous research (e.g., Chivers, 2005), failing to detect category specificity in either group of women using the traditional change in mean VPA and category specificity index analyses. However, for the heterosexual women, smoothing spline analyses indicated that this group showed a higher level and different patterns of arousal to the heterosexual film than to either the lesbian or gay male films (see Figure 1). Smoothing splines revealed that lesbian women showed different levels and patterns of arousal to the three films (although these patterns did not necessarily reflect their self-reported sexual preferences; see Figure 3). Smoothing splines also allow for the evaluation of within-subjects effects, the influence of each individual subject on arousal response. For both the heterosexual and lesbian women, differences in arousal to the films were strongest when assessed within subjects (see Figures 2 and 4). This suggests that individual characteristics of each woman play an important role in her genital sexual arousal response. Though one previous study with heterosexual women found that they showed higher genital sexual arousal to still images of aroused male genitals than to images of aroused female genitals (Spape, Timmers, Yoon, Ponseti, & Chivers, 2014), to our knowledge ours is the first study to demonstrate category specificity in women's genital sexual arousal in response to erotic films.

The identification of category specificity in women's arousal with smoothing splines highlights the importance of using appropriate analytic techniques to examine genital arousal data. Physiological measures like vaginal photoplethysmography provide continuous assessment, leading to a rich set of data that can tell a story over time. Using the average to evaluate genital arousal response fails to take advantage of the continuous nature of this data. Smoothing splines provide the opportunity to examine two components of genital arousal data: overall level of sexual arousal and trajectory of arousal over time. Overall level represents the strength of the arousal response. Trajectory or pattern over time shows the behavior of arousal across the testing session. As smoothing spline analyses are completely new to physiological sex research, the meaning of level of genital arousal and trajectory of genital arousal to the field will undoubtedly be refined with further study and research using this analytic technique.

To date, the literature on vaginal photoplethysmography as a tool for the assessment of genital sexual arousal indicates that women's arousal increases in response to erotic films (Laan et al., 1995), but does not reveal information about women's sexual preferences. Prior literature on category specificity has called the lack of specificity in women's arousal a robust effect (Bossio, Suschinsky et al., 2014; Chivers, 2005). The inability of vaginal photoplethysmography to describe sexual preferences is a commonly cited drawback of this assessment tool (Suschinsky et al., 2009). The current study suggests that vaginal photoplethysmography may reveal more about women's sexual preferences than previously believed. The potential for vaginal photoplethysmography to describe women's sexual preferences opens up new research applications as well as potential opportunities for the use of plethysmography in clinical and forensic settings.

Research Applications

Smoothing splines provide a highly sensitive and individualized assessment of genital arousal data in the form of two indices, level and trajectory. Results from the current studies suggest that women's genital response discriminates between features of erotic

stimuli to a much larger degree than previously understood (e.g., Figures 2 and 4). Women may respond uniquely to a number of characteristics of the erotic stimulus such as the setting of the film, sexual activities depicted, sexual positions presented, and physical attractiveness of the actors. Aside from the robust finding that women show higher arousal to sexual activity of greater intensity (Bossio, Suschinsky et al., 2014; Chivers et al., 2007), the relative influence of factors such as setting, sexual positions, and actor characteristics on women's genital arousal response are unknown. Future studies are needed to determine the stimuli characteristics most sexually arousing to women in order to develop better quality erotic stimuli for research studies. Preferences for stimuli characteristics may vary along demographic lines such as age, sexual orientation, racial or ethnic background, and past sexual experiences such as sexual abuse. Previous studies of erotic stimuli development have indicated that heterosexual women prefer female-produced erotica (Laan et al., 1994), and that heterosexual and bisexual women prefer stimuli featuring vaginal intercourse in male-on-female sexual positions (Woodard et al., 2008). Review of the literature reveals a notable lack of research on ideal erotic stimuli for lesbian women. As smoothing regression splines allow for a more sensitive assessment of genital arousal response than was previously possible, future research could examine women's sexual preferences at a much more micro level. Better quality stimuli that are more likely to lead to a high level of arousal in the laboratory could improve sex research experiments. It might also be possible to customize preferred or "ideal" stimuli for each individual subject prior to running a study. Although this suggestion brings up concerns about standardization, if each woman was equally aroused to her customized film(s) in pretesting, this approach could possibly lead to more ecologically valid testing results.

Another way in which smoothing splines could improve sex research experiments is by comparing arousal responses between different manipulations or treatments. In the same way that smoothing splines reflect variations in women's genital arousal response to different categories of erotic stimuli, they could also reflect differences in arousal response to levels of a manipulation or treatment for sexual arousal dysfunction. Pharmacological treatments for female sexual dysfunction provide a case example. Smoothing splines could be applied to questions about response latency and appropriate dosage. Information on the length of time it takes drugs to affect sexual arousal would be highly important to the development of an effective drug for female sexual arousal dysfunction. Traditional methods of analyzing women's genital arousal response relying on the average response do not afford the opportunity to examine the time trajectory of effects. To date, the Food and Drug Administration has not approved any drugs for female sexual dysfunction (Clayton et al., 2010), and access to more detailed information on the impact of drugs on women's arousal over time could shed new light on this influential area of research.

Smoothing regression splines could also be applied to data on continuous subjective sexual arousal in order to evaluate concordance of genital and subjective sexual arousal. Self-reported psychological or subjective sexual arousal is often collected alongside the assessment of genital sexual arousal in sex research experiments. Subjective sexual arousal is typically assessed with a lever-like instrument that subjects adjust continuously during the film presentation to indicate changes in subjective sexual arousal (Rellini, McCall, Randall, & Meston, 2005). Concordance provides information on the meaning of self-reported sexual arousal, which is relevant to both models of the human sexual response as well as

defining and treating sexual dysfunction. Similar to category specificity, a gender difference has been identified in studies on concordance with men showing high concordance between genital and subjective arousal and women showing low concordance (Chivers, Seto, Lalumière, Laan, & Grimbos, 2010). Although some studies have identified somewhat higher levels of concordance among women using hierarchical linear analysis (Meston, Rellini, & McCall, 2010; Rellini et al., 2005), this issue remains a puzzling question in research on women's sexual health. Smoothing splines could be applied to both physiological and subjective sexual arousal over time, and then concordance could be tested by examining the ability of the subjective arousal trajectory to predict the genital arousal trajectory. Although an examination of concordance was outside the scope of this paper, it is an important question to consider in future research.

Clinical Applications

Smoothing regression splines may also enable new clinical applications of vaginal photoplethysmography. This analytic technique could provide subjects with real-time feedback on their genital arousal response, or even the concordance between their genital and subjective arousal responses during laboratory experiments. Although the efficacy of this new biofeedback application and its acceptability to women need to be tested and validated, feedback on arousal response has the potential to treat arousal dysfunction in subgroups of women with arousal difficulties. Women's sexual arousal problems can be divided into three groups: genital arousal dysfunction, subjective arousal dysfunction, and combined genital and subjective sexual arousal dysfunction (Basson et al., 2003). Women with both genital and combined arousal dysfunction tend to report low awareness of their genital sexual arousal response (Basson, 2002; Meston et al., 2010). Research on sensate focus, a well-known sex therapy technique, indicates that enhanced awareness of physiological sensations leads to higher sexual arousal (Masters & Johnson, 1970; Regev & Schmidt, 2009). Recent research on mindfulness-based sex therapy has also indicated that enhanced physiological awareness can improve sexual arousal in women with sexual dysfunction (Brotto, Basson, & Luria, 2008; Brotto, Seal, & Rellini, 2012). Real-time feedback on genital sexual arousal via visual or tactile cues could be provided to women with genital and combined arousal dysfunction in an effort to increase their awareness of their arousal response. Women may be able to train themselves to increase their attention to genital arousal sensations. Research suggests that greater awareness of genital arousal enhances both genital and subjective sexual arousal in women. When sexually functional women were asked to report on their vaginal blood flow while engaged in erotic fantasy, both VPA and subjective sexual arousal increased (Prause, Barela, Roberts, & Graham, 2013). Although concordance between genital and subjective sexual arousal has not been definitively linked to higher sexual function in men or women (Chivers et al., 2010), concordance is still often evaluated as a marker of treatment improvement among women with sexual arousal dysfunction (Brotto et al., 2012). Live feedback on concordance between genital and subjective sexual arousal could be presented to women struggling with combined arousal dysfunction in order to increase awareness of when there is agreement between their genital and subjective sexual arousal. Future research is needed on the potential clinical applications of real-time feedback of genital arousal response.

Another potential clinical application relates to the assessment of genital sexual arousal for people with paraphilic sexual interests. One prior study indicated differences in category specificity between men and women with masochistic sexual interests and men and women with conventional sexual interests (Chivers, Roy, Grimbos, Cantor, & Seto, 2013). Currently, the main clinical application of category specificity of genital sexual arousal in men is the assessment and treatment of men with pedophilic disorder (Blanchard et al., 2001; Seto, 2008). Men's arousal response to stimuli featuring children is assessed pre- and posttreatment for pedophilia to examine treatment efficacy. With further validation of smoothing splines as an analytic technique for examining women's genital arousal response, the same procedures could be applied to women with pedophilic disorder. The prevalence of pedophilic disorder in women is unknown (American Psychiatric Association, 2013), and the incidence of female sexual offenses against children is low (Knack, Murphy, Ranger, Meston, & Fedoroff, 2015). Treatment for pedophilic disorder is complicated by the stigma attached to this sexual preference, making the ability to test treatment efficacy with a behavioral test rather than a self-report assessment especially useful (Seto, Kingston, & Bourget, 2014). There are few empirically supported treatments for this disorder in women (Lawson & Rowe, 2010); therefore, valid and reliable markers of treatment outcomes might spur the development of improved treatments for this clinical population.

This study had a number of limitations that warrant mention. Our failure to find the same type of category specificity in lesbian women that we found in heterosexual women may be due to the use of an inappropriate lesbian stimulus in our study. Peterson and colleagues (2010) examined category specificity in heterosexual and lesbian women and found that their lesbian subjects also showed lower arousal to the lesbian film than the heterosexual film. It may be more difficult to select an erotic film that is sexually arousing to the majority of lesbian women than to select a heterosexual film that is arousing for the majority of heterosexual women. It is also possible than a nonaudiovisual stimulus, such as an excerpt of erotic literature, may be more appropriate for lesbian women. In our study, 64.3% of the lesbian women reported a prior history of heterosexual experiences, which is consistent with reports of heterosexual experiences in larger samples of lesbian women (Diamond, 2008). Prior sexual experiences with men might have affected lesbian women's genital arousal responses to the heterosexual stimuli in our study. It is possible that, with more appropriate lesbian stimuli, lesbian women would also show expected category specificity differences in genital sexual arousal.

Another limitation relates to the new analytic technique we used: smoothing regression splines. As this was only the second application of smoothing regression splines to vaginal photoplethysmograph data (Pulverman et al., 2015), there is much we still do not know about the application of this analysis technique to genital arousal. Category specificity of women's genital sexual arousal could be further tested by reexamining women's arousal responses to other types of nonpreferred erotic stimuli, such as nonhuman primates engaged in sexual activity and stimuli depicting sexual assault. It remains unknown whether the genital arousal patterns we observed in our studies would be stable over time, or stable to films with slightly different content. Our results require replication and expansion before they can be applied in clinical settings to assess treatment efficacy.

In conclusion, this is the first study of which we are aware to demonstrate category specificity in women's genital sexual arousal in response to erotic films. Heterosexual women showed higher

arousal to the heterosexual erotic film than the other films, and lesbian women showed different patterns of arousal to the different categories of films. For all women, the impact of the different sex-

ual films showed a larger effect on genital sexual arousal when data were analyzed within subjects using smoothing regression splines.

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