Discrete operant discrimination maintained by conditioned reinforcement*

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Operant discrimination in rats in a two-lever situation was maintained by conditioned reinforcement. A response on Lever 1 in the presence of a tone turned on two lights and turned off the tone; subsequently, a response on Lever 2 in the presence of the lights produced water. Later, a response on Lever 1 during the tone produced lights, while a response on Lever 2 turned off the lights but did not produce water. Concurrently, the lights were presented at regular intervals on an independent schedule, not immediately after the tone nor after responding on either lever, and on these occasions responses on Lever 2 again produced water.

In recent years there have been numerous studies of conditioned reinforcement in infrahuman organisms in which operant behavior has been maintained under intermittent schedules by presentation of brief stimuli that have been paired with primary reinforcement (see, for example, Hendry, 1969; Stubbs, 1971). However, there have been relatively few studies of operant discrimination based on conditioned reinforcement. Historically, the notion of conditioned reinforcement or secondary reinforcement has been used to explain complex performances that are under discriminative control, especially in human behavior. But experimental demonstrations of discrimination maintained by presentation of stimuli in the absence of primary reinforcement have been infrequent.

The present paper describes a technique by which it has been possible to maintain discrete discriminated operant responding in rats by conditioned reinforcement. A two-component chain of responses in a leverpressing situation was established. After presentation of an exteroceptive stimulus, a tone, the first response on one lever produced another stimulus, lights, in the presence of which the first response on a second lever produced water. Following each water reinforcement at the end of the chain there was an interval of at least 45 sec before the next presentation of the tone.

Later, primary reinforcement was omitted at the end of the chain, but responding in the initial component continued to produce the stimulus. In the presence of the tone, responding on Lever 1 produced the lights, while responding on Lever 2 terminated the lights but did not produce water.

Concurrently, the lights came on at regular intervals, not immediately after responses and not immediately after the tone, and on these occasions responses on Lever 2 produced water. In this way, the terminal component of the chain was maintained by primary reinforcement on occasions when it was not preceded by the initial component.

METHOD

The Ss were eight Sprague-Dawley male albino rats, about 105 days old at the beginning of the experiment. They were given daily 1 h sessions, 7 days a week, under 22-h water deprivation. Dry food was continuously available in the home cages. The apparatus consisted of two modified Gerbrands Model C-3 chambers, each with two levers located on opposite panels, 89 mm above the floor, enclosed in ventilated ice chests. A 750-Hz tone was presented through a speaker, and two pilot lamps with white crystals were in each chamber on opposite panels near the levers. Water was delivered by a dipper-type feeder near

the floor, just below and to the left of Lever 2. Responses were recorded on digital counters.

During the first 26 sessions, the initial chain was established. At the end of the period, the sequence of events was as follows. After the presentation of a tone, the first response on Lever 1 terminated the tone and turned on two white pilot lights. In the presence of the lights, the first response on Lever 2 terminated the lights and produced access to .1 cc of water in a dipper for 5 sec. The procedure is shown schematically in Fig. 1, A.

After water presentation, there was an interval of at least 45 sec before the next presentation of the tone. During this interval, a response on either lever reset a timer that had to complete a 25-sec cycle before the next presentation of the tone. Also, another timer had to complete a 45-sec cycle before the tone. In this way, a response on either lever during the last 25 sec of the 45-sec interval postponed the tone for another 25-sec period, so that the tone always came on at least 45 sec after water and always at least 25 sec after a response on either lever. Beginning in the 12th session, there were 60 presentations of the tone in each daily session. During the extinction procedures, described below, there were 30 presentations of the tone in each daily session.

In the next part of the experiment, the sequence of events was the same, except that water reinforcement was omitted after responses on Lever 2 in the presence of the lights. Responding in the presence of the tone produced the lights, but responding on the other lever in the presence of the lights only turned off the lights and did not produce water. In addition, the lights

Fig. 1. Diagram of experimental procedure.

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Fig. 2. Relative frequency distributions of latencies of responses on Lever 1 after presentation of tone during last eight sessions of initial chained schedule and all sessions except the first two under other procedures. Figure includes data for four rats that received EXT-1 procedure after conditioned reinforcement procedure.

were presented at intervals of about 4 min, not immediately after responses and not immediately after the tone, and on these occasions the first response on Lever 2 produced water (Fig. 1, B).

During the last 25 sec of the 4-min interval, a response on either lever postponed the lights by 25 sec. Each presentation of the tone came at least 45 sec after the response on Lever 2, as before. In other words, presentation of the lights, with subsequent primary reinforcement of responses on Lever 2 came at intervals of approximately 4 min (about 1 of 5 cycles), while presentations of the tone, without subsequent primary reinforcement of responses on Lever 2, came at intervals of approximately 45 sec (about 4 of 5 cycles). In this way, there was a regular association of lights and primary reinforcement on occasions when the initial component of the chain was omitted. At the same time, the discriminative control of the tone in the initial component was observed repeatedly on occasions when the terminal component was omitted.

Two extinction procedures were examined. In the first extinction test (EXT-1), the sequence of events was the same as in the conditioned reinforcement procedure described above, except that responses on Lever 1 in the presence of the tone no

longer produced the lights. Presentation of the lights on other

occasions continued as before, and on these occasions responses on Lever 2 produced water. The intervals between events were similar to those previously described, and responding in the intervals postponed the presentations of lights and tone, as before.

This extinction procedure was designed to rule out the possibility that a discrimination could be based on delayed or adventitious reinforcement, generalization of responding on Lever 1 in the presence of the tone from responding on Lever 2 in the presence of the lights, or reinforcing effects of termination of the tone, apart from presentation of the lights. After five extinction sessions, the conditioned reinforcement procedure was reinstated for another seven sessions to determine whether the discrimination could be recovered on the basis of conditioned reinforcement after an extinction period.

In a second extinction test (EXT-2), water reinforcement was omitted entirely, but responses on Lever 1 after presentation of the tone continued to produce the lights. Each presentation of the tone came at least 45 sec after the previous one, as before, and responses on either lever during the 45-sec interval postponed the tone by an additional 25 sec. This procedure was designed to examine the possibility that a discrimination could be based on reinforcing effects

Fig. 3. Relative frequency distributions of latencies of responses on Lever 1 after presentation of tone. Figure includes data for four rats that received EXT-2 procedure after conditioned reinforcement procedure.

Fig. 4. Median latency of responses on Lever 1 after presentation of tone during each experimental session. Figure includes data for four rats that received EXT-1 procedure after conditioned reinforcement procedure.

of onset of the lights, apart from a pairing with primary reinforcement. After six sessions of this extinction procedure, the conditioned reinforcement procedure was reinstated for another eight sessions to determine if the discrimination could be recovered by additional conditioned reinforcement.

After the initial establishment of the chain, four rats (A1, A2, A3, and A4) had one extended period under the conditioned reinforcement schedule (10 sessions, including 600 stimulus presentations), followed by five extinction sessions (EXT-1), and then another conditioned reinforcement procedure for seven sessions. Another four rats (B1, B2, B3, and B4) had the same sequence of conditions, except that the second extinction procedure replaced the first. For these rats, the extinction procedure lasted for six sessions and the second conditioned reinforcement procedure for eight sessions.

RESULTS AND DISCUSSION

Under the chained schedule, responding on Lever 1 was controlled by the tone, and responding on Lever 2 was controlled by the lights, while responses on either lever in the absence of the appropriate stimulus were infrequent. Responding became stable after about 12 sessions, and

there was no systematic change from one session to another. In all rats, latencies were usually less than 2 sec after about the 12th session. After the initial schedule was established and throughout the remainder of the experiment, rate on Lever 1 was near zero in the absence of the tone and rate on Lever 2 was near zero in the absence of the lights.

When the procedure was changed in the 27th session so that responses on Lever 1 in the presence of the tone produced the lights without primary reinforcement of responses on Lever 2, discriminative control was maintained over extended periods. Latencies became somewhat longer and more variable. After as many as 300-360 presentations of the tone, a response usually occurred within 5 to 10 sec on about one-half of the occasions. Responding in the absence of the tone was not greater than under the original chained schedule, and the interval between presentations of the tone remained near 45 sec, since few presentations were postponed by inappropriate lever responses.

The top sections of Figs. 2 and 3, labeled "water," show relative frequency distributions of latencies under the initial chained schedule. The distributions in these figures include all responses in the last eight sessions of the chained schedule and in all sessions except the first two under each of the other procedures. The next sections, labeled "lights" (second from the top), show relative frequency distributions in the conditioned reinforcement procedure. Figs. 4 and 5 show median latencies during each daily session. The first section is performance under the chained schedule, and the second section is performance under the conditioned reinforcement procedure.

In the first extinction procedure, when responses in the presence of the tone no longer produced the lights and while association of the lights and water continued (EXT-1), there was a marked shift in the frequency distribution and appearance of very long latencies. The result of this change in procedure is shown in the sections labeled EXT-1 of Figs. 2 and 4. When the lights came on again after responses in the presence of the tone, latencies again decreased to about the same values as before the extinction sessions. The result of this change is shown in the section labeled "lights" at the bottom of Fig. 2 and in Fig. 4.

When responses in the presence of the tone continued to produce the lights while association of lights and water was discontinued (EXT-2), extinction occurred more slowly. Again there was a shift in the frequency distributions. The result of

Fig. 5. Median latency of responses on Lever 1 after presentations of tone during each experimental session. Figure includes data for four rats that received EXT-2 procedure after conditioned reinforcement procedure.

this change is shown in the sections labeled EXT-2 of Figs. 3 and 5. When association of lights and water was reinstated after six extinction sessions, distributions of latencies shifted back toward their previous values in two rats but not noticeably in the other two rats. The result is shown in the section labeled "lights" at the bottom of Fig. 3 and in Fig. 5.

In the present experiment, the effectiveness of the lights in maintaining responding in the presence of the tone apparently depended on a regular association of the lights and water at times when the tone was not present. Many recent studies (cf. for example, Hendry, 1969) have employed techniques in which a conditioned reinforcer is continuously maintained by pairing with primary reinforcement in the experimental situation. Usually, there were two reinforcement contingencies in competition, one tending to maintain keypecking or leverpressing behavior, the other tending to maintain behavior other than keypecking or leverpressing. For example, in a technique used by J. Zimmerman (1963), keypecking responses produced a brief operation of the grain magazine on a variable-interval schedule without presentation of grain, while the magazine operated and

allowed access to grain on an independent schedule but not as a consequence of keypecking. Presumably, these latter presentations of primary reinforcement tended to establish behavior other than keypecking.

In the present experiment, these reinforcement contingencies did not compete with one another, since they occurred in the presence of different exteroceptive stimuli because of the original discrimination that had been established. In the initial chained schedule, responding on each lever was under the control of an appropriate stimulus and responding in the absence of either stimulus extinguished. Later, the response-dependent presentations

of the lights came only in the presence of the tone, while the regular presentations of the lights that were postponed by leverpressing came only in the absence of the tone. Any adventitious reinforcement occurred during the 45-sec period between stimulus presentations, when behavior other than leverpressing already had been differentially reinforced under the initial schedule.

In general, the results of the present experiment were consistent with recent findings of reinforcing properties of brief stimuli in various concurrent schedules and second-order schedules. In the present situation, changes in discriminated behavior resulting from response-dependent

presentation of a stimulus were evident, and it is easy to rule out explanations in terms of properties of a stimulus other than reinforcing ones. However, as in other recent studies (see, for example, Stubbs, 1971), the role of pairing of a stimulus and primary reinforcement is less clear.

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