Psychophysiological correlates of task performance

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Thirty male volunteers were subjected to computerized visual vigilance task (VVT) and spatial orientation task (SOT) for 35 min, and stress appraisal by urine analysis for epinephrine (E), norepinephrine (NE), vinylmandelic acid (VMA), methoxy hydroxy phenyl glycol (MHPG) and hydroxy tryptamine (5-HT) was studied against personality factors (16PF) and state and trait anxiety index (STAI). High SOT scorers had significantly low resting E and high NE/E ratio, and showed significant rise in E after task and also a higher rise in VMA and MHRG. High VVT scorers showed significant rise in NE, NE/E and NE/5-HT ratio. Though the 16PF and STAI scores had poor correlation with VVT and SOT scores, some of the 16PF factors and STAI scores correlated significantly with resting and post-task levels of E, VMA, MPHG, and NE/E and NE/5-HT ratios. This study indicates that emotional stability, intelligence and alertness relate to better performance on computerized mental tasks of VVT and SOT.

Keywords: Vigilance task; Orientation task; Catecholamine.

Quantification of physiological processes in psychological research is a complex problem. It is now considered that most satisfactory studies on stress are those which consider psychological and physiological aspects together since they complement each other and extra information is provided by the study of relationships between them.

The psychological response to stress is accompanied by other physiological changes. The physiological response appears to be dominated by activity in the autonomic nervous system and in the endocrine system. The changes appear to be integrated, and in some situations have an obvious relationship with behavioural response.

The present study was designed to establish psychophysiological correlates of task performance. In view of the above, a combination of psychological tests consisting of visual vigilance task (VVT) and spatial orientation test (SOT), which measure vigilance and spatial orientation capability and are considered as job-specific performance tests, were administered to assess the performance capability on these tasks in relation to personality attributes and urinary stress variables with a view to establish:

(a) The interrelationship between urinary stress variables and personality attributes.

(b) The effect of performing a definite task on neuronedocrine response.

(c) The effect of currently used stress indices, namely, 3-methoxy-4-hydroxyphenylglycol (MHPG) and norepinephrine (NE)/5-hydroxytryptamine (5-HT) ratio, on psychological tests and their validity.

Material and methods

Thirty healthy male volunteers participated in this study. They were fully apprised of the protocol and served voluntarily for the duration of these experiments. Psychological evaluation of the subjects was done at two levels.

(a) *Personality evaluation.* The personality was evaluated on 16PF test, which is a multidimensional set of 16 questionnaire scales arranged in an omnibus form [1]. It is comprehensive in coverage and gives information regarding a man's standing on 16 primary and 4 second-order factors.

The subjects were also given a self-evaluation questionnaire consisting of two sets of 20 questions each to evaluate the present level of anxiety (state) and the general level of anxiety of the individual (trait) [2]. Depending upon the answers two scores were calculated, one for 'state' anxiety and other for 'trait'

anxiety. From these the percentage scores were read off from the tables. Any score of 70 and above indicates a high level of anxiety.

(b) *Psychological task performance*. The subjects' task performance was assessed on a computerized test consisting a combination of VVT and SOT [3, 4]. All the subjects were given trial runs until they were fully familarized with the test procedure. Together, both the tasks required less than 40 min for completion. As the emphasis was on performance rather than on learning, every effort was made to ensure the subjects' understanding of the task before testing began.

Immediately prior to the collection of resting and experimental urine sample, each subject emptied his bladder and was encouraged to drink about 250 ml of water. The resting urine sample was obtained before starting the psychological tests and the experimental urine samples after the completion of the psychological tests. The exact length of time for each collection period was noted and the urine volume measured.

For determining urinary stress variables, about 100 ml urine was adjusted to pH 3 with HCl and refrigerated. The urine sample was analysed for epinephrine (E), norepinephrine (NE), 3-methoxy-4-hydroxyvinylmandelic acid (VMA), MHPG and 5-HT by standard techniques [5, 6]. The concentration of each analyte was multiplied by volume, divided by time and expressed as excretion rate either in ng/min or µg/min.

Pearson's product moment 'correlation coefficient test' was employed to establish:

(a) Correlation between 16PF/STAI scores and urinary stress variables.

(b) Correlation between 16PF/STAI scores and scores on VVT and SOT.

(c) Correlation between urinary stress variables and scores on VVT and SOT.

Student's '*t*' test was employed to analyse the differences in 16PF/STAI scores and urinary stress variables for high and low scorers on VVT and SOT.

Results

The average scores for all the subjects on 16PF/STAI were within the normal limits (Table 1). The mean performance scores on VVT and SOT were 215 + 96 and 30 + 9, respectively. The mean scores in factor B were significantly lower for low scorers on SOT. However, differences for the rest of the scores on 16PF and on STAI for low and high scorers on SOT and VVT were not significant (Tables 2 and 3). The performance scores on SOT showed a nearly significant positive correlation with factor C, while correlation observed for the rest of the scores on 16PF/STAI with performance scores on SOT/VVT was not significant (Table 4). After psychological task, urinary levels of VMA, MHPG and 5-HT showed a significant increase while the rest of the changes were not significant (Table 5). High scorers on SOT had a significantly lower resting level for E, higher NE/E ratio and post-task performance exhibited a higher percentage rise for E, VMA and MHPG than the low scorers (Table 6). The post-task changes in NE, post-task values for NE/E ratio, Δ values for NE/E and NE/5-HT ratio were significantly higher for high scorers on VVT (Table 7).

The resting E showed a significant positive correlation with factor I, STAI score and a significantly negative correlation with factor C. A nearly significant positive correlation with factor Q_4 was also observed. The resting NE showed a nearly significant positive correlation with factors O, I and a nearly significant negative correlation with factors III and C. The resting NE/E ratio showed a significant negative correlation with factor Q_4, STAI scores and a nearly significant negative correlation with factor C. The resting VMA showed a significant negative correlation with factor C. The resting MHPG showed a nearly significant negative correlation with factors B, O and III and a nearly significant positive correlation with factor Q_4 and STAI scores.

The resting NE/5-HT ratio showed a nearly significant positive correlation with factors Q

Table 1. Test scores on 16PF and STAI (mean ± SD, $n = 30$)

16PF test scores			STAI scores	
Primary		Secondary	State	Trait
B 5.45 ± 1.72	I	5.70 ± 1.5	33.14 ± 22.1	45.1 ± 24.4
C 6.21 ± 2.02	II	5.20 ± 1.7		
O 5.97 ± 1.82	III	5.71 ± 1.4		
Q 6.10 ± 1.82	IV	5.53 ± 1.5		

Table 2. Scores on 16PF and STAI for high and low scorers on SOT

	High scorers	Low scorers	A	P
Scorers on SOT	39.6 ± 5.16	23.5 ± 3.5	16.1	< 0.001
16PF				
Primary				
B	6.33 ± 1.56	4.82 ± 1.59	− 1.51	< 0.02
C	6.75 ± 1.42	5.82 ± 2.32	− 0.93	NS
O	5.50 ± 1.73	6.29 ± 1.86	0.79	NS
Q_4	5.50 ± 2.11	6.52 ± 1.50	1.02	NS
Secondary				
I	5.53 ± 1.51	5.23 ± 1.75	− 0.1	NS
II	5.08 ± 1.73	5.29 ± 1.80	0.21	NS
III	6.12 ± 1.37	5.41 ± 1.41	− 0.71	NS
IV	5.48 ± 1.42	5.56 ± 1.60	0.08	NS
STAI				
State	27.46 ± 20.48	37.75 ± 22.95	10.29	NS
Trait	41.69 ± 22.75	48.83 ± 26.08	7.14	NS

Table 3. Scores on 16PF and STAI for high and low scorers on VVI

	High scorers	Low scorers	A	P
Scorers on VVI	288 ± 41	133 ± 72	154	< 0.001
16PF				
Primary				
B	5.69 ± 1.81	5.15 ± 1.62	− 0.54	NS
C	6.50 ± 2.13	5.85 ± 1.91	− 0.65	NS
O	5.44 ± 2.06	6.62 ± 1.26	1.18	NS
Q_4	5.56 ± 1.82	6.77 ± 1.64	1.21	NS
Secondary				
I	5.39 ± 1.62	6.08 ± 1.36	0.69	NS
II	5.24 ± 1.91	5.15 ± 1.59	− 0.09	NS
III	6.08 ± 1.11	5.25 ± 1.24	− 0.83	NS
IV	5.92 ± 1.25	5.05 ± 1.69	− 0.87	NS
STAI				
State	29.7 ± 23.8	37.4 ± 19.9	7.70	NS
Trait	45.5 ± 21.5	45.3 ± 28.6	− 0.19	NS

Table 4. Correlation coefficient (r) between scores on 16PF/STAI with scores on SOT/VVT

	VVT		SOT	
	r	P	r	P
16PF				
B	0.292	NS	0.28	NS
C	0.107	NS	0.32	NS
O	0.077	NS	−0.137	NS
Q_4	0.299	NS	−0.26	NS
I	−0.01	NS	−0.199	NS
II	−0.257	NS	−0.144	NS
III	0.068	NS	0.076	NS
IV	0.057	NS	0.072	NS
STAI				
State	−0.136	NS	−0.297	NS
Trait	0.056	NS	−0.245	NS

Table 5. Urinary biochemical stress variables before and after task performance

	E (ng/min)	NE (ng/min)	NE/E (ratio)	VMA (μg/min)	MHPG (μg/min)	5HT (μg/min)	NE/5HT (ratio)
Resting	30.85 ± 2.82	54.66 ± 5.31	2.05 ± 0.25	2.47 ± 0.22	0.60 ± 0.84	128.5 ± 17.2	0.68 ± 0.13
Post-task	31.88 ± 2.90	61.62 ± 7.08	2.27 ± 0.29	4.02 ± 0.47	1.07 ± 0.15	214.7 ± 29.2	0.51 ± 0.12
Δ	1.03 ± 3.52	6.95 ± 7.38	0.22 ± 0.29	1.55 ± 0.43	0.47 ± 0.11	86.2 ± 21.7	−0.17 ± 0.14
P	NS	NS	NS	< 0.001	< 0.001	< 0.001	NS
Change (%)	28.7 ± 17.2	43.5 ± 20.5	—	91.65 ± 28.1	114.7 ± 28.1	111.6 ± 35.8	—
P	NS	NS	—	< 0.001	< 0.001	< 0.001	—

Table 6. Comparison of urinary stress variables for low and high scorers on VVT

	Low scorers	High scorers	P
Δ NE	−9.8 ± 10.7	21.45 ± 8.8	< 0.05
Post-tast (NE/E ratio)	1.53 ± 0.30	2.92 ± 0.43	< 0.02
Δ NE/E ratio	−0.43 ± 0.38	0.79 ± 0.39	< 0.05
Δ NE/5-HT ratio	−0.45 ± 0.06	0.08 ± 0.13	< 0.05

Table 7. Comparison of urinary stress variables for low and high scorers on SOT

	Low scorers	High scorers	P
Resting E	36.27 ± 3.24	23.45 ± 4.24	< 0.05
Δ E	−5.00 ± 3.49	10.74 ± 6.14	< 0.05
Change (%) in E	−7.9 ± 11.8	77.6 ± 32.6	< 0.05
Resting NE/E ratio	1.59 ± 0.20	2.68 ± 0.49	< 0.05
Change in VMA	44.4 ± 19.7	154.7 ± 56.6	< 0.05
Change in MHPG	57.9 ± 18.7	190.3 ± 53.5	< 0.02

Table 8. Correlation between the resting urinary stress variables and scores on selected variables on 16PF/STAI

	E	NE	NE/E	VMA	MHPG	NE/5-HT
16PF						
B	−0.19	0.07	0.17	−0.19	−0.30	0.14
C	0.54	−0.21	0.27	−0.36	0.13	−0.11
O	0.03	0.23	0.2	−0.17	−0.31	0.11
Q_4	0.30	0.03	−0.35	0.01	0.22	0.27
I	0.42	0.24	0.25	−0.02	0.02	0.31
II	−0.13	0.08	0.09	0.01	−0.09	0.14
III	0.31	−0.24	−0.03	0.22	−0.29	−0.26
STAI						
State	0.50	0.08	−0.36	−0.10	0.20	0.23
Trait	0.59	0.10	−0.35	0.19	0.31	0.22

Table 9. Correlation between post-task values of urinary stress values and scores on selected variables on 16PF/STAI

	E (% change)	NE (% change)	NE/E	VMA (% change)	MHPG (% change)	5-HT
16PF						
B	0.37	0.05	−0.40	0.23	0.05	−0.28
C	0.13	0.15	0.12	0.14	0.27	−0.11
O	0.03	0.36	−0.15	0.17	0.01	−0.08
Q_4	0.34	−0.08	0.08	0.21	−0.43	−0.28
I	−0.39	0.21	−0.2	0.18	−0.29	−0.14
III	0.22	0.23	0.24	0.08	0.16	0.30
STAI						
State	−0.20	0.01	0.10	0.22	0.0	−0.19
Trait	0.17	−0.01	0.03	0.16	−0.13	−0.22

Table 10. Correlation between resting urinary stress variables and scores on VVT and SOT

	Biochemical variables					
Scores	E	NE	NE/E	VMA	MHPG	NE/5-HT
VVT	−0.17	−0.11	0.10	−0.12	0.02	0.09
SOT	−0.37	0.19	0.62	−0.22	−0.15	0.12

and I and STAI scores and a nearly significant negative correlation with factor II (Table 8).

Post-task E (percentage change) showed a significant positive correlation with factor B and a significant negative correlation with factors Q_4 and I. Post-task NE (percentage change) showed a significant negative correlation with factor O and a nearly significant positive correlation with factor III. Urinary NE/E ratio showed a significant negative correlation with factor B and a nearly significant positive correlation with factor III. Post-task VMA (percentage change) showed a nearly significant positive correlation with factors B and Q_4 and STAI scores. Post-task MHPG (percentage) showed a nearly significant positive correlation with factor C and a significant positive correlation with Q_4. A nearly significant negative correlation was also seen with factor III. Post-task NE/5-HT ratio (change) showed a nearly significant negative correlation with scores on factors B and Q_4 and STAI, and a nearly significant positive correlation with factor III (Table 9).

Table 11. Correlation between resting urinary stress variables and scores on VVT and SOT

	Biochemical variables					
Scores	E (% change)	NE (% change)	NE/E	VMA (% change)	MHPG (% change)	NE/5-HT
VVT	0.03	0.33* *(Δ NE = 0.47)	0.40	0.006	0.09	0.32
SOT	0.35* *(Δ E = 0.29)	0.04	0.28	0.23	0.40	0.02

The resting levels of E and NE/E ratio showed a significant negative and positive correlation, respectively, with scores on SOT (Table 10). Changes in NE (%), Δ values for NE and NE/E and NE/5-HT ratios showed a significant positive correlation with scores on VVT. On the other hand, percentage change in E and MHPG showed a significant positive correlation with scores on SOT. Scores on SOT also showed a nearly significant positive correlation with percentage change in VMA and a nearly significant negative correlation with Δ values for NE/E ratio (Table 11).

Discussion

Selection and classification procedures for both training and job placement have relied heavily on personality variables and a variety of psychological tests. It is quite evident that personality variables such as emotional–motivational–alertness, stability–neuroticism and extroversion–introversion influence performance as does the intelligence, the mainstay of traditional selection techniques [7]. In addition, ability and willingness to maintain vigilance for a specified period of work schedule also affects an individual's ability to perform under trying and stressful situations [7]. In this study these personality variables were considered for segregating subjects in relation to their performance scores on VVT and SOT. The results demonstrated that these personality dimensions did not have any significant influence except for intelligence score, which did have a significant effect with subjects displaying improved performance capability on SOT. However, even these observations were not substantiated by our correlation analysis.

Evidence is accumulating that these personality attributes also correlate with physiological variables that reflect activation levels [7–11]. The battery of urinary stress variables used in the present study was considered appropriate for assessing psychogenic stress since it has been used successfully in a series of flight and laboratory studies [7, 9–26].

It has been demonstrated that E increases during emotional arousal and correlates with feelings of anxiety and apprehension, whereas NE increment reflects the activity of sympathetic nerves and shows elevation in association with attentiveness, aggression and task-oriented responses [13–16, 20, 21]. In our studies, we observed significantly higher resting levels of E in anxious and tense individuals than in emotionally stable and alert individuals. The observation of a significant positive correlation for the resting urinary E levels with various anxiety factors and a significant negative correlation with factors such as emotional stability and alertness suggests that anxiety is associated with adrenomedullary hyperactivity while emotional stability and alertness lead to reduced responsiveness. A mild degree of hyperactivity in sympathetic nervous system was also observed in anxious subjects but the difference from emotionally stable/alert individuals and correlation with various personality factors were not significant, thus confirming a lower threshold for E release than for NE in emotional state.

According to Krahenbuhl *et al.* [20], NE/E ratio approaching a value of unity indicates incapacitating psychological stress. We observed

a significantly lower resting NE/E ratio in anxious/tense individuals than in emotionally stable/alert individuals. The observation of significant negative correlation between resting NE/E ratio with various measures of anxiety score and a nearly significant positive correlation with emotional stability factor suggests that NE/E ratio is useful for evaluating and differentiating the anxiety and emotional stability of an individual.

It has been demonstrated that subjects with high anxiety exhibit higher excretion rate for VMA [24]. In this study basal excretion levels for VMA did not exhibit a direct relationship with various anxiety factors but were significantly lower in emotionally stable subjects and can be used for segregating anxious and emotionally stable subjects.

Gitlow *et al.* [27] reported that 20–35% of MHPG excreted in the urine arose from cerebral CA metabolism and the changing levels in urine reflected the changing levels of brain activity [7, 10, 22]. We observed a significantly lower basal excretion rate for MHPG in intelligent, alert/poise individuals than in tense/anxious subjects. Low excretion rates for MHPG indicate relatively slow release of central NE whereas high excretion rates suggest relatively high rates of NE utilization.

An increase in the activity of serotogenic pathway produces changes which are indicative of lowered mental alertness while an increase in the activity of noradrenergic pathway results in a pattern of electrical activity which is characteristic of arousing stimuli [28]. Since both these pathways act in a mutually antagonistic fashion, the dominance of one activity over the other might be better reflected in NE/5-HT ratio [28]. The observed positive correlation between resting NE/5-HT ratio and the various anxiety factors suggested that anxious subjects are in a state of heightened arousal while a negative correlation with alertness score indicated a relaxed status for alert/poise individuals.

There is substantial and increasing evidence to suggest that significant variation in the basal excretion levels of these stress variables is associated with physiological disturbances that may lead to deteriorated performance efficiency. We did not observe any significant differences in the resting levels of these urinary stress variables in subjects with high and low scores on VVT. However, high scorers on SOT had a lower resting E and higher NE/E ratio than the low scorers. The resting urinary E showed a significant negative correlation and NE/E ratio showed a significant positive correlation with scores on SOT, suggesting that emotionally stable subjects with lower anxiety score perform better on SOT. These findings are consistent with the data which have provided evidence that subjects whose CA levels rapidly return to baseline are psychologically better adjusted than those whose levels return to baseline slowly [14]. A similar trend of lower basal excretion rate for VMA and MHPG was also observed in emotionally stable, intelligent and alert individuals than in subjects with high STAI scores. Also high SOT scorers had lower basal excretion rates for VMA and MHPG than low scorers but were not corroborated by correlation analysis.

We observed a significant positive correlation between changes in E excretion rate and intelligence and alertness levels of the subjects, but a significant negative correlation with the anxiety score of the subjects. These observations when viewed together suggest that intelligent, alert/poise and emotionally stable subjects perform better on SOT than subjects with high anxiety scores.

NE, which provides evidence of work-associated hyperactivity of sympathetic nervous system, showed significant inter-group variability. High scorers on VVT showed hyperactivity of sympathetic nervous system. In these subjects changes in sympathoadrenal activity after the task were not significant, indicating that unlike SOT, VVT is not psychologically stressful. We found a significant positive correlation of changes in NE excretion rate with scores on VVT and with the alertness of the subjects,

while a negative correlation was noted with anxiety and apprehensiveness scores. These observations suggest that alert/poise individuals perform better on VVT than anxious/apprehensive subjects.

These two groups of subjects were further differentiated on the basis of their Δ values for NE/E ratio, which showed a reduction in high scorers on SOT – reflecting the stimulation of adrenomedullary activity – and a significant rise in high scorers on VVT, probably due to stimulation of sympathetic activity. These values showed a significant negative correlation with scores on SOT – suggesting that adequate stimulation of sympathoadrenal activity is absolutely essential for improved performance capability – and with intelligence scores, suggesting that performance on SOT is directly related to sympathoadrenal activity and the intelligence level of the subjects. On the contrary, a significant positive correlation was observed with scores on VVT – suggesting that adequate stimulation of sympathetic activity is a prerequisite for improving performance on VVT – and with alertness level, suggesting that performance on VVT is directly related to sympathetic activity and the alertness level.

It is seen from the above discussion that many of the urinary stress variables employed in this study provide a valid and useful indication of an individual's ability to perform a task requiring sustained vigilance and comprehension of spatial orientation. On the other hand, psychological attributes of the subjects as evaluated by 16PF and STAI inventory did not show any worthwhile association in predicting the levels of performance on these tasks. However, some of the personality variables were found to be significantly correlated with pre-task as well as task-induced changes in urinary stress variables.

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