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Impulsivity, Time of Day, and Stress: Effects on Intelligence Test Performance

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Interactive effects of impulsivity (Imp), time of day and time-pressure stress on two uncorrelated intelligence tests were studied in 192 female *S*s in India. *S*s were tested under both low and high stress conditions in either the morning (8.00–10.00 a.m.) or the evening (6.30–8.30 p.m.). In general, the pattern of Imp × time of day × stress interactions for correct answers on both intelligence tests was consistent with the hypothesis of phase shift in the diurnal arousal cycles of low and high Imp *S*s: Low Imp *S*s outperformed high Imp *S*s with morning testing, and high Imp *S*s' performance was improved by stress-induced arousal with evening testing. Less consistent with the diurnal arousal hypothesis was the finding that low Imp *S*s showed better performance than high Imp subjects under stressful conditions, irrespective of time of day. These data point to the importance of diurnal arousal in the effects of impulsivity on intelligence test performance, but suggest that stress may lead to increased effort in individuals sensitive to aversive stimuli sufficient to abolish the deleterious effects of high arousal.

In the present experiment we examine the comparability of time-pressure stress and caffeine-induced arousal in impulsivity and time of day interactions on intelligence test performance. We also examine the possible motiva-

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tional differences between the effects of caffeine and stress in terms of automatic *arousal* and controlled *effort* processes.

Extraversion and caffeine-induced arousal show complex interactions as a function of time of day. Revelle, Humphreys, Simon & Gilliland (1980) reported that, for measures of cognitive performance, introverts tend to outperform extraverts with morning testing under low arousal; but as arousal is increased, extraverts tend to show an increase, and introverts a decrease, in performance efficiency. With evening testing, this interaction pattern is reversed, with introverts doing best under high arousal, extraverts doing best under low arousal.

Revelle et al. (1980) interpret these data as suggesting that introverts are relatively aroused in the morning, less aroused in the evening; extraverts less aroused in the morning, more aroused in the evening. This interaction pattern is consistent with the hypothesis of a phase difference in diurnal cycles (cf. Blake, 1967, 1971), with introverts reaching their arousal peak before extraverts.

In personality research, it is sometimes thought that manipulations such as caffeine and time stress impact upon a unitary arousal system (e.g., Revelle, 1987; although this unitary arousal system hypothesis is under constant challenge; e.g., Neiss, 1988). In apparent support of a common arousal system, Revelle, Amaral and Turriff (1976) reported that intelligence test performance of introverts' was impaired by stress + caffeine, while that of extraverts' was improved, suggesting both variables had a common influence on general arousal. However, this finding poses a problem for the interpretation of Revelle *et al.*'s (1980) time of day effects: Revelle *et al.* (1976) tested *S*s at ''night'' (p. 149), yet their pattern of caffeine + stress effects paralleled Revelle *et al.*'s (1980) caffeine effects with morning testing. Therefore, it is not clear whether caffeine and stress interact with impulsivity in the same manner over the course of the day.

In addition, Revelle *et al.* (1980) reported that the impulsivity component of extraversion showed more consistent effects than the sociability component, but in Revelle *et al.*'s (1976) study these two components of extraversion were not separated. Therefore, it is unclear whether impulsivity truly mediated the effects of stress in the 1976 study.

There are theoretical reasons for thinking that the effects of caffeine and stress on cognitive performance may not be identical. Humphreys and Revelle's (1984) motivation theory of arousal and performance suggests that, in addition to arousal (intensity) effects, which are relatively automatic, there is a second motivational system of controlled effortful processing which ''..is commonly understood to mean trying harder or being involved in a task'' (Revelle, 1987, p. 442). Effort, or the direction of behaviour, is influenced by such motivational factors as feedback, and reward and punishment. It is therefore possible that caffeine affects automatic *arousal*, while stress affects *effort;* furthermore, these motivational effects may be moderated in different ways by personality.

The above discussion highlights a number of unresolved issues. The principal aim of this study is to examine the interaction of impulsivity × stress × time of day to determine whether the effects of stress are similar to the effects of caffeine reported by Revelle *et al.*'s (1980). As low impulsivity has been previously shown to influence reactions to aversive stimuli (Corr, Pickering, & Gray, 1995b), we also investigated a possible difference in low and high impulsives' reactions to stress in terms of arousal and effort processes.

There are two secondary aims of this study.

Firstly, two relatively separate measures of intelligence were taken to examine the generalizability of impulsivity × stress × time of day interactions. Revelle *et al.* (1976, 1980) used academic-type intelligence tests; the present study used a broader battery of measures.

Secondly, as this study was conducted in India, as part of a research programme concerned with stress and personality effects, it was possible to assess the cross-cultural validity of impulsivity × arousal relations. Assuming that stress/arousal effects are biologically-based, then there is no a priori reason to predict a different pattern of effects than those reported for USA samples.

METHOD

Subjects

One hundred ninety-two female undergraduate and postgraduate students (19–25 yrs) were recruited from populations of various colleges and universities of Varanasi, India.

Impulsivity Measure

The Impulsivity (Imp) scale from the Hindi version (Gupta, 1987; Gupta & Poddar, 1979) of the Eysenck Personality Inventory (EPI, Form A; Eysenck & Eysenck, 1964) was used. As noted by Gupta (1987), ''While translating the E.P.I., Form A, into Hindi language, an effort was made to retain the essential content of the original English items'' (p. 15). Correlations between the English-language EPI and the Hindi version are ≈0.90 (Gupta, 1987).

The rationale and selection of impulsivity items from the EPI has been given by Revelle *et al.* (1980). Given the wording and content of these 9 impulsivity items from the EPI, and especially their lack of cultural nuance, the questions in the Hindi EPI are literal translations (Q1: ''Do you long for excitement?''; Q3: ''Are you usually carefree?''; Q5: ''Do you stop and think things over before doing anything?''; Q8: ''Do you generally do and say things quickly without stopping to think?''; Q10: ''Would you do almost anything for a dare?''; Q13: ''Do you often do things on the spur of the moment?''; Q22: When people shout at you, do you shout back?; Q39: ''Do you like doing things in which you have to act quickly?''; Q41: ''Are you slow and unhurried in the way you move''?). The content of these items leaves little doubt about the comparability of EPI impulsivity in English and Hindi.

As part of a large research programme, the Hindi EPI was administered to 1000 females. Out of these, 69 were excluded because they had lie scores of 5 or above; and of the remaining

*S*s, low Imp (Imp−; score of 2 or below) and high Imp (Imp+; score of 5 or above) groups were formed from those falling approximately ±1 SDs around the mean (M = 2.96, SD = 1.50). From these groups 192 *S*s (48 *S*s in each between-*S*s cells) were randomly selected to take part in the present experiment (other Imp−/Imp+ *S*s were randomly allocated to other experiments). Imp− and Imp+ *S*s, therefore, were clearly differentiated in terms of EPI impulsivity items.

The mean ages (±1 *SD*) of Imp− (20.26, 1.59) and Imp+ (20.34, 1.67) *S*s were nearly identical.

Intelligence Test Measures

The instruments employed were Raven's Standard Progressive Matrices test (Raven, 1960), and the Hindi version (Singh, 1966) of Hundal's (1962) General Mental Ability Test. Raven's test is thought to provide a good measure of fluid intelligence (G_f; Anastasi 1988), Hundal's test a measure of crystallized intelligence (G_c; Hundal, 1969).

Hundal's test battery has been widely used in India and it has good psychometric properties; it provides a range of subscales which together comprise an adequate measure of academic-type ability. Raven's test is applicable cross-culturally, representing a knowledge-free test of cognitive power. Thus, the two tests measure different aspects of cognitive functioning, allowing a good test of the pervasiveness of personality, arousal and time of day influences.

Hundal's test comprises 100 items arranged in ascending order of difficulty; these items are distributed over seven subtests: Number Series, Analogies, Classification, Inferences, Following Directions, Opposites, and Synonyms. The *S*'s task is to choose the correct answer from the available alternatives (4–6), with the exception of Number Series and Following Directions which requires *S*s to produce an answer.

Raven's test 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 to E).

Design

A three-way split-plot design was used in which there were two levels of Imp (low, n = 96; and high, n = 96), two levels of time of day (Time; 8–10 a.m., n = 96; 6.30–8.30 p.m., n = 96), both serving as between-*S*s factors (48 *S*s in each of the 4 factorial cells); and two levels of Stress (low and high stress conditions; see below), serving as a within-*S*s factor. Therefore, the four groups of 48 *S*s were tested twice, once under low stress and once under high stress, either in the morning or evening. Hundal's and Raven's tests were administered in counterbalanced order.

Menstrual phase status was obtained from all *S*s participating in this research programme, so it was possible at the time of personality testing to counterbalance this variable over all the experimental conditions, thus allowing for the control of this additional source of error variation.

Procedure

Stress was induced with time pressure instructions. Under the low stress condition, *S*s were given 20 min to work on Hundal's test and 20 min to work on Raven's test; under high stress, 20 min was also given to work on each test, but after every 3 minutes *S*s were told, ''Try your best. Hurry up, only x minutes are left'' (where x referred to the number of minutes remaining).

After *S*s had been tested for the first time, they were requested to return for the second session, 2 days later at the same time (they were not told that they would be required to

TABLE 1
Mean (*SD*), Correct Answers (CA), and Commission Errors (CE) for Hundal's and Raven's Tests

		Hundal's test		Raven's test	
		CA	CE	CA	CE
Low Imp					
Low Stress:	A.M.	49.12 (9.24)	12.02 (6.78)	31.04 (4.81)	11.06 (6.38)
	P.M.	41.73 (7.93)	11.27 (5.47)	29.42 (5.51)	9.81 (5.66)
High Stress:	A.M.	52.52 (10.14)	19.19 (7.09)	31.48 (5.24)	17.83 (7.28)
	P.M.	51.37 (6.89)	17.75 (6.92)	30.94 (5.28)	16.71 (5.79)
High Imp					
Low Stress:	A.M.	47.17 (8.21)	18.96 (7.46)	31.19 (6.64)	15.92 (6.86)
	P.M.	49.98 (9.36)	17.64 (7.48)	34.94 (6.95)	14.31 (6.60)
High Stress:	A.M.	49.44 (7.12)	24.62 (7.46)	32.31 (6.27)	17.62 (5.68)
	P.M.	46.46 (9.41)	24.02 (8.26)	32.85 (6.98)	18.20 (7.21)

complete the same tests). An equal number of *S*s were tested under the low-high stress order and high-low stress order, and these orders were fully counterbalanced across Time and Imp factors. Raven's and Hundal's tests were both administered under low stress and high stress; and their order of presentation was counterbalanced over these Stress conditions.

RESULTS

The dependent variable was number of correct answers. Pearson correlation between Hundal's and Raven's correct answers was low ($r = 0.08$, ns).[1]

Correct answers and commission errors (i.e., number of incorrect answers given) were significantly correlated for Raven's test ($r = -.546$, $p < .001$), but not for Hundal's ($r = -.117$, ns). The negative sign of these correlations relates to a higher rate of commission errors (i.e., higher level of carelessness) being associated with a lower number of correct answers (with a number of possible answers to each question, a speed/accuracy trade-off in favour of speed lowers the probability of selecting the correct answer).

Three-way split-plot analyses of variance (ANOVAs), comprising 2 levels of Imp, 2 levels of Stress, and 2 levels of Time, were conducted on correct answers. for clarity, Hundal's and Raven's tests were analysed separately. Descriptive statistics for correct answers and commission errors are shown in Table 1.

Hundal's Test

The ANOVA results for correct answers are shown in Table 2.

The Time effect revealed that *S*s tested in the morning ($M = 49.56$, ± 1

[1] Principal components analyses, performed separately for low and high stress conditions, showed that correct answers on Hundal's and Raven's tests loaded on orthogonal factors.

TABLE 2
ANOVA Summary Table Showing Effects of Impulsivity, Time of Day, and Stress on Correct Answers on Hundal's Test

Source	DF	MS	*F*	Sig of *F*
		Between-subjects effects		
Within Cells	188	113.26		
Imp	1	17.51	.15	.695
Time	1	455.01	4.02	.046
Imp × Time	1	420.84	3.72	.055
		Within-subjects effects		
Within Cells	188	35.02		
Stress	1	834.26	23.82	.000
Imp × Stress	1	1225.51	34.99	.000
Time × Stress	1	1.26	.04	.850
Imp × Time × Stress	1	870.01	24.84	.000

SEM = .78) did better than those tested in the evening (47.38, ± .76); the Stress effect that high stress (49.95, ± .63) improved performance (low stress: 47.00, ± .67). These effects indicated that correct answers were sensitive to both time of day and stress manipulations.

The Imp × Time interaction showed that with morning testing, the Imp− group (50.82, ± .87) outperformed the Imp+ group (48.30, ± .68); but with evening testing, the Imp+ group (48.22, ± .81) outperformed the Imp− group (46.55, ± .71). This interaction is consistent with the view of a phase difference in diurnal arousal levels between low and high Imp groups.

The Imp × Stress effect revealed that the Imp− group's performance markedly improved from low (45.45, ± .95) to high (51.95, ± .88) stress; but the Imp+ group's performance was similar under low (48.57, ± .91) and high (47.95, ± .86) stress. This effect suggests that the Imp− *S*s were sensitive to the manipulation of stress.

These two-way effects confirmed that Imp moderated the effects of the two main experimental factors, Stress and Time.

A triple Imp × Time × Stress interaction was also found (Fig. 1). To unravel this effect, two-way Time × Stress ANOVAs were separately conducted for Imp− and Imp+ groups.

For the Imp− group, Time, $F(1, 94) = 7.29$, $MSe = 120.02$, $p < .01$ and Stress, $F(1, 94) = 69.56$, $MSe = 29.34$, $p < .01$, were significant, showing that performance was better in the morning and under high stress. Also the Time × Stress interaction was significant, $F(1, 94) = 15.97$, $MSe = 29.34$, $p < .01$, revealing better performance in the morning than in the evening, but only under low stress; high stress abolished this time of day effect, leading to equally superior performance at both times of day.

For the Imp+ group, Time × Stress was significant, $F(1, 94) = 9.89$,

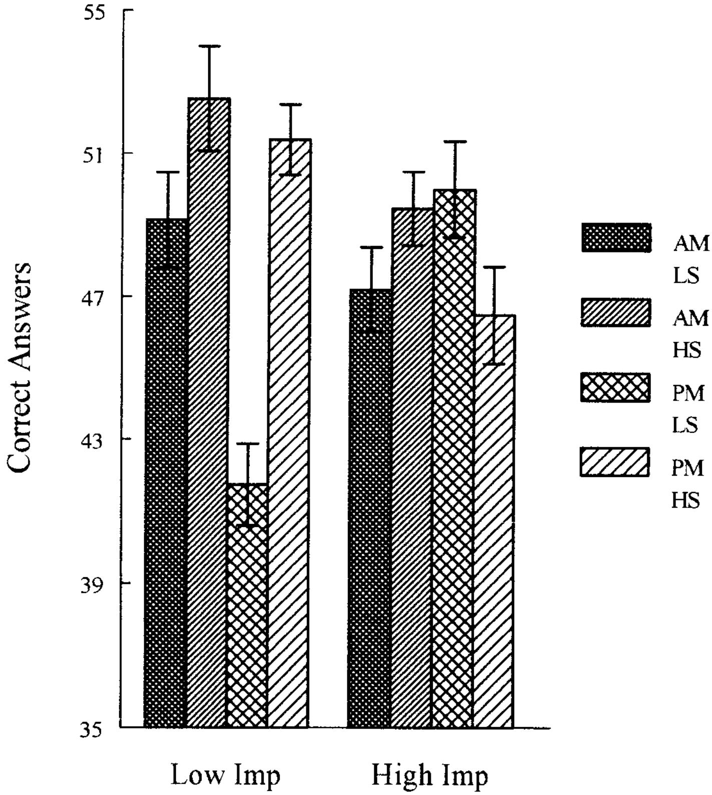

FIG. 1. Mean number of correct answers on Hundal's test (error bars: ±1 *SEM*) for Low and High Imp groups tested under low stress (LS) and high stress (HS) conditions either in the morning (AM) or in the evening (PM).

*MS*e = 40.70, $p < .01$. Consistent with Revelle *et al.* (1980), performance was improved by high stress in the morning, but impaired by it in the evening, indicating that the Imp+ group tested in the morning was less aroused than the Imp+ group tested in the evening. High stress seemed to serve to push arousal towards a more optimal level in the morning, but in the evening, it seemed to push arousal beyond its optimal point.

Raven's Test

The ANOVA results for correct answers are shown in Table 3.

The Imp effect revealed that the Imp+ group (32.83, ± .63) outperformed the Imp− group (30.72, ± 48).

The Imp × Time effect showed that the Imp− group tested in the morning (31.26, ± .66) did better than the Imp− group tested in the evening (30.18, ± .69); but the Imp+ group tested in the evening (33.89, ± .90) did better

TABLE 3
ANOVA Summary Table Showing Effects of Impulsivity, Time of Day, and Stress on Correct Answers on Raven's Test

Source	DF	MS	*F*	Sig of *F*
		Between-subjects effects		
Within Cells	188	59.82		
Imp	1	425.04	7.11	.008
Time	1	27.09	.45	.502
Imp × Time	1	250.26	4.18	.042
		Within-subjects effects		
Within Cells	188	12.50		
Stress	1	6.00	.48	.489
Imp × Stress	1	51.04	4.08	.045
Time × Stress	1	27.09	2.17	.143
Imp × Time × Stress	1	110.51	8.84	.003

than the Imp+ group tested in the morning (31.75, ± .87). As with Raven's test performance, this effect points to a phase difference in diurnal arousal levels between low and high Imp groups.

The Imp × Stress interaction showed that Imp− *S*s did better under high stress (31.21, ± .76) than under low stress (30.23, ± .75), while Imp+ *S*s did slightly better under low (33.06, ± 1.01) than high (32.58, ± .95) stress. As with Hundal's test performance, this effect indicates that Imp− *S*s were sensitive to stress and responded with robust cognitive performance.

The triple Imp × Time × Stress interaction revealed that, within each Imp group, there was a similar pattern of effects to those already reported for Hundal's test (Fig. 2).

Once again, separate two-way Time × Stress ANOVAs were conducted for Imp− and Imp+ groups.

For the Imp− group, Stress, $F(1, 94) = 4.43$, $MSe = 10.39$, $p < .05$, was significant, showing that performance was better under high stress. The Time × Stress interaction was not significant, $F(1, 94) = 1.36$, $MSe = 10.39$, $p > .05$, showing that time of day did not modify the beneficial effects of high stress for Imp− *S*s.

For the Imp+ group, Time × Stress was significant, $F(1, 94) = 8.45$, $MSe = 14.61$, $p < .01$. Again consistent with Revelle *et al.*'s findings (1980), performance was improved by high stress in the morning, but impaired by it in the evening, indicating that the Imp+ group tested in the morning was less aroused than the Imp+ group tested in the evening.[2]

[2] We also repeated the major analyses using commission errors as the dependent variable. For both tests, Imp+ *S*s were error prone, and high stress led to an increase in errors. For Raven's test only, the Imp × Stress interaction showed that Imp+ *S*s were more error prone under low stress; under high stress all *S*s were relatively error prone. We did not find the

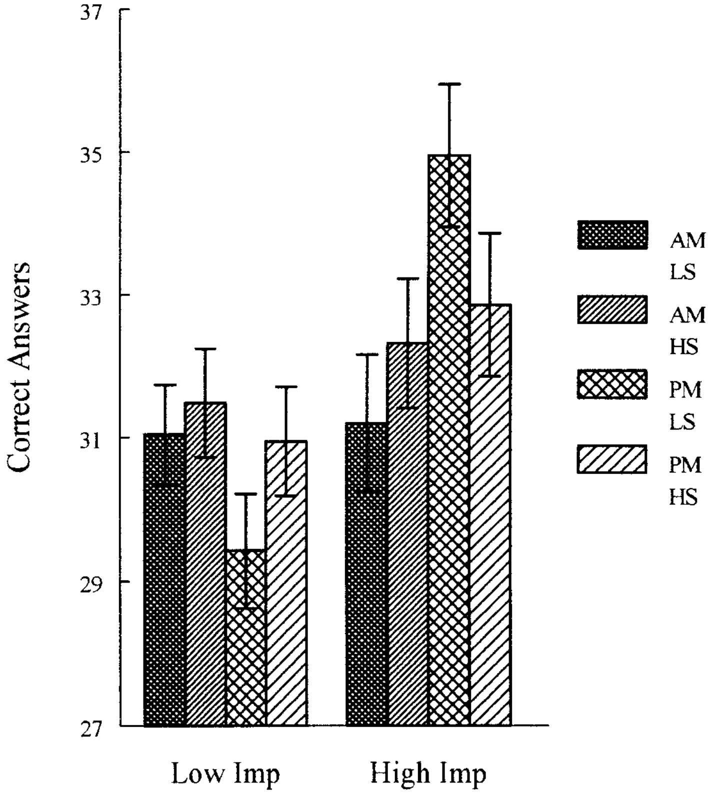

FIG. 2. Mean number of correct answers on Raven's test (error bars: ±1 *SEM*) for Low and High Imp groups tested under low stress (LS) and high stress (HS) conditions either in the morning (AM) or in the evening (PM).

DISCUSSION

We examined whether the pattern of Imp × time of day × arousal effects found with caffeine (Revelle *et al.*, 1980) would also be found with time pressure stress. We found significant interactions of Imp × time of day × stress on both measures of intelligence test performance, indicating that time of day effects are important in stress × impulsivity effects. We also found evidence of increased cognitve *effort* in low impulsivity *S*s, suggesting that,

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triple interactions observed for correct answers on either tests' error rates, which suggests that high impulsive *S*s' quick (and therefore inaccurate) response bias cannot account for the results obtained for total correct answers. Covariate analysis of errors also failed to change the triple interaction for correct answers.

unlike caffeine, stress manipulations may have two separate motivational influences, the first on automatic arousal, the second on controlled effortful processing.

The stress × time of day effects for highly impulsive *S*s were similar to the caffeine × time of day effects reported by Revelle *et al.* (1980), as were the time of day effects seen under low stress for low impulsivity *S*s. These effects are consistent with an interpretation in terms of diurnal arousal phase differences. However, under high stress, time of day effects were abolished for low impulsivity *S*s.

The effects of low impulsivity under high stress could be accommodated within an arousal-based interpretation if it were assumed that low impulsivity *S*s under low stress in the morning were in a state of under-arousal, and high stress pushed their arousal level towards a more optimal point on the arousal-performance curve (Figs 1 & 2). However, assuming this to be true, it is perhaps surprising that the high impulsivity group tested in the morning did not show a stronger reaction to high stress than the low impulsivity group by virtue of relative under-arousal. However, further work would be required to eliminate completely an arousal-based explanation of the reaction of low impulsivity *S*s under high stress.

It is possible that high stress in low impulsivity *S*s led to greater cognitive effort and thus a high level of performance which was unaffected by arousal-related time of day effects. But why should low impulsivity *S*s respond to stress with increased effort? Previous work has shown that low impulsivity is associated with responses to aversive stimulation (Corr, Pickering & Gray, 1995b), suggesting two possibilities: either low impulsivity is related to *sensitivity* to aversive stimuli, or high impulsivity is related to *insensitivity* to aversive stimuli (for a discussion of these issues, see Corr et al., 1995b).

There is evidence that reactivity to aversive stimuli produces a shift from automatic to controlled processing (Pickering, 1997), leading to enhanced information processing of novel features in the environment (Gray, 1987). Therefore, one sensible interpretation of these data is that the effects observed for low impulsivity *S*s under stress reflected a shift from automatic arousal processing to effortful controlled processing as a consequence of reactivity to the aversiveness of the high stress manipulation. It would be interesting to know whether similar effects would be found for the sociability component of extraversion (for a discussion of the sociability/impulsivity debate, see Corr & Kumari, 1997; Corr, Pickering, & Gray, 1995a).

A theoretical account of the different effects of arousal and effort on cognitive performance is provided by Humphreys and Revelle (1984). According to their model, increasing levels of general arousal impair short term memory (STM) (but facilitate sustained information transfer; e.g., performance on simple reaction time tasks); in contrast, effort improves STM performance, and can override the debilitating effects of arousal. Assuming that both Hundal's and Raven's intelligence tests make demands upon STM resources, then the pattern of effects found in our study can be understood. The reason for enhanced performance of Imp− *S*s under stress might have been the result of stress-induced effort which improved STM performance. The effects seen under low stress are consistent with a general arousal process which, at high levels, impairs STM performance.

An important caveat to the conclusions reached in this article concerns the effectiveness of the stress manipulation. Was the time pressure stress manipulation de facto stressful? Apart from the expected triple interaction effects, suggesting that time pressure stress did indeed serve the purpose for which it was designed, stress also increased correct answers on Hundal's tests, and on both tests led to more commission errors. Such data lends itself to the conclusion that stress served to motivate performance.

Several aspects of the experiment need scrutiny. Firstly, *S*s were retested on Hundal's and Raven's tests, although they were not told this prior to the second testing session and they did not receive feedback on their performance in the first testing session. The possibility that retesting might have led to better performance on the second occasion, cannot be discounted. However, the manner in which such an effect could have influenced the observed triple interactions effects is not clear.

Secondly, the possibility that prior consumption of caffeine might have interacted with personality effects on stress reactions 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. This low level of caffeine may be seen to strengthen the case for the conclusion that low impulsivity *S*s in the morning may have been below their optimal point of arousal and for this reason showed enhanced performance under arousal-inducing stress.

Thirdly, the study was limited to females, therefore the results need replication on a male sample. However, there is little a priori reason to think that males and females react to stress in fundamentally different ways.

In conclusion, the results indicate that stress effects are similar to caffeine effects in their interaction with impulsivity and time of day. In addition, these interactions affect different, and uncorrelated, measures of intelligence test performance in highly similar ways. Our data also raise the possibility that in individuals sensitive to aversive stimulation, stress serves to produce a shift from automatic to controlled processes, leading to enhanced effort and improved cognitive performance.

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