Recovery from conditioned suppression to a partially overlapping compound stimulus*

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In a conditioned suppression paradigm, a partially overlapping compound stimulus signaled occurrences of electric shock. That compound CS consisted of 3 min of continuous illumination of the houselight with three discrete 5-sec presentations of a tone superimposed. A .5-sec electric shock was coterminous with each tone presentation. Rats that received this treatment in early conditioning sessions showed considerable recovery from conditioned suppression to the houselight as the experiment progressed. However, the effect was not reversible, and it could not be demonstrated in rats that experienced extensive prior conditioning to the houselight alone. These results are discussed in relation to a hypothesis concerning the modulation of behavioral control exerted by elements of compound stimuli and as they relate to a recent theoretical model for Pavlovian fear conditioning.

The hypothesis that contextual stimulus control in certain Pavlovian conditioning situations is modulated by the existence of special CSs that reliably signal US events is suggested by results from two lines of research. One of these lines of research is Seligman's (1968) study of contextual cues as reliable predictors of the absence of electric shock (i.e., as "safety signals"). That research demonstrated that when rats (already trained to press a lever to obtain food) experience signaled electric shock they show reduced baseline response rates in early sessions of the experiment, gradually recover preshock baseline rates, and finally show reduced rates only during CS presentations. Rats for whom electric shocks and CSs are uncorrelated also show reduced baseline response rates in early sessions, but in later sessions of the experiment they evidence no recovery. They remain suppressed in the presence of CSs and contextual stimuli alike. These results indicate that, in a situation where electric shocks occur, the existence of CSs signaling those shocks is a necessary condition for recovery of appetitively reinforced baseline performance in the presence of contextual stimuli alone. When CSs predict shocks, contextual stimuli (in the absence of CSs) come to serve as cues for performance of the baseline response.

The second line of research which has produced results suggesting the above hypothesis is that of Hershiser and Trapold (1971). Those investigators examined the preferences of rats given a choice between environments where appetitive reinforcements were either signaled or unsignaled. Since reinforcement consisted of the injection of a sucrose solution directly into the rat's mouth by means of a surgically implanted tube, reinforcers could be delivered completely unsignaled. In those experiments rats came to prefer the environment in which reinforcements were unsignaled.

This result suggests that the relative attractiveness of contextual cues depends upon whether appetitive USs that occur in their presence are signaled by explicit CSs.

Taken together, the results of Seligman (1968) and Hershiser and Trapold (1971) strongly suggest that, when CSs reliably signal US events, contextual stimulus control differs qualitatively from contextual stimulus control exerted when USs are not signaled. Given this suggestion, it is reasonable to ask whether the behavioral control exerted by explicit signals for US events can be modulated by the presence of superimposed, partially overlapping signals for US events. The following two-phase conditioned suppression experiment was directed at that question.

In Phase 1 one group of rats, designated the experimental group (E), experienced conditioned suppression training in which electric shock was always signaled by a partially overlapping stimulus compound (CS_1/CS_1CS_2) in which CS_2 was a better predictor of shock. The second group of rats, designated the control group (C), received identical treatment except that CS_2 was absent; electric shock was signaled by CS_1 only. In Phase 2 the treatments of the two groups were exchanged.

If the stimulus control exerted by an explicit CS is modulated as hypothesized above by the existence of brief, partially overlapping CSs that are better predictors of electric shocks, then performance of the baseline response during CS_1 by Group E should show the following pattern of development. In Phase 1 performance during CS_1 should be suppressed during early sessions and then gradually recover in later sessions as CS_1 loses its capacity to elicit conditioned suppression. In Phase 2, when CS_2 is not present for Group E, conditioned suppression to CS_1 should be reacquired. On the basis of the same hypothesis, Group C may be expected to show strong conditioned suppression to CS_1 during Phase 1 but to recover during Phase 2, when CS_2 is introduced.

*This research was supported by National Institute Mental Health Grant MH 18053 to Milton A. Trapold.

Fig. 1. Mean suppression ratios over blocks of sessions for Groups E and C in Phases 1 and 2 of the experiment.

METHOD

The Ss were eight naive male albino rats weighing between 200 and 300 g prior to deprivation. The apparatus consisted of two identical Grason-Stadler E3125A-300 operant conditioning chambers with a single response lever, two Grason-Stadler E1064GS shock generators, and other necessary programming and recording equipment.

Prior to the beginning of the experiment, the Ss were divided randomly into two groups of equal size and reduced to 80% of their ad lib body weight. The Ss were maintained at this weight throughout the experiment by a single feeding of Purina lab chow after each daily session. Sessions were 30 min in length. Early sessions consisted of adaptation to the chamber, barpress shaping, and continuous reinforcement training. On Day 6 a variable-interval 30-sec schedule of food reinforcement was introduced, and 20 days of barpress training followed. This reinforcement schedule was maintained throughout the entire experiment. Each reinforcement consisted of the delivery of a single .045-g Noyes food pellet. After all preliminary training was complete and response rates were stable, conditioned suppression training was begun.

Two conditioned suppression trials were presented during each session. The occurrence of trials was variable in time, with the restrictions that no trial could occur within 5 min of the beginning or end of a session and that a minimum of 4 min separated the two trials. Each trial consisted of a 3-min period during which the houselight (CS_1) was illuminated and three electric shocks of .5-sec duration and .5-mA intensity were presented. The occurrence of shocks during CS_1 was variable, with the restrictions that no two shocks could occur within 20 sec of each other and that the final shock of the trial always occurred 5 sec prior to CS_1 offset.

In Phase 1, which consisted of 52 sessions, Group E was presented a 5-sec tone (CS_2) prior to each shock, while Group C did not experience CS_2 . In Phase 2 the stimulus conditions for the two groups were reversed, and training continued for 43 additional daily sessions.

RESULTS

Suppression ratios were calculated according to the conventional formula $B/(A + B)$, where A is the number of responses during the 3-min period immediately preceding a CS_1 presentation and B is the number of responses during CS_1 (or CS_1/CS_1CS_2). A suppression ratio of .5 indicates no suppression of barpressing, while a suppression ratio of .0 indicates complete suppression. Since CS_1CS_2 occupied only 8.3% of the CS_1/CS_1CS_2 interval, this suppression ratio may be considered a good index of response tendencies to CS_1 alone. In order to

obtain an index of response tendencies to CS_1CS_2 , suppression ratios were calculated for each trial according to the formula $b/(b + .083A)$, where b equals the number of responses during the three 5-sec CS_1CS_2 intervals and A equals the number of responses in the 3-min period preceding CS_1/CS_1CS_2 . Unfortunately, for purposes of this analysis that index yielded highly variable results. This variability can be attributed largely to the frequent, but inconsistent, tendency for Ss to overrun CS_2 onset with response bursts initiated during CS_1 . Thus, no analysis of response tendencies to CS_1CS_2 is reported here.

Figure 1 shows group average suppression ratios to CS_1 (or CS_1/CS_1CS_2) for both phases of the experiment. Blocks 1-13, four sessions each, represent Phase 1 conditioning. Blocks 14-24 are from Phase 2, where all blocks except Block 24 (three sessions) are averaged over four sessions. During Phase 1, Group E showed, on the average, considerable recovery of barpressing to CS_1 . However, only three of four Ss represented in that curve showed that pattern; a single S showed no noticeable recovery. All Ss in Group C were strongly suppressed throughout all 52 sessions of Phase 1. Analysis of variance revealed a significant Groups by Days interaction ($F = 3.63$, $df = 51/306$, $p < .0005$).

Figure 1 also shows that in Phase 2 there was a slight temporary increase in suppression for Group E. Group C, which received the partially overlapping compound in Phase 2, showed no evidence of recovery of barpressing; rather, suppression appeared generally stronger, or more stable, than in Phase 1. In this case, analysis of variance revealed a significant between-groups difference ($F = 7.60$, $df = 1/6$, $p < .05$).

DISCUSSION

This experiment shows that in the conditioned suppression paradigm the behavioral control exerted by an explicit signal for US events can be modulated by the presence of other superimposed signals for those US events. The gradual loss of conditioned suppression shown by Group E in Phase 1 clearly supports that conclusion. This effect might be referred to as "fear robbery," since suppression usually attributed to fear conditioned to CS_1 diminished over conditioning sessions when CS_2 was also present.

However, the results for both groups in Phase 2 do not follow the original expectations. On the contrary, Group E showed only a slight temporary increase in conditioned suppression following CS_2 removal, and Group C showed no loss of conditioned suppression to CS_1/CS_1CS_2 . In fact, conditioned suppression may have been strengthened among Ss in Group C. A future replication of this experiment might assess these effects by including the following two control groups. One group would experience CS_1/CS_1CS_2 throughout the entire experiment. Comparisons between that group and

Group E would provide a basis for the evaluation of any increase in conditioned suppression observed upon the removal of CS₂. The second control group would experience CS₁ throughout, and its performance could be compared with that of Group C to examine the possibility that superimposing CS₂ in Phase 2 strengthens suppression or, alternatively, prevents suppression from diminishing as the experiment progresses. Other questions raised by the results in Phase 2 of the present experiment deserve further attention.

First, why did conditioned suppression fail to be reacquired by rats that recovered from suppression to CS₁/CS₁CS₂ and then experienced CS₁ alone paired with the US for several sessions? Although this question cannot be answered satisfactorily at the present time, a version of the operant counterconditioning hypothesis might be considered; during trials in which fear robbery develops, food-reinforced barpress responses gradually come to supplant fear responses elicited by CS₁. That is, rats learn to barpress to obtain food in the presence of gradually decreasing amounts of fear elicited by CS₁. Following this experience, rats might be capable of continued barpressing in more fearful situations. The animals might, for example, continue to barpress even while CS₁ reacquired its former levels of fear following the removal of CS₂.

The second question that must be considered is why animals in Group C failed to show the fear robbery effect when the treatment they received in Phase 2 was identical to that of Group E in Phase 1. Fortunately, a reasonable hypothesis exists; acquisition of stimulus control by the superimposed stimulus, CS₂, was blocked. Kamin (1969) has demonstrated that, in a conditioned suppression paradigm, prior conditioning to one stimulus may prevent subsequent conditioning to a second stimulus when the two are presented as a simultaneous compound. Perhaps prior conditioning to one stimulus may also prevent conditioning to a superimposed stimulus of brief duration when the two are presented as a partially overlapping compound. If conditioning to a superimposed stimulus is blocked, change in the behavioral control exerted by the first stimulus would not be expected. The finding that Group C did not show recovery from conditioned suppression to CS₁/CS₁CS₂ is consistent with that explanation. However, for the main purposes of this discussion the importance of this finding is to indicate caution about broadly generalizing conclusions concerning the fear robbery effect; prior conditioning to a CS may prevent fear robbery from occurring during subsequent conditioning with a superimposed better predictor of US events.

The results reported here bear upon current theories concerned with a variety of Pavlovian conditioning phenomena, e.g., blocking (mentioned above) and overshadowing (a phenomenon where conditioning to a

compound CS, consisting of one relatively salient stimulus and a second, less salient one, results in conditioning only to the more salient component). One theory concerned with these phenomena has been put forth by Rescorla and Wagner (1972). This theory states that increments in associative strength of responses to any stimulus are a decreasing function of the difference between the current associative strength of the entire compound to which that stimulus belongs and the maximum associative strength which the particular US is capable of supporting. According to this model, blocking occurs because the associative strength of one element of the compound is already asymptotic prior to the addition of the second component, and overshadowing occurs because associative strength approaches asymptote more rapidly in the case of the more salient element in the compound.

This model for Pavlovian conditioning can be applied to the fear robbery effect also. According to this theory, early conditioning trials result in acquisition of associative strength to both CS₁ and CS₂, since the US occurs only in the presence of those two stimuli. However, CS₁ actually occurs under two conditions: It occurs in compound with CS₂ where it is paired with the US, and it occurs alone, unpaired with the US, just prior to CS₂ onset. Thus, CS₁ acquires associative strength when it occurs in compound with CS₂ and loses associative strength on presentations when it occurs alone. Over sessions, CS₁ continues to acquire and subsequently lose strength until CS₂ reaches asymptote.

This theoretical model is of further interest with respect to the two other findings reported here. First, this model can account for failure of fear robbery to occur in Group C in Phase 2. According to this model, the associative strength of CS₁ reaches asymptote prior to the introduction of CS₂, so that no associative strength is available for acquisition by CS₂ when it is finally introduced. The remaining finding, failure to reacquire suppression following fear robbery, apparently cannot be explained by this theory. In this case, the theory clearly predicts that presentation of CS₁ alone prior to US events will result in reacquisition of associative strength to CS₁.

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(Received for publication February 26, 1973;
revision received December 1, 1973;
second revision received December 10, 1973.)