PUNISHMENT CONTRAST DURING FREE-OPERANT AVOIDANCE

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Punishment of bar-pressing responses of rhesus monkeys with electric shock in one component of a multiple free-operant avoidance schedule suppressed responding in that component. These decreases were concomitant with response rate increases in the unpunished component (punishment contrast). Response rates in both components increased when punishment was removed and decreased in successive sessions. These effects of punishment on unpunished responding were similar to those obtained during single and multiple schedules of positive reinforcement and they suggest a further similarity in the development of discriminations during positive and negative reinforcement schedules.

Behavioral contrast, originally defined as a negative correlation between response rates in the presence of different stimuli following a change in the value of one of the stimuli, is frequently observed during the formation of discriminations. This effect has been extensively studied under conditions of positive reinforcement where, for example, changes in the frequency of reinforcement in one component of a multiple schedule changed response rates in opposing directions in the two components (Reynolds, 1961). Reports of behavioral contrast during discriminations involving aversively controlled behavior have been conflicting. Brethower and Reynolds (1962) found that punishment of each response in one component of a multiple positive reinforcement schedule suppressed responding in that component and facilitated unpunished responding in a second component. This behavioral contrast effect is described as punishment contrast and was suggested to be similar to behavioral contrast following changes in the parameters of positive reinforcement. Punishment contrast has been reported by other investigators (Azrin, 1956; Lattal, 1969; Rachlin, 1966, Experi-

ment 2) but these effects have not been unequivocal. Positive induction, or a positive correlation between response rates in different stimulus conditions following a change in the value of one of the stimuli, also has been obtained during the development of discriminations based on punishment of positively reinforced behavior (*e.g.*, Azrin and Holz, 1966, p. 416; Dinsmoor, 1952; Rachlin, 1966, Experiment 1). Considerable variations in punishment and positive reinforcement parameters and other procedural differences make direct comparisons among these studies difficult and isolation of variables that control punishment contrast has remained evasive.

An effect that seems related to the punishment contrast effect observed during discrimination training was reported several times by Azrin and his co-workers (Azrin and Holz, 1966). They found that, after several sessions of punishing positively reinforced responses, removal of punishment resulted in transient response rate increases that exceeded the response rates observed before punishment was introduced. This effect is also called punishment contrast by Azrin and Holz, but its relation to punishment contrast during discrimination training has not been established. However, other experiments on behavioral contrast have shown that alternating conditions of positive reinforcement during successive sessions was similar in its effects to within-session alternation of multiple schedule components (Bloomfield, 1967; Premack, 1969). Thus, the difference between alternating periods of punishment and

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no-punishment across blocks of sessions, instead of alternating them within individual sessions, may be one of degree rather than of kind.

Wertheim (1965) investigated behavioral contrast during another type of aversively controlled behavior. After rats were trained on a two-component multiple free-operant avoidance schedule, the interval between a bar-press response and shock delivery (response-shock, R-S, interval) was either increased or decreased in one component while the R-S interval in the other component remained constant. Rates of response in the component with the constant R-S interval were negatively correlated with the response rates in the component containing the varying R-S interval. These behavioral contrast effects were attributed to changes in the relative shock rates in the constant component.

Wertheim's findings suggest a similarity between behavioral contrast effects during discriminations involving behaviors controlled by positive and negative reinforcement schedules. One implication of this similarity is that contingencies that result in contrast during positive reinforcement schedules have similar effects during negative reinforcement schedules. However, the conditions under which contrast effects are manifest during aversively controlled behavior, either with punishment or with negative reinforcement schedules, are largely unknown. Since previous investigations of the residual effects of punishment on unpunished responding have been confined to positive reinforcement schedules, the present experiment examined the interactions between punished and unpunished responding during a multiple free-operant avoidance schedule. Particular attention was also given to an analysis of the effects of punishment on the distribution of responses during free-operant avoidance.

METHOD

Subjects

Two female rhesus monkeys (*Macaca mulatta*) had continuous access to food and water except during experimental sessions. The monkeys were maintained in restraining chairs five days a week and returned to their home cages on weekends.

Apparatus

A Lehigh Valley Electronics model 1330C primate cubicle was equipped with a stimulus light panel and a response lever. Electric shock was delivered through foot electrodes (Weiss and Laties, 1962). The shock source was a BRS model SG002 shock generator. Electromechanical scheduling and recording equipment were located in an adjacent room.

Procedure

Lever pressing was shaped and then maintained on a multiple free-operant avoidance schedule. The two components alternated every 15 min and were signalled by red and green stimulus lights (red and green components). Components were separated from one another by a 15-sec blackout period in the chamber during which the chamber was darkened and lever pressing had no scheduled consequence. Each 3.5-hr session began with the green component. Sessions were conducted five days a week.

Identical free-operant avoidance schedules (Sidman, 1966) were in effect in both components in all subsequent phases. Each lever-press response postponed for 20 sec (R-S interval) a 500-msec, 12.5-mA electric shock. Once the 12.5-mA shock was delivered, successive shocks occurred every 2 sec (shock-shock, S-S, interval) until a bar press occurred. Thus, the schedule was a *mult* R-S 20-sec S-S 2-sec R-S 20-sec S-S 2-sec schedule. After 124 sessions (rhesus C) or 103 sessions (rhesus H) of the multiple avoidance schedule, a punishment contingency was introduced into the red component. Each lever-press response in this component produced a 50-msec, 2.6-mA electric shock to the monkeys' feet. An earlier study of punishment shock intensity effects indicated that this intensity resulted in substantial response suppression without completely eliminating responding. The avoidance contingency remained in effect during punishment so that a failure to respond continued to result in delivery of the more intense, longer duration electric foot shock. This latter shock will be described as intense shock to distinguish it from the milder intensity punishment electric shock. The punishment contingency was in effect for the next 15 sessions, after which it was removed for 13 sessions. To establish the replicability of the effect,

the punishment contingency was reintroduced in the red component for six sessions at an electric shock intensity of 1.1 mA (50-msec duration) and then removed during the final three sessions.

RESULTS

To eliminate transient effects associated with the beginning of the session, data during the first hour of each session were recorded separately and only data from the last 2.5 hr of each session are included in the figures. Since the green component was presented first in the session, response rates were typically higher in that component than in the red component during the first hour. As

shown in the first panel of Figure 1, this effect did not persist during the last 2.5 hr of the session. Response rates during the first hour in green were higher than the response rates in green during the remainder of the session in all conditions. A similar effect was observed in red only after the punishment was removed.

The punishment of avoidance responses in red immediately reduced response rates by as much as 95% in that component during both the first and second blocks of punishment sessions (Figure 1). Increases in the rate of unpunished free-operant avoidance responses in green were concomitant with punishment of responses in red. These increases were as high as 97% above the preceding baseline response

Fig. 1. Responses per minute in the red and green components during successive sessions of the experiment. The first hour of each session was omitted. $\bar{P}$ and P indicate, respectively, the absence or presence of punishment in the red component. The intensity of the punishment was 2.6 mA during the first block of punishment sessions and 1.1 mA during the second block. Only the last six sessions of the first unpunished baseline condition are shown (Sessions 1 to 6).

2 SEC IRT CATEGORIES

Fig. 2. Percentages of total responses in the red component distributed in successive 2-sec interresponse time categories. Category 1 includes IRTs in the 0 to 2 sec time period, category 2 includes those in the 3 to 4 sec time period and so on. Category 11 contains all IRTs > 20 sec. This latter category represents the number of intense shocks delivered to the animal (see text). From top to bottom, the data in each graph were obtained from the last three days before introducing the 2.6-mA punishment in red (pre), the last three days of punishment (pun), and the first and last three days after the removal of punishment (post a and b).

rates in green. Removal of the punishment from red resulted in transient response rate increases in both components which returned to pre-punishment baseline levels within a few sessions. The 1.1-mA shock used during the second block of punishment sessions had similar effects in red and green to the 2.6-mA shock used in the first block of punishment sessions. Because of circumstances beyond the control of the experimenters, the experiment was terminated before completion of unpunished baseline recovery after the second block of punishment sessions.

Figure 2 shows the proportion of responses emitted in successive 2-sec interresponse time (IRT) categories in red. Before punishment was introduced (top graphs) over half of all responses of both monkeys occurred within 4 sec of one another and no two responses were separated by more than 14 sec for Monkey C or by more than 8 sec for Monkey H. Punishment of each response predictably shifted the distribution of responses in time toward the longer IRT categories (second graphs). Except for occasional bursts of responses (0 to 2 sec category), few responses occurred closely together in time. Over half of all responses of the animals were separated from one another by at least 15 sec. When punishment was removed, the IRT distribution shifted immediately to the left [post (a) graphs], indicating a return to predominantly short IRTs. During the next several sessions, responding in red decreased to pre-punishment baseline levels and the frequency of response bursts decreased [post (b) graphs].

A comparison of timing behaviors in the presence and absence of punishment was made by computing interresponse times per opportunity (IRTs/op). This statistic is a statement of conditional probability in which the number of IRTs of a given duration is divided by the number of IRTs of that duration or longer. The value of IRTs/op as an indicator of temporal discrimination was discussed by Sidman (1966). In Figure 3, the IRTs/op curve of Monkey C during the pre-punishment baseline reveal a weak temporal discrimination. An even weaker effect was found with Monkey H. However, during punishment (dashed lines) the IRTs/op curves of both monkeys became markedly positively accelerated, suggesting more precise temporal discriminations. Such discriminations were

Fig. 3. Interresponse times per opportunity (IRTs/op) in the red component in the absence (solid lines) and presence of punishment (2.6 mA) in the red component. Data were averaged over the last three days of the pre-punishment and punishment conditions and over the first three days of the post-punishment condition.

disrupted by removal of the punishment.

Despite these changes in the rate and temporal distribution of responding during punishment, changes in the frequency of intense shock were small. IRT category 11 in Figure 2 shows the per cent of responses following an IRT longer than 20 sec in the red component, *i.e.*, those responses that terminated a S-S interval rather than a R-S interval. Virtually all intense shocks were avoided by the monkeys in both red and green in the absence of punishment. During Sessions 1 to 3 of the first exposure to punishment, the per cent of escape responses in red (escape responses/total responses) increased from 0% to 3% (Monkey C) or from 0% to 30% (Monkey H). These percentages represent 1 to 70 intense shocks per session. S-S intervals that occurred were terminated after a single intense shock. The frequency of intense shocks declined in subsequent sessions. The graphs labelled "pun" in Figure 2 show that after several sessions of punishment, the percentage of escape responses had decreased to 0% (Monkey C) or 4% (Monkey H). Virtually all intense shocks were avoided in green during punishment in red.

DISCUSSION

The punishment contrast observed during free-operant avoidance was similar to that reported by Brethower and Reynolds (1962) when responding was punished in one component of a multiple positive reinforcement schedule. Punishment contrast effects are not limited to situations involving positively reinforced behavior and such data also support

Wertheim's suggestion that contrast may be a relatively general phenomenon observed during the formation of discriminations involving aversively controlled behavior. The occurrence of punishment contrast with rhesus monkeys also extends the species generality of such effects, since previous observations of contrast have been confined to pigeons or rats.

Transient increases in response rates in red after punishment was removed were similar to those reported by Azrin and Holz (1966) when punishment of positively reinforced behavior was discontinued. The cause of the positive induction observed as simultaneous transient response rate increases in green when punishment was removed from red is unclear. Many studies of behavioral contrast have reported negative contrast effects when baseline positive reinforcement conditions were reinstated (*e.g.*, Reynolds, 1961) but positive induction effects such as those found here have also been reported with rats upon reinstatement of positive reinforcement after extinction (Pear and Wilkie, 1971) and with pigeons upon the removal of punishment from a positive reinforcement schedule (Brethower and Reynolds, 1962, Figure 5, bird 152, 1.35-mA to 0-mA curve).

Brethower and Reynolds (1962) reported several instances where the introduction of punishment suppressed responding to an extent that the frequency of positive reinforcement in the punished component was decreased. In such instances, contrast effects could be jointly attributed to the punishment and to the increase in relative reinforcement frequency in the unpunished component. In an analogous manner, in those instances where punishment suppressed free-operant avoidance responding to an extent that the frequency of intense shock delivery was increased in that component, contrast effects might be jointly attributed to the punishment and to increases in the frequency of intense shocks delivered in the red component. Several arguments against increases in intense shock frequency as the controlling variable can be made. First, the increases in intense shock frequency in red during punishment were extremely small when the total number of opportunities for intense shock delivery in a session are considered (if it is assumed that no avoidance responses were made and

that an escape response occurred after delivery of only one intense shock, then there were 315 opportunities for intense shock in the red component in a session). Second, and more important, there were many sessions in which response rates during green were above the preceding baseline rates while the frequency of intense shock in both components was no different from the unpunished baseline. Finally, Wertheim (1965) showed that positive contrast in a constant component of a multiple free-operant avoidance schedule was a function of increases in relative intense shock frequency in that component and was thus inversely related to the absolute frequency of intense shocks delivered in the other component.

As a general explanation of contrast during free-operant avoidance, Wertheim's account in terms of relative shock frequency in the constant component was not supported by the present data. According to that interpretation, the increases in shock frequency in red during punishment should have had little effect on responding in green because the relative shock rate in green either remained at zero or decreased slightly, depending on whether zero intense shocks or a few intense shocks (never more than three per session) occurred in that component. The present example of punishment contrast seems consistent with the hypotheses of Premack (1969) and Bloomfield (1969) that contrast occurs as the result of a change in the aversiveness, or worsening of conditions, in one component of the multiple schedule. Although comparable data for negatively reinforced behavior are not available, studies of positively reinforced behavior have shown that no-punishment is preferred to punishment (Rachlin, 1967) and that stimuli associated with punishment resulted in inhibitory gradients during stimulus generalization testing (Honig, 1966). Wertheim's finding that amount of positive contrast was inversely related to shock frequency in the variable component, and thus to the length of the R-S interval, is difficult, if not impossible, to reconcile with the Premack and Bloomfield accounts. For example, Sidman (1966) reported that shorter R-S intervals were non-preferred when compared to longer R-S intervals. In both examples of contrast during free-operant avoidance, response rate reductions in the variable component, produced

by either punishing responding or by lengthening the R-S interval, were associated with positive contrast. Premack (1969) and Bloomfield (1969) suggested limitations on this interpretation of contrast in positive reinforcement situations and it seems that none of the currently popular explanations of contrast adequately account for all instances of such effects.

Punishing each response of monkeys during a free-operant avoidance schedule had similar effects to those obtained with rats. Powell and Morris (1969) found that a rat exposed to punishing shock at a relatively high intensity did not exhibit recovery in response rate when the shock intensity was reduced by half. In the present experiment, the 1.1-mA punishing stimulus did not result in less suppression than the 2.6-mA shock after prior exposure to the latter intensity. A similar effect was obtained during punishment of positively reinforced behavior by Hake, Azrin, and Oxford (1967). After several sessions without punishment, reinstating the punishing stimulus at an intensity previously observed to produce a 95% reduction in variable-interval responding of squirrel monkeys produced even greater response suppression. Gradual decreases in shock intensity were effective in alleviating this degree of suppression only when the intensity was reduced by approximately half of the original value.

Punishment of free-operant avoidance behavior was similar to effects obtained by Holz, Azrin, and Ulrich (1963) during punishment of each response on a differential-reinforcement-of-low-rate (DRL) positive reinforcement schedule. Punishment in both situations resulted in more efficient responding, *i.e.*, more accurate placement of responses in time. In the absence of punishment, DRL performance of pigeons and free-operant avoidance performance of the present monkeys were both characterized by frequent short bursts of responses and infrequent longer IRTs (which in the DRL schedule resulted in the delivery of the positive reinforcer). When DRL and free-operant avoidance responses were punished, the number of bursts decreased and there was a corresponding increase in the frequency of longer IRTs. The contingencies of punished DRL and punished free-operant avoidance seem arranged to maximize the

occurrence of longer IRTs. In the absence of punishment, short IRTs do not result in any gain to the organism either by bringing it closer to food or by producing significantly more time between successive intense shocks. Based on the data presented here and those of Holz *et al.*, (1963) such subtle "consequences" of emitting short IRTs do not appear to exert much control over the behavior. During punishment, responding was still required to produce food or to avoid intense shock. In addition, each response had the immediate consequence of producing an electric shock. Responses occurring closely together in time produced additional punishment while delaying food presentation or not significantly increasing the interval between successive intense shocks. The punishment may affect the organism in other ways, such as by rapidly enhancing attention to temporal stimuli, but such possible effects must await independent experimental analysis. The use of punishment to increase efficiency of behavior had no lasting effects as the more efficient behavior observed during punishment did not persist when punishment was removed from DRL or from free-operant avoidance.

Wertheim (1965) suggested that the use of distinct operanda in the two components was an important variable in the development of behavioral contrast during free-operant avoidance with rats. He therefore associated his multiple avoidance schedule components with distinct levers. The present experiment showed that the use of a single lever was sufficient to produce marked punishment contrast in monkeys. This difference could be related to subject species differences; to the use of punishment in one component, which might in turn make the two components more discriminable; or to other procedural differences in the two experiments.

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