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16. Abstract

The reductions in task load resulting from the increasing automation of air traffic control may actually increase the requirement for controllers to maintain high levels of sustained attention in order to detect infrequent system malfunctions. A previous study indicated that individuals scoring high on a distractibility scale found it difficult to maintain sustained attention on a monotonous, but perceptually demanding, task. The present study used the same serial reaction task to study other possible personality, as well as physiological, correlates of individual differences in performance decrement under low task-load conditions. Sixty subjects performed the task continuously for 40 minutes. Extraverted subjects showed increasing lapses of attention, while introverted subjects failed to show any evidence of a decline in attention. Of the two extraversion components (impulsivity and sociability), impulsivity was the component responsible for the obtained decrement. Heart-rate variability showed a significant relationship with performance decrement while mean heart rate did not.

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PERSONALITY AND PHYSIOLOGICAL CORRELATES OF PERFORMANCE DECREMENT ON A MONOTONOUS TASK REQUIRING SUSTAINED ATTENTION

I. Introduction.

Projected trends in the automation of air traffic control suggest the possibility that the role of the future radar controller may be more of a system monitor than an active participant in traffic control.[11] This reduction in task load is likely to increase rather than decrease demands upon the controller to maintain sustained attention in order to ensure his readiness to respond to an unexpected system malfunction or emergency situation. Although it is known that some individuals are better able than others to sustain attention under low task-load conditions, reasons for these differences are not fully understood.

In a previous study by Thackray, Jones, and Touchstone,[17] it was found that individuals who rated themselves as highly distractible in their daily lives were unable to sustain attention when required to perform a monotonous serial reaction task demanding continuous attention. In contrast, low distractibility subjects (*S*s) were able to perform the task in a superior manner with no evidence of a decline in attention. The obtained decrement took the form of increasingly variable response times with frequent gaps or pauses which various investigators have hypothesized to be a reflection of declining task attention.[2 10] The high and low distractibility groups did not show differing patterns of decrement in either mean response time or frequency of errors.

The present study was an extension of the previous investigation and was designed to investigate other possible personality, as well as physiological, correlates of individual differences in performance decrement on this task.

Although it is fairly well established that extraversion is related to performance decrement on both vigilance[1 5] and serial reaction tasks,[3 4] a satisfactory explanation of why extraverts do more poorly than introverts on these tasks has not been developed. Using a factor analytic approach, Eysenck and Eysenck[8] have determined that extraversion is not a unitary dimension but rather consists of two main components, sociability and impulsivity. Since there is evidence that impulsivity is related to distractibility,[12] the findings of a relationship between distractibility and performance decrement in the previous study by Thackray, Jones, and Touchstone[17] might suggest impulsivity rather than sociability to be the component of extraversion most directly related to vigilance decrement. The findings of a vigilance study by Krupski, Raskin, and Bakan[14] also suggest this possibility. Impulsivity and sociability subscores of the Eysenck Personality Inventory[9] were obtained and both found to be positively correlated with commission errors. While neither correlation was statistically significant, the higher value was obtained for impulsivity.

On the basis of this previous research, it was hypothesized that extraversion would be positively related to performance decrement on the serial reaction task and that the obtained decrement would be primarily manifested in increased response variability. It was hypothesized further that, of the two extraversion components (impulsivity and sociability), impulsivity would show the greater relationship with the obtained decrement.

A second aspect of the present study was to evaluate the use of heart-rate variability as a monitor of performance decrement. Evidence from a variety of studies suggests that this measure may be a sensitive physiological index of attention. Relative to resting conditions, heart-rate variability has been shown to decrease markedly when attention is initially directed to task stimuli[12 16 18] or when changes in the direction of increased task load occur.[13] To the extent that attention declines during performance on a monotonous task, this decline should be reflected in increased heart-rate variability

While the previous study by Thackray, Jones, and Touchstone[17] failed to establish a relationship between heart-rate variability and performance decrement, it was felt that the measurement intervals were too few to adequately assess whether or not a relationship existed. In the present study, heart-rate data were continuously recorded and computer processed to provide a more adequate determination of possible relationships. It was hypothesized that heart-rate variability would show a progressive increase during the task session and that this increase would be positively correlated with performance decrement (increased response variability) on the serial reaction task. Since Thackray, Jones, and Touchstone[17] failed to obtain any evidence of a change in mean heart rate during performance on this task, no relationship between mean heart rate and performance decrement was expected.

II. Method.

A. *Subjects.* Sixty paid college men served as *S*s. None had any prior experience with the task used.

B. *Apparatus.* The same serial reaction task employed in the previous study[17] was used in this study. This type of task appears ideal for studying the decrement function since it provides repetitive and monotonous stimulation, demands continuous discrimination, involves only minor physical fatigue, yields essentially continuous measures of response time, provides immediate feedback to the *S*, and gives a measure of errors as well as correct responses.

The *S*'s panel contained four lever-actuated microswitches arranged in a row 1¼ inches apart with a three-fourths inch diameter visual display centrally located over the keys. The visual display presented the numbers 1–4 corresponding to keys 1–4 as numbered from left to right. A tape reader was used to present the numerical stimuli to the *S*. Stimuli consisted of a quasi-random series of numbers with the restrictions that no number occur twice in succession and that each number occur an equal number of times in the series. The series was 300 stimuli in length and repeated itself automatically.

Each time a given number appeared, the *S* attempted to press the corresponding key. If a correct response was made, the tape reader advanced, a new number was presented, and the cycle continued. If an incorrect response was made, the visual stimulus did not change until the correct key was pressed. Elapsed time between responses was measured by means of a Welford Mark V SETAR (Welford Bioelectronics Enterprises) and the data punched on paper tape. Response times were identified as to whether they corresponded to correct or incorrect responses.

Heart rate was obtained from chest electrodes with the leads connected to a Beckman Type R Dynograph. Pulses from a cardiotachometer coupler were used as inputs to the SETAR for recording successive heart beats.

C. *Procedure.* Upon arriving for the experiment, the *S* was administered Form A of the Eysenck Personality Inventory (EPI). To minimize association between the inventory and the experiment, the *S* was not told that the personality scale was relevant to the present experiment, and one experimenter (*E*) administered the inventory while a different *E* conducted the rest of the experiment.

Following completion of the inventory, the *S* was taken to the experimental room, instrumented for physiological recording, and the task instructions presented. Besides explaining the basic procedure, the instructions emphasized that the task should be performed as rapidly as possible but not at the expense of accuracy.

After the task instructions, the *S* was given a one-minute practice trial and then told that he was to work continuously for approximately 50 minutes. To prevent the *S*'s knowing that the task was almost over, the experiment was stopped after 40 rather than 50 minutes. At this time, the *E* went into the experimental room, removed the electrodes, and asked the *S* to complete a post-experimental questionnaire.

D. *Measurement of the Performance and Physiological Data.* The performance data were computer processed and the following obtained for each *S* for each successive four-minute period of the session:

(a) Mean response time
(b) Standard deviation of the response times (response variability)
(c) Number of incorrect responses

For heart rate, a computer program was developed to yield two measures for each successive four-minute period during the performance ses

Table 1

Product-Moment Correlations Between Extraversion, Neuroticism, Impulsivity, and Sociability.

	1 Extraversion	2 Neuroticism	3 Impulsivity	4 Sociability
1		-.33**	.52**	.75**
2			.00	-.40**
3				.03

** $p < .01$

sion. These measures were the mean rate and the standard deviation. Because of occasional muscle potential artifacts and premature contractions, the computer program was designed to reject any apparent heart beat interval which, when converted to a beat-per-minute (bpm) basis, exceeded 160 bpm or fell below 30 bpm. In addition, any two successive heart beats which increased by more than 25 bpm or decreased by more than 46 bpm were also rejected. These limits were empirically determined from preliminary hand-scored analyses and were felt to represent values for this set of experimental conditions which would maximize rejection of artifacts and minimize rejection of "valid" heart-rate data.

III. Results.

A. *Personality Variables.* Mean scores on the EPI were 12.3, 9.4, 4.0, and 5.4 for the extraversion, neuroticism, impulsivity, and sociability scales respectively. Table 1 shows the intercorrelations of these measurements. As expected, extraversion showed a significant, positive correlation with both impulsivity and sociability. The significant negative correlation between extraversion and neuroticism, however, was not expected.

Although negative correlations between extraversion and neuroticism are frequently found, these are generally non-significant.[9] Because a significant relationship was obtained between these two variables in the sample employed, neuroticism was separately examined even though it was not originally intended to do so. (Neuroticism has been frequently examined in vigilance-type studies and has typically shown no relationship to performance decrement.[6]) For each of the four scales, the 15 *S*s with the highest and lowest scores were identified. The high and low cutoff scores for each distribution were as follows: extraversion (15 and 10), neuroticism (12 and 6), impulsivity (5 and 3), and sociability (7 and 4).

Since the neuroticism, extraversion, impulsivity, and sociability subgroups were each drawn from the same sample of 60 *S*s, the total group data for each performance measure were initially plotted in order to provide reference data for the comparison of differential response patterns of the various subgroups. The data for mean response time, response variability, and frequency of errors for the 60 *S*s are shown in Figure 1. Analyses of variance conducted on each set of data yielded significant F-value for the effect of four-minute periods for mean response time ($F=4.16$; $p<.01$), response variability ($F=21.19$; $p<.01$), and frequency of errors ($F=12.79$; $p<.01$). The only variable which did not reveal a progressive increase with time was mean response time. The abrupt increase in response time from period 1 to period 2 was also noted in the previous study[17] and is apparently a characteristic of this task. Scheffe[7] tests revealed that, while the difference between periods 1 and 10 was significant ($F=29.86$; $p<.005$), the difference between periods 2 and 10 was not ($F=4.96$; $p>.05$).

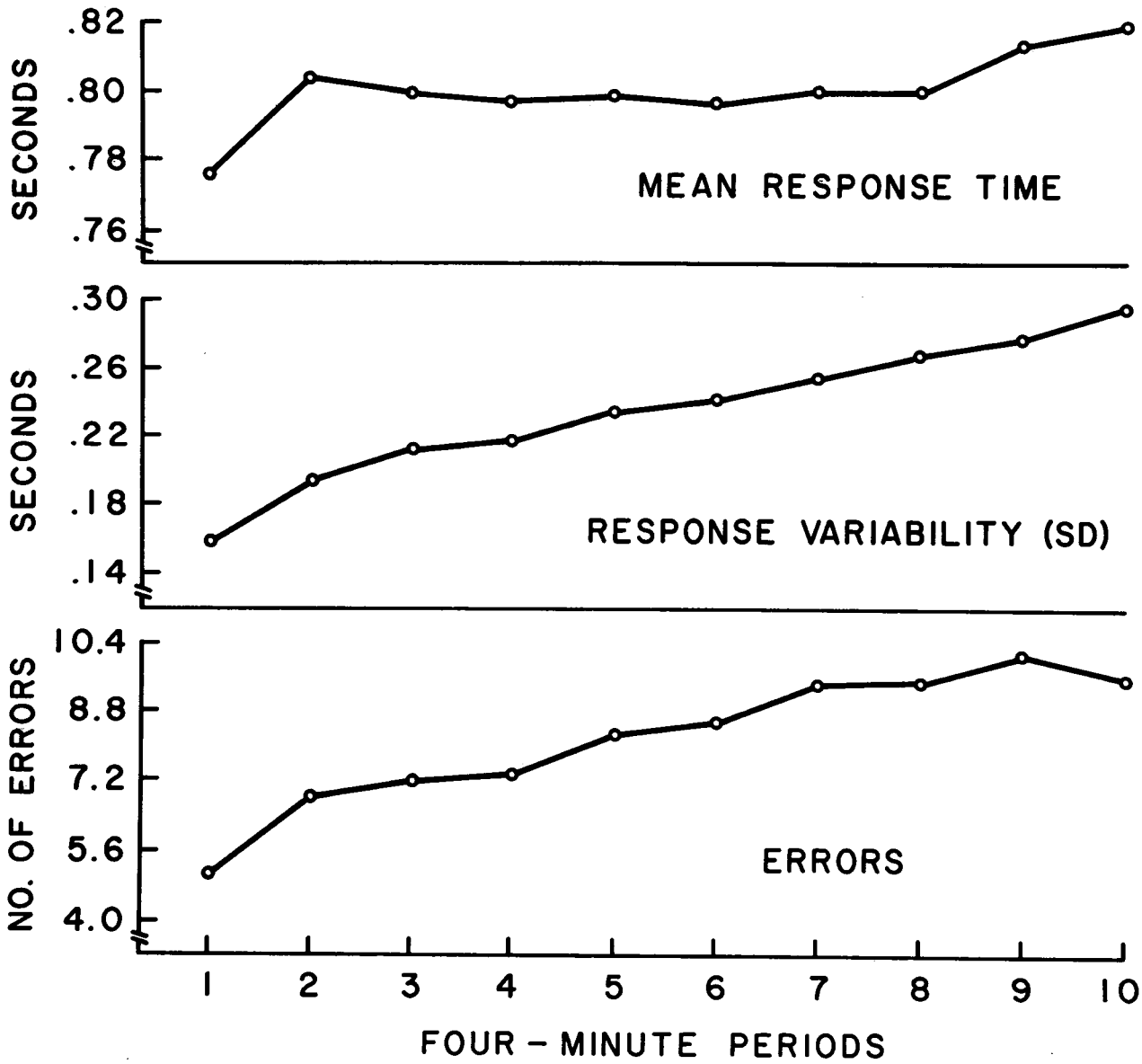

FIGURE 1. Mean response time, response variability (standard deviation), and frequency of errors for each four-minute period of the task session. Data are for the total group of 60 *S*s.

Tables 2, 3, 4, and 5 present the results of analyses of variance conducted on the performance data of each subgroup. Since the between-periods effects were significant in the analyses of variance conducted on the data for all 60 *S*s, it is not surprising that the differences between periods were significant for all variables in each subgroup with the exception of mean response time for extraversion. This F-value approached, but did not reach, significance at the 5 per cent level ($p<.10$). None of the group differences was significant, but significant interactions were obtained between groups and periods for mean response time on the extraversion factor and for response variability on both the extraversion and impulsivity factors. Figure 2, which shows mean response time for the high and low extraversion groups, displays generally increasing response times for the high group, but a mixed pattern for the low group. Tests of simple effects revealed the differences between periods to be significant for both the high ($F=2.82$; $p<.01$) and low ($F=2.00$; $p<.05$) groups. Figure 3 shows the response variability patterns for the high and low extraversion and impulsivity groups. There is a continuous rise in variability among

Table 2

Analyses of Variance of Mean Response Time, Response Variability, and Errors for Extreme Groups on Neuroticism.

Source	db	Mn Response Time		Response Variability		Errors	
		MS	F	MS	F	MS	F
Between Ss	29						
A (Groups)	1	0.2483	2.05	0.0819	1.23	4.8891	0.54
Ss Within Groups	28	0.1211		0.0666		9.0855	
Within Ss	270						
B (Periods)	9	0.0036	2.48*	0.0345	12.74***	4.9179	7.27***
A X B	9	0.0010	0.70	0.0031	1.13	0.5680	0.83
Ss Within Groups	252	0.0015		0.0027		0.6766	

* $p = .05$ ** $p = .01$ *** $p = .001$

Table 3

Analyses of Variance of Mean Response Time,

Response Variability, and Errors for Extreme Groups on Extraversion.

Source	df	Mn Response Time		Response Variability		Errors	
		MS	F	MS	F	MS	F
Between Ss	29						
A (Groups)	1	0.0013	0.01	0.0091	0.07	30.2713	3.62
Ss Within Groups	28	0.1865		0.1219		8.3636	
Within Ss	270						
B (Periods)	9	0.0033	1.80	0.0312	9.68***	6.0700	8.64***
A X B	9	0.0055	3.03**	0.0089	2.77**	0.4281	0.61
Ss Within Groups	252	0.0018		0.0032		0.7026	

* p = .05 ** p = .01 *** p = .001

Table 4

Analyses of Variance of Mean Response Time, Response Variability, and Errors for Extreme Groups on Impulsivity.

Source	df	Mn Response Time		Response Variability		Errors	
		MS	F	MS	F	MS	F
Between Ss	29						
A (Groups)	1	0.0870	0.53	0.0081	0.04	0.7802	0.01
Ss Within Groups	28	0.1630		0.1899		11.9390	
Within Ss	270						
B (Periods)	9	0.0054	2.28*	0.0509	9.51***	6.1654	8.78***
A X B	9	0.0045	1.91	0.0109	2.03*	0.4487	0.64
Ss Within Groups	252	0.0023		0.0054		0.7019	

* p = .05 ** p = .01 *** p = .001

Table 5

Analyses of Variance of Mean Response Time, Response Variability, and Errors for Extreme Groups on Sociability.

Source	db	Mn Response Time		Response Variability		Errors	
		MS	F	MS	F	MS	F
Between Ss	29						
A (Groups)	1	0.0337	0.28	0.0008	0.01	4.1298	0.41
Ss Within Groups	28	0.1185		0.1608		9.9754	
Within Ss	270						
B (Periods)	9	0.0066	3.22**	0.0601	9.43***	4.7696	6.28***
A X B	9	0.0031	1.52	0.0055	0.86	0.6066	0.80
Ss Within Groups	252	0.0020		0.0064		0.7597	

* $p = .05$ ** $p = .01$ *** $p = .001$

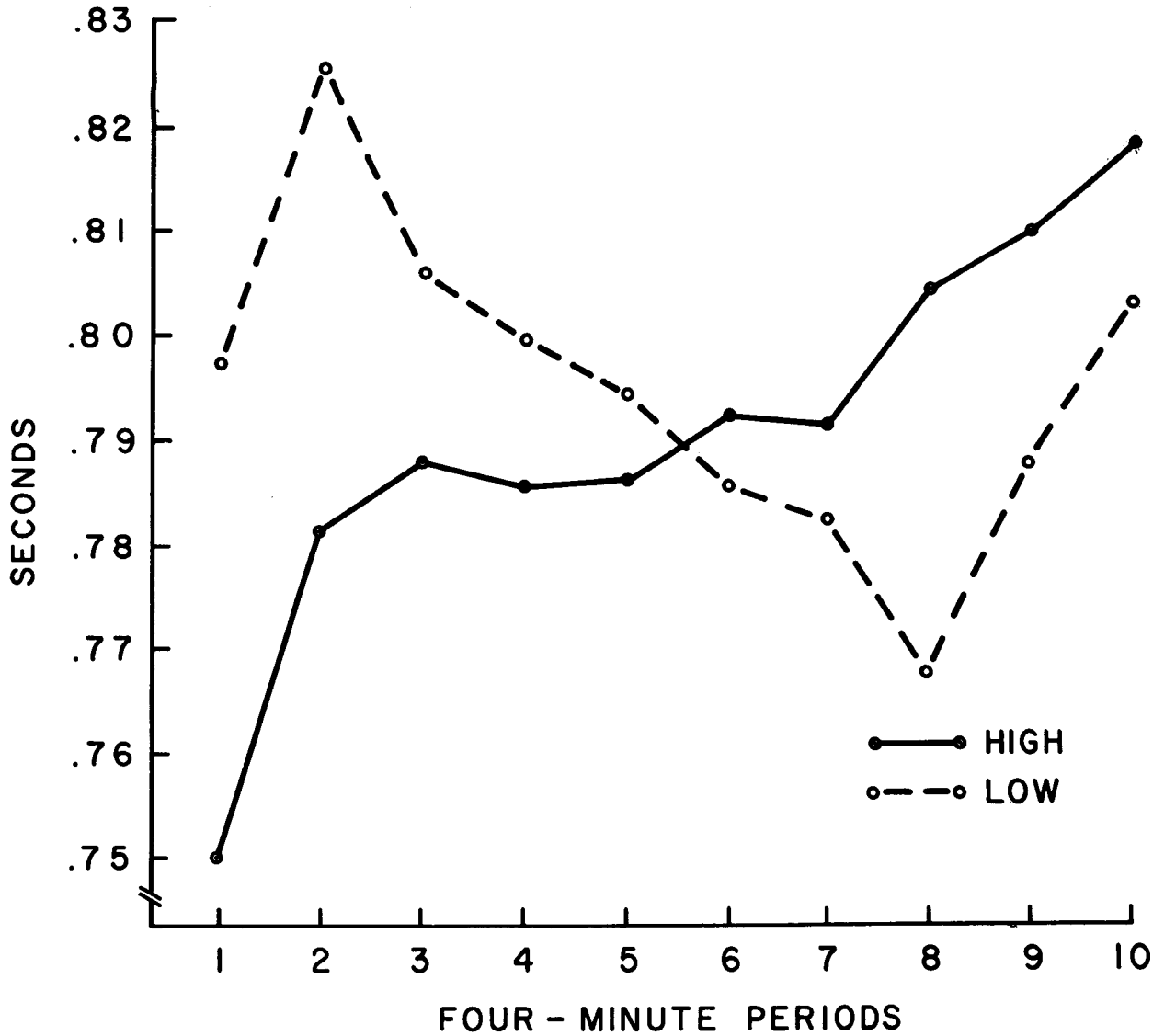

FIGURE 2. Mean response times for the high and low extraversion groups across periods.

the high extraversion and impulsivity *S*s during the experimental sessions with a relatively stable level of response variability among the low *S*s. Tests of simple effects of periods revealed the differences between periods to be significant for the high extraversion ($F=11.03$; $p<.001$) and high impulsivity ($F=9.59$; $p<.001$) groups. There were no differences between periods for either the low extraversion ($F=1.42$; $p>.05$) or low impulsivity ($F=1.74$; $p>.05$) groups.

B. *Heart-Rate Measures.* As expected, heart-rate variability for the entire sample of 60 *S*s showed a progressive, significant increase ($F=20.64$; $p<.001$) during the session. Mean heart rate showed a slight, but significant, decrease ($F=2.54$; $p<.01$). These data are shown in Figure 4. Since the previous study by Thackray, Jones, and Touchstone[17] failed to find any change in mean heart rate, further tests were conducted on mean heart rate. Scheffe tests revealed no difference between periods 1 and 8 ($F=1.53$; $p>.05$) or between periods 1 and 10 ($F=8.57$; $p>.05$). The only significant difference was obtained when the periods with the highest (period 2) and lowest (period 10) heart rates were compared ($F=16.84$; $p=.05$.

The correlations of heart-rate variability and mean heart rate with performance variability are shown in Figure 5).

None of the correlations between performance variability and mean heart rate was significant for any of the periods. Heart-rate variability was not significantly correlated with performance

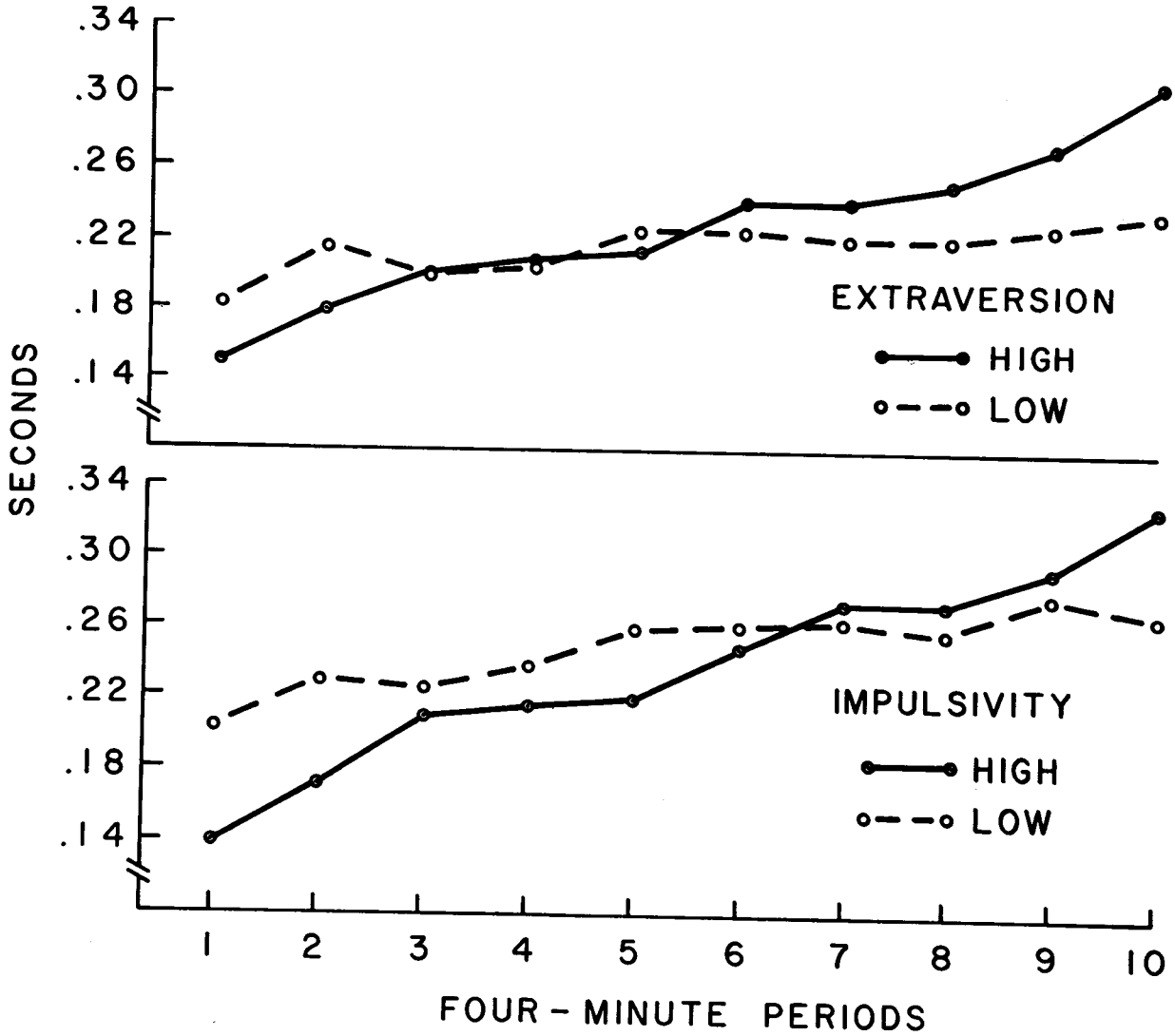

FIGURE 3. Response variability for the high and low extraversion and impulsivity groups across periods.

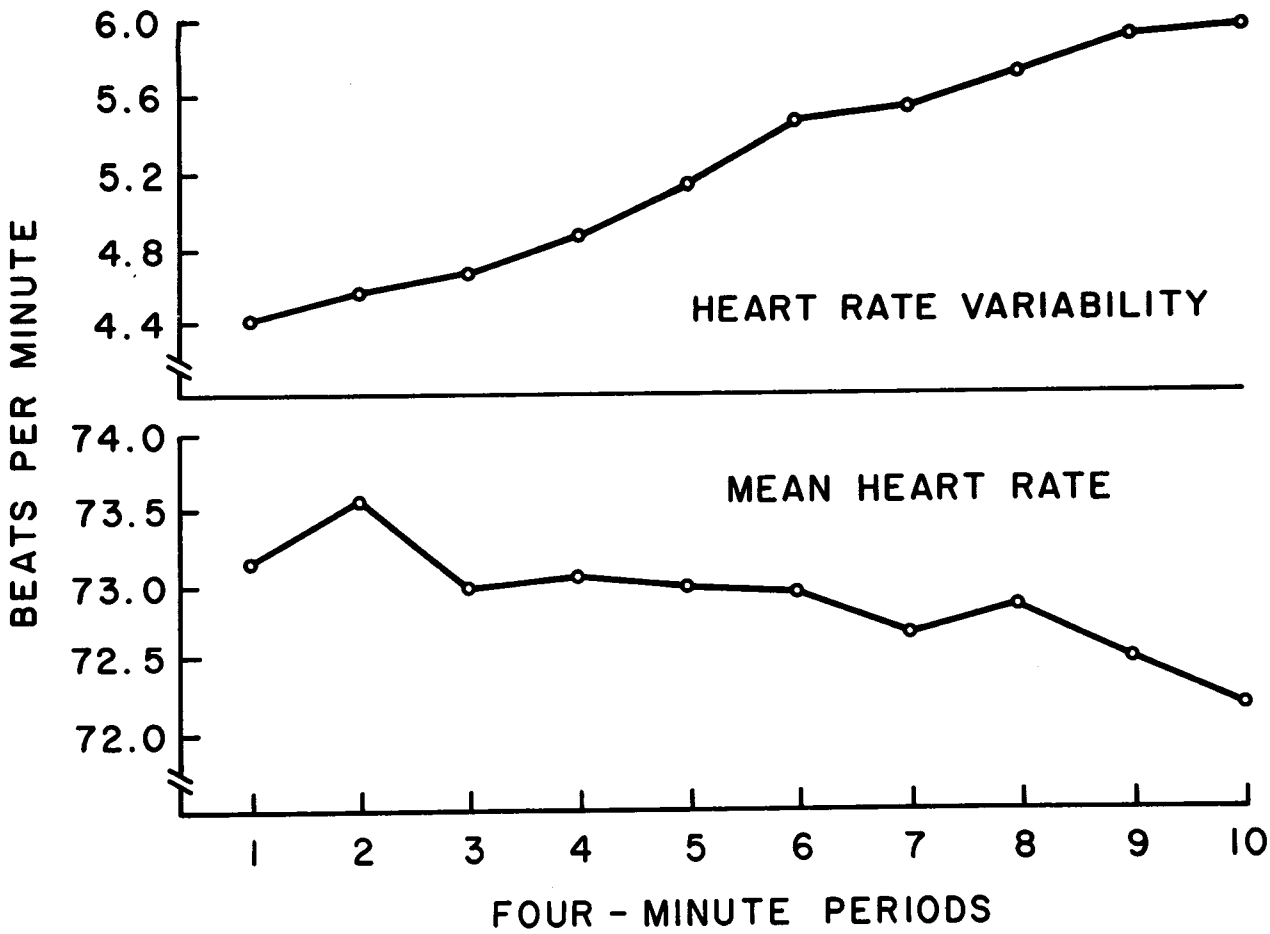

FIGURE 4. Mean heart rate and heart-rate variability (standard deviation) for each of the four-minute periods. Data shown are for all 60 *S*s.

variability during the first three periods, but showed significant and generally increasing correlations during the remaining seven periods.

IV. Discussion.

Increases in response variability on a serial reaction task have been shown to be largely the result of increases in the frequency and duration of gaps or pauses in performance.[17] The present study revealed that *S*s scoring high in extraversion displayed a continuous increase in response variability during the performance session, while *S*s scoring low in extraversion (introverts) maintained a relatively uniform rate of responding. Since extraverts are known to exhibit more frequent pauses or blocks during performance on serial reaction[4] and simple tapping[15] tasks than do introverts, the present results would appear to support these previous findings.

Of greater interest was the predicted finding that impulsivity rather than sociability was the extraversion factor primarily responsible for the obtained decreemnt. Although both impulsivity and sociability were significantly correlated with extraversion, only the high and low impulsivity groups showed response variability patterns which were similar to those of the high and low extraverts. This cannot be attributed simply to a sampling bias in which a greater proportion of impulsivity than sociability *S*s were drawn from the extraversion groups. The proportions were approximately equal with 57 per cent of the high and low impulsivity *S*s and 63 per cent of the high and low sociability *S*s common to the two extraversion groups.

Neither errors nor means response time showed any appreciable relationship with any of the personality variables. The only exception was the

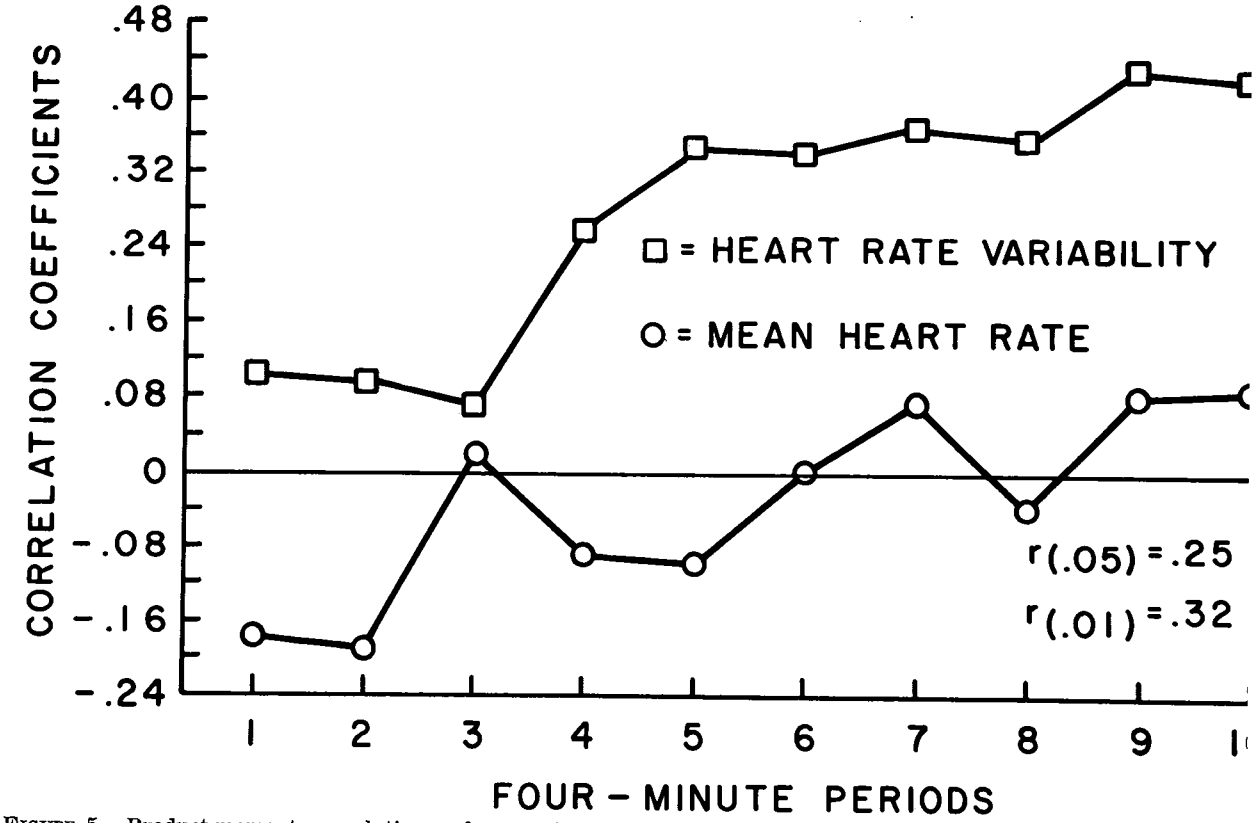

FIGURE 5. Product-moment correlations of mean heart rate and heart-rate variability with performance variability across periods. Data are for all 60 *Ss*.

interaction obtained between extraversion and periods for mean response time. Extraverts showed a continuous increase in response time during the session, while introverts showed a mixed pattern consisting of an initial increase followed by a progressive decrease and a final increase. The meaning of this latter pattern is uncertain, although it reflects the general pattern obtained for the total group of 60 *Ss*. The lack of relationship between frequency of errors and any of the personality variables agrees with the lack of relationship between this measure and susceptibility to distraction obtained in the previous study.[17] Since Corcoran[4] also failed to find a relationship between extraversion-introversion and frequency of errors using a similar task, it would appear that an increase in error frequency during serial reaction performance is either a poor index of declining attention or it reflects attentional processes unrelated to those manifested by increased response variability.

While the negative correlation between extraversion and neuroticism was not anticipated, this small, though significant, correlation does not alter interpretation of the results obtained. First, no relationships were found between neuroticism and any of the performance measures. An second, although impulsivity showed no correl tion with neuroticism, the decrement pattern o tained for impulsivity was essentially the same that obtained for extraversion. Thus, the neg tive correlation is interpreted to reflect a comm factor not related to performance decrement this type of task.

The possible employment of heart-rate vari bility as a useful monitor of declining task atte tion is suggested by the finding of a general increasing correlation between heart-rate vari bility and performance variability during t session. Mean heart rate, on the other han showed no relationship to response variabilit Research currently being planned will exami the utility of employing heart-rate variability a monitor of declining attention during perforn ance of a more complex task involving a lar number of visual inputs with infrequency chan ing critical stimuli.

V. Summary.

The present study revealed that *Ss* scorir highest on an extraversion scale found it difficu to maintain a uniform rate of responding on serial reaction task over a 40-minute period. T

›btained decrement took the form of increasingly 'ariable response times which previous studies ıave suggested is a reflection of declining task ;ttention. Individuals scoring low in extraver-:ion (introverts) showed no evidence of this kind ›f performance decrement. The study further 'evealed that, of the two dimensions of extraver-:ion (impulsivity and sociability), impulsivity vas the component more closely related to the ›btained decrement. Taken together with the indings of a previous study by the same authors, there is evidence of a pattern of tempermental variables including distractibility, extraversion, and impulsivity which describe individuals who find it difficult to maintain sustained attention under monotonous, low task-load conditions.

The study also explored the use of mean heart rate and heart-rate variability as indices of declining attention. As predicted from previous studies, heart-rate variability showed significant relationships with performance variability during the session while mean heart rate did not.

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