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METHODOLOGY

Assessment of female sexual arousal: Response specificity and construct validity

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Abstract

Specificity of vaginal pulse amplitude and vaginal blood volume in reaction to visual sexual stimuli was investigated by comparing responses to sexual, anxiety-inducing, sexually threatening, and neutral film excerpts. Subjective sexual arousal, body sensations, emotional experience, skin conductance, and heart rate were monitored along with the genital measures. Self-report data confirmed the generation of affective states as intended. Results demonstrated response specificity of vaginal vasocongestion to sexual stimuli. In terms of both convergent and divergent validity, vaginal pulse amplitude was the superior genital measure. Skin conductance discriminated among stimuli only to a small degree, whereas heart rate failed to discriminate among stimuli altogether.

Descriptors: Female sexual arousal, Response specificity, Vaginal photoplethysmography, Electrodermal activity, Heart rate

Although in the field of sexual psychophysiology researchers claim that vasocongestion of the vaginal wall is specific in reaction to sexual stimuli, the empirical evidence available is sparse. To date, studies employing the vaginal photoplethysmograph have not paid sufficient attention to the issue of response specificity. In earlier studies (e.g., Geer, Morokoff, & Greenwood, 1974; Heiman, 1977), researchers investigating the validity of the vaginal photoplethysmograph for measuring responses to erotic and nonerotic stimuli showed increases in vasocongestion to the erotic stimuli only. They did not test the possibility, however, that similar patterns of response may be observed during other (nonsexual) emotional states.

The most widely used type of vaginal photoplethysmograph is a menstrual tampon-sized device containing an infrared light-emitting diode as a light source and a phototransistor as a light detector. Changes in blood volume within the vagina produce changes in the amount of light backscattered to the light detector, as a result of the large difference in transparency between blood and bloodless tissue. Changes in blood volume within the tissue can therefore be easily recorded as changes in the output of the light detector. Two components of variation in vaginal blood volume can be recorded simultaneously. With AC coupling, a measure of vaginal pulse amplitude (VPA) is obtained, reflecting short-term changes in vaginal engorgement. Fluctu-

ations in VPA reflect the phasic change in blood content or volume of the illuminated tissue at each heart beat, with larger amplitudes reflecting higher levels of vasoengorgement. When the signal is DC coupled, slowly developing changes in vaginal blood volume (VBV) are observed, which are thought to reflect pooling of blood in the vaginal tissue (Hatch, 1979). The question of which signal (AC or DC) is more sensitive to surface changes in the vaginal capillaries is still unresolved. Weinman (1967) reasoned that the DC measure should be the more sensitive measure because blood volume changes produced by the heart (the AC measure) represent only a small fraction of total blood volume in a capillary bed. In studies that compared both signals, however, the AC measure was considered a more sensitive measure of sexual arousal (Geer et al., 1974; Heiman, 1977; Osborn & Pollack, 1977).

In only one study (Hoon, Wineze, & Hoon, 1976) was a sexually arousing stimulus and a control stimulus (oceanographic lecture) contrasted with a nonsexual, dysphoric stimulus (Nazi war atrocities), thus investigating the possibility that a dysphoric stimulus would also produce vasocongestion of the vaginal wall. Unfortunately, this study only used VBV as the index of genital arousal, whereas the majority of female sexual arousal studies to date have utilized VPA (Rosen & Beck, 1988). However, response specificity of VPA has not been investigated.

The objective of the present study was to investigate construct validity of both indices of genital arousal by looking specifically at aspects of convergent and divergent validity. In terms of convergent validity, one would expect measures of genital arousal to show the highest responses to strong sexual cues and modest responses to more subtle sexual cues. In terms of divergent validity, one would expect measures of genital arousal not to be reac-

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tive to neutral or nonsexual emotional stimuli. Furthermore, employing both indices of genital arousal in the study allowed us to address the question of which measure, VPA or VBV, is the more specific and sensitive measure of genital arousal.

We compared responses to sexual, neutral, anxiety-inducing, and sexually threatening film excerpts. To determine the effectiveness of the experimental manipulations, subjective reports of sexual arousal, emotional experience, and two autonomic measures (skin conductance and heart rate) were monitored along with the genital measures. Anxiety (expected to be evoked by the anxiety-inducing and the sexually threatening film excerpts) was chosen as the emotional state incorporated in the comparison, because the effect of anxiety on responses to sexual stimuli has been studied extensively (e.g., Hoon, Wincze, & Hoon, 1977; Laan, Everaerd, van Aanhoud, & Rebel, 1993; Palace & Gorzalka, 1990; for a review of the effects of anxiety on sexual arousal in men, see Barlow, 1986). Results of most studies indicated an enhancing effect of anxiety on subsequent sexual arousal in functional subjects. Those results will be supported if it can be established that anxiety in itself does not yield higher genital arousal levels but only in interaction with a sexual stimulus. The sexually threatening film excerpt was included to assess sensitivity of the genital measures to more subtle sexual cues. To date, only two studies have assessed women's genital responses to sexually threatening stimuli. Beggs, Calhoun, and Wolchik (1987) found that both sexual pleasure and sexual anxiety narratives produced a significant increase in VPA relative to baseline, with sexual pleasure stimuli yielding higher levels of genital arousal than the sexual anxiety stimuli. Stock (1983) found that subjects were equally genitally aroused by an audio-taped eroticized rape narrative and by a narrative depicting consenting intercourse. Although the genital measure proved responsive to a realistic rape depiction as well, this narrative yielded significantly lower levels of genital arousal than did the other two stimuli.

Subjective sexual arousal and increases in genital arousal were expected to result from the sex stimulus and the sexual threat stimulus. In addition, genital and subjective sexual arousal during the sex stimulus were presumed to be higher than during the sexual threat stimulus as a result of stronger sexual cues in the former. Subjective sexual arousal and increases in genital arousal were predicted to be absent during the anxiety stimulus and not to differ from those during the neutral stimulus. In addition, we expected both the anxiety stimulus and the sexual threat stimulus to induce anxiety. The sexual threat stimulus was expected to evoke anger as well (cf. Stock, 1983). The sex stimulus was not expected to induce negative emotional experience and not to differ from the neutral stimulus in this respect. In the light of previous research (e.g., Fehr & Schulman, 1978; Hoon et al., 1976), the three emotional stimuli were hypothesized to yield increases in skin conductance levels. Given the equivocal findings concerning heart rate changes during sexual arousal (cf. Rosen & Beck, 1988; Zuckerman, 1971), no specific hypothesis regarding heart rate change during the sexual stimulus was stated in advance. Increases in heart rate were expected during the anxiety stimulus and the sexual threat stimulus.

Method

Subjects

Subjects were 49 healthy female undergraduate psychology students, who received course credit for their participation. The

mean age was 22.25 years (range = 18–46 years, $SD = 5.38$ years). Subjects were quite sexually experienced; self-reports indicated that 47 (96%) had experienced coitus, 45 (92%) had experienced orgasm, and only 1 had never masturbated. Twenty-three subjects (47%) had sex with a steady partner. Forty-eight subjects had a heterosexual orientation, and one subject considered herself to be bisexual. Forty-four subjects (90%) previously had seen erotic films.

Subjects were not tested during menstruation. Thirty-two women (65%) used hormonal contraception (birth-control pills), 13 women (27%) used condoms, 2 women used some other contraceptive means, and 2 women used no contraception at all. Of the 17 subjects who did not use hormonal contraception, 8 were tested in the follicular phase, 3 were in the ovulatory phase, and 4 were in the luteal phase. None were in the premenstrual phase. Phases were derived from the standard menstrual cycle phases of Rossi and Rossi (1977). Two subjects menstruated too irregularly to give a reliable estimation.

Confidentiality, anonymity, and the opportunity to withdraw without penalty from the experiment were assured for all subjects. To minimize coercion, the procedure, including the use of erotic film excerpts and genital measures, was described beforehand. Subjects were given a tentative second appointment for another day to give them time to consider participation. One subject reported having difficulty inserting tampons and therefore opted not to participate. None of the other subjects declined.

Design

A 4 (order) \times 4 (stimulus) \times 10 (repeated measures) design was employed, with order as the between-subjects variable. All subjects were exposed to four film excerpts (neutral, anxiety, sexual threat, sex). The four order groups were created using a 4 \times 4 Latin-square design (Kirk, 1968). In our design, each excerpt occupied any of the four ordinal positions only once and was preceded or succeeded by each of the other excerpts only once. Subjects were randomly assigned to one of the four order groups.

Apparatus and Response Measurement

Stimulus materials. The four film stimuli consisted of 5-min videotapes with sound. The sex stimulus was the female-initiated, female-centered erotic videotape as described by Laan, Everaerd, van Bellen, and Hanewald (1994), depicting petting, cunnilingus, and intercourse. The neutral stimulus consisted of a video travelogue describing old buildings in a Dutch village. The anxiety stimulus was an excerpt from the film *Cujo*, in which a woman is being attacked by a wild dog with rabies. The scene portrayed the woman cautiously leaving her car, with music creating a strong atmosphere of suspense, when suddenly she is being attacked by the dog. The sexual threat stimulus was taken from the film *Extremities*, starting with a shot from a male perpetrator, forcing a woman up the stairs of her house with distinct sexual intentions. The next scene shows the perpetrator lying on top of the woman, kissing her and caressing her breasts and body, and forcing her to kiss him by hitting her occasionally. During this scene, the perpetrator shows clear signs of sexual arousal. No actual intercourse was included in the excerpt. The clip was unambiguous in the sense that it was evident, from the way the woman tried to defend herself, that the perpetrator was acting against her will. The anxiety and sexual threat

stimulus were used in earlier research in our laboratory (van Moorst, 1992) and had evoked substantial levels of anxiety.

Physiological recordings. All physiological measures were recorded on a WEKA OEM 821060 thermowriter (paper speed = 100 mm/min). A vaginal photoplethysmograph measured VPA (the AC component of the signal) and VBV (the DC component). The AC signal (time constant = 1 s) was band-pass filtered (0.5–30 Hz) and digitized (20 Hz) using a personal computer (IBM AT) and a Keithley system model 570 for analog/digital conversion. A low-pass filter (0.5 Hz) separated the low-frequency blood volume from the pulse amplitude component, and the sampling rate of the DC signal was 10 Hz. To minimize potential light history and temperature sensitivity effects of the DC signal, the genital device was allowed a 45-min warm-up period prior to insertion. Depth of the probe and orientation of the light emitting diode were controlled by a device that was attached to the photoplethysmograph by the experimenter before each session. This consisted of a 9- × 2-cm acrylic plate with a hole in the center that allowed for the photoplethysmograph to be pulled through and fixed to the cable at a distance 5 cm from the center of the photo transistor. Subjects were instructed to insert the photoplethysmograph such that the plate would touch their labia. Both the photoplethysmograph and the placement device were sterilized in a solution of Cidex-activated glutaraldehyde between uses (Geer, 1980).

Skin conductance (SC) was recorded by an alternating current voltage (30 Hz ± 0.75 V) with Ag/AgCl electrodes (1 cm² contact area) filled with 0.05 M NaCl Unibase electrode paste (Fowles et al., 1981). The output of the resistance-to-voltage converter was integrated (time constant = 300 ms), adjusted to 0.2 V/μS (linear within a skin resistance range of 5–200 kΩ), and digitized (10 Hz). The recordings were taken from the medial phalanges of the index and middle fingers of the nondominant hand following a 20-min stabilization period.

Heart rate (HR) was recorded using a Hellige HR monitor SM-152-M and a Hellige photoelectric transducer that was attached to the left earlobe (sampling rate = 10 Hz).

All physiological responses were recorded continuously during baselines and stimulus presentations. A software program developed at our department timed the administration of the stimuli, employed a trigger signal to initiate sampling of the physiological measures, and marked changeover between stimuli and interstimulus intervals.

Subjective measures. Unipolar visual analog scales were used to assess subjective sexual arousal (both overall [mean] and strongest [maximum] feelings of sexual arousal), anxiety, and strongest genital sensations. Another five items, adapted from the study by Palace and Gorzalka (1990), were intended to measure autonomic arousal (see Table 1 for item labels). After each stimulus presentation, the subject had to state for each item on a 100-mm line (0 = not at all; 100 = very strong) to what extent she had experienced the corresponding feelings or body sensations while watching the film excerpt. She was also asked to assess on a 7-point Likert scale the degree to which she was experiencing 10 emotions (interest, surprise, disgust, distress, shame, contempt, guilt, anger, fear, enjoyment) taken from the Differential Emotion Scale (Izard, 1972). This scale was abbreviated by giving only one description of each emotion. Another eight items were added and expected to form threat and anger factors

together with the other items. Six sexual descriptors (sensual, horny, desire to make love, desire to masturbate, passionate, lascivious) were added to the scale. The extremes of these 7-point scales were *not at all* and *very strong*. The items were presented in a random order, differing from the order in which they are described here. All ratings (except strongest sexual arousal) were also collected prior to the experimental procedure.

Procedure

To help subjects make an informed decision about whether to participate in this experiment, they first took part in an introductory session in which all experimental procedures were explained in detail. They were told that they would be exposed to four film excerpts that might contain erotic and/or threatening material. They were shown the vaginal photoplethysmograph and were informed about the sterilizing procedures.

To reduce subject awareness of the experimental hypotheses with regard to the SC and HR recordings, they were told that the electrodes on fingers and earlobe measured natural, involuntary physiological reactions evoked by complex visual stimuli such as film (Cacioppo, Petty, Losch, & Kim, 1986). They were asked not to discuss any detail regarding the experiment with anyone until they had received the mailed debriefing, which was sent to all subjects after the last subject had been tested. Random spot checks during an exit interview revealed that subjects had complied with these instructions. Subjects were assured privacy, anonymity, and confidentiality. It was stressed that they could withdraw from the experiment at any time, without penalty. Any questions were answered at this time. At the end of this session, subjects were asked to make a tentative future appointment for the experimental session.

In the experimental session, each subject was tested individually by a female experimenter (E.L. or A.E.). On arrival at the laboratory, the subject read and signed an informed consent form. Several questions were asked pertaining to contraception, sexual problems, length of menstrual cycle, and date of last menstruation. The experimenter then attached the SC electrodes to obtain a stabilization period of at least 20 min. She then explained all the details of the experimental procedure.

After the experimenter had left the room, the subjects inserted the probe in private and attached the HR electrode to the ear lobe. When the subjects signalled (using a one-way intercom system) that the transducers had been placed, subjects rated their feelings of sexual arousal and anxiety and body sensations using visual analog scales. They then rated their emotional experience by answering questions presented on the TV monitor. They could answer by pressing one of seven buttons that corresponded with the seven answer categories shown underneath each question. Once a question was answered, the next question was presented. The answers were stored in an IBM AT personal computer. This session was followed by a 5-min adaptation period and a 2-min baseline period. During this 7-min resting period, subjects listened to music. The first film excerpt was then presented. After the film excerpt, subjects rated their feelings of sexual arousal, anxiety, body sensations, and emotional experience. This rating period was followed by a 4-min return-to-baseline interval during which subjects listened to music. To minimize carryover effects, the computer was programmed to indicate when genital responses had returned within a 5% range of the first baseline. When responses failed to return to baseline rapidly subjects were asked to count aloud backwards. This delay occurred in 25 subjects after the sex stimulus and in 8 sub-

jects after the sexual threat stimulus. The interval was followed by a second 2-min baseline recording period, during which subjects listened to music. Then the next film excerpt was presented, until all four excerpts were shown. At the end of the experiment, subjects were asked to respond to a series of questions pertaining to their reactions to the experimental procedure, their use of the genital device, and their expectancies concerning the objectives of the study. In addition, as a manipulation check, they were questioned about the degree to which they had paid attention to the film excerpts, the degree to which they had looked away from the TV monitor during stimulus presentations, and whether they had seen the film excerpts before.

Data Reduction, Scoring, and Data Analysis

VPA was sampled across baselines and subsequent stimulus presentation periods. Data were entered into a computer program developed at our laboratory that enabled off-line graphical inspection of the AC channel. Artifacts in the AC channel are caused by movements of the lower part of the body or by voluntary or involuntary contractions of the pelvic muscles. Spectral analysis revealed that artifacts do not occur in a distinctly different frequency band, but they can be readily detected by eye because they show an extreme increase in amplitude. After these artifacts were deleted, peak-to-trough amplitude was calculated for each remaining pulse. Movement artifacts in VBV were deleted in the same manner as for VPA. Each physiological measure was averaged over 30 s, resulting in 10 data points/stimulus. For each 2-min baseline recording, responses were averaged over 15 s, resulting in eight repeated measures baseline scores per baseline recording. In addition, a mean baseline score was calculated, obtained by averaging over the entire 2-min baseline recording.

The 24 emotions were considered to reflect positive and negative affect. Principal component factor analysis with Varimax rotation using pretest scores confirmed the structure of the emotion scales; 21 emotions were divided into 7 pleasurable emotions reflecting feelings of lust (consisting of all sexual emotions plus enjoyment; Cronbach's $\alpha = .82$), 4 emotions relating to anger (Cronbach's $\alpha = .85$), 8 emotions relating to threat (Cronbach's $\alpha = .71$), and 2 emotions reflecting tension (Cronbach's $\alpha = .79$). The factor solution explained 80% of the variance. Three of the 24 emotions did not contribute to the factor solution.

The BMDP 4V program (BMDP, 1990) was used for the multivariate and univariate analyses of variance (MANOVA, ANOVA) and covariance (ANCOVA). VBV data for six subjects had to be excluded from the analyses because of abrupt shifts in the level of response due to movements (cf. Levin, 1992). HR data for six subjects were missing because detection of HR at the earlobe was not possible in all subjects. The physiological measures were submitted to 4 (order) \times 4 (stimulus) \times 10 (repeated measures) ANCOVAs with order as the between-subjects variable and stimulus as the within-subjects variable, using the mean baseline score preceding each stimulus as a covariate. Subjective sexual arousal and anxiety ratings were submitted to a 4 (order) \times 4 (stimulus) repeated-measures MANOVA. The same was done for subjective ratings of body sensations and for factors measuring emotional experience. The Greenhouse-Geisser epsilon procedure was applied to all repeated-measures AN(C)OVAs to correct for the violation of the sphericity assumption in repeated-measures designs (Vasey & Thayer, 1987).

Following significant F ratios for each dependent measure, univariate contrast analyses (multiple comparisons between all possible pairs of means) were performed with the overall level of significance set at $\alpha = .05$ using the Bonferroni procedure.

The coefficient of statistical association, ω^2 (Stevens, 1990, p. 61), was computed when significant stimulus effects occurred. This statistic provided an index of the relative sensitivity of the physiological and subjective measures for the four stimulus presentations.

Results

Manipulation Check

Responses at exit interviews indicated that subjects had felt comfortable during the experiment despite the inserted genital device and the attached electrodes. None of the subjects had been aware of the nature of the physiological recordings. Most subjects (96%) said they had paid close attention to the sex stimulus and the anxiety stimulus, but four subjects had some trouble concentrating during the sexually threatening stimulus. Thirty-five subjects said that their attention had drifted on one or more occasions during the neutral stimulus. One subject had looked away from the screen several times during the sex stimulus, whereas 12 said they had done so during the neutral stimulus. Ten subjects reported to have looked away on one or more occasions during the anxiety stimulus, and five did so during the sexual threat stimulus. These data indicate that the content of the anxiety, sexual threat, and sex stimuli may have been more interesting than the neutral stimulus.

Effects of Stimulus Presentations

There were no significant effects of order on any of the dependent measures. Also, there were no significant interactions between order and stimulus and between order and repeated measures, showing the absence of differential effects depending on the order in which subjects were exposed to the stimuli.

Subjective sexual arousal and anxiety. There were no differences among order groups on the pretest for any variable, therefore raw posttest scores were used for the multivariate analysis.

The stimulus presentations had their intended effects upon subjective ratings. A main effect of stimulus was found (multivariate $F[9,324] = 73.42, p < .0001$). Univariate tests for overall sexual arousal ($F[3,135] = 130.78, p < .0001, \epsilon = 0.69$) and strongest feeling of sexual arousal ($F[3,135] = 124.29, p < .0001, \epsilon = 0.73$) were highly significant. Contrasts showed that subjects rated themselves more sexually aroused during the sex stimulus than during the other stimuli (Table 1). The sexual threat stimulus resulted in significantly higher ratings of subjective sexual arousal than did the neutral and anxiety stimuli, although ratings were significantly lower than during the sex stimulus. The univariate test for anxiety was also significant ($F[3,135] = 138.48, p < .0001, \epsilon = 0.64$), indicating that subjects rated themselves as most anxious during the anxiety stimulus. The sexual threat stimulus yielded significantly higher anxiety ratings than did the sex and neutral stimuli. Anxiety ratings differentiated among all possible combinations of stimuli, with lowest levels during the neutral stimulus. Ratings of sexual arousal during the sex stimulus and anxiety ratings during the anxiety stimulus fell above the middle, indicating that the findings in this study are

Table 1. Mean (SD) Subjective Ratings and ω^2 for Sexual Arousal, Anxiety, and Body Sensations to Neutral, Anxiety, Sexual Threat, and Sex Stimuli

| Subjective ratings ^a | Stimuli | | | | ω^2 |
|---------------------------------|--------------------------|---------------------------|---------------------------|---------------------------|------------|
| | Neutral | Anxiety | Sexual threat | Sex | |
| Overall sexual arousal | 4.8 ^b (10.8) | 3.2 ^b (3.8) | 13.5 ^c (18.7) | 52.6 ^d (22.0) | .72 |
| Strongest sexual arousal | 7.1 ^b (11.8) | 7.8 ^b (13.4) | 19.0 ^c (23.0) | 63.1 ^d (23.5) | .71 |
| Anxiety | 2.3 ^b (4.5) | 64.9 ^c (23.3) | 37.7 ^d (28.9) | 7.6 ^c (12.5) | .73 |
| Body sensations | | | | | |
| Genital | 13.5 ^b (19.2) | 13.1 ^{bc} (18.2) | 21.5 ^{bd} (22.3) | 60.5 ^c (25.4) | .66 |
| Heart rate | 7.3 ^b (14.7) | 52.5 ^c (27.7) | 36.9 ^d (27.5) | 38.9 ^d (27.6) | .49 |
| Respiration | 5.5 ^b (11.7) | 36.3 ^c (25.2) | 27.3 ^d (23.0) | 28.3 ^{cd} (22.7) | .36 |
| Transpiration | 6.3 ^b (11.9) | 18.2 ^c (21.2) | 17.1 ^c (25.4) | 13.9 ^c (14.6) | .15 |
| Body temperature | 9.1 ^b (14.0) | 31.5 ^c (24.4) | 26.4 ^c (26.0) | 31.4 ^c (25.5) | .26 |
| Other | 9.1 ^b (20.2) | 28.6 ^c (29.6) | 28.7 ^c (31.1) | 14.1 ^b (23.3) | .15 |

Note: For each dependent measure, means without common superscripts are significantly different at $p < .008$. ω^2 = coefficient of statistical association.

^a1 = not at all; 100 = very strong.

valid for moderate levels of arousal, comparable to levels obtained in most female sexual arousal studies.

Body sensations. Again there were no differences between order groups on the pretest for any variable, therefore raw post-test scores were used for this multivariate analysis. A main effect of stimulus was found (multivariate $F[18,360] = 21.09$, $p < .0001$).

All univariate tests were highly significant: strongest genital sensations, $F(3,132) = 99.02$, $p < .0001$, $\epsilon = 0.77$; heart rate, $F(3,132) = 45.86$, $p < .0001$, $\epsilon = 0.97$; respiration, $F(3,132) = 28.04$, $p < .0001$, $\epsilon = 0.93$; transpiration, $F(3,132) = 9.38$, $p < .0001$, $\epsilon = 0.83$; body temperature, $F(3,132) = 17.02$, $p < .0001$, $\epsilon = 0.88$; other extragenital sensations, $F(3,132) = 9.35$, $p < .0001$, $\epsilon = 0.95$ (see Table 1). Vaginal and extragenital muscle contractions were mentioned most often in this latter category.

Emotional experience. There were no differences in emotional experience between order groups on the pretest, therefore raw posttest scores were used. The stimulus main effect was significant (multivariate $F[12,350] = 90.89$, $p < .0001$).

Univariate tests of emotional responses were highly significant: lust, $F(3,135) = 105.98$, $p < .0001$, $\epsilon = 0.69$; anger, $F(3,135) = 146.48$, $p < .0001$, $\epsilon = 0.81$; threat, $F(3,135) = 196.99$, $p < .0001$, $\epsilon = 0.79$; tension, $F(3,135) = 72.22$, $p < .0001$, $\epsilon = 0.79$. Subjects reported more feelings of lust during the sex stimulus than during the other stimuli (see Table 2). The sexual

threat and the anxiety stimuli yielded equal levels of feelings of threat. In addition, subjects reported feelings of anger during the sexual threat stimulus.

Physiological responses. To determine whether our efforts to minimize carryover effects were successful, for each physiological variable a 4 (order) \times 4 (stimulus) ANOVA was undertaken with mean baseline preceding each stimulus as the dependent variable. For VPA, a main effect of stimulus ($F[3,135] = 10.01$, $p < .0001$, $\epsilon = 0.96$) and an Order \times Stimulus interaction was found ($F[9,135] = 5.51$, $p < .0001$, $\epsilon = 0.96$). The interaction effect was due to a systematic elevation of baselines following the sex stimulus in all order groups, irrespective of whether the sex stimulus had been presented first, second, or third. This pattern was also reflected by the contrast analyses on the stimulus effect, which showed that the baseline preceding the sex stimulus was significantly lower than baselines preceding the anxiety stimulus ($F[1,45] = 31.28$, $p < .0001$), the neutral stimulus ($F[1,45] = 12.03$, $p < .001$), and the sexual threat stimulus ($F[1,45] = 21.33$, $p < .0001$). For VBIV, the order ($F[3,39] = 3.39$, $p < .05$) and stimulus ($F[3,117] = 3.92$, $p < .05$, $\epsilon = 0.70$) main effects and the Order \times Stimulus interaction ($F[9,117] = 4.89$, $p < .001$, $\epsilon = 0.70$) were significant. In contrast to what was found for VPA, the Order \times Stimulus interaction for VBIV pointed to a baseline-order effect. A similar ANOVA using baseline scores in the order in which they were measured, regardless of which stimulus they preceded, indeed

Table 2. Mean (SD) Ratings and ω^2 for Emotional Responses to the Neutral, Anxiety, Sexual Threat, and Sex Stimuli

| Emotional experience ^a | Stimuli | | | | ω^2 |
|-----------------------------------|------------------------|------------------------|------------------------|------------------------|------------|
| | Neutral | Anxiety | Sexual threat | Sex | |
| Lust | 1.7 ^b (0.5) | 1.2 ^c (0.3) | 1.7 ^b (1.0) | 3.9 ^d (1.2) | .69 |
| Anger | 1.2 ^b (0.6) | 2.3 ^c (0.9) | 3.8 ^d (0.9) | 1.4 ^b (0.4) | .75 |
| Threat | 1.5 ^b (0.4) | 4.1 ^c (0.9) | 4.1 ^c (1.0) | 1.8 ^d (0.6) | .80 |
| Tension | 1.4 ^b (0.7) | 4.2 ^c (1.4) | 3.4 ^d (1.4) | 2.3 ^c (1.1) | .60 |

Note: For each dependent measure, means without common superscripts are significantly different at $p < .008$. ω^2 = coefficient of statistical association.

^a1 = not at all; 7 = very strong.

yielded a baseline-order effect ($F[3,117] = 12.41, p < .0001, \epsilon = 0.81$). This effect signified that for all order groups, VBV baselines increased over time, irrespective of which stimulus had been presented next. Two order groups had somewhat higher mean baselines than the two other order groups. Contrasts on the stimulus effect showed that the baseline preceding the sexual threat stimulus was significantly higher than baselines preceding the anxiety stimulus ($F[1,39] = 8.28, p < .01$) and the sex stimulus ($F[1,39] = 7.68, p < .01$). Baselines preceding the sexual threat stimulus and the neutral stimulus did not differ significantly. For HR, only an Order \times Stimulus interaction was found ($F[9,117] = 4.55, p < .001, \epsilon = 0.81$). This interaction signified a baseline-order effect as well ($F[3,117] = 10.76, p < .0001, \epsilon = 0.91$). A decrease in HR baselines over time was present in all order groups, regardless of which stimulus had followed. For SC, there were no significant main or interaction effects. Apparently, our criterion that responses had to return within a 5% range of the first baseline still allowed for small but systematic variation in most of the physiological measures.

To account for these baseline differences, $4 \times 4 \times 10$ (Order \times Stimulus \times Repeated Measures) ANCOVAs were performed with preceding mean baselines as covariates. For the sake of consistency, an ANCOVA was undertaken for SC as well, even though no baseline differences were present. A homogeneity of covariance test, which was performed by treating data from the four stimulus presentations as if they were obtained from distinct groups of subjects, revealed that the slopes of the regression lines were similar for all four stimulus groups. Reliability of each of the four covariates was determined by calculating Cronbach's α for the eight repeated-measures baseline scores and their mean (Nunnally, 1978). All covariates were highly reliable ($.99 < \alpha < .994$ for VPA; $.986 < \alpha < .994$ for VBV; $.993 < \alpha < .996$ for SC; all α s = .99 for HR). These findings legitimized the use of the ANCOVA.

For VPA, results of the ANCOVA revealed a significant effect for the covariate ($F[1,134] = 6.53, p < .05$), the stimulus main effect ($F[3,134] = 85.21, p < .0001$), the repeated-measures effect ($F[9,405] = 19.95, p < .0001, \epsilon = 0.32$), and the Stimulus \times Repeated Measures interaction effect ($F[27,1215] = 30.40, p < .0001, \epsilon = 0.24$) were significant (see Figure 1). VPA was significantly changed by the stimuli, and the pattern of response over time differed significantly between stimuli (see Figure 2). There were large increases in VPA during the sex stimulus, smaller but significant increases during the sexual threat stimulus, and no changes during the anxiety and neutral stimuli. For each physiological variable, Table 3 provides F values for contrasts between all possible pairs of means.

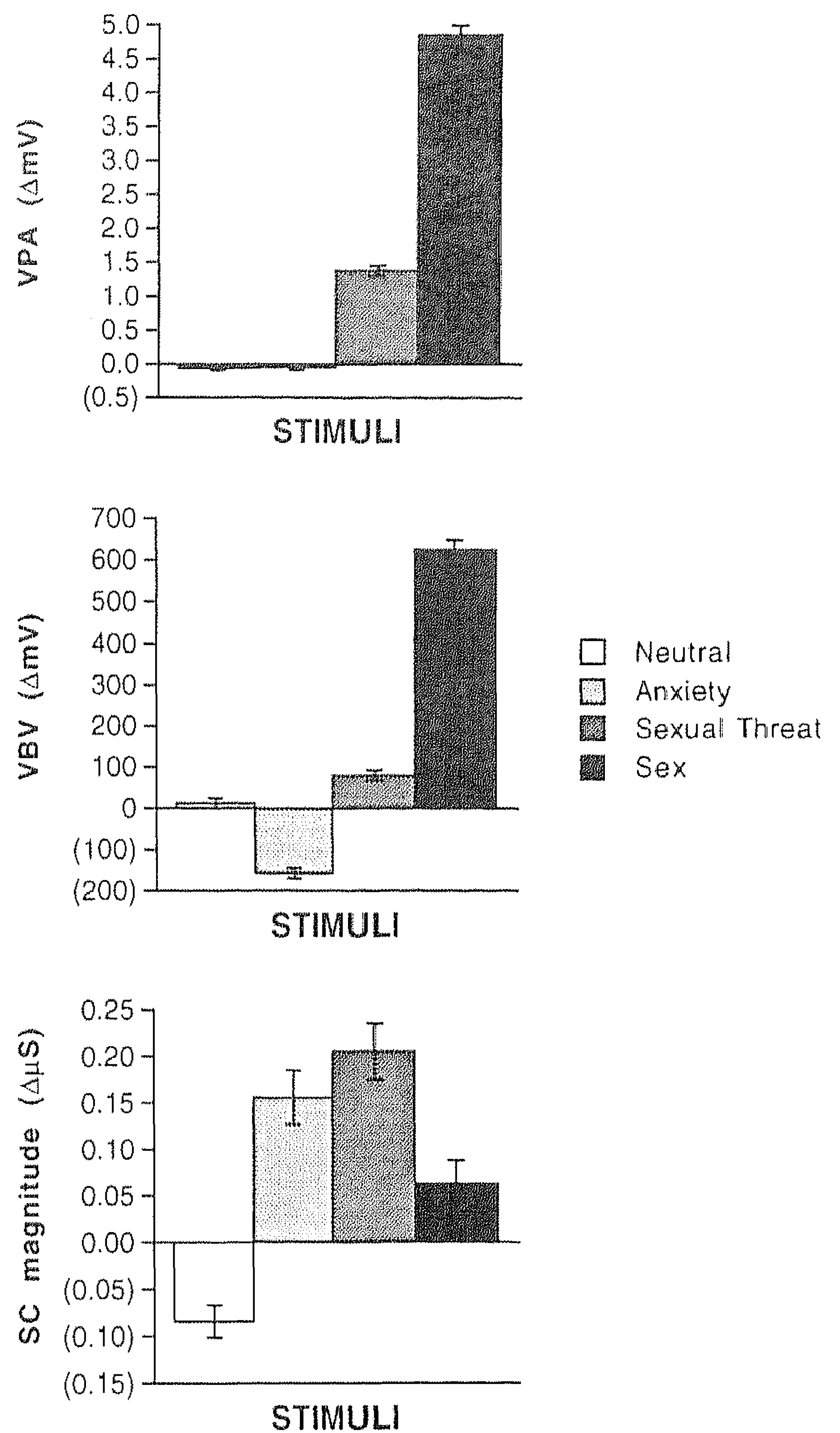


Figure 1. Mean (and standard error of the mean) vaginal pulse amplitude (VPA), vaginal blood volume (VBV), and skin conductance (SC) responses to the neutral, anxiety, sexual threat, and sex stimuli. Means are displayed as deviations from preceding baseline.

VBV yielded almost similar results (see Figure 1). A significant effect for the covariate was found ($F[1,116] = 41.84, p < .0001$). Again the stimulus main effect was significant ($F[3,116] = 73.74, p < .0001$), as were the repeated-measures main effect

Table 3. Contrasts Between All Possible Pairs of Means and ω^2 for Each Physiological Variable

| Physiological responses | F values | | | | | | ω^2 |
|---------------------------|---------------------|---------------------------|-----------------|---------------------------|-----------------|-----------------------|------------|
| | Neutral vs. anxiety | Neutral vs. sexual threat | Neutral vs. sex | Anxiety vs. sexual threat | Anxiety vs. sex | Sexual threat vs. sex | |
| Δ VPA ($n = 49$) | n.s. | 36.72** | 103.82** | 40.82** | 65.50** | 46.06** | .64 |
| Δ VBV ($n = 43$) | 31.40** | n.s. | 62.93** | 32.79** | 156.99** | 57.53** | .64 |
| Δ SC ($n = 49$) | 9.73* | 14.12* | n.s. | n.s. | n.s. | n.s. | .11 |

Note: VPA = vaginal pulse amplitude ($df = 1,44$); VBV = vaginal blood volume ($df = 1,38$); SC = skin conductance ($df = 1,44$). ns = not significant. * $p < .008$. ** $p < .0001$.

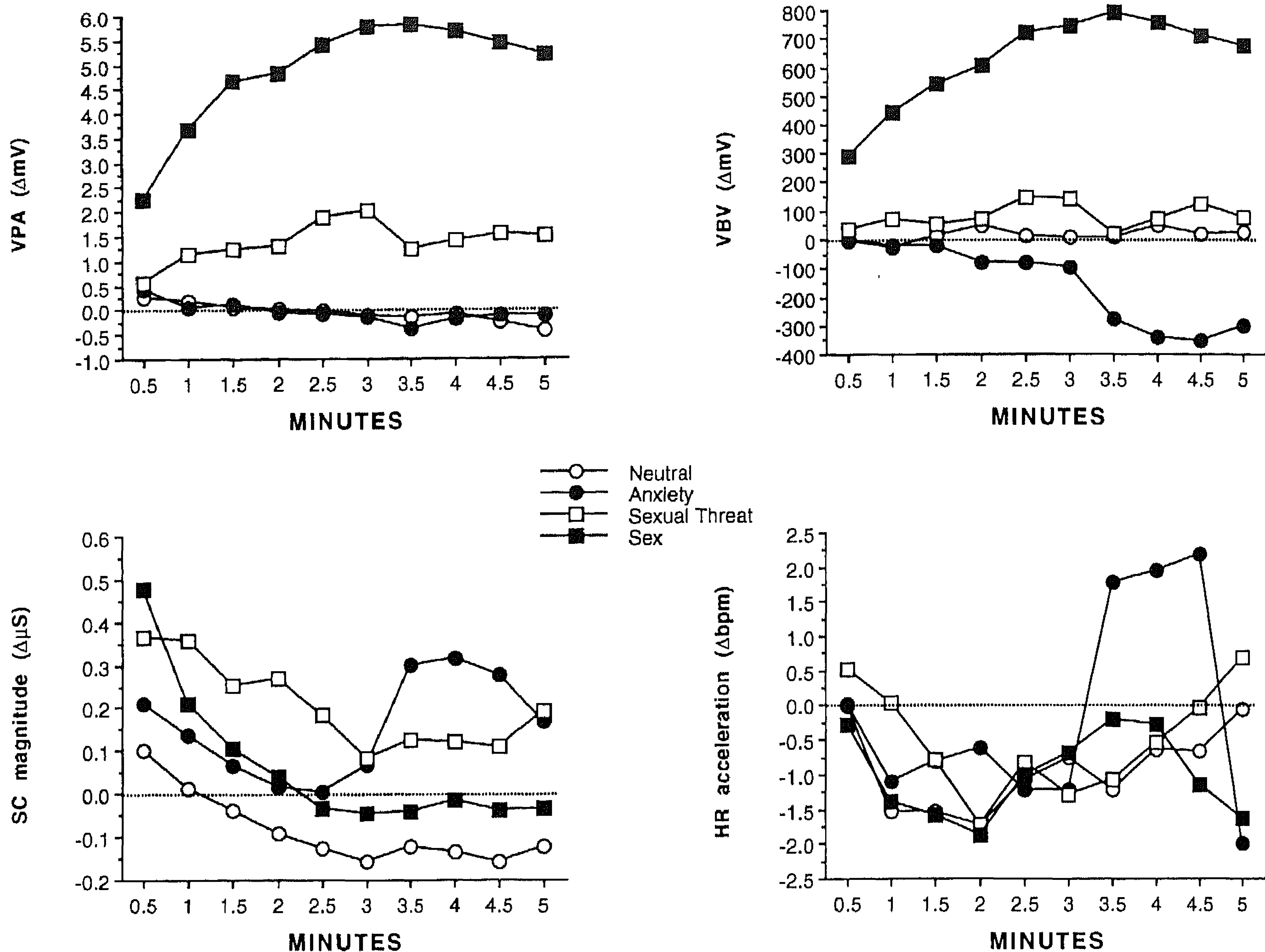


Figure 2. Mean vaginal pulse amplitude (VPA), vaginal blood volume (VBV), skin conductance (SC), and heart rate (HR) responses to the neutral, anxiety, sexual threat, and sex stimuli over 5-min stimulus duration. Means are displayed as deviations from preceding baseline.

($F[9,351] = 9.66, p < .0001, \epsilon = 0.26$) and the Stimulus \times Repeated Measures interaction ($F[27,1053] = 27.34, p < .0001, \epsilon = 0.22$). Increases in VBV were largest during the sex stimulus. This time there were no differences between the neutral and the sexual threat stimulus (see Table 3). The anxiety stimulus, however, yielded significantly lower levels of VBV than did all the other stimuli. Figure 2 shows that during the anxiety stimulus, VBV went well below baseline after 3 min of stimulus presentation.

For SC, the ANCOVA showed a significant effect for the covariate ($F[1,134] = 138.01, p < .0001$). The main effect of stimulus ($F[3,134] = 7.52, p < .0001, \epsilon = 0.85$), the main effect of repeated measures ($F[9,405] = 14.21, p < .0001, \epsilon = 0.27$), and the Stimulus \times Repeated Measures interaction ($F[27,1215] = 4.31, p < .005, \epsilon = 0.12$) were significant (see Figures 1 and 2). As expected, largest SC levels were found during the three emotional stimuli (see Table 3). Differences between the sex stimulus and the neutral stimulus were not significant. Figure 2 shows that during the anxiety stimulus, SC showed a strong increase after 3 min.

HR did not discriminate among stimuli. The covariate effect was significant ($F[1,116] = 191.23, p < .0001$), but the stimulus main effect was not. There was a repeated-measures main effect ($F[9,351] = 7.71, p < .0001, \epsilon = 0.48$), and a Stimulus \times

Repeated Measures interaction effect ($F[27,1053] = 5.07, p < .0001, \epsilon = 0.30$). Figure 2 shows that during the anxiety stimulus, again after 3 min, HR accelerated greatly.¹

Additional Analyses

The 15 subjects with known menstrual cycle time who did not take hormonal contraceptives were evenly distributed over follicular, ovulatory, and luteal phases and order groups ($\chi^2[6] = 4.38, p > .60$). This finding and the fact that a within-subjects design was used in this study and stimulus conditions did not interact with the order in which the stimuli were presented indicate that it is unlikely that menstrual cycle time would bias tests of the experimental hypotheses.

Differences between the group of subjects using oral contraceptives ($n = 32$) and the group using none or other (non-

¹ Because the stimulus effects also affect the covariates, ANOVAs were performed for all physiological measures using deviations from the preceding baseline as the dependent variables, thus investigating whether the ANCOVAs modified the stimulus effects. These analyses, including the contrasts between stimuli after significant stimulus effects, yielded equivalent results in all instances.

hormonal) contraceptive devices ($n = 17$) were examined. No significant differences emerged on any of the dependent variables.

Twenty-one subjects (43%) had seen the sexual threat stimulus earlier. Removal of those subjects from the analyses did not change the pattern of results for the physiological and subjective measures, despite considerable loss of power. The same was true when the 10 subjects (20%) who had seen the anxiety stimulus earlier were removed from the analyses.

Construct Validity of the Dependent and Independent Variables

Convergent and divergent validity of the independent variables. The effectiveness with which stimulus presentations were capable of altering genital arousal, subjective sexual arousal, and emotional experiences indicates, as intended, the construct validity of the independent variables. Construct validity is substantiated when genital responding during the sex stimulus is related to genital responding during the sexual threat stimulus because they both contain sexual cues and when genital responding among the other nonsexual stimuli is unrelated. VPA during the sex stimulus was indeed related to VPA during the sexual threat stimulus ($r[48] = .60, p < .001$), and VBV during the sex stimulus was related to VBV during the sexual threat stimulus ($r[42] = .47, p < .01$). VPA during the sexual threat stimulus was also related to VPA during the anxiety stimulus ($r[48] = .34, p < .05$). VPA and VBV between the remaining pairs of stimuli were unrelated. Similarly, SC and HR responses during the anxiety stimulus should be related to SC and HR responses during the sexual threat stimulus and not to those during other stimuli. Because the four stimuli produced only a 11% reduction in error variance on SC (ω^2 , see Table 3) it is not surprising that significant correlations were found between sex and anxiety ($r[48] = .47, p < .001$), between sex and sexual threat ($r[48] = .63, p < .001$), between sexual threat and anxiety ($r[48] = .75, p < .001$), and between sexual threat and neutral ($r[48] = .31, p < .05$) stimuli. HR failed to show a significant stimulus effect altogether. Strong correlations were found for this dependent variable between all possible pairs of stimuli ($.81 \leq r \leq .91$).

Stability and sensitivity of the dependent variables. To obtain an indication of the stability of the physiological variables, for all baselines of the four physiological variables the eight repeated-measures scores were submitted to a multivariate repeated-measures analysis. Baseline scores were used because baseline periods were assumed to be largely nonemotional (listening to music). A significant effect of repeated measures was found (multivariate $F[28,849] = 1.75, p < .05$). Univariate tests revealed that only for VBV did baselines increase over time ($F[7,238] = 2.91, p < .05, \epsilon = 0.61$).

Tables 1–3 show the percentage of variance explained by the stimulus effect (ω^2). The four stimuli produced a 64% reduction in error variance on VPA and on VBV and an 11% reduction on SC. Subjective ratings and factors measuring emotional experience were sensitive (ω^2 s = .71–.73 for subjective ratings; ω^2 s = .60–.80 for emotional experience). Subjective ratings of body sensations were less sensitive, except for subjective ratings of genital sensations (ω^2 s = .66).

Convergent and divergent validity of the dependent variables. Pearson product-moment correlation coefficients were calculated separately for each stimulus condition to determine the

relationship among physiological measures. Correlations between VPA and VBV were significant during the anxiety stimulus ($r[42] = .48, p < .001$), during the sex stimulus ($r[42] = .69, p < .001$), and during the sexual threat stimulus ($r[42] = .57, p < .001$). These correlations indicate that VPA and VBV are indices of related but not entirely similar genital processes (cf. Levin, 1992). VPA and VBV were unrelated to HR and SC during all stimulus conditions except for a significant relationship between VBV and HR during the anxiety stimulus ($r[42] = -.41, p < .01$). Because both SC and HR measure distinct autonomic processes, both variables were not expected to be related, which was indeed the case ($-.15 \leq r \leq .09$).

Correlations between genital measures and subjective sexual arousal were moderately significant during the sex and sexual threat stimuli only. VPA was significantly correlated with overall sexual arousal ($r[48] = .33, p < .05$) and strongest sexual arousal ($r[48] = .30, p < .05$) during the sex stimulus and with overall sexual arousal ($r[48] = .47, p < .001$), strongest sexual arousal ($r[48] = .41, p < .01$), and genital sensations ($r[48] = .31, p < .05$) during the sexual threat stimulus. VBV was significantly related to overall sexual arousal ($r[42] = .38, p < .01$) and strongest sexual arousal ($r[42] = .31, p < .05$) during the sex stimulus and to overall sexual arousal ($r[42] = .45, p < .01$) and strongest sexual arousal ($r[42] = .42, p < .01$) during the sexual threat stimulus. These correlations of VPA and VBV with measures of subjective sexual arousal were not significantly different. The findings add to the convergent validity of the genital measures.

VPA was not related to emotional experience. VBV was significantly related to emotional experience in only two instances: to tension during the anxiety stimulus ($r[42] = -.40, p < .01$) and to threat during the sexual threat stimulus ($r[42] = -.36, p < .05$).

Both SC and HR were unrelated to subjective ratings of sexual arousal, anxiety, emotional experience, and body sensations, with the exception of a relationship between SC and transpiration ($r[48] = .31, p < .05$) and SC and body temperature ($r[48] = .32, p < .05$) during the sexual threat stimulus.

Discussion

The stimulus conditions had the intended effects on subjective sexual arousal, emotional experience, and physiological arousal. That is, the sex stimulus evoked highest ratings of subjective sexual arousal and feelings of lust, virtually no anxiety, anger, or threat, and significantly lower ratings of tension as compared with the anxiety and sexual threat stimuli. More importantly, the sex stimulus yielded highest levels of VPA and VBV relative to the other emotional stimuli and the neutral stimulus and lower, albeit not significantly lower, levels of SC than did the other emotional stimuli. The anxiety stimulus produced highest ratings of anxiety and tension, no subjective sexual arousal or feelings of lust, and highest ratings of threat, together with the sexual threat stimulus. In addition, the anxiety stimulus evoked no increase in VPA relative to baseline and the neutral stimulus, a decrease in VBV relative to the neutral stimulus, and intermediate levels of SC. The sexual threat stimulus evoked highest ratings of anger, highest ratings of threat together with the anxiety stimulus, and second highest ratings of tension, anxiety, subjective sexual arousal, and feelings of lust. This stimulus yielded highest levels of SC, no increase in VBV relative to the neutral stimulus, and second highest levels of VPA. The neu-

tral stimulus may have caused subjects to relax as is demonstrated by the slow decrease in SC over time (see Figure 2). As predicted, this stimulus did not evoke any subjective, emotional, or genital arousal. The effect of stimulus conditions on SC, discriminating between the neutral stimulus and the anxiety and sexual threat stimuli, provides evidence that in terms of autonomic activity the latter two stimuli were not neutral.

These response patterns clearly demonstrate that VPA is specific for and sensitive to sexual stimuli and insensitive to anxiety-evoking stimuli. Support for this finding is demonstrated by the subjective ratings of sexual arousal (see Table 1) and by the significant correlations between VPA and subjective sexual arousal during the sex and sexual threat stimuli. This result supports those of previous research that demonstrated an enhancing effect of anxiety concurrent with sexual stimulation on VPA in female subjects. The demonstrated enhancing effects cannot be explained by autonomic arousal due to anxiety alone but are more likely the result of anxiety interacting with a sexual stimulus in an as yet unresolved manner.

In contrast to VPA, VBV was sensitive to the sex stimulus but not to the sexual threat stimulus. Responses to the sexual threat stimulus did not differ from responses to the neutral stimulus, even though subjects did report feelings of sexual arousal in response to the sexual threat stimulus. The most striking difference between VPA and VBV was, however, that VBV was also responsive to the anxiety stimulus; it showed a marked decrease after 3 min of stimulus presentation. In this respect, our findings differ from those of Hoon et al. (1976), who found significant increases during a sex stimulus relative to neutral and dysphoric stimuli but no significant differences between neutral and dysphoric stimuli.

The reason for these differential effects of VPA and VBV remains open to speculation. VPA may be a more sensitive indicator of sexual arousal than VBV, which is consistent with assertions made by Geer et al. (1974), Heiman (1977), and Osborn and Pollack (1977) and is supported by our finding that VBV did not discriminate between the neutral and sexual threat stimuli whereas VPA did. Another possibility is that the decrease of VBV during the anxiety stimulus may be a mere reflection of the relative instability of VBV during nonemotional episodes, as was demonstrated by the baseline instabilities of this measure. This decrease was not due to an incidental elevation of its preceding baseline relative to the other baselines, which may have allowed for a decrease in response solely as a result of the passage of time. On the contrary, the anxiety baseline was the lowest of baselines. Although VBV may be an unstable measure, the rate of decrease in VBV during the anxiety stimulus closely mirrors the increase in SC and HR (see Figure 2), which coincides with the most frightening part of this particular film excerpt. This finding suggests a more systematic phenomenon. Some studies have found evidence of finger vasoconstriction under conditions of fear (e.g., Ekman, Levenson, & Friesen, 1983; Stemmler, 1989; Vanderhoff & Clancy, 1962). VBV may be affected by a similar process of vasoconstriction in the capillaries of the peripheral bed, which may not affect arterial inflow. This suggestion is likely only if VBV detects mostly surface changes in the capillary bed and when VPA predominantly reflects arterial inflow that takes place underneath. Although this question may be relatively immaterial in relation to the use of both VPA and VBV as indicators of the sexual arousal status of the vagina, it is of importance when it comes to understanding where the vasodilatation induced by sexual arousal is actually taking place. Because

it is still uncertain what each signal represents and whether they are analogues of distinct vascular processes, our suggestion remains highly speculative (R. L. Levin, personal communication, November 1993). Whatever the cause of the differential effects of VPA and VBV, our findings do not contradict the results of studies that found an enhancing effect of anxiety to subsequent sexual stimulation on VBV (Hoon et al., 1977; Palace & Gorzalka, 1990) because they indicate a decrease rather than increase in responding during anxiety.

Although VPA and VBV were equally sensitive in terms of the amount of variance that was explained by the stimulus effect (64% for both measures), in terms of both convergent and divergent validity VPA appeared to be the superior measure. That is, VPA was highly reactive to the sex stimulus and moderately reactive to the sexual threat stimulus, whereas VBV was reactive to the sex stimulus only. In addition, VBV was reactive to the nonsexual emotional stimulus. In practical terms, both measures have their problems. In the present study, for each order group the VPA baseline was highest following the sex stimulus, indicating a failure to return to baseline rapidly, despite various interstimulus intervals. For VBV, not only did baseline scores increase over each 2-min baseline recording but mean baselines increased over the entire experiment, irrespective of order of stimulus presentation. Whereas the first practical problem can be overcome by increasing the length of interstimulus intervals or by providing effective distraction tasks, the second can only be accounted for post hoc by means of analyses of covariance. VBV has an additional complication in that it may show abrupt shifts in response levels due to movement (e.g., readjustment of position in the chair). In the present study, data for six subjects had to be excluded from the analyses for this reason.

Suggestions in the literature (e.g., Palace & Gorzalka, 1990) that sympathetic activation may play a more prominent role in genital arousal than parasympathetic activation were not supported by our data (cf. Zuckerman, 1971). Palace and Gorzalka (1990) based their suggestions on subjective reports of increased autonomic arousal only (faster breathing, faster heart beat, transpiration, increased body temperature). Our results suggest that these subjective reports are poor indicators of actual HR increase, because all subjective ratings of body sensations were unrelated to HR. More importantly, HR did not discriminate between emotional and neutral stimuli and among emotional stimuli. This finding is consistent with the findings of Hoon et al. (1976) and with the conclusion of Zuckerman (1971) that small increases in HR during an erotic stimulus cannot be consistently replicated.

Our results concerning SC are in line with the findings of Fehr and Schulman (1978) and Hoon et al. (1976). Although SC discriminates between neutral and emotional stimuli as a function of increased arousal (cf. Lang, Greenwald, Bradley, & Hamm, 1993), it does not discriminate among emotional stimuli. Therefore, SC should not be regarded as a specific indicator of sexual arousal.

Generalization of these results is limited by possible problems with external validity. Previous studies have shown that participants in sexuality studies, in contrast to nonparticipants, tend to be more sexually liberal and permissive, have less sex guilt, are less sexually inhibited, hold more positive views of erotic materials, and have higher mean levels of sexual intercourse and masturbation (cf. Catania, Gibson, Chitwood, & Coates, 1990; Morokoff, 1986; Wolchik, Braver, & Jensen, 1985; Wolchik,

Spencer, & Lisi, 1983). Comparison of participants and nonparticipants in the present study was not possible because only one woman declined after the introductory session. Such a low rejection rate in itself is favorable with respect to external validity. Furthermore, of the subjects who did participate, 22% ($n = 11$) on one or more occasions had experienced sexual abuse, which was conservatively defined as sexual assault, completed rape, or incest (these data are not reported here). In a recent German study in which no genital measures were employed, a similar percentage of sexual abuse among female college students was found (Heim, Gutberlet, Ehlert, Hellhammer, & Hanker, 1994). This finding suggests that for our participants sexuality does not

have merely positive meanings and that for Dutch women the threshold for participating in research employing vaginal measures may be lower than expected. Even if the present results may be of limited value to a more general population of women, they are certainly valuable for studies employing similar methodology because participation bias may be expected to operate in a similar way.

Our results convincingly demonstrate response specificity of vasocongestion of the vaginal wall to sexual stimuli. We recommend that researchers employing the vaginal photoplethysmograph utilize VPA rather than VBV because VPA is superior in terms of construct validity and has less practical limitations.

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