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CONTROL OF HUMAN VIGILANCE BY CONCURRENT SCHEDULES[1]

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Twenty four subjects were studied for ten 1-hr sessions to determine whether the human observer's visual monitoring of individual meters in a complex display can be differentially controlled by concurrent scheduling of signals. Subjects were divided into two main groups of 12 each. One group was given fixed-interval, variable-interval, and differential-reinforcement-of-low-rates schedules. The second group was given fixed-interval, fixed-ratio, and differential-reinforcement-of-low-rates schedules. Test subjects were instructed only to detect as many signals as possible. Results indicated that observing responses to the individual meters corresponded to the temporal patterns known to be associated with the schedules for the group given fixed-ratio instead of variable-interval as a component schedule. The group given the variable-interval schedule in the three-schedule combination tended to exhibit the same pattern of viewing across each of the three meters during any given session. However, subsequent testing was performed on two more subjects over 64 sessions, by adding initial feedback of signal detection results, and instructions concerning schedule construction. These results indicated that with knowledge of schedule construction and initial feedback of detection data, differentiated responding can be maintained efficiently over long periods of time by the combination including fixed-interval, variable-interval, and differential-reinforcement-of-low-rates schedules.

Holland (1958) showed that the human observer's visual monitoring of a single-meter display can be controlled by the schedule of signal occurrence. His subjects could briefly illuminate a test meter by pressing a switch. Their task was to detect pointer deflections, which occurred according to several classical reinforcement schedules. The subjects' temporal patterns of "observing behavior" (pressing the switch) conformed to the schedule of pointer deflections in the same ways as did animal behavior reinforced with food on similar schedules (Ferster and Skinner, 1957). Schroeder and Holland (1968) reported that eye movements can be controlled by signal presentation schedules in the same way as the more conveniently recorded measurement of observing responses, using switches to illuminate a test meter.

The present study was performed to determine whether the human observer's visual monitoring of a multiple-meter display can be differentially controlled by concurrent scheduling of signals. If each of three test meters present signals according to different schedules, will the observing responses to an individual meter correspond to the temporal pattern of responding known to be associated with that schedule? Alternatively, a complex interaction of the schedules might result (Sidman, 1957; Sidman, 1958; Herrnstein and Sidman, 1958; Kelleher and Cook, 1959), leading to other findings.

METHOD

Subjects

Twenty-four male graduate and undergraduate students were obtained on a paid volunteer basis from a local university. Four other students were rejected because they failed to complete the entire experiment. Two other students from the same university were tested for the 64-trial portion of the study.

Apparatus

The subject panel is illustrated in Fig. 1. Test subjects monitored three Shurite Model No. 850 meters recessed behind silvered glass panes. A meter face could be briefly illuminated by activating a pushbutton switch. The three pushbutton switches were located on the left side of the panel for left-hand operation.

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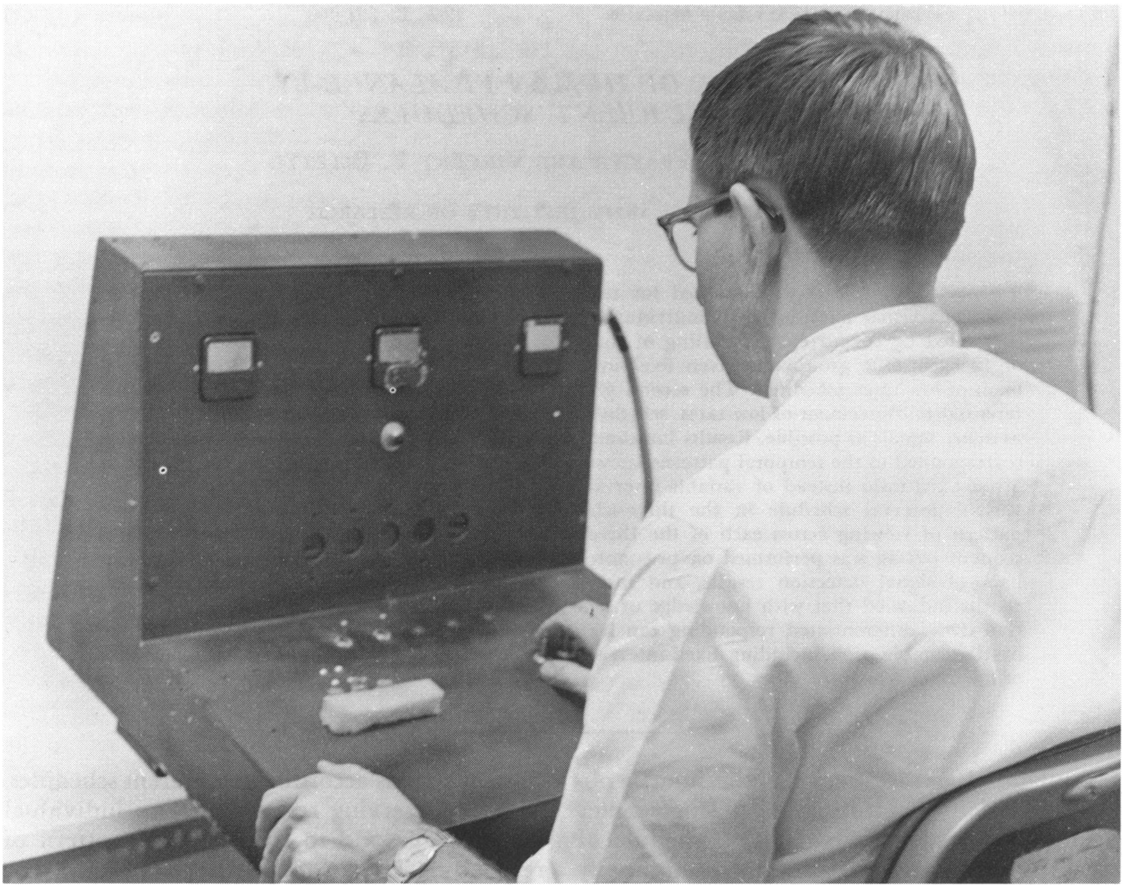

Fig. 1. Photograph of subject operating test panel used to study concurrent schedules of signals.

When an observation (switch closure) was made, the corresponding meter face was illuminated for 0.1 sec. A force of 50 g was required to depress each of the three observing switches. Observing switches were located 1.0 in. apart. The three meters were located 7.0 in. apart. Pointers normally rested at zero positions. A deflection represented an excursion of about 43 degrees from the null position. No more than one meter face could be illuminated simultaneously, although more than one observing key could be depressed at the same time. While the left hand could be used more conveniently for observing switch presses, the right hand was substituted from time to time by many subjects. A detection lever was provided for each of the three meters, to reset the corresponding pointers. The three detection-lever switches were located on the right-hand side of the panel, 1.25 in. apart. The subject's task was to illuminate the meters by pressing pushbutton switches (observing response) and to reset the meter pointers by pressing the appropriate levers (detection response).

Observing responses to each test meter were recorded on a separate cumulative recorder. Signals, detections, and observing responses were also recorded on a 20-channel event recorder.

Procedure

Test subjects were divided into two groups of 12 subjects each. The first major group was given a fixed-interval (FI) schedule on the left meter, a variable-interval (VI) schedule on the center meter, and a differential-reinforcement-of-low-rates (DRL) schedule on the right meter. Schedule parameters were varied slightly in one half of the group to test consistency of results. Six subjects in this group were thus given FI 30-sec, VI 30-sec, and DRL

7.5-sec. The other six subjects were given FI 1-min; VI 1-min; and DRL 10-sec.

The second group of 12 subjects was given a fixed-ratio (FR) schedule on the middle meter, instead of the VI schedule. Six were given FI 30-sec; FR 30; and DRL 7.5-sec. The other six were given FI 1-min; FR 20; and DRL 10-sec.

Each test meter was arranged so that the pointer reset automatically after a signal duration of 15 sec if the subject failed to detect the deflection.

Test subjects were given no information which might suggest that pointer deflections were scheduled differently. During their initial exposure, they were told that the purpose of the experiment was to study effectiveness of panel monitoring. They were asked to detect as many signals as possible, and as rapidly as possible. Following these instructions a subject was shown how to operate an observing switch and a detection lever. They were shown which detection lever and observing key corresponded to each panel meter. Signals were manually presented for them to observe and detect. When the subject had learned the operation of the panel the instructions were repeated, as follows: "Your task is to detect as many signals as possible and as quickly as possible. You will be told through the intercom system when to begin and when to stop."

RESULTS

Of the 24 test subjects, 18 showed changes in observing rate patterns from their initial observing behavior. The remaining six subjects failed to show any change in pattern of re-

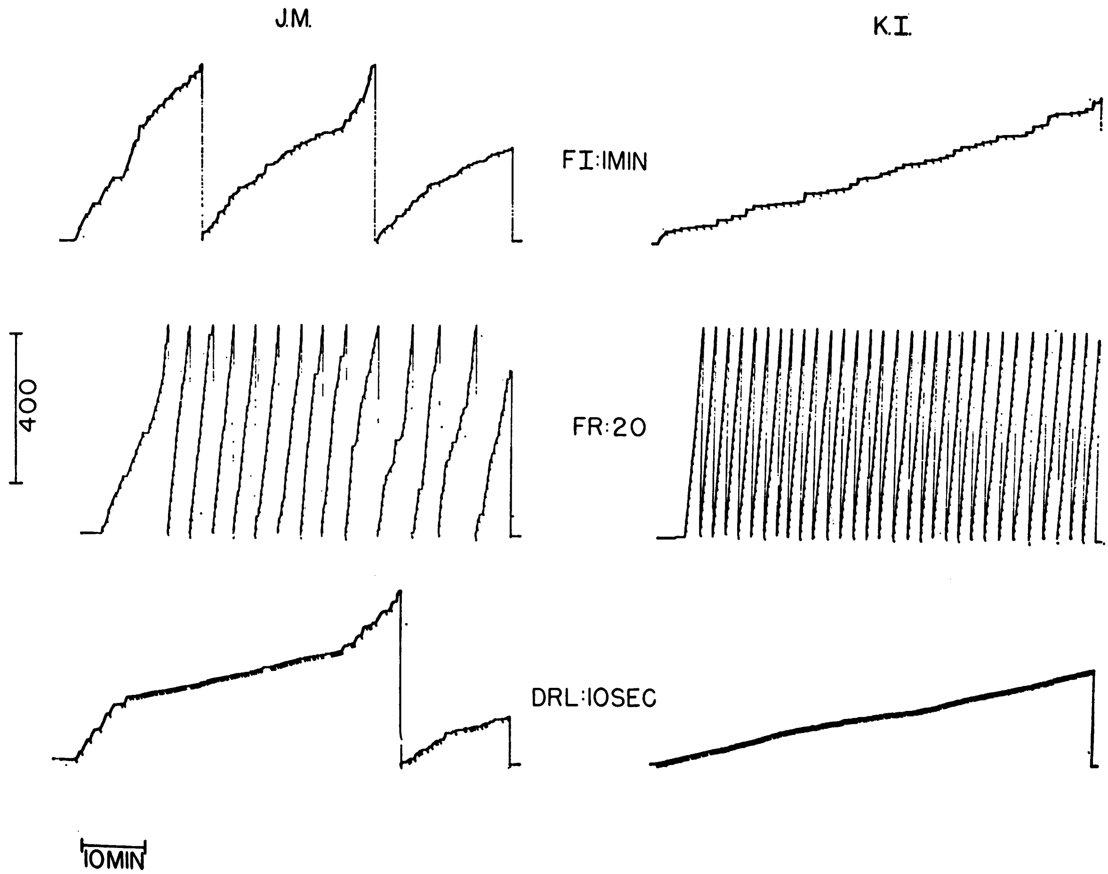

Fig. 2. Cumulative records of observing rate for two subjects for each of the three meters. The two records in the top row show responding to the left meter, which was operated by a fixed-interval schedule. The two records in the middle row show responding to the center meter, which was operated by a fixed-ratio schedule. The two records in the bottom row represent responding to the right meter, which was operated by a differential-reinforcement-of-low-rates schedule.

sponding from one session to another, or from one schedule to another for the duration of 10 sessions. Nine of the 18 subjects who showed alterations of observing rate patterns in the course of the 10 sessions showed two or three different patterns of responding concurrently. The different patterns observed conformed, in major respects, with the patterns previously associated with the presentation schedules employed (Ferster and Skinner, 1957). Of the subjects who showed the emergence of differentiated concurrent responding to panel meters, seven were from the group given the FR schedule. The group given the VI schedule as a component schedule tended to develop nondifferentiated patterns of observing, in which it was difficult or impossible to distinguish between response patterns from one meter to another. In most of these latter cases, responding to all three meters appeared to be the pattern of responding associated with DRL.

Figure 2 shows cumulative records representing performance on the tenth monitoring session for two test subjects in the group given FI, FR, and DRL component schedules. The top records represent responses to the left meter, which presented signals at 1-min intervals. The middle records represent responses to the middle meter, which presented signals after every 20 observations of the meter. The bottom records represent performance on the DRL schedule, in which only pauses of 10 sec or greater in observing the right meter led to signal presentation.

Observing responses are registered on these cumulative records by cumulative pen tracings. Signal detections are represented by

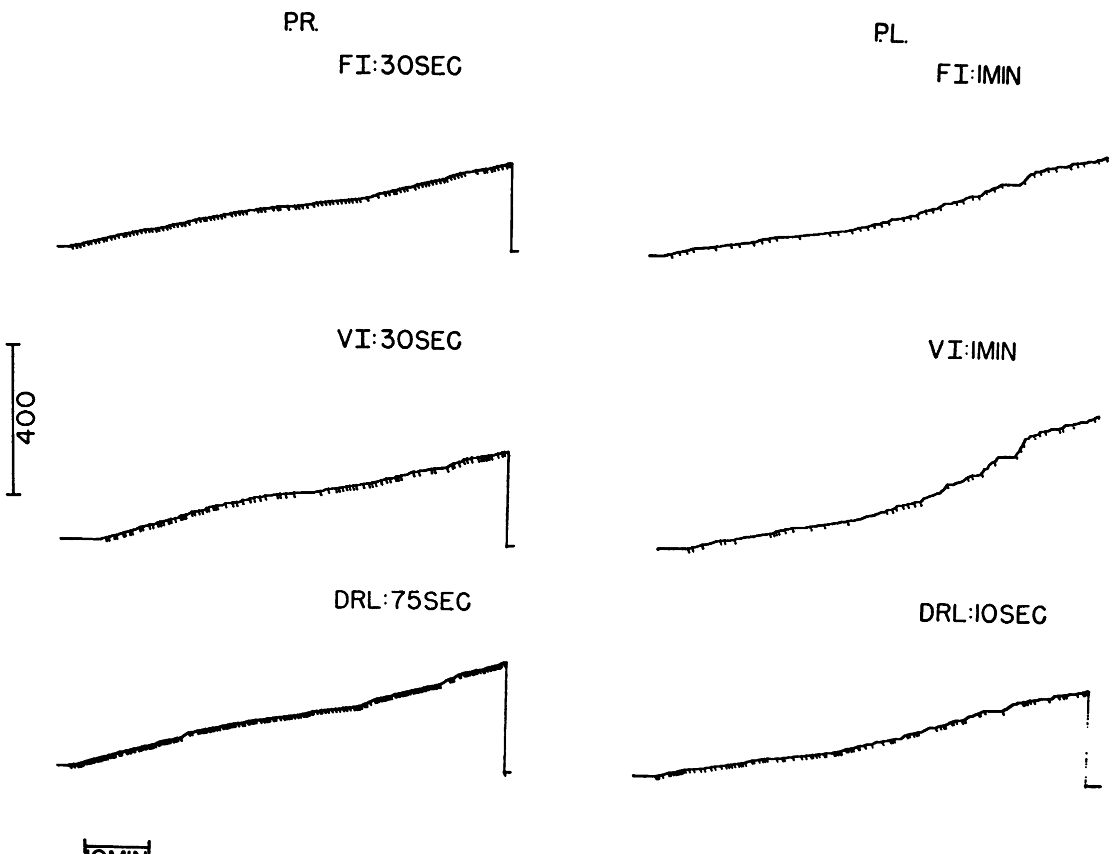

Fig. 3. Cumulative records of observing rate for two subjects for each of the three meters. The two records in the top row show responding to the left meter, which was operated by a fixed-interval schedule. The two records in the middle row show responding to the center meter, which was operated by a variable-interval schedule. The bottom row shows responding to the right meter, which was operated by a differential-reinforcement-of-low-rates schedule.

oblique marks on the cumulative record. Both examples show evidence of differentiated monitoring patterns. The records for Subject K.I. represent precisely the response patterns expected for each of the three schedules on the basis of the literature on reinforcement schedules. On the left meter (FI), observing usually accelerated shortly before a signal was presented. After signal detection, observing stopped until shortly before the next signal was due. On the FI meter, every signal was detected by Subject K.I. Observing behavior for the middle (FR) meter consisted of extremely high and constant rates of responding, resulting in presentation and detection of many signals. On the right (DRL) meter, the cumulative record shows a very low rate of responding which was relatively constant and which maximized the frequency of signal presentation and subsequent detection.

Subject J.M. also developed three clearly different patterns of responding to the three test meters, although the degree of precision developed by schedule control was less.

Figure 3 depicts results from the tenth session for two subjects whose observing responses on all three meters were of the form associated with DRL. Each cumulative record displays the very low, relatively constant rates of responding associated with this schedule. These two test subjects were representative of the group in which the VI schedule was substituted for the FR schedule.

Figure 4 presents a group of cumulative records showing development of differentiated response patterns over the course of the experiment for Subject K.I. The left column of records represents responding to the FI 1-min meter. The center column represents responding to the FR meter. The right column represents records of responding to the DRL schedule. This subject maintained a clear variable-interval pattern for Session 1, using a viewing sequence primarily consisting of a left, center, right, center pattern. This pattern led to a doubling effect in rate of responding on the center meter. The first evidence of behavioral change was observed in Session 6

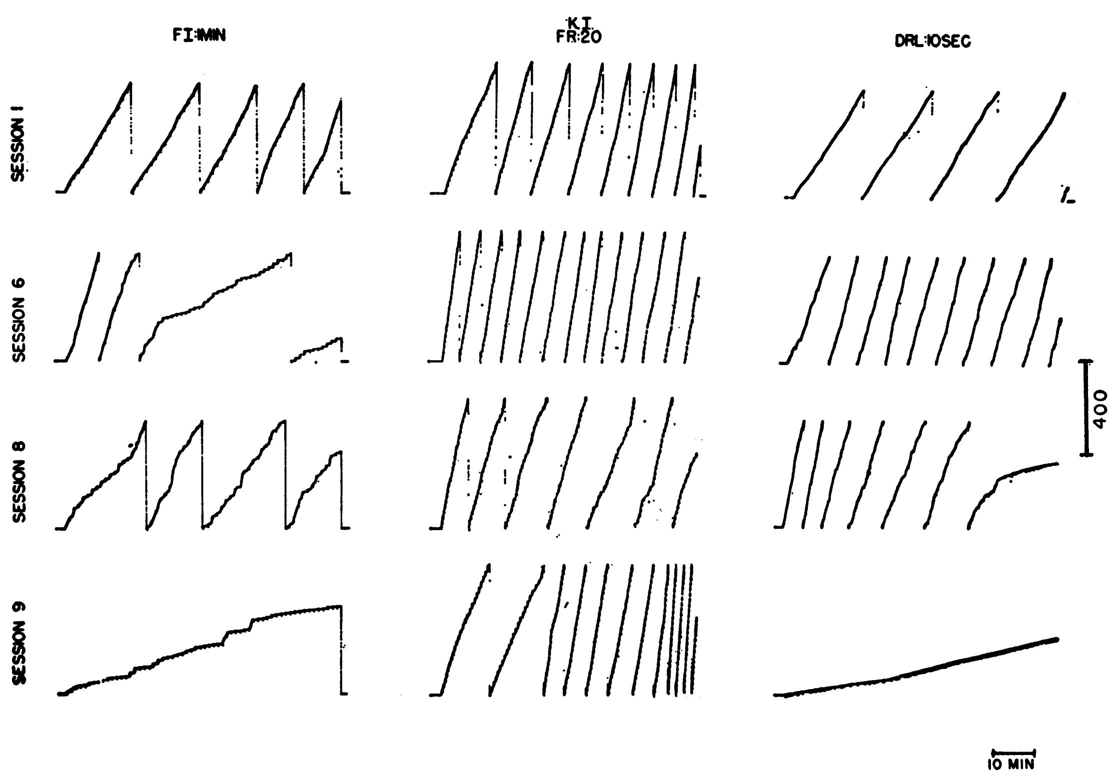

Fig. 4. Cumulative records of observing rate for one subject for each of the three meters. Records from different stages of the experiment are presented to show the progressive development of differentiated observing response patterns.

for the FI meter. Early in the session, a fixed-interval pattern emerged, while responding on the other two meters continued to display a VI pattern, with some increment in the overall rate of responding. The next behavioral change was observed in Session 8. This change was an emergence of a DRL pattern of responding to the right meter. At this time, responding to the left (FI) meter deteriorated, but continued to show FI characteristics. In Session 9, responding to the FR meter accelerated until it reached a high rate of the kind associated with FR reinforcement schedules. At this time, clear FI responding was observed for the left meter, and clear DRL responding was observed for the right meter.

A group of selected cumulative records, showing the development of nondifferentiated response pattern, is presented in Fig. 5 to show the temporal course of nondifferentiated control over observing behavior. The initial pattern of responding for Subject M.S. was of a VI pattern, with a doubling of responding to the middle meter. This doubling effect again resulted from the tendency to use a left, center, right, center observing sequence. During the early minutes of the third session, rate of responding to the right meter decreased to the DRL range. A few minutes later this reduction was noted for responding to the left and center meters. On the next trial, rates of responding to the individual meters corresponded to clear DRL behavior. One further change became clear by the tenth session. This change represented a shift in frequency of responding to the individual meters from the left and center meters to the right meter. This change might be attributed to the much higher availability of reinforcement on the right meter. Certainly, responding to the left meter had almost extinguished, resulting in many detection failures.

The present results suggest therefore, that the human monitor's panel monitoring behavior can fall under the simultaneous control of three concurrent schedules of signals. These results suggest that whether or not differentiated patterns of viewing will emerge in the uninstructed monitor's panel observing depends upon the interaction effects among component schedules. The development of control over responding to all three

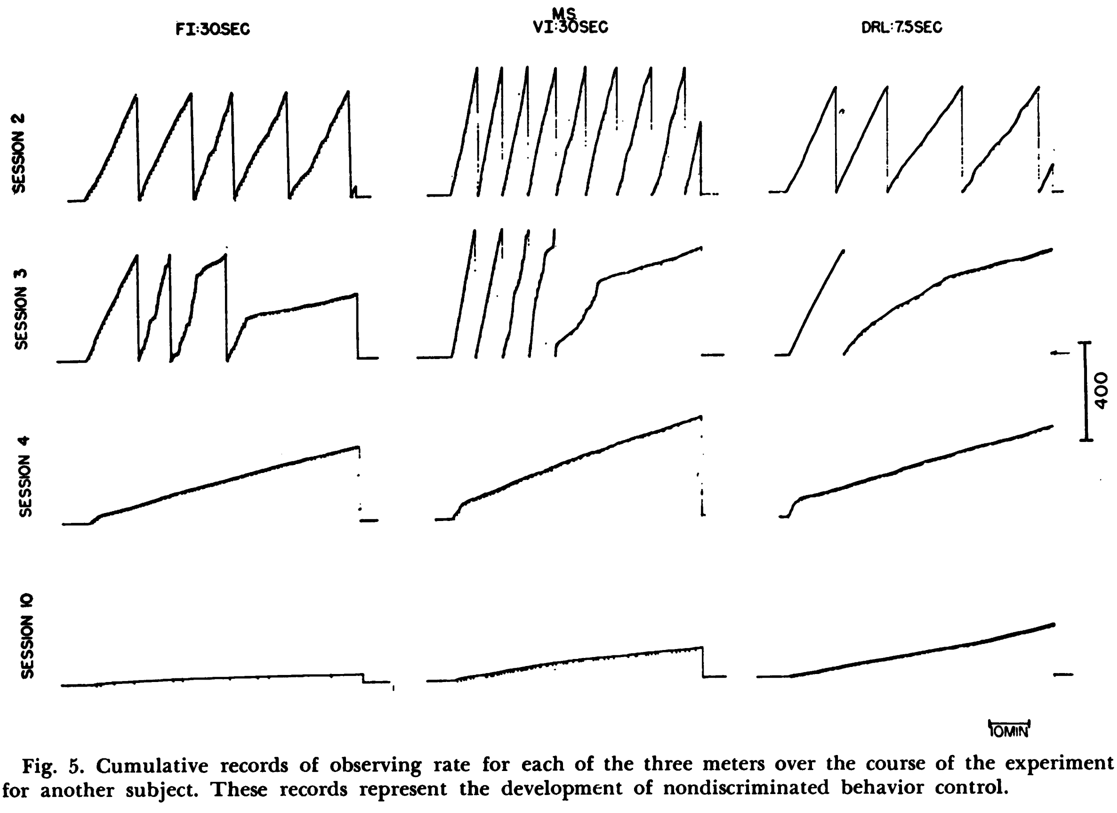

Fig. 5. Cumulative records of observing rate for each of the three meters over the course of the experiment for another subject. These records represent the development of nondiscriminated behavior control.

meters by a schedule employed to present signals on one of the three meters is only a slightly less impressive demonstration of behavioral control. This control would appear to represent a phenomenon of significance to the study of vigilance performance.

These results are in agreement with animal work by Sidman, Herrnstein, and Conrad (1957) and Sidman (1958) on two concurrent schedules of reinforcement, in which variable-interval scheduling of reinforcement tended to preclude development of differentiated response patterns, while fixed-ratio scheduling tended to facilitate development of differentiated response patterns in monkeys.

PART II

Two additional subjects were tested to study whether instructions regarding schedule construction and initial feedback of results in signal detection could overcome the previous failures to develop differentiated patterns of responding to the FI, VI, and DRL schedule combination. That is, by giving information regarding schedules employed and feedback of results as pretraining, would the effects of including the VI schedule be overcome?

The two subjects were tested for a total of sixty-four 45-min sessions within a period of eight days. An FI 2-min schedule operated for the left meter, a VI 2-min schedule operated for the middle meter, and a DRL 15-sec operated for the right meter. A 7.5-sec limited hold was used for timing signals across each meter.

Test subjects were told that they were to detect as many signals as possible, and as rapidly as possible. They were correctly told the schedule relationships (though not the expected response patterns), and given initial practice in signal detection for the first three 45-min sessions. During these sessions they were immediately told each time they failed to detect a signal on a test meter. After this pretraining, both subjects were given five sessions more on the first day, and eight ses-

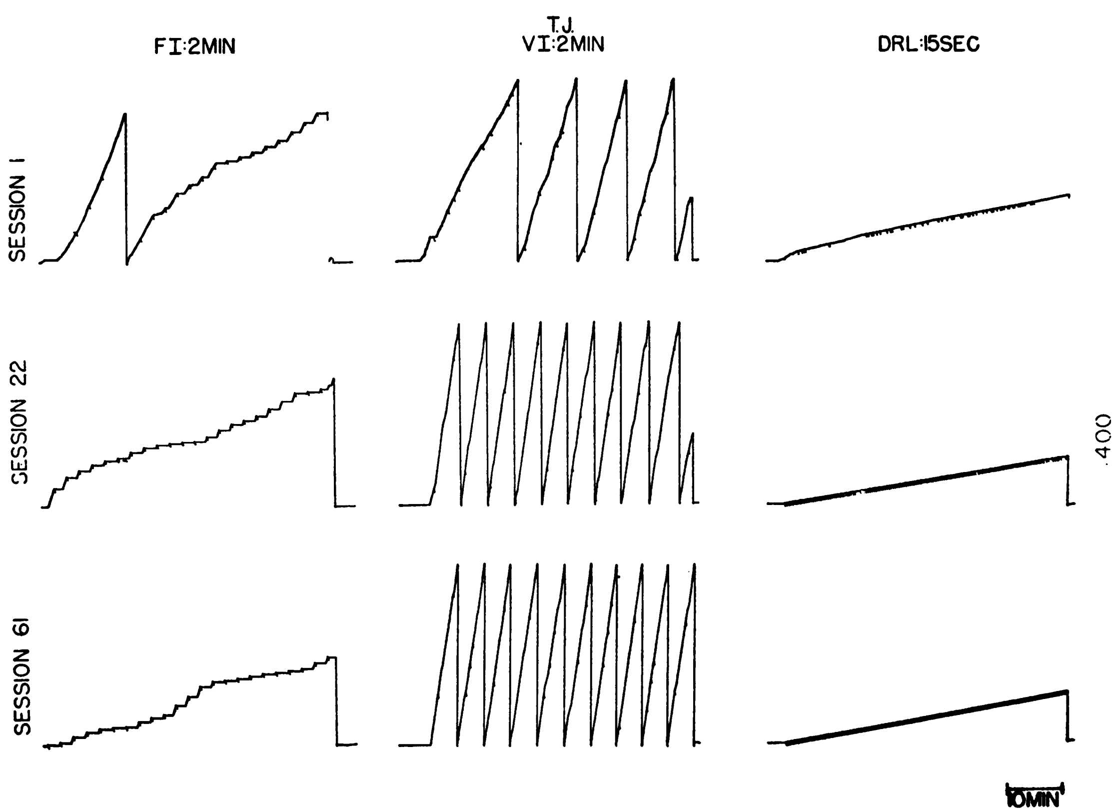

Fig. 6. Cumulative records of responding to the three meters for one subject given initial schedule descriptions and feedback of results, with the FI, VI, and DRL combination of schedules.

sions on each of the next seven days. Sessions were distributed at 1.5-hr intervals across the normal waking day. After the first three sessions, feedback was no longer available. A subject would stay in the test chamber only during the session. He would be given a verbal signal to begin, and was told when to stop. No watches were worn during a session.

RESULTS

Figure 6 presents cumulative records of responding to each of the three meters for Subject T.J. on meter 1, meter 2, and meter 3, from left to right. This subject showed a transition to fixed-interval responding to the left meter which began after about 15 min of the initial trial. The variable-interval pattern initially observed for both the left and center meters persisted with some acceleration of rate for the center meter. For the right meter, a rate of observing appropriate to the DRL schedule developed after the first few minutes of the session, but the subject never was able to obtain efficient detection rates.

The second row of records represents performance during Trial 22 for the same individual. By this time, the test subject had developed a stable pattern of responding for each of the three meters which was highly efficient in maximizing signal detectability through key-pressing patterns previously associated with the schedule of reinforcement employed. The third row of records represents monitoring performance on Trial 61. There is very little difference in the molar characteristics of responding from trial 22 performance, indicating that signal detection remained effective as reinforcement for all 61 trials.

Figure 7 presents cumulative records by trial for Subject J.S. in the same manner as the previous figure. This subject showed somewhat poorer initial performance in signal detection for the left meter. He began the first trial with a VI pattern of responding to the center meter and maintained it for the entire 45-min session. He missed numerous signals on the right meter for the first few minutes but developed a rate of response appropriate to the DRL schedule. His detection rates for

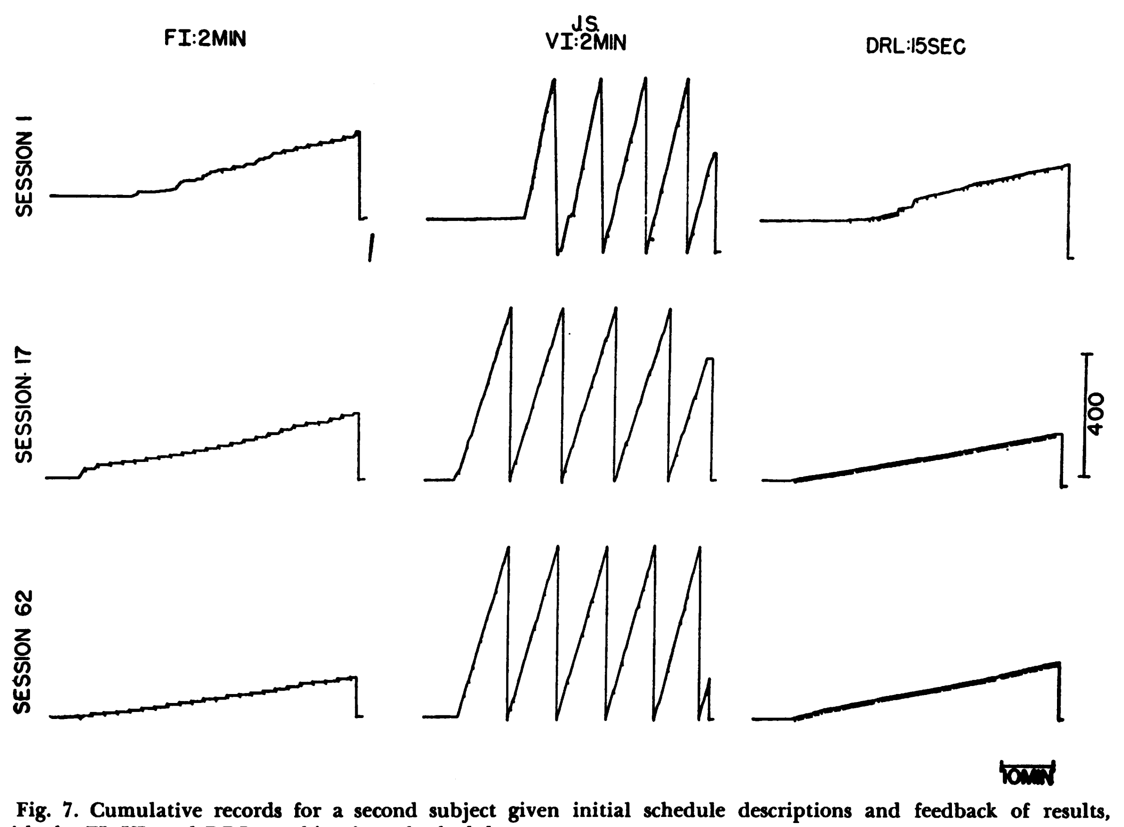

Fig. 7. Cumulative records for a second subject given initial schedule descriptions and feedback of results, with the FI, VI, and DRL combination of schedules.

the right meter showed that he never did develop a very high probability of signal detection for the DRL schedule.

The center row of cumulative records displays Trial 17 performance for Subject J.S. At this time, patterns of responding were observed which were appropriate for maximizing probability of reinforcement from each meter and which closely resembled the classical rate response patterns associated with the three schedules.

On Trial 62, Subject J.S. maintained the differentiated responding without any evidence of deterioration, indicating again that signal detection maintained reinforcing properties for the duration of the experiment.

DISCUSSION

Holland's work has indicated that the human monitor's visual observation of his environment operates under the control of the display he monitors. To this we can add that the observing behavior of humans can operate under the control of concurrent schedules. The patterning of observing behavior on concurrent schedules would seem to depend upon just what schedules are employed. With some schedule combinations, control may be exerted by a single component schedule, as opposed to observing according to all component schedules. Finally, verbal instruction and feedback of detection failure can facilitate acquisition of differentiated observing patterns.

To account more fully for the observation that schedule interaction effects can occur in concurrent schedules, it may be necessary to perform a detailed analysis of the stimuli which induce switching or changeovers from one meter to another. A schedule interaction hypothesis might suggest that responding on concurrent schedules represents the development of complex chaining patterns, in which a few individual complex patterns may or may not satisfy the independent requirements of all of the component schedules. This issue will require further investigation, but several clues did emerge during the present experiment and will be discussed briefly. One of two test subjects who did display a differentiated pattern of responding in the initial group given VI as a component schedule tended to change over from the center (VI) meter after a relatively fixed number of observing responses. He responded to the VI schedule, in other words, as members of the other group did for the FR schedule.

In the present study no changeover delay was employed. This fact may have contributed to the failure of the group given VI as a component schedule to develop differentiated observing patterns. Studies by Herrnstein (1961) and Catania (1962) showed that when changeover delays are not employed with interval schedules, the frequency of changeovers is maximized. On the other hand, when FR is a component of a concurrent schedule experiment, changeover frequency is less and tends to occur after a reinforcement (Herrnstein, 1958). A high frequency of changeovers might be expected to interfere with initial acquisition of a complex observing pattern which would satisfy well the requirements of three different schedules. On the other hand, the tendency to change over after reinforcement on an FR schedule would provide a much more stable component for development of a differentiated observing pattern.

The main conclusion drawn from Part II is that if test subjects are given information concerning schedule construction and initial feedback of results when detection failures occur, they can then develop differentiated response patterns in performance even on difficult concurrent schedule combinations. Thus, instructional variables are relevant to issues of response differentiation on concurrent schedules.

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