IS BAR-HOLDING WITH NEGATIVE REINFORCEMENT PREPARATORY OR PERSEVERATIVE?¹

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Three of four white rats learned to press first one bar and then another to escape or avoid electric shocks. Cumulative bar-holding-time records showed that holding occurred frequently on the second bar but hardly ever on the first, indicating that bar-holding is more "perseverative" than "preparatory". The response chain, first-bar press second-bar press, was more easily established by a forward than by a backward chaining procedure.

When rats are subjected to shock-escape or shock-avoidance training procedures in a bar-pressing apparatus, they often develop marked tendencies to bar-hold (Dinsmoor and Hughes, 1956; Feldman and Bremner, 1963; Keehn, 1967a; Migler, 1963). Such behavior places an animal in an advantageous position to execute subsequent escape or avoidance bar-presses. Bar-holding may thus be interpreted as a preparatory response. Such an interpretation is supported by Dinsmoor, Matsuoka, and Winograd (1958). But when bar-holding occurs between two shocks it is difficult to tell whether the behavior is a carryover from the response to the preceding shock ("perseverative") or whether it is "preparatory" to a response to the succeeding shock.

It is possible to distinguish between these two possibilities if the escape or avoidance requirement is a response chain in which the terminal member does not leave an animal in a favorable position to begin the next response chain; *i.e.*, if an animal has to press first one bar and then another to terminate or avoid shock. In this case, if bar-holding occurs as a preparatory response it should occur primarily on the first bar; if it is a perseverative response it should occur primarily on the second bar. The present experiment, conducted in two parts, was designed to settle this question.

In Part I, rats were trained to press and release a bar to escape or avoid signalled shocks. A press-release response was utilized to provide a partial answer to the problem

studied: if bar-holding is preparatory then it should increase during this part of the experiment. In Part II, a response chain was established. This raised a subsidiary question concerning the manner of establishing a response chain with negative reinforcement. With positive reinforcement, chains are typically established backwards: the terminal response is established first, then the stimulus controlling this response is made contingent upon performance of another response, and so on (Keehn, 1959; Premack, 1959; Skinner, 1938). Such a procedure does not look promising when the reinforcement is negative because it requires an animal to emit a response which produces a signal for a forthcoming noxious event. Therefore, a forward chaining procedure may be more appropriate with negative reinforcement (Millenson, 1967; *cf.* Breland and Breland, 1966). In such a procedure the first response in the chain would be established first and subsequent responses added later so that negative reinforcement, through shock-escape or shock-avoidance, does not occur until the whole response chain is completed. A forward and a backward chaining procedure were used in the present experiment, but no attempt was made to establish the relative merits of the two procedures in general.

METHOD

Subjects

Four experimentally naive male albino rats, about 170 days old at the beginning of the experiment, were maintained in individual home cages with free food and water. They

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had been handled and gentled for about 15 min daily for 2 weeks before the experiment.

Apparatus

The experimental chamber was a Grason-Stadler two-bar rat box type E3125D with internal dimensions of $11\frac{1}{2}$ by $9\frac{1}{4}$ in. base by $7\frac{5}{8}$ in. The response bars were 2 in. wide and protruded $\frac{5}{8}$ in. from the chamber wall. The tops of the bars were $3\frac{3}{4}$ in. above the chamber floor and their outside edges were $2\frac{3}{4}$ in. from the side walls. Three stimulus lights were located on the same wall as the bars. Red and white stimulus lights were slightly above and about $1\frac{1}{2}$ in. from the outside edges of Bar A (right bar) and Bar B respectively. These lights, in combination with a medium intensity 1000 cps tone, constituted the pre-shock signal. A dim green light, centered between the bars about $1\frac{7}{8}$ in. above them, remained on during experimental sessions. A Grason-Stadler Shock Generator with output set at 0.5 ma was used to deliver scrambled shocks to the grid floor of the chamber.

The procedure was programmed by electronic relay and timing circuitry. A weight of 20 g on the bar was sufficient to activate the programming and recording apparatus.

Procedure

A discrete-trial, discriminated-avoidance procedure was used in which intertrial responses were nonfunctional. The warning signal was a light-tone combination which came on 5 sec before a shock was due. A response in the signal-shock interval terminated the signal and avoided shock on that trial; a response after shock onset terminated both signal and shock. The next trial began 15 sec later. In Part I, only one bar was functional and a response was defined as a bar press and release. Animals R7 and R8 responded to Bar A; R9 and R13 to Bar B. In Part II, both bars were functional and all animals were required to press and release Bar A and then press Bar B to terminate or avoid shock.

Part I covered nine experimental sessions. In Session 1 each animal was trained to press and release the appropriate bar and then given 50 further trials after it had made five successive unaided escape responses. Later the same day, a second session of 50 trials was given to each animal. Thereafter for seven

consecutive days (Sessions 3 through 9) each animal was given 100 training trials. Part II covered five experimental sessions (Sessions 10 through 14). In Session 10 each animal was trained to press Bar A and then Bar B. This was a forward chaining procedure in the case of R7 and R8 and successfully established the chain in both animals. The backward chaining procedure was successful with R13 but not with R9, which did not acquire the chain by Session 14. After five successive unaided escape responses in Session 10 the other animals were given 50 more trials in that session and then 100 trials in each of Sessions 11 through 14 on consecutive days.

Escape latencies were summed in each session and bar-holding times were accumulated on a Gerbrands cumulative recorder which stepped once at the end of every 0.2 sec that a bar was held down. Shocks were registered on the cumulative records

RESULTS

All four animals terminated shocks promptly by Session 9. Mean escape latencies in this session for R7, R8, R9, and R13 respectively were 1.37 sec, 0.68 sec, 1.39 sec, and 0.46 sec. Only R13 made more than an occasional avoidance response. This animal avoided 67 of the 100 possible shocks in Session 9; R8 avoided one shock, the other animals none at all. This result is consistent with other experiments using similar procedures (Keehn, 1967a; Meyer, Cho, and Wesemann, 1960).

Typical bar-holding records of each animal, taken from Session 9, are shown in Fig. 1. Apart from R7, which frequently released the bar too quickly to step the recorder, all animals exhibited a fair amount of bar-holding, and every animal's pattern of sequential hold durations was recognizable from day to day. Animal R9 typically escaped from several successive shocks without returning to the bar between shocks, and then, after terminating a shock, pressed and held the bar through to the next shock, and so on. On only one occasion did R9 release the bar and press it again without receiving a shock. The other animals' within-session bar-holding patterns were less regular. In the case of R8, hold durations tended to decrease during a session, but bar-holding occurred only immediately after a

Fig. 1. Representative cumulative bar-holding records of each animal when a press and release of the designated bar was necessary to escape or avoid shock. The recorder stepped once for every 0.2 sec press-release duration. Lateral spurs indicate shocks. Each record shows an animal's performance over an entire session of approximately 35 min.

shock. Animal R13, on the other hand, occasionally pressed and held the bar later in the intertrial interval. Because this animal avoided many shocks, its holding record is less easily subdivided by eye than those of the other animals, and the reproduced record does not unambiguously show precisely when bar-holding occurred. Observation, and examination of original records which also showed signal onsets on the event marker, made it clear that most of R13's bar-holding occurred immediately after it had made an avoidance response.

As the escape response was a bar-release, the fact that no animal consistently held the bar between shocks argues against the hypothesis that bar-holding is preparatory to escape by bar-releasing. Evidence that it is perseverative is shown by the records in Fig. 2, which were collected in Session 14. The cumulative records show accumulated bar-holding durations on the second response in the chain for the three animals that learned to perform the chain. In the case of R13, this was the response to the same bar as had been functional in Part I; for R7 and R8 it was the response to the other bar. Once again each animal's bar-holding performance was recognizable from day-to-day, and bar-holding almost always occurred immediately after a shock terminated. Only on a few occasions, in the case of R13, was either bar pressed other than right after shock. Responses to the first link in the chain are shown by depressions in

the horizontal event records in the figure, and the only signs of holding in this case are at the places marked A, B, C, D, E, in the record of R8. When first-link (Bar A) bar-holding records were collected cumulatively they resembled the record of R7 shown in Fig. 1. None of the animals, then, showed more than minimal preparatory holding of the bar that formed the first link in the chain, but all showed perseverative holding of the second bar, especially R8. In fact, all three animals exhibited more bar-holding in Part II, when the bar to be pressed next was not the bar being held, than they had in Part I when it was.

As in Part I, only R13 made more than occasional avoidance responses, this time when the response was a chained Bar A press-Bar B press. The animal avoided 17 of the 100 possible shocks in Session 14; the others avoided none at all. In this session all three animals escaped promptly. Mean escape latencies for R7, R8, and R13 respectively were 2.89, 1.89, and 1.39 sec.

DISCUSSION

All three animals that learned to perform the Bar A-Bar B response sequence exhibited bar-holding on Bar B but not on Bar A; although there were marked individual differences, the characteristic holding patterns of each animal were recognizably similar in both parts of the experiment. This suggests

Fig. 2. Representative cumulative records of Bar B hold durations when a response chain Bar A press-bar B press was necessary to escape or avoid shock. Bar A responses are shown by depressions of the lower trace of each animal. Bar A holding is indicated at points A,B,C,D,E in the record of R8. Lateral spurs indicate shocks. Each record shows an animal's performance over an entire session of approximately 35 min.

that whether a bar-press or a bar-release terminated or avoided shock had no differential effect on holding behavior. That is, the pattern of Bar A-holding exhibited by R8 when a press-release response was necessary to terminate or avoid shock (Part I) resembles this animal's pattern of Bar B-holding when only a Bar B-press was required after a Bar A press-release (Part II). Likewise, the pattern of Bar B-holding exhibited by R13 when a press-release response was necessary to terminate or avoid shock (Part I) resembles this animal's pattern of Bar B-holding when only a Bar B-press was required after a Bar A press-release (Part II).

The present results provide no evidence that bar-holding with negative reinforcement is preparatory and strong evidence that it is perseverative. That is, the reinforcement for bar-holding appears to derive not from the fact that the behavior allows for more prompt escape from a subsequent shock but from the fact that it has components in common with behavior that has just terminated shock. This is consistent with Boren's (1961) finding that response bursts generated by a variant of Sidman's (1953) avoidance procedure occur on an escape-bar rather than on an avoidance-bar. The data bear importantly on the development of bar-pressing behavior in Sidman-avoidance situations. In such situations bar-holding is not uncommon (Hurwitz and Dillow, 1967; Keehn, 1967a), and the questions arise as to how this behavior is first established, how it is maintained, and how it is interrupted sufficiently often so that bar-presses avoid shocks. Some suggestions in this respect have been made elsewhere (Keehn, 1967a, b, c).

Conclusions drawn about the status of bar-holding in the present experimental arrangement do not necessarily generalize to its status in procedures like those just discussed, but the possibility cannot be ignored. Behavior is multiply determined (Skinner, 1957), and preparatory as well as perseverative aspects of bar-holding with negative reinforcement have been detected (Dinsmoor *et al.*, 1958). If the stimulus control of behavior with negative reinforcement is to achieve the same level of precision as that currently obtainable with positive reinforcement, then all sources of control must be identified and their relative importance assessed. The present experiment provides information in these respects.

Some comment on the establishment of escape or avoidance response chains may also be in order. In the present experiment, the forward procedure was more effective than the backward one. The reason is easy to see. Animals R7 and R8 were trained first under the conditions of signal on, shock on, Bar A response, signal and shock off, and then under signal on, shock on, Bar A response, Bar B response, signal and shock off. With the latter conditions it was relatively easy to add the Bar B response to the Bar A response by withholding signal and shock termination until the animals moved towards Bar B after press-

ing Bar A. Animals R9 and R13 were trained first under signal on, shock on, Bar B response, signal and shock off, and then under signal on, shock on, Bar A response, Bar B response, signal and shock off. With the latter conditions there was nothing the experimenter could do to reinforce a movement towards Bar A without losing control of the Bar B response, and in fact, R13 appeared to learn the forward chain, Bar B response, Bar A response, Bar B response, rather than the backward Bar A response, Bar B response chain. But shaping and chaining are too involved with experimenter skill and luck to allow anything to be said at this stage about the relative merits of forward and backward chaining with negative reinforcement, or even which of the conceivable methods of obtaining the latter is preferable (Dinsmoor and Clayton, 1963). But it should not go unnoticed that although the backward procedure is the method of choice in strengthening chains with positive reinforcement, the technique of shaping response topography (as against response chains) has features in common with the forward chaining procedure of the present experiment.

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