An analysis of "signaled double-alternation patterning" in the rat

W. B. PAVLIK and ALEXIS C. COLLIER

Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061

Rats given training with double alternation of rewards and nonrewards in which the first reward or nonreward of each pair occurred in a black runway and the second in a white runway developed fast running on rewarded trials in both runways and slow running on nonrewarded trials in both runways—signaled double alternation patterning. A subsequent shift in the reinforcement schedule produced a period of reversed patterning—slow on rewarded trials and fast on nonrewarded trials. The results are consistent with a compound stimulus discrimination interpretation of signaled double-alternation patterning rather than with a selective memory-retrieval explanation.

Rats in a runway have little difficulty learning appropriate response patterning (i.e., fast running on rewarded trials and slow running on nonrewarded trials) under a single alternation (SA) pattern of rewards (R) and nonrewards (N). Under normal circumstances, however, they apparently are unable to learn appropriate response patterning under a double-alternation (DA) schedule (e.g., Bloom & Capaldi, 1961). Recently, Capaldi (1971) has reported that rats given a DA schedule (RRNNRRNN), in which the first R and first N of each pair occurred in a black (B) alley and the second R or N of each pair occurred in a white (W) alley, developed accurate patterning behavior (i.e., consistently ran faster on R than on N trials in both B and W alleys). Essentially, these results are identical with those reported by Pavlik, Franchina, East, and Evans (1972; Group SA-SA). The latter investigation employed a double alleyway in which the first alley was black and the second was white. Rewards were present in both goalboxes on odd-numbered trials but were present in neither goalbox on even-numbered trials. Again, appropriate patterning behavior occurred in both alleys.

Capaldi's interpretation of this "signaled DA patterning" is an extension of his earlier interpretation of patterning in the SA (RNRN) situation (e.g., Capaldi, 1967). Briefly, in SA training, running is reinforced in the presence of memories of nonreward (S^N) from the previous trial, but is never reinforced in the presence of memories of reward (S^R) from the previous trial. Thus, S^N and S^R become discriminative stimuli for fast and slow running, respectively. To handle "signaled DA patterning," Capaldi (1971) assumes that the S^N and S^R which come to control fast and slow running are not simply carried over from the previous trial, but are stored memories of what happened the last time the subject was in the same situation (B or W alley). Thus,

the B or W external cues operating on Trial T elicit the memory (S^N or S^R) of what happened on Trial T-2, and this memory, depending upon whether Trial T is an R or N trial, becomes a signal for fast or slow running. Since the R or N event on Trial T-2 always is the opposite of what it is on Trial T, this form of DA reduces to two signaled SA sequences. The importance of this situation to Capaldi's theorizing is that it suggests that the rat not only stores S^N and S^R , but that these memories are subsequently retrievable in the presence of appropriate external stimulation.

There is, however, an alternative interpretation of "signaled DA patterning" which does not require the rat to selectively remember what happened "two trials ago." Assuming that the rat remembers on Trial T what happened on Trial T-1 (which seems clear from the SA literature), and given that particular external cues, B or W, are present on Trial T, four possible *compounds* of aftereffects (memories) and external cues are possible— $B + S^R$, $B + S^N$, $W + S^R$, and $W + S^N$. Given the schedules of alleys and Rs or Ns indicated above, two of these compounds, $W + S^R$ and $B + S^N$, will be present when responses are reinforced; the remaining two compounds, $B + S^R$ and $W + S^N$, will be present when responses are nonreinforced. It is assumed that fast and slow running come to be controlled by the appropriate stimulus compounds.

While both interpretations account for the signaled DA patterning that develops in the situations used by Capaldi (1971) and Pavlik et al. (1972), the interpretations generate different predictions if, following the development of signaled DA patterning, a particular shift in the reinforcement schedule is imposed. Given that the recurring four-trial sequence— $B + R$, $W + R$, $B + N$, $W + N$ —is suddenly shifted to the sequence— $B + R$, $W + N$, $B + N$, $W + R$ —Capaldi's interpretation should predict that, except for the second trial ($W + N$) of the new sequence, rats should continue to run fast on all R trials and slowly on all N trials. This prediction stems from the fact that, except for one trial,

Requests for reprints should be sent to W. B. Pavlik, Department of Psychology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

Alexis C. Collier is now at the University of Washington, Seattle, Washington 98105.

single alternations of R and N still persist for runs in the B alley and for runs in the W alley. Except for one trial, remembering what happened (S^N or S^R) the last time that external cue (B or W) was present still provides perfect predictions of R and N events on postshift trials. In contrast, the *compound* discriminative stimulus interpretation predicts that postshift performance will take the form of reversed patterning (i.e., fast on N trials and slow on R trials). This is because the postshift schedule constitutes a discrimination-reversal problem for the rat. Whereas, during the preshift phase, $W + S^R$ and $B + S^N$ signaled an R trial and $B + S^R$ and $W + S^N$ signaled an N trial, during the postshift phase (except for the first postshift trial), $W + S^R$ and $B + S^N$ now signal N trials and $W + S^N$ and $B + S^R$ now signal R trials. Thus, if the rat has learned during the preshift phase to respond to compounds of "immediate" memories plus external cues rather than to signaled "remote" memories, his behavior should be inappropriate to the altered reinforcement contingencies. This was the hypothesis tested in the present study.

METHOD

Subjects

The subjects were seven naive male hooded rats from the local department colony. The subjects were approximately 65 days old at the start of the experiment and were maintained on a daily food ration of 10 g of powdered Purina Chow mixed with 2 tsp of water. Water was available ad lib in the home cage.

Apparatus

The apparatus was that described in detail by Sgro, Giotfelty, and Podlesni (1969). Briefly, it was an L-shaped double runway, 7.5 cm wide and 12.5 cm high throughout, consisting of a black first alley (B) and a white second alley (W). B was divided by guillotine doors into a 25-cm startbox (SB), a 91.5-cm runway, and a 56-cm L-shaped goalbox (GB) which also served as the SB for W. W consisted of a 183-cm runway separated by a guillotine door from a 35.5-cm L-shaped GB. The entire apparatus was covered by transparent Plexiglas. Photobeams and associated timing circuits provided for starting latencies measured over the first 7.5 cm of both B and W and running latencies measured over the next 84 cm in B and the next 175 cm in W.

Procedure

The procedures used followed closely those described by Pavlik et al. (1972) for Group SA-SA. Following 1 week of adaptation to handling and the maintenance schedule, each subject was given one 4-min exploration period in the apparatus (all doors open) on each of 2 successive days, and one 2-min exploration period followed by one 2-min detention period in each GB on the following 3 days. A quantity of wet mash to be used as reinforcement was present in the GB during the detention periods.

Training consisted of 12 trials per day for a total of 19 days. A trial consisted of placing the subject in the black SB; 5 sec later the door was raised and subject was allowed 40 sec to enter the GB. The GB door then was closed and subject was confined for 20 sec. On R trials approximately $\frac{1}{4}$ tsp of wet mash was present in a foodcup. This amount of food was readily consumed within 20 sec. On N trials, only the empty foodcup was present. After 20 sec in the black GB, the door leading to W was opened and subject was allowed 40 sec to enter the white GB. Subject

Figure 1. Mean daily running speeds on rewarded (R) and nonrewarded (N) trials in the black (B) and white (W) runways.

was then confined in the white GB under R or N conditions like those used in the black GB. If the subject did not break the second photobeam in B or in W within 40 sec, the appropriate GB door was closed and subject was placed directly into the GB under the appropriate R or N condition for that trial, and a latency of 40 sec was recorded. The ITI was maintained at 20 sec during which the subject was detained in an unpainted wooden box (37.5 x 17.5 x 20 cm). Each subject was given all its daily trials before the next subject was run.

For the first 17 days of training, for all subjects, odd-numbered trials involved R in both GBs and even-numbered trials involved N in both GBs. Thus, the sequence of alleys and reinforcement contingencies was a recurring pattern of four events—B + R, W + R, B + N, W + N. On Day 18, the above pattern occurred three times (i.e., for the first six trials). Beginning with Trial 7, however, the sequence shifted to a new recurring pattern of four events—B + R, W + N, B + N, W + R. This new pattern occurred three times on Day 18 and six times on Day 19.

RESULTS

All latency measures were converted to speed scores ($1/\text{latency}$), and the mean speed score was computed for each subject for each day for both R and N trials in both the B and W alleys. For Day 18, separate preshift and postshift means were computed. The first postshift event (B + R) was included in the preshift data. These individual means were subjected to statistical analyses. Because of large variability in the starting-speed scores, only the running-speed data are presented.

As can be seen in Figure 1, patterned running does develop in both alleys. By approximately Day 10, subjects are running rapidly on R trials in both alleys and slowly on N trials in both alleys. This indicates the replicability of the signaled DA phenomenon.

Of principal interest are the data of Day 18, when the shift in reinforcement schedule was imposed. It will be recalled that Capaldi's memory-retrieval hypothesis predicts that running should have continued to be fast on postshift R trials and slow on postshift N trials, while the stimulus-compound hypothesis predicts a period of

postshift performance marked by slow running on R trials and fast running on N trials. As is clear in Figure 1, the data of Day 18 support the latter hypothesis. There is an abrupt decrease in speed on the postshift R trials and an abrupt increase in speed on the postshift N trials, the net effect of which was to produce faster running on N than on R trials. It also is clear that this set of effects was transitory; the subjects were running equally fast on both R and N trials on Day 19.

To assess the trends apparent in Figure 1, separate analyses of variance were done on the data of Day 18 for both the B and W alleys. In both analyses, preshift vs. postshift trials and R vs. N trials formed the two orthogonal variables. In both analyses, the interaction of these variables was significant; for the B alley, $F(1,18) = 31.7$, $p < .001$, and for the W alley, $F(1,18) = 50.9$, $p < .001$. Subsequent analyses of these interactions by within-subjects t tests ($df = 6$ in all cases) indicates that, in the B alley, preshift running was faster on R than on N trials ($t = 5.94$, $p < .01$), postshift running was faster on N than on R trials but not significantly so ($t = 1.52$, $p < .20$), running on R trials was significantly slower on postshift trials than on preshift trials ($t = 4.15$, $p < .01$), and running on N trials was significantly faster on postshift trials than on preshift trials ($t = 3.18$, $p < .02$). For the W alley preshift running was faster on R than on N trials ($t = 8.48$, $p < .01$), postshift running was faster on N than on R trials ($t = 3.42$, $p < .02$), running on R trials was slower on postshift than on preshift trials ($t = 3.28$, $p < .02$), and running on N trials was faster on postshift than on preshift trials ($t = 6.63$, $p < .01$).

DISCUSSION

The principal findings of the present experiment are: (1) that signaled DA patterning is a highly replicable and robust phenomenon and (2) that rats which have developed stable signaled DA patterning then show significant reversed patterning following a shift in the

reinforcement schedule which reversed the relationship between current R or N events and stimulus compounds composed of apparatus cues and memories of the R or N event on the previous trial.

The shift in reinforcement schedule was such as to leave unchanged the relationship between the R or N event on any trial and the earlier R or N event which occurred on the preceding trial in the presence of the same runway cues. This would appear to rule out explanations of signaled DA patterning which require the rat to store a succession of memories of R or N events coded according to apparatus cues and then selectively retrieve the appropriate memory when cued by particular apparatus stimuli (Capaldi, 1971). While it appears clear that rats do store and retrieve memories (e.g., Capaldi, 1971; Spear, 1971), questions can be raised about the general utility and accuracy of such a facile explanatory device. The results of the present experiment suggest that, given alternative ways of generating a particular complex behavior sequence, the rat takes the more parsimonious (less cognitive?) route.

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