ACQUISITION AND MAINTENANCE OF POSTSHOCK RESPONSE PATTERN IN NONDISCRIMINATED AVOIDANCE WITH RATS

SATOSHI SHIMAI AND HIROSHI IMADA

FUKUSHIMA MEDICAL SCHOOL AND KWANSEI GAKUIN UNIVERSITY

Five experimentally naive albino rats were placed under a nondiscriminated lever-press avoidance schedule in which the delay to the next shock for responses after a shock was longer than the delay for responses after a response. Four rats acquired the postshock response pattern and maintained it for a prolonged period. The results revealed that postshock responding was under operant control and was not purely shock-elicited. It was suggested that the two kinds of response-shock interval, i.e. the shock-response-shock interval and the response-response-shock interval, could and should be independently controlled in nondiscriminated avoidance schedules.

Key words: nondiscriminated avoidance, postshock response, lever press, rats

In the nondiscriminated lever-press avoidance situation, it has been frequently observed that animals press the lever soon after receiving a shock and wait out the response-shock interval (Sidman, 1962). According to Sidman (1966, p. 458), most animals pass through this phase of postshock responding before they achieve a more effective mode of avoiding shocks, and its duration may range from a few minutes to several sessions. Although Boren (1961) regarded this postshock response (PSR) as a pseudo-escape response and Pear, Moody, and Persinger (1972) as a shock-elicited response, no further investigation has been carried out to clarify the nature of the PSRs.

The present authors assumed that the PSRs could be under operant control, and an attempt was made to establish a postshock response pattern in rats by adopting a procedure that would favor the acquisition and maintenance of the PSRs. More concretely, an additional temporal parameter was introduced into the conventional Sidman procedure: two kinds of response, i.e. the postshock response (PSR) and the postresponse response (PRR), were differentially reinforced by making the delay of shock following the former (shock-response-shock interval; SRS) longer than that following

the latter (response-response-shock interval; RRS). It was expected that all rats would develop and maintain the postshock response pattern over a prolonged period.

METHOD

Subjects

The subjects were five experimentally naive male rats of the Sprague-Dawley strain. They were approximately 12 weeks old and weighed from 340 to 403 g at the start of the experiment. All animals were housed individually and given free access to food and water in their home cages throughout the experiment. One rat (R5) was discarded because it made only a few responses at the beginning of the first session and did not respond during the following three sessions.

Apparatus

The experimental chamber was a modified BRS/LVE (RTC-022) chamber with one lever. The inside dimensions were 24.0 by 30.5 by 27.3 cm. Three small electric lamps mounted over the lever were illuminated for 40 msec each time the lever was depressed, which required a force of .25 N. The houselight was 26 cm above the floor at the center of the front panel and was turned on during experimental sessions. The floor of the chamber consisted of stainless steel rods 5 mm in diameter and 19 mm apart from center to center. Scrambled electric shock (300-V ac, 60 Hz) with a dura-

This research was partly supported by a Grant in Aid for Scientific Research (No. 245016), Ministry of Education of Japan, to Hiroshi Imada. Requests for reprints should be sent to Satoshi Shimai, Department of Hygiene, Fukushima Medical School, Fukushima 960, Japan.

tion of 300 msec was applied to the grid floor through a series resistance of 250-K ohm. The experimental chamber was placed in a sound-proof enclosure, and its blower fan served as masking noise at a level of 76 dB.

Procedure

Phase 1. Each subject was given a one-hour training session daily for 10 days. On the day before the first training session, the subject was handled for 5 min and put into the darkened experimental chamber for 60 min of habituation. During the following training sessions, 10 min after the animals were placed in the darkened experimental chamber, the house-light was turned on and the experimental contingencies started. The shock-shock (SS) interval was 5 sec throughout the experiment. The shock-response-shock (SRS) interval was 40 sec and the response-response-shock (RRS) interval was 10 sec during Phase 1.

Phase 2. During the second phase, which lasted eight sessions, the RRS interval was shortened to 2.5 sec from the 10-sec interval of the preceding phase. Otherwise, the procedure was identical to that of Phase 1.

Phase 3. In Phase 3, shortened SRS intervals (10 sec, 20 sec, and 30 sec) were introduced and their effects on the postshock response pattern were investigated. Phase 3 consisted of six sessions in the order 20 sec, 30 sec, and 10 sec.

In all other aspects the procedure was similar to that for Phase 2.

RESULTS

Phase 1

The PSR rates for the first five sessions are shown in Figure 1 in blocks of 10 minutes for each rat separately. For all rats, the PSR rates gradually increased in the first session and the rates were maintained at approximately 1.5 to 2.0 PSR's per minute (see also Figure 3). Figure 2 shows the shock rates during Phase 1 for each rat separately. The shock rates declined steadily over days in all four rats. The high rates shown by R2 in the first few sessions reflect occasional periods of nonresponding. During the last three sessions, the shock rates of R4 were approximately 1.6 per minute, one shock every 40 seconds. In other words, R4 showed nearly a perfect PSR pattern, pressing a lever only once soon after each shock. This is also shown in the left half of Figure 3: R4 made few postresponse responses (PRRs) and maintained a stable PSR rate of about one response every 43 sec for the last three sessions of Phase 1. In the other three rats, the PRR rates increased slightly over sessions as did the PSRs.

During the early sessions, R1 and R4 showed

Fig. 1. Postshock responses (PSRs) per minute for four rats in blocks of 10 min for the first five sessions of Phase 1.

Fig. 2. Rates of shocks per minute for four rats during Phase 1.

high rates of PRRs as shown in Figure 3. However, these response bursts soon became less frequent and the PSR pattern became relatively more dominant, especially in R4.

Phase 2

Although R4 came to show an almost perfect PSR pattern by the end of Phase 1, there were

some PRRs for the remaining three rats. These animals occasionally pressed the lever two or more times after shock presentations and waited out the 10-sec RRS intervals in Phase 1. It was expected that the rate of these PRRs would decrease due to the short RRS interval in Phase 2.

Figure 3 shows the rates of the postshock responses (PSRs) and the postresponse responses (PRRs) for the four animals during Phase 1 and Phase 2. Reducing the RRS interval from 10 sec to 2.5 sec had no influence on the performance of R4, because the PRR rates had been low for this rat even during Phase 1.

Fig. 3. Rates of postshock responses (PSR) and postresponse responses (PRR) for four rats during Phase 1 and Phase 2.

In the other rats, the PRR rates decreased markedly in the first session of Phase 2, whereas the PSR rates remained at the level of 1.5 to 2.0 per minute throughout Phase 2.

Phase 3

Figure 4 represents the conditional probabilities of interresponse times (IRT/OP) for the four different SRS intervals. The results shown in the bottom panel of Figure 4 are from the last two sessions of Phase 2. As is clearly shown in Figure 4, the peaks of the distributions generally shifted systematically with the change in the SRS intervals. These findings are consistent with the suggestion that the post-shock response pattern was under control of the SRS interval.

When animals consistently show the PSR pattern, the relationship between the inter-PSR time and the SRS interval should be:

$$y = x + b$$

where y is the inter-PSR time, x is the SRS interval, and b is the PSR latency from shock presentation, which should be shorter than the SS interval. Figure 5 shows the relationship between the inter-PSR time calculated from the PSR rates and the SRS intervals for R4, which showed a nearly perfect PSR pattern. The regression line obtained by the method of least squares, but omitting the data with the 10-sec SRS interval, is clearly consistent with the above theoretical relationship. The reason for omitting the data for the 10-sec SRS interval will be discussed below. R4 pressed the lever about 3.85 sec after the shock presentation and did not respond again until after the next shock presentation. The relationship between the inter-PSR time and the SRS interval for the other rats was not so clear as for R4 because of the frequent occurrence of PRRs.

DISCUSSION

The results of the present experiment demonstrated that: (a) long shock-response-shock (SRS) intervals led to the acquisition and stable maintenance of the postshock response (PSR) pattern (Phase 1); (b) the shortening of the response-response-shock (RRS) interval, holding the SRS interval unchanged, led to a decrease in the postresponse response (PRR) rate without affecting the PSR rate (Phase 2); (c) the distributions of the interresponse times

Fig. 4. Conditional probabilities of interresponse times (IRTs/Opp) for four rats on the test days of Phase 3 (SRS = 10, 20, and 30 sec), and those for the final two sessions of Phase 2 (SRS = 40 sec).

Fig. 5. Calculated inter-PSR times for the four SRS interval conditions for R4. The regression line was computed by the method of least squares excepting the data of SRS = 10 sec (see text).

were systematically changed according to the SRS intervals (Phase 3); (d) the maintained PSR occurred about 4 sec after every shock regardless of the SRS interval in R4; (e) for R1, R2, and R3, gradual acquisition of the PSR was observed (Phase 1). Taking these findings together, it could be concluded that the PSRs were very likely under operant control in the present experiment.

In Boren (1961), according to our terminology, the SS interval was zero (continuous shock), the SRS interval was 12 sec, and the RRS interval was 20 sec (cf. Hineline, 1977, p. 388). Using a two-lever situation, the animals were required to make PSRs on the first (escape) lever and PRRs on the second (avoidance) lever. Results showed that almost all the animals learned to respond steadily on the avoidance lever. But it was also shown that "the bursts of responding just after the shock occurred entirely on the escape lever" (Boren, 1961, p. 265). And Boren explained these bursts of responding as follows: "immediately after the termination of an aversive stimulus the animal behaves as if the stimulus were momentarily still present" (Boren, 1961, p. 266). However, Boren's application of this explanation to the postshock burst of responding observed in an ordinary one-lever nondiscriminated avoidance does not seem appropriate in light of the present results, especially those of R4. In the first place, R4 made only one response (and not a burst of closely spaced responses) after a shock. Secondly, as Figure 5 shows, the PSRs occurred approximately 4 sec after (and not immediately after) shocks. These findings, as well as the gradual decrease of PRRs, strongly suggest that the PSRs in R4 were reinforced not in the way Boren has suggested but by the delay of shocks following PSRs. In short, the behavior of R4 obviously came under operant control and should not be interpreted solely as shock-elicited.

A remark may seem necessary regarding the fact that R4 failed to show as perfect a PSR pattern in the shortest SRS interval of 10 sec as in the other SRS interval conditions. Perhaps reinforcement by as short an SRS interval as 10 sec was not sufficient to maintain the PSR pattern. Further experiments may clarify this issue.

With regard to the results of the remaining three rats (R1, R2, and R3), the evidence that their behavior was under operant control was less convincing at first glance. The results shown in Figure 4 are not inconsistent with the view that the rats' behavior was controlled by the SRS interval, nor do they contradict the view that the PSR pattern is a shock-elicited phenomenon. Strong evidence for operant control, however, is found in the acquisition functions shown in Figure 1. Had the PSRs been shock-elicited, their rate should not have shown such gradual acquisition curves. In addition, combining the results shown in Figures 2 and 3, the shock rates gradually declined over sessions despite the fact that both PSRs and PRRs showed gradual increases over sessions in Phase 1 for R1, R2, and R3.

Although one cannot draw any definite conclusion from the present experiment alone regarding the issue of operant versus responding control of nondiscriminated avoidance, and although complex interactions may occur between these two kinds of control, the following conclusions are warranted: (a) the results of the present experiment indicated that the PSRs were at least to a certain extent under operant control; (b) the technique of manipulating SRS intervals and RRS intervals independently seems useful for analyzing the issue.

REFERENCES

- Boren, J. J. Isolation of post-shock responding in a free operant avoidance procedure. *Psychological Reports*, 1961, 9, 265-266.
- Hineline, P. N. Negative reinforcement and avoidance. In W. K. Honig and J. E. R. Staddon (Eds.), *Handbook of operant behavior*, Englewood Cliffs, N.J.: Prentice-Hall, 1977.
- Pear, J. J., Moody, J. E., & Persinger, M. A. Lever attacking by rats during free-operant avoidance. *Journal of the Experimental Analysis of Behavior*, 1972, 18, 517-523.
- Sidman, M. Reduction of shock frequency as reinforcement for avoidance behavior. *Journal of the Experimental Analysis of Behavior*, 1962, 5, 247-257.
- Sidman, M. Avoidance behavior. In W. K. Honig (Ed.), *Operant behavior: Areas of research and application*. New York: Appleton-Century-Crofts, 1966.

Received July 23, 1981

Final acceptance December 15, 1981