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SELF-ESTIMATES OF DISTRACTIBILITY AS RELATED TO PERFORMANCE DECREMENT ON A TASK REQUIRING SUSTAINED ATTENTION

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16. Abstract

Increasing automation of air traffic control tasks may have the undesirable side effect of increased monotony as a result of the anticipated reduction in task demands. While the actual extent of increase in monotony resulting from such automation is not as yet known, it is known that performance during low task-load conditions is accompanied by declining attention. Since individuals who are unable to sustain attention under low task-load conditions would appear to be more likely to commit errors and less able to handle a sudden emergency situation, it would seem desirable to examine the characteristics of individuals unable to sustain attention under these conditions. In the present study, 50 subjects performed a monotonous, but perceptually demanding task, for approximately 30 minutes without rest. It was found that high-distractibility subjects (as determined from a questionnaire administered prior to the experiment) showed increasing lapses of attention during performance, while low-distractibility subjects failed to show any evidence of a decline in attention. Significant changes were obtained for respiration, respiration-period variability, heart-rate variability, and skin conductance during the task period, but the magnitude of these changes did not differ among the two distractibility groups.

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SELF-ESTIMATES OF DISTRACTIBILITY AS RELATED TO PERFORMANCE DECREMENT ON A TASK REQUIRING SUSTAINED ATTENTION

I. Introduction.

It has been suggested that increasing automation of air traffic control tasks may have the undesirable side effect of increased monotony and boredom as a result of the anticipated reduction in task demands.[13] While the actual extent of increase in monotony resulting from such automation is not as yet known, it is known that performance during low task-load conditions (especially if this is prolonged) is accompanied by declining[6 12] or increasingly variable attention.[9 11] Since individuals who are unable to sustain attention under low task-load conditions would appear to be more likely to commit errors and less able to handle a sudden emergency situation, it would seem desirable to examine the characteristics of individuals unable to sustain attention under these conditions.

Laboratory studies of prolonged performance on monotonous tasks commonly reveal a progressive decrement over time. Although this decline has been studied most frequently in vigilance tasks, it is also known to occur in tracking, serial reaction, and a variety of auditory and visual discrimination tasks.[17] The decline is generally exponential in form and usually becomes apparent within a half-hour of work.[8 17] Since all of these tasks demand continuous attention to a relatively monotonous or repetitive situation with minimal muscular requirements, the decrement does not seem to be a simple consequence of response fatigue. Rather, it appears to involve a decline in some central attentional process which in turn is known to promote or induce drowsiness, microsleep episodes, lapses of attention, and certain trance-like (highway-hypnotic) conditions.[19]

Although it is known that some individuals are better able than others to sustain performance under monotonous conditions, the reasons for these individual differences are not completely understood. Attempts to relate these differences to such variables as sex, intelligence, and age have generally been unsuccessful in demonstrating significant relationships.[8 17] Somewhat greater success has been obtained with measures of temperament, e.g., extroversion-introversion. A frequent finding is that extroverts tend to show a progressive decrement with time on task while introverts appear better able to sustain performance at a relatively constant level.[2 7] It should be noted, however, that a number of negative findings have been reported[8 10] and the relationship is further clouded by the fact that, with respect to errors of commission in vigilance performance, introverts sometimes show a greater error frequency than extroverts.[8]

Relatively few studies have examined relationships between cognitive variables and performance decrement on monotonous tasks. Antrobus, Coleman, and Singer[1] hypothesized that individuals who had a high propensity to daydream would become increasingly involved in their own thought processes during monotonous task performance and exhibit greater decrement than individuals with less tendency to daydream. Subjects (*S*s) were selected who scored at the extremes on a "daydreaming" questionnaire and compared with respect to their ability to detect signals on an auditory vigilance task. While high and low daydreaming *S*s did not differ in total number of signals detected, when these were averaged across trials, a comparison of the trends exhibited by the two groups revealed a progressive and significant decrease in the number of signals detected from the beginning to the end of the session for high daydreaming *S*s, but no change for the lows. The results of the Antrobus, Coleman, and Singer study suggest that individuals who have a predisposition to daydreaming in their daily life tend to shift their attention inward during monotonous performance, thereby reducing their attentiveness to the task stimuli.

The present study was concerned with the question of whether *S*s who rated themselves as highly susceptible to distraction in their daily lives would also find it difficult to maintain concentration under a low task-load condition with minimal sensory stimulation. It was predicted that such *S*s would find it increasingly difficult to sustain attention under these conditions and that this would be reflected in a progressive increase in both incorrect responses and performance variability.

A second aspect of this study was to examine the relationships between change in certain psychophysiological variables during the session and relative performance decrement of *S*s differing in self-related distractibility. The measures employed were heart rate, heart-rate variability, respiration period, respiration-period variability, and palmar skin conductance. Although heart rate and skin conductance have been frequently studied and generally found to decline during vigilance performance,[8] the direction and magnitude of change in these other measures during monotonous performance is less clearly understood. Evidence from a variety of studies, however, suggests that they may be quite sensitive to decline in attention. Increases in attentional requirements are known to be accompanied by decreased heart-rate variability, respiration period, and respiration-period variability.[14 16 21 24] Thus, declining attention during task performance should be associated with increases in these latter three variables, but decreases in skin conductance and heart rate. It was predicted that high-distractibility *S*s would show this physiological response pattern to a greater extent than low-distractibility *S*s.

II. Method.

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

B. *Apparatus.* The task employed was a self-paced serial reaction task similar to that used by Bertelson and Joffe[3] and Shor and Thackray.[7 9] 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, and gives a measure of errors as well as correct responses.[19]

The *S*'s panel contained four lever-actuated microswitches arranged in a row 1¼ inches apart with a ¾ 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 (error) responses.

A Beckman Type R Dynograph was used to record the psychophysiological variables. Palmar skin conductance, heart rate, and respiration were measured. Heart rate was obtained from chest electrodes with leads connected to a cardiotachometer. Skin resistance was recorded from zinc-zinc sulphate electrodes attached to the palmar and dorsal surfaces of the left hand. The transducer for measuring respiration consisted of a thin mercury-in-vinyl tube. The ends of the tube were attached to Velcro bands and positioned on the *S* at the base of the rib cage. The mercury belt formed one of the arms of a bridge circuit.

C. *Procedure.* Upon arriving for the experiment, the *S* was given a modified version of a scale which had been employed in several previous studies.[18 22] The questionnaire contained 23 statements describing potentially "stressful" situations. The *S* rated, on a seven-point scale, the degree to which he felt each situation would bother him. To minimize association between the questionnaire and the experiment, the *S* was not told that the questionnaire was relevant to the present experiment, and one experimenter

(E) administered the questionnaire while a different E conducted the rest of the experiment.

Following completion of the questionnaire, 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 40 minutes. To prevent the S's knowing that the task was almost over, the experiment was stopped after 25 rather than 40 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. *Scoring of Data.* Each S's mean score on five items contained in the pre-experimental questionnaire was used as the basis for assignment to either a "high distractibility" (HD) or "low distractibility" (LD) group. The assignment was made by ranking the scores from highest to lowest and splitting the distribution at the median.

The items used were as follows:

(a) Listening to a lecture when the people behind you are talking.

(b) Trying to concentrate with a faucet dripping.

(c) Deeply engrossed in trying to figure out a problem when someone turns on the radio full-blast.

(d) Studying or trying to concentrate on an important assignment in a room with flickering overhead lights.

(e) Studying for an important final exam with people standing around talking loudly.

The performance data were machine-analyzed and the following data obtained for each S for each successive one-minute period of the session.

(a) Mean response time.

(b) Standard deviation of response time.

(c) Single longest (maximum) response time.

(d) Single shortest (minimum) response time.

(e) Number of incorrect responses.

For the psychophysiological data, measurements were made during one-minute periods at the beginning and end of the test session. Each respiration cycle occurring in the one-minute scoring segments was measured from inspiration to inspiration and means and standard deviations obtained. Heart rate and heart-rate variability were obtained from the cardiotachometer tracings. Skin resistance was measured at the beginning and end of the one-minute periods, the values converted to conductance, and means computed.

III. Results.

Although it was intended to analyze performance changes over successive one-minute periods, examination of the data suggested that the use of larger time intervals would increase the stability of the measures. Consequently, the data were combined into four-minute periods. This procedure was followed for all performance variables.

Figure 1 shows mean response time across the six periods for the HD and LD groups as well as the data for both groups combined. Examination of this figure reveals a clear separation between the HD and LD groups, with the latter group displaying the faster response time. A repeated measures analysis of variance yielded significant F-values for both groups ($F=5.79$; $df=1.48$; $p<.05$) and periods ($F=2.25$; $df=5{,}240$; $p=.05$). There was no significant interaction. Tukey's HSD test[15] was used for individual comparisons between periods. Only the increase in response time between periods I and

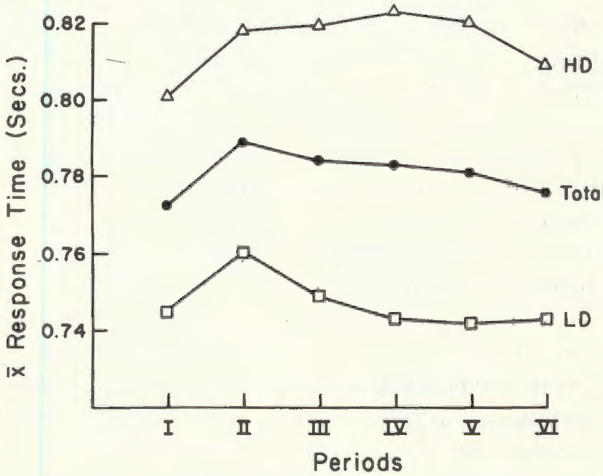

FIGURE 1. Mean response time across periods.

II was found to be significant ($p<.01$). All other comparisons yielded q-values which were nonsignificant ($p>.05$).

Figure 2 shows response-time variability. Although there is a general increase in variability during the experimental session, this increase appears to be primarily a reflection of an increase in the HD group, i.e., after a general rise in variability from period I to II, variability of the LD *S*s remains fairly constant while that of the HD *S*s continues to increase. The analysis of variance revealed the overall difference between groups to be nonsignificant ($F=2.98$; $df=1,48$; $p>.05$), but did reveal a significant difference between periods ($F=11.27$; $df=5,240$; $p<.001$) and a significant interaction ($F=2.58$; $df=5,240$; $p<.05$).

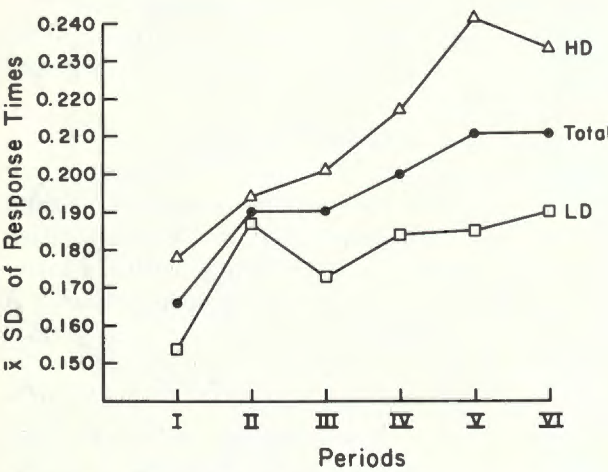

FIGURE 2. Standard deviation of response times across periods.

In examining this interaction, tests of simple effects of groups revealed the differences between groups to be significant at periods V ($F=6.96$; $df=1,288$, $p<.01$) and VI ($F=4.16$; $df=1,288$; $p<.05$), but not at periods of I, II, III, or IV. While tests of simple effects of periods revealed the differences between periods to be significant for both the HD ($F=10.38$; $df=5,240$; $p<.001$) and the LD ($F=3.46$; $df=2,240$; $p<.01$) groups, further comparisons using Tukey's HSD test, showed the significant period effect obtained for the LD group was a result of the increase between periods I and II ($p<.05$). There were no significant differences between any of the other periods for this group. These results support the impression gained from Figure 2 of an initial increase in variability for both groups which

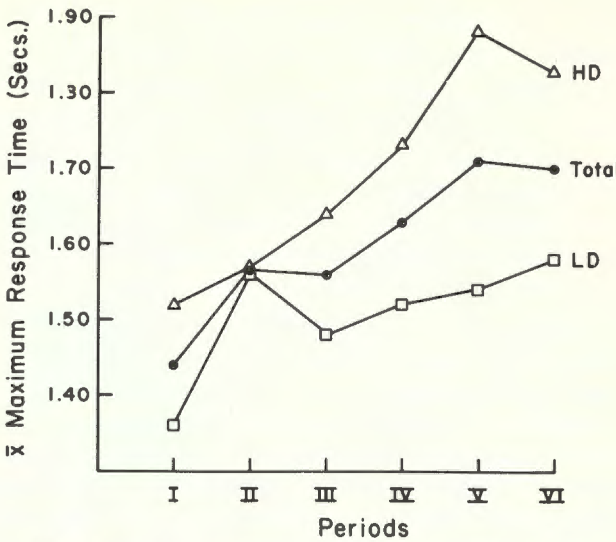

FIGURE 3. Maximum response times across periods.

levels off after period II for the LD *S*s, but continues to increase for the HD *S*s.

To gain further information regarding the nature of this increase in variability, the mean maximum and minimum response times in each block were plotted. These are shown in Figures 3 and 4 for maximum and minimum response times respectively.

The similarity between the trends displayed in Figures 2 and 3 is readily apparent, and the results of the analysis of variance performed on the maximum response times are essentially the same as those obtained for the variability data. Thus, the difference between groups was nonsignificant ($F=3.65$; $df=1,48$; $p>.05$), but there was a significant difference between periods ($F=8.43$; $df=5,240$; $p<.001$) and a significant interaction ($F=2.40$; $df=5,240$; $p<.05$). Tests of simple effects also revealed results which were comparable to those obtained for response variability. There were significant differences between the two groups at periods V ($F=7.82$; $df=1,288$; $p<.01$) and VI ($F=4.45$; $df=1,288$; $p<.05$), but no differences between groups at periods I, II, III, or IV. Simple effects of periods revealed a significant difference between periods for the HD *S*s ($F=8.19$; $df=5,240$; $p<.001$) but not for the LD *S*s ($F=1.29$; $df=5,240$; $p>.25$).

Since maximum response times increased significantly during the session while mean response times remained relatively constant, minimum response times would be expected to show a decrease. This decrease, which was probably the result of a practice effect, is shown in Figure 4. The analysis of variance revealed the overall decline to be significant ($F=3.82$; $df=5{,}240$; $p<.01$), with LD *S*s having faster minimum response times than HD *S*s ($F=4.49$; $df=1{,}48$; $p<.05$). There was no significant interaction ($F<1.00$), indicating that the decline was comparable for both groups.

Frequency of errors increased steadily throughout the experimental session and this increase was significant ($F=12.02$; $df=2{,}240$; $p<.001$). These data, as shown in Figure 5, also suggest a possible difference between groups with the LD *S*s making the *greater* number of errors. The difference between groups, however, did not reach significance ($F=2.78$; $df=1{,}48$; $p>.05$), and there was no significant interaction ($F<1.00$).

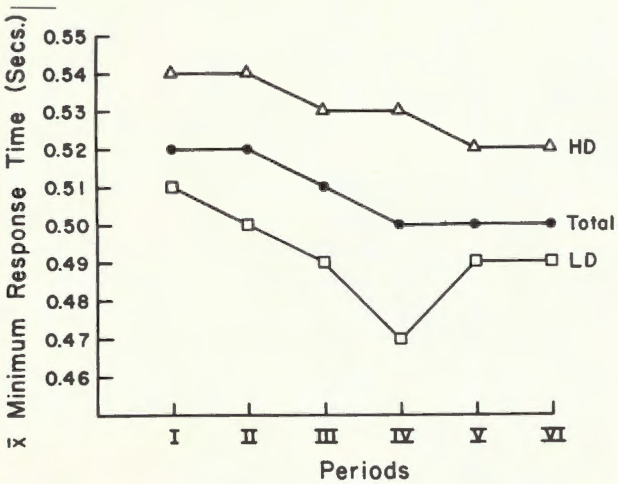

FIGURE 4. Minimum response times across periods.

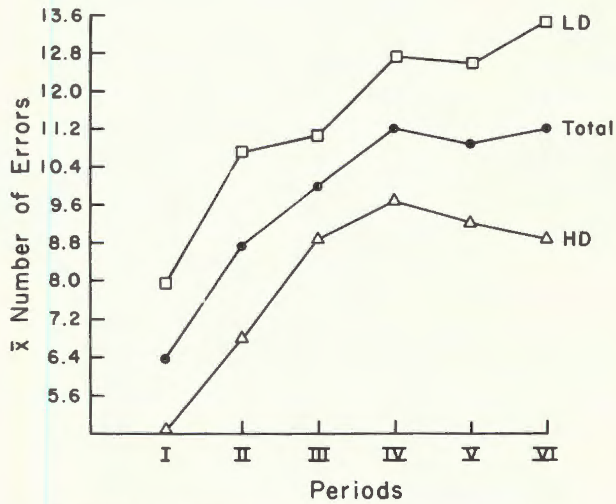

FIGURE 5. Frequency of errors across periods.

TABLE 1.

Mean values obtained for each physiological variable at the beginning and end of the experimental session.

Variable	Group	Beginning	End	Difference	F*	p
	HD	71.03	72.56			
HR (bpm)	LD	76.58	77.94			
	Total	73.81	75.25	1.44	0.04	NS
	HD	3.28	4.69			
HR SD (bpm)	LD	3.73	4.55			
	Total	3.51	4.63	1.12	10.85	<.001
Conductance (micromhos)	HD	11.34	10.75			
	LD	10.23	9.49			
	Total	10.78	10.16	- .62	15.76	<.001
Resp. Pd. (secs)	HD	2.99	3.67			
	LD	2.93	3.67			
	Total	2.96	3.67	0.71	13.42	<.001
Resp. Pd. SD (secs)	HD	0.39	1.13			
	LD	0.34	1.10			
	Total	0.36	1.12	0.76	19.04	<.001

* Only the F-values for the overall between-periods effect are given since none of the other comparisons were significant ($p > .05$).

To determine the extent of relationship between distractibility and autonomic activity during the period of task performance, repeated measures analyses of variance were performed on each of the measures obtained at the beginning and end of the session. For none of the measures (heart rate, heart-rate variability, respiration period, respiration-period variability, and skin conductance) was a significant difference obtained between the HD and LD groups. With the exception of the F-value for the heart rate analysis, which was 2.80 (df=1,48; $p>.05$), all the remaining between-group comparisons had F-values of less than 1.00. Likewise, all of the interactions were nonsignificant ($F<1.00$). All of the F-values obtained for the between-periods comparisons, however, with the exception of heart rate were significant. These values along with the means for the two groups on each variable are shown in Table 1.

Respiration period, respiration-period variability, and heart-rate variability *increased* during the session while conductance *decreased* and heart rate remained unchanged.

IV. Discussion.

The results of the present study indicate that individuals who rate themselves as high in susceptibility to distraction are not only slower in their overall rate of responding than low-distractibility subjects, but are apparently less able to maintain a uniform rate of responding under monotonous conditions. Response times of the HD *S*s showed a progressive increase in variability over the session, while performance variability of the LD *S*s remained essentially constant.

Examination of maximum and minimum response times revealed the increased variability of the HD *S*s to be primarily a reflection of distributions increasingly skewed in the direction of lengthened response times. An increase in frequency or duration of "long response times" has frequently been reported in studies of prolonged performance on serial reaction tasks, and this phenomenon has been hypothesized to be a reflection of a progressive decline in attention.[17] Since it was the HD *S*s who displayed increasingly long gaps or pauses, the results would appear to support the hypothesis that the observed decrement was the result of an inability of these *S*s to sustain attention. Although an explanation based upon simple muscle fatigue cannot be entirely ruled out, if the decrement were the result of this alone, one might have expected the LD *S*s, with their higher rate of responding, to show the greater rate of increase in long response times.

While a measure of extroversion was not obtained in the present study, there are reasons for suspecting the existence of a relationship between susceptibility to distraction and extroversion. Distractibility is believed to be related to impulsivity[14] and impulsivity is known to be a prinicple dimension of extroversion.[25] Also, there are certain similarities between the results obtained for HD *S*s in the present study and those obtained for extroverts in several studies relating extroversion to serial reaction performance. Corcoran[5] found extroverts to make fewer responses than introverts and to have more frequent gaps (long response times). Claridge[4] reported a similar relationship between speed of responding and extroversion among psychoneurotics. Long response times were not examined in this study.

Although daydreaming tendency has been shown by Antrobus, Coleman, and Singer[1] to be related to performance decrement on another type of task requiring sustained attention (auditory vigilance), it is not clear whether the measure of daydreaming tendency employed in the above study would be positively correlated with distractibility as measured in the present investigation. Indeed, in a factor analytic study of cognitive and personality variables, Singer and Antrobus[20] found either no relationship or a negative relationship between measures of daydreaming and both extroversion and distractibility. While both tendency toward daydreaming and distractibility appear related to performance decrement under monotonous conditions, the attentional mechanisms involved may be quite different.

Frequency of errors increased steadily in the present study, but no significant differences between HD and LD *S*s were obtained. It is interesting to note that extroversion-introversion has not been found to relate to frequency of incorrect responses on this type of task either.[5] While it has been noted that errors tend to increase immediately prior to a block or gap, implying a relationship to lapses of attention,[3] it has also been observed that errors seem to occur when *S*s attempt to perform a serial reaction task too rapidly.[23] The present data were examined with reference to the degree of relationship between number of errors, minimum response time, mean response time, maximum response time, and response variability. The obtained correlations between errors and each of these measures of response time were −.53 ($p<.01$), −.33 ($p<.05$), −.09, and .04 respectively. The fact that the largest correlation was obtained with minimum response time provides support for the observation that errors in this type of task appear to be associated with high rates of responding. There was no evidence of any relationship between errors and either maximum response time or response variability.

The lack of relationship between self-rated distractibility and either levels or change in any of the psychophysiological measures was unexpected. Distractibility in children is believed to be related to highly variable heart rates and respiration rates[14] and similar relationships were expected for HD *S*s in the present study. The changes which occurred in the present study for all variables except heart rate were in directions which previous research has suggested may accompany declining vigilance or attention. To the extent that HD *S*s were less able to sustain attention than LD *S*s, it is somewhat surprising that this was not reflected in a correspondingly greater rate of change in these physiological measures. Perhaps one possible explanation for the lack of relationship was in the relatively brief measurement periods employed for the psychophysiological variables, which, because of sampling error, could obscure individual differences. Unfortunately, the length of the measurement periods was largely dictated by the difficulties involved in handscoring large quantities of heart-rate variability data. A follow-up study now in progress will employ computer processing and analysis of the heart-rate variability data and thus enable the use of longer measurement periods distributed throughout the test session.

V. Summary.

In summary, the results of this study indicate that individuals who rate themselves as susceptible to distraction in their daily lives find it difficult to sustain attention when required to perform a monotonous task demanding continuous attention. The obtained decrement took the form of increasingly long gaps or pauses in performance which became quite evident after approximately 20 minutes of performance. In contrast, individuals rating themselves low in distractibility were able to perform the task in a superior manner with no evidence of a decline in attention. Other studies of performance under monotonous conditions have found similar differential patterns of decrement for subjects differing in extroversion-introversion and tendency to daydream. Taken together with the present results, these findings clearly suggest that certain temperamental and cognitive variables are significantly related to performance decrement under minimal task-load conditions. What the pattern of interrelationships is between these variables and which may be the best predictors of performance decrement under these conditions remains to be empirically determined.

Although most of the physiological variables showed progressive and significant changes in directions that previous research has suggested should reflect declining attention, none of these variables was significantly related to self-rated susceptibility to distraction. Research in progress, using a computer to assist in processing the large amounts of psychophysiological data generated, will enable a more adequate determination of the extent to which such measures as heart-rate and respiration-rate variability reflect differential changes in attention during monotonous performance.

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I. Thackray, R. I.
II. Jones, K. N.
III. Touchstone, R. M.

Increasing automation of air traffic control tasks may have the undesirable side effect of increased monotony as a result of the anticipated reduction in task demands. While the actual extent of increase in monotony resulting from such automation is not as yet known, it is known that performance during low task-load conditions is accompanied by declining attention. Since individuals who are unable to sustain attention under low task-load conditions would appear to be more likely to commit errors and less able to handle a sudden emergency situation, it would seem desirable to examine the characteristics of individuals unable to sustain attention under these conditions. In the present study, 50 subjects performed a monotonous, but perceptually demanding task, for approximately 30 minutes without rest. It was found that high-distractibility subjects (as determined from a questionnaire administered prior to the experiment) showed increasing lapses of attention during performance, while low-distractibility subjects failed to show any evidence of a decline in attention. Significant changes were obtained for respiration, respiration-period variability, heart-rate variability, and skin conductance during the task period, but the magnitude of these changes did not differ among the two distractibility groups.

Descriptors
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