

CONDITIONED INHIBITION OF FEAR RESULTING FROM NEGATIVE CS-US CONTINGENCIES¹

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Two experiments are reported which indicate that negative contingencies between CSs and shock set up conditioned inhibitors. In Experiment 1, this inhibition was measured by retardation in the subsequent acquisition of a CER to the CS. Stimuli with greater negative CS-US contingencies were more retarded in CER acquisition; various control procedures were employed. In Experiment 2, inhibition was measured by a summation technique. Conditioned stimuli with a history of greater negative relations to shock were more disruptive of the CER normally elicited by a second CS. Taken together, the experiments support the general hypothesis that CS-US contingency is an important factor in fear conditioning.

American studies of Pavlovian conditioning have concerned themselves primarily with excitatory conditioning; very little exploration has been made of the phenomena of inhibitory conditioning. Although we know a great deal about procedures for setting up a CS as an elicitor of a Pavlovian conditioned response, our knowledge of the parameters affecting the establishment of a stimulus as a conditioned inhibitor is sparse.

In a recent series of experiments (Rescorla, 1966, 1967; Rescorla & Loford, 1965) investigation was made of conditioned inhibition within a fear-conditioning paradigm. These investigations gave rise to a view of Pavlovian conditioning which differs from that traditionally offered, one which gives greater importance to the notion of conditioned inhibition. According to this view, one relevant dimension in conditioning experiments is the contingency between CS and US. The conditions for establishing an excitatory CR are met when there is a positive contingency between CS and US; that is, when the probability of the US is higher during and just following the CS than it is at other times. Conversely, CSs

which forecast a reduction in the probability of the US are supposed to become conditioned inhibitors. The experiments reported here examine the possibility that such negative contingencies produce conditioned inhibitors; they also provide more detailed information on the parameters affecting the degree of inhibition controlled by a CS.

It is considerably more difficult to measure the inhibitory tendencies controlled by a stimulus than it is to measure parallel excitatory tendencies. If a stimulus is presented and no CR occurs, we cannot distinguish between the possibilities that the stimulus is simply not excitatory and that the stimulus actively controls inhibitory tendencies. For this reason, several special techniques have been developed to allow measurement of inhibitory tendencies. One such procedure attempts to attach an excitatory CR to the suspected inhibitor. If the stimulus is an inhibitor, such conditioning should proceed more slowly than it does for a variety of control stimuli. This is the procedure of Experiment 1. Another procedure for measuring conditioned inhibition is presentation of the suspected inhibitor in conjunction with a known elicitor of the CR; if the CR generated is weaker than that produced by the known elicitor alone, then we say the stimulus is inhibitory. This summation technique is used in Experiment 2. Both experiments employ the conditioned emotional response (CER)

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in which conditioned fear is measured by disruption of ongoing operant behavior.

According to the contingency notion of conditioning, the greater the negative contingency between a CS and US, the greater the conditioned inhibition controlled by the CS. Consequently, in both of these experiments several levels of negative contingency have been explored.

EXPERIMENT I

Method

Subjects and apparatus. The *Ss* were 48 Sprague-Dawley male rats about 100 days old at the start of the experiment. They were maintained throughout the experiment at 80% of their normal body weight.

The experimental chambers consisted of eight identical Skinner boxes $9 \times 8 \times 8$ in. Each chamber had a recessed food magazine in the center of the end wall and a bar to the left of the magazine. The floor of the chamber was composed of $\frac{3}{16}$ -in. stainless-steel rods spaced $\frac{3}{4}$ in. apart. This grid could be electrified through a relay-sequence scrambler (Hoffman & Fleshler, 1962) from a high-voltage high-resistance shock source. The two end walls of the chambers were aluminum; the side walls and top were clear Plexiglas. Each Skinner box was enclosed in a sound- and light-resistant shell. Mounted on the wall of this shell was a $6\frac{1}{2}$ -w. bulb and two speakers. The speakers permitted the presentation of a constant white-masking noise and of a 750-cps tone CS. During Phase II conditioning sessions a chamber similar to the Skinner boxes but without a lever was used. Experimental events were controlled and recorded automatically by relay equipment located in an adjoining room.

Procedure. The procedure consisted of three phases. Phase I established the base-line bar-press response. In the first session, *S* was magazine trained automatically with food pellets delivered on a VI 1-min. schedule. In addition, each bar press yielded a food pellet. This session continued until *S* had emitted about 50 bar presses; shaping was used if necessary. Starting with the second experimental day, all sessions were 2 hr. long and *S* was placed on a VI schedule of reinforcement. For the first 20 min. of this session the schedule was VI 1 min.; thereafter it was VI 2 min. Variable interval training continued for five daily 2-hr. sessions.

The next day began Phase II, designed to establish stimuli as conditioned inhibitors. The conditioning chambers were substituted for the Skinner boxes and six groups of eight rats received various Pavlovian fear-conditioning treatments. Groups 0-4 and 0-1 received a negative contingency between shock and the tone CS, later to be paired with shock in Phase III; they dif-

fered in the magnitude of this negative relation. Groups 4-4 and 1-1 received control treatments involving no contingency between shock and that CS. Groups 0-4 light and 0-1 light, serving as additional controls, had a negative contingency between shock and another CS during Phase II.

For Groups 4-4 and 1-1, 12 2-min. tonal CSs were given in each session with a mean intertone interval of 8 min. In addition, .5-sec. 1-ma. electric shocks were randomly delivered throughout the session. Shocks were programmed so that they were equally likely in each 1-sec. interval of the session regardless of the occurrence of the CS. Shock frequency was .4 per 2-min. interval in Group 4-4 and .1 per 2-min. interval in Group 1-1. Groups 0-4 and 0-1 received treatments identical to those of the preceding two groups with one exception: All shocks programmed to occur during the CS or the succeeding 2 min. were simply omitted. Thus, these groups had shock frequencies of .4 and .1 per 2-min. interval except for a period of safety signaled by the CS. Groups 0-4 light and 0-1 light were treated identically to Groups 0-4 and 0-1, except that in place of the 750-cps tone CS they received a 2/sec flashing of the houselight as a CS. Pavlovian conditioning continued for five daily 2-hr. sessions.

Phase III consisted of a return to the VI bar-press schedule. On the first 2 days, no CSs were presented and a simple VI 2-min. schedule was in effect. For the next 6 days, all groups continued on the VI schedule, but superimposed on this responding were four 2-min. presentations of the 750-cps CS. This CS terminated in a .5-sec. 1-ma. shock on a random two of the four trials on each day. The mean intertrial interval was 30 min. The data of interest are the relative rates at which the groups acquire the CER as indexed by rate suppression to the tone CS.

Results

Figure 1 shows the results of the six excitatory-conditioning sessions of Phase III. The data are plotted in terms of median suppression ratios; the ratio is of the form $A/(A+B)$ where *A* is the response rate during the CS and *B* is the rate in a comparable period prior to CS onset. All groups acquired CER suppression to the tone, but it is quite clear that acquisition proceeded at different rates. This observation is borne out by an overall Kruskal-Wallis analysis of variance for the 6 conditioning days ($H = 16.01$, $df = 5$, $p < .01$).

Groups 0-4 and 0-1, the two inhibitory-conditioning groups, were both retarded in CER acquisition when compared with

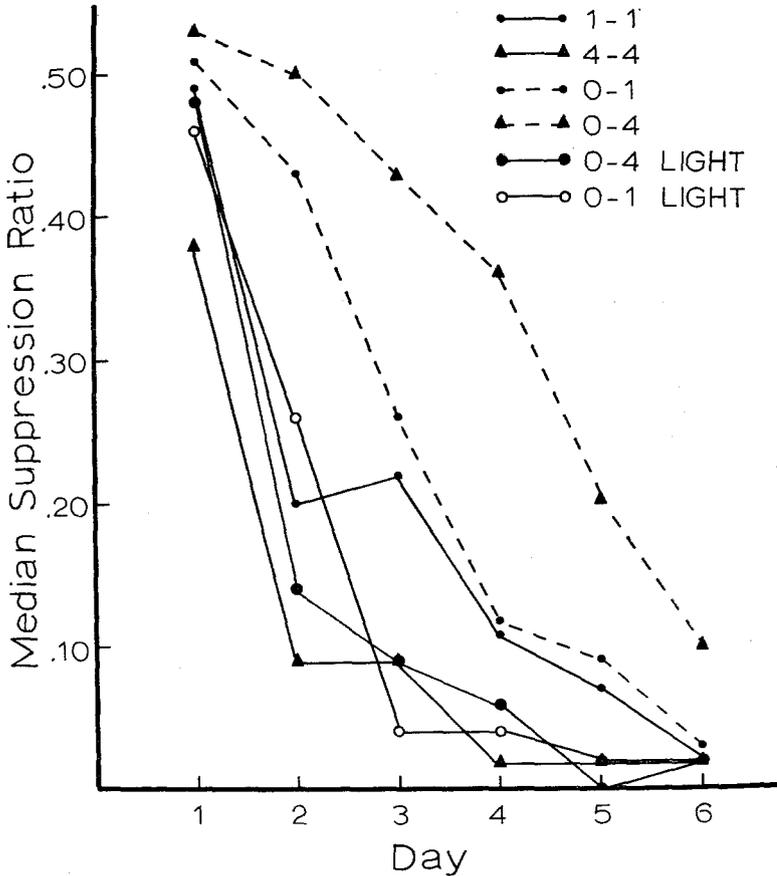


FIG. 1. Median suppression ratio for each group over the six sessions of Phase III, Experiment 1.

their respective control groups. However, the degree of retardation was greater in the 0-4 condition. Individual Mann-Whitney U tests were employed in making pairwise comparisons among the groups. They confirmed that Group 0-4 was slowest in CER acquisition, differing reliably from Groups 4-4 and 0-4 light ($p < .01$). Group 0-1 differed reliably from Group 0-1 light ($p < .01$) for the 6 days as a whole, but was only different from Group 1-1 on Conditioning Day 2 ($p < .025$). Finally, Group 0-4 showed reliably less suppression than Group 0-1 ($p < .02$). The four control groups did not differ among themselves.

In addition to these suppression ratio differences, there were marginally reliable differences among the groups in rates of responding in the absence of the CS ($H =$

11.87, $df = 5$, $p < .05$). In general, the groups that received higher probabilities of shock during Phase II gave higher response rates during Phase III. The median response rates per minute in the pre-CS periods were 5.5, 4.7, 7.4, 4.1, 6.0, and 4.3 for Groups 0-4, 0-1, 4-4, 1-1, 0-4 light, and 0-1 light, respectively. These differences do not appear to be systematically related to differences in degree of suppression elicited by the CS.

Discussion

This experiment indicates that establishment of a negative contingency between a CS and shock can retard subsequent acquisition of conditioned suppression. This is interpreted to mean that the CS has acquired conditioned inhibitory properties. There are several kinds

of evidence from this experiment that the CSs in the 0-4 and 0-1 groups are inhibitory of the CER.

First, these groups showed slower acquisition of the CER than did their companion 1-1 and 4-4 control groups. However, this finding does not distinguish between failure of the 0-4 and 0-1 groups to become conditioned during Phase II and their acquisition of conditioned inhibition. Although Rescorla (1967) has argued that these control procedures, so-called "truly random" control procedures, are the most appropriate ones for both excitation and inhibition, it is still possible to argue that some small amount of conditioning occurred during Phase II in these control groups. The difference between their performance and that of the inhibitory groups would simply be that the control-group CSs were fear eliciting while the supposed inhibitory-group CSs were neutral. It may be noted that this argument might anticipate more rapid conditioning in the 4-4 and 1-1 groups than in the light-control groups; no reliable differences were observed among these groups.

More convincing evidence that the CSs of the 0-4 and 0-1 groups became inhibitory comes from the finding that these groups conditioned more slowly in Phase III than did the 0-4 and 0-1 light groups. These latter groups had no experience prior to Phase III with the tonal CS, so it is implausible to argue that their CS elicited conditioned suppression. It seems easier to assume their CS to be neutral and that of the experimental groups to be inhibitory. There remains the possibility, however, that the CS used here has unconditioned excitatory effects to which the 0-4 and 0-1 groups had the opportunity to habituate during Phase II. Other experiments performed with the same CS do not support this hypothesis (e.g., Rescorla, 1968). Nevertheless, the simple demonstration that the two inhibitory groups are slower to condition than the two light groups does not require that a negative shock contingency be responsible for that difference. It seems sufficient to appeal to the phenomenon of latent inhibition (Carleton

& Vogel, 1967; Lubow, 1965; Lubow & Moore, 1959) in which a repeatedly presented stimulus is more difficult to condition than a novel stimulus.

The critical finding, for the hypothesis that negative CS-US contingencies set up conditioned inhibition to the CS, is that the 0-4 group conditioned more slowly than the 0-1 group in Phase III. The two groups had received the same number of tone presentations and differed only in the probability of shock in the absence of the tone; as predicted by the contingency hypothesis, the group with the more negative contingency showed greater inhibition.

EXPERIMENT 2

In the preceding experiment, the measure of conditioned inhibition was the degree of retardation in the subsequent acquisition of an excitatory CR. This experiment explores the other main measure of conditioned inhibition: summation. Rats are fear conditioned with four different levels of negative CS-US contingency. Then for all groups a second CS is established as a conditioned suppressor. Finally, the two stimuli are presented together and the degree to which the supposed inhibitor disrupts conditioned suppression is measured.

Method

Subjects and apparatus. The subjects were 32 Sprague-Dawley male rats about 100 days old at the start of the experiment. They were maintained throughout the experiment at 80% of their normal body weight. The apparatus was that of Experiment 1.

Procedure. All Ss were first trained to bar press on a VI 2-min. schedule as in Experiment 1. They received five 2-hr. sessions of VI training. Then the conditioning chambers were substituted for the Skinner boxes and five Pavlovian fear-conditioning sessions were given. The animals were divided into four groups differing in the degree of negative CS-US contingency. All groups received 12 2-min. 750-cps tonal CSs per session. For each group the period of the CS and the 2 min. following it were free of shock. However, .5-sec. 1-ma. electric shocks were administered randomly throughout the remainder of the session. Group 0-8 received an average frequency of .8 shocks per 2 min. except during and just after the CS. Similarly Groups 0-4 and 0-1 had

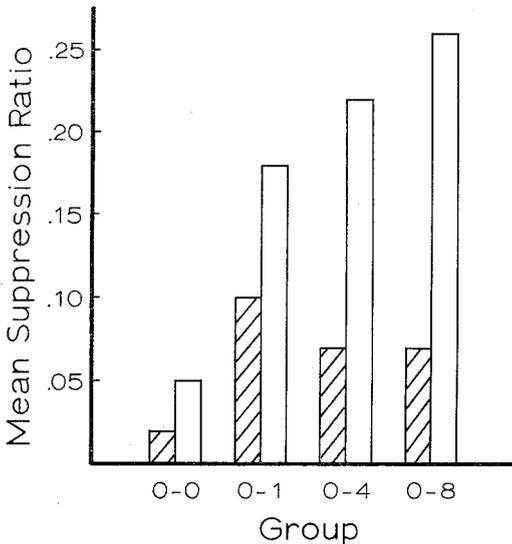


FIG. 2. Mean suppression ratio on light-alone and light-plus-tone test trials on the 2 days of summation testing in Experiment 2.

shock frequencies of .4 and .1 per 2 min. Group 0-0 received no shocks at all.

After five such conditioning sessions of 2 hr. each, VI 2-min. training was resumed. The first 3 days following the Pavlovian conditioning sessions were shock free in order to allow Ss to regain their bar-press rates. Then for 3 days four trials of a 2/sec flashing houselight were superimposed on this VI responding. On each day two of the four trials were terminated in a .5-sec. 1-ma. electric shock. This flashing light was to serve as the elicitor of the CER against which the supposedly inhibitory tones would be tested.

Finally, two test sessions were administered. During these sessions Ss continued to be reinforced on a VI 2-min. schedule, but no shocks were administered. Four test trials were superimposed on this responding. On two of the trials the flashing light was presented alone and on two it was presented in conjunction with the tonal CS. The sequence of these kinds of trials was counterbalanced.

Results

The conditioning of the light CS proceeded rapidly in all groups. By the end of the third light-conditioning day there was essentially no responding during the light. Figure 2 shows the mean suppression ratio for the light alone and the light plus tone trials of the two test sessions. Suppression to the light alone was strong and about equal in all groups. Further-

more, the groups did not differ in response rate in the absence of stimuli.

However, the groups responded differentially to the light plus tone compound. In the groups with a history of a negative relation between the tone and shock, the tone disrupted the suppression otherwise elicited by the light. Furthermore, the magnitude of this disruption was a function of the prior conditioning treatment of the tone: The greater the negative contingency between the tone and shock, the more the tone reduced the suppression to the light. A Kruskal-Wallis analysis of variance indicated that the differences in this disruption among the groups were reliable ($H = 13.59$, $df = 3$, $p < .01$).

Discussion

The results of this experiment thus demonstrate that arrangement of a negative contingency between a CS and shock establishes that CS as an inhibitor of CER as measured by a summation technique. Furthermore, the greater the negative contingency the greater the conditioned inhibition.

The results obtained here are in agreement with those of Hammond, also using the CER. In a series of experiments, Hammond (1966, 1967, 1968) has shown that in differential CER conditioning, CS⁻ for shock becomes a conditioned inhibitor. It should be noted that a CS⁻ in a differential-conditioning paradigm is a special case of a negative CS-US contingency; the probability of the US is lower in the time following CS⁻ onset than at any other time during the session. In the differential-conditioning paradigm all US events are signaled by a second CS⁺; however, this condition may be irrelevant to the establishment of conditioned inhibition to CS⁻. The results obtained here, as well as those previously reported (Rescorla, 1966; Rescorla & LoLordo, 1965), suggest that it is the negative contingency between the CS and US that is critical.

The use of both the summation and the retardation of excitatory-conditioning methods is important in asserting that a

stimulus is a conditioned inhibitor. As used here, a conditioned inhibitor is a stimulus which controls a behavioral tendency which is directly opposite to a conditioned excitor based on the same US. But the outcome of either the summation or retardation of conditioning measures taken alone admit of alternative interpretations. For instance, procedures supposed to establish conditioned inhibitors may simply come to control the stimulus dimensions to which an organism responds. They may yield either an animal which attends carefully or not at all to the supposed inhibitor. Clearly, an organism which attends poorly to a stimulus will be retarded in acquisition of an excitatory CR to that stimulus, thus producing an outcome similar to that of an inhibitor with that measuring technique. However, it is plausible to expect that a stimulus poorly attended to will have little or no effect in the summation procedure. Alternatively, a stimulus which attracts S's attention may produce disruption in a summation procedure but should not be retarding in excitatory conditioning. Use of both of these procedures may help to separate conditioned inhibition from seemingly related concepts.

The present experiments provide a first step in the analysis of parameters affecting the degree of conditioned inhibition. It is clear that stimuli predicting greater reductions in the probability of the US become greater inhibitors. This is in agreement with the finding of Rescorla (1968) that excitatory conditioning is more disrupted the higher the probability of the US in the absence of the CS. It also extends the parallel which a contingency analysis draws between excitatory and in-

hibitory conditioning. In both cases, the greater the change in US probability that the CS preceeds, the greater the degree of conditioning.

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