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Sex-Sensitive Tasks in Men and Women: A Search for Performance Fluctuations Across the Menstrual Cycle

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This study validated 6 cognitive and motor-skill tasks as sex-sensitive and used them to investigate whether women's performance changed across the menstrual cycle. Three putative female-advantage tasks and 3 putative male-advantage tasks were administered twice, at 6-week intervals, to young college women and men. Counterbalanced for order, women received the tests once during menstruation and once during the midluteal phase. The midluteal phase was determined by projection from day of ovulation, as verified by ovulation detection kits, and by confirmation of subsequent menstruation. Results revealed a significant sex difference for 5 of the 6 tasks. However, there was no evidence that performances differed with menstrual cycle phase. These results from younger women, combined with previous results from older women, may help establish the boundaries for hormonal influences on cognitive and motor-skill behavior.

The present study investigated whether women's performance systematically fluctuates with phases of the menstrual cycle. Although this basic question has existed for centuries (Richardson, 1992), it has taken on new importance with neurobiological findings of sex differences and hormonal influences on the structure and function of brain regions that are involved in higher cognitive processes. A partial list of these neural substrates includes various regions of the cerebral cortex (Juraska, 1991; Reid & Juraska, 1989; Yani, 1979), basal forebrain (Luine, 1985), hippocampus (Gould, Woolley, Frankfurt, & McEwen, 1990; Warren, Humphreys, Juraska, & Greenough, 1995; Woolley, Gould, Frankfurt, & McEwen, 1990), and corpus callosum (de Lacoste-Utamsing & Holloway, 1982; Juraska & Kopick, 1988; but see Bishop & Wahlsten, 1997, regarding putative sexual dimorphism of the human corpus callosum). One of the most interesting discoveries has been the rapidity with which hormones can alter dendritic function and ultrastructure in certain brain regions (Gould, Woolley, Frankfurt, & McEwen, 1990; Woolley, Gould, Frankfurt, & McEwen, 1990). These demonstrations (in animals) that gonadal hormones have the potential to alter neuronal function and morphology in only a few hours add to the speculation that, if similar change occur in humans, aspects of cognition could also change during the menstrual cycle.

Attempts to determine whether cognition systematically fluctuates with phases of the menstrual cycle have been plagued by two main methodological problems: the operational definition of the phases and the selection of cognitive tasks.

Definition of Phase: Variability Across Studies

The normal 28-day menstrual cycle consists of two main phases that are defined by levels of several hormones. The first 15 days make up the *follicular phase* during which follicle-stimulating hormone (FSH) stimulates an ovarian follicle to develop and secrete the hormones estradiol and estrone (collectively known as estrogen). The increased level of estrogen causes reconstruction and proliferation of the uterine lining and stimulates the pituitary to produce the luteinizing hormone (LH), which reaches its peak at midcycle (about Day 15). The LH peak causes the mature follicle to release the ovum, which then travels toward the uterus via the fallopian tube. LH also signals the development of the corpus luteum, a secretory organ developed from the original site of the ovum. The second half of the cycle is the *luteal phase,* during which estrogen and progesterone are secreted by the corpus luteum to prepare the endometrium for implantation should fertilization occur. If fertilization or implantation does not occur, secretion of estrogen and progesterone ceases, followed by degeneration and expulsion of the endometrium during menstruation. At this point, the pituitary is again stimulated by the hypothalamus to release FSH, and the cycle begins again (DeGroot, Besser, Cahill, & Marshall, 1989; Speroff, Glass, & Kase, 1994).

Most studies of cognition and the menstrual cycle have used one of three methods of delineating menstrual phase: by counting days from menstruation, by measuring basal

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body temperature (BBT), or by directly assaying hormonal change. As reviewed below, the first two methods are not highly reliable procedures for determining hormonal status, whereas hormonal assay is the most reliable method.

Day Count

Day count, when used alone, is unreliable because of between-subject variability in both cycle length and the occurrence (or absence) of ovulation. Using hormonal assay, Gordon, Corbin, and Lee (1986) found that 46% of women were not in the expected phases based on the day count of a standard 28-day cycle. Neither forward nor backward day counts are particularly reliable. A forward count from the end of menstruation is not reliable because the first half of the cycle, the follicular phase, can be variable in length (Asso, 1983; Speroff et al., 1994). A backward count from the onset of menstruation is somewhat more reliable because the second half of the cycle, the luteal phase, has a relatively fixed duration (Asso, 1983). However, the backward count is meaningful only if the woman has actually ovulated that month. This is critically important because many women, especially younger ones, do not ovulate monthly. For example, Metcalf and MacKenzie (1980) reported that, over a period of 3 months, only 62% of 20- to 24-year-old women and 88% of 25- to 29-year-old women ovulated during every cycle. Also, Bauman (1981) reported that only about 79% of the sample of women used in his study had normal ovulatory cycles. Thus, the use of forward or backward day count specification of ovulatory phase could result in a high percentage of participants who were not ovulating, especially if younger women were included. This is noteworthy because the hormonal profile of an ovulatory cycle differs significantly from that of an anovulatory cycle (Asso, 1983; Speroff et al., 1994). The causes and hormonal profiles of anovulatory cycles are both numerous and complicated (Speroff et al., 1994).

BBT

Measuring BBT is also an unreliable procedure for determining hormonal phase. Vermesh, Kletzky, Davajan, and Israel (1987) reported that BBT predicted the actual day of ovulation in only 10% of the cycles studied, whereas the majority of the actual ovulation days (70%) fell across the 3 days following the BBT prediction. Similarly, McCarthy and Rockette (1986) conducted a retrospective analysis of over 1,200 cases that revealed accurate prediction of ovulation day in less than 5% of cases and within 3 days of the BBT-based predicted day in only 32% of cases. Other studies have reported similarly poor predictions of exact day of ovulation as well as distribution of the majority of ovulations that occur within 3 days before or after the BBT-predicted day (Bauman, 1981; Morris, Underwood, & Easterling, 1976; Quagliarello & Arny, 1986).

Hormonal Assay

The most accurate method of defining menstrual cycle phase is direct assay of hormones. However, assays require procedures such as radioimmunoassay plus invasive procedures such as blood collection. Although blood collection is minimally invasive, it is often difficult to use because of increasingly strict safety regulations involving the use of body fluids. Consequently, relatively few studies have used direct hormonal assay.

Mixed Findings

Table 1 presents a sample of studies of cognition and menstrual cycle phase and illustrates some of the different methods of defining *phase*. Because other methods are questionable, only the findings from hormonal assay studies are listed. This table is expanded from data discussed in Sommer (1992) that include additional studies of cognition and menstrual phases. As shown in Table 1, of 62 studies of cognition and the menstrual cycle, only 17% measured hormone level in participating participants. Among these 11 studies, the results have been equivocal, with some reporting consistent cognitive changes across menstrual phases (e.g., Komnenich, 1974; Wuttke et al., 1976), some having reported mixed cognitive changes (e.g., D. Becker, Creutzfeldt, Schwibbe, & Wuttke, 1982; Carr-Nangle, Johnson, Bergeron, & Nangle, 1994; Hampson, 1990a; Krug, et al., 1994; Phillips & Sherwin, 1992) and others reporting no menstrual cycle variation (e.g., Girdler & Light, 1994; Gordon, Corbin, & Lee, 1986; Gordon & Lee, 1993; Pomerleau, Teuscher, Goeters, & Pomerleau, 1994). Another indication of the mixed findings is that some of the day count and BBT studies obtained positive findings (e.g., Broverman et al., 1981; Hampson, 1986; Hampson & Kimura, 1988; Klaiber, Broverman, Vogel, & Kobayashi, 1974; E.-M. Silverman & Simmer, 1975) and some did not (e.g., Graham, 1980; Komnenich, Lane, Dickey, & Stone, 1978; Redgrove, 1971; Richardson, 1991; Slade & Jenner, 1980).

Selection of Tasks: Variability Across Studies

Researchers have used a wide range of behavioral tasks when investigating cognitive fluctuations across the menstrual cycle phases. In a review of 45 such studies, Sommer (1992) listed 11 categories of behaviors that have been measured, including simple arithmetic, short-term memory, verbal skills, visual–spatial, rote speed tasks, motor coordination, frustration tolerance, and flexibility. Among the 11 categories of general cognitive skills, at least 78 specific cognitive tests have been identified by Sommer (1992), but there have been additional behaviors studied since that review. These additional behaviors included, but are not limited to, stress responsivity (Choi & Salmon, 1995; Girdler & Light, 1994), creativity (Krug et al., 1994), dressing behavior (Kim & Tokura, 1995), asymmetric hemispheric activity (Bibawi, Cherry, & Hellige, 1995), facial preference (Frost, 1994), body image (Carr-Nangle et al., 1994), and interest in erotica (Zillmann, Schweitzer, & Mundorf, 1994).

The study of sex-sensitive tasks has increased in recent years, in part because some of these tests are known to be

Table 1

Studies of Simple Cognition and Menstrual Cycle Phase Illustrating Different Methods of Defining Phase

Authors	Definition of *phase*	Findings
Altenhaus (1978)	Day count	
Baisden & Gibson (1975)	Day count	
D. Becker et al. (1982)	Hormonal assay	Some phase differences
Bibawi et al. (1995)	Day count	
Black & Koulis-Chitwood (1990)	Day count	
Broverman et al. (1981)	Day count	
Brown et al. (1984)	Day count	
Carr-Nangle et al. (1994)	BBT and hormonal assay	Some phase differences
Choi & Salmon (1995)	Day count	
Cockerill, Wormington, & Neville (1994)	BBT and day count	
Cooper, Blue, & Ross (1983)	Day count	
Cormack & Sheldrake (1974)	Day count	
Dor-Shav (1976)	Day count	
Fradkin & Firestone (1986)	Day count	
Frost (1994)	Day count	
Gamberale, Strindberg, & Wahlberg (1975)	Day count	
Girdler & Light (1994)	Hormonal assay	No phase differences
Golub (1976)	Day count	
Gordon & Lee (1993)	Hormonal assay	No phase differences
Gordon et al. (1986)	Day count and hormonal assay	No phase differences
Graham (1980)	Day count	
Hampson (1986)	Day count	
Hampson (1990a)	Day count and hormonal assay	Some phase differences
Hampson & Kimura (1988)	Day count	
Hudgens, Catkin, Billingsley, & Mazurcysk (1988)	Day count	
Hughes (1983)	Day count	
Hunter, Schraer, Landers, Buskirh, & Harris (1979)	Day count	
Hutt, Frank, Mychalkiw, & Hughes (1980)	Day count	
Jensen (1982)	Day count	
Kim & Tokura (1995)	BBT	
Kirstein, Rosenberg, & Smith (1981)	Day count	
Klaiber et al. (1974)	BBT; BBT and hormonal assay	Phase differences
Komnenich (1974)		
Komnenich et al. (1978)	Day count	
Kopell, Lunde, Clayton, & Moos (1969)	Day count	
Krug et al. (1994)	Hormonal assay	Some phase differences
Lamson-McBride & Payne (1981)	Day count	
Landauer (1974)	Day count	
Lazarov (1982)	Day count	
Little & Zahn (1974)	Day count and BBT	
Mayer (1982)	BBT	
Montgomery (1979)	Day count	
Munchel (1979)	Day count	
Peters et al. (1995)	Day count	
Phillips & Sherwin (1992)	Day count and hormonal assay	Some phase differences
Pomerleau et al. (1994)	Ovulation detection kit	No phase differences
Redgrove (1971)	BBT	
Richardson (1988)	Day count	
Richardson (1992)	Day count	
Rodin (1976)	Day count	
E.-M. Silverman & Zimmer (1975)	Day count	
E.-M. Silverman & Zimmer (1976)	Day count	
I. Silverman & Phillips (1993)	Day count	
Slade & Jenner (1980)	Day count	
Snyder (1978)	Day count	
Sommer (1972)	Day count	
Strauss, Schulteiss, & Cohen (1983)	Day count	
Wells & Payne (1979)	Day count	
Wickham (1958)	Day count	
Wuttke et al. (1976)	Hormonal assay	Phase differences
Zillmann et al. (1994)	Day count	
Zimmerman & Parlee (1973)	Day count	

Note. Because methods other than hormonal documentation are questionable, only those findings from hormonal assay studies are listed (expanded from data included in Sommer, 1992). BBT = basal body temperature.

influenced, in a complicated manner, by the presence of circulating gonadal steroidal hormones (Janowsky, Oviatt, & Orwoll, 1994; Nyborg, 1983; VanGoozen, Cohen-Kettenis, & Gooren, 1994). Although a complete review of sex differences in cognition is beyond the scope of this article (for review, see Halpern, 1992; Hampson & Kimura, 1992; Hyde & Linn, 1988; Linn & Petersen, 1985; Maccoby & Jacklin, 1974; Nyborg, 1983; Voyer, Voyer, & Bryden, 1995), there is a general consensus that adult women, as a population, outperform men on tasks of verbal fluency, manual speed and coordination, and articulation (Hampson & Kimura, 1992; Maccoby & Jacklin, 1974; Tyler, 1965). In contrast, adult men, as a population, have been found to outperform women on visual–spatial tasks that include spatial perception, mental rotation, spatial visualization, and spatial–temporal tasks (Halpern, 1992; Linn & Petersen, 1985; Shute, Pellegrino, Hubert, & Reynolds, 1983; Voyer et al., 1995).

Main Hypothesis Tested in the Present Study

By using sex-sensitive tasks, Hampson and Kimura (1992) have proposed that during the menstrual cycle, women's performances on certain male-oriented tasks (e.g., a combined measure of spatial ability) are significantly better during menstruation when levels of estradiol and progesterone are low than during the midluteal phase when estrogen and progesterone levels are high. Conversely, they reported that women's performance on certain female-oriented tasks (e.g., a combined index of articulatory speed and accuracy) are better during periods of high estrogen levels (i.e., preovulatory phase and midluteal phase) compared with periods of low hormone levels (i.e., menstruation; Hampson, 1990a, 1990b; Hampson & Kimura, 1988, 1992). As compelling as this general theory is, the findings of systematic cognitive change across the menstrual cycle have not been confirmed consistently, even when phases were defined by hormonal assay (see Table 1). For example, in a carefully designed study that included assays of LH, FSH, estradiol, and progesterone, Gordon and Lee (1993) failed to find menstrual phase differences on either verbal–sequential or visual–spatial tests, nor did they find differences among three groups of women with different hormonal status: those who were regularly menstruating, those who were taking oral contraceptives, and those who had amenorrhea.

In light of these inconsistent findings, we conducted an investigation of the effect of menstrual phase on cognition. The experimental design had both a between-subjects component and a within-subject component. The between-subjects design (women vs. men) verified that certain tasks were indeed sex-sensitive among university student cohorts. The within-subject design (menstrual vs. midluteal phases) investigated possible performance fluctuations across the menstrual cycles of individual women.

Methodology Used in Present Study

As reviewed above, hormonal phase cannot be determined with confidence unless the event of ovulation is documented, hormones are assayed, or both. In the present study, we detected ovulation by using commercially available ovulation detection kits. This procedure is noninvasive and inexpensive, but it has rarely been used. To our knowledge, only one other study (Pomerleau et al., 1994) used ovulation detection kits in a study of cognitive change across the menstrual cycle. The kits detect the occurrence of the LH surge, after which ovulation has a very high, but not 100%, chance of occurring within 24 to 36 hr (Vermesh et al., 1987). The exact probability of ovulation following an LH surge is not stated in the available literature. As a methodology by which to specify cycle phase, ovulation detection kits represent an advance over day count or BBT; however, the kits are not as reliable as direct hormonal assays. Should the kits prove to be successful in this line of research, they might open the way for additional researchers to study the problem without having to rely on direct hormonal assay methods. The particular cognitive tasks were selected because they have been used in previous studies of sex difference in cognition and the effect of the menstrual cycle on cognition, and because pilot studies in our lab had shown them to be sex-sensitive in college student populations.

Method

Experimental Design and Statistical Analysis

Men and women were tested twice on a battery of putative sex-sensitive tasks. Women were tested once during menstruation and once during the midluteal phase, in a counterbalanced order. In this 2 × 2 × 2 mixed-group design, the first independent variable was sex (male and female); the second independent variable was test session (first and second test sessions); and the third variable, for the female participants only, was menstrual cycle phase (menstruation phase and midluteal phase). There were a total of 18 dependent measures taken from the battery of six cognitive tests.

Because the design of the study was nonfactorial (men had no phase condition), the analysis was separated into two major parts, each using a multivariate analysis of variance (MANOVA). First, a 2 × 2 MANOVA was conducted for sex and session. A second 2 × 2 MANOVA on only the female participants analyzed the main effects and interaction between phase (i.e., menstruation vs. midluteal) and order of phase testing (i.e., women who were tested first at menstruation and then at midluteal were compared with women who were tested first at midluteal and then at menstruation). Of the 27 women who qualified for this study, 16 (59%) were tested first at menses (M-L group) and 11 (41%) were tested first at midluteal (L-M group). First and second test sessions were approximately 6 weeks apart for all participants. This is an important control for two reasons. First, this reduced practice effects. Second, because test sessions of both M-L and L-M women spanned two menstrual cycles, the intersession intervals were approximately equal for all groups. This would not have been the case if women had been tested twice within one cycle because the time from menstruation to midluteal is about 3 weeks, but the time from midluteal to menstruation is only about 1 week.

Participants

Participants were 20 men and 27 women who volunteered to participate for partial credit in psychology courses. The women ranged in age from 17 to 22 years ($M = 19.11$), and the men ranged from 18 to 26 years ($M = 21.05$). As shown in Table 2, the majority of women (78%) and men (70%) were below 21 years of age. Over 400 potential female participants were initially contacted at screening sessions, during which they filled out questionnaires that sought demographic and medical information (i.e., the use of medications, including birth control pills; age at onset of puberty; and regularity of menstrual cycles). Women were not included as participants if they were taking hormonal medications or their menstrual cycle was *irregular* (operationally defined as shorter than 25 days or longer than 35 days, or both). Approximately 250 of the 400 women were taking hormonal medications and were eliminated. Of the remaining 150, all but 38 were excluded because they reported irregular cycles, were outside the age range, or did not wish to comply with the procedures of tracking their cycles and using ovulation detection kits. Of the 38 acceptable participants, 8 (23%) did not ovulate during the 2-month study and were also excluded. Thus, the final group of female participants consisted of 27 women.

Men were not included as participants if they were taking hormonal medications. All aspects of the research were approved by the university's Institutional Review Board.

Apparatus

The mental-rotation task was presented on a Macintosh Quadra 610. The rod-and-frame apparatus was a Lafayette portable model (Lafayette Instruments, Lafayette, IN; Oltman, 1968). A black metal chin rest was mounted on the table at a standard distance from the rod-and-frame apparatus, which rested on a table covered in black velvet. The finger-tap task was conducted with a Lafayette telegraph key (Model 58026) and a Lafayette response counter (Model 5804). A Purdue Pegboard (Lafayette Model 32020) was used for the pegboard task. The water-level task (adapated from Lohaus, Kessler, & Thomas, 1994) consisted of eight loose sheets of paper, each depicting the same water jar tilted to various angles corresponding to the clock hour positions of 1, 2, 4, 5, 7, 8, 10, and 11, presented in the same prerandomized order for all participants. The spatial array task was adapted from Eals and Silverman (1994) and consisted of three sheets of paper, each depicting an array of uncommon objects drawn in line diagrams. Female participants used commercially available ovulation predictor kits (One-Step Clearplan Easy Ovulation Predictor Kits, Whitehall Laboratories, Madison, NJ) to detect ovulation and assist in the scheduling of the midluteal test sessions. The kit detects the LH surge that indicates that ovulation will occur within the next 24 to 36 hr.

Procedure

The two testing sessions for women were scheduled to coincide with menses (when estradiol and progesterone are lowest) and with the midluteal phase (when E and P levels are highest).

Date of first test session. To determine the date of the first test session, each woman was asked during the initial screening session to predict the date of her next menstruation. If she was less than 18 days from her next menstruation, she was assigned to the M-L group and instructed to telephone the experimenter on the 1st full day of her next menstrual period, at which time she was scheduled for her first test session, on menstruation Day 3 or 4. Days 1 and 2 were avoided to reduce possible confounding effects of physical discomfort and pain medications. If, at the initial screening, the woman was more than 18 days from expected menstruation, she was assigned to the L-M group. In this case, the participant was given an ovulation detection kit to begin using 18 days before the expected onset of her next menstruation. The kit contained 5 days worth of test sticks that detect LH in the urine. The LH surge indicates that ovulation will occur within 1.5 days, marking the beginning of the 14-day luteal phase. Our goal was to test participants in the middle of the luteal phase because this is when estradiol and progesterone are at high levels. Thus, the midluteal phase was defined as those 5 days when estradiol and progesterone maintained peak levels. Because ovulation predates menstruation by about 14 days, starting the kit 18 days before expected menstruation onset should have ensured detection of the LH surge, and thus ovulation, even if the participant's prediction was off by a few days. Consequently, the test session was conducted on post–LH-surge Day 7 or 8 (1 participant on Day 9), which placed all participants in the midluteal phase, when both progesterone and estrogen levels were high. At the end of their first session, regardless of phase, the women were instructed to telephone the experimenter on Day 1 or 2 of their next period. This was done to confirm each woman's normal cycle length and to verify that women in the L-M group had been tested in the middle of their luteal phase.

Table 2
Number of Female and Male Participants at Each Age (in Years)

Age	Female	Male
17	1	0
18	11	6
19	6	3
20	3	5
21	5	1
22	1	2
23	0	1
27	0	1
41	0	1
Total	27	20

Date of second test session. After the women notified the experimenter of the beginning of their menstruation, procedures for scheduling the second test session were started. At that point, women in the M-L group were given ovulation detection kits (18 days before their next expected menstrual onset) and scheduled for their second test session (7 to 8 days after LH-surge detection). Women in the L-M group, in contrast, waited until the beginning of their next menstrual period, at which point they telephoned the experimenter and were scheduled for their second test session on Day 3–5 of that period. Again, participants notified the experimenter of the beginning of their next period after their second test session to confirm cycle normality and to verify that women in the M-L group were tested in the midluteal phase.

All participants, male and female, were tested individually by one of four trained female investigators. Men were scheduled for their first session at the time of the initial screening and for their second session 6 weeks after their first session. All participants were given the same six cognitive tests in the order described below. Each test was administered twice.

Task 1: Mental Rotation

A wide variety of mental rotation (MR) tasks have been shown to be male-sensitive (Resnick, 1993; Voyer, Voyer, & Bryden, 1995), and pilot studies have shown our particular version to be male-sensitive as well. The MR task used in the present study was developed and used because it is simple enough to be used by children whose performance is being compared with that of adults in an ongoing study.

Participants sat in front of the computer and watched a visual sample as the experimenter read the instructions. A screen of three schematic male figures was displayed for 1.3 s. There was one upright figure (sample figure) at the top of the screen and two choice figures at the bottom, one of which was identical to the sample man and one of which was a mirror image. The two choice figures were rotated 90° left, 90° right, or 180°. Participants were asked to mentally rotate the choice figures and choose which of them matched the sample figure. Choices were made by pressing the *A* key on the keyboard if the left choice was thought to be correct or the *L* key if the right choice was thought to be correct. After each response, the screen indicated whether the response was correct or incorrect. The computer recorded the number of correct responses (out of 24 trials), the response latencies, and the orientation of the sample figures for each trial.

Task 2: Rod and Frame

The rod-and-frame task has been consistently shown to be male-sensitive (Halpern, 1992). In our study, the participant sat in front of the rod-and-frame apparatus and rested on the chin rest so that she or he was at eye level with the center of the apparatus. With the room darkened, the only visible stimuli were the illuminated straight line (rod) and surrounding white square (frame), the angles of which were controlled independently of each other by the experimenter seated behind the apparatus. For each of eight trials, the experimenter moved the square to position 19°, 3°, 9°, or 14° to the right or left of vertical, alternating between right and left. The participant was asked to turn a dial to align the rod to true vertical independent of the surrounding square. The accuracy score was the absolute error from vertical in degrees, averaged across eight trials.

Task 3: Finger Tap

Finger-tap tasks and other motor dexterity tasks have been shown to be female-sensitive (Maccoby & Jacklin, 1974). Using only the index finger, participants tapped a telegraph key as many times as possible in 10 s, while keeping the heel of the hand on the table. The electronic response counter recorded the number of taps per trial. Three 10-s trials with each hand were averaged together for a left-hand score and a right-hand score. An overall score was obtained by averaging the number of taps across both hands (all six trials).

Task 4: Spatial Array

This particular spatial array task has been reported to be female-sensitive (Eals & Silverman, 1994). In this study, the task was a paper-and-pencil memory task consisting of arrays of uncommon objects. Participants studied the first sheet, which contained 36 objects, for 1 min. After a 30-s delay, a second page was presented that contained the same 36 objects as before plus 10 new objects. Participants were given 1 min in which to circle all the new objects. The error score was the sum of the number of missed new items plus the number of original objects erroneously circled. After another 30-s intertrial interval, a third page was presented showing only the original 36 objects, 14 of which had been moved to new locations. Participants were given 1 min to circle all the objects that had been moved. The error score was the sum of the number of moved objects not circled plus the number of erroneously circled objects.

Task 5: Water Level

The water-level task has been shown to be strongly male-sensitive (Halpern, 1992). Participants were shown a drawing of a jar sitting upright (sample) with a horizontal line below it representing a table. The experimenter explained that the jar was half filled with water as indicated by a line on the jar. Participants were then given one page at a time, each of which showed the jar tilted to various angles, and instructed to use a pencil and straight edge to draw the water line as it would appear in the jar tilted at the various orientations (corresponding to the clock hour positions of 1, 2, 4, 5, 7, 8, 10, and 11). Two accuracy measures were recorded: the number correct of eight trials (where *correct* was any line drawn within 5° of horizontal) and the mean absolute error from horizontal, in degrees.

Task 6: Purdue Pegboard

The pegboard task has been shown to be female-sensitive (Hampson & Kimura, 1988, 1992). Participants performed the single-peg, double-peg, and assembly conditions of the Purdue Pegboard (Tiffin, 1968). The single-peg condition consisted of a 30-s trial in which participants used their dominant hand to insert as many pegs as possible into the board. In the double-peg condition, participants had 30 s to insert pairs of pegs using both hands at the same time. In the assembly condition, participants were given 1 min to bimanually construct as many four-part assemblies as possible. The single-peg score was the total number of pegs correctly inserted with the dominant hand. The double-peg score was the total number of pairs of pegs inserted. The assembly score was the total number of correctly placed parts.

Completion of the pegboard task signaled the end of the first session. The procedure for the second session was identical to that of the first session.

Results

The experimental design was nonfactorial because men could not be included in the menstrual phase condition. Consequently, two MANOVAs were conducted to analyze the 18 dependent measures: The first was an analysis of sex and test session (i.e., Session 1 vs. Session 2), and the second was an analysis of menstrual phase and test order (i.e., M-L vs. L-M). Additional analyses were conducted in a search for significant phase effects.

MANOVA for Sex and Test Session

Table 3 shows the means and standard deviations for men and women on each measure. In general, this analysis indicated that the participant's sex and, sometimes, the test session had a significant effect on the performance on some of the tasks. Specifically, regardless of test session, there was an overall significant sex difference on the dependent measures, $F(19, 27) = 5.55$, $p < .0001$. In addition, there was a significant overall effect of test session, regardless of sex, $F(19, 23) = 4.51$, $p < .0004$, namely, scores in the second session were superior to those in the first. There was no overall significant interaction between sex and session, $F(19, 23) = 1.12$, $p < .3942$. Because men and women were equally impacted by session effects, there was no statistical

Table 3
Means and Standard Deviations for Men and Women on Each Dependent Measure

Task and measure	Men *M*	Men *SD*	Women *M*	Women *SD*
Mental rotation				
No. correct	21.84**	2.57	19.55	3.36
90 correct	14.76†	1.53	13.81	2.07
180 correct	7.05**	1.43	5.74	1.68
Correct latency	2.28	0.47	2.22	0.52
90 latency	2.24	0.47	2.14	0.48
180 latency	2.37	0.46	2.37	0.52
Overall latency	2.26	0.41	2.22	0.46
Rod and frame				
Degrees error	1.52***	0.62	2.18	0.93
Water level				
No. correct	7.05****	1.99	3.15	3.17
Degrees error	4.40***	8.21	21.41	19.23
Purdue pegboard				
Single peg	13.95	1.47	15.22***	1.64
Double peg	11.25	1.63	12.22*	1.60
Assembly	36.83	5.51	39.41^{+}	4.98
Finger tap				
Left hand	51.22***	5.18	45.52	5.65
Right hand	56.25***	6.14	50.25	5.47
Both hands	53.73****	5.17	47.6	5.68
Spatial array				
No. object errors	8.95	3.29	9.78	2.84
No. location errors	7.38	3.39	7.26	2.38

Note. Significance is indicated next to the mean for the gender that performed better. Marginally significant values are also indicated. †$p = .0614$; $^{+}p = .0535$; $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$. $^{****}p < .0001$.

justification for conducting post hoc tests on the interaction for each dependent variable.

However, post hoc univariate procedures were conducted for each dependent measure for the sex and session main effects. Results of those tests follow and are organized by task.

Mental rotation. The number of participants for this task decreased from 20 to 17 for men and from 27 to 26 for women because of computer malfunctions. There was a significant sex difference in the total number correct, with men making more correct responses on average than women, $F(1, 45) = 7.89, p < .0073$. When degree of rotation was considered, there was a trend for a male advantage on 90° rotations, $F(1, 45) = 3.68, p = .0614$, and a significant male advantage on 180° rotations, $F(1, 45) = 10.08, p < .0027$. There were no significant sex differences (all $ps > .05$) among the four latency scores (average latency for all correct responses, for correct 90° rotations, and for correct 180° rotations, and overall latency for correct and incorrect trials). However, all four measures showed significant effects of session, with a latency decrease in Session 2: all correct responses, $F(1, 41) = 11.91, p < .0013$; correct 90° rotations, $F(1, 41) = 9.93, p < .0030$; correct 180° rotations, $F(1, 41) = 18.00, p < .0001$; latency for correct and incorrect trials, $F(1, 41) = 19.49, p < .0001$.

In summary, whereas the latency measures showed significant practice effects, but no sex differences, the accuracy measures showed significant sex differences but no practice effects.

Rod and frame. The dependent measure for the rod-and-frame task was the average of the absolute degrees from vertical across eight trials. Men were significantly better than women at aligning the rod to true vertical, $F(1, 45) = 13.53, p < .0006$. There was no significant effect of session on the rod-and-frame measure, $F(1, 41) = 1.26, p = .2675$.

Water level. This task had two measures of accuracy: the number of correct responses (water lines drawn within 5° of horizontal) and average error (average degrees from horizontal). Men had significantly more correct responses than did women, $F(1, 45) = 30.29, p < .0001$. However, there was no significant difference between sessions in number of correct responses, $F(1, 41) = 0.65, p = .4257$. In addition, men's scores were superior to women's in average degree of error, $F(1, 45) = 17.10, p < .0002$. There was no significant effect of session, $F(1, 41) = 0.04, p = .8341$.

Purdue Pegboard. There were three measures for the Purdue Pegboard task: single-peg dominant-hand score, both-hands score, and assembly score. For the single-peg condition, women's scores were superior to men's, $F(1, 45) = 14.17, p < .0005$. There was a significant increase in single-peg scores for both sexes from Session 1 to Session 2, $F(1, 41) = 9.92, p < .003$. For the double-peg condition, women's scores were superior to men's $F(1, 45) = 5.82, p < .02$; however, there was no significant session effect, $F(1, 41) = .15, p = .6991$. For the assembly condition, there was a marginally significant effect, again favoring women, $F(1, 45) = 3.93, p = .0535$. For both men and women, there was a significant improvement in assembly scores from Session 1 to Session 2, $F(1, 41) = 6.71, p < .0132$.

Finger tap. The number of taps per 10-s trial was averaged for the left and right hands separately, and a composite average between both hands was recorded, giving each participant three finger-tap scores. For all three measures, men scored better than women: left hand, $F(1, 45) = 15.11, p < .0003$; right hand, $F(1, 45) = 16.18, p < .0002$; and both hands, $F(1, 45) = 17.59, p < .0001$. There were no significant session effects on any of the three measures (all $ps > .05$).

Spatial array. The spatial array task included two measures: object memory and location memory. There were no significant sex differences on either object memory scores, $F(1, 45) = 1.45, p = .2342$, or location memory, $F(1, 45) = 0.01, p = .9929$. Both male and female participants made significantly fewer object errors in Session 2 than in Session 1, $F(1, 41) = 10.67, p < .0022$. However, there was no such practice effect for location memory, $F(1, 41) = 1.69, p = .2007$.

Summary of sex and test session. For the particular sample of participants under study, five of the six tests revealed a significant sex advantage. Some of the tests also showed statistically significant practice effects, but this occurred equally in both men and women (i.e., there was no Sex × Practice interaction).

MANOVA for Menstrual Phase and Test Order (M-L vs. L-M)

Table 4 shows the means and standard deviations on each measure for the menstrual phase and the midluteal phase. Results of this multivariate analysis revealed that regardless of testing order, there was no significant effect of menstrual phase, $F(18, 7) = 0.84, p = .6424$. In addition, regardless of menstrual phase, there was no significant effect of testing order, $F(18, 8) = 0.55, p = .8628$. However, there was a significant interaction between phase and test order for at least some of the dependent measures, $F(18, 7) = 3.72, p < .0416$.

Post hoc procedures revealed that of the 18 dependent measures, only the 4 latency measures on the mental rotation task and the object-memory measure on the spatial array task showed significant interactions between phase and test order (all $ps < .03$). However, in every case, the significant interactions were attributable to practice effects. For example, on the mental rotation task, for each of the latency measures, women in the L-M group (tested second during menstruation) had significantly shorter latencies when they were in the menstrual phase. In contrast, for each of the latency measures, women in the M-L group (tested second during midluteal phase) had significantly shorter latencies when they were in the midluteal phase (all $ps < .05$). Thus, for both groups, women performed faster in their second test session, regardless of which menstrual phase they were in at the time of testing.

In a similar fashion, the significant interaction for the spatial array measure was attributable to practice effects: Participants in the L-M group made significantly fewer object memory errors in their second session (i.e., menstrual phase), whereas participants in the M-L group made significantly fewer errors when tested in their second session (midluteal phase; all $ps < .05$).

Table 4

Means and Standard Deviations for Women in the Menstruation and Midluteal Phases on Each Dependent Measure

Task and measure	Menstruation		Midluteal	
	M	*SD*	*M*	*SD*
Mental rotation				
No. correct	19.65	3.08	19.44	3.66
90 correct	14.00	1.94	13.63	2.20
180 correct	5.65	1.57	5.81	1.80
Correct latency	2.24	0.55	2.20	0.49
90 latency	2.14	0.45	2.13	0.51
180 latency	2.37	0.52	2.37	0.53
Overall latency	2.23	0.46	2.22	0.81
Rod and frame				
Degrees error	2.27	1.03	2.1	0.81
Water level				
No. correct	3.00	3.16	3.30	3.23
Degrees error	21.34	18.54	21.48	20.24
Purdue pegboard				
Single peg	15.04	1.53	15.41	1.76
Double peg	11.85	1.38	12.59	1.74
Assembly	39.04	6.03	39.78	3.75
Finger tap				
Left hand	44.79	5.75	46.26	5.56
Right hand	49.25	5.08	51.25	5.76
Both hands	47.02	5.14	48.18	6.22
Spatial array				
No. object errors	10.26	2.82	9.3	2.83
No. location errors	7.56	2.22	6.96	2.53

Note. There were no significant differences between phases on any task.

Additional Analyses

We conducted additional analyses to ensure that no menstrual phase effects were overlooked. First-order post hoc tests were run on the Phase × Order MANOVA, and although none of the measures were significant, two measures from the main effects of phase analysis did show effects with probabilities less than .10 but greater than .05. The finger-tap measure for the right hand was slightly higher in the midluteal phase than during menstruation, $F(1, 24) = 3.17, p = .0876$, and scores on the double-peg Purdue Pegboard were slightly higher in the midluteal phase than during menstruation, $F(1, 24) = 2.99, p = .0978$.

The main effect for phase in the MANOVA essentially collapsed the phase scores across sessions and applied a correction to the criteria for significance. Given the relatively small sample size, we conducted separate univariate analyses of variance (ANOVAs) for first-session data only for the finger-tap and Purdue Pegboard measures. These measures were selected because they showed the most promise of revealing phase differences. This required the analysis to be done in a between-subjects fashion, which is a weaker test of the experimental question because it cannot show any performance differences that might occur across any given woman's menstrual cycle. There was neither a significant effect of menstrual cycle phase on the right hand finger-tap measure, $F(1, 25) = 1.54, p = .0847$, nor on the double-peg Purdue Pegboard measure, $F(1, 25) = 3.22, p = .0847$.

We were still concerned that phase effects were being overlooked, so we collapsed the data across the test sessions and ran separate univariate ANOVAs on the 13 measures that were not shown to have practice effects for the women. We did this because, with the data collapsed, the practice effects would have obscured the phase effects. The five measure on which there were practice effects were the four latency measures on the mental rotation task and the object memory measure of the spatial array task. Once again, none of the analyses revealed significant effects of phase on the dependent measures. A summary of F values and p values can be seen in Table 5.

Finally, some studies (e.g., Hampson, 1990a) have generated and analyzed composite scores when there were a number of dependent measures, as in the present study. The generation of composite scores poses the difficulty of how to judge exactly what scores should be grouped in the most meaningful way. For example, on the water-level task, is it meaningful to combine measures of number correct with degrees of error, and if so, how might such a composite be computed? Similarly, how might the errors in the object

Table 5
Results of the Separate Univariate ANOVAs Testing for Effect of Menstrual Cycle Phase

Measure	$F(1, 25)$	p
Mental rotation		
No. correct	0.01	.9059
90° correct	0.40	.5351
180° correct	0.35	.5576
Rod and frame		
Degrees error	0.60	.4448
Water level		
No. correct	0.49	.4903
Degrees error	0.00	.9533
Purdue Pegboard		
Single peg	0.56	.4605
Double peg	3.58	.0800
Assembly	0.28	.6005
Finger tap		
Left hand	3.85	.0608
Right hand	3.63	.0710
Both hands	2.12	.1574
Spatial array		
No. location errors	0.65	.4271

Note. Data were collapsed across sessions for the tasks that were not associated with practice effect. ANOVAs = analyses of variance.

memory task (recognition memory) be meaningfully combined with those in the location memory task? In the present study, each measure seemed sufficiently different such that a composite score would be fundamentally different from either constituent measure. It could be argued that rather than combining the component measures, only selected measures of the tasks are needed and can be used as composites. Here again, there is little or no theoretical impetus for choosing which scores most accurately measure the desired performances.

With these caveats in mind, using our data, we judged that the following composite scores might be reasonable: overall number correct for mental rotation; degrees of error for rod and frame; number correct for water level, double peg, assembly, or all of these, for the Purdue Pegboard; both-hands score for finger tap (a true composite measure); and number of location errors for spatial array (in light of practice effects revealed on the object memory measure). As shown above, separate univariate ANOVAs on these particular measures yielded the results that are presented in Table 5. Thus, the conclusion that the data from this study do not show any effects of phase was upheld because none of the composite measures reached significance, and only one composite (Purdue Pegboard double peg) reached a p value below .10 (i.e., .0800).

Discussion

This study used ovulation detection kits to define menstrual cycle phase and study the effects of cycle phase on cognition. This noninvasive methodology is more accurate than day count or BBT procedures, but it is not as accurate as hormonal assay.

There were positive results for between-subject sex differences and negative results for within-subject menstrual cycle phase effects. Four of the six tasks (i.e., mental rotation, rod and frame, water level, and Purdue Pegboard) showed significant sex differences in the direction predicted by previous studies: One (i.e., spatial array) showed no sex differences, and one (i.e., finger tap) showed a significant sex difference in the direction opposite than that expected from research known to us at the time of testing. However, none of the tests showed significant effects of menstrual phase regardless of the direction of sex sensitivity.

Sex Differences

Tasks that traditionally favor men. The water-level, rod-and-frame, and mental rotation tasks all showed significant differences in the predicted direction of a male advantage. The sex difference on the water-level task was particularly robust: Women averaged only three of eight trials correct, whereas men averaged seven of eight trials correct. Furthermore, women had, on average, almost five times the degrees of error as men ($M = 21.41°$ vs. 4.40°, respectively). In addition, as a group, women showed considerably more individual variation on this task than did men. The significant male advantage on the rod-and-frame task is in agreement with previous findings (Halpern, 1992). The results from the mental rotation task are also in agreement with previous findings for better performance by men (e.g., Resnick, 1993; Shepard & Metzler, 1971; Vandenberg & Kuse, 1978). Some previous studies have tested mental rotation under conditions of unlimited time and found that men are faster but not necessarily more accurate (see Linn & Petersen, 1985); however, more recent studies have found men to be more accurate than women in unlimited time conditions (Resnick, 1993). As used in our study, the task was designed to force a rapid response from all participants. This resulted in no sex differences in latency scores, but it did show a significant difference in favor of men in terms of accuracy on both 90° and 180° rotations, with an even greater male advantage on the 180° rotations. The finding of a male advantage is consistent with findings of Resnick (1993).

Tasks that traditionally favor women. The results on these tasks were more complex than the male-advantage tasks in that the outcome on one task was in the predicted direction, one outcome was in the opposite direction, and another outcome revealed no sex difference. Women outperformed men on the three measures of the Purdue Pegboard: single peg, double peg, and assembly. These results are consistent with previous findings of a female advantage on the Purdue Pegboard and other tests of manual dexterity (e.g., Hampson, 1990b; Hampson & Kimura, 1988). The results of the finger-tap task were the most surprising because there was a male advantage in the opposite direction of that reported previously (see Maccoby & Jacklin, 1974). However, these results may have been due to a difference in procedure between the present and previous studies. Because the task is a "finger"-tap task, we required all participants to rest the heel of their hand on the table and tap only with an index finger. In pilot studies, participants reported that this procedure was more tiring and required more strength than tapping with the heel of the hand raised off of the table. Thus, tapping with only one finger may have favored men. An examination of previous procedures (e.g., Hampson, 1990a, 1990b; Hampson & Kimura, 1988) does not reveal whether participants tapped with one finger or were allowed whole-hand movement. It is possible that previous studies may have allowed the movement of the whole hand, which may have decreased a strength factor in favor of a dexterity factor. In addition, since the beginning design of this study, we have become aware of evidence that men are faster than women on a finger-tap task that requires the use of a single index finger (as required in the present study). However, when using single-finger speed as a baseline covariate, women are faster than men on a finger-tap task that requires tapping four keys in succession from index to little finger (Nicholson & Kimura, 1996).

Results of the spatial array task showed no sex difference and thus did not support previous findings of a female advantage (Eals & Silverman, 1994). The reason for this finding is unclear but may be related to the nature of the objects chosen for the task. First, this is a relatively new task that has shown a female advantage in only two previous studies (Eals & Silverman, 1994; I. Silverman & Eals, 1992). The objects used were uncommon objects for which participants should not possess verbal labels (Eals & Silverman, 1994). However, in our study, several participants, mostly men, commented to the experimenter that the objects looked like car-engine parts or tools. Such verbal labeling may have differentially increased male participants' memory and thus negated the normal female advantage on this task. Future studies should explore the effect of using different categories of to-be-remembered objects.

In summary, of the six tasks that had previously been reported to show sex differences, we found significant differences on five: water level, rod and frame, mental rotation, pegboard, and finger tap.

Menstrual Cycle Phase

The primary goal of this research was to investigate whether cognition in women fluctuates with phase of the menstrual cycle. The testing of both men and women and the subsequent sex comparisons were conducted to (a) confirm that, under our testing conditions, the tasks were valid sex-sensitive tasks and (b) support the possibility of some hormonal influence on cognition.

This study was designed specifically to test, under the conditions of objectively defined menstrual phases, the hypothesis (Hampson & Kimura, 1992) that performance on male-advantage tasks would be elevated during menstrual phase (low hormones) and that performance on female-advantage tasks would be elevated during midluteal phase (high hormones). We failed to find evidence of phase-related performance differences on any task, despite the fact that five of the tasks were validated as being sex-sensitive. Our findings fail to confirm those of Hampson (1990a, 1990b) and Hampson and Kimura (1988), but they are in agreement with those of Gordon and Lee (1993) and Gordon et al. (1986).

Furthermore, there was no difference between test order; that is, women who were first tested in the midluteal phase did not perform differently compared with women who were first tested in the menstrual phase. This was true for all of the dependent measures for which sex differences were confirmed. This finding suggests that there was no differential learning of any task in one phase or the other. Women did not learn any task better if they were first exposed to it during midluteal versus menstrual phase.

Of the 18 dependent measures, 7 showed significant practice effects. Six of these involved improvements in motor reaction time, and one (object memory) involved familiarity with to-be-remembered stimuli. The practice effects should be noted in future studies that use within-subject designs.

Although ovulation detection is not a direct measure of hormonal status, and thus is not as reliable as hormonal assay, this methodology is superior to day-count methods or BBT measures. The use of commercially available ovulation kits is important in light of reports that only about 60% of college-aged women ovulate every month (Metcalf & MacKenzie, 1980). In the present study, approximately 23% of women who passed the initial screening session were not used for phase comparisons because the LH surge that precedes ovulation was not detected. This anovulatory rate is in agreement with the anovulatory rate of 24% of a group of 87 women (mean age 19.2 years ± 1.3 years) in a previous study (Broverman et al., 1981). Another strength of this study lies in the validation of particular cognitive tests as being sex-sensitive among the male cohorts and the female participants who were tested for phase comparisons.

Possible Reasons for the Present Findings and Additional Issues

Negative findings are always puzzling. There are several possible, but by no means mutually exclusive, explanations for ours. First, the low number of participants in the present study may have precluded finding phase effects. However, this low number of participants (20 men and 27 women) was sufficient to uncover significant sex differences between participants in five of the six dependent measures, and in the case of mental rotation, the number of men and women was as low as 17 and 26, respectively. In addition, the number of male and female participants was sufficient to detect significant practice effects on 7 of the 18 dependent measures. Not including men, the number of women tested was sufficient to detect practice effects on mental rotation latency and object memory. Thus, in the failure to reach statistical significance, power was not likely the critical factor. Nevertheless, we recommend the use of larger samples for future studies.

A second, and plausible, explanation for the negative findings may be that the women in our study were younger than those in some previous studies and that younger women may not have ovulatory hormone levels as high as those of older women. As shown in Table 2, 78% of the present female participants were under the age of 21 years, and the mean age was 19.11 years. In previous studies that found cognitive changes across the menstrual cycle, the women were older than those in the present study (e.g., mean ages of 24.65 years in Hampson & Kimura, 1988; 23.7 years in Hampson, 1990b; and 26.4 years in Hampson, 1990a). It is known that young women (ages 18–22) have significantly lower and shorter ovulatory progesterone profiles than older women (Ellison, Lager, & Calfee, 1987; Vuorento, Lahti, Hovatta, & Huhtaniemi, 1989). Moreover, evidence from women who ranged from 18 to 41 years of age indicated that ovulatory progesterone displays a parabolic rise and fall with age, with peak levels occurring between the ages of 25 and 35 (Lipson, O'Rourke, & Ellison, 1991). It is possible that a critical level of progesterone, or estradiol, or both, must be attained for cognitive functions to be influenced. If this is true, the present study of predominantly younger women, combined with similar studies of older women, may help establish the developmental boundaries for hormonal influences on cognitive behavior.

A third possible explanation for our negative findings can be derived from cross-species comparisons of cognitive changes across estrous and menstrual cycles. As mentioned in the introduction, several lines of evidence from animals indicate that hormonal fluctuations induce changes in neuroanatomical function and structure within higher cognitive brain regions and that these changes can result in cognitive alterations. For example, rats' cognition is reported to fluctuate across normal estrous cycles (Korol, Couper, McIntyre, & Gold, 1996), with normal hormonal declines associated with aging (Juraska & Warren, 1996), and with experimentally induced changes in estrogen (Fader, Hendricson, & Dohanich, 1996) and estradiol (Luine, Rentas, Sterbank, & Beck, 1996). At first glance, it would seem logical that similar hormonal–cognitive relationships might be found in humans, at least to some extent. However, it is not yet known if humans undergo similar changes in neuroanatomical function and morphology with hormonal fluctuations. Even if this proves to be the case, it is possible that there may be differences in outcome behavior in humans versus nonhumans. It is conceivable that humans, with increased cortical-to-subcortical ratios, may be capable of overriding hormonally modulated subcortical changes by using systems that are perhaps not available to or sufficiently developed in other animals. A related concept of behavioral flexibility involves the notion of individual differences. It is more possible in humans than in animals that, in particular individuals, hormonally influenced cognitive changes are more or less likely to be expressed, depending on personal genetic predispositions, prenatal hormonal influences, or postnatal environmental and learning histories. Perhaps the prime example of increased encephalization being correlated with behavioral flexibility is in the realm of sexual behavior. Primates, and individual humans in particular, are significantly less tied to hormonally influenced subcortical sexual systems than are nonprimates (J. B. Becker, Breedlove, & Crews, 1992).

Another way to state this third possibility has been suggested by Sommer (1992): Cognition simply may not systematically change across the menstrual cycle for women as a population. The existence of positive findings in the literature may be related to the so called "file drawer" phenomenon, in which positive findings are more likely to be published whereas more numerous negative findings languish in file drawers. The true balance of positive and negative findings concerning this particular topic may not be known.

In summary, negative findings can never be proven true, and we do not believe that ours mean that there are no effects of menstrual cycle phase on cognition. However, given our results and previous results, it is clear that the question of how hormones influence cognition in humans and nonhumans has yet to be definitively answered. It is clear that more studies, performed with a variety of behavioral and neurobiological techniques, are needed for researchers to understand why some studies show a relationship between menstrual cycle phase and cognition and others do not.

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