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EFFECTS OF SIGNAL PATTERNING UPON VIGILANCE PERFORMANCE AND PHYSIOLOGICAL RESPONSES

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ABSTRACT

EFFECTS OF SIGNAL PATTERNING UPON VIGILANCE PERFORMANCE AND PHYSIOLOGICAL RESPONSES

The purpose of the present investigation was twofold: 1) to determine the effect of signal patterning upon physiological responses and time to detect signals; 2) to study performance of subjects (Ss), with and without patterning, under conditions in which they were either informed or uninformed about the signal patterning.

Vigilance performance and physiological responses with variable interval (VI) and fixed interval (FI) signal patterns were studied in four groups of Ss. Three of the four groups were required to make responses (telegraph key presses) in order to detect signals. Reaction time (RT) was used as the performance measure while heart rate (HR), palmar skin conductance (PSC) and galvanic skin responses (GSRs) were the physiological measures. Each S was tested in two separate one hour sessions on each of two days.

The results indicated that there was a tendency for RTs to be faster under the FI schedule of signals than with the VI. The HR and PSC measures showed higher variability with the VI schedule while GSRs were more variable under the FI schedule. Faster RTs tended to be related to higher levels of HR, PSC and GSRs. It was suggested that: 1) faster RTs under the FI schedule reflected greater learning of the regular signal pattern; 2) faster RTs with higher degrees of physiological activation were due to greater numbers of sensory impulses which travelled cortically and had the effect of improving alertness and readiness to respond. Several implications of these results for training were discussed.

FOREWORD

The maintenance of alertness in the performance of tasks is a problem in many practical situations including assembly line inspections, operation of aircraft and spacecraft and in the detection of random and infrequent signals as required in radar and sonar operations. All of these situations are examples of monotonous tasks which, nevertheless, require high degrees of alertness or vigilance for their successful performance. The present study was undertaken with the assumption that supplementary physiological data can provide useful information regarding the state of persons involved in vigilance situations, and might perhaps suggest new approaches for training and operational conditions in which the task to be learned or performed in a monotonous one.

The results indicated that individuals in a vigilance situation tend to respond more quickly to a regular pattern of signals than an irregular one and that when their level of physiological activity is high there is a tendency to respond more quickly. The implications for training are that: 1) physiological measures are indicants of a man's readiness to respond and are of potential utility for monitoring his activity level in vigilance training or operational situations; 2) it may prove feasible to train men to make temporal and spatial patterns of observing responses, e.g., orientations of the eyes, when they are required to detect signals in a vigilance situation; 3) it may be desirable to induce physiological variability if shifts in magnitude can be related to superior monitoring performance.

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INTRODUCTION

Whenever individuals must engage in monotonous or repetitive tasks there is a danger that performance will show a decrement due to many factors including inattentiveness caused by lack of variation in the task or in the stimulus environment. This inattentiveness may result in a failure to respond or inappropriate responding. In certain military situations, such as the monitoring of radar or sonar signals, the stimuli are often infrequent and random in their occurrence. Mackworth (1948) has provided results which showed a decrement in ability to detect visual signals as a two-hour watch progressed and postulated that the man's task in a monitoring situation such as this is one of "vigilance". Other investigators have also demonstrated decrements in signal detection over time (e.g., Adams, 1956; Bakan, 1955; Deese and Ormond, 1953). Holland (1958) has argued that performance decrement need not occur as long as there is sufficient control over the S's observing behavior. Holland's approach involved having Ss participate more actively in the vigilance task by requiring them to make responses (key presses) in order to detect signals.

The purpose of the present research effort was to study vigilance performance and physiological responses in certain variations of the

Holland vigilance situation. More specifically there were two objectives of the present research: (1) to determine the effect of signal patterning upon physiological responses and time to detect signals; (2) to study performance of Ss, with and without patterning, under conditions in which they were either informed or uninformed about the signal patterning.

Several past studies have investigated the relation between signal patterning and vigilance performance and other investigations have been concerned with the relationship between certain physiological responses and vigilance performance. However, the question of the relationship between signal patterning on one hand and physiological activity and reaction time on the other still remains open. The paradigm developed by Holland (1958) for studying vigilance behavior was chosen to achieve the research objectives listed above. The brief literature review which follows in the subsequent section is intended to give an appreciation of some of the more pertinent studies in this area.

Holland (1958) devised a situation in which Ss (Navy men) were required to sit in a darkened room and to press a switch to light a display on which a signal was periodically presented. Holland used various schedules of signals but we will be concerned primarily with his fixed interval and variable signal scheduling. He found that under a regular signal pattern responses ceased for a time after each detection and then continued in an accelerated manner just before the next signal was about to occur. The effect of this type of responding was to produce a curve of response which resembles scalloping. The response rate under the irregular signal pattern was rather steady with a sharp slope, without any scalloping effect. Holland's major conclusion was that observing responses could be brought under the precise control of the signal schedule presented by the experimenter. A number of other studies have been conducted with respect to temporal patterning of signals, but none required Ss to make responses in order to detect signals as was the case in Holland's experiment. For example, Bevan, Hardesty and Avant (1965) studied reaction time (RT) of Ss at six constant and variable signal schedules of ten, twenty, forty, eighty, 160 or 320 seconds between signals. For all intervals except one (40 seconds), the constant interval groups had faster RTs than the variable interval groups, the difference in RTs between the constant and variable groups was an increasing function of time between signals, up to the 160 interval. For all groups, RTs were slower as the time interval between signals increased. Bevan et al. suggest that perhaps the relationship is such that as time uncertainty increases RT becomes slower.

Dimond (1966) found RTs to be significantly faster to regular than to irregular signals after nine minutes of performance. One group of ten Ss received regular signals on a RT task at the rate of 10 signals a minute while the other group of ten Ss had irregular signals presented at the same rate, with the inter-signal interval ranging between 4 and 10 seconds. Dimond interprets his results as indicating that faster RTs to regular signals represents the activity of the system which is able to distinguish the time characteristics of a task and can use them to produce improvement in performance. The effects of temporal and spatial uncertainty upon RT were studied by Adams and Boulter (1964). They found that a regular pattern of signals was more quickly responded to than a pattern of irregular signals. Spatial uncertainty (i.e., not knowing the location of signals presented on the display) was found to be more detrimental to RT measures than temporal uncertainty of signals. Adams and Boulter also found that increasing temporal and spatial uncertainty also increased the variability of the RT measures. They concluded that temporal uncertainty of signals leads to impaired expectancies and unreliable internal mechanisms for cuing the time of signal arrival, the net result being a reduced readiness to respond. The Ss in the Adams and Boulter study were allowed to become familiar with the nature of the temporal and spatial pattern of signals in a practice session, thus, for example, Ss knew whether signals were to be regularly spaced or irregular.

Some investigators have measured physiological responses in vigilance experiments in order to gain additional information about the state of individuals in these situations, perhaps with the eventual aim of being able to predict decrements in vigilance performance through the monitoring of physiological responsivity. Ross, Dardano and Hackman (1959) investigated skin conductance during a two hour vigilance session. The results suggested that higher conductance levels were associated with better vigilance performance, although the relationships found were not statistically significant. Several physiological measures were used by Eason, Beardshall and Jaffee (1965) as they studied performance in a vigilance situation. The physiological measures studied were skin conductance, heart rate, neck muscle tension and eye region responses (a composite of blinks, squints and vertical eye movements). The vigilance task required S to attend to a flashing light and to report when it stayed on longer than usual. The most important finding was that during the course of a vigil, performance and skin conductance significantly decreased. The authors interpret the decrease in conductance as being due to the drowsiness producing effects of the experimental situation, effects which resulted in a decrease in sympathetic nervous system activity. This decrease in sympathetic nervous system activity was accompanied by a decrement in performance (per cent of correct detections). Heart rate remained constant over the vigil and neck muscle tension increased significantly. The authors suggest that the increase in muscle tension may have been due to an attempt at compensation for the detrimental effects of fatigue, boredom, feelings of discomfort, and increased difficulty in concentrating on the light stimulus during the course of the vigil. The heart rate data were not very informative and the eye region response showed a slight non-significant increase suggesting that it added little information beyond that already provided by the muscle tension data.

Surwillo and Quilter (1965) studied the frequency of skin potential responses (SPRs) of Ss in an hour long watch-keeping task. The number of SPRs that occurred within the 18 second period before the critical signal was examined with respect to the number of correct detections. A significantly higher number of SPRs occurred in the 18 second period prior to detected signals as compared to SPRs in the same period immediately preceding missed signals. Other findings were that older Ss emitted fewer SPRs than did young Ss, and Ss who had a large number of SPRs had shorter RTs. The effects of signal patterning on RT and palmar skin conductance (PSC) was studied by Andreassi (1966). The responses of one S were studied over a period of 10 days. The hour long session was composed of two segments: a regular signal pattern with an inter-signal-interval of 60 seconds and a variable pattern in which the mean time between signals was 60 seconds, with a range of from 10 to 135 seconds. The S was required to respond to an auditory signal and was informed as to whether the signal pattern would be regular or irregular (a counter-balanced design was used). The RTs were significantly faster to the regular signal pattern. There was a gradual decrease in PSC over trials for both schedules with a greater range and variability in PSC values for the irregular as compared to the regular schedule. There was a general tendency for faster RTs to be associated with higher PSC values. In another experiment Andreassi (1966) obtained continuous measures of PSC as Ss responded to irregular auditory signals. Thirty-two RT trials were taken for each of 16 Ss over a 40 minute session. The results indicated that Ss had significantly faster RTs on the 10 trials in which PSC was highest as compared to the RTs for the 12 middle and 10 lowest PSC trials. There was a gradual decrease in PSC as the experiment progressed. A sharp decrease in PSC between the first and second 10 minute segment of the experiment was accompanied by a significant increase in RT.

The main trends of the studies briefly summarized above seem to indicate that: (1) RTs are faster to regular than irregular signal patterns; and (2) higher physiological activation appears to be related to better vigilance performance.

Method

Subjects: There were 32 Ss ranging in age from 18 to 40, eight were employees of the Naval Training Device Center (NTDC) and the remaining 24 were undergraduates from a nearby college. Each S was tested on two separate days with at least 24 hours between sessions.

Experimental Design: Eight different Ss were assigned to each of four conditions. Two Ss in each group were NTDC personnel. Ss were run individually in two 40 minute sessions on each of two days. The two sessions for each day were separated by a 10 minute rest period. Each 40 minute session consisted of a 20 minute fixed interval (FI) signal schedule and a 20 minute variable interval (VI) signal schedule for Group I. Groups II, III and IV had two 34 minute sessions each day, consisting of 17 minutes each for the FI and VI schedules. The FI and VI schedules were counterbalanced. When the FI schedule was being presented a small red indicator light on the upper right hand corner of the display was illuminated. A green light was used in conjunction with the VI series.

The four treatment groups were as follows:

a. Group I - The signals were 60 seconds apart in the FI series and at intervals varying from 15 to 120 seconds on the VI series, with a mean inter-signal-interval of 60 seconds. Ss illuminated the display by depressing a telegraph key, and were not informed as to the nature of the signal patterns or the relationship between these patterns and the indicator lights.

b. Group II - Signals were 34 seconds apart in the FI series and were at intervals varying from 15 seconds to 75 seconds on the VI series, with a mean inter-signal-interval of 34 seconds.

c. Group III - Conditions were identical to those of Group II except that the Ss were informed as to the nature of the signal patterns and their relationship to the indicator lights.

d. Group IV - Conditions were identical to Group II except that the display was constantly illuminated. Thus, Ss in this group did not use the telegraph key.

Instructions - The Ss were asked to sit quietly in a fixed chair which had wide arm rests. The following instructions were given to Group I Ss:

> Your task in this experiment will be to detect as many deflections of a meter needle as you can, and as quickly as possible. When the needle deflects it will move two units to the right. However, in order to detect these deflections you will have to operate a telegraph key which will light the screen from the rear. You will simply be asked to make as many

detections as possible and to reset the pointer as quickly as possible. The pointer can be reset by stepping on the foot pedal mounted on the floor directly in front of your right foot. The time you take to press down on the pedal will be recorded. While you are performing this task several physiological readings will be taken. In order to measure these physiological responses it will be necessary to attach several recording devices to the surface of your skin. To insure good readings it is important that you do not move your arms or hands during the experimental sessions. These contacts with your skin are perfectly harmless and there is no danger at all of your receiving an electric shock.

To sum up: Your task will be to detect as many needle deflections as possible and you will be able to notice a detection only when you press the key. As soon as you notice a deflection press down on the foot pedal as quickly as you can. This will reset the needle and you will then be ready to detect new needle deflections. We will have a practice session to make sure you know what to do, and you can ask questions either during or after the practice session.

Note: In a combat situation the needle deflections might represent squadrons of enemy planes coming in for an attack. Please use only the thumb of your right hand when pressing down on the key. Also, be sure and keep your right foot within the outline marked on the floor unless you are actually going to press the foot pedal.

Instructions for the other three groups were similar, but differed as the conditions of the particular group dictated, e.g., since Group IV Ss were presented with a continually illuminated display, they were not told to depress the telegraph key.

Sequence of Events - After the electrodes had been attached to the S and it was determined that the physiological recordings were being satisfactorily obtained, the S was asked to "relax as though you were going to sleep". Four 30 second resting samples were taken of each physiological measure. After two minutes the S was instructed to attend to the display and respond to several practice signals as they were presented. Following the practice trials the lights in the room were turned off, while white noise at a level of 80 db was played in the background (15 feet behind S) to mask external distractions, and the S was directed to attend to the display and respond as described in his instructions. After the last signal of each 20 minute series the S was again asked to relax and again four 30 second resting samples were taken. Resting measures were taken before and after each session and between each 20 minute series. Between the two sessions of each test day, S was disconnected from the recording apparatus and allowed to sit in the room adjacent to the experimental area for a ten minute rest. Thus, the sequence was: rest, practice, first signal schedule, rest, second signal schedule, rest, disconnect apparatus and rest, reconnect apparatus and rest, first signal schedule, rest, second signal schedule and rest. Continuous measures of physiological responses and performance were taken during detection and rest periods.

Electrode placements and apparatus: All the measures were continuously recorded with an Offner Type R Dynograph.

Heart Rate (HR) - One electrode was placed in the middle of the right forearm and the other on the left forearm. Each forearm was rubbed with alcohol and electrode jelly was rubbed in the skin prior to the electrode placement. A ground lead was clipped to Ss left ear lobe after the area was prepared with electrode jelly. The leads for heart rate were of shielded wire and were connected to the shielded ground of the Offner terminal board. Heart beats were recorded directly with an Offner A.C. coupler (Type 9806A).

Skin Resistance (SR) - Two Yellow Springs Instrument electrodes were clamped to the palm of the left hand. One electrode was placed below the index finger and the other below the base of the little finger; the center of the two electrodes was about 5 cm apart. The electrodes used consisted of two cm diameter zinc plates mounted in plastic cups, filled with zinc sulfate paste. Skin resistance was recorded directly with an Offner SR coupler (Type 9892A). The coupler was periodically balanced and SR level written on the recording paper by E.

Galvanic Skin Responses (GSRs) - GSRs in the context of the present investigation was defined as a change in basal SR greater than 1,000 ohms occurring within a 2 second time interval, as measured from the time of initial pen deflection.

Apparatus

Signal Presentation Equipment - The apparatus allowed a volt-meter needle to be deflected at intervals pre-programmed by the experimenter. The meter was 5" x 2 3/8", and mounted on a wooden panel which was 48" high and situated such that the meter was approximately 66" from the eyes of Ss. The center of the volt-meter was located 41" from the floor at approximately eye level of the seated S. The normal needle position was vertical and when deflected moved two units to the right. The meter was located two feet behind a 24" square one-way aluminum mirror. The mirror was located in the center of a 48" wide screen. This arrangement allowed the S to view the meter only when he pressed a telegraph key, which turned on a light for a period of 200 milliseconds.

Deflections of the meter needle were programmed by a Lehigh Valley Electronics tape programmer. When the tape reader fell into one of the punched holes on a film strip the needle remained deflected for five seconds and the programmer unit stopped until the S stepped on a foot pedal with his right foot. This foot action stopped the clock so that his RT could be recorded, returned the needle to the vertical position, and started the programmer unit to time the next interval. RT was recorded by a Standard electric timer and by one of the

Dynograph pens. Two Lafayette interval timers were used to control the time of needle deflections and the duration of the display illumination. The meter was illuminated by a Sylvania 100 watt lamp.

Each time S pressed the telegraph key a cumulative recorder (Scientific Prototype) was activated, thus providing a continuous record of each S's response pattern. The number of responses for each session was recorded on a digital counter (Scientific Prototype).

Samples of each physiological measure were taken for each 10 second period prior to each needle deflection. The HR measure was the number of beats which occurred in this 10 second period. These measures were multiplied by 10 to obtain beats per minute (BPM). The number of GSRs were counted within this 10 second time frame according to the criterion set and the level of SR used was that indicated at the moment of needle deflection. Reciprocals of these resistance values were multiplied by 1 million to obtain conductance units (micromhos).

RESULTS

The primary focus in this section is on the within group comparisons, i.e., the RT and physiological data of the same Ss when they were exposed to patterned as compared to unpatterned signals.

Means

The RTs were found to be shorter for the FI than the VI signal schedule for all four groups (see Table 1). However, t-tests for

TABLE 1

MEAN VALUES OF PHYSIOLOGICAL AND RESPONSE MEASURES GROUPS I - IV, UNDER FIXED AND VARIABLE INTERVAL SIGNAL SCHEDULES

Group and Condition		RT (Seconds)	HR (BPM)	PSC	GSRs	Mean Responses Per Session	Signals Missed
Group I	VI	1.05	86.40	6.22	.69	4425	0
	FI	.96	85.20	6.26	.70	4316	0
	Rest	---	81.96	5.47	.30	---	
Group II	VI	.96	81.60	4.83	.49	3032	0
	FI	.94	81.00	4.71	.50	2940	0
	Rest	---	79.20	4.13	.29	---	
Group III	VI	1.03	80.40	9.60	.70	3647	0
	FI	1.01	80.40	8.65	.69	3189	0
	Rest	---	82.80	7.54	.75	---	
Group IV	VI	.58	85.80	7.26	.66	---	0
	FI	.56	85.80	7.12	.81	---	0
	Rest	---	85.80	6.68	.46	---	

correlated data indicated that the differences were not significant. The mean number of key pressing responses was greater under the VI schedule for Groups I, II and III (Group IV was not required to press). However, the only significant difference was in a greater number of responses made on the VI schedule for Group III ($t=4.27$, 7 df, $p < .01$). There were no missed signals for any of the four groups.

HR was slightly higher under the VI schedule for Groups I and II while it was identical under both schedules for the other groups. PSC was higher under VI for all groups except the first, however, none of the PSC differences were significant. The number of GSRs was higher for the FI schedule in three of the four groups, with a significant difference for Group IV ($t=2.46$, 7 df, $p < .05$). All of the mean resting levels of the physiological variables were lower than the working levels except for HR and GSRs with Ss in Group III (Table 1).

Correlational Analysis

Table 2 shows the correlations between RT and each physiological variable for all groups. Twenty-one of the 24 correlations were negative,

TABLE 2

PEARSON CORRELATION COEFFICIENTS FOR PHYSIOLOGICAL MEASURES AND REACTION TIME GROUPS I - IV, UNDER FIXED AND VARIABLE INTERVAL SIGNAL SCHEDULES

Group and Condition		RT and HR	RT and PSC	RT and GSR
Group I	VI	+ .32	- .07	- .36
	FI	- .16	- .07	- .45
Group II	VI	- .04	- .04	- .04
	FI	- .22	- .01	- .03
Group III	VI	- .13	- .30	- .39
	FI	- .16	- .37	- .28
Group IV	VI	+ .12	- .42	- .02
	FI	+ .16	- .38	- .09

indicating a trend in which RT was faster with increased physiological activation. The three positive correlations (i.e., those not in the expected direction) all involved HR, and two of these occurred in Group IV. A correlation of .71 would be required for statistical significance with 6 df.

Variability Data

Physiological Measures

HR - The standard deviations for HR indicate consistently greater variability under the VI than the FI schedule, i.e., for each of the four groups. The standard deviations for all groups and conditions are shown in Table 3.

TABLE 3

STANDARD DEVIATIONS OF PHYSIOLOGICAL AND RESPONSE MEASURES, GROUPS I - IV, UNDER FIXED AND VARIABLE INTERVAL SIGNAL SCHEDULES

Group and Condition		RT	HR	PSC	GSRs	No. of Responses
Group I	VI	.28	2.81	3.37	.61	1.41
	FI	.24	2.74	3.31	.68	1.41
Group II	VI	.18	2.10	2.53	.31	1.26
	FI	.19	2.01	2.10	.32	1.13
Group III	VI	.44	1.78	6.89	.36	1.63
	FI	.50	1.69	6.33	.43	1.90
Group IV	VI	.43	1.64	3.75	.44	---
	FI	.43	1.53	4.00	.47	---

PSC - This measure shows more variability under the VI schedule in three of the four groups, with Group IV as the exception.

GSRs - GSRs showed greater variability under the FI schedule in all four groups.

Response Measures

RT - The RT data were not consistently more variable for either of the signal schedules.

Number of Responses - The data for number of responses show no consistent tendency for greater response variability with either of the signal schedules.

Cumulative Records

The cumulative record of two Ss out of 32 showed scalloping with the FI schedule. ("Scalloping" refers to a decrease in responding after signal detection and an increase in responding just prior to the occurrence of the next signal.) One of these Ss was in Group I and the other S was in Group III. It will be recalled that Ss in Group I were uninformed and Group III Ss were informed as to the nature of the signal patterns.

DISCUSSION

The fact that there were no missed signals indicates that the requirement to respond did not interfere with signal detection for Groups I, II and III, and the primary performance data, therefore, are RTs. There was a tendency for RTs to be faster with the patterned (FI) schedule than the unpatterned (VI) schedule. This finding may reflect greater learning by Ss of the FI schedule as compared to VI. Adams and Boulter (1964) explained the superiority of FI in terms of improved expectancies, while Bevan et al. (1965) used a similar explanation but phrased it as a decrease in uncertainty and Dimond (1966) suggested that a timing system operates within the individual.

The finding that RTs under the two schedules were not significantly different may be due to the fact that Ss responded less under the FI schedule. That is, the displays were lighted for more of the time under the VI schedule and this could have attenuated, somewhat, the advantage in RT usually found with FI signal schedules. The Ss had to work harder under the VI schedule to maintain speed of RT since they were probably more uncertain as to the appearance of signals with this condition.

The magnitude of physiological response did not differ much with the two signal schedules. However, the correlation and variability analyses of the physiological data were meaningful. The fact that the number of GSRs was slightly higher for the FI schedule than VI for three of the four groups seems to indicate that the Ss had learned to anticipate the signal, and the greater number of GSRs occurring in the

10 second period before the signal might be taken as an increased readiness to respond (increase in sympathetic nervous system activity) under the FI condition.

The correlational analyses indicated that RTs tended to be faster when Ss showed higher degrees of physiological activation (i. e., higher PSC, GSRs and HR). A similar result has been reported by Kennedy and Travis (1948) for muscle potentials and RT; by Lansing, Schwartz and Lindsley (1959) for EEG and RT; and by Andreassi (1966) for PSC and RT. One possible explanation for the faster RTs is that the higher degree of physiological activation caused more sensory impulses to travel to cortical areas via the reticular formation thereby improving alertness and readiness to respond. The effect of reticular stimulation has been shown to improve the accuracy of visual perception and speed of reaction time (Fuster, 1958) and the capacity of the visual cortex to resolve two separate visual signals appearing almost simultaneously (Lindsley, 1958). It has been suggested that reticular stimulation results in a sensitization of cortical areas to incoming sensory stimuli and a reduction in cortical processing time (Fuster, 1958 & Lindsley, 1960).

In a study by Andreassi (1966) it was found that a variable signal pattern produced significantly greater variability in PSC than did a fixed signal pattern, in a situation where S was not required to respond in detecting auditory signals. The findings of the present study confirm the earlier one of greater variability in PSC measures with a variable signal pattern, and, in addition, similar results for HR were obtained. The fact that there is greater variability in GSRs under FI could be due to the tendency for more GSRs to occur in this condition. Since the range in number of GSRs which can occur is usually of the order of 0 to 3 in the 10 second sample period, then there would be more of a tendency for higher variability under a condition in which more GSRs occur. The question now arises with respect to how many different physiological measures would show greater variability under conditions of variable stimulus patterning as compared to fixed stimulus patterning.

The lack of scalloping in the cumulative records was not expected in view of Holland's (1958) findings. However, the result can be explained since post-experimental interviews indicated that Ss either did not learn to differentiate between the FI and VI or even when informed of the difference they thought they were expected to keep up a high rate of responding. The informed group (Group III) did have one S who showed scalloping, but the rest of the Ss responded at steady rate throughout the FI and VI, although they made significantly less responses under FI. Blair (1958) has suggested that scalloping will not occur when key tensions are light (i.e., the effort required to make a response is small). Perhaps Ss would not respond so readily under both conditions if greater effort was required for making a response and they were thereby more highly motivated to reduce their energy expenditure.

IMPLICATIONS FOR TRAINING

1. Higher degrees of the physiological measures used in this study (HR, PSC, and GSRs) tended to be related to faster RTs. This finding indicates that these measures may be good indicants of a man's readiness to respond and, as such, are of potential utility in vigilance situations (both training and operational).

2. The finding of greater variability in physiological measures with variable signal patterning suggests an interesting possibility in terms of future vigilance research. If it is found that individuals react faster to signals when their physiological activity level is undergoing shifts in magnitude then it may be desirable to introduce random signal patterns to which a trainee must respond in a training or operational situation. In other words, physiological variability can be induced if it is found that this state is related to superior vigilance performance.

3. Response patterning may be an important variable to take into consideration in vigilance situations since it may be that detection performance is related to response patterning. It may prove feasible to train men to make temporal and spatial patterns of observing responses, e.g., orientation of the eyes, in vigilance situations.

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13. ABSTRACT

The purpose of the ~~present~~ investigation was twofold: (1) to determine the effect of signal patterning upon physiological responses and time to detect signals; (2) to study performance of subjects (Ss), with and without patterning, under conditions in which they were either informed or uninformed about the signal patterning.

Vigilance performance and physiological responses with variable interval (VI) and fixed interval (FI) signal patterns were studied in four groups of Ss. Three of the four groups were required to make responses (telegraph key presses) in order to detect signals. Reaction time (RT) was used as the performance measure while heart rate (HR), palmar skin conductance (PSC) and galvanic skin responses (GSRs) were the physiological measures. Each S was tested in two separate one hour sessions on each of two days.

The results indicated that there was a tendency for RTs to be faster under the FI schedule of signals than with the VI. The HR and PSC measures showed higher variability with the VI schedule while GSRs were more variable under the FI schedule. Faster RTs tended to be related to higher levels of HR, PSC and GSRs. It was suggested that: 1) faster RTs under the FI schedule reflected greater learning of the regular signal pattern; 2) faster RTs with higher degrees of physiological activation were due to greater numbers of sensory impulses which traveled cortically and had effect of improving alertness and readiness to respond. Several implications of these results for training ~~were~~ discussed.

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