Patterns of responding in second-order chained schedules*

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Responding on one lever under a fixed-interval schedule (FI 100 sec) produced an exteroceptive stimulus and responding on another lever under a different schedule (FI 50 sec or FR 1) terminated the stimulus. Under a second-order schedule, every second termination of the stimulus produced primary reinforcement (FR 2 of entire sequence). Patterns of responding in the initial component of the chain were similar to those maintained by presentation of brief stimuli in second-order schedules. When the schedule in the terminal component was changed and primary reinforcement became less frequent, rate in the initial component decreased, while pattern of responding under the second-order schedule was maintained.

An exteroceptive stimulus that controls responding in one component of a chained schedule can maintain responding in an earlier component when primary reinforcement occurs only at the end of the chain (see, for example, Kelleher, 1966). A brief exteroceptive stimulus that is paired with primary reinforcement after the last component of a second-order schedule, in which one component is a unitary response itself reinforced on a schedule, can maintain typical patterns of responding when produced by responses in earlier components (Kelleher, 1966; Stubbs, 1969; Byrd & Marr, 1969).

In the present experiment a heterogeneous chained schedule was studied. Responding on Lever 1 produced an exteroceptive stimulus that controlled responding on Lever 2, and the entire sequence produced primary reinforcement according to a fixed ratio (FR 2). The schedule can be regarded as a second-order chained schedule—that is, FR 2 (CHAIN --, --). The exteroceptive stimulus in this procedure was comparable in some ways to the brief stimuli studied in second-order schedules, since the sequence terminated in primary reinforcement intermittently. While the stimulus was paired with primary reinforcement during alternate sequences, on other occasions it was produced by responses in the initial component and terminated without primary reinforcement.

In this experiment the pattern of responding in the initial component of the chain sequence was examined. The second-order schedule was compared with a chained schedule in which primary reinforcement occurred after each sequence and with a tandem schedule in which the stimulus was omitted. In addition, changes were made in the

schedule in the terminal component, and effects on pattern of responding in the initial component were observed.

METHOD

The Ss were four Sprague-Dawley male albino rats, about 110 days old at the beginning of the experiment. They were given daily 1-h sessions under 22-h water deprivation. Dry food was continuously available in the home cages.

The apparatus, described elsewhere (Zimmerman, 1969), consisted of a modified Gerbrands Model C-3 chamber with two levers located on opposite panels, 3.5 in. above the floor, and a liquid feeder. Stimuli were two white 7.5-V pilot lamps and a 750-Hz tone from an audio generator. The chamber was enclosed in a ventilated ice chest. Responses were recorded on a Gerbrands cumulative recorder.

During the first 14 sessions, the chained schedule was established. Each response on Lever 1 produced a stimulus consisting of two lights and a tone; the first response on Lever 2 terminated the stimulus and produced access to .1 cc of water for 5 sec (CHAIN FR 1 FR 1). Beginning in Session 15, a 100-sec fixed-interval schedule (FI 100 sec) was established on Lever 1. The first response after a 100-sec interval produced the stimulus; the first response on Lever 2 terminated the stimulus and produced primary reinforcement (CHAIN FI 100 sec FR 1). This schedule continued for 12 sessions.

Next, primary reinforcement was alternately presented and omitted after completion of the terminal component of

the chain. The second-order schedule was FR 2 (CHAIN FI 100 sec FR 1). After 12 sessions, the schedule in the terminal component was changed from FR 1 to FI 50 sec, and primary reinforcement occurred again after each terminal component. That is, the schedule was CHAIN FI 100 sec FI 50 sec. This procedure lasted for 12 sessions. Next, primary reinforcement was again alternately presented and omitted after completion of the terminal component. The second-order schedule was FR 2 (CHAIN FI 100 sec FI 50 sec), and it lasted for 12 sessions.

The schedule in the initial component was changed from FI 100 sec to TANDEM FI 100 sec FI 100 sec, and the schedule in the terminal component was changed to FR 2. The schedule was CHAIN (TANDEM FI 100 sec FI 100 sec)(FR 2). Under the tandem schedule, the first response on Lever 1 after 100 sec initiated the second interval; no exteroceptive stimulus was presented. After another 100-sec interval, the first response on Lever 1 produced the stimulus, and the second response on Lever 2 terminated the stimulus and produced primary reinforcement. This schedule continued for 12 sessions. Finally, the schedule in the terminal component was changed to FI 100 sec. That is, the schedule was CHAIN (TANDEM FI 100 sec FI 100 sec) (FI 100 sec), and it continued for 12 sessions. The procedures are summarized in Table 1.

RESULTS AND DISCUSSION

Responding in the initial component of the chained schedules was positively accelerated. Rate in the initial component was higher with FR 1 in the terminal component than with FI 50 sec in the terminal component. Typical cumulative records (Rat A22) are shown in Fig. 1. In Record A the schedule was CHAIN FI 100 sec FR 1; in Record D it was CHAIN FI 100 sec FI 50 sec. In Records A, C, D, and F, stimulus presentations followed by primary reinforcement in the terminal component are indicated by downward movement of the recorder pen.

Under the second-order chained schedules, overall rate in the initial component decreased slightly, while positively accelerated responding was maintained (Records B and E). In these records stimulus presentations are

Table 1

Schedule	Sessions
Chain FI 100-sec FR1	15-26
FR2 (Chain FI 100-sec FR1)	27-38
Chain FI 100-sec FI 50-sec	39-50
FR2 (Chain FI 100-sec FI 50-sec)	51-62
Chain (Tandem FI 100-sec FI 100-sec) (FR2)	63-74
Chain (Tandem FI 100-sec FI 100-sec) (FI 100-sec)	75-86

*Supported by a grant (APA-252-2057-13) from the National Research Council of Canada.

indicated by downward movement of the recorder pen, and those followed by primary reinforcement in the terminal component are indicated by marks below the record. Under the tandem schedules (Records C and F), responding became positively accelerated throughout the entire interval in the initial component. In

Record C the schedule in the terminal component was FR 2; in Record F it was FI 100 sec.

Figure 2 shows the mean response rate in the initial component in each quarter of the interval over the last six sessions under each procedure (Rats A21, A22, A23, and A24). The left-hand section represents

Fig. 1. Cumulative records of responding in initial component of chained schedule. A: CHAIN FI 100 sec FR 1. B: FR 2 (CHAIN FI 10 sec FR 1). C: CHAIN (TANDEM FI 100 sec FI 100 sec)(FR 2). D: CHAIN FI 100 sec FI 50 sec. E: FR 2 (CHAIN FI 100 sec FI 50 sec). F: CHAIN (TANDEM FI 100 sec FI 100 sec)(FI 100 sec).

performance under the original chained schedules with primary reinforcement after each interval. The middle section represents performance under the second-order schedules. Solid points on the left of the broken line represent rate during intervals just preceding stimulus presentations not terminating in primary reinforcement. Solid points on the right of the broken line represent rate during intervals just preceding stimulus presentations terminating in primary reinforcement.

Under FR 2 (CHAIN FI 100 sec FR 1) rate was higher in the initial component during intervals preceding primary reinforcement in the terminal component than during intervals preceding omissions of primary reinforcement. However, rate was higher during the latter quarters of intervals preceding omissions of primary reinforcement than during the early quarters of the succeeding intervals. Under the second-order schedules, rate was higher with FR 1 in the terminal component than with FI 50 sec in the terminal component. In one rat the pattern of positively accelerated responding in intervals preceding omission of primary reinforcement did not appear when the schedule in the terminal component was FI 50 sec.

The right-hand section of Fig. 2 represents rate during sessions in which the initial component was TANDEM FI 100 sec FI 100 sec. Responding was positively accelerated throughout the interval, and rate was higher with FR 2 in the terminal component than with FI 50 sec in the terminal component.

These results are consistent with studies of presentation of brief exteroceptive stimuli in second-order schedules (Kelleher, 1966; Stubbs, 1969; Byrd & Marr, 1969). In the present experiment, a stimulus

Fig. 2. Mean response rate in each quarter of 100-sec interval in initial component of chained schedule. Open circles: CHAIN FI 100 sec FR 1. Solid circles: FR 2 (CHAIN FI 100 sec FR 1). Open squares: CHAIN FI 100 sec FI 50 sec. Solid squares: FR 2 (CHAIN FI 100 sec FI 50 sec). Open triangles: CHAIN (TANDEM FI 100 sec FI 100 sec) (FR 2). Solid triangles: CHAIN (TANDEM FI 100 sec FI 100 sec)(FI 100 sec).

controlling terminal-component responding in a heterogeneous chained schedule maintained typical patterns of responding in the initial component when the sequence produced primary reinforcement on FR 2 (a second-order chained schedule). In addition, there were systematic changes in rate between successive components of the second-order schedule. Rate in intervals preceding stimulus presentations that terminated in primary reinforcement was higher than rate in intervals preceding stimulus presentations after which primary reinforcement was omitted.

These changes in rate were not as great as those that occurred when the schedule in the terminal component was altered. The rate in the initial component of a chained schedule depends to a large extent upon the frequency of primary reinforcement in the presence of the exteroceptive stimulus in the terminal

component. But apparently a stimulus can maintain responding in the initial component of a chain under a second-order schedule with little change in rate between successive components of the second-order schedule.

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pattern of noncriterial responding indicates that experienced infrahuman Ss mediate initial portions of successive intervals by idiosyncratic behavior that does not incorporate, or that competes with, emission of the operant.

In contrast to widely substantiated infrahuman data, performance of humans on FI schedules may take the form of DRL or scalloping performance or of high rates of responding with topographies that are typically associated with response-based reinforcement schedules (Weiner, 1969; Lippman, Leander, & Meyer, 1970). Human Ss apparently produce more variable response topographies on FI schedules than do infrahumans. In studies dealing with FI schedules of reinforcement using infrahuman Ss, failure of a S to emit a scalloped interreinforcement response topography is often interpreted as an artifact and is discounted. Thus, one may be led to the assertion that scalloping is the necessary product of FI schedules with infrahumans.

Data of the present report were gathered to provide a baseline of FI performance for an ongoing study of reinforcement schedules. The adventitious finding of atypical performance in one S indicates that a low overall rate with a scalloped interreinforcement topography is likely, but is not necessarily the behavioral consequence of an FI contingency in infrahumans. Despite the likelihood that FI performance of infrahumans is more uniform than that of humans, the present data suggest that a superstitious or noncriterial behavior pattern can incorporate emission of the operant into the S's mediation of temporal intervals. The present data also suggest that this noncriterial behavior can occur in absence of any particular previous reinforcement histories or any current reinforcement contingencies that might affect the topographies of interreinforcement responding.

SUBJECTS

The Ss were four male experimentally naive Sprague-Dawley rats (Madison, Wisconsin), which were 90 days of age at the beginning of training. The Ss were housed two to a cage throughout training.

APPARATUS

Two standard Grason-Stadler rat chambers (Model 1110) were fitted into separate wooden boxes that were fully lined with acoustic tile. White noise played into each box, plus the sound of a ventilating fan, masked noise from associated Grason-Stadler programming

A note on variability of infrahuman FI performance*

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An adventitious finding of one rat's unusually high rate of responding on FI schedules was reported. This S's idiosyncratic mediation of interreinforcement intervals indicates that an FI schedule does not invariably lead to low-rate, scalloped performance in infrahumans.

In contrast to DRL schedules of reinforcement, the FI schedule does not provide a contingency for behavior control during interreinforcement intervals.

Despite the absence of such a reinforcement contingency, FI schedules are usually associated with a "scalloped" behavior pattern in infrahuman Ss. Such a

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