Responding in chained schedules maintained by conditioned reinforcement with and without terminal primary reinforcement¹

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The schedule of presentation of an exteroceptive stimulus linking components of a chained schedule was varied, while the schedule of primary reinforcement remained unchanged. Under one procedure, association of the stimulus and primary reinforcement occurred on occasions when responses in the initial component produced the stimulus; under a second procedure, the association occurred when the stimulus did not immediately follow lever responses in the initial component (DRO schedule). The pattern of responding in the initial component changed from one characteristic of the schedule of primary reinforcement to one characteristic of the schedule of presentation of the exteroceptive stimulus. Overall response rate was higher in the first procedure.

When an exteroceptive stimulus that accompanied primary reinforcement on a fixed-interval (FI) schedule was presented concurrently according to a variable interval (VI) or variable ratio (VR), without subsequent primary reinforcement, performance changed from a pattern characteristic of a FI schedule to a pattern characteristic of either a VI or VR schedule (Zimmerman, 1969a). The pattern of responding in the initial component of a chained schedule was altered when the schedule of presentation of an exteroceptive stimulus linking components of the chain was varied, while the schedule of primary reinforcement remained unchanged (Zimmerman, 1969b). In both procedures, lever pressing by the rat was maintained, in part, by conditioned reinforcement and, in part, by primary reinforcement. Conditioned reinforcement was indicated by a change in pattern of responding, as well as by an increase in overall rate. Control procedures showed that changes could not be attributed to effects of the stimulus that might occur even if it did not immediately follow a response, and that the effect of the stimulus depended upon its association with primary reinforcement.

In the present experiment, the first procedure described above was modified by presenting an exteroceptive stimulus in chained schedules on VI and VR schedules

after responses in the initial component. Also, the lever-pressing response in the initial component was maintained by presenting the exteroceptive stimulus on VI and VR schedules in the absence of terminal primary reinforcement. The results of these two procedures gave an indication of the extent to which responding depends upon terminal primary reinforcement and the extent to which it is accounted for by concurrently scheduled conditioned reinforcement.

METHOD

The Ss were eight Sprague-Dawley male albino rats, about 90 days old at the beginning of the experiment. They were given daily 1-h sessions under 22 h of water deprivation. Dry food was continuously available in the home cages.

The apparatus was a modified Gerbrands Model C-3 chamber, with two levers located on opposite walls, 3.5 in. above the floor. Stimuli consisted of two white 7.5-V pilot lamps and a 750-cps tone. The chamber was enclosed in a ventilated ice chest. Responses were recorded on Gerbrands cumulative recorders.

ESTABLISHMENT OF CHAINED SCHEDULE

During eight daily 1-h sessions, the chain was established. At the end of this period, the first response on Lever 1 produced a stimulus consisting of two lights and a tone; in its presence, the first response on Lever 2 terminated the stimulus and produced access to .1 cc of water in a dipper for 5 sec.

Next, a 13-min FI schedule (FI 13-min) was established in the initial component of the chain. The first response on Lever 1 after 13-min periods produced the stimulus; then, the first response on Lever 2 terminated the stimulus and produced water. Responding on Lever 2 in the absence of the stimulus had no scheduled consequences. During establishment of the FI schedule and throughout the remainder of the experiment, reinforcement consisted of eight consecutive presentations of the dipper, the rat having access to .1 cc of water for 3 sec on each presentation. Under all the procedures described below, four reinforcements occurred during each daily session.

FIRST PROCEDURE: CONDITIONED REINFORCEMENT WITH ASSOCIATION OF STIMULUS AND PRIMARY REINFORCEMENT IN TERMINAL COMPONENT OF CHAIN

After 12 sessions under the FI schedule described above, additional stimulus presentations, not followed by primary reinforcement, were scheduled according to either a variable interval or variable ratio. On the VI schedule, the first response on Lever 1 after a designated period of time produced the stimulus, with the periods varying from one presentation to another. The first response on Lever 2 terminated the stimulus but did not produce water. Presentation of the stimulus after responses on Lever 1 also continued on the original FI schedule; on these occasions, the first response on Lever 2 terminated the stimulus and produced water. On the VR schedule, the stimulus was presented after a designated number of responses on Lever 1, with the number varying from one presentation to another; the original FI schedule of primary reinforcement continued. The VI schedule (used with four rats) was an arithmetic series with a mean interval of 50 sec (VI 50-sec). The VR schedule (used with four different rats) was an arithmetic series with a mean ratio of 10 (VR 10).

SECOND PROCEDURE: CONDITIONED REINFORCEMENT WITH ASSOCIATION OF STIMULUS AND PRIMARY REINFORCEMENT ON DRO SCHEDULE

In a second procedure that followed the one described above, responding in the initial component of the chain produced the stimulus on VI and VR schedules; but primary reinforcement did not occur at the end of the chain on the FI schedule. Conditioned reinforcing properties of the stimulus were maintained by presenting it regularly, with subsequent primary reinforcement of responses on Lever 2 but not immediately after responses on Lever 1. With respect to responding on Lever 1, the procedure was a differential reinforcement of other behavior (DRO) schedule.

Following 10 sessions under the concurrent schedule in the first procedure, the DRO schedule was begun. Stimulus presentations followed by primary reinforcement of responses on Lever 2 occurred after 13-min intervals, at least 5 sec after the last response on Lever 1. On these occasions, the first response on Lever 2 produced water. After eight sessions under the DRO schedule, additional stimulus presentations, not followed by water, were scheduled after responses on Lever 1, according to either a VI or a VR, as described above. On these occasions, the first response on Lever 2

Fig. 1. Cumulative records of responding in initial component of chained schedule. Added stimulus presentations on VI 50-sec are indicated by downward movement of recorder pen in Records B and D, and primary reinforcement is indicated by vertical marks below the record.

Fig. 2. Cumulative records of responding in initial component of chained schedule. Added stimulus presentations on VR 10 are indicated by downward movement of recorder pen in Records B and D, and primary reinforcement is indicated by vertical marks below the record.

terminated the stimulus but did not produce water. The original DRO schedule also remained in effect. This procedure lasted for eight sessions.

RESULTS AND DISCUSSION

The FI schedule engendered positively accelerated responding on Lever 1. Additional presentations of the stimulus on the VI and VR schedules, without primary reinforcement, resulted in a change in pattern of responding on Lever 1 from one characteristic of a FI schedule to one characteristic of either a VI or a VR schedule and also in an increase in overall response rate on Lever 1. The result with

the VI schedule was similar to that found in previous experiments (Zimmerman, 1969a, b), and the result with the VR schedule was similar to that found in a previous experiment (Zimmerman, 1969a) with concurrent schedules on a single lever.

Figure 1, A and B, shows the performance of one rat (L1) under the VI concurrent schedule, and Fig. 2, A and B, shows the performance of another rat (M1) under the VR concurrent schedule. Record A of both figures is the original FI performance just before the change in procedure, and Record B in both figures is the per-

formance under the concurrent schedule just after the change.

In the second procedure, the DRO schedule brought about a very low rate on Lever 1. Additional presentations of the stimulus on VI and VR schedules, without primary reinforcement, resulted in an increase in rate. On the VI 50-sec schedule, a moderate rate, not as high as that under the concurrent schedule in the first procedure, was maintained over eight sessions. On VR10, the result was similar; in addition, there were brief periods with a very high rate. Figure 1, C and D, shows a performance in which the schedule following the change in procedure was VI (Rat L1), and Fig. 2, C and D, shows a performance in which the schedule following the change was VR (Rat M1). Record C of both figures is performance on the original DRO schedule just before the change, and Record D in both figures is performance just after the change.

Figures 3 and 4 summarize results for all rats under both procedures. Response rates in each quarter of the interval between presentations of primary reinforcement during the last four sessions under each procedure are plotted, as an indication of change in pattern of responding as well as increase in overall rate.

In this experiment, responding in the initial component of chained schedules was modified when an exteroceptive stimulus linking components of the chain was presented on VI and VR schedules, without primary reinforcement in the terminal component, while presentation on a FI schedule, with primary reinforcement, continued. Presentations of the stimulus on VI and VR schedules also maintained responding in the initial component indefinitely when association of the stimulus and primary reinforcement occurred regularly on a DRO schedule, but not as the terminal event in the chain.

In all eight rats, the rate under the first

Fig. 3. Mean response rate in initial component of chained schedule in each quarter of the 13-min interval between presentations of primary reinforcement. Open circles: stimulus presented on FI 13-min, with subsequent primary reinforcement in terminal component. Solid circles: continuation of FI 13-min, with added stimulus presentations on VI 50-sec. Open squares: stimulus presented on DRO schedule, with subsequent primary reinforcement. Solid squares: continuation of DRO schedule, with added stimulus presentations on VI 50-sec.

Fig. 4. Mean response rate in initial component of chained schedule in each quarter of the 13-min interval between presentations of primary reinforcement. Open circles: stimulus presented on FI 13-min, with subsequent primary reinforcement in terminal component. Solid circles: continuation of FI 13-min, with added stimulus presentations on VR 10. Open squares: stimulus presented on DRO schedule, with subsequent primary reinforcement. Solid squares: continuation of DRO schedule, with added stimulus presentations on VR 10.

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NOTE

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ZIMMERMAN, D. W. Patterns of responding in a chained schedule altered by conditioned

procedure was higher than it was under the second procedure. This result is consistent with the idea that primary reinforcers are stronger than conditioned reinforcers: When responding was maintained, in part, by primary reinforcement and, in part, by conditioned reinforcement, the rate was higher than when responding was maintained by conditioned reinforcement alone. In the second procedure, a considerable response output continued over a period of time when only conditioned reinforcement maintained responding. Here, the capacity of the stimulus to act as a reinforcer was maintained by association with primary reinforcement without primary reinforcement of lever pressing.

The results are consistent with those obtained by Kelleher (1966) and others, who found that a brief exteroceptive stimulus can modify responding on second-order schedules, and by Zimmerman, Hanford, & Brown (1967), who found that a brief exteroceptive stimulus associated regularly with food can maintain key-pecking responses in the pigeon over extended periods of time in the absence of primary reinforcement of key pecking. These results also suggest that conditioned reinforcement is important in maintaining responding in the initial component of chained schedules.

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Effect of chromatic surround during nondifferential training and generalization test upon generalization along the angularity dimension in pigeons¹

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Two groups of pigeons were nondifferentially trained in the presence of a white vertical line. For one of these, the surround was chromatic; for the other, it was black. The two groups were subdivided; half of each group was tested for generalization with a chromatic and half with a black surround. The chromatic surround during training produced steeper angularity gradients than the black surround; surround color during generalization test did not influence angularity gradient slope.

In a recent experiment (Baron & Bresnahan, 1969), generalization gradients along the angularity dimension were examined following nondifferential training

to a vertical white line. Training and test with a chromatic surround (578 mμ) in both the experiment and a replication produced somewhat (but not significantly) steeper gradients than training and test with a black surround. These data suggested that, during nondifferential training, chroma attracts attention, but that the attention is nonselective, i.e., that chroma in the surround tends to increase attention to the vertical white line.

Two experiments have provided evidence that chroma in the surround during generalization test has a somewhat different effect. Following training to a white vertical line on a chromatic (555 mμ) surround, Freeman & Thomas (1967) and Newman & Benfield (1968) tested for generalization along the angularity dimension and found a flatter gradient with the chromatic than with the black surround. These investigators suggested a cue-utilization explanation, viz,