*SOME EFFECTS OF CORRELATION BETWEEN
RESPONSE-CONTINGENT SHOCK
AND REINFORCEMENT¹*

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Rats responded on a two-component chain schedule in which a response-contingent electric shock at the end of the first component was either positively correlated, negatively correlated, or uncorrelated with reinforcement availability in the second component. With 0.4-ma shocks, rate in the first component depended on the shock-reinforcement correlation: when shock and reinforcement availability were positively correlated, after extended exposure to the contingencies, rates exceeded those in the absence of shock; when shock and reinforcement availability were negatively correlated, responding was generally suppressed throughout. The discriminative control of shock over responding in the second component, in which reinforcement was available 50% of the time, also depended somewhat on correlation. However, rate change in the first component was not specifically related to discrimination in the second component. With 0.8-ma shocks, responding was substantially suppressed in the first component at all three values of shock-reinforcement correlations.

Electric shock of medium or high intensity is usually regarded as a noxious stimulus which suppresses the behavior that produces it, and maintains behavior that delays or terminates it. Some recent experiments have shown that the effects of shock in a punishment procedure may be modified if the shock has a systematic relation to the availability of reinforcement.

Williams and Barry (1966) trained rats on a variable-interval 1-min schedule of food reinforcement, and punished responding on an identical but independent schedule under two conditions. In one condition, food and shock were delivered simultaneously, while in the other condition they were delivered separately. Complete recovery from the initial suppressive effects of the shock was observed in the first condition, but none was evident in the second. The effect was attributed to counter conditioning.

Holz and Azrin (1961), using pigeons as subjects, delivered response-contingent shocks only during sessions when reinforcement was available; no shock was given in alternated

extinction sessions. In subsequent tests during extinction, contingent shocks increased rate of responding. In another study, Holz and Azrin (1962) demonstrated that the amount of suppression produced by contingent shock depended on its temporal location in a fixed-interval cycle. If presented in the first three quarters of the interval, responding was markedly suppressed even by mild shock. However, if mild shock was given only in the final quarter of the interval, and thus was paired with reinforcement, the rate in that quarter exceeded the comparable unpunished rate. The authors attributed these effects to the discriminative properties of the response-produced shocks. Although discriminative stimuli are usually continuously present, independent of responding, the Holz and Azrin procedure makes response-contingent shock a part of the stimulus complex associated with reinforcement, so that shock may function discriminatively. More recently, they have interpreted their 1961 findings in terms of conditioned reinforcement (Azrin and Holz, 1966, pp. 419-420; see also Kelleher and Gollub, 1962, p. 591). The same interpretation could apply to their 1962 data.

In fact, the discriminative function of shock in a single-response procedure is not easily separable from its reinforcing or punishing effects. When a punished response is intermittently reinforced, and unpunished re-

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sponding is never reinforced, punishment sets the occasion for reinforcement and thus may function as a discriminative stimulus to increase rate. At the same time, correlation between shock and reinforcement may establish shock as a positive conditioned reinforcer, which will also increase the rate of a response which precedes it. A similar problem arises when shock is correlated with extinction: both the discriminative and punishing effects of the shock will serve to lower the rate of responding.

One way to separate these functions is to use a two-component heterogeneous chain, where shock is presented contingent upon one response in the first component and sets the occasion for reinforcement or non-reinforcement of the second component response. In such a situation, response rate in the first component, which precedes shock, would reflect the punishing or reinforcing effects of the shock. The discriminative function of the shock would be reflected by differential responding in the second component following shock, compared with responding when no shock had occurred.

The present experiment investigated the effects of a response-contingent shock at the end of the first component of such a chain, when this shock was related in one of three ways to reinforcement in the second component: either the shock was (1) correlated with availability of reinforcement, or (2) correlated with non-availability of reinforcement, or (3) uncorrelated with reinforcement availability or non-availability.

METHOD

Subjects

Six experimentally naive male black rats from the Swarthmore colony, about four months old at the start of the experiment, were studied approximately 22 hr water-deprived and given about 30-min access to water after each session.

Apparatus

A standard rat chamber, containing two bars 4 in. apart with a pilot light above each bar and a 0.03-ml dipper mounted midway between the bars, was used. Shock was delivered through the grid floor with a Grason-Stadler E1064GS scrambler. The experiment

was programmed and data were recorded in a separate room.

Procedure

Subjects were trained to press each bar separately and were then given four sessions of preliminary training on a two-bar chained schedule, in which presses on the left bar produced light, and presses on the right bar in the presence of light produced water. During these sessions the first component was changed from FR 1 to FI 30-sec, and the probability of reinforcement in the second component was reduced from 1.00 to 0.50. There were nine days of training on this procedure before shock was introduced. Sessions were 1 hr long, and were conducted seven days a week.

The final procedure was as follows: in darkness, subjects responded on the left bar (Bar A) on FI 30-sec; the first press on this bar made after 30 sec in darkness (1) turned on the lights above the bars, (2) reset the FI 30-sec timer, and, (3) produced shock with probability 0.50. In the positively correlated condition, light plus shock indicated availability of reinforcement for a response on the right bar (Bar B), while light and no shock indicated that a Bar-B response would not be reinforced. In the negatively correlated condition the opposite relation existed: light and shock indicated non-availability of reinforcement on Bar B, while light alone indicated reinforcement availability. For the uncorrelated condition, shock on Bar A and reinforcement on Bar B were each delivered with probability 0.50, but no correlation existed between shock and reinforcement availability. Reinforcement could be collected only while lights were on; they were turned off either by a Bar-B press or after 2 sec if no response on Bar B had occurred.² A fixed-interval schedule was chosen because all response rates above a certain minimum will result in the same number of exposures to the shock-reinforcement contingencies.

²The purpose of this 2-sec limited hold was to insure close temporal proximity between shock and reinforcement in the +1 condition, and between shock and non-reinforcement in the -1 condition. Nevin (1964), using the same basic procedure, demonstrated that the Bar-B response nearly always occurred within 1 sec of light onset, and that the probability of responding on Bar B in the presence of light remained near 1.00 until the probability of reinforcement was reduced to low values.

Operation of the procedure is illustrated in Fig. 1, which is a hypothetical record of responding in the positively correlated condition. Shock would have occurred at the end of the second and fourth intervals for the negatively correlated condition, and randomly for the uncorrelated condition. The following points should be noted. Reinforcement availability (or non-availability for the negatively correlated condition) was signaled by a compound stimulus, in which the shock was briefly presented at the onset of light. The association of light with water was constant throughout the experiment, so that only the shock could serve as a differential discriminative stimulus for pressing Bar B. Shock could not have any discriminative relation to responding on Bar A in the first component of the chained schedule, since (1) its occurrence marked the completion of the first component; (2) reinforcement availability for each completion of the schedule requirement was programmed by a random sequence, so that shock presentation in one interval and reinforcement availability in the next were independent events; (3) the scheduled frequency of reinforcement over the course of an experimental session did not depend on whether or not shock was delivered during that session, or on the programmed relation of shock to reinforcement availability.

Fig. 1. Hypothetical record of responding in the positively correlated condition. Each light offset marks one completion of the chained schedule requirement, and the beginning of another.

Each subject was studied on all conditions, first with 0.4-ma shock and then with 0.8-ma shock.³ Shock duration was always 0.1 sec. Each subject had a different order of exposure

³0.4-ma, 0.1-sec shock was chosen because previous work at the Swarthmore laboratory had shown that a shock of that intensity and duration, when presented contingent upon each response on FI 30-sec, suppresses behavior of rats to between 40 and 60% of its unpunished level. This is equivalent to the initial suppressive effect obtained by Holz and Azrin (1961). 0.8 ma was chosen because it is known to be a strong suppressor.

to the conditions, so that all possible orders were represented; the same presentation order was used for both shock intensities (see Table 1). Subjects were given 27 sessions on each shock condition and nine sessions without

Table 1

Order of exposure to the experimental conditions for individual subjects. The same order was used for both 0.4-ma and 0.8-ma shocks.

Rat	Exposure Sequence		
	I	II	III
A	-1	+1	0
B	0	+1	-1
C	+1	0	-1
D	0	-1	+1
E	+1	-1	0
F	-1	0	+1

shock before each shock period; 18 sessions were conducted before the first exposure to 0.8-ma shock and at the end of the experiment to check the stability of no-shock rates.

RESULTS

Changes in behavior observed during a series of different experimental conditions may result from the effects of the conditions themselves, from the order of their presentation, or from long-term changes attributable to uncontrolled variables. In this experiment, behavior on Bar A was generally free from long-term changes, as evidenced by the overall stability of final response rates during the no-shock period. No systematic order effects were apparent. Changes in response rate, then, may generally be considered as variations from a relatively stable baseline, independent of presentation order.

Three-day averages for individual subjects are employed for all measures unless indicated otherwise.

0.4 ma shock. Figure 2 shows the mean rate of responding on Bar A for all subjects during the preceding no-shock period, the shock period, and the following no-shock period for each of the three conditions. The use of averaged data is meant to give a general indication of behavior during the various conditions. Note the differences among conditions in suppression of responding when shock was introduced, rate recovery during the shock period, and change in rate when shock was removed.

Fig. 2. Average response rate on Bar A for six rats in three-session blocks before, during, and after exposure to 0.4-ma shocks under three conditions of correlation between shock and reinforcement. +1 designates the positively correlated condition; 0 designates the uncorrelated condition; and -1 designates the negatively correlated condition.

These group differences are in fact representative of most subjects' behavior, as shown by the data for individual rats presented in Fig. 3.

Before a discussion of behavior differences across conditions, it may be helpful to note some uniformities. All subjects but one (Rat E) showed suppression of responding in all conditions when shock was introduced. Also, subjects generally showed at least some recovery in all conditions and exhibited a change in response rate, either positive or negative, when shock ceased.

The most consistent differences in behavior appeared in the two correlated conditions. In the positively correlated condition, five of the six subjects showed their greatest recovery. In all cases, terminal rate on Bar A actually exceeded the baseline rate, and rate decreased

upon return to an unpunished condition. In the negatively correlated condition, all subjects showed most initial suppression when shock was introduced. Note also that rates generally were lowest throughout this condition and increased when shock ceased. The uncorrelated condition had little consistent effect on behavior other than the generally observed initial suppression and moderate recovery.

For the two correlated conditions, a discrimination index was obtained by dividing the number of correctly discriminated, or reinforced, Bar-B responses by the total number of Bar-B responses in the presence of light. Thus, if a subject pressed Bar B during each light-on period, the resulting discrimination index would be 0.50, while perfect discrimination would result in an index of 1.00. In general, in the no-shock and uncorrelated conditions, and during the first sessions of the positively and negatively correlated conditions, all subjects pressed Bar B during each light-on period. Also, throughout each condition, subjects usually collected each available reinforcement. Thus, positive changes in the discrimination indices indicate extinction of errors.

Equipment failures and/or discrepancies in the recording devices leave some room for uncertainty in the indices. As the error is not greater than 2%, however, the indices are used as a general indication of the level of discrimination during the shock periods (see Fig. 4). In four of the six subjects, the terminal discrimination index was higher in the negatively correlated condition than in the positively correlated condition. In general, the discrimination indices rose earlier and to higher levels in the negatively correlated than in the positively correlated condition.

Recovery during shock or final rate on Bar A does not seem to be correlated, in either condition, with change in discrimination or terminal discrimination performance on Bar B. In the positively correlated condition, all subjects showed recovery while not all learned the discrimination, with the result that various unsystematic combinations of rate and discrimination were exhibited. In the negatively correlated condition, there were instances both of recovery without change in discrimination and of increase in discrimination with very little recovery. There are no apparent systematic effects of order on dis-

Fig. 3. Response rate on Bar A for each rat in three-session blocks before, during, and after exposure to 0.4-ma shocks under three conditions of correlation between shock and reinforcement. The panels are arranged in columns by condition. +1 designates the positively correlated condition; 0 designates the uncorrelated condition; and -1 designates the negatively correlated condition. The roman numerals indicate the order of exposure to the conditions for each rat.

Fig. 4. Acquisition of discriminative control over responding on Bar B by shock under two conditions of shock-reinforcement correlation. The discrimination index was calculated by dividing the number of reinforced Bar B responses by the total number of Bar B responses in the presence of light. +1 designates the positively correlated condition, and -1 designates the negatively correlated condition.

crimination learning. However, this experiment was not designed to be sensitive to such effects, so that no definite statement can be made as to their possible influence.

0.8-ma shock. Rat C died during the first 0.8-ma shock period, so the following results are taken from the remaining five rats.

Figure 5 shows the individual rates of responding on Bar A for the preceding no-shock period, the shock period, and the following no-shock period for each of the three conditions during the 0.8-ma shock. As shown by the graphs, behavior was greatly suppressed during all three shock conditions.

Rates were generally low enough to obscure any differences that may have existed between conditions at this shock intensity. No clear relationships between shock correlation and initial suppression or recovery were observed. With only one exception, rate decreased during the shock periods, although in many instances the amount of this decrease was small. In all cases there was a rate increase with return to the unpunished condition; the amount of increase was least after the positively correlated condition for the four subjects whose data are usable. The fifth rat (Rat F) had suppressed almost completely, and had to be given a number of free reinforcements at 48-hr water deprivation to reestablish responding. Only one subject (Rat E, positively correlated condition) evidenced any discrimination learning; there were no apparent cor-

relations between Bar A rate and Bar B discrimination performance for that subject. This general lack of discrimination learning may have resulted from the maintained low rates, which in most cases provided the subjects with fewer exposures to the contingencies than they had at 0.4 ma. The only subject that learned the discrimination at all also maintained the highest rate of all subjects in the positively correlated condition.

Final shock rates, both intensities. Figure 6 shows the final rate of responding on Bar-A for each rat in each shock condition at both intensities, as a percentage of the final rate for the preceding no-shock period. This figure summarizes the major effects of the experiment, emphasizing the fact that the positively correlated condition at 0.4 ma enhanced responding for all subjects, and indicating the absence of systematic effects of the shock-reinforcement correlation at 0.8 ma.

DISCUSSION

The present results, like those of Holz and Azrin (1961, 1962) and Williams and Barry (1966), demonstrate that the effect of a punishing shock may depend on its programmed relation to the positive reinforcer which maintains performance. To summarize the present results for responding on Bar A in the first component of the chained schedule, with 0.4-ma shock:

Fig. 5. Response rate on Bar A for each rat in three-session blocks before, during, and after exposure to 0.8-ma shocks under three conditions of correlation between shock and reinforcement. The panels are arranged in columns by conditions. +1 designates the positively correlated condition; 0 designates the uncorrelated condition; and -1 designates the negatively correlated condition. The roman numerals indicate the order of exposure to the conditions for each rat.

In the positively correlated condition, recovery was greatest for the three conditions, the final rate was always greater than the previous unpunished baseline, and rate always decreased when shock ceased. Initially, then, shock was a punisher, but by the end of exposure to shock the punishing function was supplanted by that of a positive conditioned reinforcer.

In the negatively correlated condition, subjects showed most initial suppression and rates generally remained lowest of the three conditions. That shock was a punisher throughout exposure to this condition is indicated by the general lack of recovery and by the rate increase when shock ceased.

Rate in the uncorrelated condition was generally less affected by shock than in the two correlated conditions. Shock was usually a punisher at the beginning of the shock period but lost its suppressive effect by the end, so that the final level in shock was in most instances slightly above the no-shock baseline.

These differences in Bar A performance as a function of shock-reinforcement correlation cannot be attributed to discriminative effects of the shock, since the procedure was designed to exclude such effects. The same would appear to be true of the Williams and Barry (1966) procedure. The striking effects reported by Holz and Azrin (1961, 1962) may depend

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Fig. 6. Mean response rate on Bar A for the last three sessions of exposure to shock, expressed as a percentage of the mean rate for the last three sessions preceding shock. Data are presented for individual rats under three conditions of correlation between shock and reinforcement with two shock intensities. +1 designates the negatively correlated condition; 0 designates the uncorrelated condition; and -1 designates the positively correlated condition.

on the fact that shock could function both as a conditioned reinforcer and a discriminative stimulus for the same response.

When 0.8-ma shock was programmed, the correlation between shock and reinforcement did not affect the suppression of responding on Bar A. Williams and Barry (1966) also found that intense shock eliminated the effects of shock-reinforcement correlation.

In the present experiment, shock was intended explicitly to serve as a discriminative stimulus for responding on Bar B. Discrimination learning, as measured by the discrimination indices, generally appeared earlier and was better in the negatively correlated than in the positively correlated condition. This may have resulted from the different learning task present in each condition. In the positively

correlated condition, the subjects had to learn not to respond in a situation identical to the baseline condition, *i.e.*, in light alone; in the negatively correlated condition, they had to learn not to respond in a different situation, light plus shock. Intuitively, learning would be easier in the latter condition.

In most cases, discrimination learning was only partial; only one subject (Rat C) reached a discrimination index of 0.85 or better, and two subjects in the positively correlated condition (Rats D and F) never learned the discrimination. Several factors may have contributed to restricting differential responding. In all conditions, the light always accompanied reinforcement, which would make the light a strong discriminative stimulus for responding on Bar B and would also reduce the differences between the various conditions. In the correlated conditions, the essential discriminative cue was the shock, which was a brief response-produced stimulus. Such stimuli are not usually employed as discriminative cues and may be less effective than continuously present stimuli, such as the light used in this experiment. Finally, the low response requirement on Bar B may provide a relatively insensitive measure of discrimination. Increasing this requirement, however, might reduce the conditioned reinforcing effect obtained in the positively correlated condition by increasing the interval between shock and reinforcement.

Although it was possible for shock to serve as a discriminative stimulus in the two correlated conditions, the punishing and conditioned reinforcing effects of shock appear, tentatively, to have operated independently of the discriminative function. That is, the changes in rate and final level of responding on Bar A seem unrelated to the discriminative control exercised by the shock over responding on Bar B. In the positively correlated condition, half the subjects learned the discrimination only slightly, but all gave evidence that the shock became a positive conditioned reinforcer by the end of exposure to it. In the negatively correlated condition, discrimination performance again had no correlation with rate or rate change.

The enhancement of responding on Bar A in the positively correlated condition is of special interest. The light was already established as an effective conditioned reinforcer.

Why should the addition of shock raise rates above the level already maintained by the light? One possible explanation is suggested by analogy with Kelleher and Gollub's (1962) analysis of observing-response experiments in which subjects would work to substitute a multiple schedule for a schedule with identical reinforcement probabilities but without associated discriminative cues. Kelleher and Gollub (1962) suggest that the combined reinforcing effect of stimuli associated with high and low reinforcement probabilities is greater than that of a single stimulus associated with an intermediate probability of reinforcement.

In the positively correlated condition of the present experiment, light plus shock was associated with a reinforcement probability of 1.00, while light alone had an associated probability of 0.00. Using Kelleher and Gollub's (1962) reasoning, these stimuli may be more effective in combination than light alone, which in the baseline condition was associated with a reinforcement probability of 0.50. However, the same argument should apply to the negatively correlated condition, which clearly was not as effective as the baseline con-

dition in maintaining behavior on Bar A. The punishing effect of the shock may be important for this difference between the positively and negatively correlated conditions. Further research with behaviorally neutral stimuli may shed some light on this question.

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