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Conditioned inhibition of fear from negative Cs-us contingencies with shocks in the inhibitory Cs.

Elizabeth Snyder Witcher
University of Massachusetts Amherst

CONDITIONED INHIBITION OF FEAR FROM NEGATIVE CS-US CONTINGENCIES WITH SHOCKS IN THE INHIBITORY CS

A Thesis Presented

By

Elizabeth Snyder Witcher

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Elizabeth Snyder Witcher

Approved as to style and content by:

John J. B. Ayres (Chairman of Committee)

Richard T. Louttit (Head of Department)

John W. Moore (Committee Member) 4-29-74

John W. Donahoe (Committee Member)

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Abstract

The ability of negative CS-US contingencies between tones and shocks to set up conditioned inhibitors of fear was assessed by testing for subsequent retarded CER acquisition to the inhibitor and for the disruption by the inhibitor of the excitatory properties of a second stimulus. In Experiment 1, retardation testing revealed that the inclusion of a small number of CS-US pairings within a negative CS-US contingency did not interfere with the conditioning of inhibition of fear in that the "inhibitor" was subsequently retarded in excitatory acquisition relative to a CS-alone control. However, the inclusion of a larger number of pairings resulted in no retardation relative to a CS-alone control. The summation testing of Experiment 2 failed to find evidence that the "inhibitor" generated by any of the negative contingencies disrupted the excitation elicited by a second stimulus. It was possible to find such disruption by an "inhibitor" generated by a highly negative contingency, in Experiment 3, only after a large amount of data was pooled. It was suggested that the summation procedure was a weak assessor of conditioned inhibition in CER procedures. It was proposed that, in a retardation test, a CS-alone procedure can control for the attentional factors which the summation test is used to assess. Accordingly, the results of Experiment 1

indicated that the addition of a certain number of CS-US pairings disrupted inhibitory conditioning, although fewer pairings could be added without apparent effect.

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I would like to thank Dr. John J. B. Ayres, Chairman of my Thesis Committee, for his encouragement, guidance and patience, and Dr. John Donahoe and Dr. John Moore, members of my committee, for their valuable comments. I also would like to thank my family for their love and enthusiasm and Mark, especially, for putting up with all the "running."

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Rescorla (1967) has suggested that the sufficient condition for Pavlovian conditioning is not the temporal pairings of CS and US events, but rather the contingency between CS and US events. The relevant variable in determining a CS-US contingency is the relative frequency of the US in the presence and absence of the CS, and a continuum of contingency can be defined from positive to negative as a function of that variable. A positive contingency exists when the probability of a US is greater in the presence of a CS than in its absence -- i.e., $P(US/CS) > P(US/\overline{CS})$. When such a CS-US relationship is arranged, excitatory conditioning is predicted. On the other hand, when a negative contingency exists -- i.e., when the probability of a US is greater in the absence of a CS than in its presence or $P(US/\overline{CS}) > P(US/CS)$ -- inhibitory conditioning is predicted. The zero point of the contingency continuum is defined when the probability of a US is the same in the presence and the absence of a CS -- $P(US/CS) = P(US/\overline{CS})$ -- and no conditioning should take place (Rescorla, 1967). The central notion is that animals can distinguish whether events are dependent upon or independent of one another, and whether events occur together or apart (Rescorla, 1969a).

In a more recent theoretical treatment of Pavlovian conditioning, Rescorla and Wagner (1972) have suggested that the associative strength of a given stimulus is changed through reinforcement or nonreinforcement relative to the existing associative strength of that stimulus and the associative strength of other, simultaneously occurring stimuli. An asymptote of associative strength particular to a given US is proposed and the magnitude of increases or decreases in associative strength following a reinforced or nonreinforced trial is dependent upon the difference between that asymptote and the total associative strength of all stimuli concurrently present. The change in associative strength of a component of a stimulus compound on a given trial can be represented by the equation:

$$\Delta V_i = \alpha_i \beta_1 (\lambda - \overline{V})$$

where V_i = the associative strength of i, the given component

α_i = a learning rate component, dependent upon the nature of the stimulus

β_1 = a learning rate component, dependent upon the properties of the US

λ = the asymptotic level of associative strength the US will support

$\overline{V}$ = the total associative strength of all components of the compound

If $\overline{V}$ is low, the increment of V_i with reinforcement will be large, but as $\overline{V}$ approaches λ, increments in V_i will decrease in size.

Within the context of this formulation, inhibition is identified by a negative V value. The asymptotic value of associative strength, or λ, for nonreinforcement is defined as zero. The nonreinforcement of a stimulus in isolation (i.e., within a context of no reinforcement) will not result in inhibitory conditioning of that CS because a negative value of ($\lambda - \overline{V}$) is necessary for a negative V_i. Therefore, the stimulus must be nonreinforced concurrently with other cues which have positive associative strength, thus making $\overline{V}$ positive and ($\lambda - \overline{V}$) negative. In the case of conditioning with a negative CS-US contingency, the stimuli involved are conceptualized as background stimuli, A, and the compound of background stimuli and an explicit CS, AX. Unconditioned stimuli occurring in the absence of the CS, i.e., in the presence of the background stimuli, increase the associative strength of V_A, and thereby V_{AX}. Subsequent nonreinforced CS trials then give rise to a negative, or inhibitory, V_X, for as V_{AX} becomes positive, the value of ($\lambda - V_{AX}$), in the presence of nonreinforcement, must be negative. Increasing the negative CS-US contingency by adding more USs in the absence of the CS should result in greater inhibitory strength accruing to the CS as the increased V_A and V_{AX} produce a more inhibitory, or negative, V_X. This prediction from the newer associative theory parallels that of the earlier contingency point of view presented by Rescorla (1967). A further prediction of interest is that a negative contingency in which the P(US/CS) is nonzero may initially produce excitatory conditioning. With continued conditioning, and as V_A becomes larger, the effects of conditioning will become inhibitory (Rescorla and Wagner, 1972; Wagner and Rescorla, 1972).

Perhaps the most convincing evidence that negative CS-US contingencies produce inhibitory conditioning comes from Rescorla (1969b). In this study, the negative CS-US contingencies were parametrically manipulated and a direct relationship between degree of negative contingency and degree of inhibitory control was demonstrated. The effects of negative contingencies were assessed in terms of two procedures: retardation and summation. Perhaps it would be appropriate to discuss the logic of these procedures at this point. The notion behind the retardation test is that excitation and inhibition are additive. If inhibition has been conditioned to a stimulus, the subsequent excitatory conditioning of that stimulus should be retarded and the degree of retardation should be directly related to the magnitude of the inhibition conditioned to the CS prior to excitatory conditioning (Rescorla, 1969c).

Retardation of excitatory conditioning may be interpreted, however, in terms of a different mechanism than conditioned inhibition, e.g., selective attention. Repeated presentations of the CS in the absence of the US may cause S to ignore the CS and excitatory conditioning would be retarded not because the CS has acquired inhibitory control but rather because S must learn to attend to the CS. Because of this, a second measure of inhibitory control is used to complement the retardation test, i.e., the summation test. The summation test also assumes the additivity of inhibitory and excitatory tendencies. The prediction is that if a known elicitor of a response is presented in combination with an inhibitory stimulus the amount of responding to the excitatory CS should be reduced below that normally elicited. If S had come to ignore the "inhibitory" stimulus, presumably the summation test would fail to reveal any inhibitory control by that CS. However, the combination of the excitatory and "inhibitory" stimulus involves presenting a stimulus which is dissimilar to the excitatory stimulus and therefore any reduction in responding to the elicitor may be due to generalization decrement. Fortunately, if a stimulus attracts the animal's attention and thus produces a decrement in the summation test, it should not be retarded in the acquisition of an excitatory CR (Rescorla, 1969c). It is generally held that both retardation and summation procedures must be employed to demonstrate that a given conditioning procedure has produced an inhibitory CS.

To return to Rescorla (1969b), in the first experiment a retardation technique was used to demonstrate conditioned inhibition. Ss were first shaped to bar-press for food reinforcement on a VI 2-min. schedule. Then six groups of eight rats each received various Pavlovian fear-conditioning treatments for five daily 2-hr. sessions. The CS was a 750 cps tone. The US was a .5-sec. 1-ma. electric shock. Two random groups (4-4, 1-1) were run for which $P(US/CS) = P(US/\overline{CS})$. These groups received 12 2-min. tonal CSs in each session, with a mean ITI of 8 min. Shocks were delivered randomly throughout the session such that the frequency of shock was .4 per 2-min. interval in group 4-4, and .1 per 2 min. for group 1-1. Two groups received a negative tone-shock contingency -- 0-4 and 0-1. Treatments were exactly the same as for group 4-4 and group 1-1, except that all shocks scheduled to occur during the CS and in the 2 min. following it, were gated out. Two additional control groups, 0-4 light and 0-1 light, received the same schedule as the 0-4 and 0-1 groups, except that the tonal CS was replaced by a flashing houselight, thus assuring that at the onset of the retardation procedure the tonal CS would be a novel and presumably neutral stimulus for these groups. After conditioning, Ss were allowed to recover bar-press responding. Then, for six test days, 4 2-min. 750 cps. tonal CSs were superimposed on the responding of all six groups. A random 2 out of the 4 presentations per session terminated in a .5-sec 1-ma. shock. Rescorla found that while all groups eventually acquired CER suppression to the tone, the rate of acquisition differed among groups. Group 0-4 and 0-1 were retarded in acquisition when compared to the other four groups. Most significant was the fact that the 0-4 group conditioned more slowly than the 0-1 group, i.e., the group with the greater negative contingency exhibited the greater inhibitory conditioning.

A second experiment assessed the effects of negative contingencies in terms of the summation technique. Four groups of rats received different degrees of negative CS-US contingency, designated 0-8, 0-4, 0-1, 0-0. All groups received 12 2-min. 750 cps. tonal CSs per session. In all cases, the 2 min. of the CS and the 2 min. following it were free of shock. Throughout the rest of the session, .5-sec. 1-ma. shocks were randomly distributed such that groups 0-8, 0-4, and 0-1 had shock frequencies per 2 min. of .8, .4, and .1 respectively, except during the CS and 2 min. following it. Group 0-0 received no shocks. Following five daily 2-hr. conditioning sessions, Ss were allowed to recover bar-press responding. Then on each of three days, 4 trials of a 2-min.2/sec. flashing houselight were superimposed on responding. A random 2 CSs per day terminated in a .5-sec. 1-ma. shock. At the end of excitatory conditioning all groups showed essentially complete suppression to the light. Two test sessions followed in which 4 test trials were superimposed on responding each day -- 2 light alone trials and 2 light-tone compound trials. All groups were approximately equal in suppression to the light alone. However, the negative contingency groups showed reduced suppression to the light in compound with the tone. Further, the greater the degree of negative contingency between tone and shock, the greater the disruption of suppression to the light tended to be.

Rescorla (1968) ran a similar experiment to demonstrate that excitatory conditioning varies directly with the degree of positive CS-US contingency. The groups, designated in terms of P(US/CS) - P(UC/$\overline{CS}$), were .4-.4, .2-.2, .1-.1, 0-0, .4-.2, .4-.1, .4- 0, .2-.1, .2-0, and .1-0. The random groups, for which P(US/CS) = P(US/$\overline{CS}$), evidenced no suppression to the tonal CS. However, those groups with positive contingencies did show suppression and moreover were ordered according to the P(US/$\overline{CS}$). Specifically, the group with the lowest such probability showed the most suppression.

However, as Ayres, Benedict and Quinsey (1972) point out, these two experiments -- Rescorla, 1968 and 1969b -- are not symmetrical, for while in Rescorla (1968) values of P(US/CS) and P(US/$\overline{CS}$) were allowed to vary from zero, in Rescorla (1969b) the value of P(US/CS) was always zero. The contingency model predicts that so long as there is an overall negative CS-US contingency, regardless of the value of P(US/CS), inhibitory conditioning will take place asymptotically. However, that an overall negative contingency with P(US/CS) not equal to zero produces inhibitory conditioning has not been empirically demonstrated. Further, Rescorla and Wagner (1972) have indicated that the presentation of CS-US pairings within an overall negative CS-US contingency may, at least initially, disrupt inhibitory conditioning by increasing the associative strength of the CS to the detriment of the background stimuli. That is, CS-US pairings would initially produce a positive V_X. It is only as V_A becomes larger, i.e., as A gains excitatory strength, and V_{AX} exceeds asymptote, that V_X would begin to become negative.

Ayres, Benedict and Quinsey (1972) have suggested that a contiguity theory, such as Denny's (1971) "relaxation theory" may be applied to the analysis of inhibitory conditioning and indicate that within that theoretical viewpoint, a P(US/CS) greater than zero might be predicted to disrupt inhibitory conditioning. Essentially Denny's theory assumes that the animal begins to relax at some time following the termination of the aversive stimulus. This relaxation becomes conditioned to those stimuli which are contiguous to it. In the case of the explicitly unpaired procedure, relaxation may be conditioned to the CS, given that the inter-shock intervals are long enough for the animal to relax during them. However, if some shocks were to occur during the CS, fear would be conditioned to it and thus disrupt the conditioning of relaxation. Denny's theory implies that a procedure in which the overall contingency is negative but in which the P(US/CS) is greater than zero might not produce inhibitory conditioning.

In the area of avoidance conditioning, Bolles and Grossen (1969) have found that a response contingent feedback signal can produce avoidance responding in the absence of a CS-termination contingency. Bolles (1970) has drawn an analogy between such a feedback signal (FS) and a safety signal (SS) developed in a noncontingent situation where the CS is correlated with the absence of shock independently of the S's behavior (Rescorla and Lolordo, 1965). Bolles suggests that initially in avoidance learning the S's behavior is limited to those few species-specific defense reactions (SSDRs) which are elicited by the aversive situation of receiving shock. If one of these SSDRs is topographically compatible with the programmed avoidance response (e.g., jumping with hitting a bar) then reflexive behavior will result in fortuitous avoidance or shortening of some of the shocks, producing a less aversive situation. In this case, some of the S's non-SSDR responses may return, increasing the possibility that S will learn the avoidance response. The introduction of a response-contingent FS may facilitate this delicate process if, in a manner similar to Rescorla and Lolordo's SS, it becomes an inhibitor of fear. The FS may itself, then, lessen the aversiveness of the situation and therefore hasten the return of a normal response repetoire. The involvement of such a safety signal mechanism in avoidance learning would necessarily be limited to those responses which are more laboriously acquired, as the development of the safety signal value of the FS would require a number of pairings with the absence of shock. Of importance here, is the implication that any pairings of the FS with shock would destroy its value as a safety signal.

Because of possible theoretical contradictions (such as Denny's or Bolles') to the prediction of inhibitory conditioning from any negative CS-US contingency and because of an obvious gap in the empirical information on the subject, the following study was undertaken. A number of Rescorla's negative contingency groups (1969b) in which the P(US/CS) equals zero were replicated. In other groups, the P(US/CS) was parametrically manipulated while retaining an overall negative contingency during conditioning and the conditioned inhibitory effects of the CS assessed. Experiment 1 assessed those effects in terms of a retardation test, while Experiment 2 tested the same groups (independent Ss) for inhibitory conditioning by means of the summation procedure.

Experiment 1

Method

Subjects

The Ss were 42 male albino rats 90-100 days old at the time of running, purchased from the Holtzman Company, Madison, Wisconsin. They were housed individually and fed Purina Lab Chow, freely, for five days. Then for seven days following they were fed 3-5 grams daily in order to reduce them to 80% of their free-feeding body weight, at which they were maintained for the duration of the study. Ss were weighed immediately following the experimental session.

Apparatus

Six Gerbrands operant conditioning chambers with left-side dipper feeders were housed in ventilated .61m cubes of 13 mm plywood lined with acoustical tile. The CS was the onset of a 1000-Hz., 84-db. tone presented through a 10 cm. speaker mounted on the lid of the chamber. Scrambled shocks served as USs and were provided by six Grason-Stadler shock sources (Models E1064GS and 700).

The chamber was illuminated by a 6.5v cue light located 9.5cm. above the dipper opening and 7.5cm. to the left of the bar. The baseline response whose suppression was to be measured was bar-pressing, reinforced with a 4-sec. presentation of a .1cc. dipper cup containing a 32% (w/w) sucrose solution.

Procedure

Preliminary training. In one initial 2-hr. session Ss were shaped to bar press on CRF for 32% sucrose solution. Animals met criterion when they made 50 bar presses during this first session. Five daily 2-hr. sessions followed during which Ss responded for reinforcement on a VI 2-min. schedule of reinforcement (Fleshler & Hoffman, 1962). On the initial VI session, Ss responded for the first 20 min. on a VI 1-min. schedule of reinforcement and were then switched to VI 2-min.

Conditioning. The second phase of the experiment was designed to establish a tonal CS as a conditioned inhibitor in five groups of animals, 6 per group. Two control groups were also run. Five 2-hr. conditioning sessions were given off the baseline. During conditioning, bar pressing was prevented by the insertion of a four-walled Masonite insert with vertical black and white stripes. All Ss in six groups received 12 2-min. 1000-Hz. tonal CSs per session. Three of these groups, 0-.8, 0-.1 and 0-0, were identical to three groups run by Rescorla (1969b, Exp. 2). For these, the duration of the CS and the 2-min. period following it was free from shock. Throughout the rest of the session .5-sec. 1-ma. shocks were randomly distributed. Shock frequencies for groups 0-.8, 0-.1 and 0-0 were .8, .1, and 0, respectively, per 2-min. period except during and for 2 min. following each CS. Three additional groups were run -- .1-.8, .2-.8, and .6-.8 -- which were identical to group 0-.8 except that the frequency of shock for each two minute CS period was .1, .2, and .6, respectively. A seventh group of 6 Ss -- Naive -- received no experience with either the tone or the shock prior to the testing phase of the experiment. This group was included as a control for possible latent inhibition effects in the 0-0 control group (Lubow and Moore, 1959; Rescorla 1969c).

Sequences of tones and shocks conforming to the contingency requirements of each group were generated using a computer program designed to generate truly random sequences of tones and shocks. The five daily 2-hr. conditioning sessions were divided, for the purposes of making up the sequences, into 300 2-min. intervals corresponding to the CS duration. For groups 0-.8 and 0-.1 no shocks were to occur during the CS or in the 2-min. following the CS, leaving 180 of the total 300 intervals available for shock -- there were 60 CSs, 60 2-min. intervals following the CS, thus 120 intervals unavailable for shock. Shocks were then randomly assigned to those 180 intervals at a frequency of .1 per interval and .8 per interval for group 0-.1 and 0-.8, respectively. Groups .1-.8, .2-.8, and .6-.8 received the same shocks of group 0-.8 but shocks were added during some of the CSs such that the frequency of shocks during the 60 CS-intervals was .1, .2 and .6 per interval for groups .1-.8, .2-.8 and .6-.8, respectively.

Each S in each conditioning group received a different sequence of shocks and tones. But within a group, each sequence was consistent with the requirements of shock frequency during and in the absence of the CS for that group.

Recovery. On the day following conditioning, the chamber inserts were removed and the Ss were returned to the VI 2-min. bar press schedule to recover the instrumental response. During this time no CSs or USs were presented. Ss were allowed to recover the bar press over 2 daily 2-hr. sessions.

Testing. On each of six days, beginning on the day following the last recovery session, 4 2-min. tonal CSs were superimposed on responding. A random 2 of the 4 CSs per day were reinforced with a .5-sec. 1-ma. shock. Response rates were measured throughout all sessions and the acquisition of CER to the tone was assessed by forming a ratio of response rates of the form A/(A+B) where A is the response rate during the 2-min. CS and B is the response rate during the 2-min. period immediately preceeding the CS.

The experiment was run in two replications each containing three Ss from each group.

Results

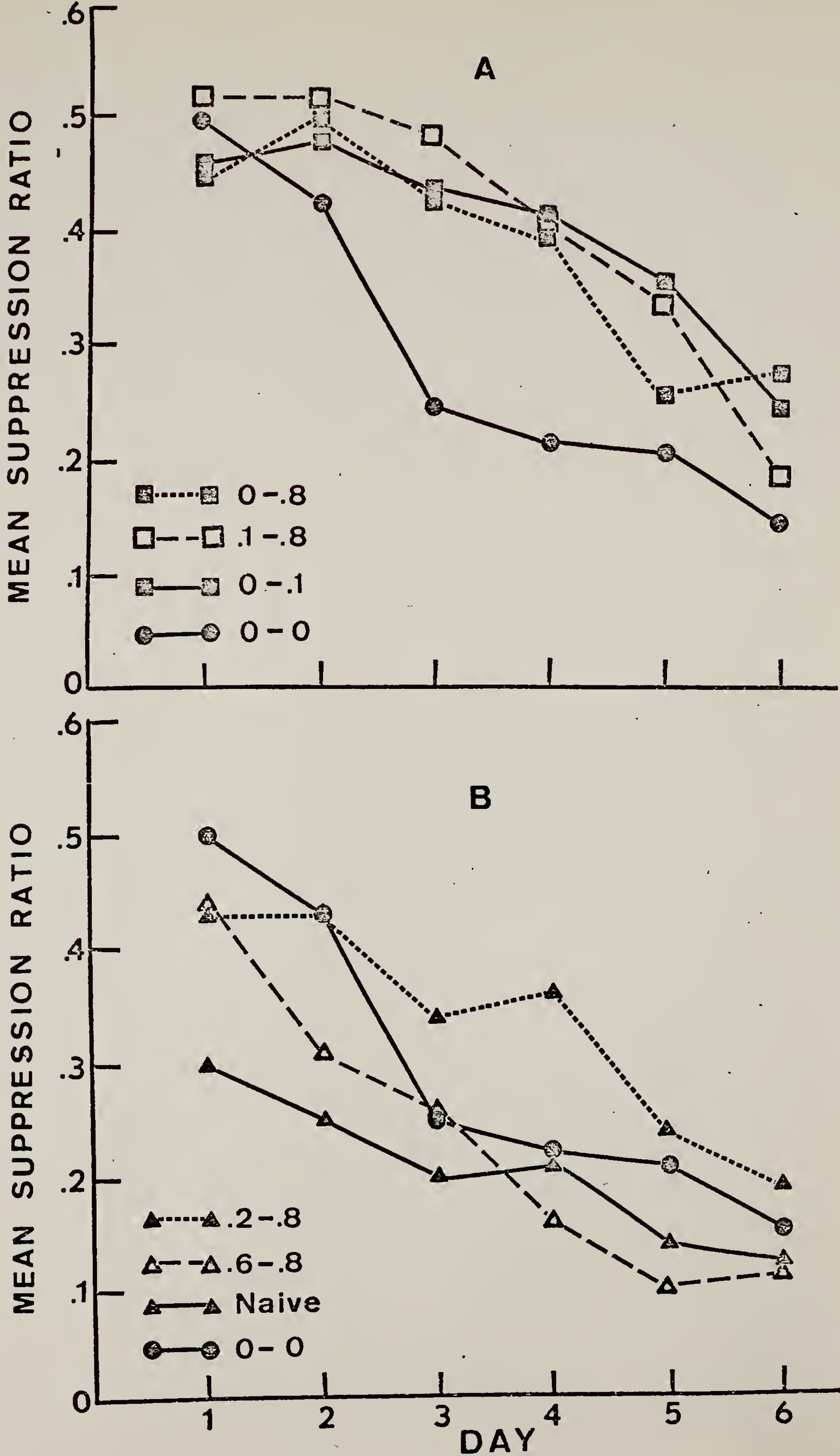
Figure 1 shows the mean suppression ratios for each group for the six days of testing for retardation. Figure 1a presents the data for Groups 0-.8, 0-.1 and .1-.8 versus the control group 0-0. Figure 1b plots the data for Group 0-0 against Groups .2-.8, .6-.8 and Naive. All seven groups acquired a CER to the tonal CS, but an analysis of variance, both for the entire six days of testing and for Days 3 and 4 only, indicate that the CER was acquired at different rates by the various groups ($F_{6\ days}$= 3.27, df = 6,28, $p < .05$; $F_{Days\ 3\&4}$ = 3.04, df = 6,28, $p < .05$).

Figure 2 plots the average suppression ratio on Days 3 and 4 of the retardation test for each group. Individual t-tests ($p < .05$, 2-tailed) were performed on these data in making comparisons between groups. Groups 0-.8, 0-.1 and .1-.8 were significantly retarded in CER acquisition with respect to the 0-0 control group on Days 3 and 4, but did not differ significantly from one another. When Group 0-0 was compared individually with Groups .2-.8, .6-.8, and

FACE PAGE FOR FIGURE 1

Figure 1. Mean suppression ratios for six days of testing for retardation in Experiment 1.

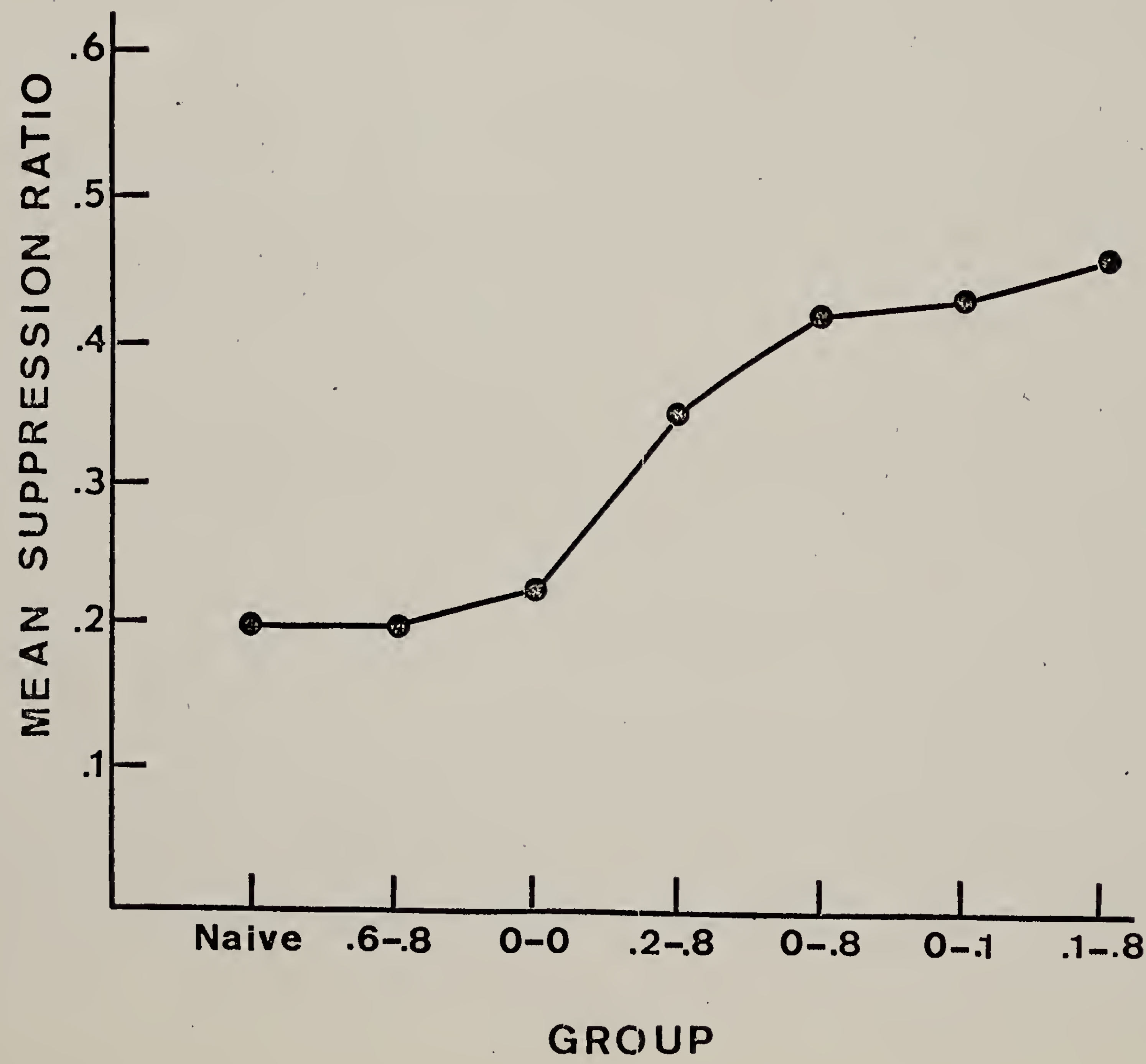
Panel A: Groups 0-.8, 0-.1, .1-.8 and 0-0.
Panel B: Groups .2-.8, .6-.8, Naive and 0-0.



A
B
MEAN SUPPRESSION RATIO
.6
.5
.4
.3
.2
.1
0
0-.8
.1-.8
0-.1
0-0
.2-.8
.6-.8
Naive
1
2
3
4
5
6
DAY

FACE PAGE FOR FIGURE 2

Figure 2. Mean suppression ratios on Days 3 and 4 of Retardation testing by groups.


MEAN SUPPRESSION RATIO
.6
.5
.4
.3
.2
.1
Naive
.6–.8
0–0
.2–.8
0–.8
0–.1
.1–.8
GROUP

Naive no significant differences in acquisition were found. These groups -- .2-.8, .6-.8 and Naive -- did not differ significantly among themselves. Groups 0-0, .6-.8 and Naive, considered together, did differ significantly from Groups 0-.1, 0-.8 and .1-.8 considered together. Group .2-.8 appeared to acquire the CER somewhat faster than Groups .1-.8, 0-.8, and 0-.1 and somewhat slower than Groups 0-0, Naive and .6-.8, but did not differ significantly from either set of groups. The Naive group appeared to acquire the CER faster than the 0-0 control group, but not significantly.

There was no significant replication effect in the analysis of variance, nor were there significant differences among the groups in pre-CS response rates during testing. Thus the differences among suppression ratios just described were not complicated by differences in baseline response rates.

Discussion

It would appear that for three of the five groups which experienced a negative tone-shock contingency during the conditioning phase of the experiment (i.e., Groups 0-.8, 0-.1, and .1-.8) the CS acquired conditioned inhibitory properties. This is indicated by the fact that these three groups were significantly retarded with respect to the control group 0-0, in the subsequent acquisition of a CER to the tonal CS. It would seem that the addition of at least a few tone-shock pairings (the .1-.8 group experienced 6 tone-shock pairings) does not disrupt inhibitory conditioning as Group .1-.8 is apparently as inhibitory as Group 0-.8.

Rescorla (1969b) reported that a group with a more negative CS-US contingency (0-.4) showed greater conditioned inhibition as measured by a retardation technique than a group with a less negative CS-US contingency (0-.1). This is not strictly the case in the present experiment. Groups 0-.1 and 0-.8 differ in terms of the probability of shock in the absence of the CS -- the 0-.1 contingency would be viewed as less negative than 0-.8 according to Rescorla (1969b) -- and yet the two groups are equally inhibitory as tested by the retardation of CER acquisition. Similarly, one would predict, on the basis of Rescorla's data, that Group 0-.8 would be more inhibitory than Group .1-.8. Again this is not the case in the present experiment. Groups 0-.8 and .1-.8 do not differ from one another. It might be that as a result of variables peculiar to this experiment some kind of ceiling effect is involved such that 0-.1 and 0-.8 cannot be differentiated.

Group .6-.8 evidences no inhibitory conditioning. This is not surprising in light of the fact that the .6-.8 group may be viewed as an approximation of a truly random control (Rescorla, 1967).

Group .2-.8 occupies an ambiguous position. It is neither obviously inhibitory or noninhibitory. The .2-.8 negative contingency would be expected, on the basis of Rescorla's data, to yield less inhibitory conditioning than 0-.8 or .1-.8, but one would still expect some inhibitory conditioning. To look at these results from one point of view, one might say that the addition of a substantial number of pairings of CS and shock (Group .2-.8 experienced 12 shocks during CS's in conditioning) disrupts inhibitory conditioning. This would be consistent with arguments presented above and based on theoretical consideration of Denny (1971) and Bolles (1970). However, the .1-.8 group received 6 CS-US pairings during conditioning and was quite retarded in CER acquisition. Speculation as to what might be a sufficient number of pairings to disrupt inhibitory conditioning in this experimental situation seems unwarranted and it is still unclear exactly what effect such pairings have on inhibitory conditioning.

The data do suggest some conclusions about the character of inhibitory conditioning. Rescorla (1968) has shown that the degree of excitatory conditioning varies directly with the degree of positive CS-US contingency. Thus a .4-.2 contingency produced more excitation than .4-.4, .4-.1 more than .4-.2 and .2-.1 more than .2-.2. Data from Rescorla (1969b) and extrapolations from contingency theory and the Rescorla-Wagner model suggest that the degree of inhibitory conditioning can be similarly ordered in terms of the degree of negative CS-US contingency. However, the findings of the present experiment indicate that this is not the case. Excitation and inhibition do not appear to be symmetric around some point of zero conditioning.

Experiment 2

Results from Experiment 1 indicated that the tonal CS acquired inhibitory properties for three experimental groups -- 0-.1, 0-.8 and .1-.8. Three other groups -- .6-.8, 0-0 and Naive -- evidenced no inhibitory conditioning. A seventh group, .2-.8, could not be designated either inhibitory or noninhibitory. In order to verify these results, Experiment 2 was undertaken to test the inhibitory properties of the CS using a summation procedure.

Method

Subjects

Ss were 42 male albino rats from the Holtzman Company, 90-100 days old at the time of the experiment. They were maintained throughout the experiment at 80% of their ad lib weight.

Apparatus

The apparatus was the same as that of Experiment 1. A flashing light stimulus was provided by changing the illumination provided by the cue light from 6.5v to 26v on a 1/sec. pulse.

Procedure

Preliminary training and conditioning to the tonal CS proceeded as in Experiment 1. All Ss were trained to bar press for a reinforcement of 32% sucrose solution, ending with five daily 2-hr. sessions of responding on a VI 2-min. schedule of reinforcement. Ss were then exposed to conditioning off the baseline. The groups run were exactly those of Experiment 1: 0-.8, 0-.1, 0-0, .1-.8, .2-.8, .6-.8 and Naive. The composition of the sequences of tones and shocks for Ss in each of these groups was identical to that of sequences given to Ss in the comparable group in Experiment 1.

Recovery. Following conditioning off the baseline, Ss were allowed to recover the bar press response in 3 daily 2-hr. sessions (following Rescorla, 1969b). During these sessions, neither CSs nor USs were presented and Ss responded for a VI 2-min. schedule of sucrose reinforcement.

Conditioning to CS2. Following recovery, Ss received on-the-baseline conditioning to a 1/sec. flashing houselight. On each of three days 4 2-min. trials of the light CS were superimposed on VI responding. A random 2 of the 4 trials each day were reinforced with a .5-sec. 1-ma. shock. The inhibitory properties of the tonal CS would be tested against the excitatory properties of the light CS.

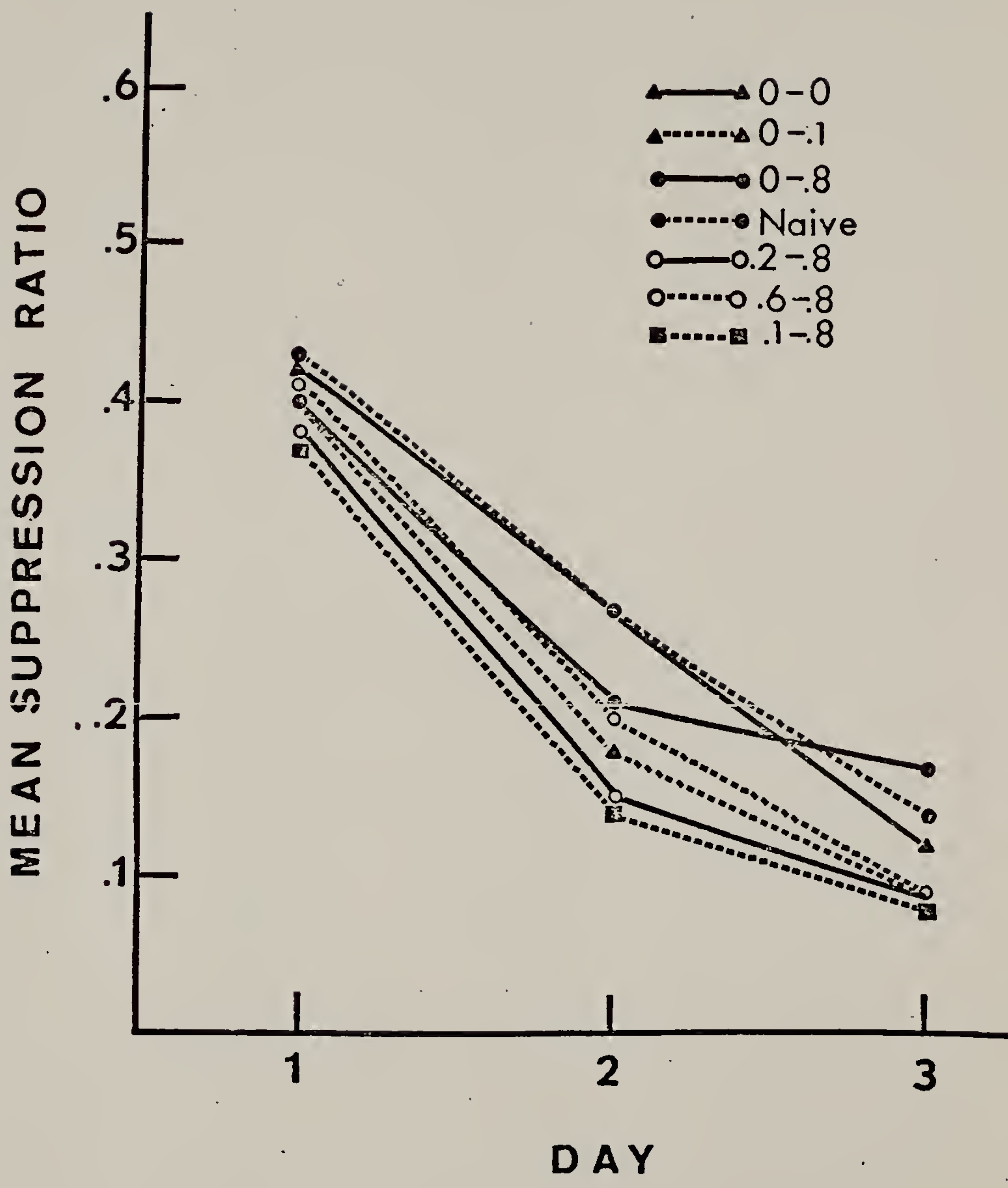
Testing. Four test trials were superimposed on VI responding on each of two test days. On two of the trials, the flashing light was presented alone. On the other two trials, the light was presented in compound with the tonal CS. No shocks were delivered at any time. The order of presentation of light-alone and light-plus-tone trials was counterbalanced across the two test sessions. On Test day 1, the stimuli were presented in the following order: light-alone, light-plus-tone, light-plus-tone, light-alone; while on Test day 2, the order of presentation was: light-plus-tone, light-alone, light-alone, light-plus-tone. Suppression ratios for responding were obtained for all stimulus trials.

Results

All groups showed strong suppression to the light stimulus prior to summation testing (Figure 3). Average suppression ratios for the seven groups were all below .20 and did not differ significantly from one another. Figure 4 shows the mean suppression ratio of light-alone and light-plus-tone test trials averaged over two days of summation testing. A Kruskal-Wallis H test revealed no significant differences between the groups in terms of how much the addition of the tone interfered with suppression to the light. Figure 5 shows the mean suppression ratios on each light-alone and light-plus-tone trial on the two test days, in the order in which the stimuli occurred. Note that the suppression ratios follow a general extinction

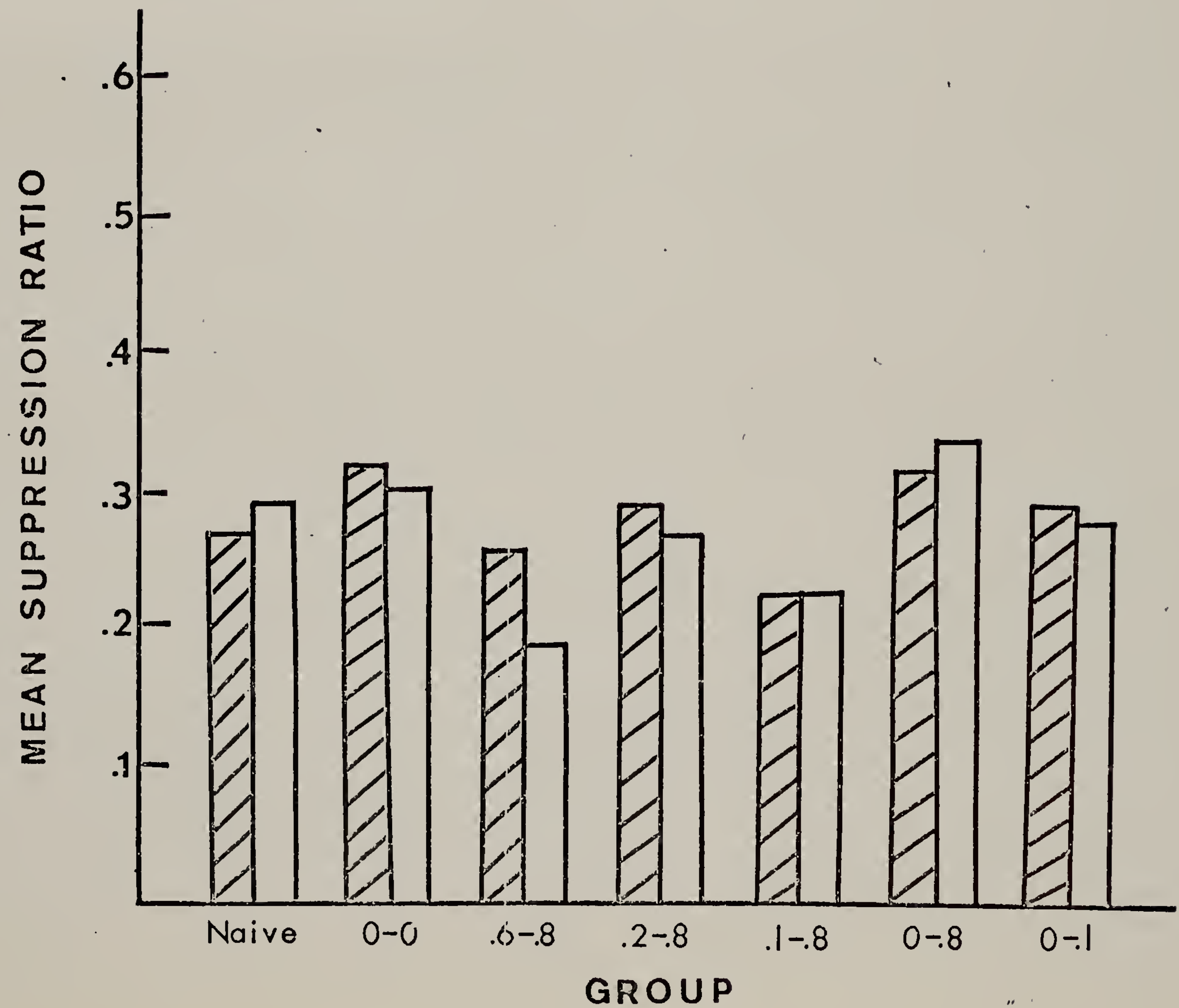
FACE PAGE FOR FIGURE 3

Figure 3. Mean suppression ratios to light on three days of light conditioning in Experiment 2.


MEAN SUPPRESSION RATIO
.6
.5
.4
.3
.2
.1
0-0
0-.1
0-.8
Naive
.2-.8
.6-.8
.1-.8
1
2
3
DAY

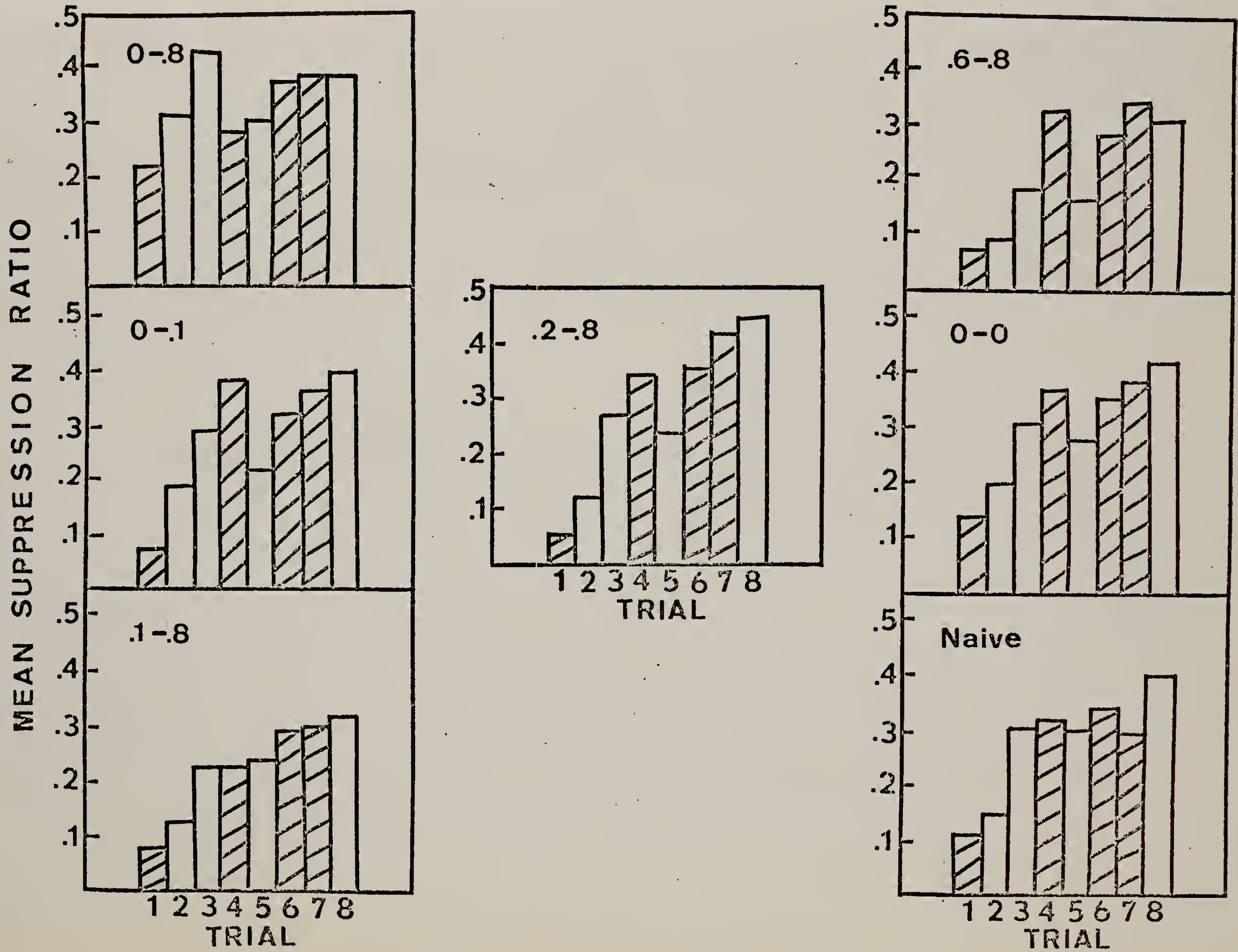
FACE PAGE FOR FIGURE 4

Figure 4. Mean suppression ratios on light-alone (shaded) and light-plus-tone (unshaded) test trials on the two days of summation testing in Experiment 2.


MEAN SUPPRESSION RATIO
.6
.5
.4
.3
.2
.1
Naive
0-0
.6-.8
.2-.8
.1-.8
0-.8
0-.1
GROUP

FACE PAGE FOR FIGURE 5

Figure 5. Mean suppression ratios on each light-alone (shaded) and light-plus-tone (unshaded) trial in summation testing in Experiment 2.



MEAN SUPPRESSION RATIO
0-.8
0-.1
.1-.8
.2-.8
.6-.8
0-0
Naive
.5
.4
.3
.2
.1
1 2 3 4 5 6 7 8
TRIAL

trend and particularly that extinction to the light-alone stimulus is very rapid. By the second light-alone trial (i.e., the 4th stimulus trial on the first test day) none of the groups gave a suppression ratio to the stimulus below .20.

Discussion

These results are very disappointing in that they do not provide evidence for inhibitory conditioning in any of the groups tested. Neither do they replicate Rescorla's (1969b) results. Certain differences between the results of this experiment and Rescorla's results can be pointed out and may explain the discrepancy. First, conditioning to the light stimulus prior to testing in Experiment 2 is strong but not as strong as that reported by Rescorla (1969b), who notes that his Ss had essentially stopped responding completely during the light CS by the end of conditioning. The smallest mean group suppression ratio to the light on the third day of conditioning in Experiment 2 was .08 and the largest was .17 which represents quite a bit of responding relative to none at all. More important, however, is the rapid extinction of the conditioning to the light stimulus during testing in Experiment 2, which may or may not be a function of the conditioning to the light prior to testing. Rescorla's data indicate that his Ss retain a great deal of suppression to the light stimulus throughout testing; group suppression ratios to the light alone averaged over the two test days not exceeding .10. Similar data from Experiment 2 show group suppression ratios to the light at a maximum of .32 and a minimum of .23. These larger ratios to the light stimulus necessarily make it more difficult to assess inhibitory effects by essentially diminishing the limits within which interference by the tone can be demonstrated. The operation of this "ceiling effect" may be responsible, at least in part, for the negative results of Experiment 2.

Experiment 3

It was thought that the negative results of the summation test in Experiment 2 might be due, at least in part, to poor conditioning to the light stimulus prior to testing. Rescorla (1969b) had employed a 2/sec. flashing light as a second stimulus, while a 1/sec. flashing light was used in Experiment 2 of this report. It seemed possible that the 1/sec. light was less salient than the 2/sec. flash. Further, it was felt that longer conditioning or more frequent reinforcement of the light during conditioning might produce stronger conditioning to the light and thus better results in the summation test. Accordingly, three groups of Ss were run in a summation procedure identical to that of Experiment 2 except for the procedure used to condition suppression to the light stimulus. All Ss received tone conditioning with a 0-.8 negative contingency as it was felt that this schedule should definitely be expected to produce good inhibitory conditioning.

Method

Subjects and Apparatus

Eighteen male albino rats from the Holtzman Company, 90-100 days old and maintained at 80% body weight were run in apparatus identical to that of Experiments 1 and 2.

Procedure

Preliminary training, conditioning to the tone, and recovery of bar pressing proceeded as in Experiment 2. All animals received conditioning to the tone involving the same 0-.8 contingency schedule as was used in Experiments 1 and 2.

Conditioning to CS2. Following recovery, Ss received on-the-baseline conditioning to a light stimulus while responding for sucrose reinforcement on a VI 2-min. schedule. Ss were divided into three groups of 6 Ss each. The groups differed in terms of the type of light stimulus they experienced and the frequency of reinforcement of that stimulus. They also differed in terms of the number of days of light conditioning they received.

Group A replicated the 0-.8 group in Experiment 2. That is, on each of the three days of light conditioning, 4 2-min. trials of a 1/sec. flashing light were superimposed on responding. A random two of the four trials each day were reinforced with a .5-sec. 1-ma. shock.

Groups B and C received more than three days of light conditioning in an attempt to get even stronger conditioning. These groups were given conditioning to the light until it appeared that they had stabilized. Group B was treated similarly to Group A except that the light stimulus used was a 2/sec. flashing light. This group received 4 trials (2 reinforced) of the light stimulus each day for five days of conditioning.

Group C received the same four presentations of a 2/sec. flashing light each day of conditioning, but in this case a random 3 out of 4 trials ended with a .5-sec. 1-ma. shock. This group received six days of conditioning.

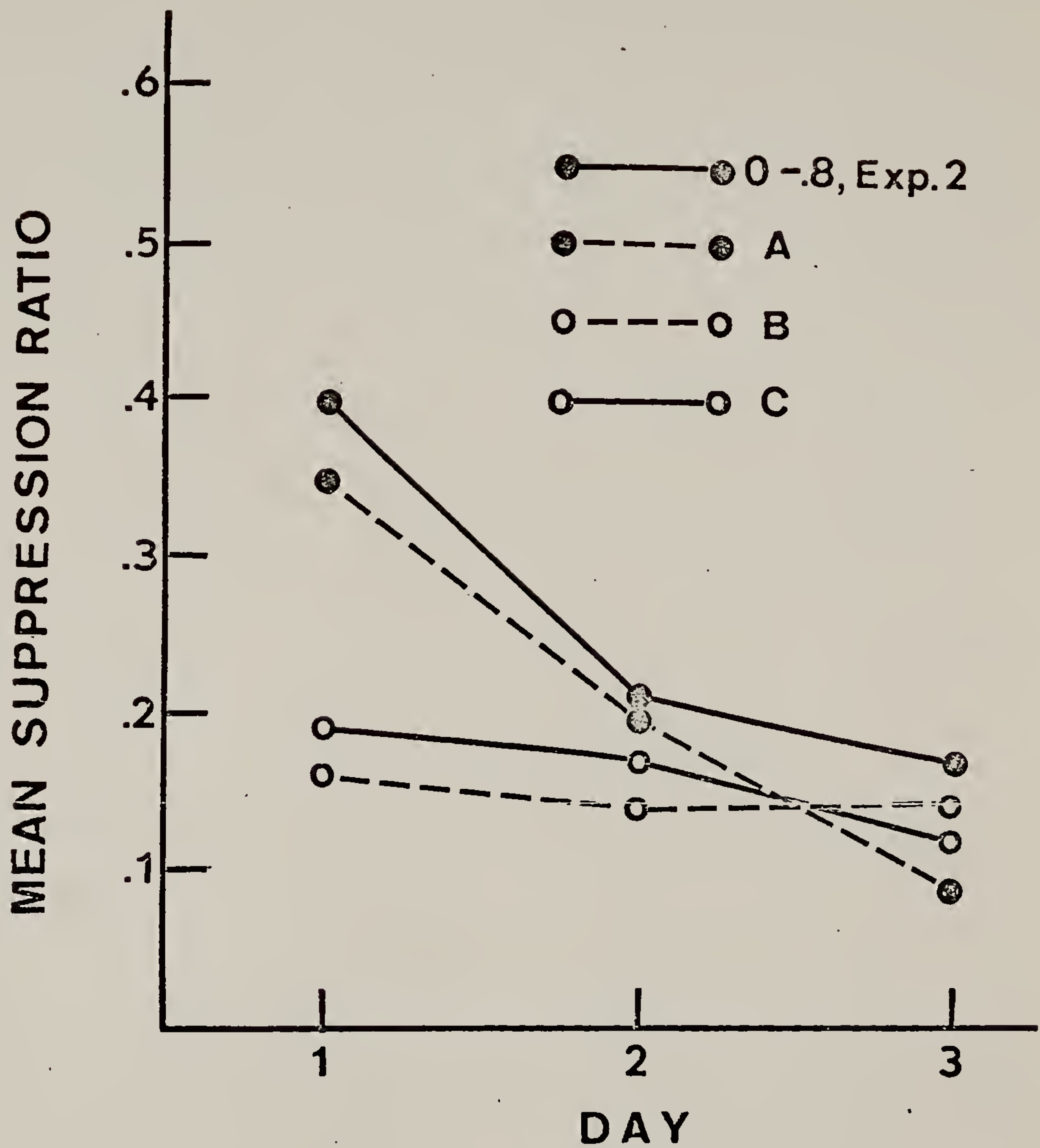
Suppression ratios were obtained for all stimulus trials. On the day immediately following the final light conditioning day for each group, Ss were tested for conditioned inhibition as in Experiment 2.

Results and Discussion

Conditioning to the light stimulus in Experiment 3 appeared to be very similar to that of Experiment 2. Figure 6 shows the mean suppression to the light stimulus on the last three days of light conditioning for each group. As a reference, similar data from Group 0-.8 in Experiment 2 are included. For Group A these data represent the mean suppression ratio to the light for Days 1, 2, and 3 of

FACE PAGE FOR FIGURE 6

Figure 6. Mean suppression ratios to the light on the last three days of light conditioning in Experiment 3.


MEAN SUPPRESSION RATIO
.6
.5
.4
.3
.2
.1
1
2
3
DAY
0 -.8, Exp. 2
A
B
C

light conditioning; for Group B, Days 3, 4, and 5; and for Group C, Days 4, 5, and 6. It can be seen that additional days of conditioning did not significantly affect suppression to the light in Groups B and C, nor did changes in the nature of the light stimulus or changes in the frequency of reinforced trials affect suppression to the light significantly. Groups A, B, and C do not differ significantly from one another in suppression to the light, nor do they differ significantly from Group 0-.8 in Experiment 2.

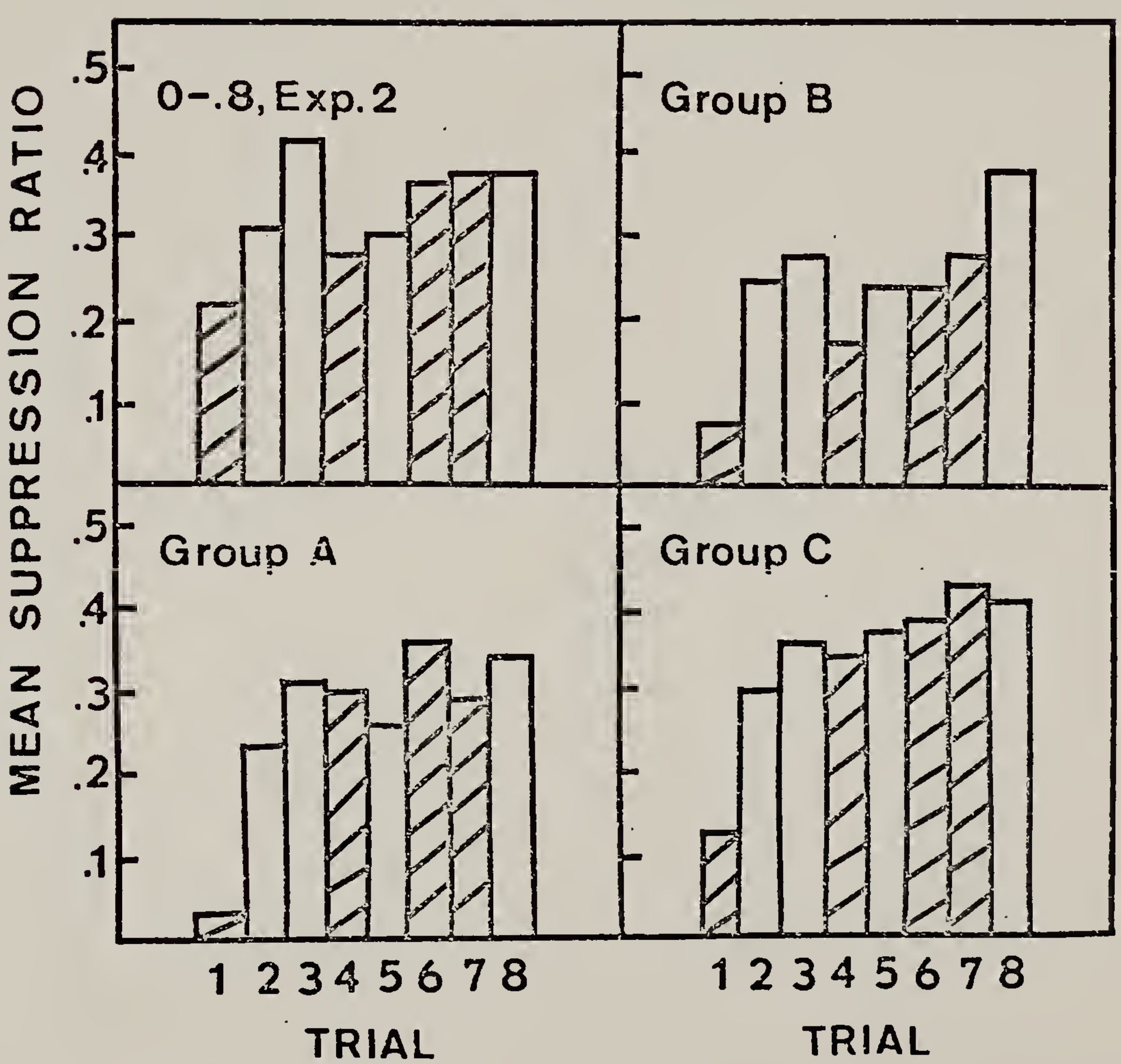
Figure 7 shows the suppression ratios on each light-alone and light-plus-tone trial during two days of testing for Groups A, B, C, and Group 0-.8 from Experiment 2. Note again the rapid extinction of suppression to the light-alone, similar to that seen in Experiment 2 (see Fig. 5).

Figure 8a shows the averaged suppression ratios to the light-alone and to the light-plus-tone for the four 0-.8 groups on Days 1 and 2 of summation testing and for Days 1 and 2 combined. All groups show differences in suppression to the light and the light-plus-tone stimulus on the first day in a direction consistent with inhibitory conditioning to the tone. This trend is also seen in the data for all groups when the suppression ratios are averaged over the two test days. In Figure 8b, the data for all four 0-.8 groups are combined.

Changes in the length of conditioning, the frequency

FACE PAGE FOR FIGURE 7

Figure 7. Mean suppression ratios on each light-alone (shaded) and light-plus-tone (unshaded) trial in summation testing in Experiment 3.

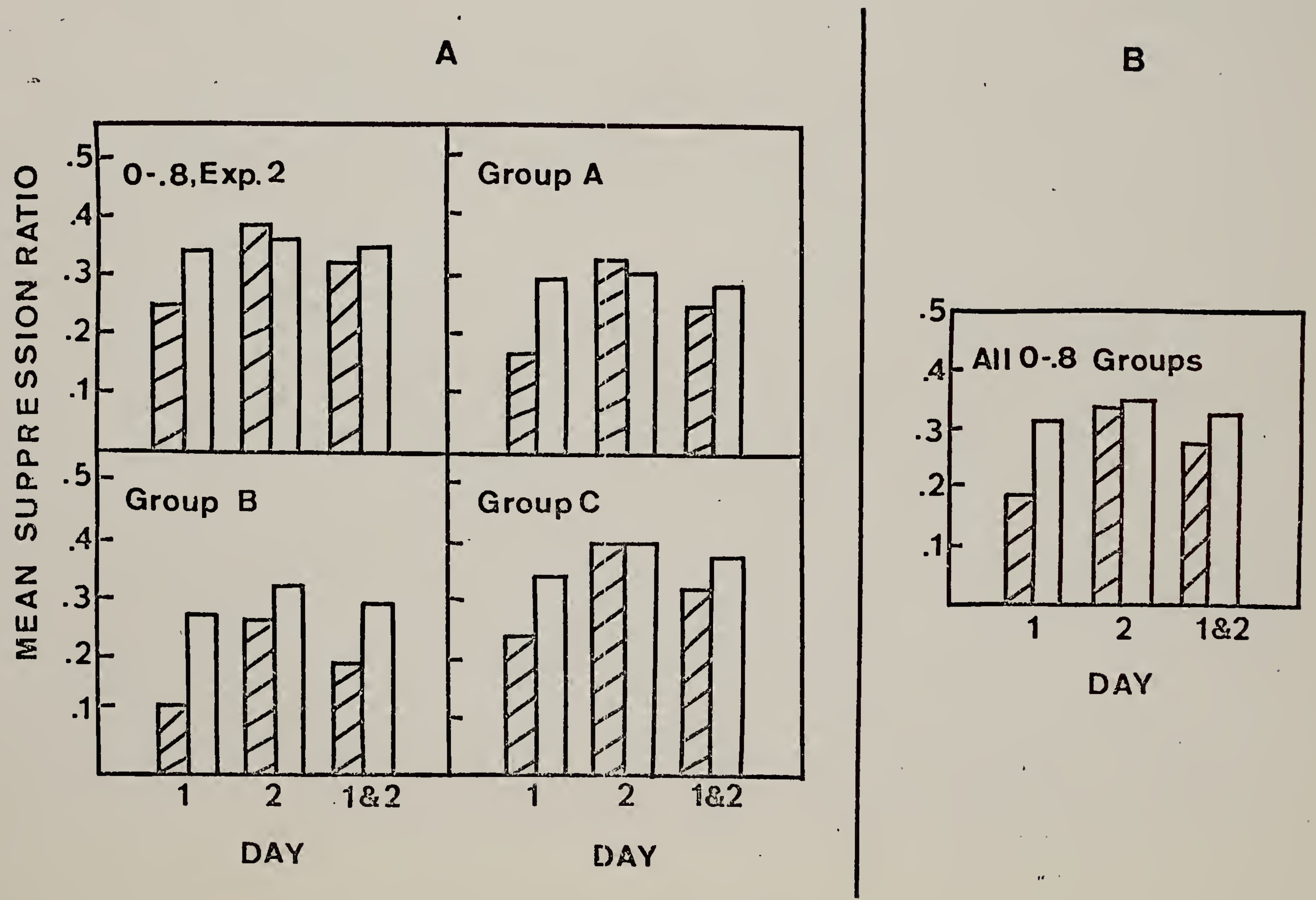


MEAN SUPPRESSION RATIO
.5
.4
.3
.2
.1
0-.8, Exp. 2
Group B
Group A
Group C
1 2 3 4 5 6 7 8
TRIAL
1 2 3 4 5 6 7 8
TRIAL

FACE PAGE FOR FIGURE 8

Figure 8. Mean suppression ratios on light-alone (shaded) and light-plus-tone (unshaded) in summation testing for all 0-.8 groups.

Panel A: 0-.8 groups, separately
Panel B: 0-.8 groups, combined


A
B
MEAN SUPPRESSION RATIO
.5
.4
.3
.2
.1
0-.8,Exp. 2
Group A
Group B
Group C
All 0-.8 Groups
1
2
1&2
DAY

of reinforcement during conditioning, and the salience of the light stimulus did not appear to significantly strengthen conditioning to the light stimulus nor did they retard the rapid extinction of suppression to the light during testing. Despite this, summation testing on Groups A, B and C indicated that the tonal CS did acquire some inhibitory properties as evidenced by its ability to disrupt suppression to the light stimulus.

While these results, then, did not shed much light on what factors accounted for the rapid extinction of light conditioning during testing in Experiment 2, quite a bit of data on Ss which had received similar experience with a specific schedule of negative CS-US contingency were obtained. Furthermore, this particular negative contingency has been demonstrated to produce inhibitory conditioning in previous experiments (Rescorla, 1969b; and Experiment 1, here, in terms of retardation testing). It seemed possible that inhibitory conditioning in this group might be demonstrated with a summation technique with the addition of more data. Therefore, the data for Ss in Group 0-.8 in Experiment 2 and for Groups A, B and C from Experiment 3 were pooled and tested against data from the summation test of Experiment 2 for groups felt to be non-inhibitory.

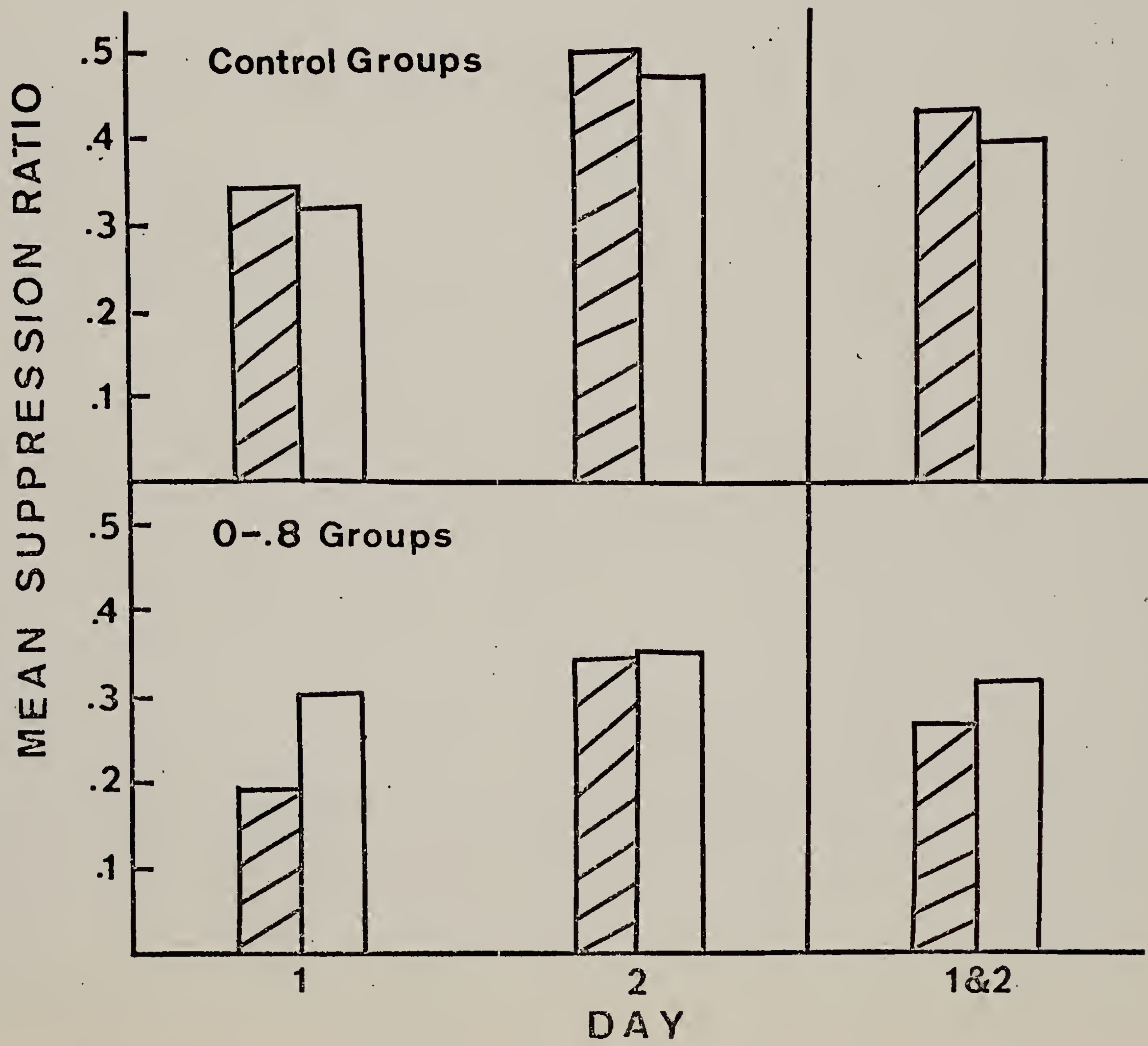
Summation data were available from Experiment 2 for three non-inhibitory groups (i.e., 0-0, .6-.8 and Naive).

Theoretical considerations predicted that these groups would most likely be noninhibitory. Further, results in Experiment 1, using a retardation procedure, indicated that these groups were in fact noninhibitory in nature and did not differ significantly from one another. Therefore, the summation data for the 18 Ss in these groups were pooled to be tested against the pooled summation data of the 24 Ss which had received experience with a 0-.8 CS-US contingency (i.e., 6 Ss from Experiment 2, 18 Ss from Experiment 3) in an effort to demonstrate inhibitory conditioning in the 0-.8Ss. A t-test was performed on the summation data for the control Ss versus the 0-.8 Ss using as a measure the differences between the suppression ratio to the light-alone averaged over the two days of testing and the suppression ratio to the light-plus-tone compound averaged over the two days.

Figure 9 shows the mean suppression ratio to the light and light-tone compound from the pooled data for the 0-.8 Groups. A t-test ($\underline{p} < .01$, one-tailed) comparing the groups revealed significant differences between them in terms of the amount of interference in suppression to the light caused by the addition of the tone. The 0-.8 Groups were clearly inhibitory when compared with the Control Groups.

FACE PAGE FOR FIGURE 9

Figure 9. Mean suppression ratios on light-alone (shaded) and light-plus-tone (unshaded) trials in summation testing for Control and 0-.8 Groups in Experiment 3.


MEAN SUPPRESSION RATIO
.5
.4
.3
.2
.1
Control Groups
0–.8 Groups
1
2
1&2
DAY

General Discussion

Rescorla (1969c) has suggested that conditioned inhibition be defined as "the learned ability of a stimulus to control a response tendency opposed to excitation" and that an inhibitory CS must both significantly reduce the response to an excitatory CS and be significantly retarded, relative to a control, in the acquisition of excitation. On this basis, only one of the five CS-US contingencies studied in this experiment generated an inhibitory CS. Only for Group 0-.8 was the CS shown both to weaken the CR to an excitatory stimulus and to be retarded in acquisition. It follows that contingencies such as 0-.1, .1-.8, .2-.8 and .6-.8 did not generate inhibitory CS, for while treatments 0-.1 and 0-.8 generated CSs that were retarded in acquisition, none of these treatments produced CSs which weakened the CR to a second excitatory CS.

These results raise serious doubts about the value of the summation procedure as an assessor of conditioned inhibition. Given that using the summation procedure it was necessary to pool data from a large number of Ss to assess conditioned inhibition following what must be assumed to be strong inhibitory conditioning (i.e., following a 0-.8 contingency), one might wonder how much data would be sufficient to allow assessment of conditioned inhibition in less inhibitory groups (e.g., 0-.1 or .1-.8). It appears that the sensitivity of the summation procedure can be questioned in earlier work (Rescorla, 1969b) as well. Rescorla's evaluation of his summation data is not overly detailed. He reports a significant overall analysis of variance, showing that the differences in disruption (i.e., the difference between suppression to the light-alone and to the light-plus-tone) among groups was significant, but fails to provide statistical results of comparisons between suppression to the two stimuli within <u>each</u> group. It may be that such comparisons would not be reliable if conducted. That is, Rescorla was not able to show that within a given group, the inhibitory CS significantly weakened the conditioned response to an excitatory CS. Essentially, the significant results he reports appear to depend upon the pooling of Ss, as was necessary in the present study.

It seems, then, that the summation procedure can be a weak device for measuring conditioned inhibition in a CER procedure. It may be appropriate, therefore, to reexamine the logic involved in requiring both a retardation and a summation procedure in assessing conditioned inhibition. Specifically, in a retardation test, it seems reasonable that a CS-alone procedure can control for the attentional factors which the summation test is used to assess. Lubow and Moore (1959) have shown that preexposure of a nonreinforced CS results in a phenomenon termed "latent inhibition" in which the repeatedly presented stimulus is more difficult to condition when subsequently reinforced than is a novel stimulus. A number of other studies have confirmed these results (Carlton and Vogel, 1967; Crowell and Anderson, 1972; Domjan and Siegel, 1971; May, Tolman and Schoenfeldt, 1967; Siegel, 1969). Rescorla (1971) has suggested that the retardation of subsequent excitatory conditioning may be due not to conditioned inhibition but to attentional factors or changes in the salience of the CS following preexposure. Rescorla has tested the nature of latent inhibition using both a retardation and summation procedure and has found that while the nonreinforced preexposure to a CS does retard subsequent acquisition, it does not cause the CS to interfere with the excitatory properties of a second stimulus when presented in compound with it. Further, Rescorla found that not only was excitatory conditioning retarded following preexposure, but so too was inhibitory conditioning. Presumably inhibitory conditioning would be facilitated if the preexposed CS did in fact have inhibitory properties. Rescorla concluded that the latent inhibition phenomenon is the result of reduced CS salience rather than true conditioned inhibition. Other studies appear to support this point of view (Reiss and Wagner, 1972; Lubow, 1973; Halgren, 1974).

Relative to the CS-alone control in a retardation test, significantly greater retardation in groups experiencing a negative CS-US contingency could be accounted for <u>attentionally</u> only by concluding that negative CS-US contingencies caused Ss to attend less to the CS than did a CS-alone procedure. It is possible to cite a number of studies, using what is essentially a summation technique, which demonstrate that a CS presented in the context of shocks, but signalling a period free of shock, is in fact attended to. For example, Rescorla and Lolordo (1965) reasoned that if avoidance were motivated by fear, then a conditioned inhibitor of fear should weaken it while a conditioned excitor should enhance it. They found that, when superimposed on avoidance responding, a CS- for shock depressed avoidance while a CS+ enhanced it. They further found that a stimulus which had been explicitly unpaired with shock in off-the-baseline conditioning likewise depressed avoidance behavior. Rescorla (1966), Moscovitch and Lolordo (1968), Grossen and Bolles, (1968), Bull and Overmeir (1968) and Weisman and Litner (1969) have similarly found that a CS which signals a shock-free period has the ability to depress ongoing avoidance behavior. Of particular interest is the fact that mere experience with the CS in the total absence of shock is not sufficient for the CS to gain any control over ongoing behavior, suggesting that such a CS is either a neutral stimulus or is not attended to (Rescorla & Lolordo, 1965). Hammond (1966) reported that a CS- for shock enhanced appetitive responding relative to a CS which had been presented in the total absence of shock and that a CS- for shock in compound with a CS+ disrupted suppression of ongoing barpressing (Hammond, 1967). Further, Hammond and Daniel (1970) have found that an explicitly unpaired CS facilitated appetitive responding when superimposed on the baseline and was subsequently retarded in acquisition of CER, thus demonstrating inhibitory properties in both summation and retardation procedures.

The available evidence indicates, then, that though both CS preexposure and CS- training may produce CSs which are subsequently retarded in acquisition, CS preexposure reduces CS salience while CS- training causes the CS to be attended to. Therefore, if a CS- is more retarded in acquisition than is a preexposed CS, it cannot be because the CS- is less attended to than is the preexposed CS. Rather, it must be because the CS- has acquired properties that actively oppose excitation. If, then, negative contingencies are found to significantly retard excitatory acquisition relative to a CS-alone control, one has strong evidence for conditioned inhibition in the negative contingency groups. (See Siegel and Domjan, 1971, for an experimental application of this reasoning.) In this case, a summation procedure would be unnecessary. If it is found that negative contingency and CS-alone procedures do not generate differences in acquisition, one need not assume that negative contingencies produce no inhibitory conditioning. Rather, both the CS-alone and negative contingency Ss may be equally retarded but for different reasons (i.e., the CS-alone Ss may be retarded because of attentional factors while the negative contingency Ss may be retarded because of conditioned inhibition). In this instance, a summation test may be necessary. If CS-alone and negative contingency training produce CSs which are actually retarded (i.e., relative to a naive control) and equally so, then a sensitive summation procedure would determine whether an attentional factor were able to account for retardation following negative contingency training. Should it be the case that a naive control is not included (i.e., the Ss acquire at the same rate, but it is not possible to know if they are actually retarded in acquisition) a summation procedure should be undertaken to determine the reason for any assumed retardation. Rescorla (1969c) states that "when attentional accounts seem plausible, it may be valuable to have information from both of these procedures [i.e., summation and retardation] for a stimulus thought to be a conditioned inhibitor" (p. 85). The above formulation appears to be consistent with this statement.

In the present study, Experiment 1, Group 0-0 conforms to the operational definition of a CS-alone group. Using this group as a control for attentional factors, it is concluded that some negative contingencies -- i.e., 0-.8, .1-.8 and 0-.1 -- led to the acquisition of inhibitory properties by the CS in question. Further, the addition of 6 CS-US pairings in the .1-.8 schedule did not disrupt inhibitory conditioning. However, it appears that the addition of a larger number of CS-US pairings in the .2-.8 schedule may have disrupted inhibitory conditioning to some extent, while the inclusion of an even larger number of pairings in the .6-.8 schedule appears to have disrupted inhibitory conditioning entirely. It is concluded that the .2-.8 and .6-.8 groups are not inhibitory. The CS-alone procedure is suggested as the most conservative measure against which to test conditioned inhibition in a retardation procedure. If there were any retardation due to attentional factors, it would be measured by such a control group. In the present experiment, the CS-alone control was not significantly retarded relative to the Naive group, suggesting that the experimental situation did not lend itself to the influence of attentional factors -- perhaps because of the delay between preexposure and testing, (Lubow, Markman, and Allen, 1968 -- but see Crowell and Anderson, 1972), or because preexposure took place in a stimulus setting different from that of testing (Dexter and Merrill, 1969 -- but see Anderson, O'Farrell, Formica, and Caponigri, 1969). If the 0-0 Group was not retarded then the .2-.8 and .6-.8 groups were not retarded and therefore were not inhibitory. Whether this would be due to factors suggested by Bolles (1970) and Denny (1971) or to a failure to adequately condition fear to non-CS cues (Rescorla and Wagner, 1972) is unclear. It does seem clear that the process of inhibitory conditioning is not symmetrical with the process of excitatory conditioning in that the parametric ordering of strength of conditioning possible with positive CS-US contingencies is not possible when dealing with negative contingencies. The failure to find inhibitory conditioning following some negative contingencies or the failure to find inhibitory conditioning in the predicted order might be due to the measurement of preasymptotic conditioning (Rescorla and Wagner, 1972). It must be noted very carefully, however, that Ss in this experiment received equal exposure to the given contingencies as did Ss in earlier studies (Rescorla, 1968 and 1969b). If the results of this experiment are preasymptotic, then it appears that asymptote is reached with less exposure to a positive contingency than to a negative contingency and that inhibitory conditioning is a slower -- or perhaps more "labile" (Pavlov, 1960, p. 99) -- process than excitatory conditioning.

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Appendix

Tables 1 - 17.

Comments on Tables:

These tables present the response data -- for each group in each experiment -- necessary to compute suppression ratios. Conditioned suppression to stimuli presentations was measured using the Annau-Kamin (1961) suppression ratio, D/(B+D). D denotes the number of responses during the CS (CS on the tables) and B the number in the two minutes before the CS (P-CS on the tables). Where an animal failed to respond in the two minutes before the CS, a suppression ratio for that trial was estimated from an average of the suppression ratios on the two nearest trials on the same day. Where data was lost due to equipment failure, suppression ratios were again estimated in the same way.

Table 1: Pre-CS and CS response rates in testing, Experiment 1, Group Naive.

		TRIAL 1		TRIAL 2		TRIAL 3		TRIAL 4	
DAY	SUBJ.	P-CS	CS	P-CS	CS	P-CS	CS	P-CS	CS
1	1	36	31	18	4	24	0	20	0
	2	97	84	87	78	75	76	71	80
	3	35	70	25	25	64	0	26	0
	4	68	36	85	85	86	2	66	25
	5	75	52	44	44	82	18	91	32
	6	35	22	31	31	25	31	22	21
2	1	31	0	17	6	33	0	27	0
	2	117	99	98	111	92	91	96	109
	3	36	0	40	2	41	5	35	12
	4	56	2	41	9	36	4	36	0
	5	55	1	82	52	55	17	43	15
	6	26	33	26	21	24	26	25	23
3	1	22	0	38	0	18	0	21	6
	2	79	91	98	73	104	123	127	87
	3	36	2	40	5	30	12	35	27
	4	49	1	56	1	63	0	39	3
	5	62	2	35	2	30	0	42	4
	6	30	14	27	14	18	9	25	28
4	1	39	1	22	0	13	0	13	5
	2	97	54	92	78	80	19	77	46
	3	52	3	58	25	63	15	36	17
	4	**	**	**	**	40	0	41	8
	5	59	1	52	2	40	5	62	12
	6	26	9	23	21	21	20	25	22
5	1	25	0	16	0	14	1	18	0
	2	103	42	101	10	132	15	73	10
	3	78	6	38	12	41	0	37	0
	4	63	2	53	0	53	4	62	1
	5	77	2	40	3	52	17	50	2
	6	24	16	32	24	26	18	20	23
6	1	19	0	25	11	23	10	22	1
	2	126	11	143	22	115	30	57	12
	3	66	2	38	4	54	7	44	8
	4	85	0	97	8	70	2	60	5
	5	56	1	60	1	40	2	62	1
	6	31	2	26	20	23	20	20	6

**Data lost due to equipment failure.

Table 2: Pre-CS and CS response rates in testing, Experiment 1, Group 0-0.

		TRIAL							
		1		2		3		4	
DAY	SUBJ.	P-CS	CS	P-CS	CS	P-CS	CS	P-CS	CS
1	1	26	36	20	17	10	17	10	8
	2	12	10	6	5	6	9	6	7
	3	10	8	50	11	18	16	6	15
	4	36	41	48	50	55	52	48	53
	5	137	122	114	103	98	90	111	91
	6	26	24	29	29	31	33	26	32
2	1	29	26	26	26	19	23	10	15
	2	8	5	5	5	1	1	2	1
	3	11	2	7	8	10	12	7	4
	4	64	63	71	61	52	51	57	29
	5	83	42	74	42	65	26	88	19
	6	35	32	33	24	20	24	24	22
3	1	33	21	38	19	18	24	26	31
	2	15	1	5	5	6	0	8	0
	3	13	2	14	7	8	0	11	2
	4	60	0	49	0	50	5	74	19
	5	98	21	92	28	100	37	91	67
	6	53	28	35	25	29	24	32	19
4	1	69	35	47	26	45	37	31	41
	2	14	0	3	0	5	0	4	3
	3	4	0	13	2	4	0	6	0
	4	**	**	**	**	46	0	51	2
	5	119	32	108	49	90	51	87	48
	6	52	23	43	33	34	27	28	25
5	1	32	26	20	12	33	18	14	17
	2	2	0	2	0	1	0	0	1
	3	5	4	4	0	5	1	8	0
	4	65	0	49	1	71	7	55	1
	5	140	29	129	37	132	43	134	39
	6	53	31	38	25	29	27	24	25
6	1	41	15	32	28	46	36	34	20
	2	2	0	2	0	2	0	1	0
	3	5	0	9	0	4	1	4	1
	4	77	0	78	7	75	7	53	14
	5	94	23	134	67	134	100	140	68
	6	33	34	55	38	36	30	35	24

**Data lost due to equipment failure.

Table 3: Pre-CS and CS response rates in testing, Experiment 1, Group 0-.1.

		TRIAL							
		1		2		3		4	
DAY	SUBJ.	P-CS	CS	P-CS	CS	P-CS	CS	P-CS	CS
1	1	29	19	29	17	31	29	22	15
	2	17	18	17	13	12	5	10	6
	3	47	44	43	53	56	52	57	49
	4	210	143	103	93	110	76	84	86
	5	33	20	29	22	31	26	36	37
	6	10	10	23	16	26	23	18	17
2	1	34	20	31	13	17	18	29	35
	2	102	73	76	104	112	96	71	68
	3	71	73	53	47	60	50	39	44
	4	107	61	58	44	83	82	57	118
	5	39	46	35	38	49	30	37	38
	6	28	21	22	23	24	27	25	28
3	1	22	12	15	16	29	27	26	31
	2	86	49	59	66	81	92	102	77
	3	58	64	69	75	56	56	57	53
	4	103	75	88	64	150	81	106	90
	5	51	29	52	55	37	50	46	43
	6	15	12	28	7	15	5	43	13
4	1	28	8	35	38	32	26	34	37
	2	74	54	66	71	70	55	70	66
	3	76	65	57	71	58	45	63	43
	4	**	**	**	**	88	100	141	102
	5	41	51	41	34	44	45	40	55
	6	19	2	28	7	21	2	24	6
5	1	32	18	35	31	47	36	42	35
	2	64	70	58	60	14	20	17	16
	3	83	59	86	20	79	34	56	37
	4	191	95	183	161	163	135	183	94
	5	64	46	74	39	49	41	46	52
	6	29	2	13	0	11	2	7	0
6	1	46	21	43	39	40	53	52	51
	2	64	44	64	52	63	69	61	55
	3	59	22	57	62	42	26	33	15
	4	184	117	167	105	147	99	199	79
	5	59	60	54	45	55	72	63	40
	6	15	1	5	0	7	1	9	3

**Data lost due to equipment failure.

Table 4: Pre-CS and CS response rates in testing, Experiment 1, Group 0-.8.

		TRIAL							
		1		2		3		4	
DAY	SUBJ.	P-CS	CS	P-CS	CS	P-CS	CS	P-CS	CS
1	1	14	5	5	8	6	3	6	2
	2	14	8	4	2	18	8	7	5
	3	5	26	15	22	12	7	8	14
	4	112	88	89	71	91	90	99	86
	5	25	26	27	16	17	12	14	8
	6	56	45	38	43	44	48	33	38
2	1	3	5	6	8	7	5	6	3
	2	7	14	8	13	6	3	1	7
	3	21	11	6	8	6	13	14	11
	4	127	123	146	106	124	56	141	66
	5	39	40	20	22	22	19	12	14
	6	66	61	22	42	52	30	55	23
3	1	6	4	0	7	5	9	2	8
	2	14	16	8	9	8	5	1	0
	3	6	14	9	5	7	10	7	11
	4	90	27	142	66	128	66	151	70
	5	32	46	38	22	36	33	34	16
	6	68	20	64	36	83	40	58	36
4	1	1	8	0	5	7	14	3	4
	2	12	10	10	19	22	16	13	17
	3	14	5	6	1	6	5	2	2
	4	**	**	**	**	60	0	109	6
	5	55	13	42	45	37	27	35	29
	6	79	31	78	48	72	54	59	46
5	1	5	12	4	3	5	3	0	12
	2	13	6	17	20	20	13	11	9
	3	9	0	4	0	6	0	2	0
	4	80	2	69	0	75	13	135	39
	5	46	10	42	19	33	16	39	24
	6	99	45	90	22	78	17	80	9
6	1	3	16	2	10	4	6	0	13
	2	6	17	7	12	28	28	10	7
	3	4	1	7	0	10	6	18	12
	4	111	28	135	45	104	51	96	39
	5	49	8	48	24	30	39	18	9
	6	99	16	103	36	127	49	89	18

**Data lost due to equioment failure.

Table 5: Pre-CS and CS response rates in testing, Experiment 1, Group .1-.8.

		TRIAL							
		1		2		3		4	
DAY	SUBJ.	P-CS	CS	P-CS	CS	P-CS	CS	P-CS	CS
1	1	25	48	38	21	22	30	33	29
	2	16	22	20	11	10	13	8	13
	3	14	15	16	26	14	19	15	16
	4	50	52	42	35	47	33	44	40
	5	68	51	36	37	39	39	48	47
	6	28	24	27	33	16	22	16	18
2	1	27	20	13	18	31	33	10	14
	2	27	33	22	38	15	25	17	18
	3	8	5	5	4	0	7	5	7
	4	63	67	66	49	53	65	57	65
	5	40	28	46	41	37	32	30	27
	6	18	24	27	38	26	34	33	34
3	1	9	5	3	5	17	2	15	14
	2	32	24	18	30	22	29	9	19
	3	4	6	11	8	13	11	10	14
	4	51	48	49	40	70	62	57	55
	5	36	32	32	26	30	34	19	22
	6	8	14	33	36	23	20	23	33
4	1	22	1	10	4	7	3	7	3
	2	24	30	13	18	10	11	4	16
	3	10	9	10	0	7	5	3	6
	4	**	**	**	**	26	25	80	57
	5	56	13	42	18	42	6	33	24
	6	26	20	17	26	21	19	24	30
5	1	10	6	6	3	9	4	8	0
	2	28	19	22	28	12	27	5	18
	3	15	1	6	2	23	2	13	1
	4	43	24	78	65	97	65	65	42
	5	8	4	17	11	43	10	41	13
	6	16	5	12	10	21	21	27	7
6	1	15	0	13	4	8	1	4	0
	2	37	18	32	27	20	22	18	13
	3	25	1	10	2	8	5	6	5
	4	57	16	55	29	57	16	39	22
	5	59	7	51	17	53	19	32	17
	6	20	9	31	25	28	23	24	17

**Data lost due to equipment failure.

Table 6: Pre-CS and CS response rates in testing, Experiment 1, Group .2-.8.

		TRIAL							
		1		2		3		4	
DAY	SUBJ.	P-CS	CS	P-CS	CS	P-CS	CS	P-CS	CS
1	1	39	36	32	26	30	26	27	19
	2	18	12	17	13	12	5	10	6
	3	15	12	15	12	12	3	16	2
	4	183	165	184	92	76	133	159	137
	5	19	20	29	23	33	22	24	24
	6	100	106	134	132	104	100	82	85
2	1	53	39	39	33	33	37	26	20
	2	18	17	5	4	10	4	2	10
	3	23	3	8	5	18	4	12	4
	4	197	168	193	136	169	143	161	139
	5	23	21	27	20	24	21	28	11
	6	102	95	116	140	130	141	104	93
3	1	57	4	30	8	31	11	8	3
	2	7	1	14	8	13	12	6	6
	3	29	1	26	1	33	4	11	8
	4	157	182	136	127	124	152	148	162
	5	29	18	25	13	24	17	39	21
	6	101	56	86	71	94	63	109	87
4	1	32	2	14	2	10	7	4	6
	2	18	26	27	26	28	33	12	17
	3	35	6	51	20	41	3	27	15
	4	**	**	**	**	170	172	132	99
	5	29	10	22	14	25	17	24	24
	6	103	5	83	54	115	26	86	29
5	1	30	6	18	3	5	1	1	0
	2	21	14	13	22	14	20	17	16
	3	35	0	37	26	20	2	15	1
	4	193	193	113	157	212	159	175	137
	5	25	1	29	5	39	9	29	7
	6	97	1	84	7	100	5	98	3
6	1	4	1	16	1	6	0	5	0
	2	22	39	19	22	18	14	12	18
	3	27	3	14	2	23	14	20	4
	4	156	110	112	148	118	102	153	121
	5	26	1	22	14	25	14	24	10
	6	100	1	107	12	171	118	132	25

**Data lost due to equipment failure.

Table 7: Pre-CS and CS response rates in testing, Experiment 1, Group .6-.8.

		TRIAL							
		1		2		3		4	
DAY	SUBJ.	P-CS	CS	P-CS	CS	P-CS	CS	P-CS	CS
1	1	32	55	52	45	63	46	43	47
	2	25	23	20	21	29	2	24	12
	3	37	53	44	35	42	7	41	4
	4	12	9	7	12	9	9	15	11
	5	39	47	37	38	48	48	45	37
	6	53	61	61	48	60	50	62	43
2	1	49	39	70	68	72	69	76	97
	2	20	7	18	6	29	2	24	3
	3	65	1	67	2	43	5	47	2
	4	13	4	11	12	18	6	17	2
	5	50	51	60	52	44	47	40	36
	6	67	50	67	66	62	32	53	5
3	1	73	76	86	71	57	72	65	90
	2	16	1	23	4	24	0	28	2
	3	65	0	39	0	44	2	30	3
	4	10	4	14	0	12	1	12	5
	5	69	50	59	43	45	46	31	23
	6	72	4	59	4	62	50	67	62
4	1	60	52	47	57	30	22	48	43
	2	25	0	23	5	23	0	27	1
	3	49	1	41	1	34	3	43	1
	4	**	**	**	**	14	0	21	0
	5	50	24	52	50	49	1	36	28
	6	85	0	70	14	66	0	88	13
5	1	58	37	62	33	62	38	81	18
	2	25	1	27	2	20	4	26	0
	3	66	1	55	2	54	3	43	1
	4	20	0	18	1	18	3	15	0
	5	67	14	65	4	55	17	29	3
	6	72	1	68	0	74	0	75	0
6	1	62	4	36	26	41	66	55	33
	2	30	0	25	0	21	0	18	0
	3	54	2	64	2	44	7	50	3
	4	24	0	16	0	13	4	8	2
	5	69	11	81	41	87	44	77	33
	6	72	3	74	4	62	18	59	8

**Data lost due to equipment failure.

Table 8: Pre-CS and CS response rates in testing, Experiment 2, Group Naive.

		TRIAL*							
		1		2		3		4	
DAY	SUBJ.	P-CS	CS	P-CS	CS	P-CS	CS	P-CS	CS
1	1	52	23	60	17	58	30	48	28
	2	45	1	38	0	31	16	24	15
	3	32	2	29	0	40	6	43	18
	4	23	3	27	14	17	10	26	14
	5	64	6	59	18	56	16	62	15
	6	45	3	48	5	33	19	53	27
2	1	54	32	62	48	43	20	59	37
	2	27	21	28	16	29	13	24	20
	3	57	28	45	19	59	25	74	58
	4	25	12	22	15	21	9	16	15
	5	67	12	61	28	62	25	62	32
	6	37	10	39	13	42	11	35	17

*Trial # represents order of presentation. On Day 1 the stimuli were:Light-alone, light-plus-tone, light-plus-tone, light-alone. On Day 2 the stimuli were:Light-plus-tone, light-alone, light-alone, light-plus-tone.

Table 9: Pre-CS and CS response rates in testing, Experiment 2, Group 0-0.

		TRIAL*							
		1		2		3		4	
DAY	SUBJ.	P-CS	CS	P-CS	CS	P-CS	CS	P-CS	CS
1	1	17	12	21	18	8	16	10	12
	2	40	6	34	12	38	23	30	27
	3	35	5	12	3	15	20	20	27
	4	56	0	59	3	62	1	46	12
	5	49	4	31	9	45	13	35	14
	6	24	1	14	0	16	0	14	2
2	1	15	13	22	20	24	28	20	23
	2	31	33	37	25	17	28	30	25
	3	23	15	20	26	22	25	35	39
	4	45	1	46	17	39	15	41	21
	5	34	12	24	13	30	10	15	13
	6	15	1	13	1	16	2	8	2

*Trial # represents order of presentation. On Day 1 the stimuli were:Light-alone, light-plus-tone, light-plus-tone, light-alone. On Day 2 the stimuli were:Light-plus-tone, light-alone, light-alone, light-plus-tone.

Table 10: Pre-CS and CS response rates in testing, Experiment 2, Group 0-.1.

		TRIAL*							
		1		2		3		4	
DAY	SUBJ.	P-CS	CS	P-CS	CS	P-CS	CS	P-CS	CS
1	1	52	7	64	11	44	19	43	11
	2	49	8	46	12	39	25	34	20
	3	25	0	37	5	26	11	31	17
	4	34	0	38	2	46	14	37	30
	5	27	1	20	8	17	5	3	4
	6	21	5	15	7	18	8	15	9
2	1	64	0	50	8	45	24	43	35
	2	61	11	43	14	50	20	45	36
	3	34	3	32	19	34	15	33	18
	4	24	31	36	32	51	32	43	24
	5	13	6	15	8	10	7	10	10
	6	26	7	19	10	28	18	27	10

*Trial # represents order of presentation. On Day 1 the stimuli were:Light-alone, light-plus-tone, light-plus-tone, light-alone. On Day 2 the stimuli were:Light-plus-tone, light-alone, light-alone, light-plus-tone.

Table 11: Pre-CS and CS response rates in testing, Experiment 2, Group 0-.8.

		TRIAL*							
		1		2		3		4	
DAY	SUBJ.	P-CS	CS	P-CS	CS	P-CS	CS	P-CS	CS
1	1	14	16	26	24	15	22	22	9
	2	38	35	31	34	41	27	45	46
	3	94	2	109	47	62	45	61	27
	4	41	0	44	0	41	1	43	1
	5	23	0	57	13	57	26	67	17
	6	33	15	59	38	51	42	51	29
2	1	8	2	19	8	25	32	16	16
	2	58	49	57	57	55	34	30	45
	3	75	35	55	39	56	32	45	31
	4	41	2	46	3	35	9	43	7
	5	31	14	44	29	42	18	63	26
	6	40	35	46	62	48	50	48	69

*Trial # represents order of presentation. On Day 1 the stimuli were:Light-alone, light-plus-tone, light-plus-tone, light-alone. On Day 2 the stimuli were:Light-plus-tone, light-alone, light-alone, light-plus-tone.

Table 12: Pre-CS and CS response rates in testing, Experiment 2, Group .1-.8.

		TRIAL*							
		1		2		3		4	
DAY	SUBJ.	P-CS	CS	P-CS	CS	P-CS	CS	P-CS	CS
1	1	21	13	28	11	22	19	20	13
	2	38	3	40	1	34	15	49	24
	3	23	1	27	9	23	14	23	15
	4	41	1	36	0	18	2	35	1
	5	71	0	74	15	92	11	103	27
	6	30	0	25	1	30	1	26	1
2	1	27	21	33	18	31	25	31	14
	2	51	6	28	15	29	17	23	18
	3	21	9	29	22	14	13	18	17
	4	38	3	27	0	15	1	23	2
	5	36	39	43	49	72	26	64	19
	6	41	0	27	3	40	8	29	15

*Trial # represents order of presentation. On Day 1 the stimuli were:Light-alone, light-plus-tone, light-plus-tone, light-alone. On Day 2 the stimuli were:Light-plus-tone, light-alone, light-alone, light-plus-tone.

Table 13: Pre-CS and CS response rates in testing, Experiment 2, Group .2-.8.

		TRIAL*							
		1		2		3		4	
DAY	SUBJ.	P-CS	CS	P-CS	CS	P-CS	CS	P-CS	CS
1	1	23	0	26	16	22	23	22	19
	2	35	3	25	4	27	13	23	14
	3	46	0	49	5	57	33	39	39
	4	32	1	20	0	32	4	22	6
	5	27	5	41	3	26	12	22	17
	6	78	3	46	1	67	0	74	3
2	1	24	8	24	16	31	36	20	28
	2	32	8	28	18	24	16	24	21
	3	66	51	47	43	26	37	28	32
	4	24	6	25	26	23	14	16	12
	5	18	6	30	16	11	10	22	29
	6	80	1	70	2	68	8	57	7

*Trial # represents order of presentation. On Day 1 the stimuli were:Light-alone, light-plus-tone, light-plus-tone, light-alone. On Day 2 the stimuli were:Light-plus-tone, light-alone, light-alone, light-plus-tone.

Table 14: Pre-CS and CS response rates in testing, Experiment 2, Group .6-.8.

		TRIAL*							
		1		2		3		4	
DAY	SUBJ.	P-CS	CS	P-CS	CS	P-CS	CS	P-CS	CS
1	1	29	20	38	29	53	40	57	45
	2	22	0	22	2	12	5	6	5
	3	33	0	41	0	39	16	28	15
	4	35	0	26	0	28	0	17	7
	5	45	0	53	2	43	5	43	22
	6	34	0	37	0	28	0	29	2
2	1	35	32	42	44	56	40	51	32
	2	33	12	31	7	30	8	36	11
	3	31	4	19	15	19	21	11	18
	4	27	1	23	9	15	14	22	11
	5	43	3	42	14	44	32	44	19
	6	36	0	41	0	31	0	33	0

*Trial # represents order of presentation. On Day 1 the stimuli were:Light-alone, light-plus-tone, light-plus-tone, light-alone. On Day 2 the stimuli were:light-plus-tone, light-alone, light-alone, light-plus-tone.

Table 15: Pre-CS and CS response rates in testing, Experiment 3, Group A.

		TRIAL*							
		1		2		3		4	
DAY	SUBJ.	P-CS	CS	P-CS	CS	P-CS	CS	P-CS	CS
1	1	10	0	5	2	8	3	11	4
	2	72	1	70	10	48	29	49	39
	3	96	5	87	32	55	20	58	26
	4	47	0	50	9	34	8	37	17
	5	44	1	38	3	38	10	38	2
	6	34	4	23	29	34	36	52	38
2	1	13	0	1	2	9	1	9	2
	2	68	32	44	26	57	33	60	41
	3	153	70	99	35	46	18	126	51
	4	68	42	65	19	49	25	63	43
	5	44	4	33	8	35	11	33	14
	6	29	29	36	30	45	33	59	43

*Trial # represents order of presentation. On Day 1 the stimuli were:Light-alone, light-plus-tone, light-plus-tone, light-alone. On Day 2 the stimuli were:Light-plus-tone, light-alone, light-alone, light-plus-tone.

Table 16: Pre-CS and CS response rates in testing, Experiment 3, Group B.

		TRIAL*							
		1		2		3		4	
DAY	SUBJ.	P-CS	CS	P-CS	CS	P-CS	CS	P-CS	CS
1	1	90	1	73	25	94	38	61	39
	2	39	0	36	6	39	24	29	0
	3	52	8	28	31	49	29	56	28
	4	29	0	19	0	17	0	17	0
	5	58	20	46	32	38	32	40	19
	6	68	1	37	8	44	9	43	0
2	1	57	35	90	40	80	58	58	60
	2	33	1	29	0	24	3	33	18
	3	49	39	61	47	104	66	60	49
	4	32	0	41	1	41	0	35	2
	5	47	38	39	15	34	18	25	14
	6	49	9	32	21	25	17	32	41

*Trial # represents order pf presentation. On Day 1 the stimuli were:Light-alone, light-plus-tone, light-plus-tone, light-alone. On Day 2 the stimuli were:Light-plus-tone, light-alone, light-alone, light-plus-tone.

Table 17: Pre-CS and CS response rates in testing, Experiment 3, Group C.

		TRIAL*							
		1		2		3		4	
DAY	SUBJ.	P-CS	CS	P-CS	CS	P-CS	CS	P-CS	CS
1	1	4	0	38	25	54	31	61	36
	2	126	5	121	13	99	48	88	31
	3	12	2	11	6	15	9	10	5
	4	58	2	48	14	34	16	22	11
	5	113	37	81	53	116	68	93	68
	6	33	17	62	33	45	30	46	25
2	1	58	40	36	28	52	39	34	43
	2	75	94	138	49	121	95	120	35
	3	12	6	11	7	13	27	14	15
	4	43	7	28	16	35	14	20	15
	5	121	102	120	86	92	42	44	22
	6	61	30	59	42	59	42	66	45

*Trial # represents order of presentation. On Day 1 the stimuli were:Light-alone, light-plus-tone, light-plus-tone, light-alone. On Day 2 the stimuli were:Light-plus-tone, light-alone, light-alone, light-plus-tone.