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ABSTRACT

Whether or not fluctuations in spatial ability as measured by S. G. Vandenberg's Mental Rotations Test cccur during the menstrual cycle was studied with 133 female students from 9 undergraduate educational psychology and nursing classes. For comparison, 28 male students also took the test. Scores from 55 females fell into the relevant menstrual phases during 3 repeated testings held approximately 7 days apart. A mixed analysis of variance procedure using G. Keppel's method for removal of practice effects indicated that female performance on the spatial test was significantly higher during the menstrual phase (days 2-7) than during the luteal phase (days 16-28). The performance of contraceptive pill users was not significantly different from the performance of nonusers. These findings confirm the findings of I. Silverman nd K. Phillips (1993) in an area where previous results have been inconsistent. The 28 males performed significantly higher than the females during the initial testing, but males' scores obtained during this initial testing were not significantly different from scores obtained from contraceptive pill users in the menstrual phase but were significantly higher than scores obtained from pill users in the luteal phase. (Contains 2 tables and 31 references.) (Author/SLD)

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FLUCTUATION IN SPATIAL ABILITY SCORES DURING THE MENSTRUAL CYCLE

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Abstract

The purpose of the study was to determine whether or not fluctuations in spatial ability as measured by Vandenberg's Mental Rotations Test occur during the menstrual cycles of college females. Participants were 28 male and 133 female students recruited from 9 undergraduate educational psychology and nursing classes. Of the 133 female students, scores from 55 females fell into the relevant menstrual phases during 3 repeated testings held approximately 7 days apart. A mixed ANOVA procedure utilizing Keppel's method for removal of practice effects indicated that female performance on the spatial test was significantly higher ($p < .001$, eta sqd. = .182) during the menstrual phase (Days 2-7) than during the luteal phase (Days 16-28). The performance of contraceptive pill users was not significantly different from the performance of nonusers. These findings confirm the findings of Silverman and Phillips (1993) in an area in which previous results have been inconsistent. The 28 males performed significantly higher ($p < .01$) than the 55 females during the initial testing. However, males scores obtained during this initial testing were not significantly different from scores obtained from contraceptive pill users in the menstrual phase but were significantly higher ($p < .005$) than scores obtained from pill users in the luteal phase.

FLUCTUATION IN SPATIAL ABILITY

SCORES DURING THE MENSTRUAL CYCLE

As the number of occupations in technical and scientific fields has increased, tests of spatial ability have become increasingly important for prediction of success (Eliot & Smith, 1983, p. 8). "The U.S. Employment Service estimates that the most technical and scientific occupations, such as draftsman, airplane designer, architect, chemist, engineer, physicist, and mathematician, require persons having spacial ability at or above the 90th percentile" (Clements & Battista, 1992, p. 442). However, researchers have found that males tend to perform significantly better than females on many tests of spatial ability to the extent that the effect size for this difference is often large enough to influence selection rates for certain occupations or training programs (Johnson & Meade, 1987, p. 738). Interestingly, the gender difference in spatial ability has not been found to be in full force until puberty, raising the possibility that hormones may be, at least in part, responsible for this difference (Hampson & Kimura, 1992, p. 361). Using as variables the hormonal changes that occur cyclically throughout the menstrual cycle, recent studies indicate that performance on sexually dimorphic spatial tasks may vary with variations in female hormonal levels (Kimura & Hampson, 1994).

According to Hampson and Kimura (1992), the preovulatory phase of the menstrual cycle corresponds to the highest level of the hormone estrogen. The menstrual phase corresponds to the lowest level of estrogen. The luteal phase occurs between ovulation and the menstrual phase and corresponds to a medium level of estrogen. These researchers and others (Silverman & Phillips, 1993) have found that women perform significantly higher on tests of spatial ability during the menstrual (i.e., low estrogen) phase of their menstrual cycle than during the higher estrogen (i.e., preovulatory and luteal) phases of their cycle. In addition, researchers have reported that the differences in performance on spatial tests between women at the menstrual phase and women at the midluteal phase are of similar magnitude as the reported gender differences in performance on spatial tests (Hampson, 1990, p. 31; Hampson & Kimura, 1992, p. 398).

Such findings may, however, be held suspect by readers familiar with the long history of menstrual cycle research in which the possibility of cyclic variations in general cognitive performance has been examined. Due to researchers' use of varying and often poor methodology, reviews of the literature in this area (Asso, 1987; Chiarello, McMahon, & Schaeffer, 1989; Dan, 1979; Hampson, 1990; Hampson & Kimura, 1992; Kimura & Hampson, 1994; Logue & Moos, 1988; Richardson, 1991; Sommer, 1973, 1982, 1983, 1992) report mixed results. As Hampson and Kimura (1992) noted, the examples of poor methodology include: use of small sample sizes, resulting in low statistical power; failure to consider the changes in hormonal levels of estrogen, and thereby, comparing between inappropriate phases of the menstrual cycle;

and the use of tests that are not sensitive enough to detect cognitive variations in performance.

In four separate studies with college-age participants, Silverman and Phillips (1993) avoided the forementioned methodological shortcomings, and thereby obtained more consistent results than results found in a review of the literature. Silverman and Phillips (1993) attribute the more consistent results mainly to the particular test used in their studies. With the use of that test, the Mental Rotations Test, developed by Vandenberg and Kuse (1978) based on Shepard and Metzler's (1971) stimuli, Silverman and Phillips (1993) were the first researchers to use a three-dimensional mental rotations task in a menstrual cycle study. The Mental Rotations Test has been reported to be the most difficult to solve through verbal means (Vandenberg & Kuse, 1978) and, perhaps causally, this test and other three-dimensional rotations tests yield the largest (Linn & Peterson, 1985) and most reliable (Masters & Sanders, 1993; Peters, Laeng, Lathem, Jackson, Zaiyouna, & Richardson, 1995) gender differences of all spatial tests.

Silverman and Phillip's (1993) first study revealed that contraceptive pill users performed significantly better during the menstrual phase than during the luteal phase. Moreover, the performance of pill users in the menstrual phase was equivalent to the performance of males. In a second study, a combination of pill users and nonusers in the menstrual phase also performed significantly higher during the menstrual phase than the luteal phase. This second study was the only one of the four studies to assess data according to a within-subjects design. For purposes of the study, the menstrual phase was defined as Days 2-7 of the menstrual cycle and the luteal phase as Days 16-23. No subjects were tested during the first day of menstruation due to the possible obtrusive effects of physical discomfort and pain medication.

There was a similar menstrual phase effect for a third study. However, for this third study and a fourth one, in order to enhance sample sizes, "the condition representing higher estrogen levels comprised all nonmenstruating subjects rather than just those in the luteal or pre-ovulatory phases" (Silverman & Phillips, 1993, p. 264). In addition, for the second, third, and fourth studies, pill users and nonusers were combined for purposes of analysis because they showed the same trends at about the same levels. In the fourth study, menstruating females' scores on the Mental Rotations Test were significantly higher than females's scores in the nonmenstruating phase but were not equivalent to scores of males who had participated in the first study. Interestingly, a significant difference in phase performance was not found for a two-dimensional mental rotations spatial test that was also given as part of this fourth study. This result lends support to the importance of using a spatial task with large, reliable gender differences when testing for a menstrual phase effect in performance.

Peters et al. (1995) have recently, in an attempt to replicate Silverman and Phillips' (1993) third study in which menstruating subjects were compared to all nonmenstruating subjects, found no significant effect for phase of menstrual cycle using a redrawn version of the Mental Rotations Test. However, these researchers concede that because they did not carefully determine subjects' phase of cycle, their "failure to find significant effects cannot be considered an effective challenge" (p.50) to the findings of Hampson and Kimura. In addition, Peters et al. (1995) did not distinguish between menstruating and nonmenstruating with the same days as those used by Silverman and Phillips (1993), nor did they use a scoring method identical to that of Silverman and Phillips (1993).

The purpose of the present study was to either confirm or refute the findings of Silverman and Phillips' (1993) within-subjects study. The main hypothesis was that on a test of spatial ability, the Mental Rotations Test (Vandenberg, 1971; Vandenberg & Kuse, 1978), college females would perform statistically significantly different during the menstrual phase than the luteal phase of the menstrual cycle. In addition, it was hypothesized that college females would perform statistically significantly different than college males and that contraceptive pill users would perform at the same level as nonusers.

Method

Participants

Participants were 28 male and 133 female college students recruited from eight undergraduate educational psychology classes and one undergraduate nursing class taught on the campus of a large southeastern university. Inasmuch as the researcher in the present study employed a within-subjects design, there was no need for equivalence of conditions across subject factors. Volunteers from two of the nine classes were offered extra credit for participation. Of the 133 female students, scores from 55 females fell into the relevant menstrual phases during the repeated testings.

Test Instrument

The test instrument selected for this study was the Mental Rotations Test (Vandenberg, 1971). This test has 20 items and 40 correct responses. The 20 items each consist of a two-dimensional computer drawing of a three-dimensional "criterion figure, two correct alternatives, and . . . two distractors . . . Correct alternatives are always identical to the criterion in structure but are shown in a rotated position" (Vandenberg & Kuse, 1978, p. 599).

Prior studies with the Mental Rotations Test have shown gender differences favoring males (Vandenberg & Kuse, 1978) and a fluctuation in performance by adult females during the menstrual cycle (Silverman & Phillips, 1993). In large samples, the Kuder-Richardson 20 internal consistency reliability has been estimated to be .88 and the test-retest reliability has been estimated to be .83 (Vandenberg & Kuse, 1978).

Design and Procedure

Three testing sessions were held approximately 7 days apart during regularly scheduled class times. The tests were administered by either the researcher or an educational psychology faculty member. The standard published instructions for the Mental Rotations Test were used. In these instructions, subjects were cautioned not to guess. The suggested but optional method of grading was not used. Instead, a point was given for each correct response and a point deducted for each incorrect response. Therefore, scores could range from -40 to +40. This method of scoring was used by Silverman and Phillips (1993) in their previously discussed studies and by Vandenberg and Kuse (1978) in a study of the gender differences in performance on this test. Prior to the first testing, participants were given the instructions (including practice problems) to take home. They were asked to read the instructions before attending each testing session. In addition, females were asked to complete and turn in with each test a questionnaire similar to the one used by Silverman and Phillips (1993). The questionnaire questions concerned contraceptive use and the dates of females' last and next menstrual periods. Each participant chose a personal code number to label each test and questionnaire turned in so that these items could be properly matched by the researcher for the repeated measures analysis without jeopardizing confidentiality.

In addition, in order to maintain confidentiality, no demographics other than gender were collected.

During each testing session, participants were allowed 3 minutes to complete the first 10 items and an additional 3 minutes to complete the last 10. The two halves of the test were timed separately to facilitate an estimation of the internal consistency reliability of the test.

In the analysis of possible score fluctuations, a split plot design using the SPSS statistical procedure MANOVA was employed with phases as the within-subjects factor and pill use as the between-subjects factor. For each subject, data from two of the three testing sessions were used. The present study defined the menstrual phase as Days 2-7 and the luteal phase as Days 16-28. One score used was the one obtained during the menstrual phase. The other score used was the one obtained during the luteal phase. Practice effects were removed from the analysis using a technique suggested by Keppel (1982). In addition to the repeated measures analyses, independent $\underline{t}$ tests were used to test for gender differences in performance on the Mental Rotations Test. An alpha level of .05 was used for all statistical tests.

Results

The results of the Spearman-Brown internal consistency analysis and the test-retest reliability analysis are shown in Table 1. Each reliability correlation coefficient reached significance.

Menstrual phase scores were statistically significantly higher than luteal phase scores (p = .001, eta sqd. = .182, Power .92). There was an indication of equivalence in scores between contraceptive pill users and nonusers (p = .552). These results are shown in Table 2. However, due to the significant interaction between phase and pill use, t tests between users and nonusers were performed in each phase and no significant differences were found at sufficient levels of statistical power.

During the initial testing males (M = 15.96, SD = 10.42) performed significantly higher (p < .01, eta sqd. = .160, d' = .69) than females (M = 9.55, SD = 7.87). However, during this initial testing, male scores were not found to be significantly different (p = .064, Power .54) from scores obtained from females who were in the menstrual phase (M = 10.79, SD = 6.84, N = 19). Male scores from the initial testing were not significantly different (p = .238) from scores obtained from pill users in the menstrual phase but were significantly different (p < .005) from scores obtained from pill users in the luteal phase.

Discussion

Because the present study indicated a statistically significant fluctuation in performance across the menstrual cycle on the Mental Rotations Test, the latest positive results by Silverman and Phillips (1993) were confirmed. The effect sizes for the differences between phases were notably large given that hormonal levels were not directly assessed. Hormonal levels were not directly assessed because the goal of the present study was to establish consistency in findings in this area and not necessarily to attempt to confirm a theory concerning hormonal levels. By having participants complete three questionnaires approximately 7 days apart, actual confirmation of menstrual phase starting dates was obtained for all but a few participants. On a practical level, the implication of distinguishing between phases based on the number of days a female is into her menstrual cycle is that females can make judgements of when and when not to take tests of spatial ability using information that is easily accessible to her.

As was the case in past research (Hampson, 1990; Hampson & Kimura, 1992), the effect sizes for gender difference (eta sqd. = .160) and phase difference (eta sqd. = .182) were of similar magnitude. Therefore, given the claim by Johnson and Meade (1987) that the effect size for gender difference is large enough to influence selection rates for certain occupations or training programs, likewise, the effect size for the menstrual cycle phase difference may be large enough to influence such selection rates. Moreover, it appears that phase effect makes a contribution to the gender difference in performance on spatial tests. The present study failed to indicate a statistically significant difference between male scores and scores obtained from females who were in the menstrual phase. A lack of statistical power may have prevented an actual between-subjects difference from being revealed. However, because, as in Silverman and Phillip's (1993) first study, pill users' menstrual scores were convincingly equivalent to scores of males and pill users' luteal scores were significantly different from scores of males, it might be reasonable to assume that a menstrual phase effect accounted at least in some small part for the difference in gender performance. These results might be used in partial explanation as to why training and exposure increase mental rotation abilities for females (Ben-Chaim, Lappan, & Houang 1988; Ferrini-Mundy, 1987; Okagaki & Frensch, 1994) but do not totally compensate for gender differences in performance.

The results of this study have several implications for companies and branches of the military (Carretta, 1987, 1989; Goldin & Thorndyke, 1981, p. 11) that use three-dimensional mental rotation spatial tests as predictors of success. As evidence mounts and females begin to feel legitimized in arranging to take tests of spatial ability during menstruation, conflicts may arise between females and employers or potential employers who refuse to accommodate these females with flexible testing schedules. Even graver conflicts may arise if employers feel justified in insisting that females take tests of spatial ability only during the luteal phase in order to obtain a measure that is indicative of the ability of a female "at her worst". Of course, this restriction would probably be difficult to implement without raising issues of right to privacy and imposing the costs of medical exams to verify the (potential) female employee's claim as to day of cycle.

This study may have social implications as well. Logue and Moos (1988) report that women's exposure to the stereotypic social belief that the menstrual phase is characterized by impaired performance may be linked to increased reports of negative symptoms and an obscuring of positive changes that occur during the menstrual phase. The findings of significantly higher performance of females during menstruation may help counter the popular notion that females are strictly negatively affected during this time of their cycles (Dan, 1979; Sommer, 1983; Walsh, 1982). Outside the area of predictive testing females should not be made to feel disadvantaged by menstrual phase effects because in day to day tasks, no one aspect of cognitive functioning is used and no general decrement has been found to occur during the menstrual cycle (Hampson & Kimura, 1992).

It was hoped that an explanation for the differences in reliability between males and females on the Mental Rotations Test could be proffered. However, due to significant differences in variability between the scores of males and females ($p < .05$) and the phenomenon of restriction of range, the differences in the reliability for males and females could not necessarily be attributed to fluctuation in females' scores during the menstrual cycle.

It might be argued that the performance of educational psychology and nursing students is not indicative of performance of students who will be applying for positions in the previously discussed occupations that require higher spatial abilities

(Peters et al., 1995). It is suggested that future research address this concern by testing a less curriculum homogeneous sample of students. Furthermore, because "mathematics generally correlates with spatial visualization, [which, according to Vandenberg and Kuse (1978), is the type of spatial ability measured by the Mental Rotations Test], in the range of .30 to .60" (Clements and Battista, 1992, p. 455), it follows that the effect of menstrual phase on performance by females on mathematics tests used as criteria in selection processes for occupations and educational programs may warrant investigation. It is suggested that the test chosen for such research be one with a large, reliable gender difference in performance. For example, the reported effect size (d') for gender difference on Educational Testing Service's 1987 GRE-Q was found to be .67 (Hyde, Fennema, & Lamon, 1990) which is very close to the effect size of .69 obtained in the present study for the Mental Rotations Test. One might also want to consider using the Mental Rotations Test as a "control" when conducting future menstrual cycle research on other tests.

References

Asso, D. (1987). Cyclical variations. In M. A. Baker (Ed.), Sex differences in human performance (pp. 55-80). Chichester, England: John Wiley.

Ben-Chaim, D., Lappan, G., & Houang, R. T. (1988). The effect of instruction on the spatial visualization skills of middle school boys and girls. American Educational Research Journal, 25, 51-71.

Carretta, T. R. (1987). Spatial ability as a predictor of flight training performance (AFHRL-TR-86-70). Brooks AFB, TX: Manpower and Personal Division, Air Force Human Resources Laboratory.

Carretta, T. R. (1989). USAF pilot classification systems. Aviation, Space, and Environmental Medicine, 60, 46-49.

Chiarello, C., McMahon, M. A., & Schaefer, K. (1989). Visual cerebral lateralization over the phases of the menstrual cycle: A preliminary investigation. Brain and Cognition, 11 (10), 18-36.

Clements, D. H., & Battista, M. T. (1992). Geometry and spatial reasoning. In D. A. Grouws (Ed.), Handbook of research on mathematics teaching and learning (pp. 420-464). New York: Macmillan.

Dan, A. J. (1979). The menstrual cycle and sex-related differences in cognitive variability. In M. A. Wittig & A. C. Petersen (Eds.), Sex-Related Differences in Cognitive Functioning (pp. 241-260). New York: Academic Press.

Eliot, J., & Smith, I. M. (1983). An international directory of spatial tests. Atlantic Highlands, NJ: Humanities Press.

Ferrini-Mundy, J. (1987). Spatial training for calculus students: Sex differences in achievement and in visualization. Journal for Research in Mathematics Education, 18, 126-140.

Goldin, S. E., & Thorndyke, P. W. (1981). Spatial learning and reasoning skill (R-2805-ARMY). U.S. Army Research Institute for the Behavioral and Social Sciences. Santa Monica, CA: Rand.

Hampson, E. (1990). Variations in sex-related cognitive abilities across the menstrual cycle. Brain and Cognition, 14, 26-43.

Hampson, E., & Kimura, D. (1992). Sex differences and hormonal influences on cognitive function in humans. In S. Becker, M. Breedlove, & D. Crews (Eds.), Behavioral endocrinology (pp. 357-398). London: MIT Press.

Hyde, J. S., Fennama, E., & Lamon, S. J. (1990). Gender differences in mathematics performance: A meta-analysis. Psychological Bulletin, 2, 139-155.

Johnson, E. S., & Meade, A. C. (1987). Developmental patterns of spatial ability: An early sex difference. Child Development, 58, 725-740.

Keppel, G. (1982). Design and analysis: A research handbook (2nd ed.) (pp. 399-404). Englewood Cliffs, NJ: Prentice Hall.

Kimura, D., & Hampson, E. (1994). Cognitive pattern in men and women is influenced by fluctuations in sex hormones. Current Directions in Psychological Science, 3, 57-61.

Linn, M. C., & Peterson, A. C. (1985). Emergence and characterization of sex differences in spatial ability: A meta-analysis. Child Development, 56, 1479-1498.

Logue, C. M. & Moos, R. H. (1988). Positive perimenstrual changes: Toward a new perspective on the menstrual cycle. Journal of Psychosomatic Research, 32, 31-40.

Masters, M. S., & Sanders, B. (1993). Is the gender difference in mental rotation disappearing? Behavior Genetics, 23, 337-341.

Okagaki, L., & Frensch, P. A. (1994). Effects of video game playing on measures of spatial performance: Gender effects in late adolescence. Journal of Applied Developmental Psychology, 15, 33-58.

Peters, M., Laeng, B., Latham, K., Jackson, M., Zaiyouna, R. & Richardson, C. (1995). A redrawn Vandenberg and Kuse Mental Rotations Test: Different versions and factors that affect performance. Brain and Cognition, 28, 39-58.

Richardson, J. T. E. (1991). The menstrual cycle and student learning. Journal of Higher Education, 62, 317-340.

Shepard, R. N., & Metzler, J. (1971). Mental rotations of three dimensional objects. Science, 171, 701-703.

Silverman, I., & Phillips, K. (1993). Effects of estrogen changes during the menstrual cycle on spatial performance. Ethology and Sociobiology, 14, 257-269.

Sommer, B. (1973). The effect of menstruation on cognitive and perceptual-motor behavior: A review. Psychosomatic Medicine, 35, 515-534.

Sommer, B. (1982). Cognitive behavior and the menstrual cycle. In R. C. Friedman (Ed.), Behavior and the menstrual cycle (pp. 101-127). New York: Marcel Dekker.

Sommer, B. (1983). How does menstruation affect cognitive competence and psychophysiological response? Women and Health, 8, 53-90.

Sommer, B. (1992). Cognitive performance and the menstrual cycle. In J. T. E. Richardson (Ed.), Cognition and the menstrual cycle. New York: Springer-Verlag.

Vandenberg, S. G. (1971). Mental Rotation Test. Boulder: University of Colorado, Institute for Behavioral Genetics.

Vandenberg, S. G., & Kuse, A. R. (1978). Mental Rotations: Group test of three-dimensional spatial visualization. Perceptual and Motor Skills, 47, 599-604.

Walsh, M. R. (1982). The quirls of a woman's brain. In R. Hubbard, M. S. Henifin, & B. Fried (Eds.), Biological woman --- the convenient myth (pp. 241-263). Cambridge, MA: Schenkman.

Table 1

Spearman-Brown Internal Consistency and Test-Retest Reliability Correlations

	Participants					
	Female		Male		All	
Session	r	n	r	n	r	n
Spearman-Brown						
First	0.58**	55	0.75**	23	0.68****	78
Second	0.44*	53	0.75**	21	0.58****	74
Third	0.79****	54	0.75*	15	0.80****	69
Test-Retest						
First to Second	0.78****	55	0.92****	21	0.85****	76
Second to Third	0.71****	51	0.78*	9	0.74****	60

Note. *p < .05. **p < .01. ***p < .001. ****p < .0001

Table 2

Tes' s of Pilluse Between-Subjects Effect and

Phases Within-Subjects Effect

Source	df	F
	Between subjects	
Pilluse (U)	1	0.36
S within-group error	53	(133.88)
	Within subjects	
Phases (P)	1	11.81***
P x U	1	5.87*
P X S within-group error	53	(21.47)

Note. Values enclosed in parentheses represent mean square errors. *S* = subjects.

*$p < .05$. **$p < .01$. ***$p \le .001$.