Effects of the correlation between a positive and negative US on conditioned suppression in rats*

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For three groups of rats, an auditory CS, presented while the animals were responding on a variable-interval schedule for food reinforcement, was terminated on half of the trials with a noncontingent footshock. For two groups, half of the trials were also followed after .5 sec by the delivery of free food. In the positively correlated condition (PC) the free food was presented on shocked trials and in the negatively correlated condition (NC) on the nonshocked trials, while the remaining group (S) never received free food. In a fourth group the shock was omitted and free food delivered on half of the trials. Although all shocked groups showed a significant suppression, the magnitude was greater for Group PC than for Groups NC and S, which did not differ. Suppression did not result from the pairing of the CS with food alone. These results do not support the counterconditioning hypothesis that the pairing of a normally noxious stimulus with food reduces its aversiveness.

Interest in counterconditioning grew out of Pavlov's (1927) claim that the unconditioned reactions to a normally aversive stimulus could be modified by pairing it with food in a classical conditioning paradigm. He reported that "In one particular experiment a strong noxious stimulus—an electric current of great strength—was converted into an alimentary conditioned stimulus, so that its application to the skin did not evoke the slightest defence reaction [Pavlov, 1927, p. 29]." However, most of the subsequent experimental work has studied the effects of pairing conditioned aversive stimuli with food on the extinction of avoidance responding (Reid, 1973; Wilson & Davison, 1971), and relatively little attention has been paid to the mechanism by which the properties of primary aversive stimuli might be modified by counterconditioning.

A number of studies (Appel, 1968; Murray & Nevin, 1967; Williams & Barry, 1966) have investigated the effects of varying the correlation between response-contingent shock and reinforcement in a free operant punishment situation in which the overall frequency of both events was held constant. The restriction of punishment to reinforced responses (positive correlation) resulted in considerably less suppression than when only nonreinforced responses were shocked (negative correlation). Scull and Vechsler (1972) have reported a similar finding for the suppression of discrete-trial runway behavior. As a positive correlation results in the pairing of shock with food, the difference between the two conditions could be explained in terms of a reduction in the aversiveness of shock in positive cases due to the occurrence of

Pavlovian counterconditioning. Such an account assumes that the aversiveness of positively correlated shock is not only reduced relative to that of negatively correlated shock but also relative to that of shock unassociated with food. In order to determine the effectiveness of positively and negatively correlated shock relative to shock alone, a CER procedure was used in the present experiment. For three groups the CS terminated with noncontingent shock on half of the trials. In one group food was also presented noncontingently at the end of shocked trials (positive correlation), while in another group free food only occurred after nonshocked trials (negative correlation). For the third group the noncontingent food was omitted completely (shock alone). If the association of shock and food under the positive correlation served to reduce the aversiveness of the shock, the positively correlated group should show less suppression than both the negatively correlated and shock-alone groups. An additional group (food alone) was also run in order to determine whether the association of the CS with food resulted in suppression (Azrin & Hake, 1969). For this group, the shock was never presented and half of the trials ended with response-independent reward.

METHOD

Subjects

The Ss were 24 female hooded Lister rats about 4 months old at the start of the experiment. They were housed four to a cage and maintained on a 22-h food-deprivation schedule.

Apparatus

Two Campden Instrument rodent experimental chambers housed in sound-attenuating cubicles were used. Each chamber was equipped with a single Campden Instrument rat lever and an adjacent recessed food magazine. Food reinforcement consisted of the delivery of a single 45-mg pellet (Campden Instrument Ltd.). A loudspeaker mounted in the roof of the chamber permitted the presentation of a constant white masking noise (about 70 dB) or a 3000-Hz tone that acted as the CS. The tone

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Fig. 1. Mean suppression ratios on the pretest and conditioning sessions for the positively correlated (PC), negatively correlated (NC), shock-alone (S), and food-alone (F) groups. The suppression ratio equaled $A/(A + B)$, where A is the rate of responding during the trial period and B is the rate of responding during the pre-CS period.

generated a signal of about 80-85 dB in the region of the lever. Illumination was provided by a 24-V houselight mounted in the rear wall of the chamber. A Campden Instrument shock generator and scrambler was set to deliver .3-mA .5-sec shocks to the grid floor of the chamber.

Procedure

Training began when the Ss had reached approximately 80% of their free-feeding weight. In the first session, free pellets were delivered on a variable-time 30-sec schedule. In addition, each response was reinforced with a pellet. At all stages of the experiment, when food was delivered the houselight was switched off and a light in the magazine was illuminated for 2 sec. In the second session, each response was reinforced but no free food was delivered. Responding was reinforced on a variable-interval (VI) 30-sec schedule on Sessions 3 and 4 and thereafter on a VI 60-sec schedule during daily 1.25-h sessions. From Session 9 onward, four trials of 90-sec duration were distributed randomly within each session, with the restriction that a trial could not be initiated less than 5 min after the start of the session or after the previous trial. During a trial the white noise was turned off and the CS presented. The programming of the trials was independent of the programming of reinforcement for responding, except that any reinforcements which had been set up but not collected at the end of the trial were cancelled.

Following a stimulus pretest on Session 9 in which the unconditioned suppression to the CS was measured, the Ss were randomly assigned to four equal groups, counterbalanced across the two chambers. During the seven subsequent conditioning sessions, the groups differed only in the events that terminated the trials. Two events could be associated with the termination of a trial: A shock could be presented at the end of the CS and a food pellet could be delivered .5 sec after the CS offset.

For the *positively correlated* group (Group PC), two trials in

each session terminated with the presentation of shock and food, while no event occurred at the end of the remaining two trials.

For the *negatively correlated* group (Group NC), two trials terminated with shock and the other two with delivery of food.

For the *shock-alone* group (Group S), two trials were followed by shock and the other two by no event.

For the *food-alone* group (Group F), two trials were followed by the delivery of food and the other two by no event.

The sequence of shock and food events was randomly varied from session to session, but all Ss within a group received the same sequence of events within each session. Groups PC, NC, and S received shocks on the same conditioning trials and Group F received food on the trials when Group PC received shock and food.

Throughout the experiment the measure of conditioning was the amount of suppression produced by CS presentation. This was calculated in terms of a suppression ratio, $A/(A + B)$, where A is the rate of responding during the trial period and B is the rate of responding during a 90-sec pre-CS period immediately preceding the trial. Thus, a ratio of 0 indicates no responding during the CS (complete suppression) and a ratio of .5 indicates similar rates during the pre-CS and trial period (no suppression).

RESULTS

The suppression ratios on the pretest and each of the conditioning sessions are shown in Fig. 1. There was no significant difference between the groups either in the rate of responding during the pre-CS period ($F = 1.19$, $df = 3/20$, $p > .25$) or in the degree of suppression ($F < 1$) on the pretest session. When all of the groups were combined, there was evidence of suppression to the CS on the pretest ($p = .03$, binomial test), the mean suppression ratio of all Ss being .475. The response rates of various groups on the pretest during the pre-CS period were PC—13.5, NC—13.2, S—16.4, and F—11.8 responses per minute.

The introduction of conditioning resulted in the development of suppression in the shocked groups, with Group PC showing more suppression throughout than Groups NC and S, which did not appear to differ. Group F showed little or no suppression during the conditioning sessions. A two-way analysis of variance on the data from the conditioning sessions showed a significant effect of groups ($F = 9.42$, $df = 3/20$, $p < .01$) and of sessions ($F = 16.1$, $df = 6/120$, $p < .01$), as well as a significant Group by Session interaction ($F = 2.93$, $df = 18/120$, $p < .01$). Newman-Keuls planned comparisons between the groups showed that the suppression ratios of Group PC differed significantly from those of Group NC ($p < .02$), Group S ($p < .05$), and Group F ($p < .01$). Groups NC and S each differed significantly from Group F ($p < .05$) but did not differ from each other. Group F did not suppress significantly on any of the seven conditioning sessions, while Group PC showed significant suppression on Conditioning Sessions 3-7, Group S on Sessions 4-7, and Group NC on Sessions 5-7 ($p < .05$ in all cases, t test).

The rate of responding during the pre-CS period did not differ for the various groups and did not change systematically during the conditioning sessions. The effect of groups ($F < 1$), sessions ($F = 1.72$, $df = 6/120$,

$p > .10$), and the Group by Session interaction ($F = 1.20$, $df = 18/120$, $p > .25$) were all insignificant for the pre-CS response rates. The rates of responding for the various groups during the pre-CS period averaged over all conditioning sessions were PC-13.9, NC-12.7, S-15.8, and F-16.0 responses per minute.

DISCUSSION

In relation to the known effects of varying shock-reinforcer correlation on instrumental punishment, the present findings are very surprising. The CER and punishment procedures seem to result in opposite effects; when a CER measure is used, positive correlation produces greater suppression than negative and, furthermore, this increment represents an enhancement of suppression below the level produced by shock alone. This increment is not simply due to the addition of CS-food pairings, for, in isolation, this association results in negligible suppression.

The counterconditioning hypothesis implies that the modification of the effects of noxious stimuli by association with food is mediated at some central level and represents a real decrement in the aversiveness of the stimuli (Pavlov, 1927; Reid, 1973; Wilson & Davison, 1971). The absence of a counterconditioning effect in the present CER procedure questions the validity of this hypothesis and suggests that the ameliorative effects of shock-food pairings on the punishing property of the shock might well be specific to that procedure. However, according to certain contemporary conceptualizations of the Pavlovian conditioning process which stress the importance of the contingency between CS and US rather than the contiguity between the two events (Rescorla, 1967), the requirements for conditioning were far from optimal for Group PC. The scheduling of reinforcements to maintain baseline responding resulted in a significant probability that the US (food) would occur in the absence of the CS (shock), thereby reducing the contingency between the two events. Even so, the contingency between the shock and food was higher in the positively correlated condition than in the negatively correlated or shock-alone conditions, so that any differences between the groups should have been in the opposite direction of those found if counterconditioning serves to reduce aversiveness.

As the high suppression of Group PC was totally unexpected, any explanation of the effect must be post hoc. Both Azrin and Hake (1969) and Meltzer and Brahlek (1970) found that pairing food with a short CS resulted in suppression of ongoing operant responding for food in rats. In view of these findings, the enhanced suppression of Group PC over the level maintained by shock alone could have resulted from the simple addition of a positive conditioned suppression effect due to the pairing of the CS with response-independent food.

The objection to this explanation is that the absence of suppression in Group F and the similarity of performance in Groups NC and S show that the CS-food pairings had little direct effect. The reason might lie with the .5-sec delay introduced between the termination of the CS and food presentation. Kamin (1965) has shown that in CER conditioning with a relatively long CS the introduction of a .5-sec delay between the end of the CS and the shock severely retards conditioning. The distinguishing feature of the positively correlated condition was that an extra stimulus (shock) was introduced selectively on trials in which CS-food pairings occurred, and this may have allowed the mediation of the suppressive effects of food by establishing a second-order conditioning procedure in which the shock becomes a secondary reinforcer. Such mediation would not be operative in Groups NC and F because the CS presentations associated with food never terminated with shock. Murray and Nevin (1967) have suggested that the attenuated suppression of a punished response under the positive correlation is due to the fact that the shock becomes a secondary reinforcer. What the present results imply is that the acquisition of secondary reinforcing properties by the shock does not necessarily result in a modification of its intrinsic aversiveness, for in the CER procedure, unlike punishment, the two properties might be expected to act in the same direction so that the addition of shock-food pairings actually augments the degree of suppression.

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