CLOCK CONTROL OF HUMAN PERFORMANCE ON AVOIDANCE AND FIXED-INTERVAL SCHEDULES¹

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The avoidance and fixed-interval performances of human subjects were studied in two experiments. Addition of time-correlated stimuli (added clock) improved behavioral efficiency, since response rates decreased without decreases in reinforcement rates. Response-dependent display of the clock maintained a second, observing response and reductions in clock duration weakened such observing behavior. Generally, the reinforcing properties of the clock were more apparent with the avoidance than with the fixed-interval schedule, a finding attributed to temporal cues already provided by delivery of the fixed-interval reinforcers. Reduced rates of the main response when the clock was dependent on an observing response were more than offset by rates of the observing response in the majority of subjects. Thus, the results do not support an interpretation of the reinforcing properties of added clocks simply in terms of work reduction.

Key words: clock, observing behavior, information, fixed-interval schedules, avoidance schedules, adult humans

Schedules of positive and negative reinforcement can be based on the passage of fixed periods of time. Familiar examples are fixed-interval schedules, where the reinforcing stimulus is delivered following the first response after a time period has elapsed, and avoidance schedules, where the aversive event is delivered if a response is not made before a time period has elapsed. Time-based schedules usually are arranged to exclude external cues correlated with the passage of time. To perform efficiently, subjects must rely either on their own behavior or on unspecified cues of internal origin.

It also is of interest to study performances in the presence of external sources of stimulation that vary with time. The classic work was done by Ferster and Skinner (1957), who found that the addition of time-correlated stimuli (a procedure termed "added clock") could control patterns of fixed-interval responding. In their research with pigeons, clocks improved temporal patterning, a finding subsequently confirmed by other researchers (Kendall, 1972;

Segal, 1962). Parallel results have been reported for shock-avoidance schedules. Grabowski and Thompson (1972), using monkeys, found that an added clock shifted interresponse-time distributions toward longer pauses. The effect became more pronounced as the precision of the clock was increased by dividing the response-shock interval into a larger number of stimulus-defined segments.

Taken together, these studies of fixed-interval and avoidance performances suggest that clocks improve behavioral efficiency by reducing response rates toward the minimum required to produce the maximum number of reinforcers. Another conclusion, suggested by the work of Segal (1962) and Kendall (1972), is that clock stimuli serve conditioned reinforcing as well as discriminative functions. In Kendall's study, pecks on one key were reinforced with grain, and the clock stimuli followed pecks on a second, observing key. Responding on the observing key was acquired and maintained when responses briefly displayed the stimulus correlated with the current portion of the fixed interval. Omission of the clock stimulus nearest delivery of the primary reinforcer weakened observing behavior as well as temporal control by the fixed-interval schedule.

The present experiments, designed to obtain more information about the functions served by clocks, embodied several novel features:

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(a) schedules of negative reinforcement, as well as positive reinforcement were studied using similar procedures; (b) the clock stimuli, either response-independent or response-dependent, were contained within the components of multiple schedules; (c) young-adult humans, rather than pigeons or monkeys, were the subjects.

Experiment I investigated control exerted by response-independent and response-dependent clocks over behavior maintained by schedules of avoidance of timeout from monetary payment. Experiment II went on to study some of the same issues when behavior was maintained by fixed-interval schedules of monetary payment. In both experiments, the temporal value of the baseline schedule was the same, that is, both the fixed interval and the response-timeout interval were set at 20 sec.

EXPERIMENT I AVOIDANCE OF TIMEOUT WITH ADDED CLOCK

METHOD

Subjects

Five young-adult female college students (Subjects MS, SP, JS, SM, LK) served for an extended series of sessions, usually about 10 each week. They were referred by the campus employment agency; only those with limited knowledge of or apparent interest in psychology were selected. The experiments were explained as a parttime job with the special feature that payment would depend on performance. Subjects were told that the average worker earned about \$1.80 per 50-min session, but that payment could be as little as \$0.50 or as much as \$2.00 per session. Each subject was required to sign a contract stipulating that: (a) payment would be made at the end of the project, (b) she would, if needed, continue for as many as 60 sessions, (c) all payment would be forfeited if she dropped out before the end, and (d) she would be fined \$1.00 for each absence without prior notice and excuse. By the end of the experiment, average hourly earnings for each subject were at or above the campus minimum wage for students.

Apparatus

The subjects' work area was a sound-attenuated room, approximately 1.8 m square. They sat facing a table on which was mounted a vertical panel containing the manipulandum,

a crank-like device, and an array of small lights covered with colored plastic caps. Six lights were spaced evenly across the top of the panel; the first five, the clock stimuli, were yellow and the sixth was green. Other lights, located below the clock lights, indicated when the session was in progress and signalled the components of the multiple schedule.

The manipulandum was mounted on a shaft protruding from the face of the vertical panel about 2.5 cm above the table. A 10-cm lever, attached to the end of the shaft, was vertical in its resting position and could be rotated 90°, either clockwise or counterclockwise, until stopped by the tabletop. To define the response, small blue lights to the right and left of the lever went on when it was moved sufficiently in either direction.

The shaft to which the lever was attached was connected to a spring and pulley system, arranged so that the force required to operate the lever increased as it was rotated through its clockwise or counterclockwise arc. During most of the experiment, a response was defined as rotation of 45° from the vertical, a movement requiring 23 N of force (5 lb dead weight). As indicated below, rotations of 20°, 60°, and 90° also were used, responses requiring approximately 9 N (2 lb), 54 N (11 lb), and 113 N (25 lb), respectively.

Programming and recording equipment were located in a room adjacent to the work area. Operation of the equipment was inaudible to the subject.

Procedure

Printed instructions informed the subject that she could not bring her watch, purse, or writing materials into the work area, but that books and magazines were permitted. Further instructions were held to a minimum and encompassed three points: (a) when the lower-right light was illuminated, the session was in progress; (b) when the green light was illuminated, money was being earned continuously at the rate of four cents per minute; (c) the lever could be turned in either direction and one or the other of the two blue lights would go on momentarily when it was properly operated. After the subject had read the instructions, she was allowed to work for 15 min in the booth, and then was asked to make a definite commitment about future participation. All subsequent sessions lasted 50 min.

Table 1

Experiment I (avoidance baseline): sequence of conditions and number of sessions in each condition.

Condition	Subjects				
	MS	SP	JS	SM	LK
Acquisition	3	5	1	1	2
Simple: NC	7	10	10	5	4
Simple: RI	5	7	7	5	4
Mult: RI-RD	4	8	4	7	7
Mult: NC-RD	5	10	7	4	4
Mult: NC-RD, 1"	9, 13*	6	6	5	4
Mult: RI-RD, 5-15"	—	—	—	15	14
Mult: NC-RD, 5-15"	—	—	—	16	14
Total Sessions	46	46	35	58	53

Abbreviations. NC = no clock; RI = response-independent clock; RD = response-dependent clock; 1", 5-15" = duration of response-dependent clock.

*Response force level varied.

The sequence of conditions and number of sessions in each condition are summarized in Table 1. Except for the acquisition phase, each condition was continued either until behavior stabilized over four sessions (stability required a difference between the means of the first two and last two of four consecutive sessions of less than 10% of the overall mean) or for a maximum of 10 sessions.

Acquisition. The baseline schedule was a free-operant avoidance schedule with 15-sec periods of timeout from payment (offset of the green light) as the aversive event. The avoidance response was rotation of the lever at least 45° in a clockwise direction (force = 23 N), and responses were followed by onset of the right blue light for 1 sec, during which time further responses were ineffective. The lever had to be returned to its resting (vertical) position before it could be operated again. If responses did not occur, the green light followed a cycle of 5 sec on and 15 sec off, *i.e.*, the timeout-timeout interval (measured from the end of one timeout to the beginning of the next) was 5 sec. Each response postponed the onset of timeout by 20 sec, *i.e.*, the response-timeout interval was 20 sec. Except during the early sessions of the acquisition phase, responses during the 15-sec timeouts were ineffective, *i.e.*, timeout was avoidable but not escapable.

The response was developed in a three-step shaping procedure. Initially, 9 N force (20° rotation) was required, and timeout was escapable as well as avoidable: responses during timeout turned the green light back on and

postponed the next timeout for 20 sec. When subjects were responding regularly, the response requirement was increased to the standard value of 23 N (45° rotation). The final step removed the escape contingency. All subjects acquired the response rapidly, usually during the first session, and the baseline avoidance schedule was instituted somewhere between Sessions 2 and 6.

Simple schedules: no clock and response-independent clock. Training was continued on the simple avoidance schedule without the clock, following the procedures described above. When performances were stable (or 10 sessions had been completed) the clock was added, with the five yellow lights at the top of the panel serving as the time-correlated stimuli. At the start of each response-timeout interval only the left-most light was on. At intervals of 4 sec the remaining lights went on sequentially, so that during the last 4 sec of the response-timeout interval all five lights were lit. Following an avoidance response, the lights blinked out momentarily and the first light then came on again to start the new interval. When the 20-sec response-timeout interval expired without a response, all five lights remained on throughout the 15-sec timeout period and throughout subsequent timeout-timeout intervals, until a response was made.

Multiple schedules: response-independent and response-dependent clocks. During this condition, a two-component multiple schedule was signalled by the presence or absence of a red light. The components had durations of 12.5 min and appeared twice during each session. When the red light was off (the S1 component) the clock stimuli were displayed on a response-independent basis, as described for the previous condition. When the red light was on (the S2 component) the clock was absent but could be produced by rotating the lever 45° (23 N) in a counterclockwise direction, the direction opposite the main response. Completion of this counterclockwise observing response also turned on the left blue light for 1 sec. The first observing response within each response-timeout interval displayed the clock for the remainder of the interval, and subsequent responses had no consequences. As with the response-independent clock, each avoidance response terminated and reset the response-dependent clock.

Multiple schedule: no clock and response-dependent clock. The response-dependent clock continued to be available in the S2 component, contingent on at least one observing response per response-timeout interval. During the other S1 component, the clock was unavailable (no clock).

Multiple schedule: no clock and brief response-dependent clock. Procedures of the previous phase continued except that during the S2 response-dependent component, the duration of the clock was abbreviated to 1 sec. Each additional response during the response-timeout interval displayed the clock for another second. During this phase, a second series of observations was conducted with Subject MS: the force of the observing response was increased to 54 N (60° rotation) for five sessions, then 113 N (90° rotation) for five sessions, and finally returned to the standard 23 N level.

Multiple schedule: variations in the duration of the response-dependent clock. Two subjects, SM and LK, participated. The multiple schedule contrasting the response-dependent clock (S2) and the response-independent clock (S1) was reinstituted, but the maximum clock duration following an observing response was shortened from 20 to 15 sec. After stable behavior was obtained, the duration of the clock was further reduced to 10 and finally to 5 sec. Throughout these manipulations the clock was freely displayed during the S1 component. The entire procedure of varying clock duration in the S2 component then was repeated (*i.e.*, 15 sec, 10 sec, and 5 sec), except now the clock was unavailable in the S1 component.

RESULTS

The main results are summarized in Table 2, which gives absolute avoidance rates, and Figure 1, which shows relative interresponse times, during the terminal sessions of the various phases. The panels of Figure 1 also include proportions of response-timeout intervals in which an observing (counterclockwise) response occurred.

Simple Schedules: No Clock and Response-Independent Clock

The avoidance response was acquired rapidly, within a session or two by all subjects. Table 2 shows that although subjects differed substantially in their terminal rates, they were uniformly proficient in avoiding timeouts. Throughout the experiment, the number per session rarely exceeded two or three.

The first column of Figure 1 summarizes interresponse times on the simple schedules, initially without the clock (open bars) and then with the clock (closed bars). It is apparent that avoidance rates without the clock exceeded the minimum required by the schedule, most notably in the cases of Subjects MS, SP, and JS. Adding the clock markedly improved the efficiency of avoidance performances to the extent that all but one of the subjects made the majority of their responses (in some cases, all responses) during the last 8 sec of the response-timeout interval. Figure 1 also shows that the second, counterclockwise response rarely occurred during this phase; Subject SP was an exception.

Table 2

Experiment I (avoidance baseline): avoidance responses per minute during terminal sessions with no clock, response-independent (RI) clock and response-dependent (RD) clock. Also given (in parentheses) are numbers of timeouts per 50-min session for the simple schedules and per 25-min component durations for the multiple schedules.

Conditions		Subjects				
		MS	SP	JS	SM	LK
Simple	No Clock	20.5 (1.0)	11.7 (0.0)	16.6 (0.5)	3.9 (1.0)	3.6 (1.0)
	RI Clock	3.1 (0.0)	3.7 (1.5)	4.6 (1.5)	3.1 (0.0)	3.0 (0.0)
Multiple	RI Clock (S1)	3.1 (0.5)	4.2 (1.5)	4.1 (0.5)	3.2 (0.0)	3.0 (1.0)
	RD Clock (S2)	3.1 (0.0)	4.3 (1.5)	3.9 (2.5)	3.1 (0.0)	3.0 (1.0)
Multiple	No Clock (S1)	17.7 (0.0)	5.8 (3.0)	9.4 (1.5)	3.9 (0.0)	3.4 (3.5)
	RD Clock (S2)	3.9 (0.5)	4.4 (3.5)	3.6 (0.5)	3.2 (0.0)	3.0 (0.0)
Multiple	No Clock (S1)	17.6 (0.0)	6.8 (1.5)	7.6 (1.0)	4.0 (0.0)	3.6 (2.5)
	Brief Clock (S2)	16.4 (0.5)	6.7 (0.5)	7.1 (1.5)	3.9 (0.0)	3.6 (2.5)

Fig. 1. Experiment I (avoidance baseline): relative interresponse times in successive fifths of the 20-sec response-timeout interval. Responses when the interval was allowed to elapse are in the category labelled TO. In the first column (Simple NC-RI), the light bars represent performances during the No-Clock phase (NC) and the dark bars the Response-Independent Clock phase (RI). The remaining columns show multiple schedule performances with the light bars representing the S1 components and the dark bars the S2, Response-Dependent Clock components (RD). Per cent observing responses are shown in each panel. Data are based on the last two sessions of each condition.

To illustrate local rates, Figure 2 presents cumulative records for three of the five subjects. As during subsequent phases of the experiment, local rates corresponded closely to the averaged performances, described above. Noteworthy in the records is the uniform control exerted by the response-independent clock. Before the clock was added, JS and MS responded at rates substantially higher and less regular than SM. But addition of the clock produced uniformly low rates, with all three subjects showing substantial and regular pauses after each response.

Multiple Schedule: Response-Independent and Response-Dependent Clocks

When the counterclockwise observing response was required for display of the clock in the S2 component (the clock continued to be freely available in the S1 component), the behavior was acquired within a few sessions; by the terminal sessions, observing responses occurred during 90% or more of the response-timeout intervals. By comparison, these responses in the S1 component remained at previous low levels (Figure 1, column 2). Ob-

Fig. 2. Experiment I (avoidance baseline): cumulative response records for three subjects on the simple schedule with no clock (NC) and with the clock added (C). Pairs of records for each condition represent 25 consecutive minutes of the 50-min test session. Timeouts are indicated by downward deflections of the response pen.

serving responses usually were made early in the response-timeout interval, a second or two after completion of an avoidance response, with the consequence that the clock was present during most of the response-timeout intervals.

The lowered avoidance rates associated with display of the clock were maintained during this condition. Table 2 and Figure 1 show that rates during the S1 (independent clock) and S2 (dependent clock) components of the schedule were approximately the same, thus indicating that clock control did not depend on how the clock was produced.

Multiple Schedule: No Clock and Response-Dependent Clock

Table 2 and Figure 1 show results generally consistent with those of previous conditions. Observing responses during the response-dependent component continued at high levels when there was no clock in the other component (Figure 1, column 3). Avoidance rates remained low in the S2 component, where the response-dependent clock usually was displayed, but increased in the S1 component, where the clock always was absent. Comparisons of S1 performances with simple schedule performances without the clock do not indicate complete recovery of the initial higher rates (note, especially, Subjects SP, JS, and LK). Thus, contact with the clock led to a degree of improved temporal control of avoidance in its absence.

Multiple Schedule: No Clock and Brief Response-Dependent Clock

Reduction of the response-dependent clock in S1 to 1 sec rapidly weakened observing behavior. In four subjects (SP, JS, SM, and LK) responding declined substantially within one or two sessions, and by the end of the phase few observing responses were made (Figure 1, column 4). Associated with these changes were increases in S2 avoidance rates to the levels maintained in the no-clock component.

Observing behavior of the remaining subject (MS) was atypical during this phase, and the first series of observations are omitted from Figure 1 and Table 2. She persevered in producing the brief clock and by responding at high rates (close to one per second) maintained it almost continuously. To test the limits of this pattern, the force required for the observ-

ing response was increased from 23 N to 113 N, and then, after a series of sessions at the higher level, returned to 23 N. The consequence of those manipulations was that observing behavior dropped out, and data obtained from Subject MS during the second series of observations with the standard 23-N force (see Figure 1, column 4) show terminal performances similar to those of the others. At this point in the procedure, observing responses were infrequent and avoidance rates were equally high in the clock and the no-clock components.

Multiple Schedule: Variations in the Duration of the Response-Dependent Clock

Table 3 summarizes the performances of Subjects SM and LK when the duration of the response-dependent clock in the S2 component was varied from 20 to 1 sec and the S1 component contained either no clock or the 20-sec response-independent clock. Data given for 20 sec and 1 sec were obtained during previous phases.

Table 3 shows that with both multiple schedules, observing behavior was maintained up to a point, but that observing dropped out with durations shorter than 5 sec for Subject SM and 10 sec for Subject LK. When the clock duration was 10 or 15 sec, both subjects continued to respond early in the response-timeout interval; Subject SM frequently made a second response, thus ensuring that the clock was displayed throughout the interval.

Comparisons of avoidance rates and observing percentages indicate that the response-dependent clock was associated with increased avoidance efficiency, most clearly in the case of SM. Table 3 (columns 1 to 4) shows that as long as SM produced the clock in the S2 component, her avoidance rates were close to the minimum required by the schedule (although never as close as when the clock was response-independent), and that her avoidance rates in the S2 component increased when reductions in clock duration led to abandonment of observing behavior. The same pattern occurred with LK when the schedule contained the response-independent clock in the S1 component (columns 5 and 6), but not in the schedule with no clock in S1 (columns 7 and 8). In the latter case, LK persevered in producing the clock when its duration was 15 and 10 sec, but corresponding avoidance rates in its presence

Table 3

Experiment I (avoidance baseline): avoidance responses per minute and per cent response-timeout intervals containing observing responses when the clock duration was varied from 1 to 20 sec. Also given (in parentheses) are numbers of timeouts per 25-min component durations.

Clock Duration	Subject SM				Subject LK			
	Mult:		Mult:		Mult:		Mult:	
	RI (S1)	RD (S2)	NC (S1)	RD (S2)	RI (S1)	RD (S2)	NC (S1)	RD (S2)
20 sec*	3.2 (0.0) 1%	3.1 (0.0) 100%	3.9 (0.0) 1%	3.2 (0.0) 92%	3.0 (1.0) 0%	3.0 (1.0) 93%	3.4 (3.5) 1%	3.0 (0.0) 98%
15 sec	3.2 (0.0) 0%	3.5 (0.0) 100%	4.1 (0.5) 1%	3.4 (0.0) 100%	3.0 (1.0) 0%	3.4 (1.0) 100%	3.3 (2.0) 0%	3.4 (0.0) 100%
10 sec	3.3 (0.0) 1%	3.5 (0.0) 81%	4.4 (0.0) 2%	3.3 (0.0) 100%	3.1 (3.0) 1%	3.4 (0.5) 100%	4.1 (0.5) 2%	4.0 (0.5) 99%
5 sec	3.2 (0.0) 0%	3.5 (0.5) 98%	4.2 (0.0) 0%	3.4 (0.5) 83%	3.0 (0.5) 0%	3.8 (0.0) 2%	4.0 (0.5) 0%	4.1 (1.0) 1%
1 sec*	—	—	4.0 (0.0) 2%	3.9 (0.0) 2%	—	—	3.6 (2.5) 0%	3.6 (2.5) 3%

Abbreviations. RI = response-independent clock; RD = response-dependent clock; NC = no clock.

*Data from previous phases.

(S2) were no lower than rates in its absence (S1).

DISCUSSION

The results of Experiment I show the control that time-correlated stimuli can assume over avoidance performances of human subjects. Previous investigations of avoidance of loss and timeout (*cf.* Baron and Kaufman, 1966; 1968; Kaufman and Baron, 1969) revealed considerable inefficiency as well as intersubject variability, and similar patterns emerged before the clock was added in the present research. Although all five subjects successfully avoided most of the timeouts when the clock was absent, absolute rates ranged from three or four responses per minute to as many as 20 per minute. Major consequences of adding the clock were increases in efficiency and decreases in variability, which resulted from reductions in avoidance rates to the minimum required to avoid the aversive events, that is, rates of about three responses per minute.

In general, these findings are comparable to those of Grabowski and Thompson (1972), whose research with monkeys also showed substantial reductions in shock-avoidance rates in the presence of clock stimuli. Noteworthy is that three of the five present subjects came to respond almost exclusively in the presence of the fifth stimulus, the one immediately preced-

ing the impending timeout. Grabowski and Thompson observed similar, although not as complete control, and analogous tendencies have been reported in research with rats when a single stimulus accompanies the last part of the response-shock interval (*e.g.*, Badia, Culbertson, and Lewis, 1971; Ulrich, Holz, and Azrin, 1964).

Differences in avoidance rates depending on whether the clock was present or absent illustrate the discriminative function that may be served by time-correlated stimuli. Another aspect of the results pertains to the reinforcing function of such stimuli. Under those conditions where the clock ordinarily was absent but could be produced through a second observing response, the necessary behavior was readily acquired and maintained. The procedure using multiple schedules provides a strong basis for the conclusion that the clock stimuli were the source of reinforcement for the observing response, since comparable levels of responding did not occur when the clock contingency was removed, that is, in components where the clock was completely absent or where it was freely available. Although there is evidence from animal research that clock stimuli associated with schedules of positive reinforcement may acquire reinforcing properties (Kendall, 1972; Segal, 1962), the present findings with human subjects do not appear to have a direct counterpart in the

avoidance literature. One other line of research suggesting that temporal stimuli correlated with avoidance schedules function as positive reinforcers is the finding that rats and humans prefer shock-avoidance schedules containing a brief stimulus before shocks to those in which the stimulus is absent (Badia *et al.*, 1971, Badia, Culbertson, and Harsh, 1974).

The final part of Experiment I analyzed the reinforcing properties of the clock in more detail. The general finding was that when the duration of the clock was reduced sufficiently, the observing response was not maintained. A related outcome was that observing and avoidance rates were interdependent, with high observing rates correlated with low avoidance rates. Two discrepant findings should be noted: Subject MS responded to produce the clock even at its briefest duration and Subject LK did not always show the correlation between observing and avoidance behavior.

The general results as well as the discrepant findings bear on the hypothesis that clocks are reinforcing because they improve the efficiency of behavior. The present findings support this interpretation. For example, adding the clock to the simple avoidance schedule decreased avoidance rates from -17% to as much as -85% , and similar decreases occurred when the clock was available in one component of the multiple schedule but not the other.

But a closer analysis of the results suggests qualification of the conclusion that clocks are reinforcing simply because they reduce work. The further question needs to be asked whether *total* work output was reduced as a consequence of clock production, that is, the work entailed in the observing, as well as the avoidance response. Analyses of the multiple schedule contrasting the response-dependent clock with no clock help answer this question. Two subjects (MS and JS) did show reduced total responding when the clock was added, -63% and -22% respectively, but the other three subjects (SP, SM, and LK) substantially increased their total responses, $+71\%$, $+64\%$, and $+75\%$ respectively. In other words, for these latter subjects the reduced work in the presence of the clock was more than offset by the additional work required to produce the clock.

The discrepant findings noted earlier also argue against a simple version of the efficiency hypothesis. The subject who persisted in re-

sponding to display the clock for only 1 sec made far more total responses than when the clock was not available. But her behavior was not completely insensitive to considerations of efficiency, since she was induced to give up the behavior through increasing the effortfulness of the observing response. Performances of the subject who produced the clock without always showing lowered rates in its presence suggest that information provided by clocks can be reinforcing without being put to apparent use.

EXPERIMENT II FIXED-INTERVAL REINFORCEMENT

METHOD

Subjects and Apparatus

Five additional young-adult females (Subjects MB, NB, GE, NR, and CR) were hired on the same basis as in Experiment I. The apparatus also was the same.

Procedure

The procedures followed those of Experiment I with modifications appropriate to use of fixed-interval rather than avoidance schedules. Instructions were changed to indicate that payment would depend on the number of times the green light was presented; each brief presentation signified that one cent had been earned, and these earnings were added to a base rate of \$0.65 per session. Additionally, two subjects (MB and CR) were instructed that payment required report of each green light by pressing a button located approximately 0.5 m to the left of the response lever.

The different conditions are described below and summarized in Table 4, which gives the sequence of conditions, and the number of sessions within each condition. Decisions to advance a subject to the next condition were based on the stability criterion described previously.

Acquisition. Clockwise rotation of the lever produced the green payment light (for 1 sec for Subjects NB, GE, and NR, and until reported for Subjects MB and CR) according to a fixed-interval schedule in which the first response 20 sec after delivery of the previous reinforcer was followed by reinforcement (FI 20-sec). As in Experiment I, a force of only 9 N constituted an effective response at the start.

Table 4

Experiment II (fixed-interval baseline): sequence of conditions and number of sessions in each condition.

Condition	Subjects				
	MB	NB	GE	NR	CR
Acquisition	1	1	1	1	1
Simple: NC	5	6	10, 7 ^a	10	9
Simple: RI	4	10	13, 10 ^a	5	5
Mult: RI-RD	9	8	4 ^a	5	8, 4 ^b
Mult: NC-RD	5	7	4 ^a	—	4
Mult: NC-RD, 1"	7	7	—	—	—
Mult: RI-RD, LH	—	—	—	5	8
Mult: NC-RD, LH	—	—	—	8	—
Mult: RI-RD, LH/NF	—	—	—	4	—
Mult: RI-RD, LH	—	—	—	6	—
Total Sessions	31	39	49	44	39

Abbreviations. RI = response-independent clock; RD = response-dependent clock; NC = no clock; LH = limited hold; NF = no feedback.

^aResponse force level = 113 N.

^bSessions followed mult: NC-RD condition.

Beginning with the second session, the requirement was increased to the standard level of 23 N. An effective response was signalled by onset of the blue light to the right of the lever (0.5-sec duration); before a new response could be made it was necessary to return the lever to the vertical position.

Simple schedules: no clock and response-independent clock. When the stability criterion was met, the clock was added to the fixed-interval schedule. At the start of each 20-sec interval only the leftmost light was on. The remaining four lights went on sequentially at 4-sec intervals, so that during the last 4 sec (and until the reinforcer was delivered) all five were on. A necessary difference from the avoidance procedures was that responses during the fixed interval did not reset the clock. Instead, the clock reset in conjunction with delivery of the reinforcer.

The performance of Subject GE was atypical in that she responded at high rates, sometimes approaching two responses per second. For this reason, her force requirement was increased from 23 N to 54 N and eventually to the highest level of 113 N. The simple schedule procedures (no clock and response-independent clock) then were repeated with the 113-N requirement, the level used for the remainder of the experiment.

Multiple schedules. Procedures generally paralleled those of Experiment I. Thus, the same discriminative stimuli (red light on and

off) and component durations (12.5 min) were used in multiple schedules with the response-dependent clock always contained in the S2 (red light on) component. The same three schedules were examined: (a) response-independent clock (S1) and response-dependent clock (S2); (b) no clock (S1) and response-dependent clock (S2); and (c) no clock (S1) and brief response-dependent clock (S2). As in the first experiment, the observing response was a 23-N counterclockwise rotation, except for the Subject GE, whose force was 113 N.

Certain aspects of the procedure were varied either because of individual reactions to the various schedules or time constraints. Subjects NB and MB went through all three multiple schedule conditions sequentially. Subjects GE and CR were studied with the first two of the schedules and Subject NR only with the first schedule.

Because Subjects NR and CR were only moderately responsive to the response-dependent clock contingency, they were exposed to procedures designed to enhance the reinforcing properties of the clock. A 5-sec limited hold was added to the fixed-interval schedule, so that a new 20-sec fixed interval started if a response did not occur within 5 sec after the previous interval expired. In a subsequent manipulation with Subject NR, the procedure was further altered to omit reinforcement feedback (Baron, Kaufman, and Stauber, 1969). Printed instructions indicated that she would be paid as before, but that the green light would no longer go on to inform her when money had been earned. There was insufficient time to study Subject CR under this last condition.

RESULTS

Fixed-interval rates during the terminal sessions of the various phases are summarized in Table 5, and Figure 3 expresses these performances as relative rates during successive fifths (4-sec segments) of the 20-sec fixed interval. Also shown in Figure 3 are the per cent of intervals when at least one observing response was made.

Simple Schedules: No Clock and Response-Independent Clock

The fixed-interval response was acquired by all five subjects during the first session. Absolute rates in Table 5 and relative rates in Fig-

Table 5

Experiment II (fixed-interval baseline): fixed-interval responses per minute during terminal sessions with no clock, response-independent (RI) clock, and response-dependent (RD) clock. Also given (in parentheses) are numbers of reinforcers per 50-min session for the simple schedules and per 25-min component durations for the multiple schedules.

Conditions		Subjects				
		MB	NB	GE	NR	CR
Simple	No Clock	4.3 (135)	3.0 (110)	22.4 (128)	5.0 (118)	6.7 (126)
	RI Clock	3.8 (146)	2.7 (124)	5.8 (123)	3.2 (124)	4.6 (139)
Multiple	RI Clock (S1)	4.2 (71)	3.2 (66)	3.9 (62)	3.3 (58)	4.7 (67)
	RD Clock (S2)	4.4 (73)	3.1 (65)	3.4 (59)	3.6 (63)	4.7 (65)
Multiple	No Clock (S1)	7.4 (70)	4.3 (60)	5.3 (59)	3.5 (64) ^a	4.9 (67) ^a
	RD Clock (S2)	4.9 (69)	2.8 (63)	3.3 (54)	4.6 (52) ^a	6.5 (60) ^a
Multiple	No Clock (S1)	6.3 (65)	4.1 (59)	—	2.8 (59) ^b	—
	Brief Clock (S2)	6.4 (66)	3.9 (61)	—	2.8 (64) ^b	—

^aMultiple RI-RD, Limited hold added.

^bMultiple RI-RD, Limited hold and no feedback added to the schedule.

ure 3 (column 1, open bars) show terminal performances characterized by low rates and responses either late in the interval or after the reinforcer had been set up. An exception is Subject GE, for whom the force requirement had to be increased. Data presented for this subject were with the 113-N force requirement; rates were even higher previously.

Addition of the response-independent clock had uniform effects. Response rates were reduced further (Table 5), and the distributions of relative rates shifted to the last 4 sec of the fixed interval and the period thereafter (Figure 3, column 1, closed bars). Counterclockwise responses (the response that subsequently displayed the clock) were virtually absent.

Cumulative records for three of the subjects during this phase, displayed in Figure 4, show that local rates of response generally were similar to the averaged performances described above. Although consistent temporal control occurred without the clock, its addition improved the efficiency of performance; now usually a single response, and rarely more than two or three responses, occurred per fixed interval.

Multiple Schedule: Response-Independent and Response-Dependent Clocks

Two patterns were seen. Subjects GE, MB, and NB acquired the observing response smoothly. Their data in Figure 3 (column 2) show observing responses during at least 90% of the fixed intervals, and responding limited to the end of the interval.

Development of observing behavior in the other two subjects (NR and CR) was considerably less orderly. Subject NR responded irregularly and rarely during more than 20% of the intervals. More observing responses were made by Subject CR, but the response unaccountably dropped out when the next condition was introduced (multiple: no clock and response-dependent clock). In an effort to develop stable observing behavior in these subjects, a 5-sec limited hold was added to the fixed interval (Figure 3, column 3). It is apparent that this procedure did not increase observing behavior, although rates of the main response increased in the S2 component, where the clock, although available, was not produced. The final step of omitting reinforcement feedback for Subject NR in conjunction with the limited hold (Figure 4, column 4) did have major effects. Observing increased to virtually 100% of the intervals, and, in addition, patterns of fixed-interval responding came to resemble those of the three subjects acquiring the observing response earlier. Additional observations with this subject (not presented in Figure 3) confirmed that reinforcement feedback interfered with observing, since when feedback was restored, observing reverted to previous low and irregular levels (about 20% of the intervals).

Multiple Schedule: No Clock and Response-Dependent Clock

Data obtained from Subjects GE, NB, and MB replicated the results of the previous

Fig. 3. Experiment II (fixed-interval baseline): relative response rates in successive fifths of the 20-sec fixed interval. Responses after the interval had elapsed are in the category labelled R+. In the first column (Simple NC-RI), the light bars represent performances during the No-Clock phase (NC) and the dark bars the Response-Independent Clock phase (RI). The remaining columns show multiple schedule performances, with the light bars representing the S1 components and the dark bars the S2, Response-Dependent Clock components (RD). Per cent observing responses are shown in each panel. Data are based on the last two sessions of each condition.

Fig. 4. Experiment II (fixed-interval baseline): cumulative response records for three subjects on the simple schedule with no clock (NC) and with the clock added (C). Pairs of records for each condition represent 25 consecutive minutes of the 50-min test session. Reinforcers are indicated by brief downward deflections of the response pen.

phase. The manipulation of omitting the clock from the S1 component had little or no influence on S2 performance where responding to display the clock was maintained (Figure 3, column 3). The absence of the clock in S1 increased rates of fixed-interval responding in the direction of levels previously observed with the initial simple schedule without the clock.

Multiple Schedule: No Clock and Brief Response-Dependent Clock

During this, the final phase for Subjects NB and MB, reductions in clock duration to 1 sec weakened observing behavior (Figure 3, column 4). But unlike performances in the parallel condition with the avoidance baseline, observing continued sporadically. Figure 3 also

shows that patterns of fixed-interval responding within the two components of the schedule generally were similar in this condition.

DISCUSSION

Previous investigations of human performances on fixed-interval schedules have observed both temporal control by the schedule (e.g., Holland, 1958; Laties and Weiss, 1963) and high rates of undifferentiated responding (e.g., Blair, 1958; Weiner, 1962). Some studies have identified special procedures, which when added to the schedule, lower rates and increase sensitivity to the temporal contingency, such as a cost for responses (Laties and Weiss, 1964; Weiner, 1962), pretraining with schedules controlling low rates (Weiner, 1969), and instruc-

tions about the duration of the fixed interval (Baron *et al.*, 1969; Lippman and Meyer, 1967). It therefore is noteworthy that with one exception the present subjects showed low rates and good temporal control in their initial reactions to the simple fixed-interval schedule of reinforcement. This outcome is consistent with the suggestion by Laties and Weiss (1963) that temporal differentiation improves with increases in the force of the response. In their study as well as in the present one, the response required considerably more effort (15 N or more) than in studies finding high undifferentiated rates, *e.g.*, the force was 0.2 N in Weiner's (1962) study. In addition, the present findings indicated that improved temporal control was attained in the atypical subject by increasing the force of the response.

Although subjects showed temporal control before the clock was introduced, adding the clock on a response-independent basis sharpened temporal patterning. This finding generally is similar to findings with pigeons when clocks are added to fixed-interval schedules (Ferster and Skinner, 1957; Segal, 1962) and findings with human subjects when a single stimulus is correlated with the last part of the fixed interval (Azrin, 1958; Long, 1962). Increased temporal control was accompanied by consistent reductions in fixed-interval rates, ranging from -10% to -74%. These reductions did not adversely influence reinforcement rates; in fact, four of the five subjects showed small increases in earnings after the clock was added.

A further finding was that clocks added to fixed-interval schedules can serve as reinforcers, although the results were not as clear as those of Experiment I. Three of five subjects consistently observed from the start and a fourth reached comparable levels when reinforcement feedback was omitted. As in the first experiment, reductions in clock duration to 1 sec substantially weakened observing behavior. A difference was that low, albeit irregular performances were maintained, suggesting that for fixed-interval schedules reductions in duration curtail rather than eliminate the reinforcing properties of clocks.

An important question raised earlier concerns the effects of clock production on total work. Analysis of performances of the three subjects trained on the multiple schedule contrasting the response-dependent and no-clock

conditions indicated that decreased fixed-interval responding was accompanied by varying degrees of increases in total responding, that is, main plus observing responses: Subject GE = +4%; Subject MB = +32%; Subject NB = +81%. Thus, the results indicated that reductions in rates of the main response were more than offset by increased responding needed to add the clock.

GENERAL DISCUSSION

Although avoidance and fixed-interval schedules share the common feature of being based on a fixed temporal contingency, they differ in several important ways. An obvious difference is in the types of reinforcing events employed with the two schedules. In addition, the contingency itself is different, since all responses are equally effective in postponing the aversive stimulus, whereas only responses after the interval has elapsed produce the fixed-interval reinforcer.

In light of these differences, it is of interest that clocks added to the two schedules exerted similar forms of control. In both experiments, addition of the response-independent clock improved the efficiency of performance. Rates of the main avoidance or fixed-interval response decreased without decreases in rates of reinforcement. A second general finding was that clocks added to both schedules possessed reinforcing properties. Display of the clock strengthened and maintained a second, observing response on which the clock was dependent.

The principal difference between the results of the two experiments pertained to the reinforcing value of the added clock. When the main response was maintained by avoidance, all five subjects smoothly acquired the observing response, which continued at high levels through later phases of the experiment. By comparison, the reinforcing properties of the clock added to the fixed-interval schedule, although clear for three of five subjects, were equivocal for the remaining two. This difference, and the additional finding that omission of feedback from the fixed-interval schedule facilitated observing, can be attributed to differences in the ways the contingencies of the two schedules are contacted.

In the case of fixed-interval schedules, responding leads to production of the reinforc-

ing stimulus, and adjustment of the schedule brings the subject into repeated contact with its temporal basis, as denoted by each delivery of the reinforcer. Avoidance responding, by comparison, results in omission of an aversive stimulus, so that adjustment to the schedule reduces contact with the event defining the temporal contingency.

It follows that clocks are potentially less informative when added to fixed-interval schedules, since the schedule regularly presents a stimulus serving a timing function. This "clock", dependent on delivery of the reinforcer, is a binary one, with each response revealing either that the fixed interval has elapsed (the reinforcer follows the response) or that it has not (the response has no consequence). With avoidance schedules, the event potentially serving such a timing function, the aversive stimulus, is the one the subject is behaving to avoid. Consequently, the usefulness of other time-correlated stimuli is enhanced as avoidance becomes more proficient and contact with the aversive stimulus is reduced.

This is not to say that a clock accompanying a fixed-interval schedule cannot convey information, or that in the absence of a clock the temporal contingencies of an avoidance schedule are concealed from the subject. The information provided by the fixed-interval reinforcer is incomplete, since nonreinforced responses do not reveal how much time must elapse before the next reinforcer is due. Thus, an added clock provides a basis for the more efficient distribution of responses. And avoidance responding cannot be maintained indefinitely without contact with the aversive event. This contact, when it occurs, is informative about the duration of the temporal interval.

A basic question raised by the findings concerns the source of the reinforcing properties of the clock stimuli. An interpretation in traditional terms attributes these properties to differential association with more primary sources of reinforcement. A different interpretation is that clocks are reinforcing simply because of the information they convey. The results do not provide much support for the differential association hypothesis, since rates of the main (monetary) reinforcer were approximately the same during clock and no-clock conditions of the experiment. Differences in the work involved in responding represent another potential source of differential rein-

forcement. While rates of the main response did, in fact, decrease when the clock was available, total responding (*i.e.*, observing as well as main responding) actually increased as a function of the clock. A more complex account in terms of work might go on to argue that temporal control without a clock requires special effort in the form of counting or some other mediating behavior. But such behaviors were not recorded in the present experiment, nor is it clear how their effortfulness can be compared to other responses. Thus, following Berlyne (1960) and Hendry (1969), one is left with the conclusion that subjects responded to display the clock simply because information about a current schedule of reinforcement is, in and of itself, reinforcing.

REFERENCES

- Azrin, N. H. Some effects of noise on human behavior. *Journal of the Experimental Analysis of Behavior*, 1958, 1, 183-200.
- Badia, P., Culbertson, S. A., and Harsh, J. Relative aversiveness of signaled vs. unsignaled avoidable and escapable shock situations in humans. *Journal of Comparative and Physiological Psychology*, 1974, 87, 338-346.
- Badia, P., Culbertson, S., and Lewis, P. The relative aversiveness of signalled vs. unsignalled avoidance. *Journal of the Experimental Analysis of Behavior*, 1971, 16, 113-121.
- Baron, A. and Kaufman, A. Human, free-operant avoidance of "time out" from monetary reinforcement. *Journal of the Experimental Analysis of Behavior*, 1966, 9, 557-565.
- Baron, A. and Kaufman, A. Facilitation and suppression of human loss-avoidance by signaled, unavoidable loss. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 177-185.
- Baron, A., Kaufman, A., and Stauber, K. A. Effects of instructions and reinforcement-feedback on human operant behavior maintained by fixed-interval reinforcement. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 701-712.
- Berlyne, D. E. *Conflict, arousal, and curiosity*. New York: McGraw-Hill, 1960.
- Blair, W. C. Measurement of observing responses in human monitoring. *Science*, 1958, 128, 255-256.
- Ferster, C. B. and Skinner, B. F. *Schedules of reinforcement*. New York: Appleton-Century-Crofts, 1957.
- Grabowski, J. and Thompson, T. Response patterning on an avoidance schedule as a function of time-correlated stimuli. *Journal of the Experimental Analysis of Behavior*, 1972, 18, 525-534.
- Hendry, D. P. Introduction. In D. P. Hendry (Ed.), *Conditioned reinforcement*. Homewood, Ill.: Dorsey, 1969. Pp. 1-33.
- Holland, J. G. Human vigilance. *Science*, 1958, 128, 61-67.

- Kaufman, A. and Baron, A. Discrimination of periods of avoidance-extinction by human subjects. *Psychonomic Monograph Supplements*, 1969, 3, No. 5 (Whole No. 37), 53-60.
- Kendall, S. B. Some effects of response-dependent clock stimuli in a fixed-interval schedule. *Journal of the Experimental Analysis of Behavior*, 1972, 17, 161-168.
- Laties, V. G. and Weiss, B. Effects of a concurrent task on fixed-interval responding in humans. *Journal of the Experimental Analysis of Behavior*, 1963, 3, 431-436.
- Laties, V. G. and Weiss, B. Response cost and confirming behavior. *Psychonomic Science*, 1964, 1, 355-356.
- Lippman, L. G. and Meyer, M. E. Fixed interval performance as related to instructions and to subjects' verbalizations of the contingency. *Psychonomic Science*, 1967, 8, 135-136.
- Long, E. R. Additional techniques for producing multiple-schedule control in children. *Journal of the Experimental Analysis of Behavior*, 1962, 5, 443-455.
- Segal, E. F. Exteroceptive control of fixed-interval responding. *Journal of the Experimental Analysis of Behavior*, 1962, 5, 49-57.
- Ulrich, R. E., Holz, W. C., and Azrin, N. H. Stimulus control of avoidance behavior. *Journal of the Experimental Analysis of Behavior*, 1964, 7, 129-133.
- Weiner, H. Some effects of response cost upon human operant behavior. *Journal of the Experimental Analysis of Behavior*, 1962, 5, 201-208.
- Weiner, H. Controlling human fixed-interval performance. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 349-373.

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