Changes in the Intensity and Pleasantness of Human Vaginal Odors During the Menstrual Cycle

Abstract. *Men and women estimated (by the method of magnitude estimation) the pleasantness and intensity of the odors of vaginal secretions sampled from consecutive phases of 15 ovulatory menstrual cycles of four women. On the average, secretions from preovulatory and ovulatory phases were slightly weaker and less unpleasant in odor than those from menstrual, early luteal, and late luteal phases. However, considerable variation in odor patterns was present across cycles from the same donor, as well as across cycles from different donors. These results indicate that human vaginal odors change slightly in both pleasantness and intensity during the menstrual cycle, but do not support the notion that such odors are particularly attractive to humans in an in vitro test situation.*

Considerable speculation has appeared in scientific journals on the question of whether odors of biological secretions influence, consciously or unconsciously, reproductive processes and behaviors of man (*1*). In many nonhuman mammals, odors communicate sexual receptivity, gender, and dominance status; they also influence estrous synchronization, reproductive maturation, and implantation (*2*). Direct evidence of similar influences of chemical stimuli on human reproductive processes is not available, although several areas of research have been interpreted by some authors as lending credence to such a possibility. These include (i) suggestions by psychoanalytic theorists that odors play a role in early psychosexual development, (ii) findings that many sex steroids and their metabolites have odors detectable to humans, and (iii) reports that vaginal odors of some primates communicate information about their estrous state (*3*). We present evidence that the odors of human vaginal secretions vary in both intensity and pleasantness across the stages of the menstrual cycle.

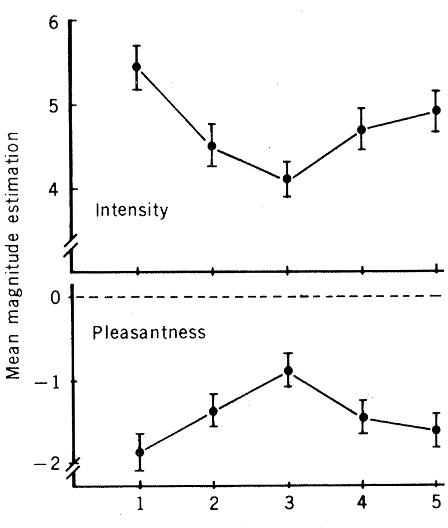

Fig. 1. Mean magnitude estimates of intensity and pleasantness of odors of human vaginal secretions that were sampled from consecutive phases of the menstrual cycle. Vertical bars indicate standard errors of the mean. Each data point represents an average of 256 cases. The majority of the pleasantness estimates fall on the unpleasant side of the neutral zero point. Phases are designated as: 1, menstrual; 2, preovulatory; 3, ovulatory; 4, early luteal; 5, late luteal (see text for details).

Vaginal secretions were sampled every other day, excluding weekends, from four women donors for a total of 23 menstrual cycles (*4*). Secretions were collected on weighed sterile tampons that were inserted in the evening before retiring and removed the next morning. The tampons were reweighed immediately after removal, sealed in glass jars, and frozen at -60°C until psychophysical testing. On the basis of daily basal body temperature (BBT) charts, only 15 of the 23 cycles were judged unequivocally ovulatory and thus used for subsequent analysis (*5*).

Tampons from a cycle of a given donor were thawed to room temperature before testing and placed in separate 100-ml glass jars that were covered on the outside by aluminum foil. Two layers of sterile gauze were taped over the jar openings and the bottles were sealed with caps lined with Teflon when not in use (*6*).

A total of 37 men and 41 women served as observers in this study, with 13 to 20 evaluating each cycle (*7*). Testing took place in a large air-conditioned room with relatively rapid air turnover. During a test session, the stimulus bottles that contained the secretions from an entire cycle of a given donor were presented to each observer randomly at 30-second intervals. During a trial, an experimenter opened a bottle and held it beneath an observer's nose for approximately 5 seconds. The observer could use any convenient sniffing strategy during this time, but was asked to sniff in a consistent fashion from trial to trial. The method of magnitude estimation with no designated modulus was used to evaluate the intensity (I) and pleasantness (P) of the secretions (*8*). With this procedure, each observer compared, in separate I and P test sessions, the relative I and P of the odors from the different cycle days by assigning numbers in ratio proportion to the I and P. For example, in an I test session, a sample that was perceived to be twice as strong as another was assigned twice as large a number. One that was perceived to be one-tenth as strong as another was assigned a number one-tenth as large, and so on. In the P test sessions, zero was used to designate neutral hedonicity, and + and − numbers were assigned in ratio proportion to the relative pleasantness and unpleasantness of the odors. At least 10 minutes were interspersed between test sessions, and only one I and P judgment was made by each observer for each stimulus (*9*).

Each observer's magnitude estimates were averaged into five values that corresponded to the phases of the menstrual cycle from which the stimulus secretions were sampled (*10*). The day of ovulation, estimated from the BBT chart, was established as the midpoint of the ovulatory phase (phase 3). Two days on each side of this midpoint were included in this phase, thus making it 5 days long. The menstrual phase (phase 1) included those days during which menstrual bleeding occurred. The preovulatory phase (phase 2) encompassed the days between the menstrual and ovulatory phases, whereas the early luteal and

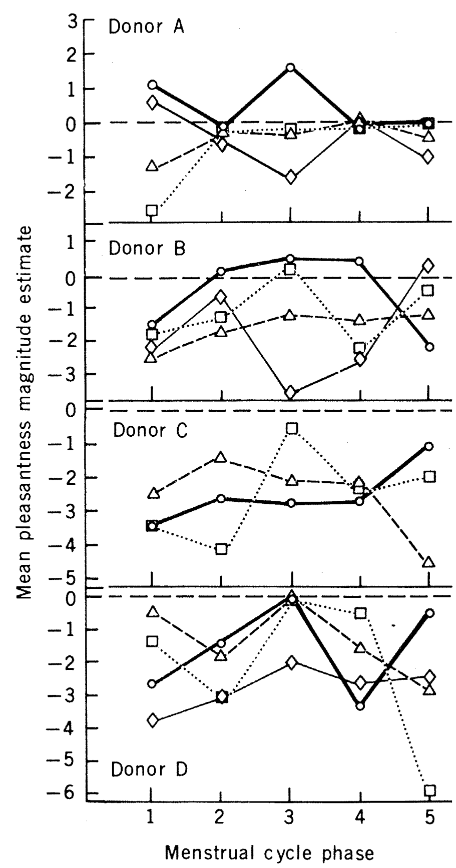

Fig. 2. Mean magnitude estimates of pleasantness of odors of human vaginal secretions that were sampled from consecutive phases of 15 menstrual cycles of four donors. First cycle, ○—○; second cycle, △- - -△; third cycle, □· · · ·□; fourth cycle, ◇—◇.

late luteal phases (phases 4 and 5) made up the first and second halves of the period from the end of the ovulatory phase to the beginning of the next menses.

Analyses of variance to evaluate the effects of cycle phase, cycle, and sex of the observer were performed separately on the I and P estimates (*11*). Odors from different phases of the menstrual cycle differed in both P and I (Fig. 1; respective F's = 10.11 and 6.10; d.f. = 4/922; $P < .001$) (*12*). A strong and inverse correlation across the cycle phases (Pearson $r = -.97$, $P < .001$) was seen between P and I. On the average, female observers gave larger I and smaller P estimates than did male observers (F's = 8.23 and 7.33; d.f. = 1/226; $P < .005$), although it is not clear whether this was due to a difference in perception or in the choice of moduli (*13*). The P estimates for the cycles differed (F = 3.35; d.f. = 14/226; $P < .001$), as did the patterns of the P and I estimates across the cycle phases (F's = 4.35 and 5.83; d.f. = 56/905, $P < .001$).

Although the secretion odors were, on the average, slightly less unpleasant in the preovulatory and ovulatory phases (Fig. 1), considerable variation in individual cycles was the rule (Fig. 2). Thus, while all but 1 of the 15 cycles had their least unpleasant or next to least unpleasant odor during either phase 2 or phase 3, only one had both the least unpleasant and next to least unpleasant odor during these two times. Consideration of the proportion of variance accounted for by the variables suggests that emphasis should be placed on the heterogeneity of the individual cycle patterns (*14, 15*).

More than 30 compounds, most of which bear odors, have been identified in human vaginal secretions (*16*). However, it is not known what chemicals are responsible for vaginal odors. Human vaginal secretions probably consist of a number of components, including (i) vulvar secretions from sebaceous, sweat, and Bartholin's and Skene's glands, (ii) mucus from the cervix, (iii) endometrial and oviductal fluids, (iv) transudate through the vaginal walls, and (v) exfoliated cells of the vaginal mucosa (*17*). Any or all of these components may produce and/or provide substrates for bacterial production of volatiles. The identification of lactic acid and 3-hydroxy-2-butanone, as well as C_2 to C_5 aliphatic acids, suggests the presence of volatiles produced by microbal action (*16, 18*).

The heterogeneity of our data suggests that it is unlikely that humans can use vaginal odors reliably to determine the general time of ovulation. Whether vaginal odors influence human sexual behaviors is not known. Our data do not support the notion, however, that vaginal secretion odors sampled during the ovulatory phase of women are particularly pleasant to human males in an in vitro test. Whether the absence of such pleasantness in our out-of-context test situation is the result of cultural or learning factors (such as lack of coital contact between the observers and donors) or is due to man's comparatively undeveloped olfactory system or his lack of a functioning vomeronasal organ is not known (*19*).

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4. The Caucasian donors (ages 19, 19, 22, and 27) had histories of normal regular menses, and evidenced no systemic or pelvic pathology. Basal body temperature and incidents of sexual arousal or coitus (or both) were recorded daily. Use of vaginal deodorants or douches was prohibited during the study, as was the eating of asparagus, garlic, and onions. The eating of broccoli, brussel sprouts, cabbage, chili, curry, kale, pineapple, and sauerkraut was discouraged.
5. Determinations of the most likely time of ovulation were made by an experienced gynecologist (G.R.H.) from the BBT charts without reference to the psychophysical data.
6. To determine if changes in volatiles from the secretions occurred during our storage procedure, we cut ten tampons in half immediately after secretion collection. One half of each tampon was analyzed immediately for volatiles by combined gas chromatography and mass spectrometry. The other half was frozen to -60°C and was analyzed 5 months later by the same procedure. No differences in the pattern of volatiles were discernible as a result of the storage process.
7. The median number of male and female observers per cycle was 11 and 8, respectively. The median number of cycles observed by a single observer was two (semi-interquartile range, 1.50). The mean ages ± S.D. of the males and females were 26.86 (± 5.78) and 25.24 (± 9.79) years, respectively.
8. R. L. Doty, *Percept. Psychophys.* **17**, 492 (19[illegible] S. S. Stevens, *Am. J. Psychol.* **69**, 1 (19[illegible] *Psychol. Rev.* **64**, 153 (1957). In cases where the testing sessions lasted more than 2 hours, the stimulus sets were placed in a refrigerator between tests to minimize potential buildup of excessive bacteriological contaminants.
9. The nature of the stimuli was not communicated to the observers until after the completion of the study, since such knowledge might have influenced their responses. Several observers spontaneously told us we were studying either deodorizing products, cheeses, or preservatives for food such as turkey or fish. The weights of the secretions deposited on the tampons did not consistently correlate with the I and P estimates (Pearson r).
10. R. L. Doty and C. Silverthorne, *Nature (Lond.)* **254**, 139 (1975).
11. Sex by donor by cycle phase analyses of variance, with repeated measures on the cycle phase factor; see B. J. Winer, *Statistical Principles in Experimental Design* (McGraw-Hill, New York, 1962), p. 337. The data from observers whose mean I or P magnitude estimates fell above or below 2 S.D. from the respective I or P grand mean were excluded from analysis to eliminate potential biasing influences of extreme moduli. Of the original 274 cases, 6.5 percent fell into this category. The I data were also analyzed following a z-score transformation of each individual's estimates to normalize the data matrix [J. P. Guilford, *Psychometric Methods* (McGraw-Hill, New York, 1954), p. 83]. Significant cycle phase (F = 9.56; d.f. = 4/976; $P < .001$) and cycle-by-cycle phase interaction (F = 7.70; d.f. = 56/976; $P < .001$) factors were present for the transformed data. Initial data analysis suggested considerable variability within and between donors for the I and P estimates. Pearson r's between the 15 cycles across cycle phases for both I and P estimates revealed no stronger intradonor than interdonor relationships.
12. The relative I and P of the odors did not change markedly within a test session. For example, Pearson r's computed across the mean magnitude estimates of the 12 stimulus samples for the observers in the first, second, and third thirds of the two longest test sessions of the study were as follows: test session A—first third versus second third (I and P r's respectively), 0.83, 0.79; second third versus third third, 0.96, 0.75; first third versus third third, 0.73, 0.75. Test session B—first third versus second third, 0.93, 0.94; second third versus third third, 0.92, 0.96; first third versus third third, 0.92, 0.94.
13. To our knowledge, no examination for potential sex differences in the choice of moduli for magnitude estimation tasks has been made for any sensory dimension. Although women have lower thresholds than men for many odors [H. S. Koelega and E. P. Köster, *Ann. N.Y. Acad. Sci.* **237**, 234 (1974)], it is not clear whether such a difference would be exhibited in a suprathreshold task.
14. The amount of total variance accounted for by the significant factors of the I and P analyses, respectively, were: sex of observer, 2.07 percent, 1.25 percent; cycle, 1.67 percent, 7.99 percent; cycle phase, 0.98 percent, 1.00 percent; cycle-by-cycle phase interaction, 8.32 percent, 9.24 percent. After the z-score transformation of each individual's I data, the results were cycle phase, 2.57 percent; cycle-by-cycle phase interaction, 28.92 percent.
15. Only donors B, C, and D engaged in coital activity during the period of this study. Intrauterine devices were used for birth control. The mean frequency of coitus per cycle for these three donors was 6.00 (S.D., 3.38). The median proportion of days in each phase on which coitus occurred was (phases 1 to 5, respectively): 0.20, 0.25, 0.40, 0.14, 0.20 (Friedman two-way analysis of variance, $P > .20$). Only 8 of the 48 coital acts reported here (17 percent) occurred within a 24-hour period before a tampon collection, and these occurred in two cycles of donor C (●—●, phases 1, 2, 3, Fig. 2; □- - -□, phase 3, Fig. 2) and two cycles of donor D (○—○, phase 5; ◇—◇, phases 3 and 5). The trends of the P and I magnitude estimates across the cycle phases for donor A (who had no coitus) were similar to those of donors B, C, and D (shown in Fig. 2), thereby suggesting that the addition of odors derived from semen was not a major influence on the results. To further examine the possibility of seminal contamination, separate sex by cycle-by-cycle phase analyses of variance were performed on the data from each donor. In all four cases a significant cycle-by-cycle phase interaction occurred ($P < .001$) for both the I and P data. Similarly, in all four cases a significant cycle phase effect occurred for the I data ($P < .001$). Only donors B and D exhibited P cycle phase effects which were statistically significant ($P < .006$).
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18. R. P. Michael, R. W. Bonsall, P. Warner, *Science* **186**, 1217 (1974); K. V. Thimann, *The Life of Bacteria* (Macmillan, New York, 1963), p. 465; R.

Waltman, V. Triconi, G. E. Wilson, Jr., A. H. Lewin, N. L. Goldberg, M. M. Y. Chang, *Lancet* **1973-II**, 495 (1973).

19. In animal preference tests, one odor is operationally defined as preferred to another if the animal increases the probability of being stimulated by that odor over the probability of being stimulated by the other. See R. L. Doty, in *Methods in Olfactory Research*, D. G. Moulton, A. Turk, J. W. Johnston, Eds. (Academic Press, London, 1975), pp. 393–406. In sexually experienced dogs, conspecific estrous vaginal odors are clearly preferred to nonestrous vaginal odors, as well as to neutral control odors in such out-of-context test situations [F. A. Beach and A. Merari, *Proc. Natl. Acad. Sci. U.S.A.* **61**, 442 (1968); R. L. Doty and I. Dunbar, *Physiol. Behav.* **12**, 825 (1974)].
20. We thank the members of the Monell Chemical Senses Center and the Department of Obstetrics and Gynecology, University of Pennsylvania Medical School, for assistance on this project. Supported by Rockefeller Foundation grant RF-72018.

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Locus of Short-Term Visual Storage

Abstract. *A rod monochromat can preserve visual information in iconic memory even when the initial stimulus is invisible to the subject. Since the initial invisibility is due to rod saturation, it can be shown that all the information must have been stored inside the photoreceptors. Because the spectral sensitivity for producing icons in normal subjects is that of the rods, the conclusion is that in normal subjects, under ordinary viewing conditions, the photoreceptors are the primary store for iconic memory.*

After a brief exposure to an array of letters, a subject cannot usually report all the letters that he thinks he saw. This subjective phenomenon was demonstrated objectively in the classic study of Sperling (*1*), who compared complete and partial reports made by subjects. The complete report consisted of all the letters a subject could report from a 50-msec presentation of, for example, two rows of letters. In the partial report only sampled half the information available to the subject, the letter presentation. If the tone was of high frequency, the subject had to report only the letters in the top row. If the tone was of low frequency, the subject only reported the letters in the bottom row. Since the partial report only sampled half of the information available to the subject, the number of letters available is twice the number given in the partial report. This experiment demonstrated that there were more letters available for short delays than were recalled in a complete report.

This result led to the notion of a short-term visual store (STVS), also called iconic memory (*2*), which decays rapidly. Sperling tentatively identified the STVS with the persistence of sensation that follows the stimulus. This persistence, or visual image, is usually called an icon (*2, 3*). Various theories have suggested that STVS, or the icon, is located partly in the retina but also at the level of feature extraction or at other more cognitive levels. The data reported here demonstrate that under typical viewing conditions this STVS is located primarily in the retina at the level of the photoreceptors.

In the first experiment, stimuli consisted of two rows of four letters each, presented for 50 msec. Each letter was about 2° high and the pre- and postexposure fields were dark. The conditions were similar to those of Sperling except that a Maxwellian view apparatus was used instead of a tachistoscope. In the complete report condition, the subject had to report all the letters. In the partial report condition, the subject reported either the top or the bottom row, depending upon whether the auditory tone was of high or low frequency.

Figure 1 shows a typical result of this experiment, which repeats Sperling's demonstration that for short delays the number of letters available is greater than the number that can be given in a complete report (*4*). Thus the STVS contains more letters than can be reported.

The unusual thing about this experiment is that the subject was a rod monochromat. She has the usual characteristics of rod monochromats, including poor acuity, complete color blindness, and a breakdown of visual function at high luminance levels. These characteristics correspond to the properties of normal rods. As found for other rod monochromats, all of her visual functions tested were the same as rod functions in a normal individual. In particular, the iconic memory experiments produced data similar to those obtained for normal subjects.

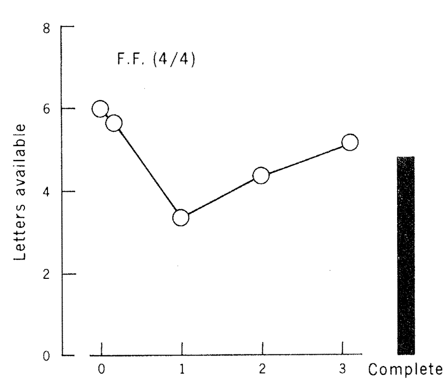

Fig. 1. Number of letters available (circles) in partial report as a function of delay of auditory tone. The bar indicates the average number of correctly identified letters in the complete report. The stimulus consisted of two rows of black letters, four per row, on a white background field that was about 14° wide by 10° high. Letter height was about 2° and the letters occupied a visual area about 10° wide by 7° high. The stimulus was presented for 50 msec and the delay of the tone was measured from the onset of the stimulus. A block design was used. Subject was a rod monochromat.

In the second experiment on this subject, an adapting field of about 20° in visual angle was used in the background. The letters were white and were added onto the white background. The background field was set to about 1000 scotopic trolands, and the letters were again about 2° high and were displayed for 50 msec. No matter how bright the letters were made, they could not be seen by the rod monochromat. She only saw the background field. However, if she closed her eyes after the letter presentation, she could see an icon of the background field and, superposed on it, a slightly brighter icon of the letters. That is, invisible letters produced ordinary discriminable icons after the rod monochromat closed her eyes. How is it possible for an icon to be produced by an invisible stimulus?

The letters were not seen on the background because of the phenomenon of rod saturation, discovered by Aguilar and Stiles (*5*) for normal rod vision and later demonstrated for rod monochromats (*6*). That is, the rod system saturates so that it cannot detect any increments above the critical intensity of about 1000 scotopic trolands. This is not due to exhaustion of the photopigment, since saturation occurs when only an infinitesimal amount of pigment has been used. The phenomenon of rod saturation is not noticed by normal subjects, because cones are operating when the rods become saturated. A rod monochromat, lacking cone function, cannot see any increments above the background when the rods are saturated, and, in particular, cannot see the letters in the experiment described. The background luminance used to demonstrate rod saturation is about the level of that in most tachistoscopes.

Although the rod monochromat had her rod system saturated and could not see the letters when they were presented, when she closed her eyes she *did* see the icon of the letters superposed on the icon of the background. Since the letters were eventually discriminable, the information about the letters must have been stored before (peripheral to) the first stage in the visual system that saturates. It could not be stored after the first stage that saturates because once saturation occurs, no discrimination is possible. The first stage that saturates produces identical signals from the background area and the area that received letters plus background. Therefore, all the in-