BEHAVIORAL INTERACTION UNDER CONCURRENT SPACED-RESPONDING, VARIABLE-INTERVAL SCHEDULES OF REINFORCEMENT

EVALYN F. SEGAL¹

WALTER REED ARMY INSTITUTE OF RESEARCH
and
UNIVERSITY OF MARYLAND²

Concurrent scheduling of reinforcement contingencies on two manipulanda has proved a useful technique for the investigation of a variety of behavior problems (e.g., Ferster, 1959; Ferster & Skinner, 1957; Herrnstein, 1958). Sidman has used the technique for probing some of the variables responsible for timing behavior (Sidman, 1956), and the present experiment is a further application of the method to that problem.

Sidman showed that when a DRL schedule of reinforcement on one lever is paired concurrently with a multiple CRF extinction schedule on a second lever, a competitive interaction occurs: The probability that the first response following onset of the S^D for the CRF component of the multiple schedule will occur appropriately on the "multiple lever" rather than on the "DRL lever" is an inverse function of the time since the last DRL response. Sidman explains this result as due to the build-up over time of a tendency to respond on the DRL lever. Immediately after a DRL response, the tendency to respond on the DRL lever is low and does not compete appreciably with the tendency to respond on the multiple lever. As time since the last DRL response passes, the tendency to respond on the DRL lever increases and competes to an increasing extent with the tendency to respond on the multiple lever.

If Sidman's analysis is correct, such a competitive interaction may be expected to appear in any reinforcement schedule paired concurrently with a DRL schedule. In the present experiment, the effect of a DRL schedule on a concurrent variable-interval schedule was studied. In addition, the complementary interaction, i.e., the effect of the concurrent VI schedule on DRL behavior, was investigated.

Prolonged exposure to a DRL schedule of reinforcement results in an inter-response-time distribution with two modes: one at the shortest recorded IRT interval and one at or just preceding the minimum reinforceable IRT interval (Sidman, 1955; Wilson & Keller, 1953). Prolonged exposure to a variable-interval schedule of reinforcement, on the other hand, results in an inter-response-time distribution with a single mode at the shortest recorded IRT interval (Anger, 1956). Competitive interactions between these two schedules may

be expected to appear as aberrations in either or both of the respective IRT distributions. Of special interest is the possibility of altering the distribution of timing responses. If timing behavior is mediated by the interpolation of other overt behavior (e.g., circling the experimental enclosure six times between each DRL response), then imposing a new pattern of interpolated behavior, namely, variable-interval responding on a second lever, should disrupt timing behavior. After sufficient exposure to the concurrent schedules, timing behavior should recover completely, and in fact might improve over base-line level, with variable-interval responding serving as a *consistently and independently reinforced* mediating behavior.

METHOD

Three adult, male, albino rats, reduced to 80 per cent of free-feeding weight, were used as subjects. They had previously been used in a study of the effects of d,l-amphetamine upon concurrent VI DRL schedules of reinforcement.

A single Foringer apparatus was used. It contained two levers mounted in one wall, approximately 5 inches apart at their midpoints. Between them was the aperture for the liquid-reinforcement dipper mechanism, which delivered diluted condensed milk as reinforcer. The usual precautions of soundproofing and adequate ventilation were observed. Daily experimental sessions lasted until 150 food reinforcements had been obtained.

In the drug experiment which preceded the present one, the subjects were magazine-trained and then placed on a DRL 16 seconds schedule of reinforcement on one of the two levers. They were then placed on a concurrent DRL 16 VI 3 minutes schedule of reinforcement. The concurrent variable-interval schedule was programmed on the second lever. Finally, the concurrent schedule was changed to DRL 16 VI 1 minute. Throughout these procedures, moderate dosages of d,l-amphetamine were occasionally administered. The present experiment began immediately afterward.

Responding on the VI lever was extinguished, while the DRL schedule continued to hold on the first lever. Within three sessions the IRT distribution of DRL responses returned to the base-line form observed in simple DRL 16. After three sessions under concurrent DRL 16 VI ext, the variable-interval schedule was re-introduced on the second lever, and five sessions of concurrent DRL 16 VI 1 were run. Next, responding on the DRL lever was extinguished, while the VI 1 schedule continued on the second lever, and five ses-

¹United States Public Health Service Postdoctoral Research Fellow under the sponsorship of J. V. Brady. Thanks are due to the Laboratory of Psychopharmacology of the University of Maryland for provision of research facilities under Grant No. MY-1604 from the National Institute of Mental Health, and to C. R. Schuster for advice and assistance in planning and executing early stages of the experiment.

²Present address: San Diego State College.

sions of concurrent DRL ext VI 1 were run. Next, the DRL 16 schedule was re-introduced on the first lever, and three more sessions of concurrent DRL 16 VI 1 were run. Then, the schedule of reinforcement on the first lever was changed from DRL 16 to VI 1, and one session was run of concurrent VI 1 VI 1. Finally, the schedule of reinforcement on both levers was changed to VI 6, and one session was run of concurrent VI 6 VI 6.

The experimental procedures are summarized in Table 1. Small numbers of sessions were run in each

base-line, simple VI behavior appear in the graphs labelled *x,1: Session 5* (concurrent DRL ext, VI 1). There is a high peak in the first IRT interval and a monotonic decline in succeeding IRT intervals.

The terminal effect on the IRT distribution of VI responses of re-introducing a spaced-responding schedule of reinforcement on the other lever is shown in the graphs labelled *16,1: Session 3*. In two of the three animals, a second, small peak in the VI-IRT distributions appeared, representing VI responses spaced 20 to

Table 1
Sequence of Experimental Conditions

Schedule		Number of Sessions	Schedule		Number of Sessions
Lever A	Lever B		Lever A	Lever B	
DRL 16 sec	VI ext	3	DRL 16 sec	VI 1 min	3
DRL 16 sec	VI 1 min	5	VI 1 min	VI 1 min	1
DRL ext	VI 1 min	5	VI 6 min	VI 6 min	1

condition, since transitional effects, primarily, were under investigation.

RESULTS

Figure 1 presents inter-response-time distributions for responses on both levers at various stages of the experiment. The top two rows of graphs refer to Rat No. 1, the middle two rows to Rat No. 2, and the bottom two rows to Rat No. 3. In each case, the upper row of graphs gives IRT's on Lever A, the DRL lever; and the lower row of graphs gives IRT's on Lever B, the VI lever. The blackened portions of the graphs represent IRT's which were reinforceable under the prevailing reinforcement contingencies. Under the DRL contingencies, only responses spaced at least 16 seconds apart were reinforced. Under the VI contingencies, all IRT's were reinforced but only intermittently.

The graphs labelled *16,x: Session 3* show IRT distributions of DRL responses on the third session of concurrent DRL 16 VI ext. The distributions are close to the base-line form expected under simple DRL 16. There is a peak in the distributions in the first IRT interval, representing DRL responses spaced 0-4 seconds apart. Thereafter, responding falls off, until a second peak occurs in the first reinforced IRT interval, representing DRL responses spaced 16-20 seconds apart.

The effect on the IRT distribution of DRL responses of re-introducing the VI 1 schedule on Lever B appears in the adjacent graphs, labelled *16,1: Session 1*. In all cases, the distribution flattens, indicating a disruption of timing behavior. But by the fifth session on this procedure, shown in the graphs labelled *16,1: Session 5*, good temporal discrimination had recovered on the DRL lever.

The IRT distributions of VI responses approximating

24 seconds apart. That this secondary "timing effect" was due to the spaced-responding schedule holding on the other lever, and not simply to the introduction of any concurrent reinforcement schedule on the second lever, is demonstrated in the next two graphs, labelled *1,1: Session 1* and *6,6: Session 1*. These are IRT distributions of VI responses on Lever B, where both levers are under the independent control of VI reinforcement contingencies. The secondary timing peak did not appear in these distributions. In fact, the similarity of the IRT distributions of VI responses on Lever B under simple VI 1, concurrent VI 1 VI 1, and concurrent VI 6 VI 6 is striking. The only effect of lengthening the mean inter-reinforcement interval from 1 minute to 6 minutes appears to have been a slight increase in the proportion of VI responses spaced very far apart.

With Rat No. 3, a secondary timing peak did not appear in the IRT distribution of VI responses when a concurrent spaced-responding schedule was in effect on the other lever. The only detectable result was a slight increase in the proportion of responses spaced far apart. The response rate maintained by this animal on the VI lever was considerably higher than the VI rates of the other two animals: At VI 1, with or without concurrent scheduling, 80-90% of responses on Lever B were spaced less than 4 seconds apart. Possibly, the high proportion of responses in the shortest IRT interval, and the relatively gross IRT class-interval width, obscured the detection of any slight timing effects carried over to VI behavior from the DRL schedule on the other lever.

DISCUSSION

Concurrent scheduling of DRL and variable-interval schedules of reinforcement produced behavioral interactions in both directions. The schedules interacted to

Fig. 1. Inter-response-time distributions of responses on the DRL lever (Lever A) and the VI lever (Lever B) under the various concurrent schedules used and after various lengths of exposure to the experimental conditions.

produce a secondary timing peak in the IRT distribution of VI responses as well as an initial disruption of timing behavior itself. The secondary timing peak in the VI distribution indicates spaced responding on the VI lever, attributable to induction of the spaced-responding behavior generated on the DRL schedule. The initial disruption of timing behavior on the DRL lever, and the eventual recovery of accurate timing under prolonged exposure to the concurrent schedules, are accountable under the notion that timing behavior is mediated by the interpolation of other overt behavior between DRL responses.

However, the inductive spacing of responses on the VI lever suggests that variable-interval lever pressing was not the only behavior that intervened between DRL responses. Such spacing of VI responses, occurring as it did concomitantly with accurate spacing of DRL responses, is most reasonably interpreted as indicating periods of no responding whatever, on either lever.

If this interpretation is correct, interactions occurred not only between response tendencies toward the VI lever and the DRL lever, but also between lever-pressing behavior, in general, and non-lever-pressing behavior, in general. Tendency *not* to lever press is simply another way of describing induction of spaced responding. Nevertheless, it is important to draw attention to the explicit nature of the inductive effect, and to emphasize that non-lever-pressing behavior, normally facilitatory on a DRL schedule, competed successfully even with an alternative, explicitly reinforced form of behavior, namely, variable-interval lever pressing.

One of the aims of the present experiment was to make available a specific form of behavior, VI responding, that might compete both with DRL lever pressing and with any DRL-mediating non-lever-pressing behavior. Thus, it was intended to render directly observable the nature of the interactions between DRL lever pressing and the presumed interpolated behavior mediating DRL responses. The initial disruption of timing when the concurrent VI schedule was introduced suggests that the attempt was partially successful. Nonetheless, if the present analysis is correct, and non-lever-pressing behavior is so strengthened under DRL contingencies that it can compete successfully both with DRL lever pressing and with VI lever pressing,

other ways of measuring this non-lever-pressing behavior and of demonstrating its control over temporal spacing of responses must be discovered.

SUMMARY

Three rats were reinforced under a concurrent DRL VI schedule of reinforcement, and the results were compared with the subjects' performance under simple DRL and simple VI contingencies. The findings were that introduction of a concurrent VI schedule temporarily disrupted timing behavior. Within a few sessions, however, timing recovered to control levels. The result is interpreted in terms of the competition of a new pattern of overt mediating behavior with an older pattern of mediating behavior, relative to the temporal spacing of responses.

In two of the three animals, introduction of a concurrent DRL schedule resulted in the appearance of a "secondary timing peak" in the IRT distribution of VI responses. This result was interpreted as due to response induction of spaced responding and competition from non-lever-pressing behavior.

REFERENCES

- Anger, D. The dependence of inter-response times upon the relative reinforcement of different inter-response times. *J. exp. Psychol.*, 1956, **52**, 145-161.
- Ferster, C. B. A complex concurrent schedule of reinforcement. *J. exp. Anal. Behav.*, 1959, **2**, 65-80.
- Ferster, C. B., and Skinner, B. F. *Schedules of reinforcement*. New York: Appleton-Century-Crofts, 1957.
- Herrnstein, R. J. Some factors influencing behavior in a two-response situation. *Trans. N. Y. Acad. Sci.*, 1958, **21** (Series II), 35-45.
- Sidman, M. Technique for assessing the effects of drugs on timing behavior. *Science*, 1955, **122**, 925.
- Sidman, M. Time discrimination and behavioral interaction in a free operant situation. *J. comp. physiol. Psychol.*, 1956, **49**, 469-473.
- Wilson, M. P., and Keller, F. S. On the selective reinforcement of spaced responses. *J. comp. physiol. Psychol.*, 1953, **46**, 190-193.

Received November 14, 1960.