Pharmacopsychoecologia (1995), 8, 1-10

0970-3926/95/0801-3,0001

Interactive effects of trait anxiety, menstrual cycle, time of day and time pressure instructions on cognitive performance

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Abstract. Regularly menstruating female students (aged 19 to 25 year), who were classified low, moderate or high-trait anxious, were tested on a general mental ability test (GMAT) either in the morning or evening under two conditions of time-pressure to study the interactive effects of trait anxiety, menstrual phases and time pressure stress-induced arousal on cognitive performance. The results showed: (1) premenstrual low-trait anxious females did better than premenstrual moderate and high-trait anxious females; (2) all menstruating females did better in the presence than in the absence of time pressure instructions; (3) the performance of low-trait anxious midcycle phase females was worse in the morning on all subtests of GMAT except the sub-test number series in the absence of time pressure instructions which became comparable to other groups when time pressure instructions were given; (4) premenstrual and midcycle females commited more errors than menstruating females; (5) low-trait anxious females commited more errors than moderate and high-trait anxious females. The findings are discussed in terms of arousal/stress, subject attributes towards menstrual cycle, on-task effort, task and situation demands, and information processing characteristics of low and high trait-anxious females.

Key Words. Trait anxiety. Menstrual phases. Time of day. Time pressure. Human performance.

Effects of trait anxiety (Eysenck, 1982, 1985, 1992; Mueller, 1992) as well as temporal variations (review, Smith, 1992) in human cognitive performance are well documented, but whether time of day would interact with trait anxiety to affect cognitive performance remains an unexplored issue. Available evidence (review, Tamkova et al. 1994) is inconsistent regarding the relationship between morningness/eveningness and neuroticism (a personality trait, having high positive correlation with trait anxiety; Shields, 1973). Indirect support for the assumption of an interaction of time of day with trait anxiety comes from the findings of Cameron et al. (1986), showing that anxious patients show elevated anxiety levels later in the day.

Several studies (e.g., Baker et al., 1979; Broverman et al., 1981; Kirstein et al., 1981; Hartley et al., 1987; Hampson & Kimura, 1988; Robinson & Kertzman, 1990; Silverman & Phillips, 1993a, 1993b; Krug et al., 1994) suggest that menstrual cycle affects cognitive functioning, though there is an equally compelling body of evidence showing no effects of menstrual cycle status on cognitive functioning (see, for a review, Sommer, 1992; Richardson, 1992; Gordon & Lee 1993; Nakatani et al., 1993). The present study set out to investigate whether menstrual phases interact with trait anxiety, time of day and time pressure-induced arousal to affect the performance. If daily activities produce changes (sufficient enough to affect cognitive performance) in arousal levels, leading to over or under-arousal in the evening (cf. Revelle et al., 1980), then it seems reasonable to hypothesize that performance would vary at various phases of the cycle as a function of time of day, since daily activities of females have been found to be related to menstrual cycle. Morris and Udry (1970) found a significant midcycle increase in spontaneous motor activity. Animal data also suggest that increased estrogen level is associated with increased motor activity, shortened sleep and de-

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creased food intake (Davidson & Levine, 1972). In rats, estrogen affects the length of circadian rhythm (Morin et al., 1977). Leibenluft (1993) hypothesized that, in humans, estrogen shortens the circadian period, lengthens the sleep phase and advances the sleep onset. Stenn and Klinge (1972) found a positive correlation (in human beings) between spontaneous arm movements (measured by pedometer) and basal body temperature (used as an indicator of hormonal variation). Although they did not find a significant cyclic pattern in activity, out of 7 women (over 17 meastrual cycles), none showed an activity peak during the five days of menstruation. Assuming that body temperature indexes basal arousal (Colquhoun, 1971), these results suggest that menstruation is a phase of low sub-optimal arousal.

Regarding menstrual cycle effects on cognition, Broverman et al. (1968) proposed that increased activation capacity caused by high estrogen levels, facilitates the performance on such simple perceptual motor tasks as reading, typing, colour naming, whereas increased inhibition capacity caused by high progesterone levels, facilitates the performance on tasks with a high inhibitory component requiring perceptual restructuring and suppression of over-learned responses such as maze tasks, embedded figures, mirror drawing etc. (cf. Graham, 1980). Waber (1976) called these two set of tasks as tests of verbal and spatial ability. Following conceptualization by Waber (1976) of Broverman et al. 's (1968) hypothesis, there should be a general facilitation of performance of ovulating (defined in the present study as midcycle) females on sub-tests of GMAT heavily dependent on verbal comprehansion (and in some cases over-learned information, such as items of opposites and synonyms sub-tests, see method section), as compared to performance on sub-test, not so heavily dependent on verbal comprehension (number series).

Time pressure is recognized to be a very potent stressor variable, and is also assumed to increase arousal (Revelle et al., 1976). Women have been found to be most susceptible to stress (Patkai et al., 1974) and less able to cope with stress around premenstrual and mestrual phases (Moos et al., 1969). Patkai (1985) confirmed after reviewing a large number of menstrual cycle studies that a majority of women report some negative moods and somatic complaints before and during menstruation. Since severity of reported premenstrual tension correlates positively with trait anxiety (Halbreich & Kas, 1977) and neuroticism (Lewis & Horn, 1991) the performance of high trait-anxious females should be more affected by time pressure instructions than low trait-anxious females during the premenstrual phase. This possiblity is likely to have particular relevance in Indian context (in which the study was conducted) where menstruation imposes many restrictions on women's activities. Yet, there is little experimental evidence bearing upon this question. The general aim of the study was to explore the effects of endogenous and exogenous fluctuations in arousal on verbal cognitive performance in terms of Yerkes-Dodson Law (Yerkes & Dodson, 1908). This Law posits a curvilinear relationship between arousal and performance, such that, for a given level of task difficulty, there exists an optimal level of arousal, with levels of under or over-arousal producing impaired perfomance. Specifically, we hypothesized: (1) premenstrual high trait-anxious females would be more adversely affected by time pressure instructions presumably when tired (in the evening) than low and moderate trait-anxious females; (2) menstruating females would perform better under time pressure instructions than without such instructions, presumably more so in the evening than in the morning [personality traits were not expected to cause much variation in the performance of these females because women report emotional tension mostly during the premenstrual phase (Doty et al., 1981), but mostly physical complaints are likely to have similar effects on all the personality types during the menstruation phase (Sheldrake & Cormack, 1976)].

Materials and Methods

Subjects

Subjects, who ranged in age between 19 and 25 years, were selected on the basis of trait anxiety scores, determined by administering the Hindi version (Spielberger et al., 1973) of the State-Trait Anxiety Inventory (Spielberger et al., 1970) to 1000 regularly menstruating (not using any type of contraceptive pill or on regular medical prescription) female students having a cycle range of 28 to 30 days. The study sample was limited to students with a regular menstrual cycle of 28-30 days length in order to make the phases more precisely definable in the absence of direct hormonal measurement; ovulation occurs almost exactly 14 days prior to the next menstruation onset, irrespective of the cycle length (Lien, 1979). The Hindi version (Gupta & Poddar, 1979) of the Eysenck Personality Inventory—EPI (Eysenck & Eysenck, 1964) was also administered. Out of these 1000 students, 69 students were excluded because they had lie scores of 5 or above on the EPI. Two forms were incomplete. The mean (± SD) of trait anxiety acores for the remaining 929 students was: Mean = 39.47 (± 7.45). On the basis of their scores, subjects were classified into three groups as per the criteria given below:

High trait anxiety group: Mean + 1.0 SD (score 47 and above; Mean = 52. 67, SD = 4.95)

Moderate trait anxiety group : Mean ± 0.2 SD (score 38 to 41, SD = 1.09)

Low trait anxiety group: Mean - 1.00 SD (Score 32 and below; Mean = 29.99, SD = 1.88).

Stimulus Material

Hindi version (Singh, 1968) of General Mental Ability Test (Hundal, 1962) was used. It consists of 100 items. These items are distributed over seven subtests, namely, number series (20 items), analogies (20 items), inferences (15 items), classification (15 items), opposites (10 Items), synonyms (10 items) and following directions (10 items). A factor analytic study of this test by Gakhar (1972) has shown that all subtests have much in common (an element named as 'verbal comprehension' characterized by its reference to the ideas and meaning of the words) except number series. Performance on all subtests but number series, mainly relies on verbal ability of mostly crystallized intelligence (Cattell, 1963).

Experimental Design and Procedure

A 3 × 3 × 2 × 2 factorial design, involving three levels of trait anxiety (high, moderate and low), three phases of menstrual cycle (menstruation, days 1-4; midcycle, days 11-17; and premenstrual, days 25-30), two times of day (morning, 8.00 to 10.00 hrs; and evening, 18.30 to 20.30 hrs), and two testing conditions (time pressure instructions -TPI, and no time pressure instructon - NTPI) with repeated measures on the last factor, was used. There were 16 subjects in each experimental cell.

Information about the menstrual cycle status (designation of phases based on Speroff & Vande Wiele, 1971) was obtained by contacting subjects well in advance of the testing session. The date of actual onset of menstruation was later confirmed by the investigator (first author), and data on the subjects where there was on error of more than ± one day (from the expected date of menstruation) were discarded and replaced by testing other suitable subjects. Subjects were requested not to take any medication for at least 8 hrs prior to reporting for an experimental session, so as to reduce the potential pharmacological effects.

The task was administrated individually. They were asked to read the instructions (given on the front page of the booklet) and to work on the practice items. After they had finished with the practice items, they were asked to begin answering the test items. Under NTPI, they were told that they would be given 20 minutes to work on GMAT Under TPI also, they were given 20 minutes to work on GMAT. but after every 3 minutes they were instructed, "hurry up, only.......... X................ minutes are left." Half the subjects in each experimental cell were tested under NTPI in the first session and then under TPI in the second session. The other half of subjects were tested under TPI in the first session and then under NTPI in the second session. After the subjects were tested for the first time, they were requested to return for the second session two days later at the same time, without telling them what they would be required to do then.

Statistical Analysis

The criterion measures were worked out in two ways: correct answers (CA scores) and commission errors (CE: wrong answers). The data on the above two indices (CA and CE scores) were then subjected to four-way analysis of variance with repeated measures on the last factor, i.e. testing condition, separately for the scores on number series and combined sccores of other six subtests. Statistically significant ($p < 0.05$) main effects, two-way and three-way interactions were taken up and further analyzed only if the same variable were not involved in highter order interactions on the same measure. Interactions were analyzed (at the lowest level) by post hoc mean comparisons (t-test). For the four-way interactions, analysis was done at three levels (Keppel, 1986): (i) an analysis of the interaction of three variables at different levels of the fourth variable, (ii) an analysis of the interaction of two variables at different levels of the other two variables, and (iii) an analysis of the effects of one variable at different combinations of the other three variables.

Results

Correct Answers

Number Series. Neither the four-way nor any three-way interaction reached accepted level of significance. Trait anxiety interacted with menstrual cycle ($F = 2.55$, $df = 2, 270$, $p < .05$, Figure la) and

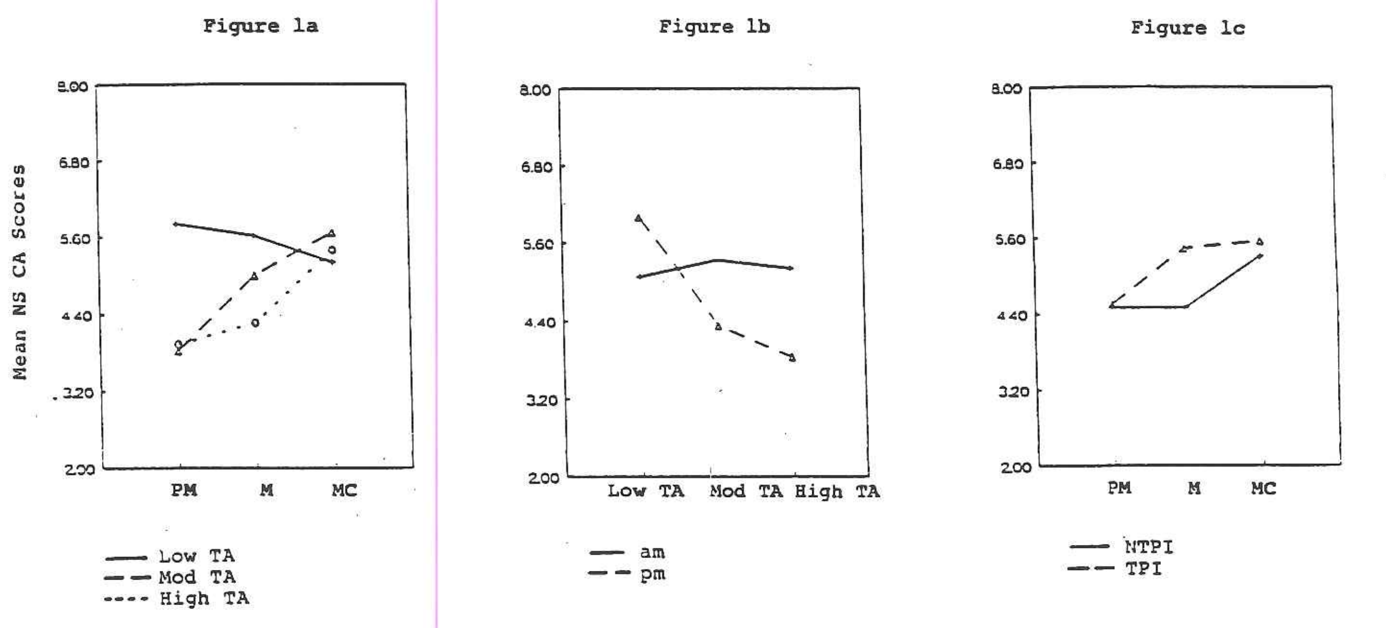

Figure 1a to 1c. Mean CA scores (Correct Answers) on number series (NS) as a function of trait anxiety × menstrual cycle interaction (Figure 1a), as a function of trait anxiety × time of day interaction (Figure 1b), and as a function of menstrual cycle × testing condition interaction (Figure 1c).

TA - Trait Anxiety, Mod - Moderate, PM - Premenstrual Phase, M - Menstruation Phase, MC - Midcycle Phase, am - Morning, pm - Evening, TPI - Time Pressure Instructions, NTPI - No Time Pressure Instructions.

also with time of day (F = 6.10, df = 2, 270, $p < .01$, Figure 1b). TPI interacted only with menstrual cycle (F = 4.30, df = 2, 270, $p < .05$, Figure 1c).

As shown in Figure la, menstrual phases did not cause variation in the performance of low-trait anxious females. When tested during the premenstrual and menstruation phases, low-trait anxious females did better than high and moderate-trait anxious females, though menstruating moderates did better than premenstrual ones. At the midcycle phase, no differences were observed and the three personality groups wesre comparable.

Figure 1b shows that in the morning there were no differences in the performance of three anxiety groups, while in the evening moderate and high-trait anxious females did worse than low-trait anxious females.

As is evident in Figure 1c, TPI did not affect premenstrual and midcycle females, but the performance of premenstrual females was always lower than midcycle females. The performance of menstruating females, although lower than midcyle females under NTPI, improved with TPI and became comparable to midcycle females.

Composite Scores

The four-way interaction (Figures 2a, 2b & 2c) involving all the four variables was significant (F = 2.66, df = 4, 270, $p < .05$), which upon further analysis showed that :

(i) At the premenstrual phase (Figure 2a), the analysis of trait anxiety × time of day × testing condition interaction revealed only the effect of trait anxiety (F = 47.15, df = 2, 90, $p < .001$). Low-trait anxious females (Mean = 37. 01, SD = 5.78) did better than moderate (Mean = 33.66, SD = 5.07 and high-trait anxious (Mean = 33.19, SD = 4.46) females.

(ii) At the menstruation phase (Figure 2b), the same analysis as for the premenstrual phase, revealed only the significant main effect of TPI, showing better performance of these subjects under TPI (Mean = 36. 36, SD = 6. 24) than under NTPI (Mean = 33.59, SD = 5.95).

(iii) At the midcycle phase (Figure 2c), the three-way interaction of trait anxiety × time of day × testing conditions was significant (F = 10.76, df = 2, 90, $p < .001$). Subsequent analysis showed that only low-trait anxious females were affected by time of day × testing condition interaction (F = 24.79, df = 1, 30 $p < .001$). These females underperformed in the morning under NTPI as compared to their performance under TPI, and also compared to low-trait anxious females tested in the evening.

Commission Errors

Number Series. Only the main effects of menstrual cycle (F = 14.58, df = 2, 270, $p < .001$) and TPI (F = 133.06, df = 1, 270, $p < .001$) were observed. Menstruating females committed fewer errors (mean = 2.35, SD = 1.57) than premenstrual (mean = 3.56, SD = 1.85) and midcycle (mean = 3.78, SD = 2.40) females. More errors were committed under TPI (mean = 4.18 SD = 2.76) than under NTPI (mean = 2.29, SD = 2.17).

Composite Scores. All the four factors had significant main effects (trait anxiety, F = 5.70, df = 2, 270, $p < .01$; menstrual cycle, F = 22.97, $p < .001$; time of day, F = 4.54, df = 1, 270, $p < .05$; TPI, F = 343.48, df = 1, 270, $p < .001$), but there was no two-way, three-way or four-way interaction.

High-trait anxious females (mean = 14.02, SD = 4.48) committed fewer errors than moderate (mean = 15.77, SD = 5. 71) and low (mean = 16.43, SD = 6.21) trait-anxious females. Premenstrual (mean = 18.08, SD = 5.25) females committed more errors than midcycle (mean = 14.99, SD = 5.44) and menstruating (mean = 13.13, SD = 4.96) females. More errors were committed in the evening (mean = 16.04, SD = 5.55) than in the morning (mean = 14.76, SD = 5.58). More errors were committed under TPI (mean = 18.80, SD = 6.99) than under NTPI (mean = 12.01, SD = 5.76).

Discussion

The first hypothesis that premenstrual high trait-anxious females would be more adversely affected by time-pressure (but under both testing conditions) particularly in the evening than low and moderate-trait anxious females was supported by the results on all subtests. Performance of moderate and high trait anxious females seemed to be sensitive to the premenstrual phase as hypothesized, with no effect of the midcycle phase. Premenstrual moderate and high-trait anxious females could have been more reactive

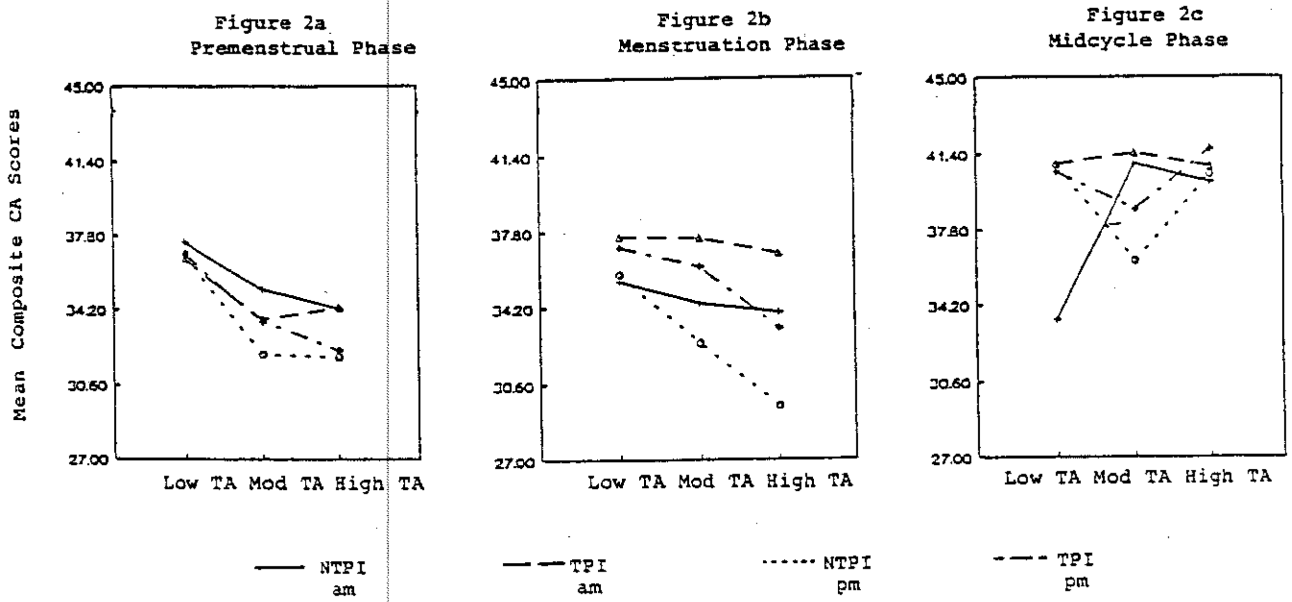

Figure 2a to 2c. Mean composite CA scores (Correct Answers) as a function of trait anxiety × menstrual cycle × time of day × testing condition interaction.

TA - Trait Anxiety, Mod - Moderate, PM - Premenstrual Phase, M - Menstruation Phase, MC - Midcycle Phase, am - Morning, pm - Evening, TPI - Time Pressure Instructions, NTPI - No Time Pressure Instructions.

to time-pressure (in both testing conditions) than low trait anxiety females. Also, this effect was stronger in the evening [reflected in trait anxiety × time of day interaction (Figure 1b) on number series, although trait anxiety × menstrual cycle × time of day interaction fell short of significance (p = .10) and also reflected in trait anxiety × time of day × testing condition interaction for the premenstrual females (Figure 2a) for the composite CA scores].

The finding that performance (CA scores) of high-trait anxions females was lower on number series than low and moderate trait-anxious females (more at the premenstrual and menstrual phases although not significant), suggests a reduced performance efficiency of this group in the evening which could be a result of daily activities (leading to a state of rather higher tension and tiredness), suggesting a possible role of trait anxiety/neuroticism in time of day effects. Colquhoun and Folkard (1978) did find by reanalysing Blake's (1967) original data that time of day effects were more marked in neurotic than in stable subjects.

The second hypothesis that menstruating females would perform better under time pressure instructions than without such instructions was well supported by the results (CA scores) on all subtests. The findings suggest that menstruating females were sub-optimally aroused/motivated, and that is why, were helped by TPI, since the performance was mostly within resource-limited range (solutions of these problems were within reach of most of the subjects as they were given enough time).

Although menstrual phases did not affect the performance (CA scores) of low-trait anxious females on number series, menstrual phases did affect the performance on all other subtests. It seems that while moderate and high trait-anxious females were more affected by premenstrual and menstruation phases (but not by the midcycle phase as much as low-trait anxious females), low-trait anxious females were presumably more sensitive to the changes of high estrogen midcycle phase, although the pattern of results showing an effect of time of testing is not easily explained.

Low trait-anxious midcycle morning group underperformed under NTPI, suggesting that this group was attentive to their internal environment (cf. Graham, 1980) in the morning, and TPI helped them in directing their attention to the task at hand (Callaway & Stone, 1960). However, it is not clear why this was not the case in the evening. Possibly interaction with the external environment during the day time had already directed their attention away from thir internal environment. Moreover, this interaction was not observed on number series, which could have been due to cognitively more demading nature of the problems on this subtest [involving automatized skills (use of numbers) and also suppression of responses (conciously manipulating the available information while trying to find a rule to complete the series)] than other subtests, suggesting the midcycle phase effects to be task-specific. The other possibility is that number series subtest consisted of only 20 items, and therefore, may have lacked statistical power.

For the commission errors, the main effects of menstrual cycle and testing condition showed similar results on all subtests. Premenstrual and midcycle females committed more errors than menstruating subjects. This could have been due to extra effort expended by menstruating females (since they knew that they were participating in a study involving menstrual cycle and tried to compensate for the commonly held belief that they were less efficient during that period; Rodin, 1976). Possibly, these females evaluated each item more carefully before being certain on the right answer, an information processing charcteristic commonly associated with high trait anxiety (Geen, 1987).

The present study, indeed, found support (composite CE scores) for the assumption that high trait-anxious individuals adopt a more cautious criteria in order to reduce the likelihood of incorrect response (Geen, 1987; Revelle, 1987). However, premenstrual females had significantly greater composite CE scores than midcycle females, suggesting a hindering effect of premenstrual phase on this index. Subjects did more commission errors under TPI than under NTPI, possibly because of perceiving these instructions as emphasizing speed more than accuracy. However, the finding that more commission errors were commited by females tested in the evening (composite CE scores) than by females tested in the morning, could have be due to an overall tiredness and lowering of motivation, since the study sample consisted of students (unpaid volunteers), who were tested mostly in the weekdays, after spending the day working in their own departments.

For the overall picture of performance on number series, considering the two indices togther, it can be said that menstruating (this was true more for the low trait-anxious females than moderate and high-trait anxious females though not significant) females showed the best performance on number series when tested under TPI. However, results on other subtests do not support the view that, in general, midcycle females would show better performance than subjects in other phases, although this turns out to be the case in the present data, if other factors (I.e., personality and time of testing) are ignored. Further work is needed to establish / explore this effect in more detail.

In conclusion, present results provide a rich source of information on how various biological and situational factors could interact to influence human cognitive performance. Findings clearly indicate, possible situation specific, time of day dependent, selective (i.e., hindering the performance on one index but leaving unaltered/improved on another) roles of personality and hormonal status in cognitive performance. These aspects require further investigation.

Acknowledgement

The suggestions of Dr. U. Gupta in the running of this study are gratefully acknowledged.

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