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CLOCK-DELIVERED REINFORCERS IN CONJUNCTIVE AND INTERLOCKING SCHEDULES[1]

RICHARD B. POWERS

EASTERN WASHINGTON STATE COLLEGE

The effects of different temporal requirements in conjunctive and interlocking schedules of reinforcement were examined. The compound schedules were arranged so that a reinforcer could be delivered by either a rat's response or a clock. As the temporal requirements increased in the interlocking schedules, the overall rate of responding increased, but the pattern of responding remained relatively unchanged. As the temporal requirement increased in the conjunctive schedules, the overall rate decreased and a pause-and-run pattern of responding emerged. When the response requirement was reduced to one in the conjunctive schedule for one animal, a low and extremely stable rate of responding developed.

Compound schedules of reinforcement contain a response and a time contingency (Morse, 1966). In one compound schedule, an interlocking schedule, the response requirement is maximal immediately after reinforcement and diminishes as a function of time. In another, a conjunctive schedule, the response and temporal requirements for reinforcement remain constant. Figure 1 portrays the contingencies that exist in these schedules. Two types of interlocking and two types of conjunctive schedules are illustrated using a slightly modified version of Skinner's (1958) notation system.

The upper two frames of Fig. 1 show two types of interlocking schedules. In the upper right frame, delivery of a reinforcer requires no more than 50 responses and this response requirement diminishes to a minimum at 5 min. The diagonal line does not go to zero because reinforcement must always be produced by a response; therefore, at least one response is required. This interlocking schedule represents the schedule suggested by Skinner, and investigated by Berryman and Nevin (1962). In the upper left frame of Fig. 1, delivery of a reinforcer also requires no more than 50 responses. However, the diagonal line does decrease to zero, which indicates that a reinforcer will be delivered without a response if the organism waits 5 min. The diagonal line is dashed to indicate that reinforcement need not be produced by a response. Whenever the time interval defined by the dashed line has elapsed, reinforcement will occur.

The bottom two diagrams portray conjunctive schedules which have similar response and temporal requirements: each requires one response and 5 min for reinforcement. In the conjunctive schedule on the right, responses made before the end of the interval do not modify the response requirement. Only one response is required and it must be made after the interval has elapsed. In short, the conjunctive schedule on the right is a fixed-interval schedule of 5 min. The conjunctive schedule on the left also requires one response, but it can be made before the end of the interval, and reinforcement will occur when the interval has elapsed.

Note that in the compound schedules with the dashed lines a delay between a response and reinforcement is made possible by the contingencies. In both schedules a response can be made before the end of the interval, and reinforcement will occur when the interval has elapsed, whether or not any further responding has occurred. The purpose of the present experiment was to examine a conjunctive and an interlocking schedule in which a reinforcer

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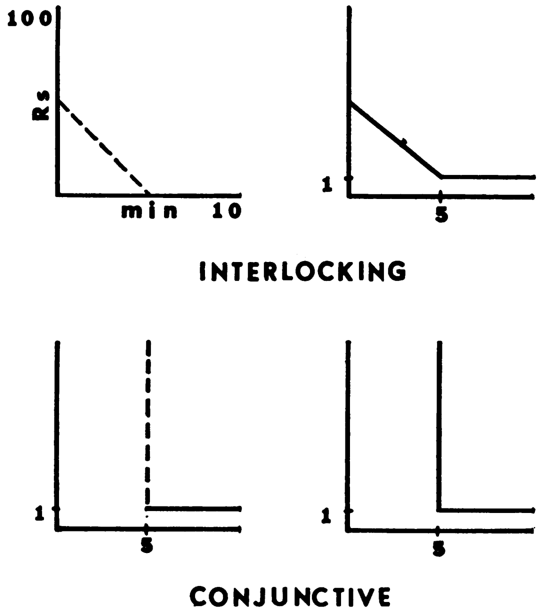

Fig. 1. Four compound schedules of reinforcement. The solid lines indicate that a reinforcer is available when the interval defined by the lines has elapsed. The first response after the interval produces reinforcement. The dashed lines indicate that reinforcement may occur as soon as the interval has elapsed and that it may be response-independent.

could be delivered by either a response or a clock.

METHOD

Subjects

Four male albino rats of the Wistar strain, approximately 150 days old at the beginning of the experiment, were maintained at 85% of their free-feeding weight. Noyes rat food pellets (45 mg) were used as the reinforcer. Food rations necessary to maintain the animals at the correct body weight were given immediately after the daily session. Daily sessions lasted until the subjects had received 100 pellets or until 30 min had elapsed, whichever occurred first. Water was continuously available in the home cages.

Apparatus

The response chamber was approximately 1 cu ft in size and was housed in a refrigerator shell which minimized apparatus noise. A blower attached to one wall kept air circulating through the response chamber and provided a masking noise. The response mechanism was a nose lever (Crossman, 1963) which required an upward force of 12 to 15 g for microswitch closure. Electromechanical apparatus was used to schedule reinforcements and to record data.

Procedure

The subjects were trained to press the nose lever within two sessions, and then the schedule requirements were gradually changed from reinforcement of each response to a fixed-ratio schedule of one reinforcement for each 16 responses (FR 16). When response rates had stabilized, Subjects R-5 and R-7 were placed on an interlocking schedule, and R-19 and R-21 were placed on a conjunctive schedule. The response requirement was 32 in the interlocking schedule and 16 in the conjunctive schedule.

In the conjunctive and interlocking schedules, a reinforcer could be delivered by either a response or a timer. Thus, in the Conjunctive 16 schedule, if the animal made 16 responses before the end of the time interval, a reinforcer would be delivered by the timer. If the interval had elapsed before the animal completed the response requirement, a reinforcer would be delivered by a response. Likewise, in the interlocking schedule, a reinforcer could be delivered by either a response or the timer. In addition, in the latter schedule, the animal could receive a reinforcer without responding.

In each schedule, the subjects were exposed to five different temporal requirements in a mixed order to minimize serial effects. The order and length of exposure to each schedule as well as the value of the various schedules are presented in Table 1.

After the series of interlocking schedules was completed, R-5 and R-7 were exposed to several conjunctive schedules. R-21 was exposed to a conjunctive schedule which required only one response after completion of the conjunctive schedules requiring 16 responses. R-21 was then exposed to a fixed-interval schedule of 27 sec (FI 27-sec). The temporal requirements of the FI schedule and the Conjunctive 1-response/27-sec schedule were identical. In this way, the two schedule performances could be compared with the temporal requirements held constant.

R-19 developed a respiratory disease shortly after the ninth session in the last condition of

Table 1

Summary of sessions with fixed-ratio (FR), fixed-interval (FI), conjunctive (Conj), and interlocking (Int) schedules.

R-5		*R-7*		*R-19*[a]		*R-21*	
Schedule	*Sessions*	*Schedule*	*Sessions*	*Schedule*	*Sessions*	*Schedule*	*Sessions*
FR 16	27	FR 16	19	FR 16	12	FR 16	15
Int 32: 18-sec	20	Int 32: 10-sec	11	Conj 16: 18-sec	7	Conj 16: 18-sec	12
Int 32: 5-sec	15	Int 32: 7-sec	7	Conj 16: 14-sec	17	Conj 16: 27-sec	12
Int 32: 50-sec	15	Int 32: 5-sec	15	Conj 16: 10-sec	14	Conj 16: 10-sec	7
Int 32: 14-sec	15	Int 32: 27-sec	8	Conj 16: 50-sec	14	Conj 16: 34-sec	11
Int 32: 7-sec	15	Int 32: 80-sec	7	Conj 16: 34-sec	9	Conj 16: 14-sec	11
FR 16	15	FR 32	9			FR 16	11
Conj 16: 18-sec	14	Conj 16: 10-sec	10			Conj 1: 18-sec	17
Conj 16: 27-sec	11	Conj 16: 7-sec	12			Conj 1: 27-sec	14
Conj 16: 34-sec	9	Conj 16: 5-sec	9			FI 27-sec	8
Conj 16: 50-sec	22	Conj 16: 18-sec	8				
Conj 16: 80-sec	8	Conj 16: 27-sec	8				

[a]This subject became ill and did not complete the experiment.

the Conjunctive 16 schedule and had to be discarded. Table 1 summarizes the replication conditions for the three remaining rats.

RESULTS

In the Interlocking 32 schedule, the overall rate of responding generally increased as the temporal component of the schedule increased. Figure 2 shows that the function relating rate to the length of the temporal component in this schedule was negatively accelerated. Figure 3 shows that at the shorter temporal requirements of 7 and 5 sec, short pauses occurred and were frequently reinforced. Although both animals tended to slow down or stop responding during the latter part of the session, they resumed responding in the next session. Occasionally, reinforcement occurred after a long pause, as in R-5's record with the temporal requirement at 50 sec (Fig. 3); these occasions also were more frequent toward the end of the session. Again the performance recovered during the next session.

In the Conjunctive 16 schedule, the rate of responding generally decreased as the temporal component increased (Fig. 4). In the schedules with the longer temporal components, a pause-and-run pattern of responding developed; it is most noticeable in the records of R-19 (Fig. 5) and R-5 (Fig. 6).

Replication Results

The performance of R-7 in the Conjunctive 16 schedule was very similar to that in the Interlocking 32. As the time requirement in the Conjunctive 16 was increased, response rate increased, and it was difficult to see any difference between FR 16 and Conjunctive 16 performances. Since there were no obvious differences between R-7's conjunctive and FR performances, the data for the conjunctive schedule are not presented.

For R-5, however, the effects of increasing the time requirements in the Conjunctive 16 were similar to those found for R-19 and R-21. Figure 6 shows that as the time requirement increased, R-5's mean rate decreased and, like R-19, the pattern of responding took on a pronounced step-like appearance.

Several interesting features of the performance shown in Fig. 6 were also present in the cumulative records of R-19 and R-21. Fre-

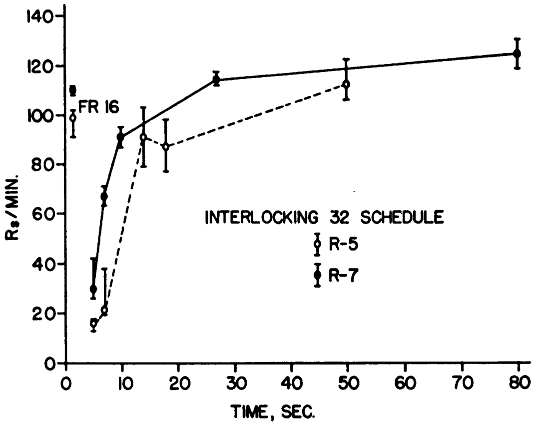

Fig. 2. Rate of response as a function of the temporal interval in the Interlocking 32 schedule. Subjects' rates are averaged over the last five sessions.

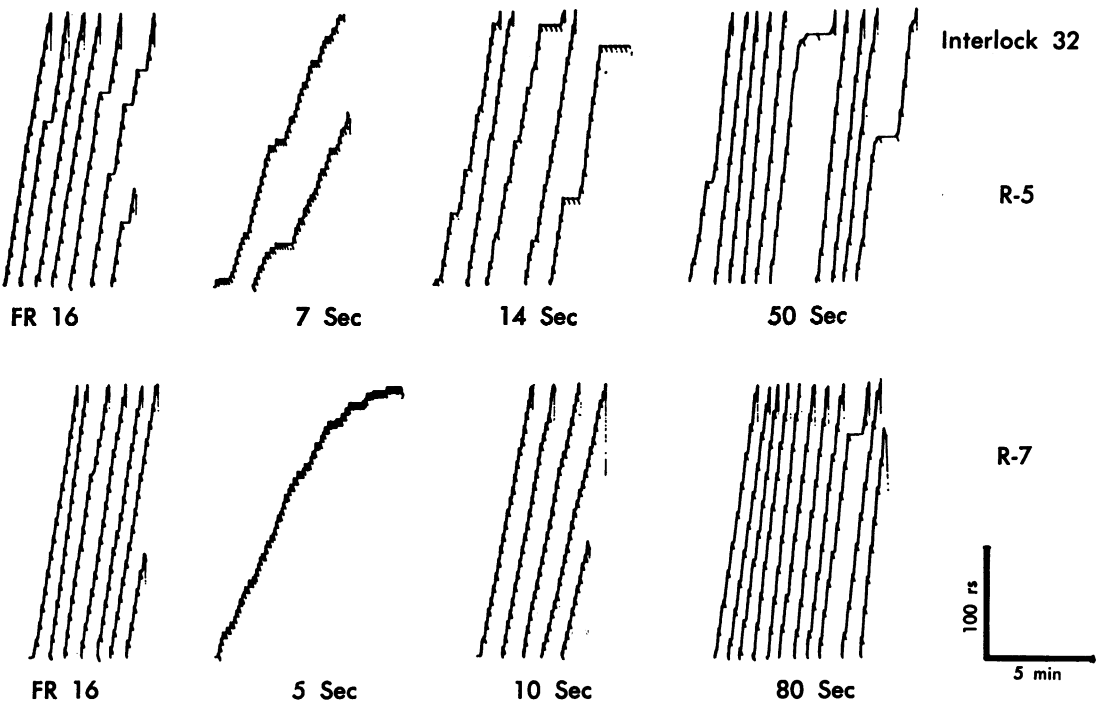

Fig. 3. Cumulative records of the last session in each of several Interlocking 32 schedules. The duration of the temporal component is given below each record.

quently, the pauses after reinforcement were short and the runs of responses long during the initial part of the session. This pattern was evident at all values of the conjunctive schedule for this animal, and is illustrated most clearly during the first 5 min of the second cumulative record (Fig. 6).

The points marked "a" in Fig. 6 show instances of a run-pause-run pattern of responding. These patterns also developed in the interlocking schedules studied by Berryman and Nevin (1962), and can be seen in the records of R-19 and R-21 at the longer temporal requirements (see Fig. 4). The points marked "b" in Fig. 6 are occasions when reinforcement followed a pause of appreciable length (greater than 5 sec).

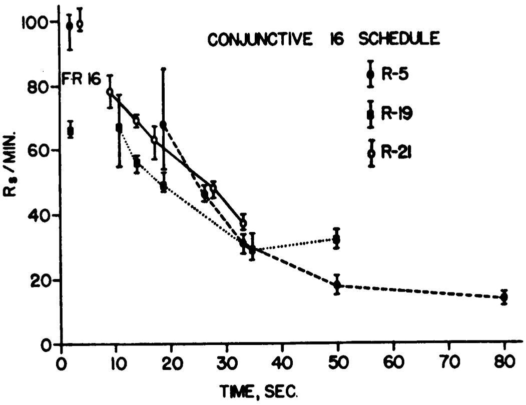

Fig. 4. Rate of response as a function of the temporal interval in the Conjunctive 16 schedule. Subjects' rates are averaged over the last five sessions.

The top part of Fig. 7 shows the last three sessions in the conjunctive schedule with a response requirement of 1 and a time requirement of 27 sec. The main feature of these records is the stability of rate. Short runs of three or four responses are relatively infrequent, and the longer runs that occurred in the Conjunctive 16 schedules have been eliminated. The performance that eventually developed was one in which the ratio of responses to reinforcement was very nearly maximal. The average number of responses per reinforcement for the sessions shown in Fig. 7 was 1.75. The lower portion of Fig. 7 shows R-21's performance in an FI 27-sec schedule after exposure to the previous conjunctive schedule. Although it appears that there are still some residual effects of the previous schedule, the general pattern of the records resembles a small-value FI performance (Gollub, 1964).

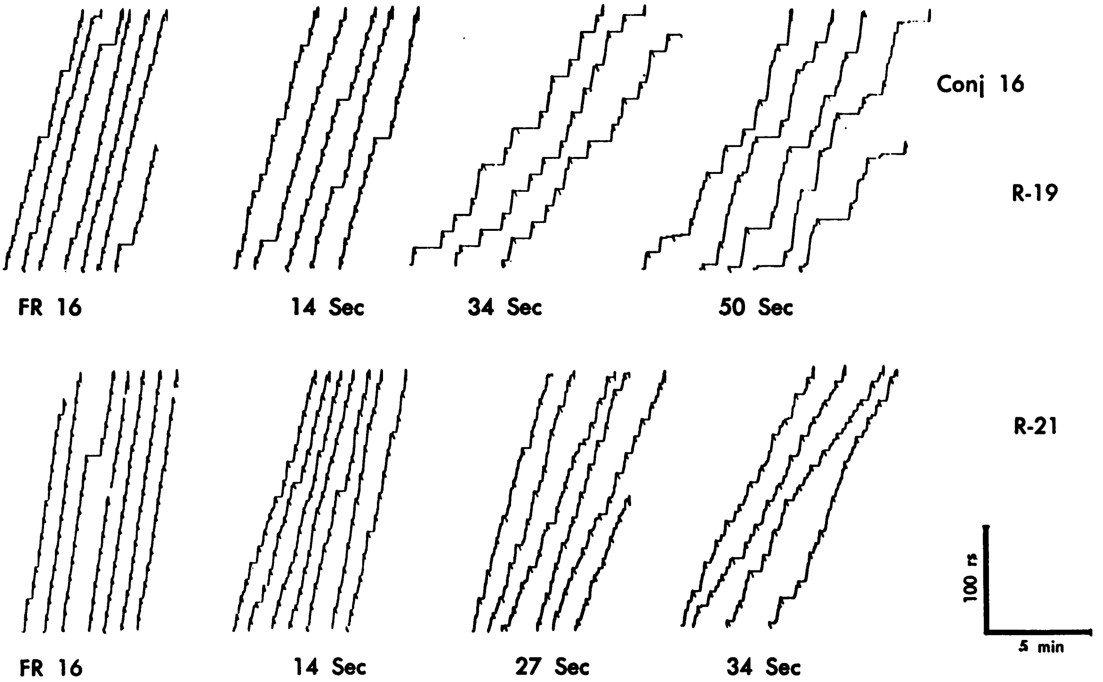

Fig. 5. Cumulative records of the last session in each of several Conjunctive 16 schedules. The duration of the temporal component in seconds is given below each record.

DISCUSSION

The overall rate increase found in the interlocking schedules as the time requirements were raised is consistent with results found by Berryman and Nevin (1962). These authors investigated several interlocking schedules and found that the overall rate increased in all interlocking schedules when the time base was increased from 2 to 4 min. Thus, it appears that the rate of responding increases as the temporal component is lengthened in interlocking schedules, whether the schedule is defined as in Berryman and Nevin's study or as in the present study.

Berryman and Nevin also found a pause-and-run pattern of responding in some of their interlocking schedules much like the patterns shown in Fig. 6 for R-5. Such patterns were notably absent from the interlocking performances obtained here. One factor that may be related to the development of the pause-and-run pattern in Berryman and Nevin's interlocking schedules was that their schedules contained a response requirement. For three of the four rats in this experiment, when a response requirement was present in the schedule, pauses developed and were, in fact, one of the more prominent features of the animals' performance.

The pattern of responding that did develop in the interlocking schedules, especially at the longer temporal intervals, did not deviate markedly from the subjects' FR 16 performance. It would seem that the delay of reinforcement made possible by having the clock deliver the reinforcer whenever the temporal contingency was satisfied had almost no effect on responding. The term "delay of reinforcement" refers to the time from the last response made in an interval to the delivery of a reinforcer. Two reasons why the delay of reinforcement might not have affected responding are related to the length of possible delay. First, the maximum duration of the delay that could occur in the smaller interlocking schedules was relatively short. At the shortest time interval, for example, a reinforcer was delivered approximately every 5 sec. A burst of three or four responses would frequently be associated with a reinforcer delivered by the clock. Such a sequence of responding and reinforcement was often indistinguishable from a burst of responses in which the terminal response produced the reinforcer. Consequently, the delay of reinforcement present at the shorter time

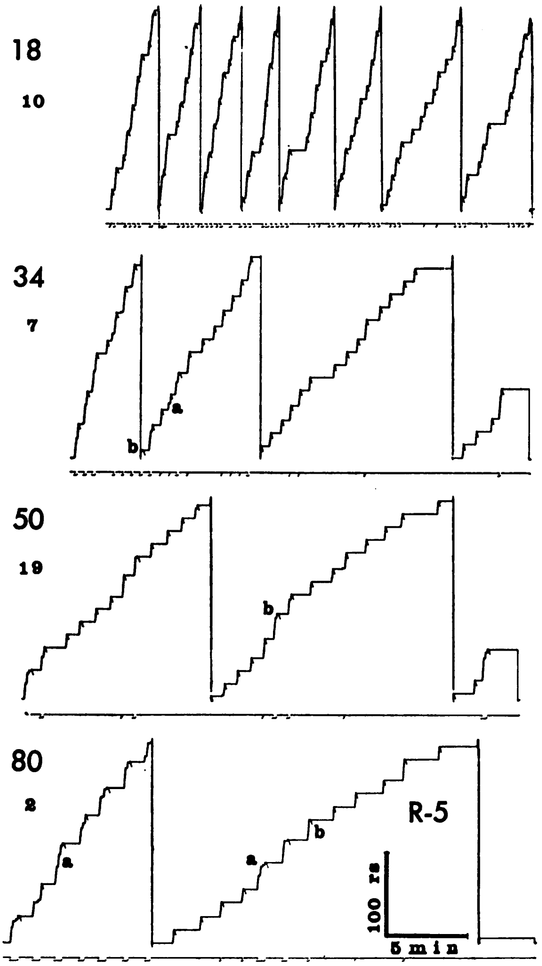

Fig. 6. Representative cumulative records of R-5's performance in several Conjunctive 16 schedules. Large numbers refer to the duration of the temporal component in seconds, small numbers refer to the session number.

intervals was so short that its effects were negligible. Recent evidence has shown that short delays of reinforcement may, in fact, facilitate responding. In a concurrent response situation, Chung (1965) found that a reinforcement delay of 1 sec increased the relative frequency of responding on the delay key.

Second, in the schedules with the longer temporal requirements, longer delays could occur but were not probable because the length of the delay was related to the subject's rate as well as to the limits imposed by the clock. That is, at a rate of one response per second, most of the delays would be less than 1 sec in length. Thus, even though the interlocking schedule permitted delays of reinforcement of 20 sec or more, such delays were infrequent because the subject's rate set limits upon the maximum duration of the delay.

The cessation of responding that did occur during the latter part of the sessions with the interval component at 5 sec may have been due to the rapid consumption of dry food in a short period of time.

In the Conjunctive 16 schedule, the decrease in the overall rate that accompanied the lengthening of the time requirement was primarily related to an increase in the post-reinforcement pause. This can be seen most clearly in R-5's performance (Fig. 6). The emergence of a pause-run-pause sequence appeared related to responding initiated before the end of the interval. When the animal completed 16 or more responses much before the clock had finished timing, it occasionally stopped responding. A reinforcer was frequently delivered during such a pause because the probability that the clock had finished timing was related to the time since the preceding reinforcement. Eventually, it might be assumed that the delivery of a reinforcer during a pause would reduce the subject's local rate by eliminating reinforcement for short interresponse times (IRTs).

However, one factor favoring the reinforcement of short IRTs was that on some occasions the animal completed the response requirement after the clock made a reinforcer available. In this instance, a short IRT was likely to be reinforced because the local runs of responses were made at a high rate not much different from the runs characterizing the animals' FR 16 performances.

If the subject's first response occurred after the interval had elapsed, and the subject paused during the run, reinforcement of short IRTs was still the most probable event. A long IRT could be reinforced only if the rat made 15 responses before pausing. Pausing after completing fewer than 15 responses always left a requirement of two or more responses. This favored the reinforcement of short IRTs, assuming that the animal's local run consisted of short IRTs when it responded.

In short, the pause-and-run patterns that eventually emerged were shaped by responding initiated before the end of the interval component. Responding early in the interval led to a large response output and an eventual

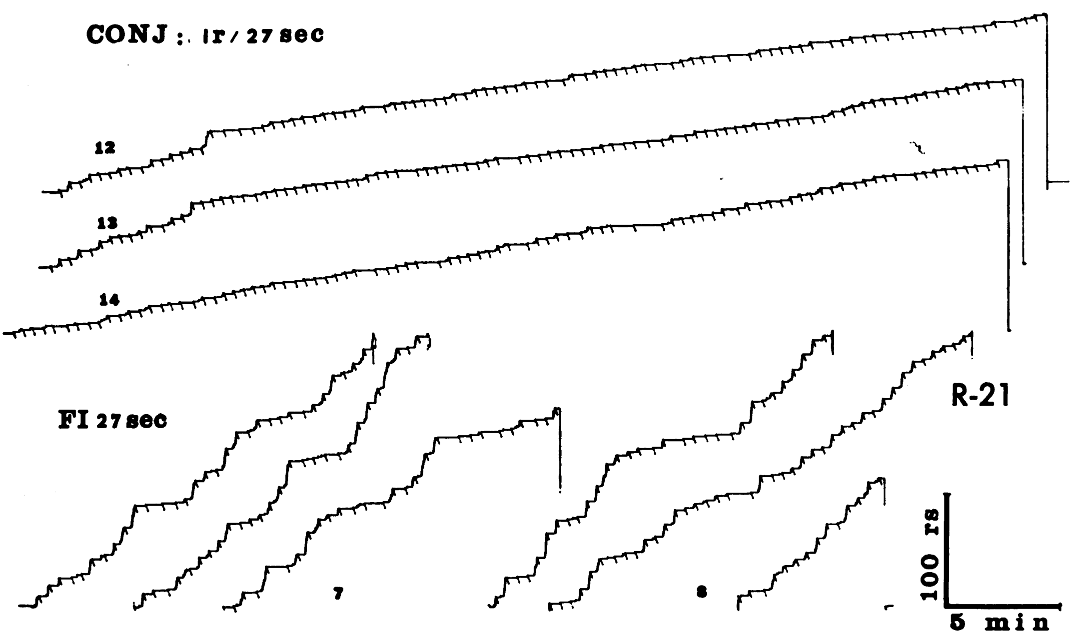

Fig. 7. Cumulative records of R-21's performance in the Conjunctive 1-response/27-sec schedule and in the FI 27-sec schedule. Numbers under each record refer to the session number.

slowdown or cessation of responding. When the animal paused, the probability of a reinforcer being delivered by the clock was high, and frequently the rat received reinforcement after such a sequence of events. If, as occasionally happened, the rat started responding after the pause, a short IRT was likely to be reinforced. In one case, reinforcement occurred during a pause preceded by a run of responses comprised of short IRTs. In the other case, the animal was reinforced for a short IRT preceded by a pause. In both cases, a pause-run-pause sequence of responding would tend to become established.

The results obtained with R-21 on the conjunctive schedules with the response requirement equal to one are interesting. As the sessions progressed, the animal's rate steadily declined and the fluctuations in the response output between reinforcements were gradually eliminated. When this animal was placed on the FI 27-sec schedule, the overall rate increased and the number of responses emitted between reinforcements fluctuated considerably.

One explanation for the difference in performance between the two schedules may be related to the contingencies present when a response occurs before the interval has elapsed. In a fixed-interval schedule, responding before the interval is completed leads to a situation where an IRT must be reinforced; *i.e.*, a response made during the interval "does not count", and at least one more response must occur to produce reinforcement. In the Conjunctive 1 response schedules, a response made before the interval has elapsed "does count" and no further responding is required; therefore, an IRT does not need to be reinforced.

As an illustration of the differential consequences that can occur in the two schedules, consider a situation where the last response occurs 1 sec before the interval elapses. In the FI 27-sec schedule, if the animal responds shortly after the interval is completed, an IRT of approximately 1 sec receives reinforcement. In this case, IRTs in the neighborhood of 1 sec are strengthened. In the Conjunctive 1 response/27-sec schedule, reinforcement would occur at the completion of the interval and some behavior other than lever-pressing would receive reinforcement. In this case, reinforcement may strengthen a response sequence in which the first component is the lever-press response. Azzi, Fix, Keller, and Rocha e Silva (1964) have observed the development of such response sequences when the lever-press response was followed by a delay of reinforcement.

Of course, responding after the interval has elapsed has the same consequence in both the fixed-interval and the conjunctive schedules. The first response is reinforced and a post-reinforcement pause of a given duration is strengthened. The fact that the fixed-interval schedule requires a response after the interval has elapsed may account for the high rates observed immediately preceding reinforcement in the typical fixed-interval performance.

In summary, for the values used in this study, the overall rate of responding was found to be inversely related to the temporal requirements in a Conjunctive 16 schedule and directly related to the temporal requirements in an Interlocking 32 schedule. In addition, an increase in the temporal requirement led to the development of a pause-and-run pattern of responding in the conjunctive schedule, but had little effect upon the pattern of responding in the interlocking schedule. Finally, when the response requirement in the conjunctive schedule was reduced to one, a low, steady rate of responding developed. The development of this low rate appears related to the strengthening of behavior other than lever-pressing which occurs when a reinforcer is delivered during a pause.

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