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The relationship between women's subjective and physiological sexual arousal

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Abstract

Previous literature presents discordant results on the relationship between physiological and subjective sexual arousal in women. In this study, the use of hierarchical linear modeling (HLM) revealed a significant concordance between continuous measures of physiological and subjective sexual arousal as assessed during exposure to erotic stimuli in a laboratory setting. We propose that past studies that have found little or no association between the two measures may have been in part limited by the methodology and statistical analyses employed.

Descriptors: Female sexuality, Physiological sexual arousal, Subjective sexual arousal, Vaginal pulse amplitude, Photoplethysmography

Comprehensive assessment of female sexual arousal in a laboratory setting involves measurement of both physiological and subjective responses. The relationship between physiological and subjective sexual responses in women is a widely studied but poorly understood phenomenon. The definition of sexual response presented by the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR; American Psychiatric Association, 2000) includes only physiological aspects of sexual arousal: "The arousal response consists of vasocongestion in the pelvis, vaginal lubrication and expansion, and swelling of the external genitalia" (p. 543). The assumption underlying this definition is that physiological and subjective sexual arousal are interdependent aspects of the same underlying latent construct of sexual arousal (Bollen & Lennox, 1991). However, clinical observations and laboratory studies have often pointed to a desynchrony in subjective and physiological sexual arousal in women, but not in men (Laan & Everaerd, 1995). In response to these results, Basson et al. (2001) have proposed a new classification of female sexual arousal dysfunction that challenges the concept of subjective and physiological sexual arousal as inseparable events in women. This study aims to further explore the relationship between physiological and subjective sexual arousal by utilizing continuous measures of the two variables and a data analysis strategy that is more sensitive to individual differences than traditional methods used in previous studies.

To date, the assessment of physiological sexual arousal in women has focused primarily on detecting changes in vaginal blood flow. Vaginal engorgement occurs in unison with vaginal lubrication and together these provide the first measurable physiological signs of sexual arousal in women. The three primary means of assessing vaginal blood flow are vaginal photoplethysmography, indirect measures of heat dissipation, and pulsed wave doppler ultrasonography (for review, see Meston, 2000). The most frequently used of these is vaginal photoplethysmography, a technique introduced by Sintchak and Geer (1975). The vaginal photoplethysmograph is a clear acrylic, tampon-shaped device used to detect engorged and unengorged tissue. The vaginal probe was designed to be easily inserted by the subject, and a positioning shield can be placed on the probe's cable to standardize the depth of insertion between uses (Laan, Everaerd, & Evers, 1995). The most reliable and sensitive (Laan, Everaerd, & Evers) component of the signal is vaginal pulse amplitude, which is believed to reflect phasic changes in vaginal engorgement with each heart beat, meaning that higher amplitudes indicate greater engorgement (e.g., Geer, Morokoff, & Greenwood, 1974). The dependent variable typically used is the amplitude of the pulse signal, which is measured from the peak to the trough of the pulse wave. Analyses of vaginal pulse amplitude are usually conducted by averaging across specific stimulus presentations, across the highest 20–30 seconds of arousal, or across selected time intervals.

With regard to the assessment of subjective sexual arousal, measurement usually involves asking the woman about her subjective experience of arousal during a prior sexual scenario. In laboratory settings, the woman typically responds to questions about whether (and to what degree) she felt "sexually aroused"

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or "turned on" during the preceding erotic film clip. A commonly used instrument is a 7-point Likert film scale introduced by Heiman and Rowland (1983) that has since been adapted and expanded upon by many researchers (e.g., Meston & Gorzalka, 1995). These questionnaires ask about feelings of subjective sexual arousal, physical sexual arousal (e.g., warmth in genitals, genital wetness or lubrication), positive affect, negative affect, autonomic arousal (e.g., faster breathing, faster heartbeat), and anxiety. Additionally, other researchers have relied on answers to women's ratings of "strongest genital sensations" (e.g., Henson, Rubin, & Henson 1979), "overall sexual arousal" (e.g., Laan, Everaerd, van Bellen, & Hanewald, 1994), and "romantic feelings" (e.g., Wilson & Lawson, 1976) to indicate subjective sexual arousal.

In response to criticisms that self-report measures of subjective sexual arousal rely on retrospective recall of sexual feelings, some researchers have developed techniques for the continuous assessment of sexual responding. Wincze, Hoon, and Hoon (1977) were the first to employ this type of methodology by using a lever mounted to a table, which could be moved by the participant throughout the presentation of nonsexual and sexual films to indicate levels of arousal. Laan and colleagues have also employed continuous measures of subjective sexual arousal in laboratory studies investigating female sexual arousal (e.g., Laan, Everaerd, van Aanhold, & Rebel, 1993; Laan, Everaerd, van der Velde, & Geer, 1995). The technique used in these studies involved a mechanical lever that produced a continuous signal connected to a panel of red light bulbs located underneath the TV monitor. In Laan et al.'s (1993) study, vaginal pulse amplitude was sampled every 13 s and continuous subjective sexual arousal was sampled every 10 s. Laan, Everaerd, van der Velde, et al. (1995) also used the subjective lever, but instructed participants to monitor their genital sensations. Vaginal pulse amplitude and continuous measures of genital sensations were averaged for 1-min film excerpts.

Independently, both responses of subjective sexual arousal (e.g., Both, Everaerd, & Laan, 2003; Meston & Worcel, 2002), and physiological measures of vaginal pulse amplitude (e.g., Laan, Everaerd, & Evers, 1995) have shown to reliably increase with exposure to erotic stimuli. Correlations between subjective and vaginal pulse amplitude measures have ranged from low to moderate (e.g., Geer et al., 1974; Laan et al., 1994; Meston & Gorzalka, 1995). Using a Likert scale to measure subjective sexual arousal, correlations with vaginal pulse amplitude have ranged from −.29 (Dekker & Everaerd, 1988) to .76 (Henson, Rubin, & Henson, 1979) for sexually functional women. Using continuous measures of sexual arousal, Laan et al. (1993) reported between-subjects correlations of vaginal pulse amplitude and subjective sexual arousal that were low overall and statistically nonsignificant ($r = .26$ to $r = .46$). Given that the relationship between erectile response and subjective sexual arousal yields high correlations in men (e.g., Laan & Everaerd, 1995), the recurrent finding of low correlations between vaginal pulse amplitude and subjective sexual arousal in women has led researchers to question whether physiological changes that occur in the absence of a subjective sexual experience should even be considered a sexual response.

A number of explanations have been proposed to account for the low concordance noted between measures of sexual arousal in women. Heiman (1976) hypothesized that it may reflect an inability for women to detect subtle changes in vaginal blood flow. Indeed, some studies have noted that higher levels of physiological sexual arousal result in improved response concordance (e.g., Meston & Heiman, 1998). However, a study found that the degree of correspondence between subjective and physiological sexual arousal measures was dependent upon detecting genital change but independent of the strength of the genital response (Laan, Everaerd, van der Velde, et al., 1995). Negative affect due to "man-made" erotica has also been tested as a potential explanation for the low concordance between subjective and physiological sexual arousal. Laan et al. (1994) reported that women showed significantly higher subjective sexual responses to "woman-made" films as compared to "man-made" films, but the relationship between subjective and physiological sexual arousal did not vary between types of film. Consistent with this finding, negative and positive mood induction changed neither subjective nor physiological sexual responses (Laan, Everaerd, van Berlo, & Rijs, 1995). Demand characteristics are another factor that could feasibly play a role in the reported low concordance between physiological and subjective measures of sexual arousal, meaning that there could be a report bias in subjective sexual arousal for women. In a study where demand characteristics were manipulated by asking a group of women to become as sexually aroused as possible, the correlations between subjective and physiological sexual arousal were not significantly different in the demand versus nondemand conditions (Laan et al., 1993).

Previous research indicates that women may estimate their sexual arousal according to cues other than changes in genital blood flow. Several areas of research have provided evidence for the notion that women may attend to external stimulus information as opposed to internal physiological states to determine their level of sexual arousal. Pennebaker and Roberts (1992) noted that men are consistently more accurate than women at detecting physiological changes (e.g., heart rate and blood pressure). In fact, Korff and Geer (1983) found that the correlation between genital and subjective arousal could be improved by instructing women to specifically attend to genital cues or overall bodily cues.

Another viable explanation for the lack of concordance often observed between measures of women's sexual arousal relates to the data handling used to assess the association between physiological and subjective sexual arousal. Many studies have sampled several data points for vaginal pulse amplitude and then computed an average of these points. This computed average has then been used in correlational analyses with a single Likert-scale question intended to assess subjective experience of sexual arousal (e.g., Brody, Laan, & van Lunsen, 2003; Geer et al., 1974; Meuwissen & Over, 1991; Morokoff & Heiman, 1980) or a mean composite of several Likert-scale questions of subjective sexual arousal (e.g., Meston & Gorzalka, 1995). This methodology significantly reduces the richness of the data and does not allow for an assessment of how changes in one measure may be associated to changes in the other measure.

There are several possible statistical reasons why many previous studies have failed to find a significant relationship between physiological and subjective sexual arousal. On average, the sample size of such studies has been approximately 20 participants, with some studies reporting on samples as small as 6 women (Wincze et al., 1977). Although small sample sizes are often appropriate when looking at physiological measures with low error variance, introducing Likert data reduces the power of the analyses, thus increasing the potential for Type II errors. In addition, the majority of previous studies investigating the relationship between subjective and physiological sexual arousal in women have computed correlations based on within-participants repeated measures (e.g., correlations and regressions run on each individual participant). These methods provide information on the experiences of individual participants, but no inferences can be made to the overall group or to between-group differences (e.g., women with and without sexual dysfunction). Other studies have tried to compensate for the lack of between-subjects analyses by conducting group correlations or regressions based on one data point for subjective sexual arousal and one data point for vaginal pulse amplitude for each individual participant. The weakness of this method is that changes in vaginal pulse amplitude and subjective sexual arousal are stripped to one average point, which provides limited information when the analysis is investigating a relationship over an extended period of time.

To take into consideration individual differences, repeated-measures ANOVAs have often been used to analyze multiple vaginal pulse amplitude and subjective data points. However, several of the assumptions that are required for repeated-measures ANOVA do not allow for the analysis of the relationship between vaginal pulse amplitude and continuous measures of subjective sexual arousal. One assumption of repeated-measures ANOVA is that observations are collected at equal intervals for all participants. If the researcher wants to reduce the data to intervals equal to or smaller than 10 s, the frequent movement artifacts present in vaginal pulse amplitude violate this assumption. Moreover, the longer the intervals used to reduce data, the more information is lost on the relationship between subjective and physiological sexual arousal. The large between-subjects variance that characterizes vaginal pulse amplitude data (Janssen, 2002) violates the repeated-measures ANOVA assumption of equal variance and covariance of the data at different points in time. Between-subjects variance in vaginal pulse amplitude can be due to probe placement and anatomical and physiological characteristics of the participant (e.g., resting levels of vaginal muscular tone) as well as an impedance effect on the amplitude of the signal (Janssen, 2002). For these reasons, repeated observations are often collected on a group of individuals, but these between-groups observations are not necessarily comparable. One way to analyze such nested data is to use structural equation modeling. However, the large samples and equal number and spacing between observations required for this technique render it problematic for assessing vaginal pulse amplitude signals.

We propose that a more appropriate way to analyze the relationship between vaginal pulse amplitude and subjective sexual arousal is to continuously and simultaneously measure the two variables throughout exposure to sexual and nonsexual films and to utilize hierarchical linear modeling (HLM) for the statistical analysis. A major advantage of HLM is that it conducts a within–subjects analysis of the subjective/physiological sexual arousal relationship and uses the coefficients that describe this relationship (i.e., slope and intercept) as outcome variables to test differences between participants. With this methodology, individual differences in vaginal pulse amplitude levels do not pose a problem with interpretation because the analysis is conducted within subjects and the only between-subjects comparison is based on the strength of the within-subjects relationship between vaginal pulse amplitude and continuous subjective sexual arousal. HLM is usually adopted to analyze repeated measures data (Level 1 data) nested within subjects (Level 2 data; Bryk, Raudenbush, & Congdon, 1996). There are several advantages to this type of analysis. HLM does not require the assumption of independence of observations, improves the estimate of effects within individual units, simultaneously estimates variance and covariance components for within-subjects and between-subjects levels of analysis, and has lower Type I error rates (Raudenbush & Bryk, 2002). Furthermore, HLM can assess individual differences as predictors of the degree of the relationship. Given that the literature has reported a broad range in levels of concordance between subjective and physiological sexual arousal in women, HLM can be a useful tool to assess the moderators in this association.

Method

Participants

Twenty-five women were recruited from the community using newspaper advertisements. Exclusion criteria assessed during a standardized phone interview included a history of diabetes, thyroid disorder, cardiovascular disease, neurological disease, stroke, psychiatric or psychological diagnosis, and current use of psychoactive medication. Participants' sexual functioning was assessed by phone interview, and only women who reported no concerns regarding sexual arousal, desire, orgasm, or sexual pain were scheduled for an appointment. Of the original 25 participants, data from 1 woman were excluded from analysis because of technical difficulties that may have distorted her results. Also, data from 2 women were excluded because they did not show a significant increase in vaginal pulse amplitude in response to the erotic film, meaning that they showed a slope of 0 in their regression of vaginal pulse amplitude over time. Although it is not unusual for 20–30% of participants to show no increase in vaginal pulse amplitude in response to erotic videos, the data from these participants were not included because the empirical question posed in the present study focused on how vaginal pulse amplitude impacts subjective sexual arousal and vice versa. Thus, lack of change in vaginal pulse amplitude would not have provided any meaningful information about changes in subjective sexual arousal. Analyses were conducted on the remaining 22 participants. All participants included in the study reported a heterosexual orientation and current involvement in a sexual relationship. For participants characteristics, see Table 1.

Table 1. *Participant Characteristics*

	Mean (*SD*)	Range	*N* (%)
Age	27.05 (8.12)	19–53	
Race			
African-American			3 (13.6)
Caucasian			14 (63.6)
Hispanic			4 (18.2)
Education			
Some high school or less			1 (4.5)
High school graduate			4 (18.2)
Some college			5 (22.7)
2 year degree			9 (40.9)
4 year degree			3 (13.7)
Marital status			
Single, never married			17 (77.3)
Married			2 (9.1)
Divorced			2 (9.1)
Separated			1 (4.5)

Further exclusion criteria included (a) under the age of 18; (b) currently pregnant; (c) self-report of an active psychological disorder including organic mental syndromes and disorders, schizophrenia, delusional disorder or psychotic disorders not classified elsewhere, bipolar disorder, eating disorders (such as anorexia nervosa and bulimia), and panic disorder; and (d) currently receiving any medications known to affect vascular or sexual functioning (including antidepressants and antihypertensives). Participants were told that the purpose of the investigation was to examine their physiological and emotional responses to brief visual stimuli, which would include erotic content.

Measures

Physiological sexual arousal. The vaginal photoplethysmograph was used to assess vaginal response to the erotic films. A data acquisition unit Model MP100WS (BIOPAC System, Inc.) and a software program, AcqKnowledge version 3.7.3 (BIOPAC Systems, Inc., Santa Barbara, CA), were used for the transformation of analog/digital data. The vaginal pulse amplitude signal was sampled 80 times per second and the amplitude of each pulse wave was recorded in millivolts.

Continuous subjective sexual arousal. To measure subjective sexual arousal continuously and simultaneously during exposure to the erotic film, the Female Sexual Psychophysiology Laboratory at the University of Texas at Austin developed a device we termed the ''arousometer.'' The arousometer consists of a computer optical mouse (Intellimouse by Microsoft®) mounted on a wooden track divided into 10 equally spaced intervals, from −2 to 7. Given that vaginal pulse amplitude is measured only in positive changes from baseline, only the positive values (0–7) were used in the analysis. Participants were instructed that −2 and −1 reflect feelings of being *sexually turned off*, 0 is *neutral*, and 1 to 7 reflect increasingly higher levels of feeling *sexually turned on*. Participants were told that ''while the vaginal photoplethysmograph detects the way your body responds to the erotic stimuli, through the arousometer you will indicate your subjective experience of how turned on or sexually aroused you feel.'' The majority of women who participate in studies in our laboratory are familiar with use of a computer mouse, thus increasing the relative ease in using the arousometer over prior continuous methodologies. At each numeric interval that the computer mouse passes, participants feel a slight resistance on the mouse indicating that they are changing from one numeric value to another. The resistance provided by the arousometer allows participants to monitor the level of arousal that they are indicating without having to focus their attention away from the television screen. We believe this technique would be less likely to distract the woman from processing erotic cues than prior techniques that provided visual rather than tactile feedback on reported arousal levels.

The arousometer is connected to a pointer on a computer in the adjacent experimenter's room. A software program written in MatLab detects the position of the pointer with respect to the *y*-axis of the computer's monitor every 0.5 s. A score of 7 on the arousometer corresponds to the highest point on the screen, and 0 corresponds to the middle of the screen. Values from 0 to 7 were the range chosen for the arousometer to match the values of the Likert Film Scale (Heiman & Rowland, 1983); however, units of movement in arousometer were calculated in percentages (0% = 0 and 100% = 7). This continuous measure improves upon previously adopted questionnaire measures because it allows monitoring of participants' levels of sexual arousal every 0.5 s rather than once per video.

Likert scale subjective response to the erotic film post exposure. To compare subjective responses to previous studies of this nature, an adapted version of the Film Scale by Heiman and Rowland (1983) was also administered in this study. Seventeen of the original 41 questions were retained in this version and four factors were derived from this questionnaire: subjective experience of physiological sexual arousal (six items), subjective experience of mental sexual arousal (two items), negative affect (five items), and positive affect (four items). Items were rated on a 7-point Likert scale indicating *not at all* to *intensely*.

Sexual functioning. To ensure that participants were in the normal range of sexual functioning, they completed the Female Sexual Function Index (Rosen et al., 2000). The sexual functioning questionnaire is composed of 19 items divided into factor-analytic derived subscales: desire (two items), arousal (four items), lubrication (four items), orgasm (three items), satisfaction (three items), and pain (three items). Each subscale has been tested to reflect internal consistency within an acceptable range (Cronbach's $\alpha = .89$–$.97$). Interitem reliability is within the acceptable range for sexually functional women (Cronbach's $\alpha = .82$–$.92$). Test–retest reliabilities assessed using a 4-week interval ranged between Pearson's $r = .79$ and .86. Divergent validity has been established using the Locke–Wallace Marital Adjustment Scale (Pearson's $r = .53$ for women with female sexual arousal dysfunction, Pearson's $r = .22$ for sexually functional women).

Stimulus Materials—Films

Film stimuli consisted of a 14-min audiovisual film which included (a) 1-min display of the word ''relax,'' (b) 3 min of a travel film (neutral stimuli), and (c) 10 min of an erotic film. The erotic stimuli depicted a heterosexual couple engaging in foreplay and sexual intercourse and have previously been shown to induce sexual arousal in women in our laboratory (e.g., Meston & Worcel, 2002).

Procedure

Visits were scheduled between days 14 and 28 of the menstrual cycle to control for potential differences in sexual response associated with hormone levels. Upon arrival, the participant signed a consent form and completed the sexual functioning questionnaire (Rosen et al., 2000) and questionnaires assessing demographic variables. In a private internally locked room, the participant inserted the vaginal photoplethysmograph and relaxed on a reclining chair for 10 min (habituation time) before exposure to a nonerotic/erotic film sequence. Throughout the exposure, continuous levels of physiological and subjective sexual arousal were recorded. Participants were instructed to move the arousometer throughout the erotic film exposure to indicate their levels of subjective sexual arousal (''turned on''). The films were shown on a 42-in. Sony plasma TV mounted on a wall approximately 6 feet from the chair in which the participant rested. The experimenter controlled the VCR and the data collection from an adjacent room. Following the film sequence, the participant completed the Film Scale, was debriefed, and compensated $50.

Data Reduction

Vaginal pulse amplitude was sampled 80 times per second across the neutral and erotic film segments. An experienced researcher visually inspected the data for outliers and deleted movement artifacts, which were defined as sudden and drastic changes in vaginal pulse amplitude. Using the AcqKnowledge software program, the researcher then recorded the peak-to-trough value in millivolts for each pulse during the entire experimental session. Data from the arousometer and the photoplethysmograph were then averaged across 10-s intervals, resulting in 18 data points during the neutral and 60 data points during the erotic film. A pulse that fell across two 10-s intervals was assigned to the interval in which the peak ended.

Data Analysis

HLM can be categorized as a multilevel process (for a discussion of HLM, see Bryk et al., 1996). The intercepts and slopes of linear regressions of subjective sexual arousal predicted by vaginal pulse amplitude were computed for each participant (Level 1). The slopes and intercepts of Level 1 became the outcome variables for Level 2 in a linear model to test whether overall women showed a significant relationship between continuous subjective sexual arousal and vaginal pulse amplitude.

The results described in this study are based on the following models: Level 1 analyses evaluated both vaginal pulse amplitude prediction of continuous subjective sexual arousal and the reverse (continuous subjective sexual arousal prediction of vaginal pulse amplitude). The following is an example of the model wherein subjective sexual arousal is predicted by vaginal pulse amplitude (VPA):

$$\text{Subjective sexual arousal} = \beta_{0j} + \beta_{1j}(VPA) + r_{ij}, \quad \text{(Level 1)}$$

where β_0 is the intercept or the expected subjective sexual arousal of a participant whose vaginal pulse amplitude is the participant's average; β_1 is the slope or the expected change in subjective sexual arousal associated with a unit increase in vaginal pulse amplitude; and r is the error term, or the unique effect associated with each observation.

Additionally, four Level 2 models (Bonferroni $\alpha = .05/4 = .01$) were run on the strength with which each of the Film Scale factors (mental sexual arousal, reported physiological sexual arousal, positive affect, negative affect) predicted growth in continuous subjective sexual arousal during exposure to the erotic film (Level 1: subjective sexual arousal predicted by time). The following is an example of the model wherein the overall Film Scale is the predictor and subjective sexual arousal is the outcome variable:

$$\text{Subjective sexual arousal} = \beta_{0j} + \beta_{1j}(Time) + r_{ij} \quad \text{(Level 1)}$$

$$\begin{aligned} \beta_{0j} &= \gamma_{00} + \gamma_{01}(Filmscale)_j + u_{0j} \\ \beta_{1j} &= \gamma_{10} + \gamma_{11}(Filmscale)_j + u_{1j}, \end{aligned} \quad \text{(Level 2)}$$

where γ_{00} is the mean subjective sexual arousal for all participants; γ_{01} is the change in the subjective sexual arousal associated with one unit increase in Film Scale; γ_{10} is the average subjective-time slope for all participants; γ_{11} is the change in the subjective-time slope associated with one unit increase in Film Scale; u_{0j} is the unique effect of each participant on subjective sexual arousal holding Film Scale constant; and u_{1j} is the unique effect of each participant on the subjective-time slope holding Film Scale constant.

Table 2. *Means (SD) of Participant Sexual Functioning*

Sexual functioning domains (range)	Participants ($N = 22$)	Healthy controls reported by Rosen et al. (2000)
Desire (2–10)	7.86 (1.39)	6.9 (1.89)
Arousal (4–20)	17.81 (1.92)	16.8 (3.62)
Lubrication (4–20)	19.05 (1.20)	18.6 (3.17)
Orgasm (3–15)	13.38 (1.77)	12.7 (3.16)
Satisfaction (3–15)	12.05 (3.61)	12.8 (3.03)
Pain (3–15)	13.6 (1.73)	13.9 (2.79)

These four Level 2 models were computed to explore the validity of the continuous subjective sexual arousal. A moderate to high relationship between the subscale of mental sexual arousal and the continuous subjective sexual arousal was expected to confirm the validity of the continuous subjective sexual arousal method.

Results

Sexual Functioning

Participants were evaluated for current sexual functioning using the sexual functioning questionnaire (Rosen et al., 2000). All women included in the final sample ($n = 22$) scored within one standard deviation from the mean of women who are sexually functional as reported by Rosen et al. (2000; see Table 2).

Correlations between Vaginal Pulse Amplitude and Likert Film Scale

Average vaginal pulse amplitude values were calculated for the entire nonerotic and erotic film sections and the percentage of increase from neutral to erotic was calculated for each participant (1 data point per participant). This data reduction procedure has been commonly used in studies of this nature (e.g., Brody et al., 2003). Pearson's correlations showed that vaginal pulse amplitude was not significantly associated with the Likert Film Scale and, specifically, no significant relationship was found between vaginal pulse amplitude and subjective physiological sexual arousal, $r(20) = -.134$, $p = .56$, subjective mental arousal, $r(20) = -.082$, $p = .73$, negative affect, $r(20) = -.067$, $p = .77$, and positive affect, $r(20) = .121$, $p = .60$.

Relationship between Vaginal Pulse Amplitude and Continuous Subjective Sexual Arousal

A Pearson's r correlation calculated on continuous subjective sexual arousal and vaginal pulse amplitude for each participant (within-participant correlation) ranged between $r = .08$ and $.79$. Sixteen of the 22 women showed a significant correlation ($r > .37$). Additionally, individual regressions indicated that vaginal pulse amplitude significantly predicted continuous subjective sexual arousal in 16 of the 22 participants. When using HLM, the analysis showed that for the overall sample, vaginal pulse amplitude significantly predicted the levels of continuous subjective sexual arousal, $\beta = 46.81$, $t = 3.63$, $p < .01$. Figure 1 illustrates the slopes for all the participants and indicates the average slope for this population. The comparison of the unconditional model (model with no predictors) with the model using vaginal pulse amplitude as a predictor showed that residuals are smaller in the model with vaginal pulse amplitude, $\chi^2(4) = 341.0$, $p < .001$, suggesting that vaginal pulse amplitude contributes significantly to the prediction of continuous subjective sexual arousal.

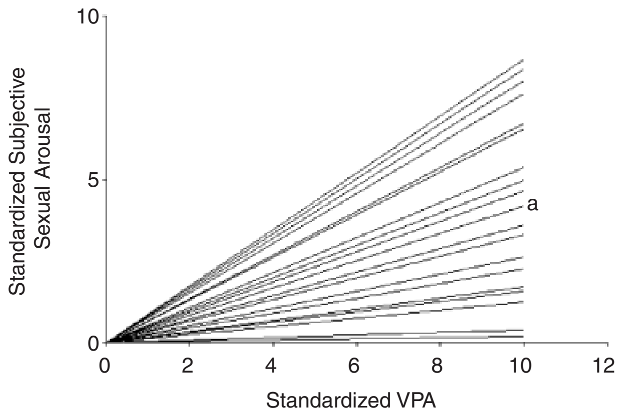

Figure 1. Individual regressions for vaginal pulse amplitude (VPA) predicting subjective sexual arousal. *Note* a. Regression line that best describes the population of slopes.

Figure 2 illustrates the changes in vaginal pulse amplitude and continuous subjective sexual arousal for 4 participants for which the relationship can be clearly seen. After graphing the relationship for each participant, one of the participants showed a relationship between vaginal pulse amplitude and continuous subjective sexual arousal distinctly superior to that of all other participants. The participant also showed a vaginal pulse amplitude baseline that was almost 10 times larger than the ones shown by the other participants. To test if the significance previously found was due to this outlier, a second HLM was run on the entire sample without this participant's data. The relationship between vaginal pulse amplitude and continuous subjective sexual arousal remained significant without the outlier, $\beta = 36.52$, $t = 3.80$, $p < .01$. To ensure that excluding the outlier from the analyses would not create problems, all analyses were first conducted on the entire sample and then on the sample without the outlier. The significance levels remained the same in both analyses;

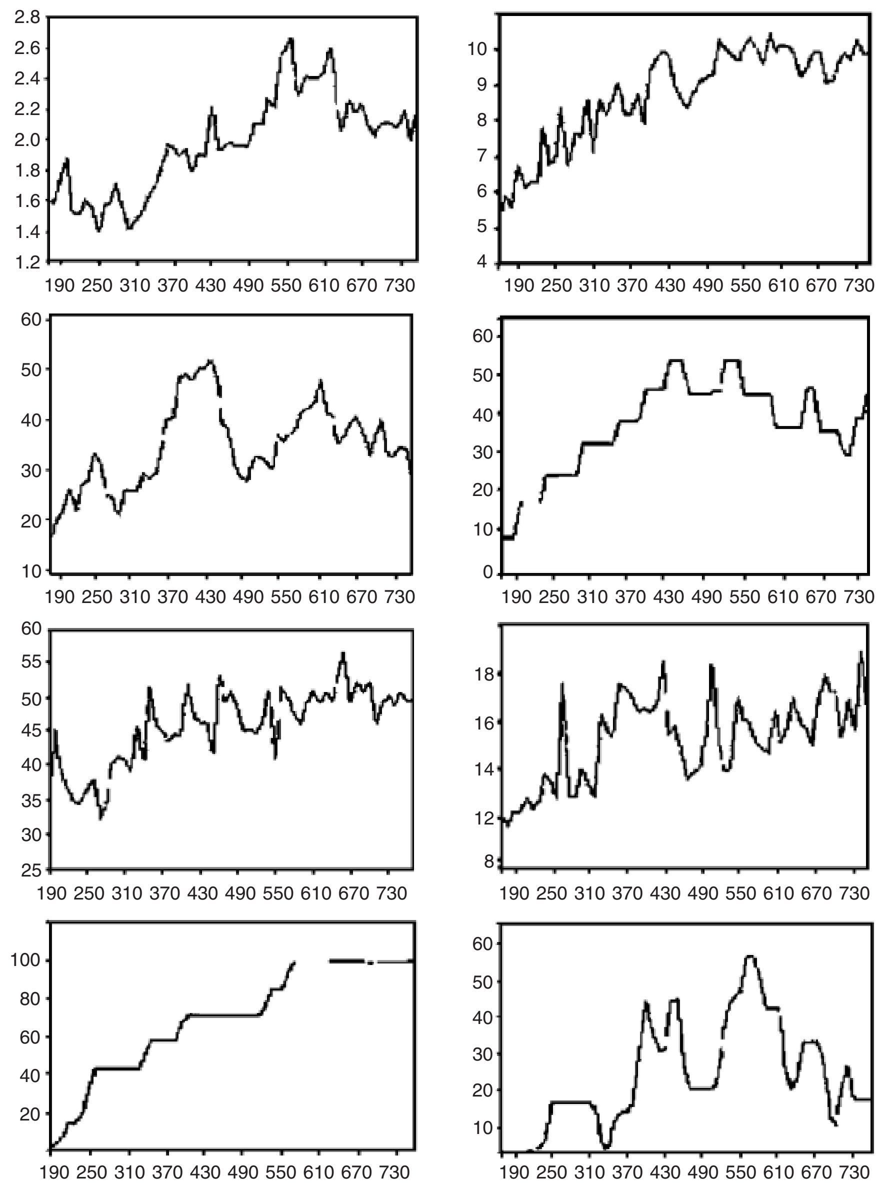

Figure 2. Examples of vaginal pulse amplitude (VPA) and continuous measures of subjective sexual arousal during the erotic film regressed by time for four participants.

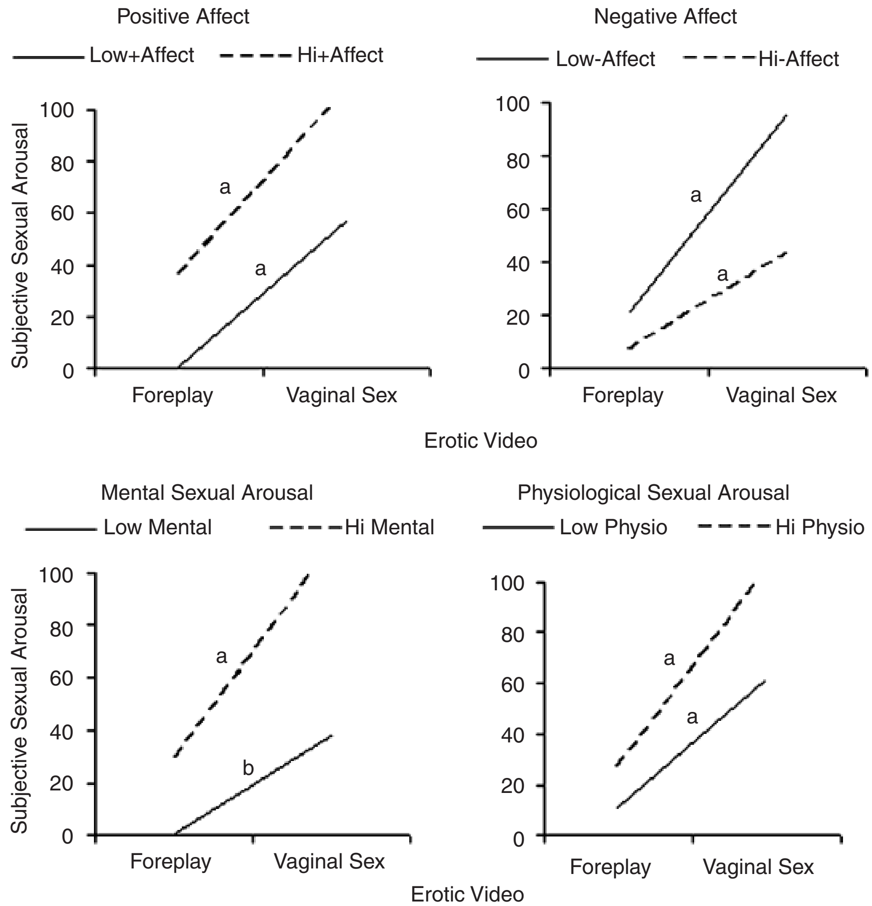

Figure 3. The impact of the four scales measured with the Film Scale questionnaire (positive affect, negative affect, reported physical sexual arousal, and reported subjective sexual arousal) on the changes in continuous subjective sexual arousal during exposure to the erotic videos. The regression line corresponding to "low" indicates the increase in continuous subjective sexual arousal for an individual with a score of 1 on the Film Subscale, whereas the regression line corresponding to "high" indicates the increase in continuous subjective sexual arousal for an individual with a score of 4 on the subscale. Different lower case letters (a, b) indicate statistical difference between slopes. No significant statistical difference between intercepts within graphs.

therefore, only results of analyses on the sample minus the outlier are reported.

In the results presented here, the β coefficient means that for 1 mV of increase in vaginal pulse amplitude, continuous subjective sexual arousal showed a 36.52 unit increase. Because the average *SD* in continuous subjective sexual arousal during the exposure to the erotic film is 22.40, the increase of 36.52 units in subjective sexual arousal corresponds to 1.6 *SD,* which is considered a large effect size. A test of the between- and within-subjects variance (variance components of Level 1 and Level 2) showed that 42% of the variance in continuous subjective sexual arousal was due to within-subjects variance, indicating that there is 58% of variance in the model that is attributable to between-subjects variance. This was confirmed by a test of the significance of between-subjects differences in vaginal pulse amplitude, $\chi^2(20) = 1525.10$, $p < .001$, indicating the presence of a substantial between-subjects difference on the subjective/vaginal pulse amplitude relationship. These results confirm the importance of using a method to analyze the data that is sensitive to between-subjects variance. Variance at Level 2 was 1557.69, $\chi^2(20, N = 21) = 105{,}160.93$, $p < .001$. In other words, although on average continuous subjective sexual arousal was strongly associated with vaginal pulse amplitude, some individuals showed a weaker or even a nonsignificant relationship.

In addition to vaginal pulse amplitude predicting continuous subjective sexual arousal, continuous subjective sexual arousal also predicted vaginal pulse amplitude, $\beta_{1j} = 0.12$, $t = 2.1$, $p < .01$. Individual variability in vaginal pulse amplitude was on average 58.56 mV, $\chi^2(20, N = 21) = 11{,}464.57$, $p < .001$, which corresponds to 95% of the variance explained by the model, indicating that vaginal pulse amplitude varied more between subjects as compared to the variance during exposure to the nonerotic/erotic video sequence.

Relationship between Likert Film Scale and Continuous Subjective Sexual Arousal

Levels of mental sexual arousal as measured by the Likert Film Scale predicted the increase of continuous subjective sexual arousal during the erotic video, $\gamma_{11} = 0.01$, $t = 5.88$, $p < .006$. This can be interpreted as an increase of 10 units on the continuous subjective sexual arousal scale (range 0–100) for each increase of 1 point in the mental sexual arousal of the Likert Film Scale (range 1–7). This result can be also understood as an increase of 10% on the continuous subjective sexual arousal scale for each 14.3% increase on the mental sexual arousal factor of the Likert Film Scale. The analysis of variance showed a significant difference between participants in this relationship that remains unexplained by the model, $\chi^2(20,\ N = 21) = 1399.08$, $p < .001$. Negative affect, $\gamma_{11} = -0.01$, $t = -1.66$, $p = .10$, positive affect, $\gamma_{11} = 0.001$, $t = 0.49$, $p = .62$, and perceived physical sexual arousal, $\gamma_{11} = 0.001$, $t = 1.03$, $p = 0.30$, did not predict continuous subjective sexual arousal (see Figure 3).

Discussion

The present study was the first to analyze the relationship between continuous subjective sexual arousal and vaginal pulse amplitude using HLM, a statistical technique designed to analyze between- and within-participants differences simultaneously without losing sensitivity toward individual differences. The results of this study suggest that vaginal pulse amplitude and subjective sexual arousal are indeed significantly related in women during laboratory studies, and that the limitations of past studies in finding an association between the two measures may have, in part, been the result of the methodology and statistical analyses employed. This study also confirmed the high between-participant variance in vaginal pulse amplitude also shown in past research (for review, see Janssen, 2002). Thus, we believe it is important that statistical analyses used to examine this type of data take into consideration individual differences.

Past studies have often found significant correlations between vaginal pulse amplitude and subjective sexual arousal when examining data within an individual participant (e.g., Korff & Geer, 1983; Wincze et al., 1977). However, none of these studies reported the average strength of this relationship and, more importantly, they failed to determine whether the relationship between vaginal pulse amplitude and subjective sexual arousal is significant overall in women. The study of the relationship between vaginal pulse amplitude and subjective sexual arousal often uses data with a nested structure that has characteristics incompatible with the assumptions of repeated-measures ANOVA, correlation, and linear regression. To use these statistical methods, data for each participant need to be reduced to one point which corresponds to the mean for vaginal pulse amplitude and the mean for subjective sexual arousal. This method does not take into consideration the richness of the repeated data and, more importantly, assumes that vaginal pulse amplitude represents the same physiological experience for all participants, an assumption that is violated by what is known about vaginal pulse amplitude. HLM, on the other hand, was developed to analyze nested data and is highly sensitive to individual differences. In addition, HLM can simultaneously calculate within- and between–subjects variance, provides a more efficient estimation of effect, and has lower Type I error rates (Raudenbush & Bryk, 2002).

Significant individual differences in vaginal pulse amplitude and in prediction of continuous subjective sexual arousal were noted in this study. Correlations were not significant between the subfactors of the Likert Film Scale and percentage of vaginal pulse amplitude increase during the nonerotic/erotic video sequence (as per analyses conducted in most prior studies). However, significant associations between vaginal pulse amplitude and continuous subjective sexual arousal were observed when using HLM to analyze the same data. Interestingly, a significant portion of the variance in the subjective/physiological relationship was associated with between-subjects differences. This provides support for the hypothesis that the lack of significant relationship between subjective and physiological sexual arousal noted in prior correlational studies may have partially been attributable to the type of analyses used to analyze data that is characterized by substantial between-subjects variance. In the present study, we found that, on average, an increase of 1 mV in vaginal pulse amplitude corresponded to an increase of approximately 37 units (range 0–100) in continuous subjective sexual arousal, which corresponds to a large effect size ($SD = 1.6$) in continuous subjective sexual arousal. It is interesting to note that the literature on the relationship between self-reported emotional states and nonsexual physiological sensations are low (Pennebaker, Gonder-Frederick, Cox & Hoover, 1985), suggesting that internal physiological states are not necessarily associated with an emotional response. The significant relationship between physiological and subjective sexual arousal noted here may, thus, be particularly meaningful if considered within the larger context of subjective responses.

Given that the arousometer is a new instrument, an alternative explanation of these results could be that this device measures something separate from a woman's subjective experience of sexual arousal. To test the validity of the arousometer, a series of HLM analyses were used to examine the relationship between questionnaire measures of mental and physiological sexual arousal and data from the arousometer. Likert scale levels of the mental sexual arousal but not physiological sexual arousal significantly predicted continuous subjective sexual arousal, suggesting that the mental sexual arousal factor of the Likert Film Scale and the arousometer measure closely related constructs. Also, measures of positive and negative affect were not associated with levels of continuous subjective sexual arousal, thereby providing further evidence that the arousometer was detecting changes specific to mental sexual arousal rather than affect or physiological sexual arousal.

In conclusion, vaginal pulse amplitude was found to significantly predict levels of subjective sexual arousal in sexually healthy women and the inverse relationship was also true. We suggest that future studies that examine the relationship between subjective and physiological sexual arousal in women sample data throughout the film stimuli for both subjective and physiological indices and employ statistical analyses that are designed to analyze nested data. The natural question that follows from this study will involve investigating what moderates the strength of the relationship between subjective and physiological sexual arousal. Given that some women seem to have a much stronger association between physiological and subjective sexual arousal than others, it is important to understand the individual differences that may explain this variance. For example, orgasm consistency during intercourse was observed to correlate with the relationship between subjective sexual arousal (measured using a Likert scale) and vaginal pulse amplitude in 26 menopausal women (Brody et al., 2003). We propose that future studies should adopt continuous measures of subjective and physiological sexual arousal in combination with HLM in the investigation of other potential moderators or mediators such as age, sexual functioning, and sexual self-efficacy.

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