LEVER HOLDING UNDER FREE-OPERANT AVOIDANCE¹

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Rate of response under a free-operant avoidance procedure decreases as the response-shock interval increases. The present experiment demonstrated an inverse relation between rate of response and lever-holding time. An invariance was found in the total time per session that a subject was in contact with the lever. It is suggested that lever-holding behavior may be as sensitive as response rate to changes in the response-shock interval.

Several attempts have been made to account for the learning of avoidance behavior in the absence of environmental warning stimuli, *e.g.*, Schoenfeld (1950), Sidman (1953), Dinsmoor (1954), Mowrer and Keehn (1958). More recently, Anger (1963) proposed an explanation for both the acquisition and the temporal patterning of the response under a free-operant avoidance (Sidman-type) schedule where each response postpones the aversive stimulus by a fixed time period, the response-shock (R-S) interval. He postulated that because stimuli associated with long postresponse times have a high probability of preceding shock, a response which terminates such stimuli is more frequently reinforced than when it terminates stimuli associated with a short postresponse time. In addition, the greater fear-arousing property of stimuli immediately preceding shock gives them added discriminability so that they acquire better control over the designated avoidance response. (A similar argument applies to stimuli associated with a postshock period.) But these stimuli are entirely response inferred and cannot be manipulated; a direct test of Anger's analysis does not therefore seem possible. On the other hand, a closer examination of the behavior generated under a free-operant avoidance schedule may shed light on the basic problem: what aspect of behavior does shock change?

An earlier study of avoidance behavior in the absence of a warning signal (Hurwitz and

Millenson, 1961) showed that subjects developed a strong tendency to hold the lever, a phenomenon well documented for escape learning (Dinsmoor, Matsuoka, and Winograd, 1958; Migler, 1963). The present study sought to discover if lever holding was correlated with the principal parameter of the free-operant avoidance schedule, the response-shock interval. Studies by Sidman (1953), Verhave (1959), and Clark and Hull (1966) had shown that the rate of lever pressing, or the more refined measure of interresponse interval, as used by Wertheim (1965), may be functionally related to the value of R-S. If holding behavior is modulated by the R-S interval, such temporal response patterning could be explained by noting that changes in the rate of response observed under different R-S values are the outcome of the control of holding behavior by the punishment contingency.

METHOD

Subjects

Three 4-month-old litter mates were selected from the inbred rat colony maintained by the Department of Psychology at Birkbeck College. They had free access to food and water in their home cages.

Apparatus

A 12-in. long by 6-in. wide by 9-in. high all-metal chamber was equipped with a lever, which responded to 7-g dead weight by closing a microswitch. A 0.6-ma electric shock lasting 0.2 sec was delivered to the walls, grid floor, and to the lever from a constant current

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source through a scrambling device. Each of the three chambers used was enclosed in a sound-insulated cubicle ventilated by an extractor fan which also provided a masking noise against the recording and programming equipment in the adjoining room. Recordings were made on counters, cumulative recorders, and on a computer compatible data acquisition system, SETAR, which converted events and time measures (to 1/100 sec) into a punched tape record. The data-tapes were subsequently analyzed on a Mercury computer.

Procedure

Each subject was given 28 four-hour sessions under a free-operand avoidance procedure (Sidman, 1953). The postponement of shock was contingent on a press of the lever, rather than on its release. During the early sessions, the shock-shock interval was set at 9 sec for 10 sessions; 18 sec for four sessions; 36 sec for six sessions; 9 sec for four sessions and 27 sec for four sessions. Thus, before the main phase of the experiment, each subject had had extensive experience under a variety of R-S intervals. The experiment itself consisted of three sets of 10 one-hour sessions. The R-S interval was 36 sec, 18 sec, and 9 sec in the first, second, and third sets respectively. The shock-shock interval remained at 5 sec throughout. Lever holding was recorded during the final five sessions of each set only. Unfortunately, many of the data tapes on which individual response durations (press-release times) and response intervals (release-press times) were recorded were later found to be faulty and unacceptable to the computer. This applied especially to the tapes produced by Rat B.

RESULTS

The average interresponse times, the reciprocal of rate of response, for each subject obtained during the experimental sessions under each of the R-S intervals are shown in the upper section of Fig. 1. The results are comparable to those reported by Sidman (1953) and show that the maximum rate occurred under the shortest interval. If the maximum rate for R-S = 9 sec is taken as standard, the average change in rate for the three subjects in this study is 0.66 for R-S = 18 sec and 0.40 for R-S = 36 sec compared to 0.66

for R-S = 18 sec and 0.41 for R-S = 36 sec in Sidman's study. (The figures used in these calculations had to be obtained by interpolation from Sidman's graphs since he used R-S intervals of 10, 20, 30, and 50 sec respectively). Results from training and experimental sessions in terms of shocks per hour were also compared. The ratio of shock per hour for the final training session under a particular R-S value and the final experimental session showed only minor deviations from unity. This evidence supports the claim for the stability of the R-S function.

The mean lever-holding time for each subject as a function of the R-S is shown in the middle panel of Fig. 1. Lever holding is seen to increase systematically with an increase in the response-shock interval. The total holding time per session for the final set of five sessions expressed as a per cent of session time is given in the lower panel of Fig. 1. It shows that the per cent time spent in holding varied only slightly (Rat A showed no change) as the R-S was changed from 36 sec to 9 sec. Holding times, or press-release intervals, and time intervals between release and press for Rat A and C, are analyzed in Fig. 2 and 3 respectively. The data for these were taken from the final session under each R-S interval.

Each bar of the histogram expresses per cent of total time spent in holding (or non-holding) as a function of the time categories indicated on the base lines. For example, in Fig. 2, when R-S = 9 sec, 78% of total holding time was attributable to response durations in the 0.01 to 3-sec class interval; when R-S = 36 sec, only 26% of the total holding time was attributable to holding times greater than 24 sec. This conversion of the raw data (frequency of responses per 0.5-sec. class intervals) allows comparisons to be made between distributions without reference to either the real time, which Fig. 1 shows to be relatively constant and uncorrelated to the R-S interval, or to the frequency of response, which is known to decrease with an increase in R-S interval.

The distributions also indicate that during final sessions on each R-S interval, very few shocks were received for holding the lever, but it should be remembered that shocks rarely occurred at this stage of training.

Finally, one may wish to compare the effect of R-S on holding, *i.e.*, press-release, as against non-holding, *i.e.*, release-press times.

Fig. 1. *Upper Panel:* Mean interresponse interval for Rats A, B, and C, as a function of the response-shock (R-S) interval. Data points represent means computed for the final five sessions under each R-S interval. *Middle Panel:* Duration of lever holding times for each subject. This figure should be read in conjunction with histogram distributions, Fig. 2 and 3. Data points represent mean values computed for the final five sessions under each R-S value. *Lower Panel:* Per cent of total session length spent by each subject in holding the lever. The graph indicates little change in holding time as a function of the R-S interval. The figure uses the data displayed in the upper and middle panel.

The results suggest that holding changed more consistently than non-holding. These data need to be augmented by further investigation.

DISCUSSION

The experiment provided evidence for a functional relation between lever holding and the R-S interval in a free-operant avoidance procedure. It also showed that changes in lever holding were correlated with changes in the rate of response. It is possible that response rate under these conditions reflects changes in lever holding. Consider the actual holding times observed: when R-S = 9 sec, the group mean was only 1.5 sec, and when R-S = 36 sec, the mean was 5 sec; that is, the average duration of each holding response occupied

Fig. 2. The histograms represent lever holding (left panel) and non-holding (right panel) times. Each histogram shows the per cent of total time spent in each of the time categories indicated on the base-line. A single bar was obtained by multiplying the frequency of a hold (or non-hold) category by the mid-point of that category and expressing this product as a percentage of the total holding (or non-holding) time. The data were obtained from the final sessions under each R-S interval for Rat A.

Fig. 3. The histograms represent lever holding (left panel) and non-holding (right panel) times. Each histogram shows the per cent of total time spent in each of the time categories indicated on the base-line. A single bar was obtained by multiplying the frequency of a hold (or non-hold) category by the mid-point of that category and expressing this product as a percentage of the total holding (or non-holding) time. The data were obtained from the final sessions under each R-S interval for Rat C.

about 14% of the response-shock interval. (In view of the skewed nature of the holding distributions these estimates are probably too high). These data provide tentative support for the claim that the primary effect of the schedule was to modify holding behavior. Also, there is some collateral evidence which should be borne in mind. More recently, in unpublished experiments by Hurwitz and Bounds, a strong holding tendency was found during early sessions under free-operant avoidance, long before the rate of response rose to a level where shocks were consistently avoided. In other words, during early sessions when escape behavior predominates, subjects learned to respond to shock by holding, as also noted by Migler (1963), but not to avert shock; the R-S interval was almost wholly occupied by

holding. The problem is to account for the lessening of such holding time so that the probability of a press before delivery of shock is increased. According to the present analysis, holding behavior diminished because it consistently preceded shock, *i.e.*, holding appears to have been modulated by shock.

On the basis of this analysis, one could still describe the effect of the procedure as involving "temporal discriminations". Anger's (1963) suggestion that such a discrimination is based on response-produced stimuli would assume new meaning since the response which serves to provide the stimulus source is not the press, but the hold. It pushes back the explanation and suggests the hypothesis that reinforcement of holding forms the basis of the temporal discrimination and is also the basis of the frequently cited observation that the rate of response is a decreasing function of the increase in the R-S interval.

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