Effects of sucrose concentration and food deprivation on fixed-ratio punishment of licking*

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In Experiment 1, four groups of eight hungry rats were given a shock following every 200th lick of a 4%, 8%, 16%, or 32% sucrose solution. Shock intensity was increased every four sessions. After response rates were reduced by punishment, response rate was a linear function of sucrose concentration. In Experiment 2, two groups of seven rats were maintained at either 75% or 90% body weight and given fixed-ratio (FR) 200 punishment for licking an 8% sucrose solution. Prepunishment differences in response rate associated with deprivation level were maintained regardless of amount of response suppression.

EXPERIMENT 1

It is often asserted that the greater the reward a response produces, the more difficult it is to suppress. Although there is some empirical support for this common-sense proposition, there are a number of negative instances. In punishment situations where magnitude of reward has been varied, mixed results have been obtained. Bower & Miller (1960) found that rats ran more slowly down a runway and were stopped by lower shock intensities when the goalbox was baited with 1 pellet instead of 10. Ferraro (1966) trained rats on a continuous reinforcement schedule with water reward and later superimposed continuous punishment. Different groups of rats received the water reward in different-sized dipper cups. In contrast to Bower and Miller's results, suppression of barpressing increased with amount of reward.

Incentive has varying effects in conditioned suppression experiments also. Sucrose concentration has been the incentive manipulation employed in these studies; it can be thought of in terms of magnitude, since caloric density changes with sucrose concentration, and in terms of quality, since sweetness increases with concentration. Vogel & Spear (1966) found that rats licking 4% sucrose took longer to complete 10 licks in the presence of a CS that had been paired with shock than did rats licking 32% sucrose. Ayres (1968), however, compared 8% and 32% sucrose between groups in a differential conditioned suppression experiment and observed no difference in

suppression of variable interval barpressing during CS+. A further experiment (Ayres & Quinsey, 1969), using an off-the-baseline conditioned suppression paradigm, again found no difference in amount of CS-elicited suppression between rats licking 8% and 32% sucrose. No incentive difference was observed at any shock intensity (.5, .8, 1.6, and 2.5 mA). Rats receiving 32% sucrose, however, recovered their rate of licking after the conditioning sessions much faster than did rats receiving 8%. It is possible that the incentive effect on suppression during the CS obtained by Vogel and Spear reflected differences in recovery of baseline lick rate (Ayres & Quinsey, 1969).

In view of the equivocal role that incentive plays in conflict situations, more parametric data are needed. In the present experiment, four levels of sucrose concentration were compared in a fixed-ratio punishment of licking situation. One purpose of the present study was to determine if sucrose concentration affected resistance to punishment like magnitude of water reward or number of pellets. The second purpose was to clarify the results obtained in the conditioned suppression experiments by using more values of sucrose concentration. Since suppression in punishment and conditioned suppression procedures are closely related theoretically (Estes, 1969), incentive effects found in one procedure should be observed in the other.

Subjects

The Ss were 32 experimentally naive albino rats obtained from Sprague-Dawley, Inc., Madison, Wisconsin. They ranged in weight from 365 to 439 g before food deprivation was begun. Starting 10 days before the experiment, the rats were reduced to 80% of their ad lib weights and then maintained at this level throughout the study. Water was continuously

available in each S's home cage. Animals were weighed before, and fed Purina Lab Chow after, each session.

Apparatus

Four chambers, 23 cm long x 20 cm wide x 15 cm high, with grid floors, were housed in sound-attenuating shells equipped with ventilating fans. The ends and one side of each box were wood, while the other was Plexiglas. Light was provided by a 7.5-W bulb located above the opaque plastic ceiling. There was a hole of 1.3-cm diam approximately 4 cm above the grid at one end of the box. The sucrose solution was available from a spout with an opening of approximately 3 mm in diam, 5-9 mm outside of the hole. In licking the spout, a S made a connection between it and the metal plate surrounding the 1.3-cm hole, activating one of four Grason-Stadler drinkometers (Model E4690A-1). Licks were recorded on counters, an event recorder, and a cumulative recorder. Shocks were provided by four E1064GS Grason-Stadler shock sources. Recording and programming equipment, home cages, and experimental chambers were each located in separate rooms.

Procedure

Ss were run four at a time. On a single day, each box contained one of the four solutions. To control for box differences, the position of the sucrose solutions was rotated each day in a 4-day cycle. Each S was exposed to only one solution throughout the experiment. Ss were arbitrarily assigned to four equal-sized groups which differed only in the concentration of sucrose solution they licked. The tap water and sugar solutions were 4%, 8%, 16%, and 32% by weight.

There were five daily ½-h sessions per week for each animal. The experiment consisted of four 4-day cycles. In the first cycle there was no punishment for licking, and rats had continuous access to the spout. Punishment with shocks of .5-sec duration and .3-mA intensity was introduced on an FR 200 schedule in the second cycle. Shock intensity was increased to .6 mA at the beginning of the third cycle and to 1.0 mA at the start of the fourth. The same FR schedule remained in effect throughout the punishment phase and insured that each block of 200 responses "cost" the same, regardless of response rate, and that there was a direct correlation between number of responses and number of shocks.

Treatment of the Data

Responses per session were analyzed in the form of punishment ratios, $D/(B + D)$, where D is the number of responses in a punishment session and

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B the number of responses in the last nonpunishment session. Licks per session were also blocked over four session cycles for analysis. Because there were several Ss who made no responses until the middle of the first session, this session was omitted and the first cycle was based on only three sessions. One S from the 4% group was discarded because of illness after Day 5; his data were estimated for the analyses of variance and the degrees of freedom adjusted accordingly.

Results and Discussion

The mean number of licks per cycle is shown in Fig. 1. The relation between sucrose concentration and number of licks found in the first cycle, in which response rate increases and then declines at higher concentrations, is somewhat similar to that reported by Guttman (1953) for continuously reinforced barpressing. This effect represents a satiation-like process, since the lick rates for the first 5 min of each session were similar in the 8%, 16%, and 32% groups, whereas the 16% and 32% groups' response rates for the 30-min session as a whole were lower than in the 8% group.

Not much suppression was observed at the lowest shock intensity, but as the shock intensity was increased, response rates declined ($p < .001$), and there was a reordering of the groups, as indicated by a Session by Concentration interaction in the punishment ratio data ($F = 3.13$, $df = 33/296$, $p < .001$). The increasing suppression over cycles shown in Fig. 1 was due to shock intensity increases and not merely increased exposure to the FR schedule, since the lower rate associated with each shock intensity was evident on the first day of the cycle. The punishment ratios decreased with increases in sucrose concentration ($F = 4.74$, $df = 3/27$, $p < .01$). Note that these sucrose differences were maintained despite the higher shock frequency associated with the higher response rates.

It appears from Fig. 1 that the largest effect of sucrose concentration was at the intermediate shock intensity. Sucrose concentration accounted for 34% of the variance in the data during this cycle. A trend test for the .6-mA cycle showed a strong linear component ($F = 74.5$, $df = 1/27$, $p < .001$). Since no difference was found between 8% and 32% sucrose in the conditioned suppression of licking study cited earlier (Ayres & Quinsey, 1969), this comparison was of some interest. The 32% group was less suppressed than the 8% group ($F = 9.74$, $df = 1/27$, $p < .005$). A two-tailed Wilcoxon rank sum test showed this response-rate difference to be reliable during the first 5 min of the

Fig. 1.

.6-mA cycle also ($p < .02$), although there was no first 5-min difference between these groups in the prepunishment phase. This difference between punishment-induced and CS-elicited suppression suggests that there may be differences in the mechanisms underlying the two phenomena.

The effect of sucrose concentration on punished licking found in this study is similar to that of number of pellets on punished running (Bower & Miller, 1960). These studies are in opposition to that of Ferraro (1966), who obtained a positive relation between suppression of barpressing and amount of reward. Although there are many procedural differences among these studies, the most obvious variable that separates the runway and licking studies from the barpressing experiment is the kind of deprivation. Ferraro's barpressing study involved thirsty rats, while the others involved hungry rats. But, regardless of whether type of deprivation interacts with amount of reward, it appears that different operational definitions of "amount of reward" are not functionally equivalent.

EXPERIMENT 2

In most theoretical treatments of conflict (e.g., Bower & Miller, 1960; Estes, 1969), increased deprivation is supposed to alleviate suppression like more attractive incentives. Studies of conditioned suppression have shown, as expected, that increases in hunger are associated with decreases in CS-elicited suppression, although the effects are sometimes small (e.g., Ayres & Quinsey, 1969). A number of

Fig. 2.

punishment studies have also supported this expectation; for example, food deprivation has been found to attenuate suppression of keypecking in pigeons. Azrin, Holz, & Hake (1963) superimposed FR punishment on a VI keypecking baseline and showed that decreases in the birds' body weights produced profound increases in responding. However, quite different results have been obtained with water deprivation and FR punishment of licking (Leaf & Muller, 1965). These latter investigators observed no difference in resistance to FR 10 punishment in rats that had been deprived of water for 24, 48, or 72 h.

The purpose of this second study was to find out if increases in hunger decreased punishment-induced suppression of licking similar to increases in sucrose concentration. A subsidiary goal was to determine if an effect of food deprivation like that observed by Azrin, Holz, and Hake could be found in an experimental preparation similar to that of Leaf and Muller.

Method

Sixteen albino rats, similar to those in Experiment 1, ranged from 352 to 529 g before the beginning of deprivation. Eight rats were reduced to 75% of their free-feeding body weight and eight were maintained at 90%. All Ss were given tetracycline in their home-cage water bottles because of respiratory disease that killed two Ss, one from each group. The 75% and 90% body weight groups were treated identically. The experimental procedure was the same as that in Experiment 1, except that each S was always tested in the same chamber and all Ss received 8% sucrose solution. The apparatus remained unchanged.

Because of greater variability in prepunishment response rates, B in the suppression ratios was calculated as the average of the last three sessions in the prepunishment phase.

Results

The response rate data are shown in Fig. 2. Response rates were reduced by punishment ($p < .001$). The prepunishment difference in response rate between the two hunger levels was maintained regardless of the amount of punishment-produced suppression ($F = 5.36$, $df = 1/12$, $p < .05$, for the main effect of deprivation and $F = 1.32$, $df = 3/36$, $p > .20$, for the Cycle by Group interaction). In the suppression ratio data, the effect of deprivation was not significant ($F = 2.74$, $df = 1/12$, $p > .10$). These data appear similar to those in a figure depicting differences in wheel turning rate between different hunger groups as a function of effortfulness of the response (Kurtz, 1970).

GENERAL DISCUSSION

Both increased incentive and increased deprivation were associated with higher response rates in the punishment phase, although it was unclear if the differences between prepunishment and punishment rates were affected similarly. Suppression in the punishment and conditioned suppression procedures appears to be affected similarly by differences in food deprivation but not by differences in sucrose concentration. The finding that increased incentive has little effect on conditioned suppression, at least within the 8%-32% range, but a large effect on resistance to punishment within the same range and the inconsistencies in the literature reviewed in the introduction raise problems for Estes's theory (1969), which explains the amount of suppression in conditioned suppression and punishment situations as being determined by a conflict between appetitive and aversive motivation.

These data bear on another aspect of conflict theory. Since punishment was scheduled on a FR schedule, it might be supposed on a variety of grounds (Brody, 1968; Bower & Miller, 1960) that response rates would be highest at the beginning of the ratio and decline as the ratio ran out. Despite extensive exposure to the FR 200 schedule in the present studies, however, there was no evidence in the cumulative records of differential response rate as a function of position in the ratio, except for short postshock pauses. These data are in accord with the results of other studies which indicate that no negative acceleration occurs between shocks in FR punishment situations when the manipulandum is not part of the shock circuit (Azrin, Holz, & Hake, 1963; Hendry & Van Toller, 1964).

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The effects of chlorpromazine on self-punitive behavior*

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After usual treatment conditions were instated to produce the self-punitive behavior phenomenon, different dose levels of chlorpromazine (or appropriate amounts of saline) were administered to different groups of rats. The overall effects of the drug were suppression of performance. The most interesting result occurred at the low dose level, in that only the punished group was affected by the drug. These findings support the Mowrer-Brown theoretical explanation of self-punitive behavior. In addition, these findings indicate that the self-punitive paradigm has promise as a drug-screen technique.

One possible consequence of punishment is suppression of the punished response. Whenever punishment facilitates the response, however, this particular kind of maladaptive behavior is called self-punitive, or vicious circle, behavior (Brown, Martin, & Morrow, 1964). During the past few years, most of the necessary and sufficient conditions for the production of self-punitive behavior have been isolated (see review by Brown, 1969). At the same time, the Mowrer-Brown theoretical explanation, which emphasizes motivational and reinforcement aspects, has been strongly supported. Within the Mowrer-Brown explanation, it is presumed that there are at least three sources of contribution to the motivational level operating in the self-punitive situation: (1) the punishment itself, (2) conditioned fear, and (3) residual emotionality.

Based upon the reasoning that a significant reduction in motivation should lower response strength, several attempts have been made to stop self-punitive behavior by reducing the level of motivation. Martin (1968) and Ervey (1969) reduced residual emotionality by removing the S from the test situation for a time and thus decreasing self-punitive behavior. Since major tranquilizers presumably lower motivation, different dose levels of chlorpromazine were used in the present study in an attempt to stop self-punitive behavior. Miller, Murphy, & Misky (1957) have shown that fear-reducing properties of chlorpromazine were not attributable to motor and/or sedative effects of the drug at dose levels near 1.2 mg/kg.

SUBJECTS

The Ss were 108 naive female rats of the CFE strain obtained from Carworth Labs. The Ss were received as weanlings and were handled daily for 1 week. When Ss weighed approximately 90 g, they were housed in individual cages with food and water available ad lib. When used in the experiment, Ss weighed

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