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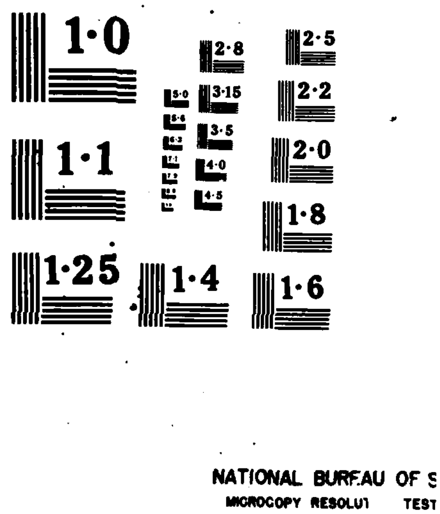
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Complex Monitoring Performance and the Coronary-Prone Type A Behavior Pattern

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16. Abstract

The present study examined the possible relationship of the coronary-prone Type A behavior pattern to performance of a complex monitoring task. The task was designed to functionally simulate the general task characteristics of future, highly automated air traffic control systems in which passive monitoring is expected to be a principal job requirement. Thirty- six male subjects, half classified as Type A and half as Type B, monitored the simulated radar display over a 2-hour session for infrequent critical changes in alphanumeric targets. In addition to performance, physiological changes and subjective reactions were also assessed. Type A individuals were found not to differ from Type B individuals in either task performance or in subjective reaction to the task. Task-related changes in heart rate, blood pressure, and general restlessness failed also to provide any evidence of greater arousal in Type A's than in Type B's. The findings are discussed relative to other studies of Type A behavior and performance and to the specific problem of finding useful predictors of performance in operational monitoring situations.

17. Key Words

Air Traffic Control, Attention, Automation, Monitoring, Performance, Type A, Vigilance

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COMPLEX MONITORING PERFORMANCE AND THE CORONARY-PRONE TYPE A BEHAVIOR PATTERN

INTRODUCTION

Increasingly sophisticated levels of air traffic control (ATC) automation that are planned to be implemented over the next 20 years will result in a gradual shift in the role of the controller from that of an active participant in control decisions to that of a rather passive monitor of a computer-controlled process. Such a shift in role suggests the possibility that those controllers able to tolerate and perform successfully in future, highly automated systems may differ considerably in personality type from successful controllers in today's systems. Although it is known that some individuals are better able than others to both tolerate and effectively perform monitoring tasks, attempts to define the personality profile of effective monitors have proven to be extremely difficult (Berch and Kanter, 1984).

Within recent years, there has been increased interest in the relationship of a particular type of behavior pattern, commonly referred to as the coronary-prone Type A pattern, to adjustment in the work setting (Chesney and Rosenman, 1980). This pattern, as originally formulated by Friedman and Rosenman (1974), consists of "an action-emotion complex that can be observed in any person who is aggressively involved in a chronic, incessant struggle to achieve more and more in less and less time, and if required to do so, against the opposing efforts of other things or other persons" (p. 67). Behaviors that characterize the Type A pattern include aggressiveness, hostility, lack of tolerance for inactivity, an exaggerated sense of time urgency, impatience, and a competitive drive for achievement (Matthews, 1982). Individuals displaying relatively few of these behaviors are considered to be Type B. A number of these behaviors, e.g., time urgency, impatience, intolerance for inactivity, and a need to work in a competitive environment, would appear to be at variance with behaviors that one might expect to be associated with individuals able to tolerate monitoring or vigilance-type tasks. Consequently, a relationship between the Type A behavior pattern and an inability to tolerate such tasks might be expected.

The few studies that have compared Type A and B individuals with respect to monitoring tasks, however, have not supported this expectation. For example, Lundberg and Forsman (1979) failed to find any differences between Type A and B individuals in their performance of a simple visual vigilance task, with both Types showing comparable declines in correct detections over the 1-hour session. In addition to performance, subjective measures of boredom, concentration, effort, impatience, interest, irritation, relaxation, tenseness, and tiredness were also obtained. While most of these changed significantly during the session, again there were no Type A/B differences on any measure. Finally, although there was a tendency for cortisol excretion of Type A's to exceed that of Type B's during the vigilance task, there were no Type A/B differences in either heart rate change or in adrenaline excretion.

To our knowledge, the only other study of Type A behavior and monitoring performance was conducted by Lundberg, Warm, Seeman, and Porter (1980). This study also employed a visual vigilance task with performance measured over a 1-hour session. It was predicted that the group classified as Type A would be less able to sustain attention to the task and would experience it as more stressful than would the Type B group. The results revealed an equivalent performance decline in both groups, and there was no evidence that the groups differed in experienced boredom, fatigue, or irritation. Surprisingly, however, Type A's consistently detected more signals during the task, and thus appeared to be generally more alert during performance than Type B's. While this finding was contrary to their initial expectations, the authors interpreted the finding as being consistent with descriptions of Type A's as being more hyperalert than Type B's.

Neither of the studies just considered found any evidence that would suggest Type A's to be less able than Type B's either to tolerate monitoring tasks or to sustain attention during the performance of such tasks. On the contrary, there is evidence to suggest that Type A's may actually be more alert during monitoring performance than Type B's. As we noted initially, increases in ATC automation will result ultimately in increased monitoring responsibilities. As these job requirements assume greater importance, the desirability of identifying those characteristics of individuals who are able to both tolerate and perform effectively on monitoring tasks increases in significance. The possibility that individuals possessing the Type A behavior pattern might actually be superior to Type B's in monitoring performance deserves further investigation.

The task employed in the present study was an updated version of the radar monitoring task used in many of our previous studies (e.g., Thackray and Touchstone, 1980) and represents an on-going attempt to devise a task that more closely approaches real-life monitoring requirements. As investigators are beginning to recognize, modern operational vigilance tasks, such as those involving the monitoring of automated processes, involve more than simply detecting and responding to infrequent changes in unidimensional stimuli. They frequently involve complex multidimensional discriminations (Mackie 1984) in which stimulus detection or identification may be followed by interpretation of significance, decisions as to appropriate action, implementation of actions, and evaluation of consequences (Craig 1984). The present task, although still in the development phase, represents an attempt to incorporate these additional elements. Only data pertaining to the detection of critical events are reported in this study. Those data relevant to other subtask elements are being analyzed in the context of the development process and will form the basis of a subsequent study. For purposes of providing the reader with details regarding the total task performed by the subjects, all aspects of the task are described in the procedure.

METHOD

Subjects. Type A/B classification of individuals was based on Jenkins Activity Survey (JAS) scores (Jenkins, Rosenman, and Zyzanski, 1974) using the Form T version developed for use with college students (Glass, 1977). Eighty-five male introductory psychology students from classes at the University of Oklahoma were administered the JAS. A median split was used, with those falling above and below the median score (median=8) classified as Type A and Type B respectively. The median score of 8 corresponds closely to values reported for college populations (Glass, 1977). Eighteen Type A and an equal number of Type B individuals volunteered to participate in the study. Subjects ranged in age from 18 to 29 years, were nonsmokers, and had no prior experience with the task used or previous ATC training. All had corrected or uncorrected 20/20 vision.

Apparatus and Task Design. The basic experimental equipment consisted of a Digital Equipment Corportion (DEC) VS11 19-in (49-cm) graphics display, keyboard, and joystick, all of which were interfaced with a VAX 11/730 computer (DEC). The computer was used both to generate input to the display and to process subject responses. The VS11 was incorporated into a console designed to closely resemble an ATC radar unit. Two diagonal, nonintersecting flight paths were located on the display, along which aircraft targets could move in either direction. A given aircraft's location was displayed as a small "blip" on the flight path, and an adjacent alphanumeric data block identified the aircraft and gave its altitude and groundspeed. Aircraft were updated in position and any change in alphanumerics every 6 s. Figure 1 shows a typical target pattern as displayed to the subject, with the total console-display configuration shown in Figure 2.

The subject's task was to continually monitor the display for one of two types of change in the alphanumeric data blocks. The duration of each type of change (referred to as a *critical event*) was 90 s; if a subject failed to detect a critical event within this 90-s period, the data block containing the change reverted to its previous state.

The first type of critical event was readily detectable and consisted of three X's in place of the three altitude numbers in a given data block. Subjects were told that this replacement of an altitude value signified that a malfunction had occurred resulting in a loss of altitude information. Upon detection of such an event, subjects were told to press a button on the console labeled "XXX malfunction," move a joystick-controlled cursor over the data block containing the critical event, and to press another button on the joystick control unit. This last response "corrected" the malfunction by replacing the three X's with the previous altitude value. The second type of critical event was more difficult to detect, since it was not immediately apparent. This event was the occurrence of two aircraft at the same altitude on the same flight path. As soon as such an event was noted, subjects pressed a second console button labeled "Altitude Check." Subjects next determined whether the two aircraft were moving towards each other, away from each other, or in the same direction. On the basis of this determination, subjects then pressed either a "Conflict" button (indicating that the aircraft were moving towards each other) or a "No Conflict" button (indicating that the aircraft were either moving away from each other or were moving in the same direction). All aircraft in this simulation were assigned a speed of 450 mph. Thus, aircraft could not overtake one another, and only targets moving towards each other would constitute a potential conflict situation. Following a "conflict" decision, the cursor was positioned over one of the two conflicting aircraft and the joystick control button was pressed. This caused a new altitude value to appear in the lower left of the screen that, subjects were told, represented a value selected by the computer to resolve the conflict. Subjects then verified that the computer-assigned altitude did not result in a conflict with some other aircraft on the flight path. If no new conflict was created, a keyboard entry was made that assigned the new altitude value to one of the two previously conflicting aircraft. (Under the simulation used, a computer-assigned altitude never conflicted with the altitude of any other aircraft.)

Whenever a "no conflict" response was made, no further action ensued, since no change in altitude was required. Subjects were told that the altitude of one of the two nonconflicting aircraft would eventually change to some other value (this time interval was variable, but always less than the 90-s stimulus duration period) and that they had to remember that they had responded to this particular pair of aircraft. If they failed to remember and responded a second time, an error was recorded.

The number of targets on each flight path was kept equal at all times; as one left the screen, another appeared. To prevent data block overlaps, two constraints were necessary: (a) speed was held constant at 450 miles per hour for all aircraft, and (b) all data blocks for targets moving from left to right were positioned above the flight path, while those moving right to left were located below. Nine critical events occurred in each 30-min period, with no more than one event present at any given time. Of these nine events, three were XXX's, three were conflicting altitude changes, and three were nonconflicting changes. These events were arranged in a quasi-random order with the restriction that each of the three types of events had to occur at least once in both the first and second 15 min of each 30-min period. Subjects were given no information regarding the frequency of events or their order of occurrence. The times between events (interstimulus intervals) ranged from 126 to 302 s with a mean of 200 s.

The subject was observed from an adjacent room via closed-circuit TV. Indirect lighting was used in the subject's room, and the level of illumination at the display was 5.6 lux.

Physiological Instrumentation and Measurement. Measurements of systolic blood pressure (SBP) and diastolic blood pressure (DBP) were made using a Narco Bio-Systems Model PE-300 Electro-Sphygmomanometer, the output of which was connected to one of the channels of a Beckman Type R611 recorder. SBP was determined from the first Korotkoff sound to be recorded in the descending pressure cycle, with DBP taken to be the first Korotkoff sound having an amplitude less than one-third the amplitude of the maximum recorded sound. This technique has been used by Cartwright (1973) and correlates well with conventional clinical measurements. Heart rate (HR) was obtained from a photoelectric plethysmograph attached to the middle finger of the left hand. The output of this transducer led to a Beckman cardiotachometer and was recorded on a second channel. A measure of gross

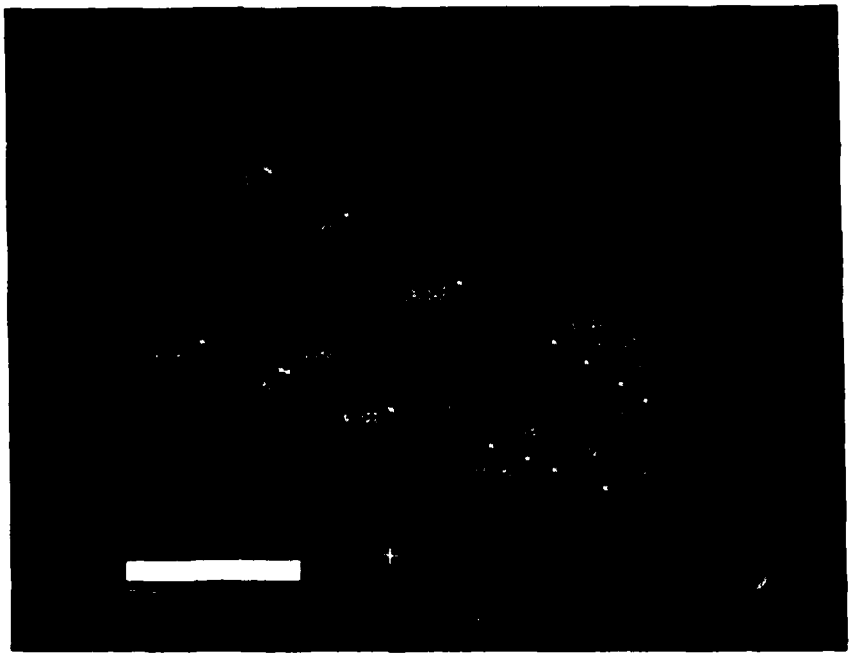

Figure 1. A typical target configuration as displayed to the subject.

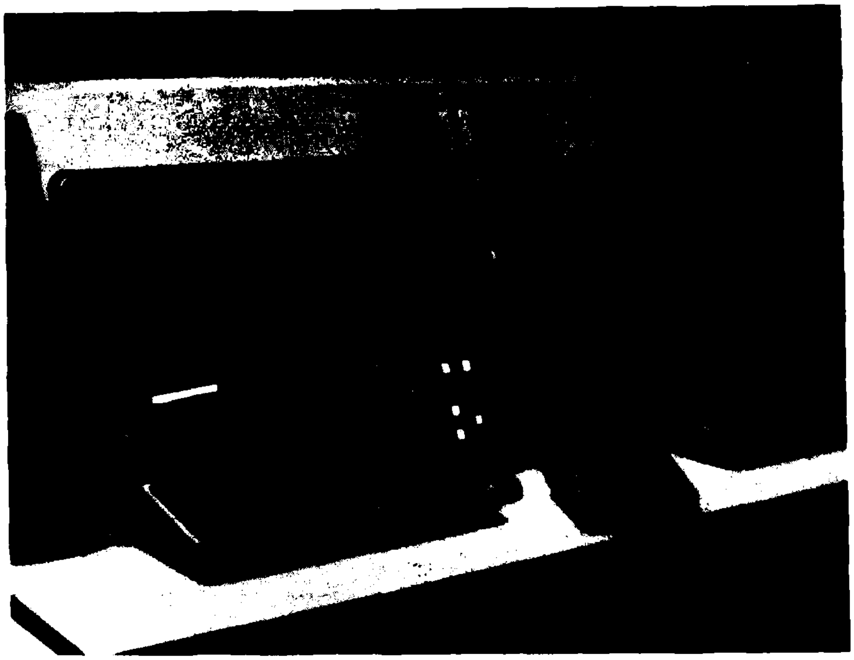

Figure 2. The simulated ATC work station. Only the console on the left was used in this study.

body movement (restlessness) was derived from a modified crystal finger-pulse transducer that was attached beneath the seat of the subject's chair. The analog output of this transducer was pulse integrated and then led, along with the cardiotachometer output, to digital inputs of the computer.

Heart rate was recorded continuously and blood pressure intermittently both during an initial baseline period and during the 2 hours of task performance. Blood pressure determinations were made every 2 min during the baseline period and every 10 min during the task session. The baseline period, which lasted at least 6 min for all subjects, was terminated when 6 min had passed and 2 successive systolic readings within +- 5mmHg were obtained. For purposes of data analysis, baseline HR consisted of the mean of the final 5 min of this period, while baseline SBP and DBP were mean values derived from the last 2 measurements. During the 2-hour task session, mean HR values were obtained from 5-min measurement periods located at the beginning of the session and every 30 min thereafter. Blood pressure was obtained during times that corresponded to the HR periods. Body movement was recorded only during the task session and consisted of the sum of the integrator pulses within each successive half hour.

Procedure. Upon arriving at the laboratory, each subject was given general information about the experiment. At the completion of this initial orientation, subjects received an informed consent statement to read and to sign if they wished to participate in the study. (None refused to sign.) The blood pressure cuff and finger pulse transducer were then attached and the baseline period ensued. Immediately following this period, subjects rated their feelings of fatigue, attentiveness, strain, boredom, drowsiness, irritation, impatience, and tension on line scales, the extremes of which were anchored at 0 (minimum) and 100 (maximum).

After completion of the rating scales, subjects received task instructions and separate practice in responding to each of the three kinds of critical events. This was followed by an additional practice session in which the various kinds of critical events were presented in a random order. Twenty-one critical events (seven of each kind) occurred during the 21-min practice session. On rare occasions, additional practice was given if the subject appeared to have difficulty with any of the procedures.

The experimental session lasted 2 hours. In order to add a greater element of realism to the task, a tape recording of background noises recorded in actual air traffic control radar rooms was played continuously during the 2-hour task session. Sound level of this noise at the subject's head location was 62 dBA. It was not expected that this would affect performance, since an earlier study, using a previous version of our monitoring task, failed to find any significant performance effects of this noise at a considerably higher (80 dBA) level (Thackray 1982).

At the completion of the 2-hour task period, a second form of the subjective scales was administered. This form was identical to the first, except that subjects were instructed to rate each item with respect to how they felt near the end of the task just completed, and an item was added dealing with how much effort was required to continue performing the task as the session progressed. Following this, subjects were given a thorough debriefing with regard to the purpose of the experiment.

RESULTS

Performance Data. As described earlier, two levels of stimulus difficulty were employed in this study. In the first level, subjects were required to simply scan the display for three X's that replaced a three-digit altitude value in one of the targets on the screen. The second, more difficult level required subjects to continually compare each target's altitude with the altitude values of all other targets on a given flight path to detect the occasional occurrence of two targets at the same altitude. These two levels of stimulus difficulty will henceforth be referred to as the low difficulty (LD) and high difficulty (HD) levels respectively.

Figure 3 shows mean detection times across successive 30-min periods for Type A and B individuals for the two levels of stimulus difficulty. A repeated measures analysis of variance (ANOVA) applied to the LD data revealed no significant effects for group, for time period, or for the

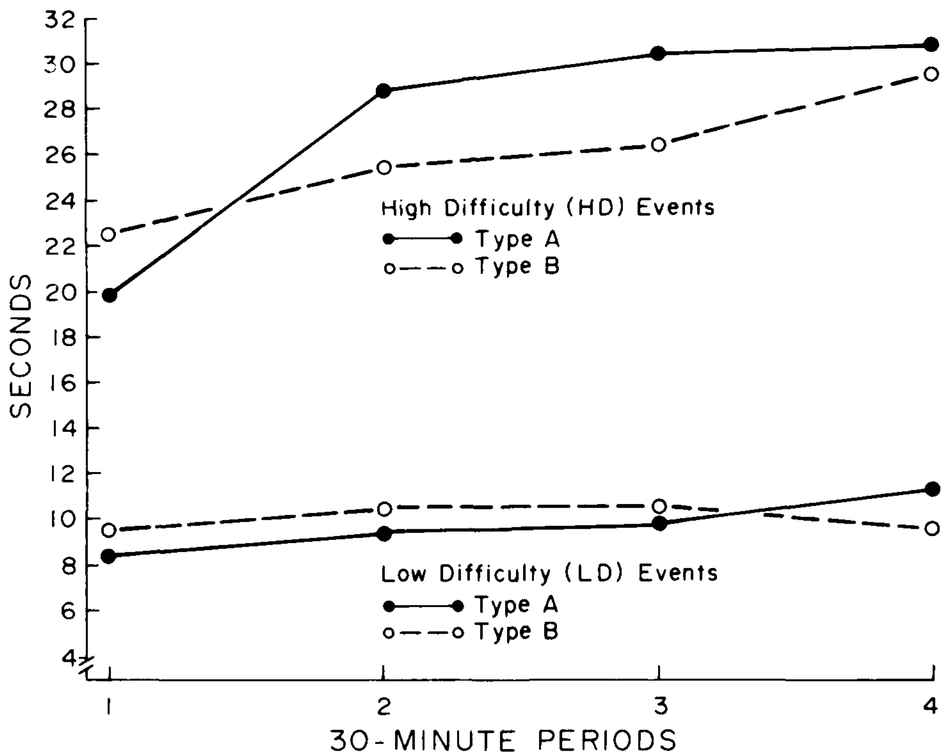

Figure 3. Mean detection times across 30-min periods for Type A and B individuals for the two levels of stimulus difficulty.

group by period interaction ($p>.10$ in each case). For HD data, Figure 3 shows a general increase in detection time across periods for both groups, and an ANOVA performed on these data revealed this effect to be significant ($F(3/102)=6.81$, $p<.05$). Once again, however, the group effect was not significant nor was the group by period interaction ($p>.10$ in both cases).

With regard to errors of omission, the more readily detectable LD events were seldom missed by subjects in either group. In total, only 6 LD events were missed; four of these were missed by Type A individuals and 2 were missed by Type B's. For HD events, virtually all subjects, irrespective of group, missed at least 1 event during the 2-hour session. The mean number of HD events missed by individuals in both groups during the first and second hours of the session is shown in Table 1. Examination of these data

Table 1. Mean number of HD events missed by Type A and B individuals during first and second hours of the task session.

Group	Time Period First Hour	 Second Hour
Type A	.83	2.11
Type B	1.06	1.89

reveals that approximately 1 event was missed by subjects in both groups during the first hour with this increasing to approximately 2 during the second hour. Separate Wilcoxon tests revealed the increase from first to second hour to be significant ($p<.05$) for both groups, but a Mann-Whitney U test showed this increase in errors to be no greater for Type A's than for Type B's.

Physiological Data.

Mean baseline values for SBP, DBP, and HR are shown in Table 2. Separate tests conducted on each measure revealed the difference between groups to

Table 2. Mean physiological baseline values for the Type A and B groups.

	Mean Values (n's in Parentheses)		
Group	SBP (mmHG)	DBP (mmHg)	HR (bpm)
Type A	121.3 (18)	68.0 (18)	78.4 (12)
Type B	116.0 (18)	66.3 (18)	67.2 (12)

be significant for HR ($t(22)=2.55$, $p<.05$), but no Type A/B differences existed for either SBP or DBP. (Note: The HR analysis was based on only 24 subjects because of recording difficulties with the equipment employed.) Remaining analyses of the cardiovascular data were performed on change scores obtained by subtracting each subject's baseline score from each of the scores obtained during the task period. Mean change scores are shown in Figure 4.

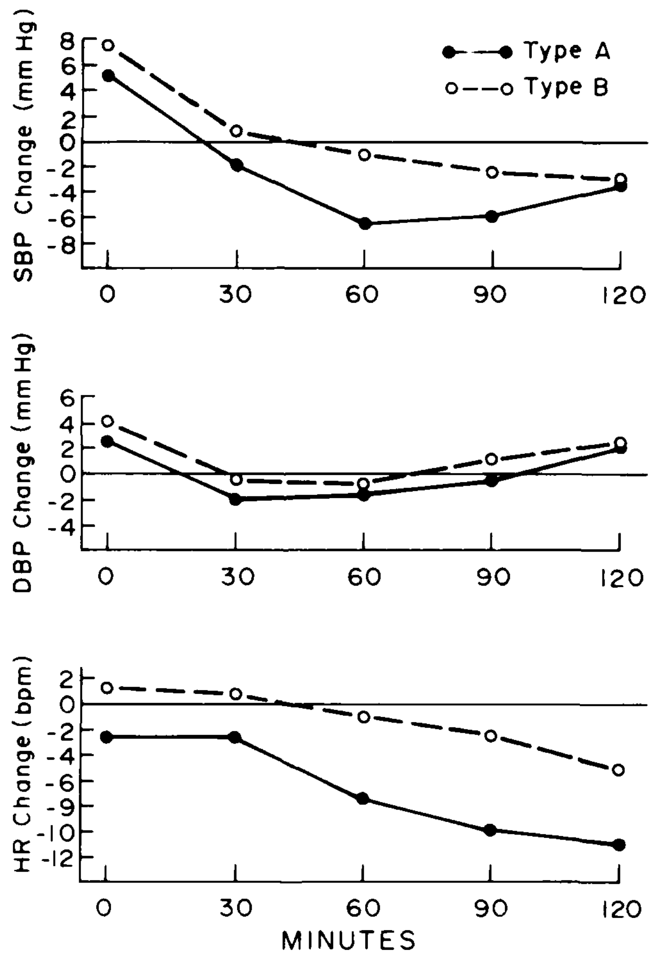

Figure 4. Mean change scores for HR, SBP, and DBP obtained at the beginning of the session and at 30-min intervals thereafter.

Repeated measures ANOVAs revealed a significant time periods effect for SBP ($F(4/136)=25.95$, $p<.001$), for DBP ($F(4/136)=3.31$, $p<.01$), and for HR ($F(4/88)=35.44$, $p<.001$). Of the remaining effects, only the group effect for HR was significant ($F(1/22)=7.15$, $p<.01$). Examination of Figure 4 reveals that, relative to baseline, Type A's showed greater change in HR throughout the session than did Type B's. Interestingly enough, the Type A HR change consisted of a decrease in rate that was present even at the start of the session.

Data for body movement (restlessness) obtained over successive 30-min periods of the task session are shown in Table 3. (As noted earlier, baseline recordings were not obtained for this measure.) The ANOVA conducted on these data revealed the increase in restlessness during the session to be significant ($F(3/84)=7.84$, $p<.001$), but there was no significant difference between groups and no significant interaction.

Table 3. Mean number of body movements (integrator pulses) for Type A and B individuals over successive 30-minute periods of the task session.

	Thirty-minute Periods			
Group	1	2	3	4
Type A	2692	3023	3107	3137
Type B	2905	3066	3273	3903

Subjective Data.

Table 4 shows mean scores for the subjective rating-scale data. The values shown represent measured distances in mm from the left or zero point of the line scale for each item. Values could range from 0 to 190, with a score of 95 representing the midpoint. Increased Fatigue ($F(1/34)=29.74$, $p<.001$), Strain ($F(1/34)=38.55$, $p<.001$), Boredom ($F(1/34)=42.16$, $p<.001$), Drowsiness ($F(1/34)=26.87$, $p<.001$), Irritation ($F(1/34)=15.30$, $p<.001$), and Impatience ($F(1/34)=18.12$, $p<.001$), as well as decreased Attentiveness ($F(1/34)=39.05$, $p<.001$) were reported by subjects in both groups (see Table 4). Tension was the only variable failing to show a significant pre- to posttask change. None of the group or interaction effects was significant for any of the above variables. A one-way ANOVA performed on the Effort data obtained at the completion of the session revealed the group effect to be nonsignificant.

TABLE 4. Mean values obtained for each rating scale item for Type A and Type B individuals.

Item	Group	Measurement Period Pretask	Posttask
Fatigue	Type A	34	75
	Type B	31	83
Attentiveness	Type A	151	86
	Type B	130	77
Strain	Type A	23	69
	Type B	26	82
Boredom	Type A	18	92
	Type B	40	99
Drowsiness	Type A	40	93
	Type B	44	94
Irritation	Type A	11	42
	Type B	21	59
Impatience	Type A	19	67
	Type B	32	76
Tension	Type A	37	35
	Type B	42	71
Effort	Type A	--	111
	Type B	--	98

DISCUSSION

Of the two previous studies of Type A behavior and vigilance, one failed to find any evidence of differences in the performance of Type A and B individuals (Lundberg and Forsman, 1979), while the other study found that Type A's, although not differing from Type B's in the rate at which signal detection declined during the session, consistently detected signals at a higher overall level throughout the session than did Type B's (et al., 1980). If confirmed, the finding that Type A individuals might actually be somewhat better monitors than Type B's could have important implications for the selection of controllers in future, highly automated ATC systems. The results of the present study, however, failed to support the earlier Lundberg et al (1980) finding. Type A individuals were found not to differ from Type B's on any of the performance measures employed. Nor was there evidence from either the physiological or subjective measures to indicate that Type A's found the task to be any more stressful or arousing than did Type B's. If anything, the HR data suggests less reaction to the task by Type A's than by Type B's. The findings of the present study, then, are in general agreement with the results obtained by Lundberg and Forsman (1979), who likewise were unable to demonstrate significant differences between Type A and B individuals in performance, physiological response, or subjective reaction to the vigilance task that they employed.

In attempting to account for the differences in findings of the Lundberg, et al. (1980) and the Lundberg and Forsman (1979) studies, Warm (1986) has suggested that task difficulty may have been a significant factor. The vigilance task used by Warm in the Lundberg, et al. (1980) study apparently involved rather difficult discrimination of stimulus motion. Mean detection rate on this task was initially 70%, with this dropping to 40% by the end of the session. In the spatial discrimination task used by Lundberg and Forsman (1979), however, initial and final detection rates were 80% and 70% respectively. The higher initial rate and lesser decrement over time suggested to Warm that the task used by these latter investigators may have been less difficult than the one that he and his colleagues employed. There is some evidence that differences between Type A and B individuals in both task performance and in physiological reactivity to task demands may become manifest only if the task is perceived to be sufficiently difficult (Matthews, 1982). To the extent that Type A's perceived the Lundberg, et al. task to be a challenging one, it is conceivable that they may have exerted more effort than did Type B's. Presumably, neither type found the Lundberg and Forsman (1979) task to be especially challenging. Possible support for this might be derived from the fact that Type A's in the Lundberg, et al. (1980) study expressed greater strain during the task session than did Type B's; the Lundberg and Forsman (1979) study failed to find any Type A/B differences in experienced stress or strain.

If Warm's hypothesis is applied to the present study, it would suggest that the lack of Type A/B differences may have been due to the fact that the task used was not sufficiently difficult or challenging to evoke greater effort in Type A than in Type B individuals. On the surface, this suggestion might seem difficult to accept, since the radar simulation task used here is clearly more perceptually complex than the tasks used in either of the above two studies. Yet our task, while more varied and complex than these other two tasks, is not especially difficult in its cognitive and perceptual requirements. It clearly does not require continuous difficult discriminations as does the task employed by Warm and his colleagues. Nor was there any intention to incorporate difficult discriminations into the design of our simulated radar task, since the requirement to make difficult judgements and discriminations is more likely to be reduced, than to be increased, in the more highly automated ATC systems of the future.

Two recent reviews of the literature dealing with individual difference correlates of vigilance performance have concluded that no single personality trait, or combination of traits, has yet been found that will account for more than a small portion of the total variance in task performance (Berch and Kantor, 1984; Davis and Parasuraman, 1982). Although Lundberg, et al. (1980) did find Type A's to be somewhat superior to Type B's in overall signal detection, it must be remembered that Type A's did not differ from Type B's in the rate of decline in signals detected (sustained attention) nor did the two types show much difference in their subjective response to the task. These findings, taken in conjunction with the negative findings of both the present study and the earlier one by Lundberg and Forsman (1979), would suggest that the Type A behavior pattern likewise accounts for relatively little of the variance in vigilance performance. While this could also suggest that selecting individuals on the basis of the Type A behavior pattern might contribute little toward predicting performance on future, highly automated ATC monitoring tasks, some caution should be exercised in this regard. The monitoring task used in the present study, although a reasonable approximation of future ATC task characteristics, cannot totally simulate the work/stress levels of operational environments, nor can it reasonably be used to study performance over the long duty periods that characterize real life work situations. These limitations are not unique to the present study; they represent common problems in generalizing from laboratory research to operational settings. However, because such factors (higher stress levels and longer duty periods) could conceivably alter relationships of the Type A pattern to monitoring performance in ways that are presently unknown, applying the findings of the present study to future operational monitoring situations should be made with this caution in mind.

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