MENSTRUAL CYCLE EFFECTS ON SPATIAL LOCATION TASKS

A Senior Honors Thesis

by

SARAH ANDREW

Submitted to the Office of Honors Programs
& Academic Scholarships
Texas A&M University
in partial fulfillment of the requirements of the

UNIVERSITY UNDERGRADUATE
RESEARCH FELLOWS

April 2004

Major: Psychology

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Approved as to style and content by:

Gerianne Alexander
(Fellows Advisor)

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ABSTRACT

Menstrual Cycle Effects on Spatial Location Tasks. (April 2004)

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The relationship between menstrual cycle hormones and performance on gender-linked spatial tasks was examined in college women. Healthy women and men over the age of 18 and not taking hormonal preparations completed tasks that typically show a male advantage (mental rotation, targeting) or a female advantage (object location memory, verbal fluency). Men were tested at one session lasting one hour. Women were tested at two phases of the menstrual cycle, the peri-ovulatory phase and pre-menstrual phase. Cycle phases were determined using the Donna Mini-Microscope Ovulation Detector kit. Along with tracking their ovulation, women also documented their daily mood levels using visual analogue scales. Women were randomly assigned to two testing schedules: 1) ovulatory→pre-menstrual, 2) pre-menstrual→ovulatory. Further, women and men were randomly assigned to one of three test conditions: 1) neutral, 2) sad, or 3) threat. These assignments determined the stimuli that each participant was presented with during the object location task. Data were analyzed for expected sex differences (the between group comparison) and menstrual cycle effects (the within group comparison) in task performance. A trend was found where women tend to perform poorly during the ovulatory phase of the menstrual cycle on both cognitive and spatial tasks, when estrogen levels are highest, compared to their pre-menstrual performance. The data suggest that high estrogen levels impair spatial abilities, including spatial abilities that favor women. Ongoing subject testing will provide additional tests of the effects of emotional valence on task performance.

DEDICATION

I dedicate this project and the work put into it to my parents Rae Lynn and Ellery Andrew, my sister Chassidy, my dog Mr. Puppy, and my mentors Gerianne Alexander, Heather Bortfeld, and Steve Smith for always supporting me. I appreciate all of the love and support my family has provided me with through all of my academic endeavors. I could never thank them enough.

I appreciate the guidance, time, money, and patience Gerianne has provided me with throughout the past year and a half. This project has meant a lot to me and will forever be remembered as my first major research endeavor. I am proud that I was able to work with such an incredible advisor. I would also like to thank her family, who has been so kind to me throughout the past year. I will always be thankful for their kindness.

ACKNOWLEDGMENTS

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INTRODUCTION

Studies of sex differences have demonstrated that men generally outperform women on certain types of tasks, which test spatial abilities (Halpern, 1992; Voyer et al., 1995). However, there is one spatial ability test where women demonstrate an advantage over men. This female advantage spatial ability is known as spatial location memory (Eals & Silvermen, 1994; Silverman & Eals, 1992).

When women and girls are compared to men and boys, the females display a more accurate memory for the location of objects in a spatial array. This evidence was derived from male and female performance results on a spatial ability task known as the spatial location task. This female advantage is further supported by evidence found by another study which tested for object location memory. This study incorporated the classic Memory game, and found similar results (Kimura, 1999). A possible explanation for this female advantage is that an object's location relative to other objects can be helpful for encoding its spatial location into memory. That spatial location memory can be performed using relative spatial information makes it unique from the other spatial tasks, which typically show a male advantage (Alexander, Packard, & Peterson, 2002; James & Kimura, 1997).

In light of past research, it is possible that menstrual cycle phase has an influence on women's spatial abilities (Hampson, 1990; Hampson & Kimura, 1988). For example, evidence has found that during the luteal phase, when levels of gonadal steroids are high, skills favoring females, such as verbal-articulation and fine motor

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skills, appear to be facilitated. During this same phase, skills favoring males, such as spatial ability, appear to be impeded. When estrogen levels are low during the menstruation phase, male advantage spatial skills improve while female advantage verbal skills and fine motor skills decline (Broverman et al., 1981; Hampson 1990a, 1995b; Hampson and Kimura, 1988; Hausmann et al., 2000; Komnenich et al., 1978; Silverman and Phillips, 1993; Phillips and Silverman, 1997). Therefore, as estrogen levels are high so are abilities that favor females; as estrogen levels are low female performance on abilities that favor males are high (Kimura, 1999). The female advantage for object location memory has not been tested across the menstrual cycle with the aid of an accurate hormonal predictor. Therefore, the hypothesis in this study seeks to examine whether a spatial ability that favors females will show an advantage during the midluteal phase-similar to other skills favoring females.

In accordance, across the menstrual cycle changes in women's positive and negative moods exist (Grahm & Bancroft, 1993) along with variations in women's perception of emotional stimuli (Alexander, Peterson, & Wexler, 2002). Performance on memory tasks, such as spatial location, may be influenced by these changes in mood and mood-related perceptions across the menstrual cycle. For example, in research investigating the effects of emotion on memory by looking at memory recall of emotionally threatening stimuli, participants recalled the threatening stimuli much more often than a neutral stimulus (Kulas et al 2003). Verbal memory, which favors females, has been reported to vary across the menstrual cycle with higher performance occurring at times that estrogen levels are high (Phillips and Sherwin, 1992). With these studies in mind, it could be possible that memory for emotional stimuli within a spatial location task, which favors females, might be influenced by hormonal cycles. This study attempts to examine whether women's moods and the affective valence of stimuli (neutral, sad, threatening) might also play a role in women's performance on object location tasks across the menstrual cycle.

Within the research literature on women's cognitive abilities and hormonal fluctuations across the menstrual cycle, there is much discrepancy within the findings. It is suggested that these inconsistencies are due to the lack of similar methodology between studies and the common reliance on reported cycle phase. Many studies rely on tasks which have different sensitivities to estradiol phases (Lacreuse et al, 2000). This makes it difficult to compare results and ambiguous as to what the results mean. In addition, one of the most difficult challenges these studies face is determining the precise hormonal phase. Many studies have relied on self report of menses to estimate the peri-ovulatory and luteal phases. This is highly unreliable as the menstrual cycle can vary from woman to woman, and there is no way to guarantee the exactness of the hormonal phase. One study attempted to eliminate these issues by testing rhesus monkeys on spatial abilities across the menstrual cycle (Lacreuse et al, 2000). These monkeys' menstrual cycles are very similar to the human menstrual cycle. Blood serum samples were taken every day for a complete menstrual cycle to determine the exact timing of their hormonal phases. They were also tested each day so as not to miss the hormonal phase they were looking for. The results from this study found further support that spatial abilities fluctuate as hormonal fluctuations occur across the menstrual cycle (Lacreuse et al, 2000).

This study attempts to gain more control in determining exactly when ovulation occurs and when estrogen levels are high by the use of ovulation detector kits. The kits are highly accurate and easy to use. Therefore, ovulation is tracked on a daily basis. Our hope is that as more control is gained in studies which test across the menstrual cycle results might become more consistent and credible.

METHODS

Participants

14 women and a control group of 10 men volunteered to participate in the study. The participants were all over the age of 18 and not using any hormonal preparations or oral contraceptives.

Measures

Mood: Measures of mood included the Spielberger Trait-Stait Anxiety Inventory (STAI) (Spielberger, Gorsuch, Luschene, Vagg, & Jacobs, 1984), the Beck Depression Inventory (Beck, Ward, Mendelson, Mock & Erbaugh, 1961) and a brief daily diary, which recorded subjective moods (i.e., anxiety, sadness, anger, happiness, and energy level). The participants recorded their daily moods in the daily diary by marking a spot on a 10 cm visual analogue scale (low to high).

Cognitive Abilities

Spatial Tasks: Two spatial tasks that typically show a male advantage were included in the test battery. A 24-item Two-Dimensional Mental Rotation Task (Collins & Kimura, 1997), which measured the participant's ability to identify the appearance of an object after it was rotated in two-dimensional space. Then a Ball Throw Task (Hall & Kimura, 1995) measured targeting. The target consisted of a square of backed black Velcro (36 X 36 inches), with a white dot in the center. Participants stood 10 feet from the target, threw ping-pong balls (covered with fabric designed to stick to Velcro) at the center dot using the hand with which they felt most comfortable.

The final spatial task was the object location task, which typically shows a female advantage. Three versions of the task were constructed containing neutral, sad, or threatening stimuli, respectively. Participants were presented first with a stimulus card that displays a spatial array of faces. (See Figure 1.) They were instructed to study and remember the card, but were not instructed to remember face location, because the female advantage to remember object location occurs without explicit directions (Alexander 2002). After one minute the participant was presented with an object identity response card, which displays an array of the original 24 faces along with 20 new faces. The participant then reported which faces they had seen before. This is done by having the participant mark or cross out the added faces. Then the participant was presented with a second response card for face location, which displays the original 24 faces, with a location exchange between 7 pairs of the faces. The participant was expected to report which faces switched places by drawing a mark through the pairs of faces.

Depending on the test condition (friendly, sad, or threat), the stimulus card presented slightly varied stimuli to each participant. In the friendly condition, all of the faces display friendly expressions. The sad and threat conditions were identical to the friendly condition, except that 8 of the original 24 faces exhibit a negative emotional expression. The sad condition displays 8 sad faces and 16 friendly faces, and the threat condition displays 8 angry faces and 16 friendly faces. Both of the response cards for the sad and threat conditions are identical to the response cards for the neutral condition; therefore, affective valence for the stimuli only plays a role during the encoding stage of the task.

Verbal Tasks: The final test for cognitive abilities is the controlled association task. This task required the participants to generate synonyms for four familiar words for a total time of 2 minutes 30 seconds. Each participant was presented with the same four words.

Menstrual Cycle Week

Donna mini-microscope saliva ovulation detector kits were used to document the onset of ovulation. These mini-microscopes detect fern-patterns which show up in female saliva 1-3 days before ovulation occurs.

Procedures

Males: Male participants were tested only once. During their test session, they were asked to complete a consent form, a handedness questionnaire, and the mood questionnaires. They then proceeded to the three spatial tasks and verbal (controlled association) task. These were presented to the participants in a random order. The men were also assigned to one of the three conditions for the spatial location task (friendly, sad, threatening) and the memory task was presented accordingly.

Females: Three sessions were required to obtain results of the mood measures and spatial tasks from the female participants in the premenstrual and ovulatory weeks. In order to schedule the tests according to the appropriate menstrual phase, all of the female participants were required to attend an instruction day. During this pre-test session, the women completed their consent form and were provided with a daily diary and Donna mini-microscope saliva ovulation detector kit. They were instructed on how to use the ovulation detectors, and that they needed to test their saliva daily. They were also instructed to record the results in their daily diary along with a brief rating of their moods.

Women were randomly assigned to two testing schedules: ovulatory-premenstrual week or premenstrual-ovulatory week. The ovulatory session was scheduled 1-3 days following the appearance of a fern-like pattern in the participant's saliva. This indicated ovulation and, therefore, high estrogen levels. The premenstrual week test session was scheduled 9-12 days after the appearance of the fern-like patterns in the saliva. When the women observed evidence of their ovulation (i.e., the fern pattern in their saliva) they were instructed to phone or email the investigator to arrange the appropriate scheduling of test sessions. The brief daily diary documents the onset of menses and provides additional confirmation of cycle phases. The participant condition distribution can be seen in Table 1.

Each testing session lasted about 1 hour, and took place in Room 223 of the Psychology Building at Texas A&M University. The male participants and female participants were recruited through advertising around the psychology building and from a newspaper ad place in the campus newspaper *The Battalion*. Both participants received a monetary benefit of $10.00 at each test session. The males received a total of $10.00 and the females received a total of $20.00.

RESULTS

Subjects

Subject recruitment and testing is ongoing. To date, the numbers of women that responded to the recruitment advertisement is relatively large (n=20). However, a number of participants withdrew prior to testing (drop outs n=4). Further, other women showed non-ovulatory cycles (n=2). Nonovulation makes it impossible to accurately test women in the appropriate hormonal phases (i.e., ovulatory phase). Therefore, those who experienced non-ovulation were tested, but their data was excluded from the data analysis. This final sample of women who completed the protocol and who showed ovulatory cycles included women tested first in the premenstrual phase (n=8) and women tested first in the ovulatory phase (n=6). The data analysis reported in this thesis includes measures from these participants' first test session.

Due to the high incidence of drop outs, we do not at this time have a large enough sample in each randomly assigned test condition (friendly, sad, threat) to compare the data across the three conditions. Table 1 shows the distribution of each participant to their randomly assigned condition.

Mood

Table 2 shows the results of mood measures. The STAI measures of state anxiety showed that the premenstrual phase women scored higher (M = 1.7, SD = .24) than the ovulatory women (M = 1.4, SD = .20). The premenstrual women also scored higher on the BDI measure of depression relative to the ovulatory women with (M = 9.0, SD = 3.75) and (M = 3.75, SD = 3.74), respectively.

The premenstrual and ovulatory women tracked their ovulation on daily diaries, which included a visual analogue mood rating scale. This information was collected, but is not included in the measures of this study.

Cognitive Abilities

The scores for cognitive abilities including mental rotation, spatial location, and verbal fluency can be seen in Table 2. Premenstrual women scored a mean of (M = 89%, SD = 4%) on the mental rotation task, while the ovulatory women scored a mean of (M = 83%, SD = 4%). These scores reflect the percent of correct rotations they marked. Figure 3 shows comparisons of mental rotation performance for premenstrual, ovulatory, and male groups. The average scores for the spatial location task were (M =74%, SD = 4%) and (62%, SD = 4%), respectively. These percentages reflect the percent of correctly marked faces for each spatial task. These results can be seen in Figure 4. For the verbal fluency task, the average number of correct generated synonyms for the premenstrual group was ($M = 17.75$, $SD = 2.05$) and ($M = 11.75$, $SD = 2.06$) for the ovulatory group. The premenstrual group outperformed the ovulatory group for the cognitive abilities tests. Analysis of these data using Analysis of Variance (ANOVA) showed that group differences were not significant, but the data do illustrate a trend in performance levels between the two groups that is consistent with the study hypothesis. In contrast, the results for the targeting task were statistically significant, (group difference, $p < .05$). Targeting performance was measured by inches away from target dot. As shown in Figure 5, women in their ovulatory phase performed much more poorly than the premenstrual phase women and the men. This concurs with the trend across all spatial tasks showing that women in the ovulatory phase perform more poorly than premenstrual women on male advantage spatial tasks.

DISCUSSION AND CONCLUSIONS

The purpose of this study was to investigate the female advantage for spatial location memory across the ovulatory and premenstrual weeks of the menstrual cycle. The results demonstrated a basic trend in female performance on cognitive abilities; women demonstrate higher performance on cognitive tasks that favor both males and females during the premenstrual phase of their menstrual cycle relative to their ovulatory phase performance. These results suggest that premenstrual women outperform ovulatory women on male advantage tasks, such as mental rotation and targeting. They also suggest that women in the ovulatory phase may outperform women in the premenstrual phase on female advantage tasks, such as spatial location memory. Although only the measures for targeting reached statistical significance, the consistent pattern of results across all spatial tasks suggests further investigation of menstrual cycle effects on spatial abilities is warranted.

Consistent with other reports of increased negative moods during the premenstrual phase (Grahm & Bancroft, 1993), premenstrual women in this study reported higher levels of state anxiety and depression than did the ovulatory women. These differences suggest a relationship between hormonal fluctuations throughout the menstrual cycle and cognitive performance. (See Figure 2 for hormonal fluctuations across the menstrual cycle.) However, it is noteworthy that at a time when women are reporting more negative moods, they are showing better performance in spatial abilities. This suggests that when moods are heightened so are women's sensitivities to spatial cues, which improves their spatial abilities. Menstrual cycle changes in hormone levels have been suggested to contribute to differences in mood and cognitive behavior across the menstrual cycle (Grahm & Bancroft, 1993). Estradiol levels are at their highest during the ovulatory phase. This suggests that high estrogen levels impair spatial abilities, including spatial abilities that favor women. The results also suggest that high estrogen levels impede feelings of anxiety and depression.

The present study provides further evidence that women, no matter which hormonal phase they are experiencing, outperform men during the identification stage of the spatial location task (Earls & Silverman, 1994; Silverman & Eals, 1992).

However, to our surprise, ovulatory women perform more poorly even than males during the location stage. This suggests that high estrogen levels during the ovulatory phase may impede their location performance and alter the expected sex difference in location memory ability. This is surprising evidence considering previous researchers have argued that females possess a reliable performance advantage over men on spatial location that is not influenced by the menstrual cycle (Eals & Silvermen, 1994; Silverman & Eals, 1992; Kimura, 1999). Instead, the present results are consistent with other studies that suggest that females' performance on male advantage spatial tasks improves during phases of low levels of estradiol hormones (Broverman et al., 1981; Hampson 1990a, 1995b; Hampson and Kimura, 1988; Hausmann et al., 2000; Komnenich et al., 1978; Silverman and Phillips, 1993; Phillips and Silverman, 1997). Consistent with these previous research findings, premenstrual females' performance on the mental rotation and targeting tasks was superior to ovulatory females' performance on these tasks. In contrast, the results found for females' performance on the spatial location task and verbal fluency task directly contradict these same studies (Broverman et al., 1981; Hampson 1990a, 1995b; Hampson and Kimura, 1988; Hausmann et al., 2000; Komnenich et al., 1978; Silverman and Phillips, 1993; Phillips and Silverman, 1997). According to these studies, female performance on female advantage tasks should improve during the ovulatory phase, when estrogen levels are highest. Although our results of female performance on female advantage tasks contradict with these studies, our study found very similar results to a study performed with rhesus monkeys which found that spatial memory fluctuates across the menstrual cycle, and greater performance occurs during phases with low estradiol levels (Lacreuse et al, 2000).

There are several ways to interpret these findings. For example, it might be the case that it is not only high estrogen levels that improve female performance scores on female advantage cognitive abilities, but the combination of relatively high estrogen levels with higher levels of progesterone. This would account for our high premenstrual performance results. As seen in Figure 2, after estrogen peeks during ovulation it has a slight bump in addition to increased progesterone during the luteal or premenstrual phase. Therefore, both estrogen and progesterone levels are high. This is a possibility that might need further examination, but there is little evidence to suggest that progesterone would have such an effect.

It could be the case that spatial abilities fluctuate across the menstrual cycle, but performance is not dependent on hormones alone. There could be other factors occurring in the female body across the menstrual cycle that spatial abilities are sensitive to which have not yet been identified. It is feasible that as females experience higher levels of state anxiety and depression during the lower estrogen level premenstrual phase, they are also experiencing increased sensitivity to their environment and a heightened awareness to spatial cues. It has been suggested that spatial location memory is unique, because an object's relative location in space can be used to encode the location into memory (Alexander et al, 2002; James & Kimura, 1997). It is possible that as sensitivities in mood (i.e. anxiety, depression) are heightened so are a person's sensitivities to environmental cues, which would increase awareness of relative spatial cures. This might account for the premenstrual females' performance on the spatial location task over the ovulatory females' performance. There is little research on this, but it might be worth examining.

Still, the contradicting results could be a factor of the small sample size tested in this study. Ideally, a larger sample size would be beneficial in a study such as this. Due to the one year time limit and high number of drop outs, the number of completed participants at this time is smaller than what was than originally expected. This research will continue throughout the next year in hopes of gaining a larger sample size and even cycle phase completion groups.

To our knowledge, no other menstrual cycle studies, which tested spatial abilities across the menstrual cycle, have implemented the use of the Donna mini-microscope saliva ovulation detector kits to determine hormonal cycle phases. Many past menstrual cycle studies relied on self-report of the onset of menses to determine hormonal fluctuations in participants. As menstrual cycles can vary from woman to woman this method is not very dependable. The ovulation detector kits gave us power to schedule the participants during their accurate and appropriate cycle phases.

Our study also is the first, to our knowledge, to study female performance on targeting across the menstrual cycle. The results we found with targeting performance are statistically significant and demonstrate poor female performance during their period of high estrogen levels. The daily diaries also, although not included in this study, give us a head start in performing our future correlational analysis of mood measures along with spatial ability performance across the menstrual cycle. The spatial location task used also gave us power to control the affective valence of the stimulus, which will be used in further measurements in ongoing studies in the lab.

Although the evidence found did not support our hypothesis that women's performance for spatial location memory would be at an advantage during the high estrogen ovulatory phase relative to the lower estrogen premenstrual phase, we did gain insight into female performance on cognitive tasks across the menstrual cycle. The results revealed that the relationship between hormones and spatial abilities is still unclear, but provided further evidence that spatial abilities fluctuate across the menstrual cycle. Future studies should focus on locating what exactly spatial ability performance is sensitive to across the menstrual cycle. Future studies might also examine the role progesterone plays in influencing cognitive abilities.

In conclusion, it is clear that further research is needed to more fully understand the relationship between hormonal fluctuations across the menstrual cycle and cognitive performance. This relationship is crucial to understanding the role hormones play in influencing female cognition.

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APPENDIX A

FIGURE 1

Spatial Location Memory Task

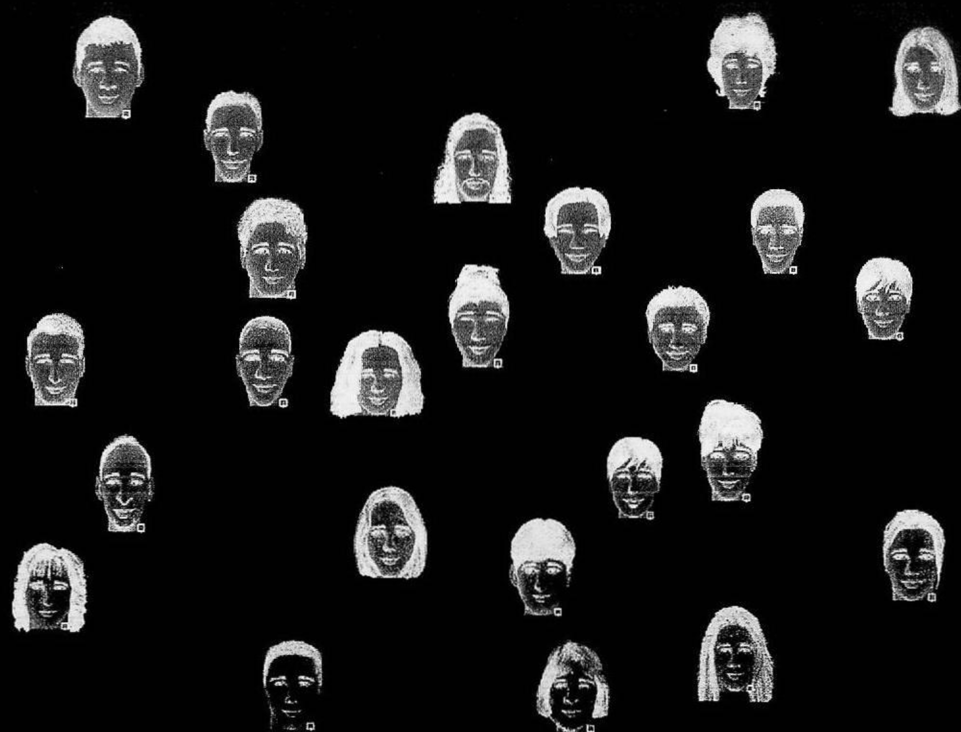


FIGURE 2

Hormonal Fluctuations Across the Menstrual Cycle

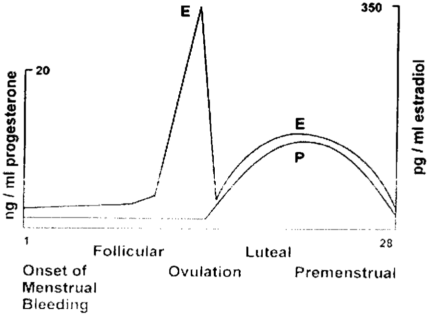
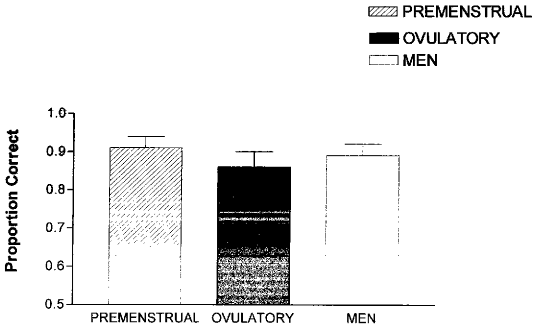


FIGURE 3

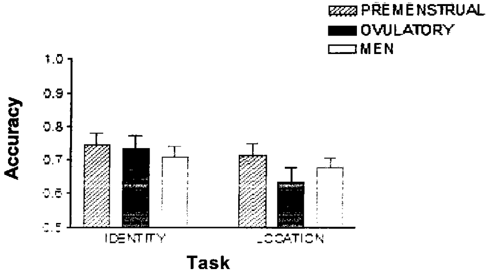
Mental Rotation Performance



Mental Rotation is poorest during the ovulatory phase.

FIGURE 4

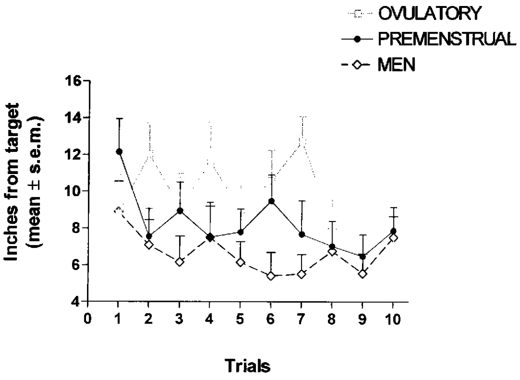
Spatial Location Performance



Location memory is poorest during the ovulatory phase.

FIGURE 5

Targeting Performance



Targeting is poorest during the ovulatory phase.

APPENDIX B

TABLE 1

Participant Condition Distribution

Emotional Expressions on Faces	Comparison Group: Men	Premenstrual-Ovulatory Group	Ovulatory-Premenstrual Group
Friendly	3	1	1
Sad	3	2	2
Threat	4	5	3

TABLE 2

Results for First Session Testing

Variable	Premenstrual	Ovulatory
Mood measures		
State Anxiety	1.7 (.24)	1.4 (.20)
Depression	9.0 (3.75)	3.75 (3.74)
Cognitive measures		
Mental Rotation	89% (4%)	83% (4%)
Face Location	74% (4%)	62% (4%)
Verbal Fluency (number of words)	17.75 (2.05)	11.75 (2.06)

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- **Education**
    - Fall 2000-Spring 2004
        - Texas A&M University, College Station, TX
        - Bachelor of Science in Psychology
        - Expected Graduation – May 2004
        - Overall GPA: 3.6
        - Top 15 % of Junior and Senior Classes
- **Research Experience**
    - Fall 2003-Spring 2004:
        - University Undergraduate Research Fellow
        - Worked closely with Advisor Dr. Gerianne Alexander
        - Studied menstrual cycle effects on spatial location tasks
        - Conducted lab and investigated female advantage on spatial location task by testing across the menstrual cycle
        - Administered tests, recruited and contacted participants, arranged testing schedule, and advertised experiment
        - Worked directly with participants
        - Presented 2 Talks on the menstrual cycle effects on spatial location tasks; Expected 3rd and final talk: April 2004
        - Poster presentation during Undergraduate Student Research Week: March 30-April 2 2004
        - Thesis Culmination – April 15, 2004
    - Fall 2002-Spring 2003:
        - 485 student (research assistant) for Dr. Heather Bortfeld
        - Helped set up infant language acquisition lab
        - Assisted word splicing and measured word durations on specialized computer software
        - Experienced the development of a research lab
- **Activities**
    - Fall 2001-Spring 2003
        - Psychology Club Member
        - Project Sunshine Member
- **Honors**
    - Fall 2002-Present
        - Psi-Chi Honors Society
    - Fall 2002, Spring 2003
        - Dean's List

April 2004