Pergamon

Person. individ. Diff. Vol. 24, No. 5, pp. 615–623, 1998
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Printed in Great Britain
0191-8869/98 $19.00+0.00

PII: S0191-8869(97)00233-X

TRAIT ANXIETY, STRESS AND THE MENSTRUAL CYCLE: EFFECTS ON RAVEN'S STANDARD PROGRESSIVE MATRICES TEST

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(Received 19 June 1997)

Summary—We investigated the effects of time-pressure stress on Raven's Standard Progressive Matrices performance in 64 low- and 64 high-trait anxious female subjects, tested either during premenstruation or menstruation. Based on previously reported associations between arousal/stress and intelligence test performance, we predicted that menstrual cycle variation would interact with stress-induced arousal/emotion and individual differences in reactions to aversive stimuli, as measured by trait anxiety. Our predictions were confirmed by Stress × Menstrual Phase and Trait Anxiety × Menstrual Phase interactions, which pointed to important moderating roles of stress and personality in menstrual cycle effects on cognitive performance. The results revealed that stress impaired performance during premenstruation, but improved it during menstruation; high trait anxiety impaired performance, irrespective of menstrual phase and only low trait anxiety was associated with an improvement in performance from premenstruation to menstruation phases of the cycle. The implications of our study for menstrual cycle and cognitive performance research is outlined. © 1998 Elsevier Science Ltd. All rights reserved

In this article, we examine the influence of trait anxiety and time-pressure stress on intelligence test performance at two phases of the menstrual cycle, viz. premenstruation and menstruation. Theoretical approaches and empirical findings suggest that cognitive performance is sensitive to endogenous variation in hormonal level (menstrual cycle), exogenous induction of arousal and emotion (e.g. by time-pressure stress) and individual differences in reactions to stressful stimuli (i.e. trait anxiety). However, the precise role of these variables on intelligence test performance is not known.

Intelligence test performance is known to be sensitive to arousal and stress manipulations (e.g., Corr & Kumari, 1998; Revelle, Amaral & Turriff, 1976; for a review of the arousal-performance literature, see Revelle, 1987) and the menstrual cycle is known to be associated with variations in arousal and emotion (Kumari & Corr, 1996). Therefore, there is good reason to postulate a link between the menstrual cycle and intelligence test performance. Indeed, menstrual cycle variation and intelligence test performance are empirically related. For example, Kumari & Corr (1996) reported that, for a test of general cognitive abilities, stress impaired performance at mid-cycle and improved performance at menstruation. These data were interpreted in terms of a curvilinear relationship between level of stress-induced arousal and performance (for discussion of the derivation of this hypothesis, see Kumari & Corr, 1996). However, these effects were not found for performance on Raven's (1960) Standard Progressive Matrices test (a widely-accepted measure of fluid intelligence; Anastasi 1988; Carpenter, Just & Shell, 1990), which suggests that some intelligence test measures may be preferentially sensitive to different phases of the menstrual cycle. Possible effects of premenstruation and trait anxiety were not examined in the Kumari & Corr study, therefore, it remains a possibility that these factors may influence Raven's test performance.

In the present study, we examined the possible interactive effects of premenstruation (vs menstruation), trait anxiety and stress on Raven's test performance. We focused on the differential effects of stress in low and high trait anxious *S*s at premenstruation and menstruation.

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There are several reasons for expecting different effects of premenstruation and menstruation on cognitive performance. Premenstrual and menstrual phases produce different profiles of self-reported negative affect and physiological symptoms (Richardson, 1992a). For example, during the premenstrual phase, energetic arousal is lowered and tense arousal is heightened (Armour & Asso, 1986; Asso, 1978; Asso & Braier, 1982; Asso & Magos, 1992); there is a general increase in negative emotions (Cumming, Cumming, Krausher & Fox, 1991; Metcalf, Livesey, Hudson & Wells, 1988); and an increased risk for depression (Keenan, Lindamer & Jong, 1992). For these reasons, premenstrual symptomatology may be regarded as a form of state anxiety (Richardson, 1992b).

In contrast to these psychological effects of state anxiety at premenstruation (Keenan *et al.*, 1992), it is often assumed that physiological symptoms are more important at menstruation (Boyle & Grant, 1992). Accordingly, psychological effects should have most impact at premenstruation and physiological effects most impact at menstruation. In particular, the effects of experimental manipulations designed to induce negative emotions should be most pronounced at premenstruation, that is during a period of heightened negative emotionality (Beck, Gevirtz & Mortola, 1990). There are indeed empirical reports of menstrual-related variability in activity to stressing/arousing environmental factors, with the greatest responsiveness to an experimental stressor occurring premenstrually (Brugger, Milicevic, Regard & Cook, 1993; Hastrup & Light, 1984; Woods, 1985).

We took trait anxiety in preference to state anxiety in order to measure individual differences in sensitivity to stressors; that is, chronic personality effects that have an influence beyond the immediate effects of exogenous stress and endogenous (menstrual cycle) variations. On the basis of previous research, we made the assumption that, on average, negative emotionality and state anxiety, would be higher premenstrually than menstrually. Given the well-established role of personality factors in moderating the effects of stress/arousal on cognitive performance (Revelle, 1987), we hypothesized that both stress and individual differences in vulnerability to stress, namely trait anxiety, would be most pronounced at premenstruation.

Our predictions differ from the arousal-based hypothesis advanced by Kumari & Corr (1996) because we assume that time-pressure stress exerts two separate effects, one on general arousal and a second on negative emotionality. At premenstruation, when state anxiety is high, we assume that time-pressure stress will have a psychological effect of increasing anxiety, in addition to any effect on general arousal; we further assume that these negative emotionality effects will be absent during menstruation. Stress at premenstruation is likely to impair performance, by virtue of the debilitating effects of negative emotionality on complex cognitive tasks. At menstruation, where general arousal is assumed to be low (Kumari & Corr, 1996), stress should improve performance, by virtue of an increase in general arousal that pushes arousal towards a more optimal point on the arousal-performance curve.

METHOD

Subjects

One hundred and twenty-eight female undergraduate and postgraduate students (19–25 years) were recruited from various colleges and universities of Varanasi, India. *S*s were not paid for their participation and they were regularly menstruating with a cycle of 28–30 days (judged on the basis of their last three menstrual cycles); none were using any form of contraceptive pill or receiving regular medication and all were non-smokers.

Trait anxiety

The Hindi version (Spielberger, Sharma & Singh, 1973) of the trait scale of the State–Trait Anxiety Inventory (Spielberger, Gorsuch & Lushene, 1970) was used to provide a measure of trait anxiety. The mean (SD) of the trait anxiety scale was 39.47 (7.45). Low and high trait anxious groups were formed by randomly selecting *S*s with scores one SD below (low anxiety: score of 32 or less; $M = 29.99$, $SD = 1.09$) or above (high anxiety: score of 47 or more; $M = 52.67$, $SD = 4.95$) the mean.

Intelligence test

Raven's Standard Progressive Matrices test (Raven, 1960) is composed of 60 multiple choice problems, arranged in progressive order of difficulty. Each problem consists of a design or matrix from which a part has been removed. The *S*'s task is to complete the design by selecting one of the available answers, 6 (sets A & B) and 8 (sets C–E).

Design

A four-way split-plot design was used, consisting of two levels of Anxiety (Low Anx, $N = 64$; and High Anx, $N = 64$), two levels of Menstrual Phase (Premenstruation and Menstruation), both serving as between-*S*s factors; and two levels of time pressure Stress (Low Stress and High Stress) serving as the within-*S*s factor. In order to explore possible time of day effects, half the *S*s were tested in the morning (08.00–10.00 h), the other half in the evening (18.30 and 20.30 h); Time of Day served as an additional between-*S*s factor.

Procedure

*S*s underwent a semi-structured interview to assess their menstrual cycle status. They were asked when their last three periods had begun and the regularities of their cycles. Only those students were selected who reported a highly regular menstrual cycle of 28–30 days and who reported being able to report with accuracy the time of onset of menstrual flow.

Premenstruation was defined as the last four days preceding menstruation onset, menstruation as four days after onset of menstruation. The date of actual onset of menstruation was confirmed by the experimenter (V.K.) and if there was a discrepancy between predicted and actual onset of more than one day (approx. 10% of cases) *S*s were discarded and replaced. Therefore, all premenstruation *S*s were tested before onset of menstrual flow, all menstruation *S*s after onset of menstrual flow.

*S*s were individually tested. Under Low Stress, *S*s were given 20 min to work on Raven's test (it has been suggested that this test can be used as a speed test when allowing only 20 min for completion; Raven, 1960). Under High Stress, *S*s were given 20 min to work on each test, but after every 3 min they were instructed, "Try your best. Hurry up, only x minutes are left".

Half the *S*s in each experimental cell were tested under Low Stress in the first session and then under High Stress in the second session; the other half were tested under High Stress in the first session and under Low Stress in the second session. After *S*s had been tested for the first time, they were requested to return for the second session, two days later at the same time (they were not told that they would be required to complete the same tests in the second session). An equal number of *S*s were tested under the Low and High Stress order and these orders were fully counterbalanced across Anxiety and Menstrual Phase conditions.

Analysis

Stress, personality and menstrual cycle effects are likely to influence both correct number of answers (accuracy) and errors (response bias). It would be misleading to conflate measures of accuracy and response bias in a single measure (e.g. percentage correct). In addition, intelligence test performance is usually measured by a single index of number of correct answers. For these reasons, analysis of correct answers was the main performance measure of interest in this study. Errors of commission (i.e. total number of incorrect answers) were also analysed in order to eliminate the possibility that the effects on correct answers were a secondary influence of response bias, as reflected in errors.

RESULTS

Table 1 gives means and standard deviation for both measures classified by experimental conditions.

The correlation between correct answers and errors was negative ($r = -0.56$, $P < 0.001$). The sign of this correlation reflects the fact that a higher rate of errors (i.e. higher level of carelessness) was associated with a lower number of correct answers (with a number of possible answers to each

Table 1. Mean (standard deviation; SD) correct answers and commission errors for Raven's Standard Progressive Matrices test

	Correct Answers		Errors	
	M	SD	*M*	SD
	Premenstruation phase			
Low Anxiety				
Low Stress	29.87	5.95	15.78	6.54
High Stress	28.69	5.04	20.44	5.09
High Anxiety				
Low Stress	29.53	5.25	13.25	6.61
High Stress	27.84	4.88	19.12	6.04
	Menstruation phase			
Low Anxiety				
Low Stress	32.03	6.19	12.16	5.34
High Stress	32.66	5.95	14.06	4.91
High Anxiety				
Low Stress	27.72	5.31	11.41	6.80
High Stress	28.16	4.51	18.28	5.55

question, a trade-off in favour of speed lowers the probability of selecting the correct answer). Although the magnitude of this correlation was fairly large, only 31% of variance was shared between the two measures.

Four-way split-plot ANOVAs were conducted (Trait Anxiety × Stress × Menstrual Phase × Time of Day). No main or interactive effects of Time of Day were found; this factor was therefore dropped from subsequent analyses.

Correct answers

Anxiety, $F(1{,}124) = 8.07$, $MSe = 49.56$, $P < 0.01$, revealed that Low Anx *S*s ($M = 30.82$, $\pm$ 1 SEM = 0.69) performed better than High Anx *S*s (28.31, 0.57).

Anxiety × Menstrual Phase, $F(1{,}124) = 4.69$, $MSe = 49.56$, $P < 0.05$ (Fig. 1), revealed that Menstruation performance was higher than Premenstruation in the Low Anx group ($t = 2.28$, $P < 0.05$); no difference was evident in the High Anx group ($t = 0.66$, $P > 0.05$), suggesting that both high anxiety and Premenstruation impaired performance. From a different perspective, Premenstruation performance for Low and High Anx *S*s were not significantly different ($t = 0.49$, $P > 0.05$), but there was a difference between Low and High Anx *S*s at Menstruation ($t = 3.46$, $P < 0.05$).

Stress × Menstrual Phase, $F(1{,}124) = 6.89$, $MSe = 9.00$, $P < 0.01$ (Fig. 2), revealed that Premenstruation performance under Low and High Stress did not significantly differ ($t = 1.14$, $P > 0.05$); but there was a marginal difference between Low and High Stress during Menstruation ($t = 1.98$, $P < 0.05$). Under Low Stress, Premenstruation and Menstruation performance were nearly identical ($t = 0.17$, $P > 0.05$), but under High Stress, Menstruation performance was higher relative to Premenstruation ($t = 2.27$, $P < 0.05$).

The three-way Menstrual Phase × Anxiety × Stress term was non-significant, $F(1{,}124) = 0.04$, $MSe = 9.00$, $P > 0.05$.

Errors

Only one identical effect to correct answers was observed for errors: Anxiety × Menstrual Phase, $F(1{,}124) = 4.76$, $MSe = 44.97$, $P < 0.05$ (Fig. 3). This effect revealed that the Low Anx Premenstruation group made more errors than the Low Anx Menstruation group ($t = 4.45$, $P < 0.05$); but this difference was not significant for High Anx *S*s ($t = 1.08$, $P > 0.05$).

The pattern of this interaction suggests that errors may have influenced correct answers. In order to explore this possibility, the three-way ANOVA on correct answers was re-run with errors under low and high stress entered as covariates: the significant Anxiety × Menstrual Phase interaction for correct answers disappeared, indicating that the effects of Anxiety and Menstrual Phase affected both measures of performance.

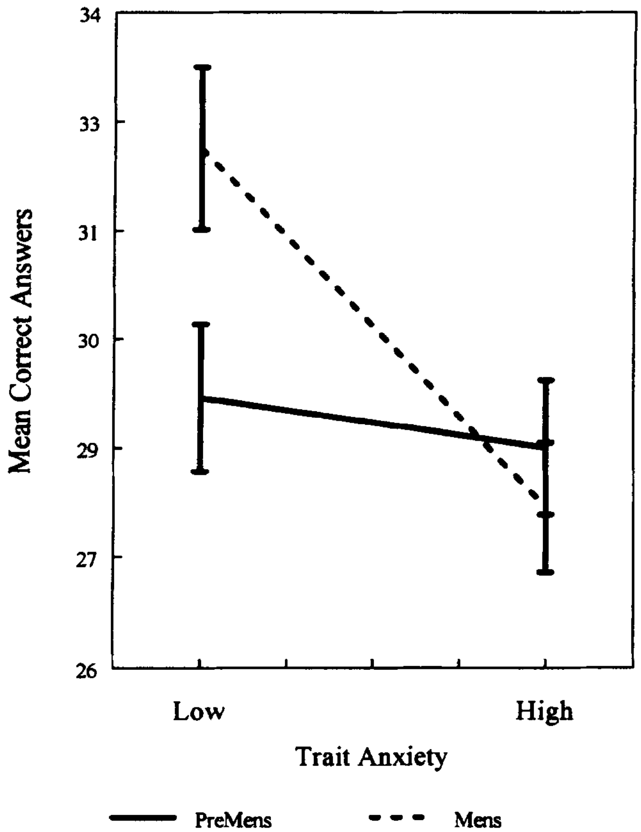

Fig. 1. Mean (± 1 SEM) number of correct answers on Raven's Standard Progressive Matrices test for low and high trait anxiety *S*s, tested either at premenstruation or menstruation.

In addition, other effects were found for errors.

Menstrual Phase, $F(1,124) = 14.32$, $MSe = 44.97$, $P < 0.01$, showed that *S*s during Premenstruation (M = 17.15, ±1 SEM = 0.62) made more errors than those during Menstruation (13.98, 0.58).

A main effect of Stress, $F(1,124) = 60.41$, $MSe = 24.70$, $P < 0.001$, showed that High Stress (17.98, 0.52) led to more errors than Low Stress (13.14, 0.57).

Anxiety × Stress interaction, $F(1,124) = 6.20$, $MSe = 24.70$, $P < 0.01$, showed that the mean increase observed for the low Anx group (3.28, 0.81), reflecting a change from Low Stress (13.97, 0.77) to High Stress (17.25, 0.74), was significantly less than the mean increase observed for the high Anx group (6.37, 0.94), as they moved from Low Stress (12.32, 0.84) to High Stress (18.71, 0.71), $t = 2.48$, $P < 0.05$, showing that high Anx *S*s made more errors under High Stress.

DISCUSSION

We predicted that the effects of induced stress and trait anxiety on intelligence test performance would be most pronounced at premenstruation. This prediction was confirmed, suggesting that both stress and high anxiety are deleterious to cognitive performance during premenstruation; during menstruation high trait anxiety continued to impair performance, but stress enhanced performance. These findings indicate that cognitive performance is vulnerable to disruption by stress at premenstruation. The different effects of high stress and high anxiety at menstruation may indicate that these two variables do not reflect a common causal process.

The Anxiety × Menstrual Phase interaction was found for both correct answers and errors, revealing that, premenstrually, both low and high anxious *S*s showed a reduction in correct answers and an increase in errors, reflecting a less careful, impulsive type of responding. This finding

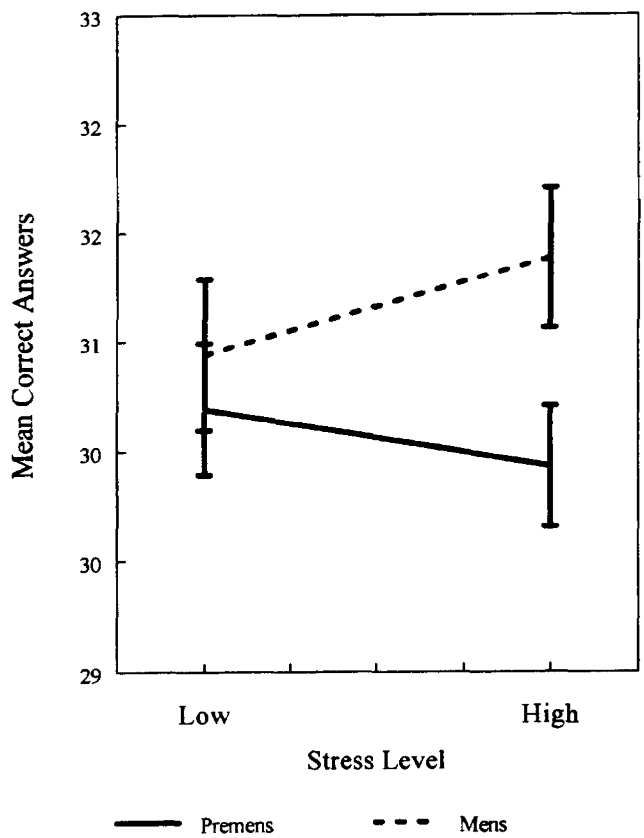

Fig. 2. Mean (± 1 SEM) number of correct answers on Raven's Standard Progressive Matrices test under low stress and high stress, tested either at premenstruation or menstruation.

indicates that both accuracy and response bias need to be taken into account when interpreting Anxiety × Menstrual Phase effects. In this regard, it is interesting to note that Howard, Gifford & Lumsden (1988) also observed increased impulsivity at premenstruation as indexed by lower go/no go differentiation in an avoidance task.

Clearly it seemed that high anxiety impaired performance, regardless of menstrual phase, whereas stress exerted different effects depending on menstrual phase: it impaired performance during premenstruation, and improved it during menstruation. Thus, stress during relatively low state anxiety (i.e. menstruation) facilitated performance, perhaps by increasing general arousal to a more optimal point on the arousal–performance curve (Kumari & Corr, 1996). In contrast, high trait anxiety served only to impair performance, irrespective of menstrual phase, pointing to a general deleterious effect of negative emotionality.

These different effects of stress and trait anxiety may help to explain the absence of an Anxiety × Stress × Menstrual Phase interaction: if stress and anxiety reflect different causal processes, then these variables would not be expected to interact. However, the absence of a three-way interaction could have reflected ceiling and floor effects in the performance measures taken. The range of intelligence test variance sensitive to experimental manipulation is much less than usually found on behavioural measures: it is constrained by an upper theoretical limit (ceiling) of true score intelligence and to a lesser extent, a floor of competence. It may be difficult to push scores much above or below these limits.

The interactive effects involving trait anxiety were not merely a consequence of anxiety changes at the two points of the menstrual cycle. Trait anxiety was measured 3–4 months prior to scheduled testing and *S*s were not aware that anxiety measures were being investigated with respect to menstrual phases. These data indicate that trait anxiety predisposes females to respond differently at the two phases of the menstrual cycle. If state and not trait, anxiety measures had been taken,

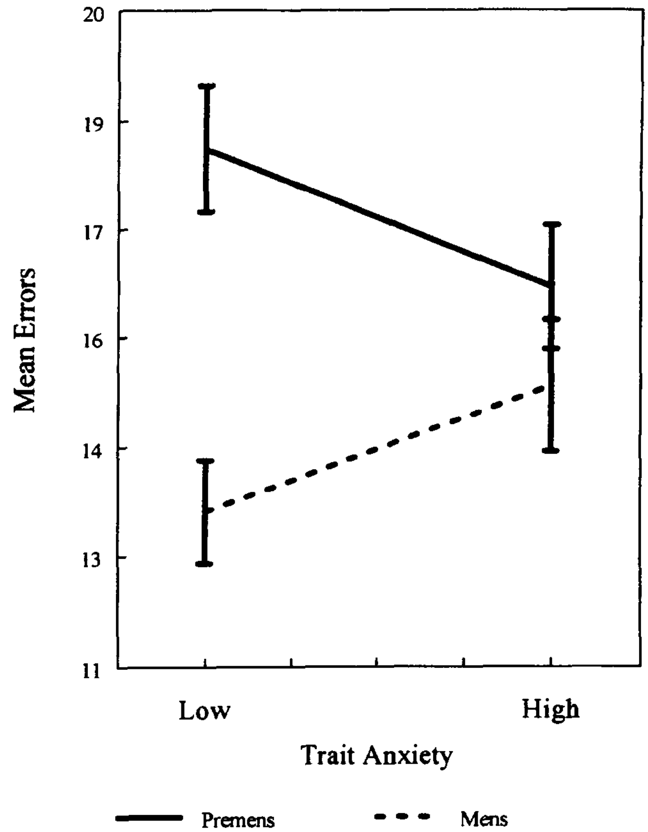

Fig. 3. Mean (± 1 SEM) number of errors on Raven's Standard Progressive Matrices test for low and high trait anxiety *Ss*, tested either at premenstruation or menstruation.

then it would not have been possible to conclude that chronic trait anxiety affects intelligence test performance at different phases of the menstrual cycle; and interpretation of the results would have been circular.

The finding that intelligence test performance, as distinct from intelligence *per se*, is influenced by personality and stress has important implications both for the validity of intelligence tests as a reliable measure of intelligence and for the validity and fairness of intelligence tests in females samples. The outcome of this research is thus of importance for theoretical and practical aspects of intelligence testing. However, interpretation of our results needs to be made in the context of previous findings and debates in menstrual cycle research.

Firstly, there is often thought to be no logical or compelling argument for postulating menstrual cycle effects on cognitive performance. However, as our study demonstrates, from the perspective of biological personality research there are very good reasons for postulating such a link. The effects of personality, arousal, stress and time of day on cognitive processes are now well established in personality research (Revelle, 1987); and it seems reasonable to suppose that hormonal fluctuations, to the extent that they affect arousal, mood states and sensitivity to stressful stimuli, should show a consistent pattern of effects on cognitive processes. The argument that the menstrual cycle should be immune from these well-established processes seems theoretically indefensible and empirically questionable. However, the relation of menstrual cycle and cognitive performance, and the factors that moderate this relationship, is complex, and it would be an understatement to say that this relationship has yet to be adequately clarified.

Secondly, there are a sufficient number of reports showing no significant effects of the menstrual cycle on cognitive performance (Gordon & Lee, 1993; Sommer, 1992) to prevent anything less than cautious conclusions being drawn at the present time. In addition, there are methodological problems with many confirmatory studies (e.g. reliance upon retrospective reports) which also counsel caution.

Although null results are difficult to interpret, we do not believe that they can be dismissed as Type II errors.

However, there is evidence for menstrual-related variability in reactivity to stressing/arousing environmental factors, with the greatest responsiveness to an experimental stressor occurring at premenstruation (Brugger *et al.*, 1993; Hastrup & Light, 1984; Woods, 1985). In addition, menstrual cycle effects have been reported on event-related brain potential reactions to emotive stimuli (Wang & Johnston, 1993); mental rotation (Silverman & Phillips, 1993); frontal lobe functioning (Brugger *et al.*, 1993); and event-related potential components that are sensitive to premenstrual symptomatology (Ehlers, Phillips & Parry, 1996). Furthermore, in females diagnosed as having Premenstrual Syndrome (PMS), a carbohydrate-rich beverage, compared with placebo, was found to be effective in improving self-reported depression, anger, confusion, carbohydrate craving 90–180 min after intake, as well as improving word recognition performance (Sayegh, Shiff, Wurtman, Spiers, McDermott & Wurtman, 1995). In fairness, these results should not be dismissed as Type I errors.

A reasonable conclusion is that menstrual cycle effects tend to be unreliable and do not affect all measures of cognitive performance in a consistent manner; however, sufficient data has accumulated to suggest that reported effects are real and are potentially of practical importance; they are clearly of considerable theoretical interest.

The popular notion that PMS, and its deleterious effects, are widespread in the workplace is sometimes dismissed as relying upon now-discredited early studies of the phenomena (Hardie, 1997). However, findings showing no menstrual cycle effects on workplace variables are not very informative, as they rarely use sophisticated designs equal to the task of uncovering moderating influences on menstrual cycle and performance relations. The present study indicates that exogenous stress and personality are two such important moderating variables. Indeed, if these variables had not been included in this study, we would have incorrectly concluded that Raven's test performance is not affected by menstrual phase.

In evaluating the significance of our results, several limitations of the study need to be mentioned. Firstly, *S*s were retested on the same measure of intelligence. Although it is a possibility that retesting might have led to better performance on the second occasion of testing, the conditions were fully counterbalanced, therefore it is difficult to conceive of this feature of the design producing the pattern of effects reported. Secondly, the present sample was restricted to women with a regular cycle range of 28–30 days length and within 19–25 years of age range. The results therefore may not be applicable to women with shorter or longer cycles or different age groups, although the cycle range is probably less important, given that this generally does not affect the incidence of paramenstrual symptoms (Hargrove & Abraham, 1982).

In addition, the possibility that prior consumption of caffeine and nicotine may have influenced our data, by, for example, affecting arousal and emotion levels which were not controlled, may be discounted: coffee and caffeine-based products are used by students in Universities of Varanasi to a much lesser extent than in European and American countries and in the present sample all females were non-smokers.

In conclusion, we present evidence to show that menstrual phases influence intelligence test scores and that their effects are moderated by stress and trait anxiety. Stress impaired performance at premenstruation, but improved it at menstruation; premenstruation performance was lower than menstruation performance, irrespective of trait anxiety; and high trait anxiety impaired performance over both menstrual phases. This article highlights the theoretical basis of such menstrual cycle effects and a need for more sophisticated designs to uncover the moderating effects of arousal/emotion and personality.

Acknowledgement—For his support during the course of this study, we wish to thank Prof. B. S. Gupta, of Banaras Hindu University, Varanasi-221005, India.

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