MODIFICATION OF OBSERVING BEHAVIOR¹

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The effects on monitoring performance of a limited hold (LH) terminated by a bell or by electric shock and of periodic rest periods were investigated. The sensitivity of basal skin conductance to different monitoring conditions was also studied. Humans monitored a visual display in several 2-hr sessions under the Holland procedure. In each session, signals were programmed by one of the following three multiple schedules: a variable interval of 6 min (VI 6) and a VI 6 with a limited hold (LH) terminated by a bell; a VI 6 and a VI 6 LH terminated by electric shock; a VI 6 LH terminated by shock and a time-out (TO). The two components of each schedule alternated at 15-min intervals. The average observing response rate of eight subjects was lowest during the VI 6 periods, higher in periods when the LH was terminated by a bell, and highest when the LH was terminated by shock. Periodic TO periods did not appreciably increase the response rate under the VI 6 LH shock component. A differential level of palmar skin conductance under the two components of a schedule was present only under the mult VI 6 LH shock-TO.

In the typical "vigilance" task, the observer monitors a visual display and detects infrequent, aperiodic signals over an extended period of time. Effective performance in this task demands a sustained readiness to respond. The criteria of the effectiveness of monitoring performance have been time-sampling measures, such as reaction time to the signals and frequency of missed signals. From the magnitude of such measures, the observer's readiness to respond during non-sampled parts of the task is inferred.

Holland (1957) devised a technique which permitted a continuous and direct measure of observing behavior. The observer was required to depress a key which momentarily illuminated the search area and permitted the observer to ascertain the presence or absence of signals. With this technique, Holland showed that the temporal properties of the observing responses were dependent upon the temporal

characteristics of the signal program. When the signal program was a long variable-interval (VI) schedule, the frequency of observing responses declined during the session. This decrement in performance has been a common finding in vigilance studies.

Utilizing the Holland procedure, the present study examined the effects of interpolated time-out (TO) periods, a limited hold terminated by a brief ring of a bell (LH bell) and a LH terminated by electric shock (LH shock) on the observing behavior under a VI 6 signal schedule. Studies which have used time-sampling measures have reported that knowledge of results and rest periods result in improved monitoring performance (Mackworth, 1949; McCormack, 1958, 1959). A further aim of this study was to ascertain any relationship between the various monitoring conditions and properties of basal skin conductance. It has been shown that an appreciable performance decrement during a monitoring session was accompanied by a continuous decline in basal skin conductance (Dardano, 1962). Assuming that the level of basal skin conductance reflects the "alertness" of the observer, differences in attentiveness under each component of a schedule would be indicated by different conductance levels under each component.

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METHOD

Subjects

Eight volunteers, ranging in age from 18 to 21, were used. Subjects 2, 4, and 6 were women. Payment for services was \$2.50/hr with reimbursement after completion of the eight scheduled sessions.

Apparatus

The experimental chamber, approximately 7 by 12 by 12 ft, was furnished with an exhaust blower, a fan, a chair with adjustable arms, and a counter. An air duct, connected to an air conditioner in the adjacent room, was located on a side wall. Temperature was controlled by a thermostatically-regulated portable heater and varied between 73 and 77 degrees F. A one-way vision window on the side of the room permitted observation of the subject. All programming and recording equipment was located in an adjacent room.

The monitoring console, approximately 24 by 16 by 30 in., was placed on the counter. A voltmeter was mounted within the console, the panel of which could be viewed by the subject through a 4 by 3.5 in. window. The signal requiring detection consisted of a deflection of the voltmeter needle to a vertical position. When the subject depressed a push-button switch, mounted below the window, with a force of 1000 g, the panel of the voltmeter was illuminated for .1 sec. The push-button was located within a well and was enclosed by a hood. The subject could place his hand within the hood and reach the push-button switch by inserting his second or third finger into the well. This arrangement limited the key-pressing response to movement of a single digit. The inconvenience of the response eliminated continuous high response rates on the key without requiring an excessive effort to operate the switch. The key depressions were recorded on a Gerbrands cumulative recorder. The depression of a foot switch by the subject reset the voltmeter needle, and the interval between onset of the signal and closure of the foot switch was recorded on a digital print-out counter in units of .1 sec.

The electrodermal measurement circuit was essentially a 1.34 v mercury cell (Mallory RM-42-R), a precision fixed resistor, and the subject, all connected in series, and a millivoltmeter (Varian G-10) connected across the fixed

resistor. Since the total voltage in the circuit was constant and the resistance of the fixed resistor was negligible in relation to the resistance of the subject, the voltage drop across the fixed resistor varied with the reciprocal of the subject's resistance. Thus, the record of voltage changes on the millivoltmeter could be read as the subject's conductance on a linear scale. The absolute values of conductance depended on the particular value of the fixed resistor which was inserted into the circuit. The alternative resistance values permitted convenient recording of subject resistances from 12.5 K to 400 K.

The electrodes for the electrodermal response were zinc discs, .25 in. in diameter, mounted on a Plexiglas base. Corn pads were fastened to the middle joints of the second and third fingers on the subject's left hand. These pads were filled with zinc sulphate paste. The electrode was fitted onto the pad and secured to the finger by plastic tape. Electrode leads ran to a wrist band and then to a jack. Details of the electrode technique are presented by Lykken (1959).

Electric shock was delivered to the upper right arm of the subject through silver discs, $\frac{13}{16}$ in. in diameter. The electrodes were secured with an elastic bandage. Intensity of shock was 1.5 ma; its duration was .2 sec. This shock level was judged as painful but tolerable. The source of the shock was a constant current stimulator.

Procedure

Each subject served for eight sessions. One session was scheduled on a single day, and each subject completed all sessions within three weeks. The session included a continuous 2-hr monitoring period, a 15-min pre-test period and 5-min post-test period. All instructions for the task were given before the first session. The subject was instructed to detect the signals and respond to them by depressing the foot switch as rapidly as possible. The subject was told that reaction times to the signals and skin conductance during the session would be recorded but was not informed about the recording of the observing responses. A brief practice period followed the general instructions.

The signal program was a VI 6 in all sessions. Three temporal patterns of signals were used. In the first session, all subjects monitored a VI 6 schedule. In the remaining seven ses-

sions, multiple schedules were programmed. Each of these schedules consisted of two components which alternated at 15-min intervals. The presence of each component was correlated with the illumination of a red or green panel light on the console. Three multiple schedules were employed: a VI 6 and a VI 6 with an LH terminated by a bell (mult VI 6-VI 6 LH bell); a VI 6 and a VI 6 with an LH terminated by shock (mult VI 6-VI 6 LH shock); and a VI 6 with an LH terminated by shock and periods of non-monitoring (mult VI 6 LH shock-TO). The duration of the LH, adjusted in accordance with the subject's reaction times in earlier session, varied from 1.0 to 1.7 sec and was 1.2 sec in most sessions. When the second component was a TO period, the subject was instructed to relax during these four periods; when the LH contingencies were programmed, the subject was told that these periods were included to inform him of reaction times which exceeded a pre-arranged minimum for that session. The duration of the LH was not revealed to the subject. The multiple schedules were utilized to furnish an intra-session measure of the reliability of the changes in observing rate resulting from the different monitoring conditions and also of

the changes in skin conductance occasioned by the different conditions.

After the experimenter left the chamber, the 15-min pre-test period was started. The subject was not interrupted during the session. After the session, the subject was questioned about room temperature, distractions, and any other factors which might have affected performance.

RESULTS

The average observing response rates under each of the three monitoring conditions for each subject are summarized in Table 1. For the mult VI 6-VI 6 LH bell and mult VI 6-VI 6 LH shock schedules, the response rates under the first and second components are listed in order. The numbers in parentheses indicate the total number of missed signals during the four periods under the LH contingency. Response rates from additional sessions under a given condition for a subject are listed in order of the sessions. The LH was 1.2 sec unless otherwise indicated by the superscript beside the response rate.

As seen in Table 1, both LH contingencies increased the rate of observing responses. The LH shock contingency exerted a stronger and

Table 1

Summary of response rates in Rs/sec under three schedules for each subject. The rates in the first and second components of the schedule are listed in order. Numbers in parentheses indicate total missed signals during LH periods.

	<i>VI 6-VI 6 LH Bell</i>				<i>VI 6-VI 6 LH Shock</i>				<i>VI 6 LH Shock-TO</i>			
S-1	1.6	2.4 ^d	(0)		1.8	3.3 ^a	(0)		3.3 ^b	(0)		
					1.9	3.1	(0)		3.4 ^a	(1)		
S-2	1.0	1.1 ^b	(0)		1.2	1.4 ^b	(1)		1.4 ^b	(0)		
					1.5	1.7 ^a	(4)		1.4 ^a	(4)		
S-3	.9	1.1	(8)		.4	1.9	(2)		2.1	(0)		
					.6	1.9 ^a	(7)		2.3	(1)		
					.3	1.2 ^a	(7)		2.8	(0)		
S-4	.6	.8	(6)		.8	1.1	(9)		1.0	(7)		
									1.1	(7)		
S-5	1.3	1.2	(8)		.7	2.1	(0)		1.8	(1)		
									2.1	(0)		
S-6	1.2	2.1	(2)		.5	2.4	(2)		3.0	(0)		
									2.6	(2)		
S-7	1.0	1.8 ^a	(6)		.8	1.8	(3)		1.6 ^c	(4)		
									1.9 ^c	(1)		
S-8	.4	1.0	(6)		.5	1.7	(4)		2.1	(2)		
									2.7	(1)		
Mean	1.0	1.4			.9	2.0			2.1			

^aLH = 1.0 sec; ^bLH = 1.5 sec; ^cLH = 1.7 sec; ^dLH = 2.0 sec.

more consistent effect. The group response rates under the VI 6 component of the mult VI 6 LH bell and the mult VI 6-VI 6 LH shock schedules were nearly identical, indicating that the higher rate under the LH shock contingency did not generalize to the VI 6 periods. Note that the response rates of subjects 3, 5, and 6 under the VI 6 were appreciably lower when this component was paired with the LH shock contingency. Comparison of the individual performances under the mult VI 6 LH shock-TO and mult VI 6-VI 6 LH shock schedules reveals that the TO contingency did not consistently increase the response rate under the LH shock contingency.

The pattern of response rates within a session is shown in Fig. 1. The average response

rates in successive 15-min periods under each monitoring condition are presented for each subject. For those subjects having more than one session under the same schedule, the data from the final session were plotted. The lower-right graph presents the average performance of the group. In each of these graphs, the LH contingencies and the TO periods were present on even-numbered periods.

The graph of the group performance shows that the differences among observing response rates under the various monitoring conditions were consistently present during the session. Response rates in periods under the LH contingencies were always higher than the rates in periods without the LH, and response rates under the LH shock contingency were always

Fig. 1. Mean observing response rate for each 15-min period for each subject. Each individual graph presents the rates for one session under each of the three monitoring conditions. The average performance of all subjects is presented in the lower right graph. Under the mult VI 6-VI 6 LH bell, labeled "bell" in the legend, and the mult VI 6-VI 6 LH shock schedule, labeled "shock" in the legend, the LH contingencies were present during even-numbered periods. Under the mult VI 6 LH shock-TO, labeled "rest" in the legend, the TO periods occurred on even-numbered periods.

higher than those under the LH bell. Regarding overall trends during the session, the average performance of the group shows slight but regularly increasing trends for the four periods under the LH bell and the four periods under the LH shock contingencies.

Cumulative records from sessions under the mult VI 6-VI 6 LH bell schedule and mult VI 6-VI 6 LH shock schedule for each of three subjects are shown in Fig. 2. The first 30 min and final 30 min of each session were deleted. These records were selected to show the range of variations in response patterns during the sessions. It can be seen that the LH contingencies, especially the LH shock, eliminated many of the irregularities in the response patterns.

The mult VI 6 LH shock-TO was the only schedule which resulted in a consistent difference between the conductance levels under each component. Six of the eight subjects had lower average conductance levels during the four TO periods relative to the four monitoring periods, one showed no consistent differ-

ence, and one had a higher average conductance during the TO periods. Figure 3 includes graphs for the seven subjects who did exhibit differences under each component of this schedule. The lower right graph presents the average conductance of the six subjects who showed higher conductance levels during the monitoring periods.

The conductance values of each subject were derived from the lowest conductance reading in successive 1-min intervals of the session. The first minute of each 15-min period was discarded to eliminate the effect of the GSRs resulting from the buzzer signal at the start of the session and from the change in the color of the panel light. The remaining 14 values in the period were averaged over successive pairs. The points in the individual graphs represent these 2-min averages expressed as the per cent of the highest 2-min average in the session. In the graph of the group average, each point represents the average conductance of one subject for that 15-min period, expressed as the per cent of that sub-

Fig. 2. Cumulative records from one session under the mult VI 6-VI 6 LH bell schedule and one session under the mult VI 6-VI 6 LH shock schedule for each of three subjects. The first and final 30 min of the session are deleted. Pips indicate signals, the arrows indicate missed signals.

Fig. 3. Mean conductance level in successive 15-min periods for individual subjects. The graph at the lower-right presents the average of the individual functions except that of S-7. Open circles represent conductance values during the TO period; closed circles, during monitoring periods. See text for explanation of values within the graph and the unit expressing conductance level.

Fig. 4. The conductance record of S-4 during a 2-hr session under the mult VI 6 LH shock-TO schedule. Each of the 15-min segments reads from right to left. The values listed at the extreme upper left of each 15-min segment are the mean conductance values for the 15-min periods. Numbered arrows during the monitoring periods denote the occurrence of signals.

ject's highest 2-min average in the session. The means of the seven points in each period are connected. The values listed within each graph are the average conductances in micromhos for the four monitoring periods (M) and the four TO periods (R) and their equivalent

in per cent of the highest 2-min conductance average in the session.

The general trend of the conductance level during a session declined for all subjects except S-4. As a result, the average conductance level for the four TO periods would be less

than the average level during the monitoring periods due to the order of presentation of the two conditions. For this reason, the average conductance values for the four periods under each condition, listed within each graph, were calculated without the data from the first monitoring period and the last TO period. The elimination of these data resulted in an order effect which favored a higher conductance level during the rest periods. Therefore, the magnitude of the differences between the conductance levels under the two conditions for six subjects is a conservative estimate. With regard to the average conductance for each 15-min period in a session, the same conductance level in a monitoring period as in the preceding TO period would indicate a relation between the monitoring condition and conductance level since it would represent a counteraction to the overall declining trend of conductance. As seen in the individual graphs of Fig. 3, most conductance levels in the monitoring condition not only counteracted the declining trend but were higher than the level in the preceding TO period.

The pattern of the conductance changes during the TO period and during the monitoring period exhibited only one obvious difference. Several subjects in one or more of the TO periods exhibited a continuous and gradual decline in conductance level with occasional smooth deflections during the decline. The conductance record of S-4 during a session under the mult VI 6 LH shock-TO schedule, shown in Fig. 4, illustrates this property. The record reads from right to left. Arrows indicate the occurrence of a signal. The value in the upper left of each segment denotes the average conductance level in micromhos for that 15-min period.

DISCUSSION

Since the probability of rapid detections is increased by a high rate of observing responses, a subject following the instructions to detect and respond to the signals as rapidly as possible should show the same rate under each component of the mult VI 6-VI 6 LH bell and mul VI 6-VI 6 LH shock schedules. In most cases, however, a rate specific to each component developed immediately. Besides this failure of complete generalization from the LH periods to the no-LH periods, there were in-

stances in which the observing response rate under the VI 6 component was appreciably reduced when the second component was changed from LH bell to LH shock.

Since active cognitive work can influence skin conductance (Woodworth and Schlosberg, 1954), the analysis of conductance levels during the TO periods of the mult VI 6 LH shock-TO schedule was complicated by possible cognitive activity by the subjects. Although the subjects were instructed to relax during these periods, their activity was undefined and can only be assumed to be non-monitoring. An attempt to determine the sensitivity of the electrodermal measurement procedure to cognitive exercise consisted of permitting S-5 to study a textbook during the TO periods of one session. This modification resulted in a slightly higher conductance level during the TO periods relative to the monitoring periods. The deviant conductance pattern of S-7, shown in Fig. 3, might reflect the elevation of conductance by such cognitive activity.

A further methodological difficulty was present in the comparison of conductance levels under each component of the mult VI 6 LH shock-TO schedule. The occurrence of GSRs to the signals would tend to raise the average levels during the monitoring periods. This effect was diminished by the use of a low VI signal and by the sampling procedure in which the lowest conductance value in a 1-min interval was used in calculations.

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