JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1978, 29, 351-361 NUMBER 3 (MAY)

SPECIES DIFFERENCES IN TEMPORAL CONTROL OF BEHAVIOR II: HUMAN PERFORMANCE[1]

C. FERGUS LOWE, PETER HARZEM, AND MICHAEL BAGSHAW

UNIVERSITY OF WALES AND AUBURN UNIVERSITY

Human subjects responded on two panels. A differential-reinforcement-of-low-rate schedule with a limited-hold contingency operated on Panel A. In Condition 1, responses on Panel B produced a stimulus on the panel that signalled whether reinforcement was available on Panel A. In Condition 2, responses on Panel B briefly illuminated a digital clock. In both conditions, performance on Panel A was very efficient; with few exceptions, Panel A was pressed only when reinforcement was available. Thus, in effect, a fixed-interval schedule operated on Panel B. In Condition 1, a "break-and-run" response pattern occurred on Panel B; with increasing temporal parameters, the duration of the postreinforcement pause on Panel B increased linearly while overall response rate and running rate (calculated by excluding the postreinforcement pauses) remained approximately constant. In Condition 2, the response pattern on Panel B was scalloped; the postreinforcement pause was a negatively accelerated increasing function of schedule value, while overall response rate and running rate were negatively accelerated decreasing functions of schedule value. The performance of subjects in Condition 2, but not in Condition 1, was highly sensitive to the contingencies in operation, and resembled that of other species on the fixed-interval schedule.

Key words: temporal cues, species differences, clocks, postreinforcement pause, differential reinforcement of low rate, fixed interval, humans

It is frequently proposed that the study of schedules of reinforcement is important because schedule effects are orderly, systematic, and replicable within and across species (Morse, 1966; Skinner, 1959; Zeiler, 1977). Indeed, the extent to which replication of "typical" schedule performance is achieved with different species may be taken as an index of the effectiveness of experimental control in a particular laboratory (Sidman, 1960). Moreover, replicability across species is thought to provide justification for extrapolation from animal to human behavior (Skinner, 1953, 1957). Curiously, however, the existing evidence indicates that on many schedules of reinforcement there are marked differences between human and animal behavior.

Consider, for example, performance on the fixed-interval (FI) schedule. On an FI schedule, the first response is reinforced after a stated interval has elapsed since the previous reinforcement; other responses do not affect the contingencies in operation. In many species, the performance typically generated by this schedule consists of a pause after reinforcement, followed by an accelerating rate of responding, which terminates at the next reinforcement (Branch and Gollub, 1974; Dews, 1978; Ferster and Skinner, 1957; Lowe and Harzem, 1977). Both the response rate and the duration of postreinforcement pause are systematically related to a number of variables, *e.g.*, the temporal parameter (Hanson, Campbell, and Witoslawski, 1962; Skinner, 1938; Wilson, 1954); reinforcer magnitude (Lowe, Davey, and Harzem, 1974; Staddon, 1970); level of deprivation (Collier, 1962; Powell, 1972); drugs (Branch and Gollub, 1974; Dews, 1968); and added punishment of each response (Azrin and Holz, 1961).

In human FI performance, however, this pause-respond pattern seems particularly elusive. The existing literature reports two main types of patterning in humans. One is a *high-rate* pattern, consisting of a high, undifferentiated rate of responding between reinforcements (Leander, Lippman, and Meyer, 1968; Lipp-

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[1] During this study, M. Bagshaw was in receipt of a graduate studentship from the Social Science Research Council, U.K. Reprints may be obtained from Fergus Lowe, Department of Psychology, University College of North Wales, Bangor, Gwynedd, U.K., or from Peter Harzem, Department of Psychology, Auburn University, Auburn, Alabama 36830.

man and Meyer, 1967; Weiner, 1965); the other is a *low-rate* pattern, consisting of just one or two responses at the end of each interreinforcement interval when the next reinforcement is due (Baron, Kaufman, and Stauber, 1969; Bullock, 1960; Matthews, Shimhoff, Catania, and Sagvolden, 1977). Which of these patterns will be observed appears not to be related to the more obvious characteristics of the experimental situation, since both patterns are frequently found, in different subjects, in the same experiment (Weiner, 1969). With the high-rate pattern, no relationship has been found between the response measures and the temporal parameter of the schedule. With the low-rate pattern, responding varies as a simple function of FI duration, the occurrence of responses matching almost perfectly the availability of reinforcement.

Such data are from experiments where the response was pressing a button or telegraph key for monetary reinforcers or points. However, there have been some studies where a pause-respond pattern, characteristic of other species, was observed with humans. Interestingly, these studies have used procedures other than the direct reinforcement of simple responses. Holland (1958), Azrin (1958), and Laties and Weiss (1963) used a signal-detection task where key presses illuminated a dial, and subjects had to press a different key when the dial-pointer was deflected. When deflections of the dial were arranged according to an FI schedule, cumulative records of dial-illuminating responses exhibited the pause-respond pattern. Gonzalez and Waller (1974), using a different procedure in which subjects' handwriting responses were reinforced, obtained similar patterning of responses. In most of these studies, the transition from pausing to a constant terminal response rate was very rapid, and scalloped response patterns were absent. However, there are no detailed parametric data in the existing literature, the findings cited being based on cumulative records. Consequently, comparison across species is difficult.

The evidence does, nevertheless, suggest that observing behavior may be more sensitive to the fixed-interval contingency than a simple key-pressing response. The present study investigated this possibility and provided a detailed parametric investigation of two different types of observing behavior. One of these (binary-clock) resembled that employed in the signal-detection studies discussed above. In the second condition (digital-clock), continuously changing temporal cues were available throughout each interreinforcement interval, contingent on observing responses.

METHOD

Subjects

Eight first-year undergraduates, four male and four female, took part. They had no previous experience of psychology experiments.

Apparatus

The experiment was conducted in a small cubicle with a floor-area of 100 cm by 180 cm. The response console, which was mounted on one wall, contained two Lehigh Valley human-response panels placed 24 cm apart (see Figure 1). The left-hand panel was labelled "A", the right-hand panel "B". A points counter was mounted 16.5 cm above Panel B and an L-E-D (light emitting diode) digital clock (type MA·100 1B, Farnell Electronic Components, U.K.) was mounted 5 cm below the counter. Scheduling and recording equipment was situated in a separate room.

Procedure

There were two experimental conditions, each employing a different type of clock: the binary-clock condition and the digital-clock condition. In both conditions, presses on Panel A were reinforced by points according to a differential-reinforcement-of-low-rate (DRL) schedule with a limited-hold (LH) contingency.

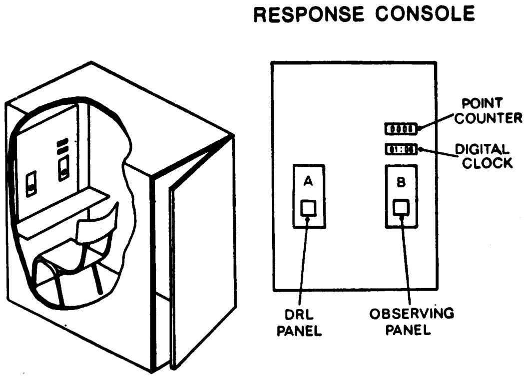

Fig. 1. Schematic illustration of the apparatus showing the experimental cubicle on the left and details of the response console on the right.

Table 1

Number of sessions conducted on each schedule value and standard deviations of mean postreinforcement pauses for each subject.

Schedule (seconds) DRL (Key A)	*Subject*	*Sessions*	*Standard Deviation (seconds)*
BINARY-CLOCK GROUP			
10	QR	3	2.0
45		4	4.4
90		4	10.9
180		6	26.7
360		7	46.9
10	LP	4	1.5
45		4	2.7
90		5	5.4
180		6	22.6
360		6	31.8
10	NE	3	1.5
45		4	5.7
90		5	6.2
180		5	8.1
360		6	43.9
10	FZ	4	1.0
45		4	8.1
90		6	14.7
180		4	15.5
360		5	25.2
DIGITAL-CLOCK GROUP			
10	CHR	3	0.8
45		4	4.3
90		4	9.0
180		6	16.4
360		6	27.5
10	SIA	3	0.8
45		3	8.6
90		4	5.2
180		4	7.5
360		6	18.5
10	MAR	3	0.8
45		4	5.8
90		4	5.1
180		5	8.1
360		6	18.6
10	SUS	3	0.9
45		4	6.2
90		5	11.9
180		4	24.7
360		8	48.0

In the binary-clock condition, a response on Panel B (observing panel) illuminated that panel for 0.5 sec. When reinforcement was available on Panel A (DRL panel) the response-contingent illumination on Panel B was a green circle on a white ground; when reinforcement was not available, the response-contingent illumination was diffuse white light. Since the DRL schedule included an LH contingency, responding on Panel B and observing the resulting stimulus made it possible to maximize point reinforcement on Panel A. Given efficient DRL performance, presentation of the green stimulus on the observing panel was in effect on an FI schedule with an LH contingency.

For subjects in the digital-clock condition, each response on Panel B produced 0.5-sec illumination of the clock, which showed the time since reinforcement in minutes and seconds. The clock reset after each point reinforcement or at termination of the limited-hold.

Four subjects were randomly assigned to each condition. The DRL values were 90, 180, 45, 360, and 10 sec, in that order, for both groups. The LH was always one-fifteenth of the DRL value. Schedule values were changed when performance was judged to be stable over three consecutive 30-min sessions (See Table 1). At the beginning of the first session, all subjects were familiarized with the details of the console, and were given the following instructions:

> "Your task is to earn as many points as you can. Points are shown on the counter above Panel B. Each point is worth ½p. In addition you will be paid 50p for every hour you spend in the experiment. Points are available for presses on Panel A. Panel B may be used to determine when points are available." (1p = 1.86 cents).

At the end of the experiment each individual was given the following questionnaire:

1. What do you think the experiment was about?
2. Did any changes take place during the course of the experiment? If so, what were they?
3. Did you employ any particular strategy in order to produce points? If so, describe the strategy you employed.
4. Please make any other comments you might have.

RESULTS

Figure 2 shows individual cumulative and event records of responding in the last 12 min of the final session of each schedule value for the subjects in the binary-clock group. The

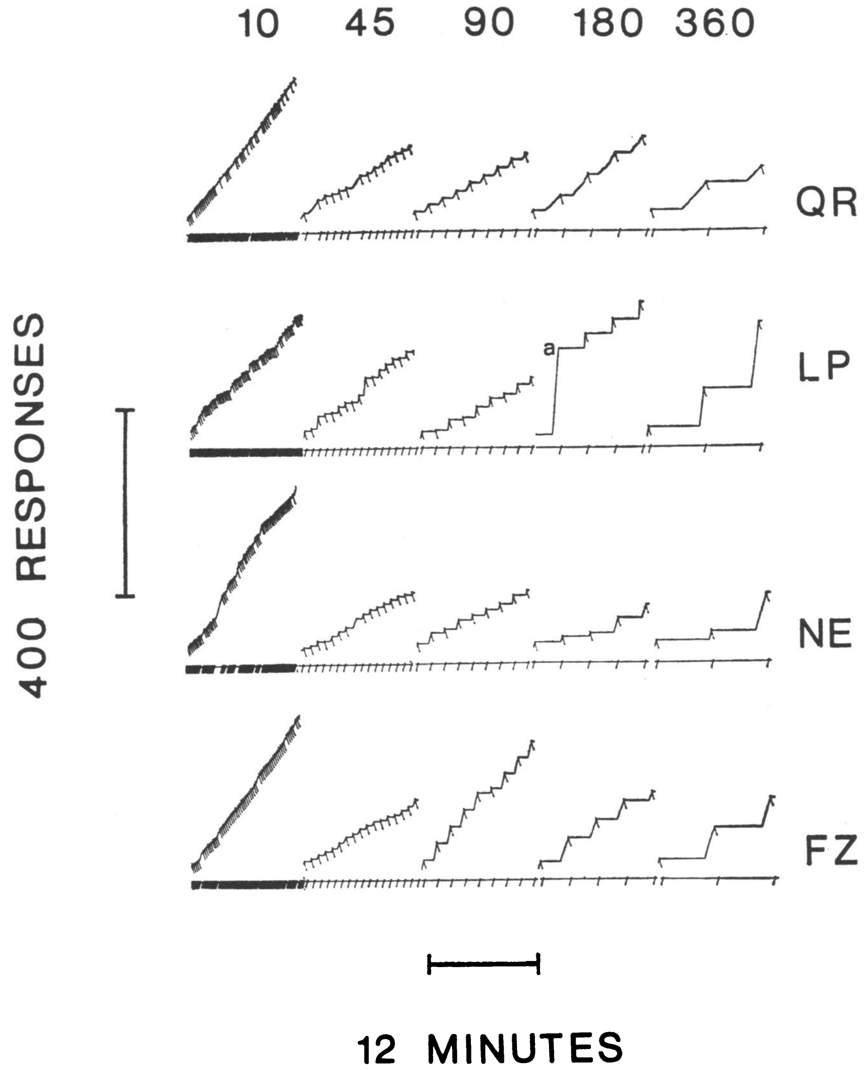

Fig. 2. Cumulative records and event records of responding for each subject in the binary-clock condition. Figures at the top indicate schedule values. The cumulative records show responding on the observing panel, B, and the event marker shows responding on the DRL panel, A. The cumulative pen was offset with each reinforcement. The point on the cumulative record marked "a" shows an example of a reinforcement that was missed on the DRL schedule. Records are from the last 12 min of the final session on each schedule value.

cumulative records show responding on the observing panel, B, the event records responding on the DRL panel, A. Downward deflections of the pen on the cumulative record indicate reinforcement, *i.e.*, delivery of a point. There was just one response per reinforcement on Panel A, with few instances of a "missed" reinforcer. The pattern of responding on Panel B was a substantial postreinforcement pause followed by an abrupt transition to a constant terminal rate; this was true of all subjects at every value of the schedule.

Figure 3 shows cumulative and event records from subjects in the digital-clock group. Again performance on the DRL panel, A, was very accurate, with only one response produced for each reinforcer. However, the pattern of responding on Panel B in this group was different from that observed with the binary-clock subjects. Here, postreinforcement pauses were followed by a gradual acceleration in responding up to the next reinforcement. Whereas there was little evidence of systematic effects of schedule value on response rate in the

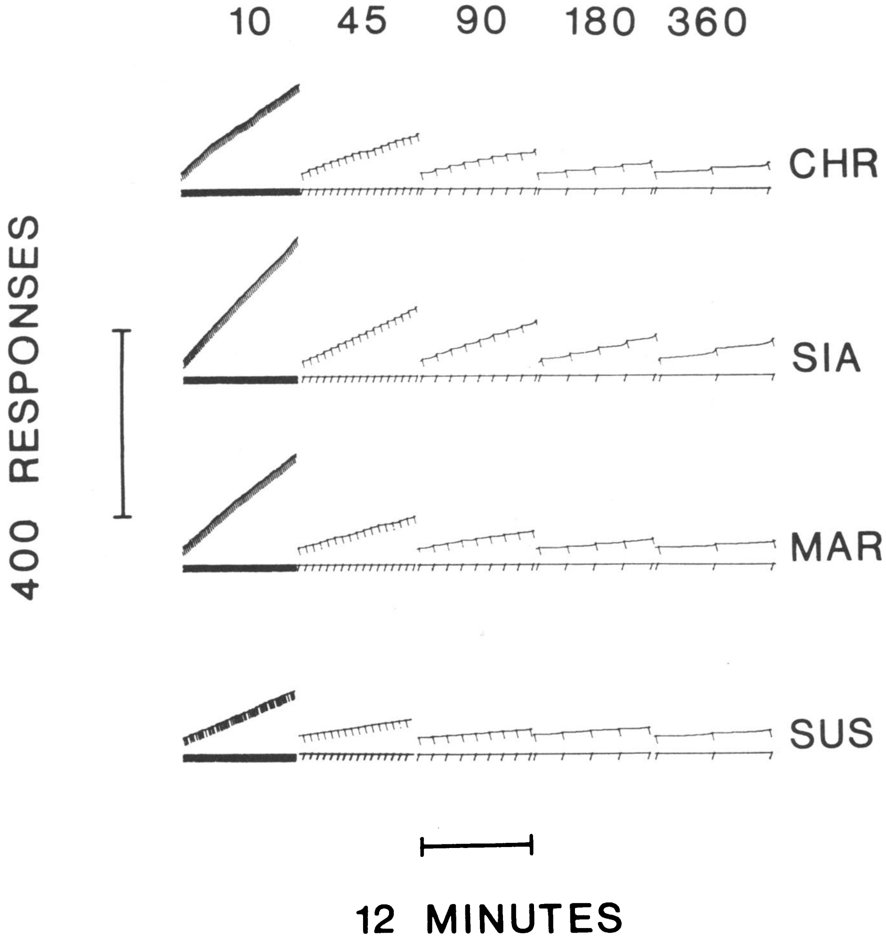

Fig. 3. Cumulative records and event records of responding for each subject in the digital-clock condition. Figures at the top indicate schedule values. The cumulative records show responding on the observing panel, B, and the event marker shows responding on the DRL panel, A. The cumulative pen offset with each reinforcement. Records are from the last 12 min of the final session on each schedule value.

cumulative records of the binary-clock group (Figure 2), there was an orderly decline in response rate as a function of schedule value in the records of all subjects using the digital clock.

Details of responding on Panel B are shown in Figure 4. (All subsequent data references are to Panel B.). Figure 4 shows each subject's overall response rate and running rate, *i.e.*, response rate calculated after excluding the postreinforcement pause. The data are averaged over the last three sessions at each schedule value. Data in the left panel are for the binary-clock and in the right panel for the digital-clock condition. Overall response rates for the binary-clock subjects were more variable than for the digital-clock subjects. There was little evidence in the binary-clock subjects of a systematic relationship between overall rates and schedule value. All subjects in the digital-clock group, on the other hand, showed an orderly and consistent negatively accelerating decline in overall response rate as schedule value was increased.

With running rates, there were no consistent effects in the binary-clock condition, but there was an orderly decline in rate as a function of schedule value for all subjects in the digital-clock condition. As with overall rates, running rates were generally lower in the digital-clock than in the binary-clock condition, particularly at higher schedule values (see also Figure 7).

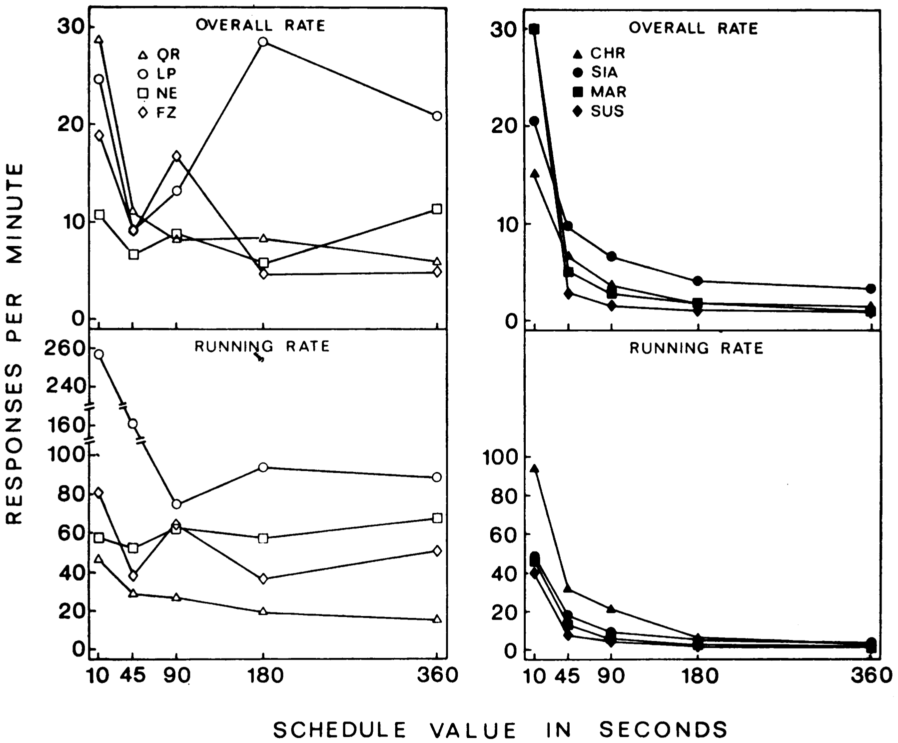

Fig. 4. Overall response rates and running rates on the observing panels for individual subjects in the binary-clock condition (left) and in the digital-clock condition (right) as functions of schedule value. Data are from the last three sessions on each schedule value.

Figure 5 shows postreinforcement pauses for each subject at the different schedule values. The top half of each panel shows the mean postreinforcement pause (see Table 1 for standard deviations); the bottom half shows the relative postreinforcement pause, *i.e.*, the postreinforcement pause as a proportion of the interreinforcement interval. For binary-clock subjects (left panel), the mean postreinforcement pause increased linearly with schedule value, while the relative postreinforcement pause remained approximately constant at all values. Postreinforcement pauses for the digital-clock subjects (right panel) increased as negatively accelerating functions of schedule value while relative postreinforcement pauses declined. Postreinforcement pauses were generally shorter in the digital-clock group than in the binary-clock group (*cf.* Figure 7). The only overlap was in the data of QR (shortest postreinforcement pauses among binary subjects) and CHR (longest postreinforcement pauses among digital subjects).

Figure 6 provides a more detailed indication of what happened within interreinforcement intervals. This shows the successive mean interresponse times at each schedule value for each subject. The top panel shows that at all schedule values subjects in the binary-clock group shifted abruptly to a high and constant response rate following the postreinforcement pause. With digital-clock subjects, on the other hand, there was a gradual decline in successive interresponse times on each schedule. Moreover, comparing the same ordinal position across different schedule values, interresponse times were an increasing function of the schedule value.

In their questionnaire replies, all subjects said that delivery of points depended on the passage of time. In reply to Question 3, all four subjects in the binary-clock group said that they counted to themselves to help time the interval; they counted until they considered the interval was nearly up and then responded to produce the clock stimulus. None of the subjects in the digital-clock group reported counting.

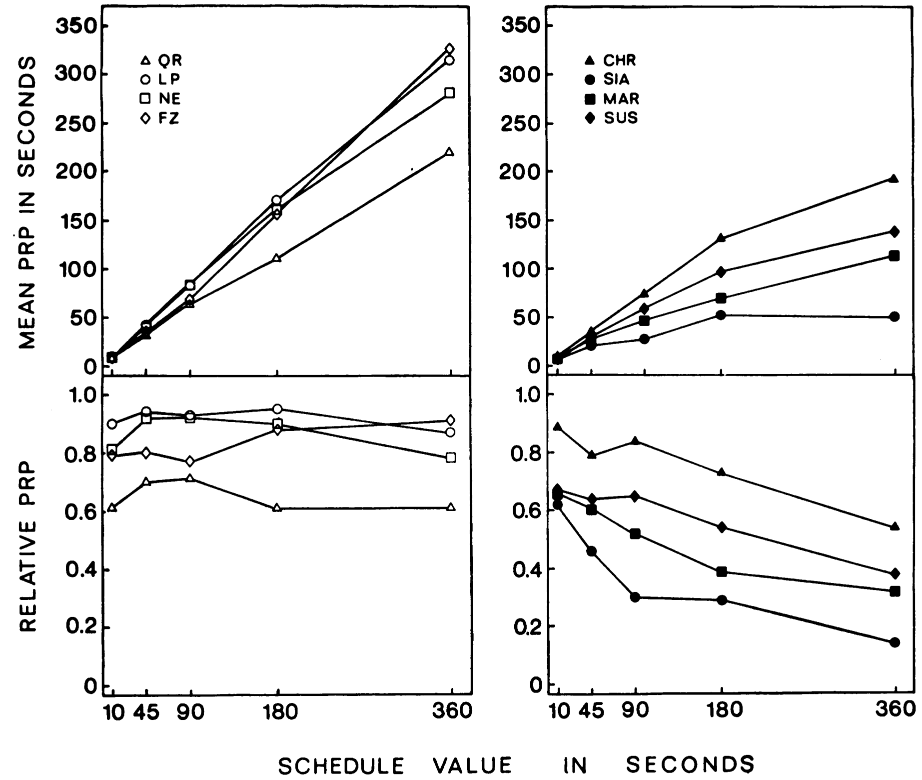

Fig. 5. Mean duration and relative duration of postreinforcement pauses on the observing panels for individual subjects in the binary-clock condition (left side of figure) and in the digital-clock condition (right side) as functions of schedule value. Relative durations were calculated as proportions of the interreinforcement intervals. Data are from the last three sessions on each schedule value.

DISCUSSION

The digital-clock data show that under appropriate conditions, human behavior on fixed-interval schedules resembles that of other species: (i) responding was characterized by a pause after reinforcement followed by a gradual increase in rate up to the next reinforcement, and (ii) all dependent variables showed the sensitivity to schedule parameters that has previously been reported only in animal studies of operant behavior. The performance of the binary-clock group, on the other hand, was not similarly sensitive to the temporal variable.

The present data are compared with the typical fixed-interval performance of rats in Figure 7. The left panel shows mean overall rates for groups of rats at different fixed-interval values, from studies by Skinner (1938) and Wilson (1954); also shown are the mean overall rates of the present binary-clock and digital-clock groups. The functions for the rats and the digital-clock subjects were similar; both showed a negatively accelerated decline in responding with increasing schedule value. Response rates in the binary-clock condition, however, showed no systematic relationship with the schedule parameter. The right panel of Figure 7 compares postreinforcement pauses of rats and humans. The rat data, from our laboratory, are means representing the stable performance of a group of four rats at different fixed-interval values. While postreinforcement pauses increased linearly with schedule value for the human binary-clock group, the increases for both rats and human digital-clock subjects were negatively accelerated.

The existing animal literature describes two kinds of fixed-interval performance: scalloping and "break-and-run" (*cf.* Cumming and Schoenfeld, 1958; Schneider, 1969; Staddon, 1972). However, recent evidence shows that even where cumulative records of animal performance suggest a rapid transition from postreinforcement pause to a constant response

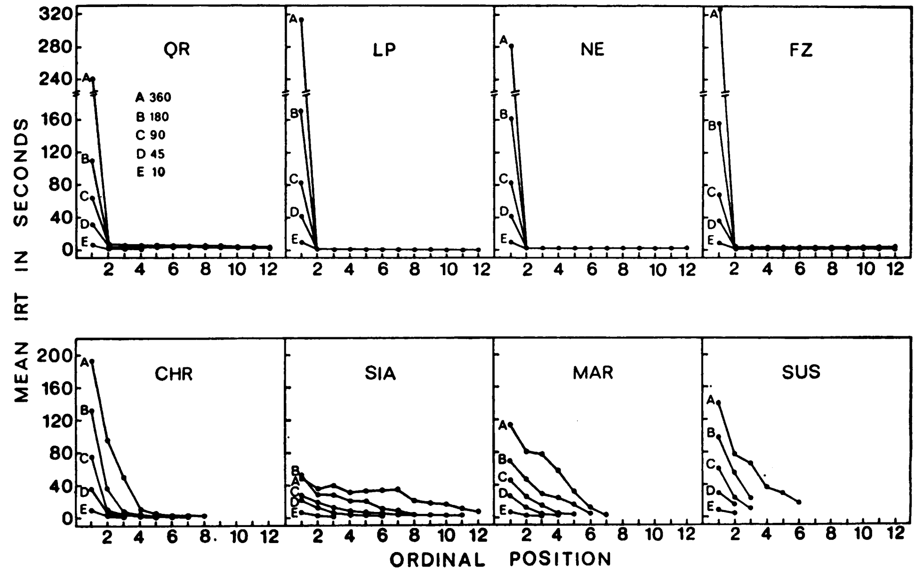

Fig. 6. Mean duration of interresponse times on each schedule value plotted against ordinal position in the interreinforcement interval. The top panel shows individual data for the binary-clock condition, and bottom panels data for the digital-clock condition. Letters indicate schedule value. Data are from the last three sessions on each schedule value. In the top panel where points overlap there is a data point for each subject.

rate, a more detailed analysis of response rate or interresponse-time duration reveals a gradual acceleration in responding following the postreinforcement pause; this is true of rats, pigeons, and monkeys, even after prolonged exposure to the contingencies (Branch and Gollub, 1974; Dews, 1978; Lowe and Harzem, 1977). While interresponse-time durations for digital-clock subjects showed a gradual decline, for the binary-clock subjects the transition from pausing to a high constant response rate was immediate (See Figure 6). Such abrupt transition has not been observed even in the break-and-run pattern of other species (Lowe

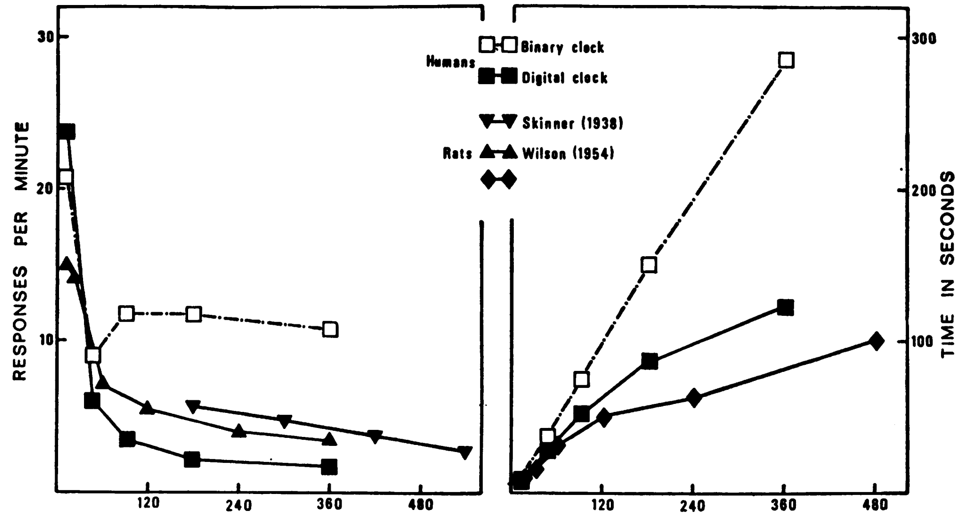

Fig. 7. Mean overall response rates (left panel) and mean durations of postreinforcement pauses (right panel) as functions of fixed-interval duration for different groups of rats and for the human subjects. Human data are from the present experiment and rat data from experiments by Skinner (1938) and Wilson (1954), and from this laboratory (filled diamonds in right panel).

and Harzem, 1977; Schneider, 1969; Shull and Brownstein, 1970). This analysis, together with the finding that in the binary-clock condition response rate was not sensitive to changes in schedule parameter, indicates that performance typical of other species occurred only under the digital-clock condition. Previous studies of human observing behavior have used procedures resembling that of the present binary-clock condition (Azrin, 1958; Holland, 1958; Laties and Weiss, 1963). These studies have provided cumulative records that have been thought to resemble those of animal fixed-interval performance. However, inspection of the records presented by Azrin (1958) and Laties and Weiss (1963) suggests that performance was more like that of the present binary-clock group. Of course, the question of which type of behavior in fact occurs under the observing-response procedures of previous studies would be best resolved by a detailed parametric analysis, similar to that reported here.

Why does the digital-clock procedure produce effects similar to the performance of animals, when other experimental procedures do not? And second, in the case of humans, why are clock-observing situations in general more likely to produce the pause-response pattern on fixed-interval schedules than the conventional key pressing procedures? Matthews *et al.* (1977) suggested that procedures that reinforce observing responses may produce behavior sensitive to fixed-interval contingencies "in the sense that they generate scalloping" because a separate response for the reinforcer at completion of the interval interrupts ongoing responding. Such procedures may also be described as two-response chain schedules. The present results show that two-response chain schedules are not *sufficient* to produce human fixed-interval responding similar to that of other species; under the binary-clock condition, scalloping did not occur and response-rate data were not sensitive to schedule parameters. This point is further supported by Matthews *et al.*'s own study of human fixed-interval performance. They employed a two-response chain schedule (fixed-interval x-sec fixed-ratio 1), which produced neither regular scalloping nor "break-and-run" patterns; responding was mostly of the low-rate pattern, previously observed in the majority of human studies (*e.g.*, Baron *et al.*, 1969; Bullock, 1960; Leander *et al.*, 1968; Weiner, 1964; 1969). It should be noted, however, that Matthews *et al.* conducted only one session with each subject and presented different schedules and schedule parameters in that session; this procedure makes difficult any comparison with the present data, which were collected after establishment of stable performance over a number of sessions at each schedule value. Whether two-response chains are *necessary* in order to produce sensitive fixed-interval performance in humans has yet to be determined, though the evidence suggests that the pause-respond pattern can occur in the absence of such response chains (Gonzalez and Waller, 1974).[2]

One possibility is that patterning was enhanced in the present study by the use of a limited-hold in both conditions. However, the limited-hold contingency cannot be a sufficient condition for the occurrence of scalloping and the parametric effects on response rates, as these were not present in the binary-clock group. Nor has scalloping been reported in other human experiments that have employed the limited-hold contingency (Laties and Weiss, 1963). It is likely, nevertheless, that a limited-hold may help to produce a pause-respond pattern, where without it there would be just one or two responses per interval (Sidman, 1962), because increased responding around the time when the reinforcer is due may result in fewer missed reinforcements (see also Ferster and Skinner, 1957). It is interesting that though the pause-respond pattern occurs in the absence of a scheduled limited-hold in observing-response studies, a limited-hold contingency may be implicit in the experimental procedures; for example, in the studies of both Holland (1958) and Azrin (1958), subjects were instructed to detect as many pointer deflections as they could and to reset the pointer as rapidly as possible.

In previous studies of human fixed-interval performance, a major difficulty was that subjects' behavior was at times under the control of extra-experimental variables (Leander *et al.*, 1968; Lippman and Meyer, 1967; Weiner, 1969). As Laties and Weiss (1963)

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[2] This issue has been resolved in a recent study (Lowe, Harzem, and Hughes, 1978) which shows that scalloped FI responding, which is sensitive to the schedule parameter, can be readily established in humans without the use of a two-response chain procedure.

argued, counting and other stimuli significant in controlling behavior may be produced by the subject, and such stimuli are not usually under the control of the experimenter (but see also Bem, 1967). Moreover, Skinner (1969) observed, "any actual formulation of the relation between a response and its consequence (perhaps simply the observation, 'whenever I respond in this way such and such an event follows') may of course function as a prior controlling stimulus". Replies to the questionnaire indicated that binary-clock subjects counted out an interval before responding on the observing panel, and that counting behavior *may* have functioned as a discriminative stimulus for responding on the observing panel (*cf.* Laties and Weiss, 1963). In contrast, none of the digital-clock subjects reported counting, which suggests that they relied on responses that illuminated the digital clock to determine the passage of time in the interval. With interference from counting eliminated, responding in the digital-clock condition was then open to the direct effect of the temporal contingencies. Although responding at a considerably higher running rate, binary-clock subjects produced much longer postreinforcement pauses than the digital-clock subjects (*cf.* Figure 5). This supports the view that counting during the early part of the interval suppressed responding on the observing panel in the binary-clock condition.

The present study, in establishing fixed-interval control of human performance in the digital-clock condition, suggests that such control occurs when subject-produced cues, such as counting, are attenuated and when the behavior can be brought under the control of exteroceptive temporal cues. This analysis is, of course, open to further investigation. Using the present procedure, however, it should now be possible to investigate with humans the range of independent variables such as magnitude of reinforcement, level of deprivation, punishment, and drugs, which have been so successfully studied with animal subjects.

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Received 9 August 1977.
(Final acceptance 13 December 1977.)