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CHANGES IN EFFECTIVE REINFORCEMENT VALUE AS A FUNCTION OF PRIOR CONDITIONING

by

©THEODORE D. WEIDER

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "Change in Effective Reinforcement Value as a Function of Prior Conditioning" submitted by THEODORE D. WEIDEN in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

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ABSTRACT

Acquisition of an aversively reinforced conditioned suppression response to the components of a compound CS, tone plus light, was assessed under conditions in which the prior reinforcement histories of the components differed. In Experiment I, two aversive USs (loud noise and foot shock) differing in modality but matched in reinforcement value were used in a two phase single- to compound CS conditioned suppression transfer task. For Group T, the modality of the US used in the first phase differed from that used in the second. For Group B, the modality of the US remained the same between phases. For Group C, the single CS conditioning phase was omitted. Results revealed that prior conditioning of the foot shock to one of the components of the compound CS reduced or blocked the other, added or redundant, component from acquiring the conditioned suppression response in Groups T and B. However, when loud noise was used in the first phase of conditioning, blocking of the added CS component was only observed in Group B.

In Experiment II, the transfer condition of Experiment I, Group T, was essentially replicated except that fewer conditioned suppression training trials were given in the first phase of conditioning in an effort to determine whether the directional effect noted in Experiment I was the result of habituation of the noise US during the extended training trials administered during the first phase of conditioning in that experiment. Results were consistent with those of Experiment I, Group T, when foot shock was used in the prior conditioning procedure. Secondly, when noise was used blocking of the added CS component was substantial, indicating that habituation of the noise US may have

accounted for the threshold effect noted in Experiment I. These results suggest that changes in the potency as opposed to the quality of the US are important in reinstating the associative process in a conditioned suppression transfer task.

In Experiment III acquisition of an aversively reinforced conditioned suppression response to a neutral stimulus, X, was assessed when that stimulus was placed in compound with a discriminative stimulus (S^D) which had an associative history involving appetitive reinforcement. The results of this study failed to show that acquisition to the X component was influenced to any marked degree by the presence of the S^D, and vice versa. This conclusion was based upon comparisons of the level of acquisition of the conditioned suppression response to control subjects who were conditioned to either X or S^D alone.

A second finding was that the X component when placed in compound with an S^D failed to acquire S^D properties during the conditioning phase of the experiment even though compounding and reinforcing conditions favored it. Thus, it appears that a stimulus can fall victim to blocking in one of two simultaneously reinforced tasks (the S^D-S^Δ task) but acquire associative strength in the other (the conditioned suppression task).

Results of these experiments were viewed as being consistent with a noninformational interpretation of conditioning in accordance with the Rescorla and Wagner model.

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Background

A robust and intriguing phenomenon in conditioning was recently revitalized by Kamin (1968; 1969) who observed that following conditioned suppression training to a compound conditioned stimulus (CS), AX, the ability of the X component to suppress behavior when tested alone was related to whether or not the A component had received prior conditioned suppression training. More specifically, in a group of rats not conditioned to the A component prior to the compound CS conditioning trials, the X component when presented alone was clearly as effective in suppressing ongoing behavior as the A component. However, in a group that received prior conditioning to the A component, the X component was found to be ineffective in suppressing behavior. Thus, prior conditioning of the A component appeared to prevent or "block" the X component from acquiring the conditioned suppression response during the compound CS conditioning trials. Following Kamin (1968) this observation will be called the blocking effect.

Although a similar effect had been observed in animal discrimination learning using a variety of go/no go tasks (see Lashley, 1942; 1970; Mackintosh, 1965; Sutherland & Holgate, 1966; Johnson, 1970; Miles, 1970; vom Saal & Jenkins, 1970), Kamin's extension of this effect to an essentially classical conditioning task, conditioned suppression, was particularly important for it served to highlight the enigma presented by this basic observation for traditional learning theory, that is, that a stimulus presented in temporal contiguity with a reinforcer can apparently be prevented from acquiring associative strength if another stimulus previously associated with that reinforcer is presented at the same time. Moreover, the extensions of this effect to a conditioning task in which reinforcement is programmed independent of responding eliminated the need to provide elaborate controls necessary in ruling out effects due to unequal distributions of "correct" and "incorrect" responding during the prior and subsequent compound conditioning phases of the training procedure.

Although explanation of the blocking effect in the animal discrimination literature had typically been cast in terms of attentional concepts (see Sutherland & Mackintosh, 1971, for an extensive review of this literature), Kamin proposed the hypothesis that blocking results from the fact that the unconditioned stimulus (US) loses its ability to function as a reinforcer in the presence of a CS which has previously been paired with it. This concept, that the effectiveness of a reinforcer is relative and that its effectiveness may be anchored in some manner to the degree to which the CS has become associated with it, was subsequently seen to provide the cornerstone of perhaps the most influential model of conditioning that has been advanced in recent years (e.g., Rescorla & Wagner, 1972; Wagner & Rescorla, 1972). Not only has the Rescorla and Wagner model of conditioning been shown to be capable of accounting for most if not all of the findings regarding the blocking effect reported by Kamin, it is also purported to account for such diverse conditioning phenomena as [illegible], conditioned inhibition, the learning of contingencies, and extinction during continued reinforcement to name but a few (see Rescorla, 1972; Rescorla & Wagner, 1972; Wagner, 1971; Wagner & Rescorla, 1972, for reviews of this literature).

The concept of relative reinforcement value was initially posed in informational terms by Kamin, and in quasi informational terms by Rescorla and Wagner. However, Rescorla (1972) has recently advanced the argument that the assumption that a CS provides "information" regarding upcoming events is not a necessary concept in their model and that the assumption has in fact outlived its usefulness. It is this issue that the present research was designed to address.

The following is a review of the findings most relevant to this issue. Accompanying this review will be a discussion of the attempts of Kamin and Rescorla and Wagner to account for these findings in informational or quasi informational terms along with Rescorla's noninformational interpretation.

Theoretical Issues

As a result of his work on the blocking effect, Kamin (1968; 1969) hypothesized that associations only seem to be formed when the US is to some degree "surprising;" that is, when its occurrence is not already predicted by other stimulus events. Thus, when element A of a compound CS, AX, predicts the occurrence of the US as a result of prior conditioning, the effectiveness of the US to act as a reinforcer is diminished and conditioning to the X component is therefore precluded or blocked.

This hypothesis is based on a number of experimental manipulations (Kamin, 1968, 1969). However, the outcome of three of these procedures is most relevant to the issue at hand. In the first case, the level of conditioning established to the A component during the prior conditioning phase of the basic blocking procedure was manipulated in an effort to change the degree to which the CS would produce suppression during the initial stages of the compound CS conditioning phase. In the second and third cases, the US event itself was changed between conditioning phases so that its occurrence during the compound CS conditioning phase would presumably be surprising.

In the first case, Kamin found that if prior conditioning of the A component was less than asymptotic before the compound CS conditioning phase, blocking of the X component was reduced proportionally. In the second case, when the intensity of the US, a brief electric shock to the feet, was increased from 1 mA to 4 mA between conditioning phases, blocking was found to be markedly reduced even though control groups receiving either a 1 mA or a 4 mA shock throughout did display the blocking effect. Thirdly, when a second unpredicted US of equal intensity was delivered 5 sec after the original US during the compound CS conditioning phase, blocking was again disrupted. In each instance, it was argued that blocking was disrupted because the occurrence of the US during the compound CS conditioning phase was in some sense surprising to the subject. On the other hand, under conditions in which the US event was not considered to be surprising, blocking was found to occur.

Starting from the same basic concept, that the effectiveness of a US to function as a reinforcer is decreased in a manner proportional to its predictability, Rescorla and Wagner (Rescorla & Wagner, 1972; Wagner, & Rescorla, 1972) hypothesized that the effective reinforcement value of a US is directly related to the difference between the amount of associative strength potentially capable of being supported by the US and the amount of associative strength actively involved in predicting or "signaling" its occurrence on any given occasion. Although the above sentence relays the essence of the hypothesis underlying Rescorla's and Wagner's model, the following quotation and now familiar equations present a more complete description of how their model accounts for differential changes in associative strength when two stimulus elements are involved.

> Consider a situation in which a compound stimulus, AX, is followed by a given reinforcer, US_1. The equations below describe the theoretical change in conditioning to the component stimuli, A and X, as a result of a single such trial. V_A represents the associative strength, or amount of conditioning to A, and is presumed to be monotonically related to such dependent measures as probability of response or latency of response.
>
> $$\Delta V_A = \alpha_A \beta_1 (\lambda_1 - V_{AX})$$
>
> $$\Delta V_X = \alpha_X \beta_1 (\lambda_1 - V_{AX})$$
>
> The parameter λ_1 represents the asymptote of conditioning supportable by the applied US_1; it is US-dependent and is subscripted to indicate that. The α and β are learning-rate parameters dependent, respectively, upon the qualities of the CS and the US. (Rescorla, 1972, p.11)

It should be noted that for present purposes the term V_{AX} in the above equations is assumed to be equal to the algebraic sum of V_A and V_X;

that is, $V_{AX} = V_A + V_X$ (Rescorla, 1972). Secondly, a special condition of this model is that when V_{AX} is greater than λ, negative associative strength is acquired.

This model accounts for the blocking data presented above in the following manner. When stimulus A, because of prior conditioning, engages all the potential associative strength that the US is capable of reinforcing ($\lambda - V_A = 0$), further increments in associative strength to either of the components will be reduced to zero during the compound CS conditioning phase. Conversely, when V_{AX} is less than λ at the beginning of the compound CS conditioning phase, either because prior conditioning to the A component was less than asymptotic or because the reinforcer used during the compound CS conditioning phase (US_2) was changed from that used during the prior conditioning phase (US_1) so that λ_2 is greater than λ_1, increments in associative strength to the components will be greater than zero. Thus, corresponding to the findings reported by Kamin cited above, degree of blocking is correctly predicted in the first instance and disruptions in blocking are correctly predicted in the second and third instances.

The difference between Kamin's notion of the relative effectiveness of reinforcement and that of Rescorla and Wagner's centers around the reasons each theorist gives for why the effectiveness of a reinforcer is reduced under conditions of prediction. For Kamin, it is as if the processing of information relevant to an event of some significance to the animal is halted once the occurrence of that event is fully predicted. On the other hand, if some aspect of the event is changed, say for instance the addition of a second US shortly after the first, It is as if the processing of information relevant to that event has been removed. For example, in accounting for the apparent ineffectiveness of a predicted US in reinforcing conditioning, Kamin (1969) suggests that perhaps such a state of affairs "strips" the US of its ability "of instigating some 'processing' of the memory store of recent stimulus input, which results in the formation of an association (p.63)."

In some respects the issue is less clear in Rescorla and Wagner's model. Although it is clear that further conditioning is blocked under predicted conditions in their model because in predicting that event the CS has accounted for all of the associative strength that the US is capable of supporting, it is not clear to what degree this process is dependent upon information as such. In their theorizing, for instance, the V value of a stimulus is often referred to as the amount of "signal value" that a stimulus has acquired. Moreover, the use of the terms "predicted" and "unpredicted" in relation to the occurrence of the US leads one to believe that they too are working within a theoretical framework that involves expectancies and information.

This issue has recently been addressed by Rescorla (1972). In that article, Rescorla took exception to the information-like language used in earlier versions of the Rescorla and Wagner model, and suggested that the V value of a stimulus should not be thought of as the degree to which a stimulus signals or predicts an upcoming event. Rather, it should be thought of as merely the amount of associative strength or conditioning that has accrued to a given stimulus. Thus, the degree to which information about the US is available to the animal as a result of some "signaling" processes is not considered to be a critical concept in the model. Rescorla then reviewed the relatively limited body of literature that has been reported to indicate that information relevant to the upcoming US is important in conditioning and proceeded to show that the model could adequately account for the data in each of the instances where the findings had been found to be replicable. Noteably, these were the experiments by (1) Rescorla (1966, 1967) which showed that animals appear to learn "contingency" relationships between CS and US events, (2) those by Wagner (1969a; 1969b) which showed that animals appear to learn the "validity" of a CS for forecasting upcoming US events, as well as (3) those by Kamin (1968, 1969) regarding the blocking effect.

The following is a review of recent findings which bear on the issue of change in effective reinforcement value as a function of prior conditioning. Reports of findings which tend to favor Kamin's informational interpretation will be presented first. These will be followed by reports favoring Rescorla's noninformational interpretation.

Recent Empirical Investigations

Wagner, Rudy and Whitlow (1973) have reported a series of experiments interpreted as supporting Kamin's hypothesis that "unexpected" or "surprising" CS-US episodes promote learning by instigating some processing of the memory store; a process which is assumed to be necessary for associative learning. Kamin (1969) suggested the term "retrospective-contemplation" as referring to the process generated by a surprising event. Wagner et al. (1973) have suggested the term "rehearsal" to refer to the same process in an effort to underline the similarity of this concept with recent theorizing in the human memory literature (see Atkinson & Wickens, 1971). Associative learning is viewed by these researchers to be the result of subject engaging in the rehearsal of events occurring in the just recent past. Since rehearsal is seen to be instigated by unexpected events, the occurrence of a US that is already predicted by a CS, or CS component, will not command rehearsal. As a consequence, further associative learning involving the CS US episode will be curtailed; a condition which is presumed to account for the blocking effect. In addition to these basic assumptions, Wagner et al. have incorporated a further assumption common to the human memory literature. This is the assumption that due to limitations in processing capacity, the rehearsal of one CS-US episode can be disrupted by the subsequent occurrence of a second episode that also commands rehearsal.

In order to test these assumptions within an animal conditioning paradigm, Wagner et al. (1973) assessed the rate of acquisition of eyelid conditioning in rabbits under conditions in which the target CS-US episode was followed 10 sec later by a second CS-US episode. In some conditions, the second CS-US episode was designed to be "incongruent" with the subjects' prior conditioning history and in others it was designed to be "congruent." The hypothesis tested was whether incongruent as opposed to congruent episodes would disrupt rehearsal of the target CS-US episode.

The data clearly revealed that rate of acquisition of the target CS-US episode was reduced when followed by a second CS-US episode that was incongruent as opposed to congruent with the animals prior conditioning history. These findings were interpreted to indicate that incongruent episodes (that is, unexpected or surprising events) command rehearsal in their own right and therefore disrupt rehearsal of the target CS-US episode, whereas congruent episodes do not. Secondly, these findings indicate that rehearsal is necessary for associative learning since presumed disruptions in the rehearsal of the target CS-US episode reduced its rate of acquisition. Thus, new learning can be retarded by disrupting its rehearsal, and the rehearsal of a target CS-US episode can be disrupted by the subsequent occurrence of an unexpected or surprising event which, by commanding rehearsal in its own right, competes with the rehearsal process of the target episode.

In addition to pointing to the importance of "rehearsal" in the acquisition of associative learning in nonhuman subjects, the findings of Wagner et al. (1973) are consistent with Kamin's (1969) hypothesis that unexpected (or incongruent) CS-US episodes command some special processing (rehearsal) necessary for associative learning, whereas expected (or congruent) episodes do not. However, what remains unclear is whether disruptions in blocking (or the reinstatement of rehearsal) result from the occurrence of US events that merely occasion "surprise" on one hand (e.g., Kamin, 1969), or represent a change in reinforcement magnitude on the other (e.g., Rescorla, 1972).

A study that purports to address this issue has recently been reported by Gray and Appignanesi (1973). In that study blocking of a conditioned suppression response was found to be disrupted when a brief, .30 sec, unpredicted exposure of the same stimulus elements that served as the CS in the conditioned suppression task were presented shortly after the US during the compound CS conditioning phase of the basic blocking procedure. In addition, it was found that post-US presentations were only disruptive of blocking when they occurred 5 sec or less after the US. When the post-US event occurred 10 sec after the US, blocking was not noticeably disrupted. Following Kamin, Gray and Appignanesi argued that blocking was disrupted under these conditions because the occurrence of the unpredicted, surprise stimulus somehow caused the subject to "...reassess the significance of the preceding compound CS (Gray & Appignanesi, 1973, p.379)."

Although this study differs in a number of ways from that of Wagner et al. (1973), the post-US event in Gray and Appignanesi's study is similar in many respects to what Wagner et al. termed an "incongruent" CS-US episode. However, interpreting Gray and Appignanesi's study in this manner tends to make their findings somewhat confusing since the occurrence of an incongruent episode shortly after the target compound-CS conditioning trials should have served to further disrupt rather than promote the acquisition of associations between the X component and the US; and this is the opposite of what was found.

An alternative interpretation of this study, and one that is more in keeping with Rescorla's (1972) position, is that due to the specific nature of the surprising post-US stimulus used (a brief exposure of the same stimulus elements that also served as the CS), the occurrence of that stimulus may have served to increase the total magnitude of the US since the post-US event would presumably have acquired secondary reinforcing properties as a result of being paired with the US during the prior conditioning procedure. Moreover, the finding that longer delays between the original US and the surprising post US stimulus were less effective in disrupting blocking in this study can be seen to be consistent with this interpretation since delay of reinforcement has commonly been shown to lessen the effectiveness of reinforcement. Gray and Appignanesi, however, argue against this interpretation, favoring instead the more cognitive interpretation that it was the surprising nature of the unpredicted post US event that caused the X component to acquire the conditioned suppression response and not the mere fact that the post-US manipulation tended to make the total US event a more effective reinforcer by increasing its magnitude. Unfortunately, however, these authors failed to report any control conditions that would serve to rule out this alternative interpretation.

In Rescorla's (1972) paper on the role of information in conditioning, an experiment was reported which tends to support this alternative position. In that experiment, prior conditioned suppression training to the A component in the basic blocking procedure was carried out with either a 2 mA .5 sec foot shock or a .5 mA 2 sec foot shock. During the compound-CS conditioning phase of the procedure, the USs were switched so that subjects previously conditioned to the short-strong US underwent conditioning to the long-weak US during the compound-CS conditioning phase, and vice versa; a change in US that may be considered to be "surprising". On the basis of earlier work carried out in Rescorla's laboratory, it was reported that both USs were able to support equal levels of conditioned suppression, thus their relative magnitudes of reinforcement were considered to be essentially equal. What this experiment revealed was that changing the US between phases in this manner did not appear to have any effect on the basic blocking effect. Thus, a noninformational interpretation of the Rescorla and Wagner model appeared to be supported and it was concluded that "... information about the qualitative properties of the US is not critical to conditioning (Rescorla, 1972, p.16)," even though changes in such qualities may represent an incongruent or surprising event. What is assumed to be important, on the other hand, is the relative difference between the magnitude of reinforcement required to support the level of associative strength accrued to the CS on the basis of past trials and that actually delivered by the US in the present trial.

Although the results of this experiment strain an informational interpretation of the blocking effect along the lines of Kamin's surprise hypothesis, the immediate question that arises is to what degree would a more dramatic change in US quality yield similar results. Perhaps the "surprise" generated by a change in US duration is not very great for a rat in a conditioned suppression task.

Bakal, Johnson and Rescorla (1974) recently reported an experiment that was intended to extend this finding to USs differing in quality more than those employed by Rescorla (1972). In this study, foot shock and a loud burst of noise from a klaxon horn were used as the two USs, with tone and light serving as CSs.

Unfortunately, the results of this experiment were confounded by a strong stimulus modality interaction in that the tone component in the compound-CS control conditions was found to acquire only a minimal level of conditioning when klaxon was used as the US. When foot shock was used, however, both the tone and light acquired good levels of conditioning. In other words, the parameters of the auditory CS and the auditory US used by Bakel et al. appeared to be unfavorable for the establishment of a conditioned suppression response involving these two stimuli when the tone stimulus was presented in compound with the light.

Although this interaction makes the interpretation of their findings very difficult, what they found was that when subjects were conditioned to foot shock during the first phase of the blocking procedure and then switched to the klaxon US during the compound-CS conditioning phase, the X component (regardless of its modality) did not acquire the conditioned suppression response; that is, blocking was not disrupted under these conditions. On the other hand, when the direction of the between phase change was from klaxon to foot shock, blocking was substantially disrupted.

In interpreting the results of this experiment, Bakel et al. suggest that the findings tend to be most consistent with a noninformational interpretation of blocking along the lines of the Rescorla and Wagner model as interpreted by Rescorla (1972). This interpretation, however, is contingent upon the assumptions that the klaxon was a less potent US than foot shock and that tone was a less salient CS than light. However, the only data reported in support of such a claim was the observation that tone failed to acquire the conditioned suppression response in the compound-CS control conditions when klaxon as opposed to foot shock was used as the US.

As a consequence of the lack of an adequate data base upon which to form any firm conclusion regarding the role of information in blocking, It is apparent that further research relevant to this issue is needed. In the first experiment to be reported, a design similar to that of Baker et al. (197[illegible]) was used in an attempt to clarify the effects of change in US modality on blocking.

In this experiment, an aversive tactile stimulus (foot shock) and an aversive auditory stimulus (a loud burst of noise) were used as USs with the assumption that a between phase change in the modality in which the US is delivered would constitute a "surprising" or "incongruent" event. Secondly, by selecting appropriate parameters for each of the two USs so that both can be shown to support similar levels of conditioning, it is argued that this experiment should not only provide a test of the surprise hypothesis of Kamin in a situation where concomitant changes in reinforcement magnitude have been controlled, but also provide a test of the generality of the Rescorla and Wagner model.

EXPERIMENT I

Method

Subjects and Apparatus

The subjects were 24 Long Evans male rats weighing 250-300 gm at the start of the experiment. They were maintained at 80% of their normal body weight throughout the experiment.

The experimental chambers consisted of four Skinner boxes (LVE Model 1417). The grid floor was connected to a custom made constant current shock source capable of delivering a photoelectrically scrambled electric shock at approximately 10 times per sec. This arrangement permitted the presentation of an aversive tactile stimulus. A protruding food cup and a single bar were mounted in opposite corners of one end wall. Located behind this end wall was a food magazine capable of delivering single 45 mg Noyes food pellets to the food cup. Mounted on the rear side wall directly adjacent to the bar and 2-in above the grid floor was a high intensity speaker (Phillips, AD 160/T8). A custom made white noise source was relayed through a 40-watt power amplifier to this speaker using a custom made electronic switch in series with an electromechanical relay. The electronic switch had a rise time of 8-10 msec which was sufficient to dampen the "popping" noise that accompanied the closure of the electromechanical relay. The electromechanical relay was used in turn to prevent the highly amplified white noise from "leaking" through the electronic switch when open. This arrangement permitted the presentation of an aversive auditory stimulus. Measurement of the frequency characteristics of the aversive auditory stimulus revealed that peak amplitude was maintained between the frequencies of .8 and 5 kHz. The amplitude of the signal was sharply attenuated below .8 kHz. Above 5 kHz, the amplitude gradually tapered off to a minimum at approximately 12 kHz.

Each Skinner box was enclosed in a light- and sound-resistant shell (LVE Model 1417C). Mounted on the inside rear wall of the shell was a 28 VDC light bulb and a second speaker. A 240 Hz pure tone source was electromechanically relayed to this speaker through a second amplifying system. These arrangements permitted the presentation of neutral visual and auditory stimuli subsequently to be used as the conditioning stimuli (CS_L and CS_T, respectively). Mounted on the side wall of the shell was an exhaust fan that produced a continuous level of background noise at 65-67 db SPL (Dawe Instruments Ltd. Type 1400G). All programming and recording equipment were located in an adjoining room.

Procedure

In the first session, subjects were magazine trained on an automatic FI-60 sec schedule for food reinforcement. In addition, each bar press yielded a food pellet. These sessions were continued until the subject made approximately 50 bar presses at which time the automatic and continuous reinforcement schedules were discontinued and a response contingent VI-30 sec schedule came into effect. No subject required more than three sessions of bar press training before being placed on the VI-30 sec schedule; shaping was used when necessary. Following an additional session of VI-30 sec training, subjects were given 3-5 subsequent sessions of training on a VI-90 sec schedule of reinforcement before being transferred to a VI-250 sec schedule for the remainder of the experiment. VI data [illegible] to baseline throughout the experiment.

Following VI training, subjects were given two Pretest sessions in which CS_L and CS_T were alternately presented twice for 60 sec each. The CS_T was presented intermittently (5 sec "on", 5 sec "off") at an intensity of 80-82 dB SPL (recorded during continuous presentation with the exhaust fan on). Intertrial intervals ranged between 8-16 min with the first trial commencing 10-15 min after the beginning of the session. Selection of CS parameters was based on pilot work that had been designed to match the salience of these stimuli (see Appendix I).

Following the Pretest trials subjects were divided into 3 groups of eight subjects each. During Phase I conditioning, Transfer (T) and Blocking (B) Groups were given four sessions of single CS conditioned suppression training. Each conditioning session consisted of four 60 sec presentations of either CS_T or CS_L terminated by a 1-sec US. For half of the subjects in each group an aversive tactile stimulus was used as the US. This stimulus was an electric shock to the feet at an intensity of 1 mA (US_s). For the remainder an aversive auditory stimulus was used as the US. This stimulus was a burst of noise at an intensity of 114-116 dB SPL (US_n); CS-US combinations were balanced within groups. Selection of US parameters was based on pilot work that had been designed to match the reinforcement values of these stimuli (see Appendix J). No single-CS conditioned suppression trials were given to subjects in the Blocking Control (C) Group. This group was maintained on the VI schedule throughout Phase I.

During Phase II conditioning, all subjects were given two sessions of compound-CS conditioned suppression training. Conditioning procedures during Phase II were similar to those in Phase I except that the former CS_1 and CS_1 were presented simultaneously to form a compound CS. In Group A, the US used in Phase II conditioning differed in modality from that used in Phase I. In Group B the modality of the US remained the same. The modality of the US was balanced for subjects in Group C.

Following Phase II conditioning, subjects were given four test sessions. During each test session the compound CS components were alternately presented in random order for 60 sec in the absence of the US on two occasions each. Intertrial intervals during conditioning and testing were randomized according to the parameters used in the Pretest condition.

Data Collection and Analysis

Bar press rate was automatically recorded during the CS period (CS rate) and the 60 sec period immediately preceding the CS (pre-CS rate). These data were then used to calculate trial-by-trial suppression ratios by dividing the sum of the CS and pre-CS rates into the CS rate. A suppression ratio of .5 calculated in this manner indicates that pre-CS and CS bar press rates were equal. A suppression ratio of 0, on the other hand, indicates complete suppression of bar press behavior during the CS period relative to the pre-CS period. In instances where both the pre-CS and CS rates were zero (0), a mean suppression ratio based on the ratios of the trials immediately preceding and succeeding this trial was used. Zero pre-CS and CS bar press rates occurred on no more than 12% of the trials in any of the experimental conditions. Moreover, these instances were randomly distributed across groups. Between group variance estimates were subjected to Cochran's C test for homogeneity of variance (Weiner, 1962). These variance estimates were not found to [illegible] level of significance in any of the analyses to [illegible]

Results and Discussion

Suppression to the stimuli subsequently to be used as conditioning stimuli, CS_T and CS_L, was minimal by the final Pretest session. In addition, there was little if any difference between means ($F=.02$; $df=1/21$; $p>.05$). The means for CS_T and CS_L were .37 and .36, respectively.

During Phase I conditioning the two experimental groups, Groups T and B, were found to acquire the conditioned suppression response at essentially the same rate ($F=0$; $df=1/8$; $p>.05$). Secondly, neither the modality of the US ($F=.30$; $df=1/8$; $p>.05$) nor the modality of the CS ($F=.84$; $df=1/8$; $p>.05$) were found to have any reliable influence on acquisition rate. Phase I acquisition rates collapsed over groups are presented in Figure 1 according to US and CS modalities. Besides the regularity of each of these learning curves it is of interest to note that subjects were performing at asymptotic levels by trials 9 or 10 in each instance.

During Phase II conditioning, Group C was found to attain substantial levels of suppression by the final compound-CS conditioning session. In fact, an analysis of the suppression ratios obtained during this session failed to reveal any statistically significant differences between the means for the three treatment groups ($F=.93$; $df=2/18$; $p>.05$). These means were .04, .10 and .05 for Groups T, B and C, respectively.

Table 1 shows the design of this experiment along with the mean suppression ratios that were obtained on the first Test presentation

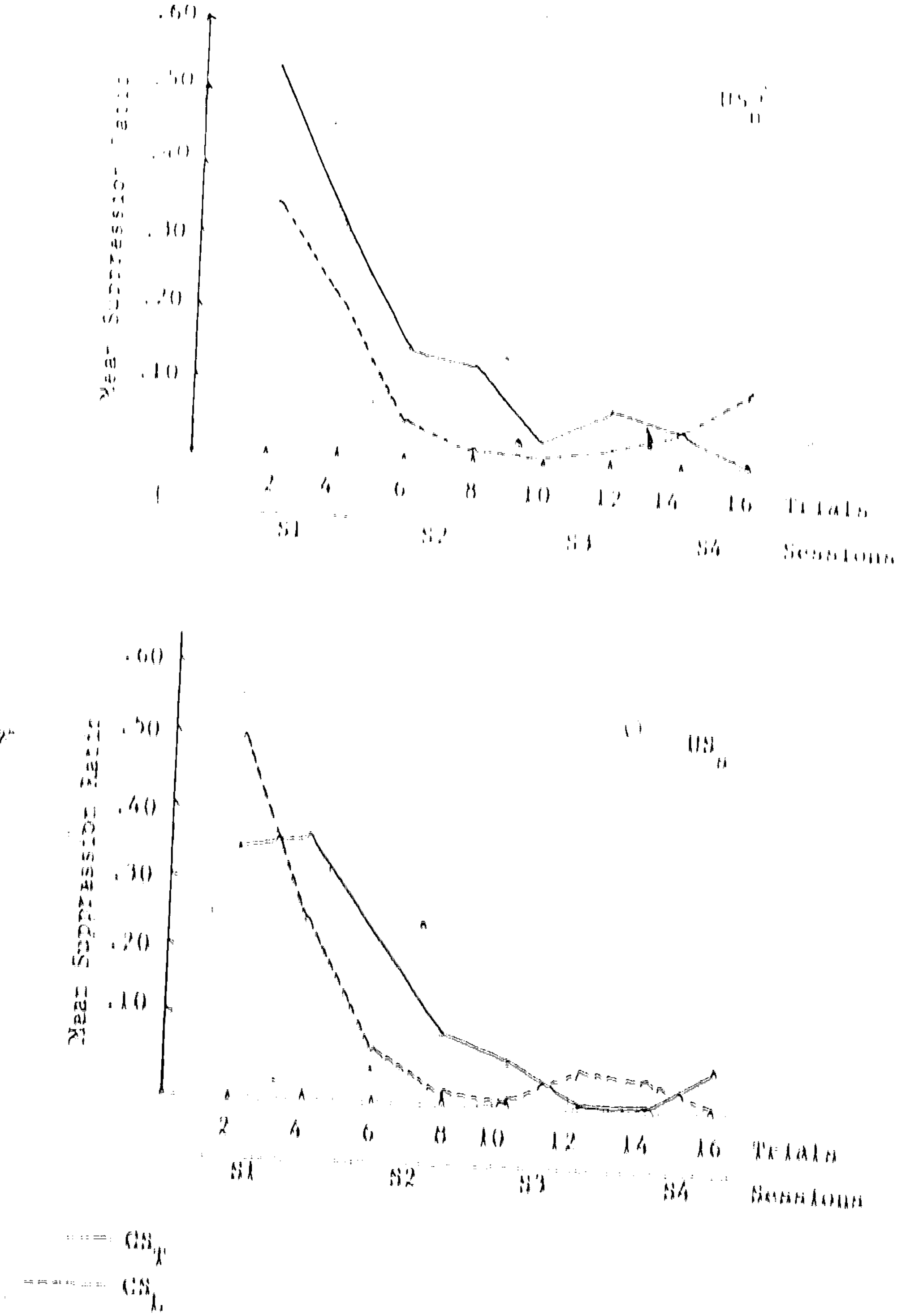

FIGURE 1

MEAN SUPPRESSION RATIOS OBTAINED TO CS_T AND CS_L IN EXPERIMENT I DURING PHASE I CONDITIONING. PLOTTED IN THE UPPER PANEL, IN BLOCKS OF TWO TRIALS EACH IS THE SUPPRESSION OBTAINED WHEN AN AVERSIVE AUDITORY STIMULUS (US_N) WAS USED AS A REINFORCER AND IN THE LOWER PANEL THE SUPPRESSION WHEN AN AVERSIVE TACTILE STIMULUS (US_S) WAS USED. DATA ARE COLLAPSED OVER GROUPS T AND B.

TABLE 1

DESIGN OF EXPERIMENT 1 PLUS GROUP MEAN SUPPRESSION RATIOS OBTAINED DURING THE FIRST TEST PRESENTATION OF EACH OF THE CS COMPONENTS

Groups	Pretest Trials	Pretest Condition	Phase I Trials	Phase I Condition	Phase II Trials	Phase II Condition	Test CS Components A	Test CS Components X
E	4	$CS_{T/L}$	16	$A+US_1$	8	$AX+US_2$	0	.20
B	4	$CS_{T/L}$	16	$A+US_2$	8	$AX+US_2$	.07	.38
C	4	$CS_{T/L}$			8	$AX+US_2$	.01	.04

of each of the CS components. The CS component common to Phase I and II conditioning is termed the "A" component. The component not used in Phase I conditioning is termed the "X" component. Since the CS components in Group C cannot be differentiated on the basis of reinforcement history, these data have been arbitrarily divided into two equal portions with one portion being designated as the A component and the other as the X component. This procedure was used to equate for the number of Test observations in between group analyses. Although data were collected over four Test sessions, the data of primary concern are those which were obtained during the first Test presentation of each of the CS components. This is so because only the initial Test presentation can be considered to be free from the effects of any new learning that may have taken place as a result of the Test procedure itself. As a consequence, suppression ratios obtained during the initial Test presentation of the CS components will constitute the principal data for analysis. When appropriate, however, these data will be compared with the data that were obtained during the total Test period.

As the means in Table 1 reveal, suppression ratios obtained to the first Test presentation of the A component were similarly low in all three groups ($F=3.47$; $df=2/12$; $p > .05$). In addition, neither the modality of the Phase II US ($F=.03$; $df=1/12$; $p > .05$) nor the modality of the CS component ($F=.01$; $df=1/12$; $p > .05$) were seen to have any reliable influence on the A component suppression ratios. An analysis of the A component suppression ratios that were obtained across all four of the Test sessions also failed to reveal any reliable differences between groups ($F=1.93$; $df=2/12$; $p > .05$). The means across Test trials for

Groups T, B and C were .06, .18 and .17, respectively. This analysis failed to reveal any reliable stimulus modality effects as well. Thus suppression ratios to the A component did not appear to be differentially influenced by any of the experimental manipulations, and conditioning was good to this component in all instances.

An analysis of the suppression ratios obtained during the first Test presentations of the CS component of primary experimental interest, the X component, revealed a significant difference between the three treatment groups ($F=11.58$; $df=2/12$; $p<.01$). Multiple comparisons between the means (Newman-Keuls test, see Weiner, 1962) revealed that Group B differed significantly from Group C ($p<.01$). Secondly, Group T was found to differ significantly from Group C ($p<.05$) and Group B ($p<.05$). The first difference represents a demonstration of the basic blocking effect. The second set of differences suggests that changing the modality of the US between conditioning phases tended to produce an intermediate degree of blocking.

An unqualified interpretation of this latter effect, however, is cautioned against due to the occurrence of a significant Groups by US modality interaction ($F=5.83$; $df=2/12$; $p<.05$). The means for this interaction are presented in Table 2. Although a significant US modality main effect was found as well ($F=11.19$; $df=1/2$; $p<.05$), the means in Table 2 reveal that this effect was restricted to the two experimental groups, Groups T and B, with Group T accounting for the largest share of the difference. In other words, the US modality main effect in this case can be attributed to the specific nature of the Groups by US modality interaction. These observations were confirmed

TABLE 2

MEAN SUPPRESSION RATIOS OBTAINED IN EXPERIMENT I DURING THE FIRST PRESENTATION OF THE X COMPONENT ACCORDING TO MODALITY OF US USED IN PHASE II CONDITIONING

Group	US_a	US_b
T	.41	0
B	.51	.26
C	0	.07
Across Groups	.31	.11

by the fact that post hoc comparisons of the cell means within Group T revealed that these means differed significantly ($F=16.15$; $df=5/12$; $p<.05$; see Scheffe's test in Edwards, 1960) whereas those in Group B did not ($F=6.32$; $df=5/12$; $p>.05$). More importantly, however, was the finding that the cell means in Group T ($F=16.15$; $df=5/12$; $p<.05$) and Group B ($F=25.04$; $df=5/12$; $p<.05$) both differed significantly from Group C when US_n was used in Phase II conditioning. On the other hand, when US_s was used, neither Group T ($F=.51$; $df=5/12$; $p>.05$) nor Group B ($F=1.24$; $df=5/12$; $p>.05$) were found to differ significantly from Group C. On the basis of these findings it is concluded that changing the modality of the US between conditioning phases did not in itself disrupt the basic blocking effect. Rather, it was the order or direction in which this change occurred that appeared to be important. When the direction of change was from US_s to US_n in Group T little if any disruptive effect on blocking was noted. However, a fairly substantial disruptive effect was noted when the direction was from US_n to US_s (a finding similar to that of Bakal et al., 1974). Secondly, blocking appeared to be disrupted when US_s was used in Phase II conditioning regardless of whether the modality of the Phase II US differed from that of the Phase I US as in Group T or remained the same as in Group B. This latter finding, that blocking was disrupted in Group B when US_s was used in Phase II conditioning, was surprising since this condition constitutes one of the basic blocking subgroups. However, the following analysis indicates this disruption was of brief duration and should therefore not be an issue of primary concern.

Figure 2 shows the X component suppression ratios that were obtained on all four Test sessions according to the modality of the

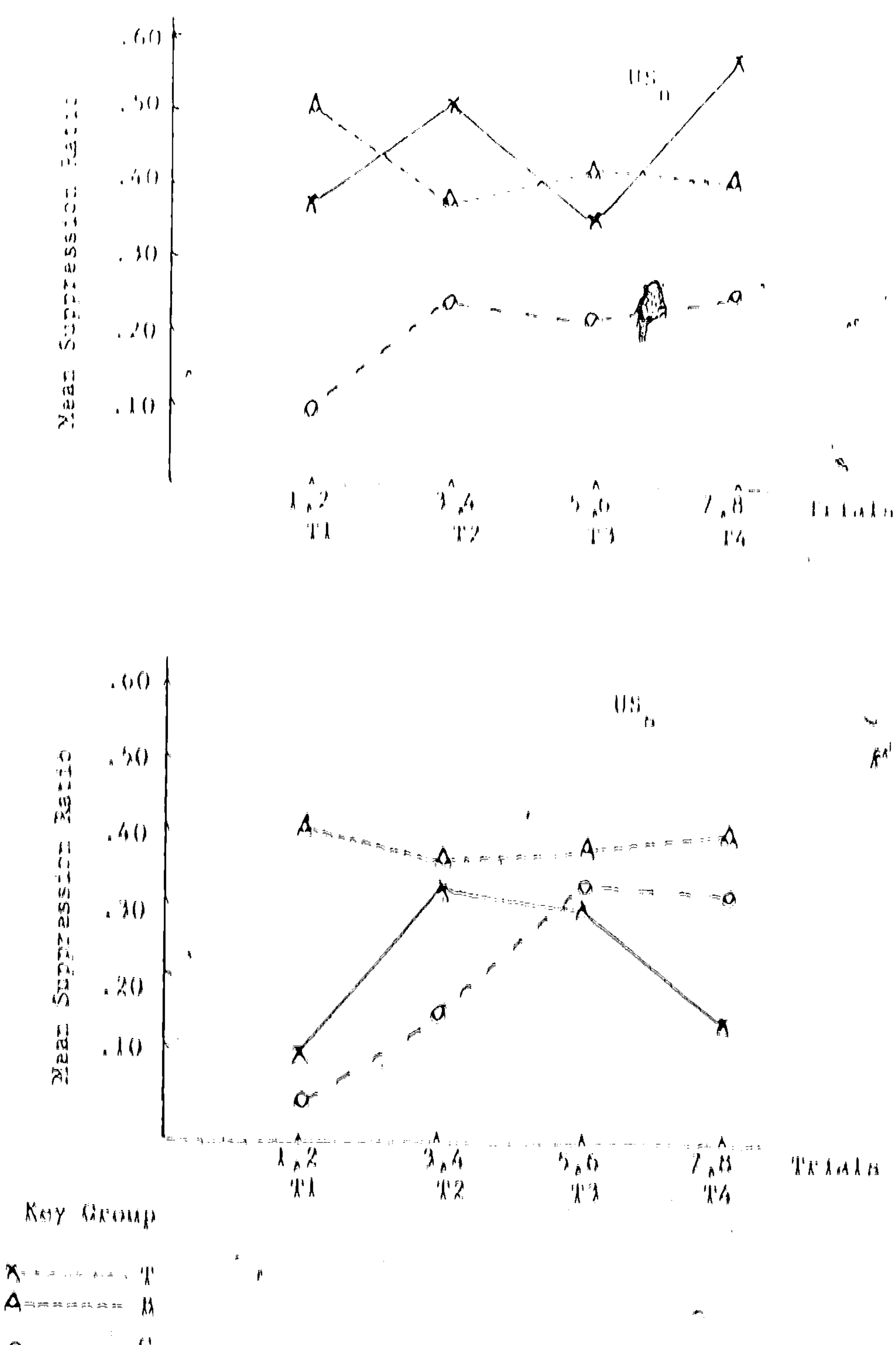

FIGURE 2

MEAN SUPPRESSION RATIOS OBTAINED IN EXPERIMENT I DURING EACH PRESENTATION OF THE X COMPONENT IN ALL FOUR TEST SESSIONS. PLOTTED IN THE UPPER PANEL IN BLOCKS OF TWO TRIALS EACH IS THE SUPPRESSION RATIOS OBTAINED WHEN AN AVERSIVE AUDITORY STIMULUS (US_a) WAS USED AS A REINFORCER IN PHASE II CONDITIONING AND IN THE LOWER PANEL THE SUPPRESSION OBTAINED WHEN AN AVERSIVE STIMULUS (US_n) WAS USED.

Phase II US. Although the Groups by US modality interaction in this analysis was not statistically significant ($F=1.83$; $df=2/12$; $p>.05$), the patterning of the means were partially consistent with the conclusions drawn from the previous analysis. As may be seen, when US_n was used in Phase II conditioning, subjects in Group T performed very similarly to those in Group B. However, when US_n was used, subjects in Group T performed more like those in Group C. This puzzling directional relationship will be examined further in a later section. Secondly, the means in Figure 2 reveal that subjects conditioned with US_n in Group B did not remain suppressed beyond the first Test presentation of the X component. This observation suggests that the disruption in blocking that was noted to occur under these conditions in the initial Test data was minimal and should be viewed with caution.

In addition to a US modality effect, the X component suppression ratios revealed a significant CS-component modality effect ($F=7.7$; $df=1/12$; $p<.05$) and a nearly significant Groups by CS-component modality interaction ($F=4.16$; $df=2/12$; $p>.05$). The means for these effects are presented in Table 3. As these means reveal, the CS-component modality effect was restricted to the two experimental groups in a manner similar to that noted in the case of the US modality effect. However, when comparisons were made of the cell means within Groups T and B, neither of the differences attained the level of significance required of post hoc analysis. On the other hand, when the cell means for Group T and B were combined, the difference between CS-component modalities did attain significance ($F=15.79$; $df=5/12$; $p<.05$). What these findings suggest is that when CS_A served as the X component,

TABLE 3

MEAN SUPPRESSION RATIOS OBTAINED IN EXPERIMENT I DURING THE FIRST TEST PRESENTATION OF THE X COMPONENT ACCORDING TO ITS MODALITY

Group	CS_T	CS_L
T	.33	.08
B	.54	.22
C	0	.07
Across Groups	.29	.13

a substantial level of suppression was acquired to this component in both Groups T and B. However, when CS_T served as the X component, only a minimal level of suppression was acquired. In other words, blocking was disrupted to one degree or another in both Groups T and B when CS_L served as the X component, but not when CS_T served as the X component.

Figure 3 shows the X component suppression ratios that were obtained on all four Test sessions according to the modality of the X component. Although this interaction was not statistically significant ($F=1.07$; $df=2/12$; $p>.05$) the patterning of the means again were consistent with the conclusions drawn from the previous analysis. That is, blocking was disrupted when CS_L served as the X component, particularly in Group T, whereas blocking was substantial in both Groups T and B when CS_T served as the X component.

The stimulus modality effects noted in suppression ratios obtained to the X component during Testing can be summarized in the following manner. When US_n was used in Phase II conditioning blocking was completely disrupted in Group T and partially disrupted in Group B. On the other hand, when US_n was used blocking was substantial in both experimental groups (see Table 2). Secondly, when CS_L served as the X component blocking was also disrupted in both groups, with the means indicating that Group T was disrupted to a greater degree than Group B. When CS_T was used, however, blocking was again substantial in both experimental groups (see Table 3).

In each of these instances, the stimulus modality effects were restricted to Groups T and B. Moreover, the consistency of the pattern

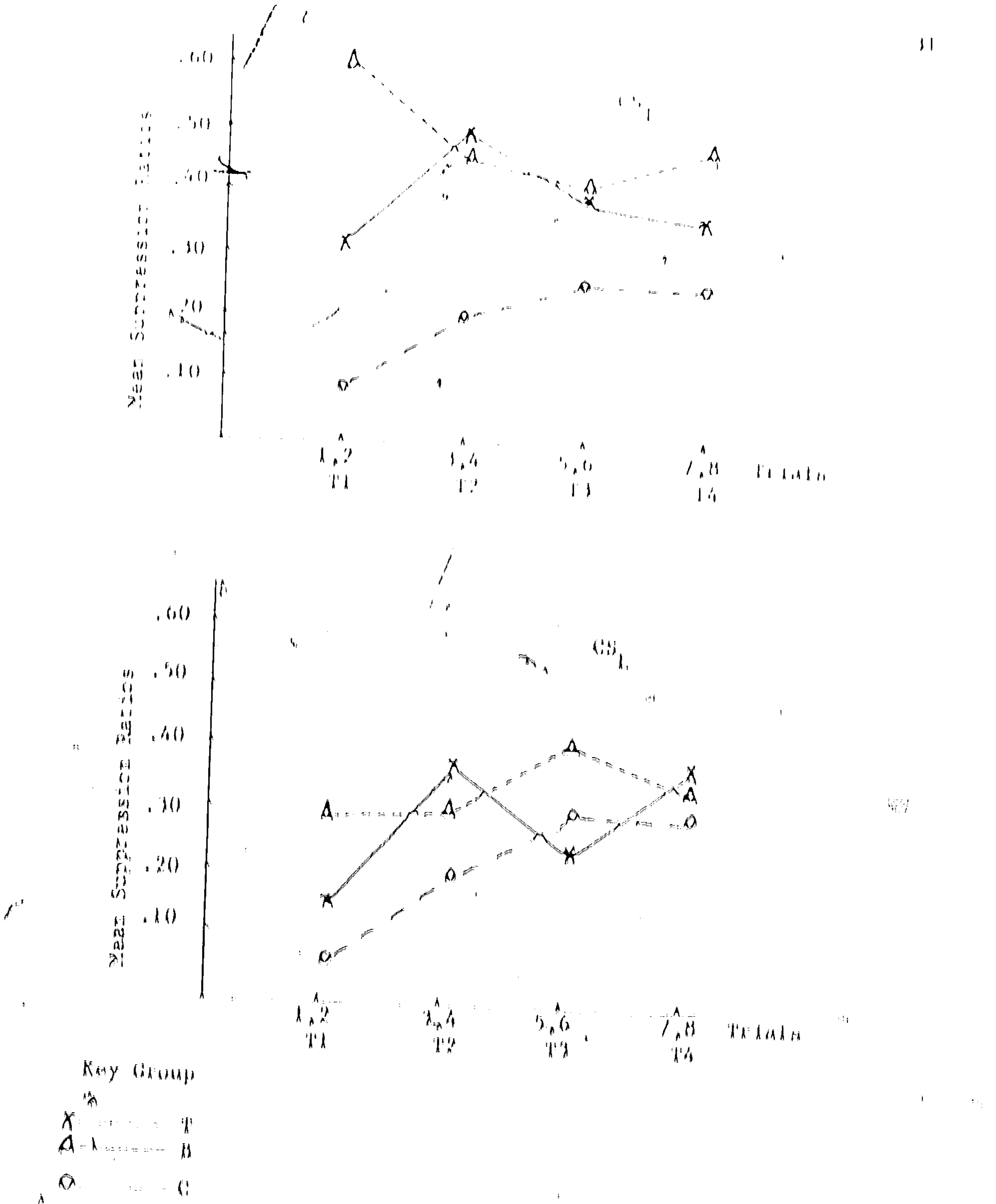

FIGURE 3

MEAN SUPPRESSION RATIOS OBTAINED IN EXPERIMENT I DURING EACH PRESENTATION OF THE X COMPONENT IN ALL FOUR TEST SESSIONS. PLOTTED IN THE UPPER PANEL IN BLOCKS OF TWO TRIALS EACH IS THE SUPPRESSION OBTAINED WHEN TONE (CS_T) SERVED AS THE X COMPONENT AND IN THE LOWER PANEL THE SUPPRESSION WHEN LIGHT (CS_L) SERVED AS THE X COMPONENT.

over all four test sessions indicates that the absence of the effects during the initial presentation of the X component in Group C cannot be attributed to novelty effects. Secondly, between the groups, the effects tended to be more pronounced in Group I than in Group B. Taken together these observations suggest that the stimulus modality effects were related to the fact that subjects in Group I and B underwent Phase I conditioning whereas those in Group C did not. In addition, the between groups differences suggest that these effects were also related to the fact that the modality of the US was changed between phases in Group I, but not in Group B.

Research by Kamin (1968; 1969) has shown that when the saliency of the X component is greater than that of the A component, blocking is disrupted. Moreover, he has shown that when the intensity of the Phase II US is greater than that of the Phase I US, a similar disruption in blocking occurs. Thus, on the basis of Kamin's findings, the results of the present experiment could be explained by assuming that CS_T was less salient than CS_L, and by assuming that US_N was less aversive than US_S. The following is a description of how, given these assumptions, the stimulus modality effects that have been observed may be explained.

In the first case, when CS_L served as the X component blocking was found to be disrupted in both experimental groups. Given that CS_L was more salient than CS_T this outcome would have been expected due to the increased saliency of the X over the A component. When CS_T served as the X component, however, blocking was not disrupted nor would it have been expected (see Table 3). In the second case, when the modality of the US was changed between Phases in Group I from US_N to US_S.

blocking was again found to be disrupted. Given that US_n was less aversive than US_s, this outcome would have been expected due to the relative increase in the intensity of the US between conditioning phases. This disruption did not occur, however, when transfer was in the opposite direction nor would it have been expected, assuming no disruptive effects due to qualitative variables alone (see Table 2).

In order to assess the differential potencies of the two USs and the two CS components used in this experiment, a separate analysis was made of all of the Test trial suppression ratios that were obtained by subjects in Group C on each of the four Test sessions. Group C was singled out for this analysis because the manipulations involved in this experiment tend to confound the interpretation of the extinction data obtained by the two experimental groups, Groups E and B.

The analysis of the Test trial suppression ratios in Group C failed, however, to reveal any reliable differences in rate of extinction as a function of US modality ($F=0$; $df=1/6$; $p>.05$). In fact, the means across test trials for US_n and US_s were .19 in each instance. Moreover, this analysis failed to reveal any reliable difference in rate of extinction as a function of CS component modality ($F=.29$; $df=1/6$; $p>.05$). The means across Test trials for components CS_T and CS_L were .21 and .18, respectively. The interaction between US and CS component modalities also failed to reveal any reliable differences ($F=.11$; $df=1/6$; $p>.05$). Thus, on the basis of these findings, plus the absence of any modality effects in the acquisition data, it is argued that the two USs used in this experiment were essentially similar in their ability to reinforce a conditioned suppression response. In addition, it is argued that the two CS components were equally similar in their ability to acquire a conditioned suppression response.

The hypothesis of differential stimulus values should not, however, be entirely abandoned. In the data that were just presented, only 8 conditioning trials were involved. Subjects in the two experimental groups on the other hand underwent 16 Phase I conditioning trials prior to the Phase II conditioning procedure. Moreover, the last 6 of the Phase I conditioning trials can be considered to be overtraining trials since asymptotic performance was reached by trial 10. Possibly these extended training trials differentially affected the resultant reinforcement values of the two USs. Similarly, though certainly less likely, these additional trials may have differentially affected the resultant saliencies of the two CSs. These hypotheses have been suggested for the following reasons: (A) There is ample evidence to suggest that aversive as well as neutral stimuli tend to habituate over trials; and (B) There is no reason to assume that rate of habituation would be the same between stimulus modalities. Thus, if US_N tended to habituate at a more rapid rate than US_S so that the reinforcing values of the two USs were no longer equal by the end of Phase I conditioning, the puzzling directional relationship that was observed in Group T could be seen to be a function of the relative difference between end of Phase I and beginning of Phase II reinforcement values for the two USs used. Moreover, if CS_P tended to habituate at a more rapid rate than CS_L, the CS-component modality effect could be interpreted in a similar manner.

Unfortunately, this experiment was not designed to test these assumptions with any degree of precision. Nevertheless, on the basis of these considerations and observations it is argued that the experimental conditions in this study may have been confounded. Not only was the modality of the US changed between phases in Group E, but the relative reinforcement value of the US may have been differentially incremented as well. That is, changing the modality of the US between phases may have disrupted blocking to one degree or another as a result of differences in US magnitude due presumably to differential rates of habituation during Phase I conditioning regardless of any purely qualitative effects that might have occurred as a result of the change itself. Secondly, potential differences at the end of Phase I in CS saliencies may have been an additional source of confounding. Assuming the presence of these confounding influences, it would follow that the degree of disruption caused by these variables in the blocking procedure would be a function of (A) the number of Phase I conditioning trials that are given and (B) the differential habituation rates of each of the stimuli used.

There is, however, an alternative explanation. Possibly there was a real difference in the initial values of either or both of the US or CS-component modalities that were not detected in the Phase I acquisition data or the Group C extinction data. That is, the blocking procedure may be a more sensitive test of subtle differences in the values of either or both of these stimuli than a comparison of their respective acquisition or extinction rates. As a consequence, recourse to a differential stimulus habituation hypothesis in explaining the observed stimulus modality effects would not be necessary.

Is the blocking effect truly impervious to between phase changes in the modality of the US? And can either or both of the US or CS elements habituate during Phase I conditioning to the degree that blocking is subsequently disrupted? Since the answer to the first question is dependent somewhat upon the answer to the second, an additional experiment was conducted in which the conditions of Group F were essentially replicated except that only 10 Phase I training trials were given instead of 16 as in the present experiment. The procedure of reducing Phase I conditioning Trials was selected in an effort to test the differential stimulus habituation hypothesis. On the basis of arguments presented above, stimulus habituation effects should be inversely related to the number of Phase I conditioning trials. Reduction in Phase I conditioning trials from 16 to 10 was selected because although blocking has been found to be influenced by pre-asymptotic levels of Phase I conditioning, it has not been related to number of Phase I conditioning trials per se (Kamin, 1969). And, as may be recalled, asymptotic performance was attained by trial 10 in the present experiment.

EXPERIMENT II

Experiment I revealed that changing the modality of the US between conditioning phases in the Kamin blocking procedure tended to produce an intermediate degree of blocking. Further analysis revealed, however, that the disruptive effect was related to the order or direction in which the change in modality occurred. When an aversive tactile stimulus was used in Phase I conditioning and an aversive auditory stimulus in Phase II, a high degree of blocking was observed. However, when the order was reversed, blocking was markedly disrupted. Experiment I revealed in addition that the order in which the modality of the two CS components were presented also had a differential effect on blocking. When a visual CS was used in Phase I conditioning and a compound auditory plus visual CS was used in Phase II, the auditory component when presented alone during testing was not found to reliably suppress behavior; that is, blocking was substantial. However, when the CS modality order was reversed, blocking was disrupted.

Although data based on acquisition and extinction rates were presented which indicated that the initial values of the two US and the two CS modalities were similar, it was hypothesized that the resultant values of the auditory US and possibly the CS as well were less at the end of Phase I conditioning than either of their stimulus counterparts because of presumed differences in habituation rates between stimulus modalities. An alternative explanation of the stimulus modality effects was offered by arguing that the initial values of either or both the auditory US and CS were in fact less than their counterparts but that acquisition and extinction rates are less sensitive than the blocking procedure in detecting these differences.

Due to the confounding of the results of Experiment I, the present experiment was designed to reassess the effects of changing the modality of the US between conditioning phases. In this experiment the transfer condition of Experiment I, Group T, was essentially replicated except that only 10 Phase I conditioning trials were given instead of 16 as in the previous experiment. On the basis of arguments presented in Experiment I, it was judged that an experiment of this nature should not only provide a replication of the US transfer effect, but it should also provide confirmation or disconfirmation of the differential stimulus habituation hypothesis.

Method

Subjects and Apparatus

The subjects were 12 Long-Evans male rats weighing 250-300 gm at the start of the experiment. They were maintained at 80% of their normal body weight throughout the experiment. The apparatus was identical to that used in Experiment I. Only three of the four Skinner boxes were used in the present experiment.

Procedure

Subjects were trained to bar press for food according to the same procedures used in Experiment I. In the present experiment, however, subjects were maintained on a VI-90 sec schedule of reinforcement throughout the experimental procedures as opposed to the VI-250 sec schedule used in the previous experiment. Following VI training, subjects were given two sessions of Pretraining in which the stimuli subsequently to be used as CSs were presented in the absence of the US according to the procedure described in Experiment 1. Stimulus parameters were similar to those in the preceding experiment except that CS_T was presented continuously as opposed to intermittently due to Experimenter error. Subjects were next given 10 single-CS conditioned suppression training trials over three sessions of Phase I conditioning. Sessions 1 and 2 consisted of 4 trials each. Intertrial intervals ranged between 8-16 min with the first trial commencing 10-15 min after the beginning of the session as in Experiment 1. Trials 2 and 4 were omitted during the third session. A trial consisted of the presentation of either CS_T or CS_L terminated by a brief aversive US according to the parameters described in Experiment 1. For half of the subjects, an aversive tactile stimulus (US_s) was used during Phase I conditioning. For the remainder, an aversive auditory stimulus was used (US_n; see Experiment 1 for a more complete description of the aversive stimuli); CS modalities were balanced within US modalities.

During Phase II conditioning, 8 compound-CS conditioned suppression training trials were given over 2 sessions. Conditioning procedures during Phase II were similar to those in Phase I except that the former CS_T and CS_L were presented simultaneously to form a compound-CS. In addition, the modality of the US was changed between phases for all subjects. Following Phase II conditioning, four Test sessions were carried out according to the same procedure used in Experiment 1.

Results and Discussion

Suppression to the stimuli subsequently to be used as conditioning stimuli, CS_T and CS_L, was minimal by the final Pretest session. In addition, their means were not found to differ significantly (F=5.44;

df=1/8; p>.05). These means were .46 and .37 for CS_T and CS_L, respectively.

Phase I acquisition rates are presented in Figure 4. As may be seen, there was a tendency, though statistically nonsignificant, for subjects conditioned with US_s to acquire the conditioned suppression response more slowly than those conditioned with US_n ($F=6.86$; $df=1/8$; $p<.05$). This difference was minimal, however, by the third conditioning session (S_3). Mean suppression ratios over trials 9 and 10 in this session were .03 and .08 for subjects conditioned with US_n and US_s, respectively. Secondly, neither CS modality ($F=2.30$; $df=1/8$; $p>.05$) nor the interaction between CS and US modalities ($F=2.15$; $df=1/8$; $p>.05$) were found to reliably influence Phase I conditioning.

Performance during Phase II conditioning was essentially unremarkable. Mean suppression ratios were .03 and .02 for subjects conditioned with US_n and US_s during this phase, respectively ($F=.12$; $df=1/9$; $p>.05$). Moreover, no significant interactive effects were found.

Table 4 shows the design of this experiment plus the suppression ratios that were obtained during the first Test presentation of each of the CS components. As these means reveal, the A component suppression ratios were similarly low regardless of the modality of the Phase II US ($F=0$; $df=1/8$; $p>.05$). Secondly, neither the modality of the A component ($F=0$; $df=1/8$; $p>.05$) nor the US by CS-component modality interaction ($F=1.45$; $df=1/8$; $p>.05$) were found to significantly influence the A component suppression ratios. When the A component suppression ratios were analyzed across all four Test sessions a tendency, though statistically nonsignificant, was noted for subjects

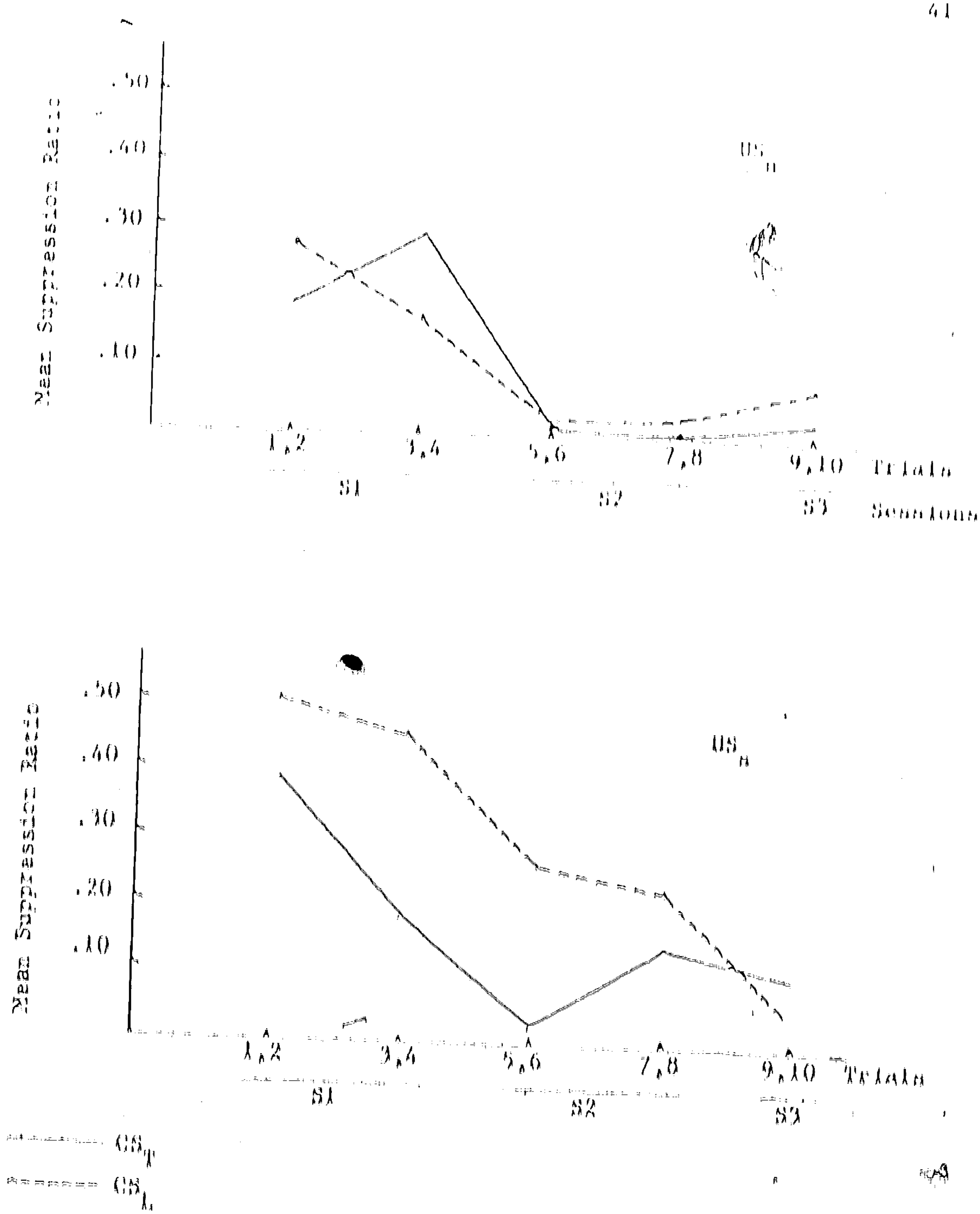

FIGURE 4

MEAN SUPPRESSION RATIOS OBTAINED TO CS_T AND CS_L IN EXPERIMENT II DURING PHASE I CONDITIONING. PLOTTED IN THE UPPER PANEL IN BLOCKS OF TWO TRIALS EACH IS THE SUPPRESSION OBTAINED WHEN AN AVERSIVE AUDITORY STIMULUS (US_A) WAS USED AS A REINFORCER AND IN THE LOWER PANEL THE SUPPRESSION WHEN AN AVERSIVE TACTILE STIMULUS WAS USED (US_R).

TABLE 4

DESIGN OF EXPERIMENT II PLUS GROUP MEAN SUPPRESSION RATIOS OBTAINED DURING THE FIRST TEST PRESENTATION OF EACH OF THE CS COMPONENTS

Pretest		Phase I		Phase II		Test	
Trials	Condition	Trials	Condition	Trials	Condition	CS Components	
						A	X
4	$CS_{T/L}$	10	$A+US_s$	8	$AX+US_n$	.04	.45
4	$CS_{T/L}$	10	$A+US_n$	8	$AX+US_s$	.01	.21

[illegible] cond[illegible]ith US_n in Phase II to be less resistant to extinction than those [illegible]tioned with US_s ($F=3.41$; $df=1/8$; $p<.05$). These means were [illegible]16 a[illegible]504 for subjects conditioned with US_n and US_s in Phase II, respe[illegible]ively. As may be recalled, a tendency was also noted for subjects [illegible]uire the conditioned suppression response more slowly in Phase I wh[illegible] US_s was used during this period as opposed to US_n (see Figure 4). Sin[illegible] the modality of the US was changed between phases for all subjects, the [illegible]bjects that tended to be slower in acquiring the Phase I response were [illegible]e same subjects that tended to be less resistant to extinction during Test presentations of the A component. Conceivably, the difference in extinction rates in the A component Test data are a reflect[illegible]of the difference in Phase I acquisition rates. Moreover, the co[illegible]bination of both of these observations suggests that these subjects may have been generally more resistant to suppression than their counterparts in either the present experiment or Experiment I.

Analysis of the first Test presentations of the X component failed to reveal a significant difference with regard to the modality of the US used ($F=1.81$; $df=1/8$; $p>.05$). Moreover, there was no reliable CS component modality main effect ($F=.12$; $df=1/8$; $p>.05$). There was, however, a notable though statistically nonsignificant US by CS component modality interaction ($F=3.73$; $df=1/8$; $p>.05$). What was notable about this interaction was the fact that blocking appeared to be totally disrupted in those subjects who were conditioned with US_n in Phase II and who had CS_L as the X component. Blocking, on the other hand, was substantial in each of the other conditions (see Table 5). As may be recalled, US_n and CS_L appeared to be the stronger of either of

TABLE 5

MEAN SUPPRESSION RATIOS OBTAINED IN EXPERIMENT II DURING THE FIRST TEST PRESENTATION OF THE X COMPONENT ACCORDING TO ITS MODALITY AND THE MODALITY OF THE PHASE II US.

X Component	Phase II US_{n}	US_{n}
CS_L	.60	0
CS_T	.31	.42

their stimulus counterparts in Experiment I (see Tables 2 and 3 in that experiment). Thus, the US_s CS_L cell in Table 5 should be the most sensitive indicator of the summative effects of these same differences in the present experiment. Since this cell mean indicates that blocking was disrupted under this particular interactive condition, there appears to be some reason to believe that a stimulus modality effect in both the US and the CS elements is present in this experiment in a manner similar to that in Experiment I. However, since the other cell means do not tend to reflect either of these stimulus modality effects singularly, it would appear that the effects in the present experiment were considerably less disruptive than those in Experiment I.

When the X component suppression ratios were analyzed across all four Test sessions a tendency, though statistically nonsignificant, was noted for subjects conditioned with US_n in Phase II to be less suppressed than those conditioned with US_s ($F=4.87$; $df=1/8$; $p > .05$). These means were .49 and .29 for US_n and US_s, respectively. There were, however, little if any differences in terms of the modality of the CS component ($F=1.45$; $df=1/8$; $p > .05$) or the interaction between US and CS component modalities ($F=2.21$; $df=1/8$; $p > .0?$) in these data.

Taken together these findings suggest that when only 10 Phase I training trials were used, changing the modality of the CS between phases did not tend to have a marked effect on blocking. On the other hand, a tendency did remain for blocking to be disrupted when the between phase transfer was from US_n to US_s and CS_L as opposed to CS_n served as the X component (see Table 5). When the X component means in the present experiment are compared to those of the transfer condition of

Experiment I, as shown in Table 6, the following additional observations can be made. Extinction and [illegible] of initial in both [illegible] noticeably improved in Experiment II as opposed to Experiment I when the conditions of transfer were in the opposite direction and CS_1 served as the X component (see Table 5).

Thus, the findings of Experiment II are consistent with the hypothesis that the aversive auditory stimulus, US_n, habituated to a significant degree over the last 6 training trials of Phase I conditioning in Experiment I, even though this effect could not be detected in the Phase I acquisition data. As a consequence, it appears as though it is the change in the magnitude of the US that seems to be important in disrupting blocking in the present experiments and not the modality in which they are presented. In other words, information relevant to variables of the US other than its ability to support a conditioned suppression response, that is, variables other than the magnitude of reinforcement available, do not appear to be important in the establishment of blocking in a conditioned suppression task employing the Kamin blocking procedure.

It is conceivable, however, that for unknown reasons some specific aspect of the stimuli used in these experiments other than their presumed differences in potency may be responsible for the findings noted. A indications have emerged as a result of pilot work carried out in our lab (see Appendix K) that tones having frequency characteristics falling within the envelope of that of the reinforcing noise stimulus are not particularly effective as CSs when noise as opposed to foot shock

TABLE 6

MEAN SUPPRESSION RATIOS OBTAINED DURING THE FIRST TEST PRESENTATION OF THE X COMPONENT IN EXPERIMENT I (GROUP I) AND EXPERIMENT II ACCORDING TO MODALITY OF US USED DURING PHASE II CONDITIONING

	US_H	US_S
Experiment I (Group I)	.41	0
Experiment II	.45	.21

is used as the CS. However, the frequency characteristic of the tone stimulus, CS_T, used in the present studies was, as a result of these pilot investigations, specifically selected to fall well outside the envelope of the aversive noise stimulus that was used. Moreover, the absence of a US by CS stimulus modality interaction during Phase I conditioning in either Experiment I or II, plus the absence of a US by CS component modality interaction in the extinction data of Group C in Experiment I argue strongly against the notion that the findings of the present investigations are the result of some special interaction between the qualitative properties of the stimuli used.

Returning to the general findings, the absence of a CS component modality main effect in the present experiment suggests that the procedural differences between Experiments I and II may have had some influence on this effect. Unfortunately, however, the parameters of the auditory stimulus differed between the two experiments as well as did the number of Phase I conditioning trials. In Experiment I, CS_T was presented intermittently, whereas in the present experiment it was presented continuously due to Experimenter error. As a consequence, it is not clear whether it was the change from an intermittent to a continuous auditory stimulus or the reduction of Phase I conditioning trials that reduced the CS component modality effect between experiments. Nevertheless, the possibility that the saliency of a CS may habituate during conditioning trials, and that the blocking procedure may be uniquely suited to detect such an effect is, however unlikely, of considerable theoretical importance for it is completely at odds with an attentional view of the effects of conditioning on CS saliency (cf.

Sutherland & Mackintosh, 1971). More specifically, if it could be demonstrated that just as preexposure of a stimulus subsequently to be used as a conditioning stimulus causes that stimulus to lose some of its "functional impact" (Carlton & Vogel, 1967), extended presentation of the CS during conditioning tends to have a similar effect, an attentional view of the effects of conditioning on CS saliency would be seriously jeopardized.

GENERAL DISCUSSION OF EXPERIMENTS I AND II

The results of Experiments I and II have shown that changing the modality of the US between conditioning phases in the Kamin blocking procedure does not in itself markedly disrupt the blocking effect. In fact, these experiments suggest that if the magnitude of reinforcement is held constant between phases, changing the modality of the US will have no noticeable effect on blocking. Experiments I and II consistently showed that when an aversive tactile stimulus was used in the first phase of conditioning and an aversive auditory stimulus in the second, little if any disruption in blocking could be found. Moreover, it was shown that when the order was reversed so that the direction of change was from an aversive auditory to an aversive tactile stimulus, blocking was either completely disrupted, as in Experiment I, or only minimally disrupted, as in Experiment II, depending on the number of Phase I conditioning trials that were used. Since this latter finding was interpreted to be the result of a difference in the relative magnitude of the aversive auditory stimulus to that of the aversive tactile stimulus, this finding tends to further support the conclusion that information relevant to variables of the US other than its ability to support a conditioned suppression response, that is, its reinforcement magnitude, do not appear to be important in either the establishment or the disruption of blocking in a conditioned suppression task employing the blocking procedure of Kamin (1968, 1969).

These findings are consistent with those of Bakal et al. (1974) who found that changing the modality of the US between phases of the blocking procedure did not disrupt blocking if the direction of change was from foot shock to Klaxon horn. Secondly, when the change in US modality was in the opposite direction in the Baker et al. study, disruptions in blocking were observed; a finding similar to that of Experiment I in the present investigation. Although it was argued that the interpretation of the study by Baker et al. was questionable due to a strong CS by US modality interaction in their control groups, confirmation of their findings in the present experiments (see particularly Experiment II) tends to strengthen their interpretation that a between phase change in the modality of the US does not disrupt blocking when the potency of the reinforcers is held constant. These findings are seen to support Rescorla's hypothesis that qualitative properties of the US are not important in either the establishment or the disruption of blocking. Moreover, they extend the generality of this concept to qualitative changes in the US that are more extensive than changes in its duration, as was the case in Rescorla's (1972) study.

It should be pointed out that the interpretation of these experiments does not argue against the hypothesis that "retrospective contemplation" (Kamin, 1969), or "rehearsal" (Wagner et al., 1973) are important in the acquisition of associative learning. What it does suggest, however, is that the reinstatement of such a process is a function of a change in the magnitude of the reinforcer and not merely the occurrence of a "surprising" US event. This suggests that the disruptions in blocking observed in the post-US "surprise" studies of Kamin (1969) and Gray and Appignanesi (1973), were due to the fact that the specific nature of the post-US "surprise" stimuli used in those studies had the concomitant effect of increasing the reinforcement magnitude of the total US event between conditioning phases as previously argued.

Apart from the design of the present investigations, it would appear that the only other manipulation that would constitute an appropriate test of the surprise hypothesis would be to present a nonreinforcing or neutral, "surprise" stimulus just after the US during the compound-CS conditioning phase. Such a study was in fact run in our laboratory as part of a series of pilot investigations into the nature of the blocking effect (see Appendix F). In that study an unpredicted 2800 Hz tone was presented for 2 sec immediately after the occurrence of the US during the compound-CS conditioning phase of the basic blocking procedure. The US used in this study was a brief 1 mA shock to the feet. The CS elements consisted of white noise and light. In one group, the post-US "surprise" stimulus was set at 80 db SPL. In a second group this stimulus was set at 106 db SPL. A third group received no post-US "surprise" presentations. Consistent with Rescorla's noninformational interpretation of blocking, the results of this study showed that all groups demonstrated equal and complete blocking of the X component regardless of either the presence or absence of the unpredicted post-US "surprise" stimulus or its intensity.

Before discussing the implication of these findings further, methodological difficulties experienced in the present experiments as well as in the study by Bakal et al. (1974) deserve comment. As these two studies attest, it is extremely difficult to select multiple CS and US parameters that are matched for CS saliency and US potency in both the single- and compound-CS conditions. Moreover, as in Experiment 1, even when such conditions are met in terms of matched acquisition and extinction rates, there is no guarantee that the blocking procedure will be unaffected by subtle differences in stimulus potencies that go undetected by these standard matching procedures. Thus, in further blocking research involving multiple CS and US combinations, it may be prudent to use a more sensitive index such as a "savings" measure to provide the basis for matching stimulus potencies.

A second methodological difficulty encountered in the present research as well as in the study by Bakel et al. involved the use of an aversive auditory US. This US, whether it be produced by a klaxon horn as in Bakel et al. or a white noise generator as in the present investigation, is a very labile US subject to habituation on one hand (see Experiments I and II, and Rescorla, 1973), and annoying interactive effects with auditory CSs on the other (see Appendix K, Experiment II, and Bakel et al., 1973). Admittedly, this latter effect may be interesting in itself, but it only serves as a confounding factor in the experimental designs that are at issue here. In summary, these qualities make the use of such a US in transfer designs involving multiple CSs and USs extremely difficult to work with. As a consequence, future research of this nature may avoid some of the difficulties that have been encountered by using something other than an aversive auditory US.

On the other hand, a reason for continuing to use an aversive auditory US in future experiments of this nature is to clarify the directional effect observed in both Experiment I and in the study by Bakel et al. Although the results of Experiment II are consistent with the interpretation that the directional effect can be reduced when the auditory US is similar in reinforcement magnitude to that of the tactile US at the end of Phase I conditioning, it is still conceivable that the directional effect noted in these experiments is due to some intrinsic characteristic that results when transfer is from noise to foot shock. Perhaps some aspect of the UCR to foot shock is changed in subjects that have previously been exposed to an aversive auditory stimulus. Given this to be the case, the interpretation of the directional effect given above may or may not require reevaluation. For example, if the hypothetical change in the response to foot shock serves to heighten its reinforcement magnitude, then no change in interpretation need be made. If, on the other hand, specific qualitative changes in the UCR elicited by the transfer US are what cause a disruption in blocking, a reinterpretation of the findings would be in order.

In returning to a general discussion of the results of Experiments I and II, it may be informative at this point to pursue an attentional interpretation of these findings. Following this discussion, the relationship between the findings of the present investigation and the theorizing of Rescorla and Wagner as interpreted by Rescorla (1972) will be presented.

Up until Kamin's work, the blocking effect was most easily explained in terms of attention (see for example Mackintosh, 1965; and Sutherland & Mackintosh, 1971). As a consequence, it was used to lend prime support to a two-stage model of discrimination learning advanced initially by Lashley (1929) and Krechevsky (1938). Although a variety of two-stage models have been proposed since Lashley and Krechevsky's work, the model presented by Sutherland and Mackintosh (1971) appears to be the most recent and the most clearly elaborated model specific to the animal discrimination literature. Briefly, this model holds that subjects in a conditioning task must first learn to attend to the relevant stimulus dimension, or "switch in" the relevant stimulus analyzer, before associative connections can be established between stimuli on that dimension and appropriate responses. Furthermore, due to limitations of the system, the more a subject attends to any one stimulus or stimulus dimension, the less he will be able to attend to any other stimulus during the same period. Blocking is therefore seen to be a case of the subject attending so strongly to the initial stimulus (the A component in the present studies), as a result of the prior conditioning experience, that he is unable to attend to and therefore learn anything about the additional relevant but redundant cue (the X component) during the subsequent compound CS conditioning session.

Although Kamin proposed the surprise hypothesis as an alternative to an admittedly naive attentional interpretation of the blocking effect, the attentional theory of Sutherland and Mackintosh clearly provides for changes in attention as a consequence of unpredicted US events. The critical provision of this theory for the issue at hand, is stated in Rule 2 of the Rules for the Operation of the Model. This rule states in part that: "An analyzer is strengthened when its outputs consistently make correct predictions about further events (e.g., trial outcome) of importance to the animal." And, "When no analyzer makes consistently correct predictions, all analyzers revert towards the base level (Sutherland & Mackintosh, 1971, p.39)." Thus, under conditions in which the US event is unpredicted or surprising, this theory of attention explicitly predicts that blocking will be disrupted in a manner similar to that predicted by the surprise hypothesis of Kamin.

There is, however, an important difference between these positions. Sutherland and Mackintosh state that only the occurrence of unpredicted events that are of "...importance to the animal" will result in a subsequent disruption in blocking (Sutherland & Mackintosh, 1971, p.39). Kamin, on the other hand, suggests that surprise alone is the critical variable. If it is assumed that in a conditioned suppression task involving aversive reinforcement, correct predictions about the magnitude of the US are the most important aspects of the task and not the modality in which it is presented nor the occurrence of a nonreinforcing post US "surprise" stimulus, then the findings and conclusions of the experiments that have been presented and/or discussed above are clearly consistent with the attentional position of Sutherland and Mackintosh.

Nevertheless, there is at least one major difficulty with this attentional theory in terms of the present findings. In elaborating on the effects of unpredicted trial outcomes on analyzer strengths, these authors suggest that an "...analyzer making the strongest prediction is increased, and the others are decremented (1971, p.489)." Thus, although analyzers relevant to the A component of the compound CS in the basic blocking procedure may not correctly predict a US that has been incremented in terms of its reinforcement magnitude, it seems reasonable to assume that it does predict the occurrence of that US better than analyzers relevant to the X component. This theory would therefore appear to predict a continual strengthening of the analyzers relevant to the A component at the expense of that of the X component under conditions in which the magnitude of the US is incremented between phases. However, this is not what has been observed to occur.

The model of conditioning that is most compatible with the findings of the present investigation is that which has been proposed jointly by Rescorla and Wagner (Rescorla & Wagner, 1972; Wagner & Rescorla, 1972). The key assumption in this model is that the amount of associative strength that can be accumulated to any element of a CS on any given trial is an inverse function of the sum of the amount previously accumulated to all of the CS elements. Moreover, these effects are assumed to be bounded by the asymptotic level of conditioning that can potentially be supported by a given US (the reader is referred to a discussion of this model in an earlier section of this report for a more detailed description).

According to Rescorla (1972), this model is claimed to be able to account for the blocking effect without recourse to assumptions regarding the informational value of a CS relative to the occurrence of the US. Rather, the model predicts that only the relationship between the level of associative strength accrued to a CS and the asymptotic level of conditioning supportable by the US (its reinforcement magnitude) is important for conditioning. Thus, manipulation of qualitative prope[illegible] US between phases of the blocking procedure should have [illegible]cking so long as the level of conditioning that can be [illegible]S is held constant. The finding that blocking was [illegible] present experiment when the apparent relative magnitude of the US was incremented between phases is therefore seen to be consistent with this hypothesis. Moreover, the finding that between phase changes in CS modality in which the US was delivered was not in itself found to be disruptive of blocking not only provides further confirmation of this hypothesis but also extends its generality.

Nevertheless, in applying the Rescorla and Wagner model to the results of this investigation, difficulties arise in two areas. The first concerns the question of a discrepancy between what the model predicts when the saliencies of the CSs are unequal, as was presumed to be the case in Experiment 1, and what actually occurred in that experiment. The second concerns the question of just what it is that gets conditioned to the CS that causes a reduction in the effectiveness of a US to reinforce subsequent associative learning.

As may be recalled the tone CS appeared to be "overshadowed" by the light CS in both the blocking (Group B) and the transfer (Group T) conditions of Experiment 1. In interpreting this finding it was argued that a subtle discrepancy existed between the saliency of the tone relative to that of the light, even though this discrepancy could not be detected in acquisition or extinction rates. This was suggested on the basis of an observation by Kamin (1968) that showed that blocking was disrupted if the A component was less salient than the X component.

Since a weak CS acquires associative strength slower than a strong CS in Rescorla and Wagner's model (due to differences in the respective α parameters), disruptions in blocking resulting from overshadowing of the A by the X component are consistent with the model when it can be assumed that the prior conditioning procedure is not sufficient for the weaker CS to acquire an asymptotic level of conditioning. However, in Experiment 1, 6 overtraining trials were given in Phase I conditioning. As a consequence, it is difficult to maintain the assumption that conditioning to the presumably weaker tone CS was less than asymptotic at the end of this training procedure. Although further research on this issue is needed before any firm conclusions can be made, the data of Experiment 1 do suggest that the Rescorla and Wagner model of conditioning is not adequate in accounting for the phenomenon of overshadowing (see Mackintosh, 1971, for a parallel argument).

Although it appears that the effectiveness of a reinforcer is relative and that its effectiveness is anchored in some manner to the degree to which the CS has become associated with it, it remains unclear what the critical aspect of the association is. Rescorla and Wagner as interpreted by Rescorla (1972) suggest that it is merely the "strength" of the association; a quantity that "...is presumed to be monotonically related to such dependent measures as probability of response or latency of response (Rescorla, 1972, p.11)." However, nowhere in the model is it stated whether or not the specific quality or topography of the response is important. We are told that a CS can have more or less associative strength and that this amount of associative strength (the V value of a CS) can be increased, decreased, or maintained as a result of a given conditioning trial depending upon certain characteristics of the US, presumably its reinforcement value. However, we are not told what the nature of the association is. In fact, there is a marked circularity in their theorizing regarding this issue. A given US is seen to affect the level of associative strength, V, to the degree that

[illegible]

resolution of this [illegible]. [illegible], of course, the modality of the US in the present study [illegible] effect on blocking. It could be argued that the V values reported by the two UCS used are also different; not because they represented different amounts of associative strength, but because they were associated to different responses.

Although this investigation suggests that the qualitative properties of an aversive US do not appear to be critical for blocking in a conditioned suppression task, there is no reason to believe that such qualities are equally unimportant for conditioning in general. In fact, there is every reason to believe that qualitative properties of a US such as its point of impact, modality of deliverance, UCR, etc., are extremely critical to conditioning depending upon the specific nature of the response being conditioned or measured. However, to what degree would blocking be affected by a manipulation of those relevant US qualities in those particular conditions?

It appears reasonable to this author that some aspect of a conditioned response (CR) could be changed by changing some quality of the US between phases of a two phase conditioning task, but that blocking of an added but redundant cue during the second phase would not be affected by that change. In other words, a given US may have qualitative properties important for determining the specific nature of the response being conditioned as well as some nonspecific reinforcing property. And it may be the nonspecific reinforcing property of US. [illegible] value that is critical for blocking. For example, it is not [illegible] unique responses, CR_1, when the US was foot shock and another, CR_2, when the US was a loud burst of noise to the left side of the head. These responses may, for instance, be specific "preparatory responses" in accordance with the views of Perkins (19[illegible]). Thus, qualitative properties of the US may have been critical for some aspect of conditioning (the occurrence of CR_1 versus CR_2) even though they were not found to be critical for blocking of the commonly supported conditioned suppression response. As a consequence, it is conceivable that the V value of a stimulus in Rescorla and Wagner's model may be related to the nonspecific reinforcing property of the US and not to those qualitative properties of the US that determine the exact nature of the CR. Clarification of these relationships through empirical investigation therefore appears necessary in order to sort out the degree to which US characteristics critical for conditioning specific responses are similar or different from those critical in influencing the relative effectiveness of reinforcement as determined through the blocking procedure.

EXPERIMENT III

A special assumption of the Rescorla and Wagner model of conditioning (Rescorla & Wagner, 1972; Wagner & Rescorla, 1972) is that the V value of a stimulus, its associative strength, can take on negative as well as positive values. For example, a negative V value is attained when the CS is negatively correlated with the occurrence of the US; a procedure often used in establishing conditioned inhibition (Rescorla, 1969; Rescorla & Wagner, 1972). A second way in which a stimulus can acquire negative V value is when it is paired with a CS that, as a result of prior conditioning to a stronger US, has acquired a greater V value than the present US is capable of supporting (Wagner, 1971).

Specific interactive effects are uniquely predicted by the model when conditioning is carried out to a compound CS in which the signs of the V values associated with the various components differ. Moreover, some of these predictions have been tested and results favorable to the model have been found (Rescorla, 1970; Wagner, 1971).

As a consequence of the ambiguity surrounding the question of just what is it that the V value of a stimulus relates to, as previously discussed, it is difficult to predict what the effects would be of placing a stimulus that had acquired positive V value through prior conditioning with an appetitive reinforcer in compound with a neutral stimulus during a conditioned suppression task involving aversive reinforcement.

A prevalent hypothesis regarding the interactive effects of hedonically opposite reinforcers holds that the motivational states resulting from the two types of reinforcers interact in a subtractive manner. That is, the motivational state associated with an appetitive reinforcer is reduced in the presence of a motivational state associated with an aversive reinforcer, and vice versa (Konorski, 1967; Millenson, 1971; Mowrer, 1960; Rescorla & Solomon, 1967).

As may be appreciated, conditioned suppression is particularly suited to this type of interpretation. In fact it is not uncommon to find interpretations of the conditioned suppression phenomenon in precisely these terms (see, for example, Millenson, 1971). In these interpretations, uncontrolled background stimuli, B, are seen to amplify if not elicit an appetitive emotional state by virtue of the fact that they occur in the presence of the appetitive reinforcer made available in the operant task. By the same token, the explicit pairing of an aversive reinforcer, the noxious US, with a particular CS, A, is seen to elicit an aversive emotional state during the occurrence of the A stimulus. Suppression of the operant task to the compound stimulus, AB, is therefore seen to be the result of the two motivational states simply subtracting each other out.

In analyzing the acquisition of conditioned suppression in terms of the model, however, Rescorla and Wagner have appeared to ignore the potential interactive effects of the hedonically opposite motivational states. Rather, they discuss changes in the V values of A and B exclusively in terms of their relative correlation with the occurrence of the noxious US. Thus, with regard to the conditioned suppression response, or fear, the A component is seen to acquire positive V value whereas the B component is seen to acquire zero V value as a result of repeated conditioned suppression training trials (Rescorla & Wagner, 1972). But what of the positive V value accrued to B relative to the appetitively reinforced task? Are we to assume that a given stimulus can possess simultaneously active but noninteracting V values? It is this issue that the following experiment is designed to address.

In this experiment food and water deprived rats were first trained on a modified S^D S^{Δ} task in which bar pressing on Bar 1 was reinforced with food in the presence of either tone or light, the S^D, and bar pressing on Bar 2 was reinforced with water in the absence of the S^D, that is, during the S^{Δ} period. Following S^D S^{Δ} training, a conditioned suppression task reinforced by foot shock was superimposed upon the S^D S^{Δ} task. In one group the S^D also served as the CS for the conditioned suppression response. In another group a novel stimulus served as the CS. In a third group, the experimental group, a compound consisting of the simultaneous presentation of the S^D plus the novel stimulus served as the CS. Amount of conditioned suppression acquired to the elements of the compound CS were then assessed relative to that of the single CSs in the other two groups having similar reinforcement histories.

Due to the exploratory nature of this experiment specific predictions have not been made. However, the question of primary concern is to what degree acquisition of the conditioned suppression response to the novel stimulus in the experimental group would be facilitated or impeded by the concurrent presence of a stimulus, S^D, that had acquired positive V value for another simultaneously active response established to a reinforcer of opposite hedonic value.

Method

Subjects and Apparatus

The subjects were 25 Long Evans male rats weighing 250-300 gm at the start of the experiment. They were maintained at 80% of their normal body weight and placed simultaneously on a 23 hr schedule of water deprivation throughout the entire experiment.

The apparatus was the same as that used in Experiment 1 except for the inclusion of an additional bar (Bar 1) and a water dipper. Bar 1 was located on the same end wall as the original bar (Bar 2) and positioned approximately 2 in directly above the protruding food cup. The water dipper was positioned midway between the protruding food cup and Bar 2. Bar 2 was programmed to activate the water dipper and Bar 1 the food magazine.

Procedure

S^D-S^Δ training: Subjects were initially trained to bar press for water reinforcement according to the same procedure described in Experiment 1. Bar 1 was withdrawn during this training procedure. Following two 90 min sessions of responding for water on a VI-30 sec schedule of reinforcement, subjects were trained to bar press for food reinforcement according to the same procedures except that Bar 1 was inserted and Bar 2 was withdrawn. In addition, the stimulus subsequently to be used as the discriminative stimulus, S^D, was presented during the food reinforced sessions. For half of the subjects a 28 VDC house light served as the S^D. For the remainder a 240 Hz tone presented continuously at 80-82 db SPL served as the S^D.

Following two sessions of responding for food on the VI-30 sec schedule, four sessions of differential bar press training were begun. For the remainder of the experiment daily sessions were 90 min in duration and a VI 30 sec schedule of reinforcement was used throughout for both reinforcers. During the first differential training sessions, Bar 2 was inserted and Bar 1 was withdrawn. This arrangement permitted subjects to bar press for water. During the second session, Bar 1 was inserted and Bar 2 was withdrawn, permitting subjects to bar press for food. During sessions three and four, both bars were inserted; however, only one was active in each session. In session three, Bar 2 was active, permitting subjects to bar press for water. In session four, Bar 1 was active permitting subjects to bar press for food. The S^D was presented during the Bar 1 - food reinforced sessions, but not during the Bar 2 - water reinforced sessions.

The next seven sessions constituted the S^D-S^Δ training procedure. The purpose of this training procedure was to train subjects to bar press for food on Bar 1 during the presence of the S^D and to bar press for water on Bar 2 during its absence, that is, during the S^Δ period. During S^D periods Bar 1 was active and Bar 2 was inactive. These conditions were reversed during S^Δ periods.

During the first S^D-S^Δ training session, S^D conditions were in effect for the first half of the session and S^Δ for the remainder. During the second and third sessions S^D and S^Δ periods were alternated twice; each period being approximately 22 1/2 min in duration. During sessions four and five, four 4-min S^D periods were distributed at equal intervals throughout each session; the S^Δ condition was in effect for the remainder of each session. During the last two S^D-S^Δ training sessions, four

1 min S^D periods were presented per session, with S^{Δ} conditions being in effect during the remainder. The first S^D period was presented 10-15 min after the beginning of the session. The next three S^D periods were presented at intervals ranging from 8-16 min each.

Conditioned suppression training: Following S^D-S^{Δ} training subjects were divided into three groups of 8 subjects each and given 16 trials of conditioned suppression training over four sessions. A conditioned suppression trial consisted of the presentation of a 1 min CS terminated by a 1 mA footshock of 1 sec duration. In the experimental group, the CS was composed of a compound stimulus, AX, (Group C-CS) in which the A component and the S^D were one and the same stimulus. In the first control group (Group S-CS), the same stimulus used as the S^D also served as the CS. This is termed an "A" stimulus in the conditioned suppression task. In the second control group (Group D-CS), a stimulus different from that used as the S^D served as the CS. This is termed an "X" stimulus in the conditioned suppression task. Throughout conditioned suppression training no further S^D presentations were given to subjects in Group D-CS; however, S^D-S^{Δ} conditions of reinforcement remained in effect for Groups C-CS and S-CS.

Following conditioned suppression training, subjects were given a single Test session in which the tone and the light were each presented for 1 min in the absence of the US on 2 separate occasions; S^D-S^{Δ} conditions remained in effect during Test trials. Intertrial intervals during conditioning and testing sessions were presented according to the parameters used for S^D presentations in the last two sessions of S^D-S^{Δ} training.

Data Collection and Analysis

In order to assess the degree to which the S^D S^Δ task was learned, "discrimination" ratios were calculated independently for Bars 1 and 2. These ratios were calculated in a manner similar to the suppression ratios described in Experiment 1. The discrimination ratios were based on bar press rates during S^D periods relative to those of preceding S^Δ periods of equal duration. Thus for a given bar, a discrimination ratio greater than .5 indicates a higher rate of bar pressing on that bar during S^D as opposed to S^Δ periods. Conversely, a ratio less than .5 indicates a lower rate of bar pressing on that bar during the S^D period (see Table 7). Since the purpose of the S^D S^Δ training procedure was to train subjects to press Bar 1 for food during S^D periods and Bar 2 for water during S^Δ periods, the degree to which this task was learned should be evident in the discrimination ratios calculated to either of the two bars. In fact, the two measures are somewhat redundant. A high ratio on Bar 1 indicates good S^D-S^Δ performance as does a low ratio on Bar 2. Both measures are nevertheless included in this report.

During conditioned suppression and testing procedures, two sets of trial-by-trial suppression ratios were calculated based on mean pre-conditioning S^D and S^Δ bar press rates respectively. These means were obtained during the last S^D-S^Δ training session. The mean S^D rate for a given subject was based on his Bar 1 bar press rate during four 1 min S^D intervals. The mean S^Δ rate was based on his Bar 2 bar press rate during a similar set of four 1 min S^Δ intervals. The two sets of suppression ratios permitted independent analysis of conditioned suppression levels relative to performance on Bar 1 and Bar 2 during CS presentations

TABLE 7

METHOD OF OBTAINING DISCRIMINATION RATIOS IN EXPERIMENT III

	Bar 1	Bar 2
S^{Δ} bar press rate (1 min pre S^D)	a	b
S^D bar press rate	c	d
Discrimination ratio	c/a+c	d/b+d

(See Table 8). These procedures were instigated so that appropriate comparisons could be made between test trial results. Direct comparisons between Bar 1 and Bar 2 are inappropriate in this experiment due to the fact that the reinforcement values of food and water had not been equated.

Results

S^D-S^Δ training

Discrimination ratios obtained during the last session of S^D-S^Δ training showed that subjects were successfully trained to press Bar 1 for food and Bar 2 for water during appropriate S^D-S^Δ periods. The mean discrimination ratios during S^D periods were .96 and .14 for Bars 1 and 2 respectively. The high discrimination ratio on Bar 1 reveals that subjects pressed this bar more frequently during S^D as opposed to S^Δ periods. Secondly, the low discrimination ratio on Bar 2 reveals that subjects pressed this bar more frequently during S^Δ as opposed to S^D periods. Standard deviations across trials were .08 and .18 for Bars 1 and 2, respectively, revealing a high degree of consistency between subjects in S^D-S^Δ performance. No reliable differences were found in either of the discrimination measures when subjects were divided according to conditioning groups. Moreover, there were little if any differences in discrimination ratios relative to the modality of the S^D used.

Further examination of the data revealed that Bar 1 - food reinforced bar press rates during S^D periods were significantly greater than Bar 2 - water reinforced rates during comparable S^Δ periods ($F=34.44$; $df=1/18$; $p<.01$). The mean bar press rate per min for the last session

TABLE 8

METHOD OF OBTAINING SUPPRESSION RATIOS IN EXPERIMENT III

	Bar 1	Bar 2
Preconditioning bar press rate	a: mean of 4 1 min S^D periods obtained on the last day of S^D-S^{Δ} training	b: mean of 4 1 min S^D periods obtained on the last day of S^D-S^{Δ} training
CS bar press rate	c	d
Suppression ratio	c/a+c	d/b+d

of S^D-S^Δ training [illegible] for Bar 1 and 2 during appropriate S^D and S^Δ conditions, respectively. [illegible], though [illegible] between bar [illegible] of higher rates for food than for water during appropriate S^D [illegible] conditions [illegible] this difference presumably reflects a higher motivational level for food than water, as bar press rate was consistently higher for food as opposed to water throughout S^D-S^Δ training.

Acquisition of the Conditioned Suppression Response

Figure 5 shows the rate and level to which each group acquired the conditioned suppression response relative to their performance for the reinforcer most appropriate. For example, in Group C CS, the suppression ratios plotted are those calculated for Bar 1 since the A component of the compound CS, AX, also served as the S^D in this group and subjects had been trained to press Bar 1 for food in the presence of the S^D. In Group S CS, the suppression ratios plotted are again those calculated for Bar 1 since the CS in this group, stimulus A, also served as the S^D. In Group D CS, on the other hand, the suppression ratios plotted are those calculated for Bar 2 since the novel CS in this group, stimulus X, had been superimposed upon the S^Δ period. Due to the fact that the reinforcement values of food and water had not been equated, directed comparisons between rate and level of acquisition of the conditioned suppression response can only be made for groups that can be considered to be working for the same reinforcer in the operant task during the conditioning trial; that is, Groups C CS and S CS. As the means in Figure 5 reveal, little if any difference can be seen between the acquisition rates of Groups C CS and S CS. Moreover, both attained moderate levels of conditioned suppression by the last day of conditioning.

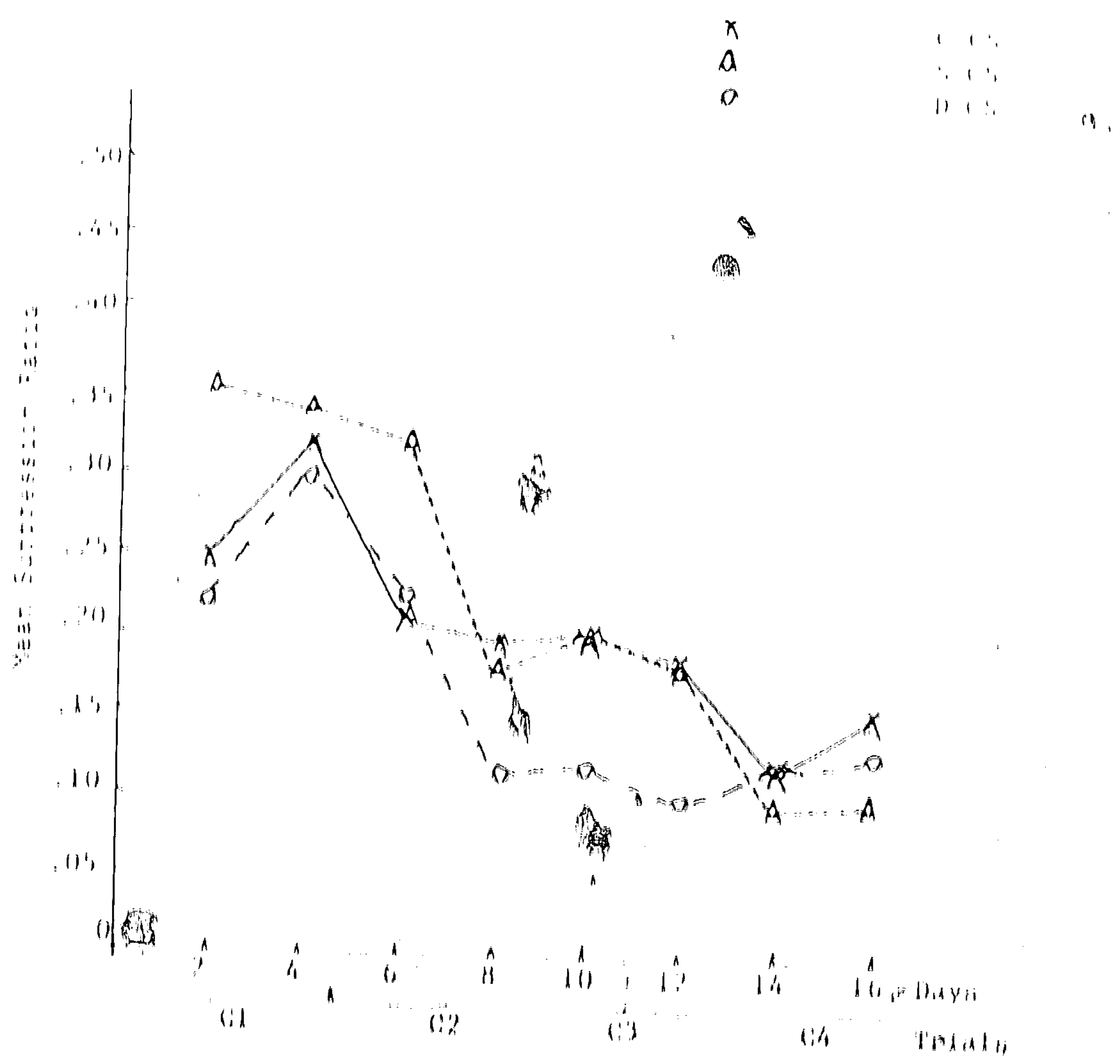

FIGURE 5

ACQUISITION OF THE CONDITIONED SUPPRESSION RESPONSE IN EXPERIMENT III (SEE TEXT FOR A DISCUSSION OF THIS FIGURE).

[illegible]

Performance [illegible] different [illegible] test trials.

Table 9 shows the design of this experiment plus the suppression ratios that were obtained during the test presentations of each of the stimulus elements. Suppression ratios to each component of the compound CS in Experimental Group C-CS are presented separately along with the suppression ratios for their appropriate single CS control conditions. Suppression ratios to the A component in Experimental Group C-CS are most appropriately compared to those of the CS, or A stimulus, in Control Group S-CS since the same stimulus served as the S^D and the CS element in each group. In addition, suppression ratios calculated to test presentations of the stimulus that served as the S^D, or A stimulus, in Control Group D-CS are also presented in this comparison. The data for these comparisons are shown in Table 9 in the last column under the heading "Stimulus Element A". Analysis of variance of the means of the A component suppression ratios calculated over test trials in Experimental Group C-CS and those of the comparable stimuli in Control Groups S-CS and D-CS showed that the means differed significantly ($F=9.59$; df 2/18; $p<.01$). These means were .10, .16 and .46 for Groups C-CS, S-CS and D-CS, respectively. Orthogonal comparisons revealed that the D-CS mean differed reliably from both the C-CS mean ($t=2.21$; df=21; $p<.05$) and the S-CS mean ($t=4.17$; df=21; $p<.01$). The C-CS and S-CS means, however, did not differ significantly ($t=1.92$; df=21; $p>.05$). Stimulus modality was not found to reliably influence the A component suppression

TABLE [illegible]

[illegible]

[illegible]

Group	S^D Training	Conditioned Suppression Training	Test Stimulus Elements: A calculated for Bar 1	Test Stimulus Elements: A calculated for Bar 2
C-CS	S^D A: Press Bar 1 for food; S^D A: Press Bar 2 for water	AX+US	.30	.18
[illegible]-CS	Same as above	A+US	.16	.21
D-CS	Same as above	X+US	.46	.05

[illegible]

These findings [illegible] that [illegible] conditioned suppression response [illegible] stimulus [illegible] the availability of appetitive reinforcement, the S^D or A stimulus, regardless [illegible] whether the S^D [illegible] presented in compound with a neutral stimulus, S, during conditioned suppression training as in Experimental Group C-CS, or alone as in Control Group S-CS. Since the S^D, or A stimulus, in Control Group D-CS was not associated with aversive reinforcement during the conditioned suppression procedure, little change between pre-conditioning and test trial responding would be expected during S^D presentations. The mean test trial suppression ratio of .48 that was observed in this group is therefore consistent with expectations based on the design of the experiment. Moreover, this observation tends to rule out the possibility that any of the other test trial results are a function of sensitization as opposed to associative mechanisms per se.

With regard to the Test trial data obtained to the X component of the compound CS in Experimental Group C-CS, suppression ratios calculated on Bar 2 have been selected as indicating the degree to which this stimulus acquired the conditioned suppression response. This selection was made on the basis of the observation that bar pressing performance during the presentation of the X component during Test trials was almost exclusively restricted to Bar 2; mean bar press rates during X component presentations in Experimental Group C-CS were .2 and 3.5 bar presses per min for Bar 1 and 2 respectively. Thus, since S^Δ conditions were clearly in effect during the X component Test

[illegible]

Experimental Group C-CS are most appropriately compared to those of the CS, or X stimulus, in Control Group D-CS. In addition, suppression ratios calculated to test presentations of the X stimulus in Control Group S-CS, a novel stimulus for this group, are also presented in this comparison.

The data for these comparisons are shown in Table 9 in the last column headed "Stimulus Element X". Analysis of variance of the means of the X component suppression ratios calculated over test trials in Experimental Group C-CS and those of the comparable stimuli in Control Groups S-CS and D-CS were not found to differ significantly ($F=1.38$; $df=2/18$; $p>.05$). As with the A component suppression ratios, stimulus modality was not found to reliably influence the X component suppression ratios ($F=1.95$; $df=2/18$; $p>.05$).

These findings suggest that a conditioned suppression response involving aversive reinforcement is acquired to a neutral stimulus, X, regardless of whether the neutral stimulus is presented in compound with an S^D, the A stimulus, for appetitive reinforcement during conditioned suppression training as in Experimental Group C-CS, or alone as in Control Group D-CS. The relatively low suppression ratio of .21 obtained during Test trials in Group S-CS should not be of concern here as this ratio probably reflects the suppressive effects of the presentation of a novel stimulus on ongoing behavior rather than some nonassociative effect such as sensitization. Support for this argument is found in the similarly low suppression ratios that were obtained during such comparable conditions as the first pretest session of Experiments I and II; these means were .31 and .25 respectively.

In addition to the within Bars comparisons that have been discussed, visual inspection of the test trial data in Table 9 reveals a between Bars effect as well. As can be seen, suppression ratios on Bar 1 to the A component of Experimental Group C CS are higher than those on Bar 2 to the X component. On the basis of this observation it could be argued that a tendency existed for the A component to acquire the conditioned suppression response at a slower rate than the X component due to the differential conditioning histories of the stimulus components. However, since the appropriate control conditions in each instance, that is, the A stimulus in Control Group C CS and the X stimulus in Control Group D CS, respectively, showed proportional differences in their suppression ratios, it appears that the between Bars effect is not a result of the differential conditioning histories of the stimulus components. Rather, it is argued that the between Bars effect is due to the apparently higher level of motivation for food as opposed to water reinforcement that was observed earlier in this study (see Millenson & De Villiers, 1972, for a supportive discussion of the effects of appetitive motivational levels on conditioned suppression responding).

Secondly, the consistently higher suppression ratios for the CS components A and X of Experimental Group C CS relative to their control conditions are taken to indicate that the burden of associative strength carried by a compound CS is distributed among its components.

Therefore, it is argued again that the fact that the X component had been conditioned to the availability of appetitive reinforcement and the X component had not had little if anything to do with the distribution of associative strength between these CS components during acquisition of the conditioned suppression response.

Blocking in the S^D-S^Δ Task

Ignoring for the moment the superimposed conditioned suppression task, it is of some interest to reexamine the fact that when the X component of Experimental Group C CS was presented alone during testing, responding was virtually restricted to Bar 2 as opposed to Bar 1. These means, as may be recalled, were 3.5 and .2 bar presses per min, respectively. On the other hand, discrimination ratios obtained during conditioned suppression training trials for this group clearly revealed that the A component, that is the S^D, was in control of responding during this period. These discrimination ratios across conditioning sessions were .80 and .14 for Bars 1 and 2 respectively. Actual bar press rates during CS presentations on the last conditioned suppression training session for this group were 4.8 and 1.1 bar presses per min for Bars 1 and 2 respectively. Thus, the data collected during conditioned suppression training trials strongly suggest that the occurrence of the X component was most strongly correlated with responding on Bar 1 as opposed to Bar 2. Secondly, since S^D-S^Δ conditions were in effect throughout this period, the responses that were made on Bar 1 were appropriately reinforced whereas the few responses that w[illegible] Bar 2 were not. As previously noted, however, when the X [illegible] was presented alone during testing, responding was almost exclusively restricted to Rat 2. The X component apparently failed to acquire S^D properties even though responding and primary reinforcement conditions favored it. Due to the fact that the X component had acquired S^D properties during a prior conditioning phase, it could be argued that failure of the X component to acquire such properties during the "compound S^D" presentations can best be explained as a case of blocking.

Discussion

Experiment III was designed to assess the degree to which subjects acquired an aversively reinforced conditioned suppression response to a neutral stimulus, X, when that stimulus was placed in compound with a discriminative stimulus, A, which had an associative history involving appetitive reinforcement. The results of this study failed to show that acquisition to the X component was influenced to any marked degree by the presence of the A component, and vice versa. This conclusion was based upon comparisons of the level of acquisition of the conditioned suppression response in control subjects who were conditioned to either the X or the A stimulus alone. Although Test trial suppression ratios did tend to be greater (though not significantly) to the elements in the compound CS condition as compared to their single stimulus controls, this was attributed to the fact that associative strength tends to be distributed equally among equally salient elements of a compound CS and not because of any interactive effects that may have occurred as a result of the differential reinforcement histories of the elements per se. Test trial suppression ratios also appeared to be greater to the A stimulus as opposed to the X stimulus in both the compound CS condition and the appropriate single stimulus control conditions. However, this finding was confounded by the fact that the operant reinforcers, food and water, for which subjects were working during the Test presentations of the A and X stimuli, respectively, were not equated in terms of reinforcement value. Thus, the differences in suppression ratios noted may have been the result of a higher motivation level for food as opposed to water and not the differential reinforcement histories of the A and X stimuli. Higher bar press rate for food as opposed to water noted during S^D-S^Δ training tends to support this argument.

Another finding was that the X component when placed in compound with an S^D, the A component, failed to acquire S^D properties during the conditioning phase of the experiment even though responding and reinforcing conditions favored it. Thus, it appears that a stimulus can fall victim to blocking in one of two simultaneously reinforced tasks (the S^D-S^Δ task) but acquire associative strength in the other (the conditioned suppression task). Further confirmation of this finding would not only prove detrimental to an attentional view of conditioning, it would provide further disconfirmatory evidence for the surprise hypothesis of Kamin (1968; 1969) regarding effective reinforcement value in addition to that reported in Experiments I and II.

In terms of Rescorla and Wagner's model of conditioning, the findings of this study suggest that V values based on appetitive and aversive reinforcers should not necessarily be viewed as being opposite in sign. Were this the case, acquisition of the conditioned suppression response to the X component in the compound-CS condition should have been facilitated and acquisition to the A component should have been impeded relative to their appropriate single-stimulus control conditions. This, however, was not the case. Secondly, these findings suggest that V should not be viewed as relating simply to the nonspecific arousal value of the reinforcer. Were this the case, acquisition of the conditioned suppression response to the X component in the compound-CS condition should have been impeded or "blocked" relative to its single stimulus control condition.

These conclusions are potentially confounded, however, by the fact that, besides differences in the nature of the reinforcer used, the nature of the response being reinforced in the S^D-S^Δ task differed from that being reinforced in the conditioned suppression task. As a consequence, the absence of an interaction between the A and X components in the experimental condition may be interpreted to indicate that (1) V values related to the motivational properties of appetitive and aversive reinforcers are independent of one another, or (2) V values related to different response systems (bar pressing on one hand, and "fear" on the other) are independent of one another.

Due to the fact that this experiment was exploratory in nature, many problems in interpretation were not foreseen. For example, the interpretive difficulty arising out of the fact that the value of the operant reinforcers had not been equated was not appreciated at the onset of this experiment. A second, and potentially more serious problem in interpretation arises out of the unknown role S^Δ may have played in Control Group D CS in which the novel stimulus, X, served as the CS in the conditioned suppression task. For example, it is conceivable that S^Δ played a role in this condition similar to that of the S^D, or A component, in the experimental condition. That is, the CS could be thought of as being composed of a compound involving the X stimulus plus either the S^D or the S^Δ in the compound CS and "single-stimulus control" conditions, respectively. Given this to be the case, X in the "single-stimulus control" condition would not constitute an appropriate control for X in the compound CS condition since both may have been influenced by the presence of an appetitively reinforced stimulus component. It is argued, however, that since S^{Δ} was not a discriminative stimulus, it probably would not have interacted to any marked degree with the acquisition of the conditioned suppression response to the discriminative X stimulus in the control condition. In contrast, since the A, or S^{D}, and X stimuli in the compound CS condition were both discriminative stimuli and since both were equally correlated with the US, the interactive effects in this condition should have been maximized if, indeed, any had existed.

GENERAL DISCUSSION

The results of the preceding experiments strongly suggest that the "surprise" value of an unconditioned stimulus is not the critical variable in determining the relative effectiveness of that stimulus as a reinforcer in conditioning as postulated by Kamin (1968; 1969). From another point of view, these findings do not seem to be supportive of a two stage-model of conditioning along the lines of the attentional theory of discrimination learning proposed by Sutherland and Mackintosh (1971). These findings are, on the other hand, most compatible with Rescorla and Wagner's model of conditioning (Rescorla & Wagner, 1972; Wagner & Rescorla, 1972). And, they are particularly compatible with Rescorla's (1972) recent interpretation of that model.

In Rescorla and Wagner's model as interpreted by Rescorla (1972), the relative effectiveness of a reinforcer in conditioning is not seen to be a function of the "information value" of the CS as it relates to the US. Rather, it is a function of the level of associative strength accrued to the CS relative to that potentially supportable by the reinforcer. Although the model is vague in many respects regarding the critical aspects of this associative process, several aspects are clearly defined. For example, the focus of action is clearly placed on the intensive property of the associative process for it is the amount of associative strength, V in their model, that is deemed critical. Secondly, magnitude of reinforcement appears to be directly tied to the intensive property of the associative process in that (1) more-or-less associative strength can be supported by a given reinforcer, (2) a given [illegible] support, [illegible] [illegible] and/or the level of associative strength accrued to other stimuli simultaneously active. Thirdly, qualitative properties of the reinforcer other than its reinforcement magnitude do not appear to be important in determining the intensive property of the associative process (except perhaps in determining which associative process is reinforced).

It is primarily in terms of this third statement that the present experiments may be seen to contribute to the model. In Experiments I and II it was found that the modality of/in which the reinforcer, the aversive US in this case, was delivered was not important in determining the relative effectiveness of the reinforcer in a conditioned suppression transfer task, at least as far as could be determined by the blocking procedure. This finding was seen to support and extend Rescorla's (1972) hypothesis that qualitative properties of the US are not important in determining the effective reinforcement value. Thus, it appears that what is important is some less specific property of the reinforcer such as its motivational value, or perhaps simply its arousal value.

In attempting to probe the limits of this hypothesis, Experiment III was carried out. In that experiment, it was found that acquisition of a conditioned suppression response involving aversive reinforcement to the components of a compound CS did not appear to be facilitated or impeded when one of the components had previously been conditioned to an appetitive reinforcer. This finding was interpreted to indicate that [illegible] value of the reinforcer that is critical, appetitive and aversive motivational states should not be viewed as being reciprocally related. It should be pointed out, however, that due to the fact that the design of this experiment did not allow for the partialling out of a variety of potentially confounding variables, these findings should be viewed with caution. In particular, since different response systems were conditioned in this experiment to the appetitive and aversive reinforcers, it is uncertain to what degree differences in the CRs as opposed to differences in the motivational value of the reinforcers used accounted for the data obtained.

This latter qualification points out an important issue that has been appreciated only at the termination of this research. Although the thread of this issue can be seen at various points throughout this study it appears clear at this point that one of the key issues in Rescorla and Wagner's model is whether it is (1) the amount of associative strength accrued to the CS relevant to the response being conditioned that is critical, or (2) the amount of associative strength accrued to the CS relevant to the motivational property of the reinforcer itself, such as its incentive property (see for example, Bindra, 1974), that is critical. For example, holding the motivational property of the reinforcer constant, to what degree would there be a change in effective reinforcement value if the nature of the CR (through manipulation of the task demands) was changed between phases of a transfer experiment?

or, vice versa, to what degree would there be a change in effective reinforcement value if the aversive or appetitive motivational property of the reinforcer was changed between phases and the nature of the CS was held constant?

These questions obviously require further research before any firm conclusions can be made, however, the view that it is the motivational property of the reinforcer that becomes associated to the CS tends to be favored at this point. This position has been taken for two reasons. First, since a variety of individual and possibly independent CRs appear to be conditioned in any given conditioning situation (see Bindra, 1974, and Black & De Toledo, 1972), it is unclear whether the amount of associative strength involved in some or all of these responses is what is critical, or, in fact, whether this question can ever be answered. Secondly, the motivational interpretation is favored because it appears to be consistent with the present findings. For example, the finding that changing the modality of the US in Experiments I and II did not influence the relative effectiveness of the US is consistent with the hypothesis that the critical variable was the degree to which the aversive property of the reinforcer had become conditioned in these experiments. Moreover, given that specific preparatory and/or orienting CRs were differentially supported by the two USs used in these experiments, as was speculated, the motivational as opposed to the response hypothesis would be able to accomodate the occurrence of these differential CRs while leaving the blocking effect intact. In Experiment III, on the other hand, the finding that a stimulus associated with an appetitive reinforcer did not influence the subsequent acquisition of a conditioned suppression to noise suggests again that it was the conditioning of the aversive property of the reinforcer to the conditioned suppression test that is critical.

Thus, although the response hypothesis cannot be ruled out on the basis of present data, it appears that the effectiveness of a reinforcer in supporting conditioning is likely to be anchored in the degree to which the CS has become associated with the motivational properties of the reinforcer as a consequence of prior conditioning. In other words, to the degree that the CS acquires the motivational properties of the reinforcer, the ability of that reinforcer to support conditioning appears to be reduced.

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APPENDIX A

GENERAL METHODOLOGY OF APPENDICES

The following is a selected review of pilot studies designed to examine some basic features of conditioning and blocking. In all studies to be reported a conditioned suppression procedure was used in which either water or food deprived hooded rats weighing 250-350 gm served as subjects. The rats were first trained to bar press for water (food) in a standard operant chamber under a continuous reinforcement schedule. They were then transferred to a variable interval schedule of reinforcement comprised of an equal number of intervals typically between 1 and 180 sec, sampled in 15 sec increments, and randomly distributed over a 1 hr session: A VI-90 sec schedule of reinforcement. After approximately 5 sessions of VI training, conditioned suppression training was initiated. A typical conditioned suppression trial consisted of the presentation of a CS terminated by an aversive stimulus, the US. Testing was carried out in the absence of the US according to the same procedures described for conditioning.

APPENDIX B

PILOT STUDY I

The first three pilot studies were designed to examine acquisition and extinction rates to different CSs and CS intensities. In the first study, 3 rats were given conditioned suppression training to two different CS. On odd numbered days the CS was the onset of a 28 vdc house light. On even numbered days the CS was the onset of white noise set at 62 db with exhaust fan off. The CS was 2 min in duration and the US was a 0.5 sec 1 mA foot shock. Subjects were given 16 acquisition trials to each CS at a rate of 4 trials per day over an 8 day period. Two days of extinction were then instigated with CSs alternating over trials: 2 trials per CS per day. Mean suppression ratios are plotted in Figure 1 (A, B, and C are plots of individual subjects, whereas D is a cumulative plot). As may be seen, rate of acquisition was faster for the light CS as compared to the noise CS, and resistance to extinction was greater.

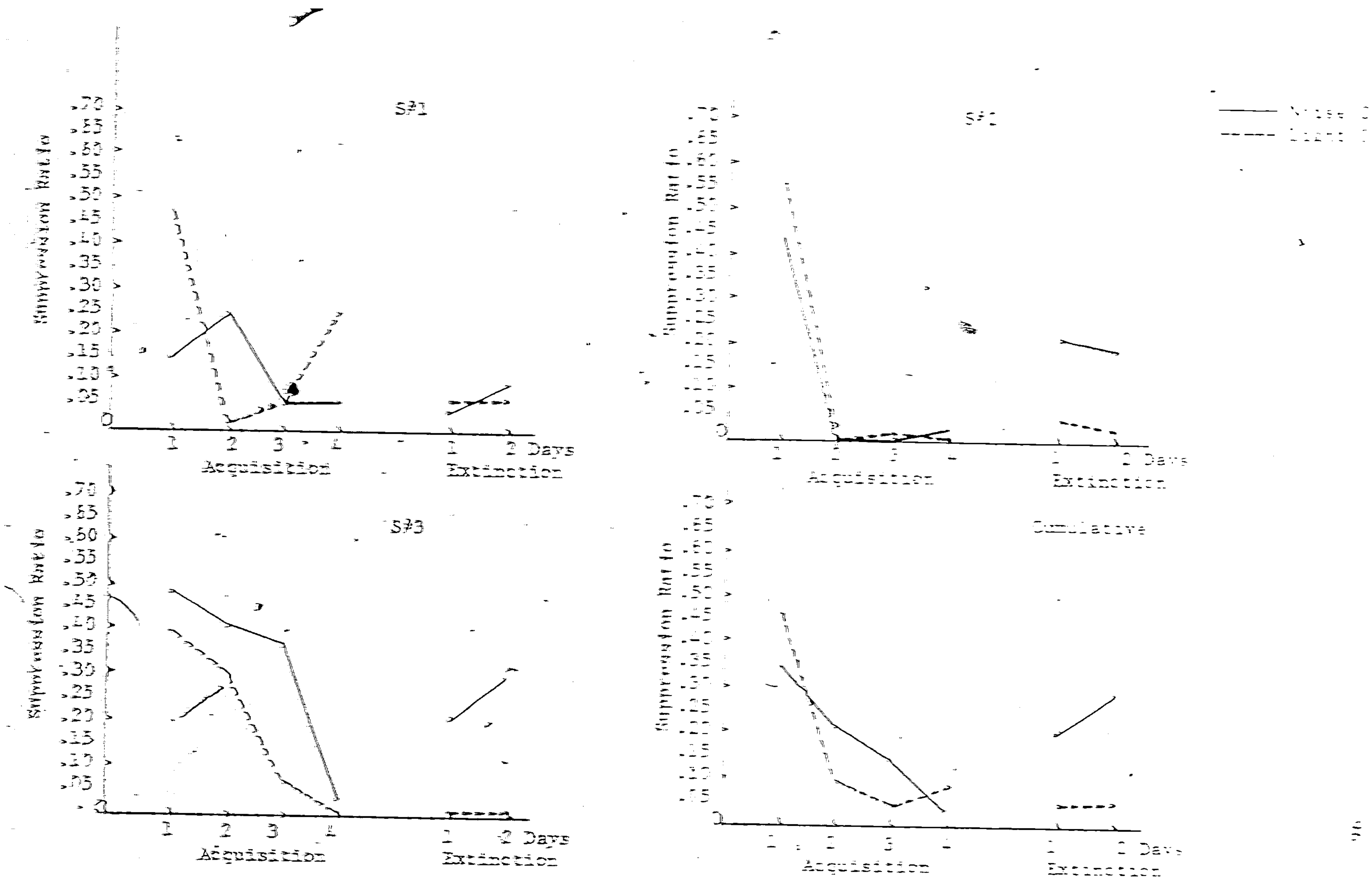

FIGURE 1. INDIVIDUAL AND CUMULATIVE MEAN SUPPRESSION RATIOS OBTAINED DURING ACQUISITION AND EXTINCTION IN PILOT STUDY 1.

APPENDIX C

PILOT STUDY 2

In the second study the intensity of the white noise was increased in an effort to equate acquisition and extinction rates for light and noise stimuli. In this study both stimuli were presented simultaneously during acquisition. Three subjects were given 16 acquisition trials with the compound CS at a rate of 4 per day followed by 2 days of extinction. During extinction light and noise components were presented alone on alternate trials, giving 2 extinction trials per component per day. The intensity of the noise component was increased to 64-65 db with exhaust fan off. Mean suppression ratios are plotted in Figure 11. As may be seen, rate of extinction was similar for the light and noise components, suggesting that each component acquired similar amounts of associative strength during compound conditioning.

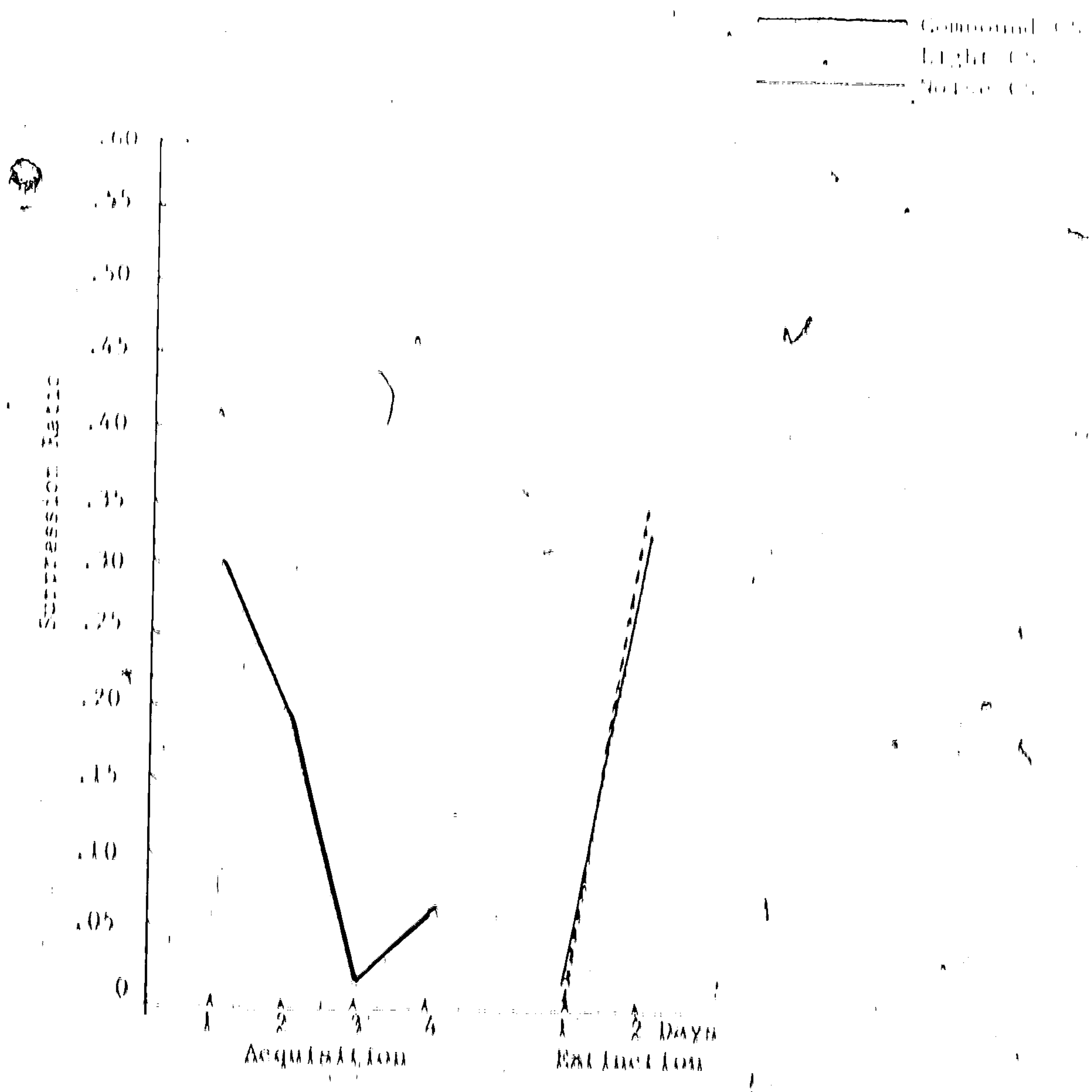

FIGURE 11. MEAN SUPPRESSION RATIOS OBTAINED DURING ACQUISITION AND EXTINCTION IN PILOT STUDY 2 (n=3).

APPENDIX D

PILOT STUDY 3

The third study was similar to the second except that the intensity of the noise component was further increased to 68-69 db. Mean suppression ratios for this study are plotted in Figure 11. As may be seen, the light component effected only minimal suppression during extinction as compared to the noise component. This suggests that one component of a compound CS can be retarded in acquiring associative strength when paired with a relatively more intense or salient component; 'overshadowing' (see Kamin, 1968).

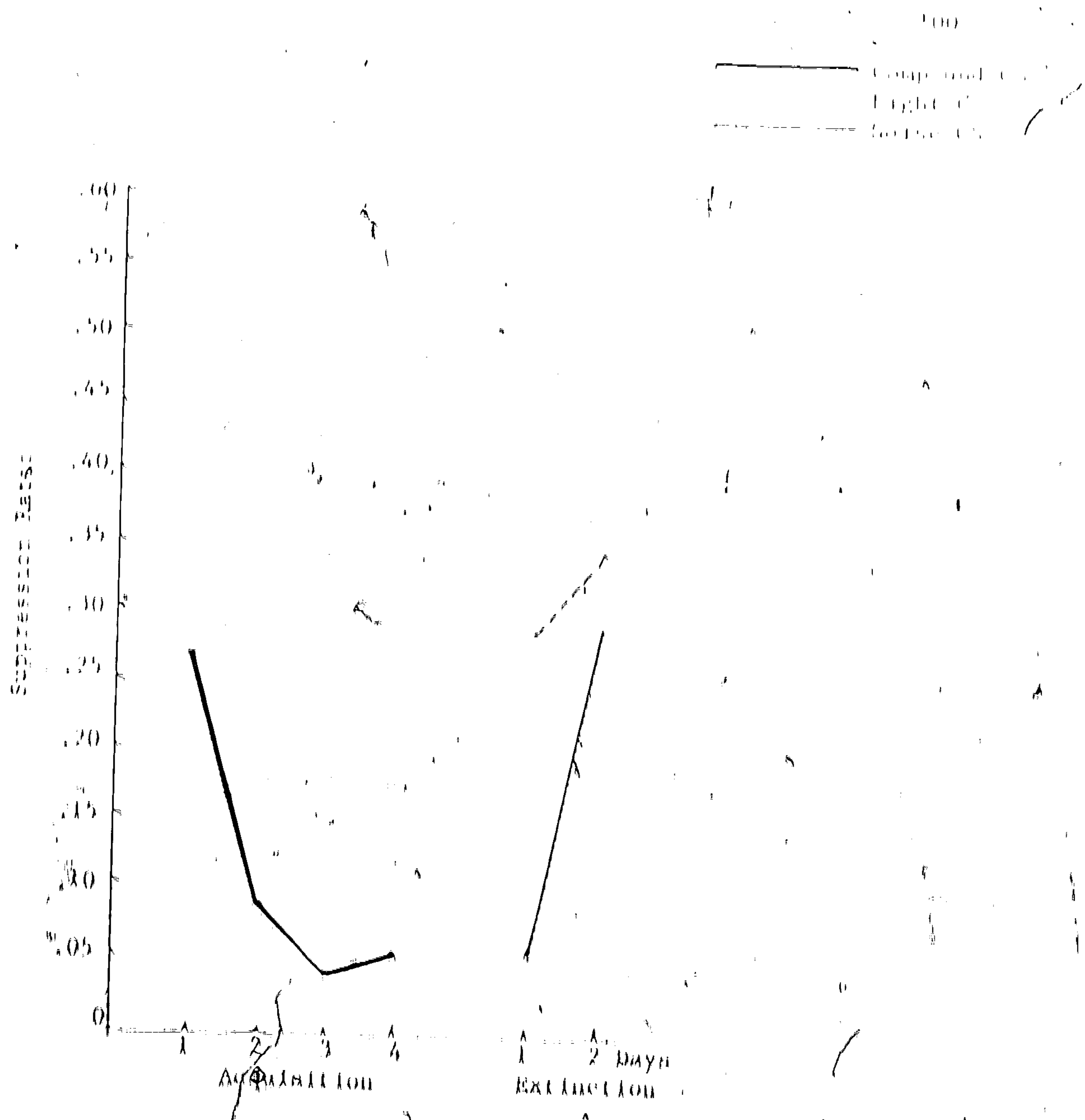

FIGURE III. MEAN SUPPRESSION RATIOS OBTAINED DURING ACQUISITION AND EXTINCTION IN PILOT STUDY 3 (n=3).

APPENDIX I

PILOT STUDY 4

The next study examined the effects of explicitly unpairing a CS with shock. In this study, 4 CSs (a 2 min, 2800 Hz tone set at 65-66 db) and 4 USs (a 0.5 sec shock of approximately 1 mA) were presented to 3 subjects in each of four 1 hr sessions. The CS and US events were arranged so that the US occurred no sooner than 4 min after CS offset and no later than 4 min before CS onset. Mean suppression ratios are plotted in Figure 1e. As may be seen, there was a tendency for the CS to facilitate bar press rate over days.

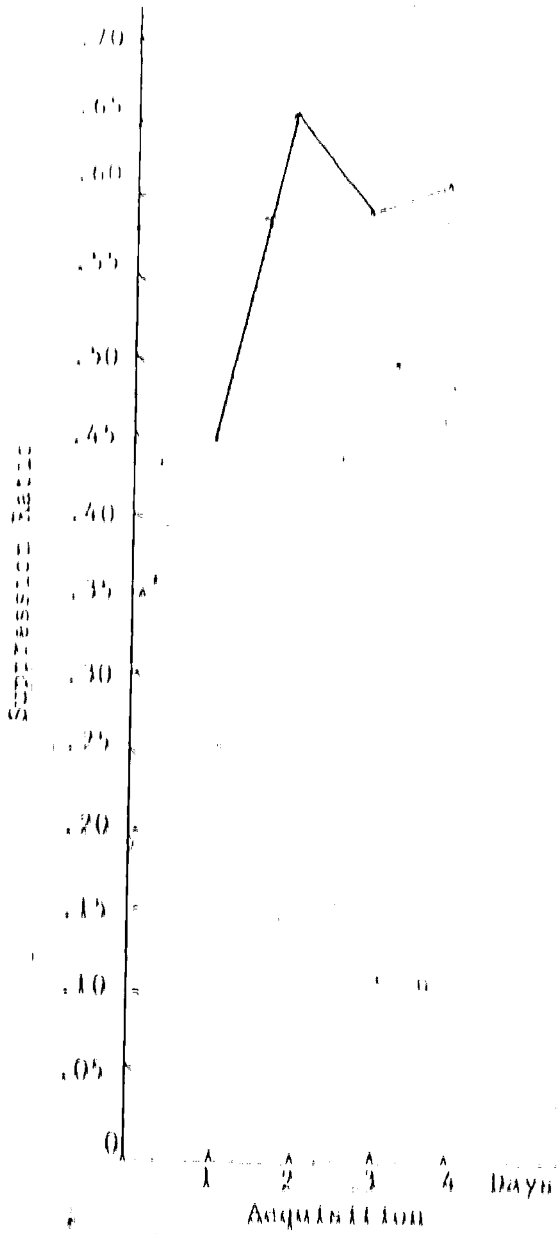

FIGURE iv. MEAN SUPPRESSION RATIOS OBTAINED DURING ACQUISITION IN PILOT STUDY 4 (n=3).

APPENDIX F

PILOT STUDY 5

The next two studies were designed to examine some basic features of the blocking phenomena. In the first blocking study, three groups received conditioned suppression training to light and light plus noise in pretraining and compound conditioning phases, respectively. (Subjects in this study had been used in a non reported pilot study using light as CS.) The intensity of the noise component during the compound conditioning phase was set at 64-65 db, an intensity found to be similar to the light component in salience (see Study 2). A 0.5 sec shock of approximately 1 mA was used as the US in both phases. However, during the compound conditioning phase a 2 sec tone followed US offset. The intensity of the tone was 105 db for Group I (n=4), 80 db for Group II (n=2), and 0 db for Group III (n=2). The tone was intended to elicit varying degrees of post-US surprise between groups. Three days of pretraining were followed by 3 days of training on the compound CS. Testing on the components was carried out under conditions of extinction: 2 trials per component per day for 2 days. Mean suppression ratios are plotted in Figure v. As may be seen post-US surprise as generated by the loud noise seemed to have little effect on the basic blocking phenomena.

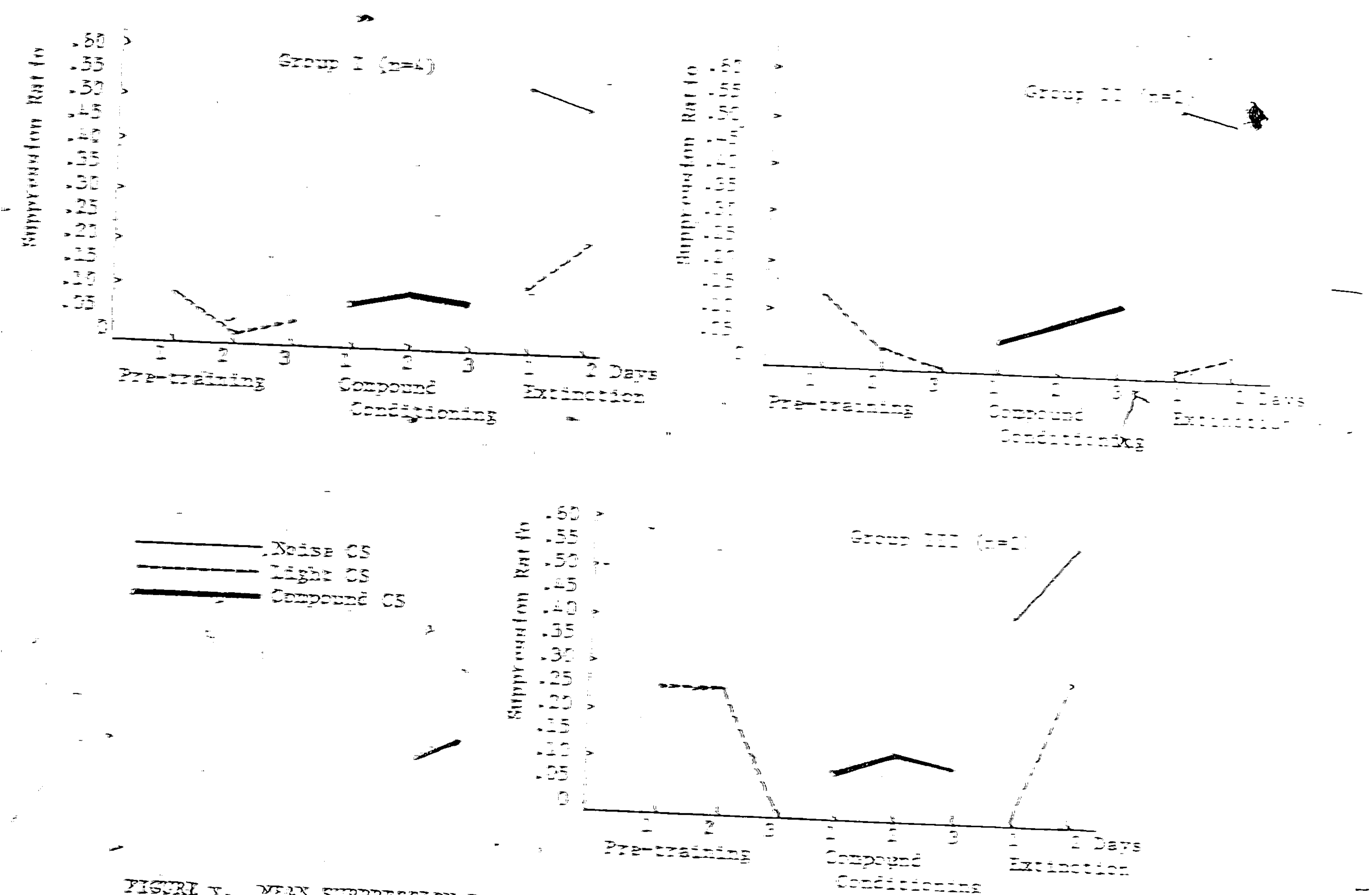

FIGURE V. MEAN SUPPRESSION RATIOS OBTAINED DURING ACQUISITION AND EXTINCTION IN PILOT STUDY 5.

APPENDIX G

PILOT STUDY 6

The second blocking study was intended to replicate and extend Kamin's finding that blocking could be reduced if not eliminated when two successive USs were presented during the compound conditioning phase to subjects that had experienced only a single US during pretraining (Kamin, 1969). In this study, three groups received conditioned suppression training to light and light plus click in pretraining and compound conditioning phases, respectively. The intensity of the 4-per sec click component was set at 62-63 db, and intensity found to be similar in salience to the light component in an unreported pilot study. The first two groups were similar to two of the groups in Kamin's study in that both received a single US during the pretraining phase. Moreover, during the compound conditioning phase, one of these groups (Group II; n=3) received a second US 5 sec after the offset of the first, while the other (Group I; n=2) did not. The third group in this study (Group III; n=3) received two successive USs during the pretraining phase, and a single US during the compound conditioning phase. It was reasoned that if the surprise value of the US during compound conditioning is critical for blocking, subjects in Group III should perform in a similar manner during testing as those in Group II. Four days of pretraining were followed by two days of compound conditioning. Testing involved the presentation of the click component alone for 4 unreinforced trials on the seventh day. Mean suppression ratios are plotted in Figure VI. As may be seen, Group II showed a slight tendency to be more resistant to extinction than Group I, a finding similar to

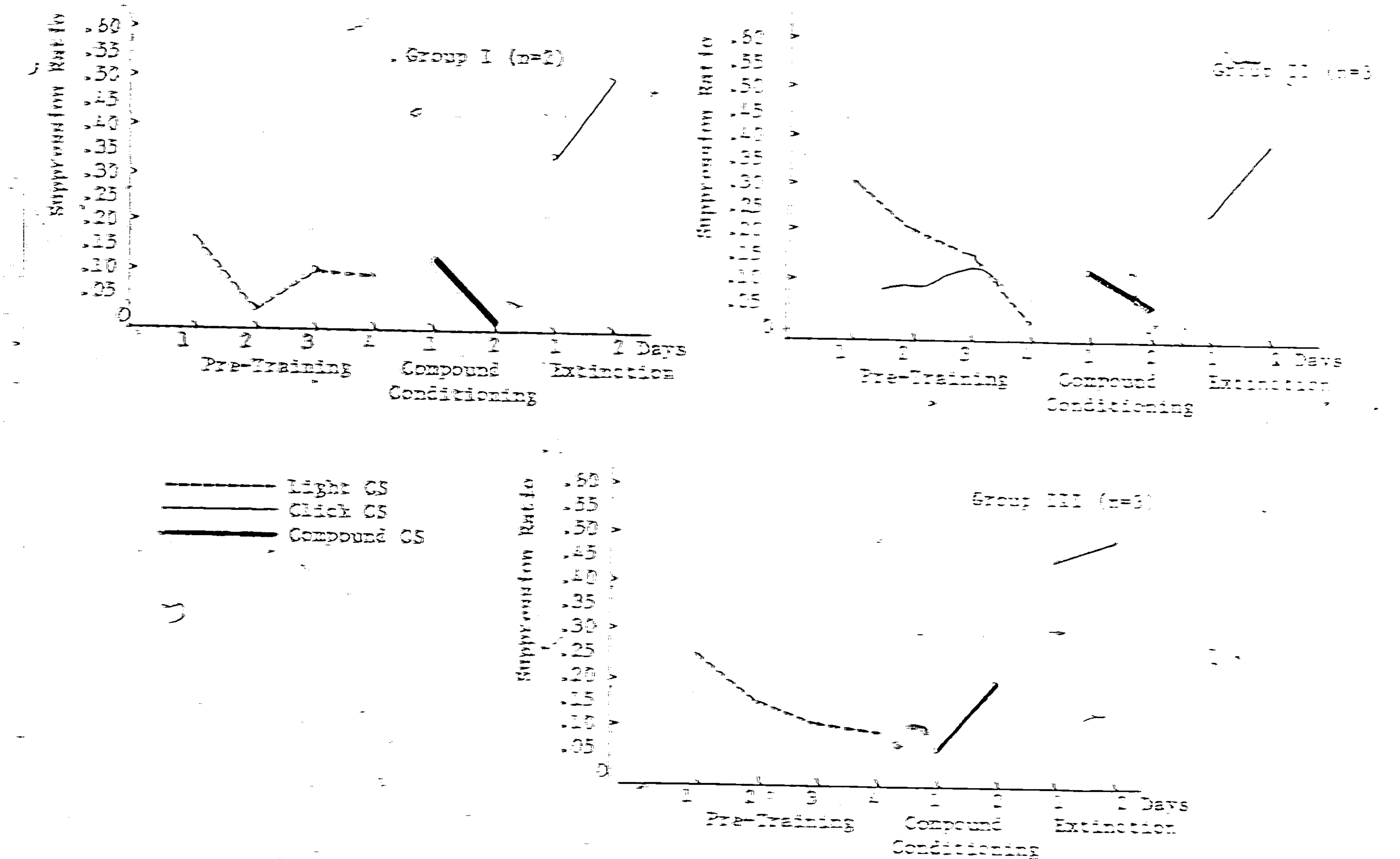

FIGURE vi. MEAN SUPPRESSION RATIOS OBTAINED DURING ACQUISITION AND EXTINCTION IN PILOT STUDY 6.

Kamin's though not as strong. The performance of Group III, however, did not appear to differ from Group I during testing, suggesting that the click component was blocked from acquiring associative strength during compound conditioning in a similar manner in both groups.

APPENDIX B

DISCUSSION OF PILOT STUDIES 1-6

The first three pilot studies may be seen as serving two purposes: To confirm the fact that CS intensity affects acquisition and extinction rates under conditions of conditioned suppression, and to find stimuli of comparable salience to serve as stimulus components in blocking studies. Kamin argued that if conditioned suppression is to be considered a classically conditioned event, it would be advantageous to demonstrate that it is influenced by parameters known to affect other classically conditioned responses (Kamin, 1965). Temporal and intensity characteristics of the CS were in fact found by Kamin (1965) to affect conditioned suppression in a manner similar to other classically conditioned responses. The first three pilot studies in this series may be seen to support the conclusion that increases in CS intensity, or salience, increase conditioned suppression acquisition rate and resistance to extinction. Secondly, it was reaffirmed that under conditions of compound stimulus conditioning, the presence of a relatively more salient component tends to retard the acquisition of associative strength to less salient components, a phenomenon labelled "overshadowing" by Pavlov and examined by Kamin (see Kamin, 1968; 1969).

The fourth pilot study was similar in design to studies by Rescorla which lead him to suggest that subjects learn 'contingencies' between CS and US events (Rescorla, 1969). It is argued that the US can be made to be positively contingent, negatively contingent, or non-contingent upon the CS in conditioning studies, and that subjects learn these relationships. In other pilot studies in this series the US was made to be positively contingent upon the CS. In the study under discussion the US was made to be negatively contingent upon the CS. That the subjects learned different things under the two conditions examined is demonstrated by the fact that on-going operant behavior was suppressed under conditions where the US was made positively contingent upon the CS, and facilitated where the contingency was negative.

The two blocking studies revealed several factors of interest. First, a demonstration of the basic blocking effect may be seen by comparing the performance of subjects in Group III of Study 5 with that of subjects in Study 2. The critical difference between these two groups is that pretraining to the light component was given to subjects in Group III of Study 5, but not to subjects in Study 2. In accord with Kamin's basic finding, the noise component appeared to be blocked from acquiring conditioned suppressive qualities in the pretrained group, but not in the non-pretrained group (Kamin, 1968). Secondly, it was found that the addition of a surprising event (loud tone) following the US during the compound conditioning phase had little if any influence on the basic blocking effect (see Study 5). This finding is difficult to reconcile with the notion that retrospection as generated by post-US "surprise" is sufficient for learning. If one assumes, however, that it is the event that generates the surprise that becomes the object of conditioning, i.e., loud tone being associated to light plus noise and/or shock in this case, then a new understanding emerges. Unfortunately, if a tone of 108 db is not sufficiently aversive to support conditioned suppression using a 2 min CS, the design of this study would not allow one to assess the presence of such an association.

It is apparent that further research is required before this issue can be resolved.

The final blocking study may be interpreted in a manner similar to Study 5 if one assumes that during compound conditioning the added US in Group II (i.e., the surprising event) became the object of conditioning, while the original US served only to support the association established during pretraining. Granting this assumption, the tendency for the click component to be more resistant to extinction in Group II as compared to Group I may in fact be the result of the click component acquiring associative strength to the second US and not the first, as has been suggested by Kamin (p.61, 1969). The fact that the click elicited only minimal suppression when tested alone in this study may be accounted for by the fact that the second US occurred 5 sec after CS offset, i.e., under trace conditioning procedures which are known to retard conditioned suppression acquisition rate (Kamin, 1965). This interpretation does not explain, however, why Kamin obtained virtual elimination of the blocking effect using this procedure (Kamin, 1969). Possibly CS and US events were arranged in the Kamin study so that the CS terminated with the offset of the second US, thus avoiding the trace conditioning paradigm. Unfortunately, the description of his study does not allow one to be sure what the exact arrangement of CS and US events were.

It is interesting to note that this general interpretation may also account for the inability of the click component to elicit suppression during testing in Group III of Study 4. Given that the 'absence of the second US' served as the object of conditioning in this group. One may not expect such an association to result in suppressive behavior. In fact, one might expect some facilitation over base level bar press rate during testing to the click component. Though a facilitation of bar press rate was not generally found, on the very first test trial, 2 out of 8 subjects did show an increase in bar press rate with click onset.

APPENDIX I

PILOT STUDY 7

The goal of this series of pilot investigations was to find an aversive auditory stimulus to serve as the second US in a US modality transfer design involving the basic blocking procedure (see Experiment 1). Secondly, parameters of the modality specific USs as well as the modality specific CSs had to be matched so that equal acquisition and extinction rates could be obtained for each of the four CS-US combinations.

In this first study a 1 sec burst of pure tone (4 KHz) set at 115-118 db SPL was used as the aversive auditory US. The CS was either light or white noise or the compound of light and noise in three groups of 4 subjects each. CS parameters were the same as those used in Pilot Study 2 except that CS duration was reduced from 2 min to 1 min. Absolutely no signs of the acquisition of the conditioned suppression response could be obtained in up to 20 trials. In other related studies not to be reported, frequency of the auditory US was manipulated as well as was duration of the CS (reduced to 30 sec on some occasions) and duration of the US (increased to 2 sec on some occasions). Under no circumstances was pure tone at 115-118 dbs found to support a conditioned suppression response.

APPENDIX I

PILOT STUDY 8

In this study, the white noise that had formerly served as the auditory CS was used as the aversive auditory US (US_n). This stimulus, US_n, was presented for 1 sec at 114-116 db SPL. A second US, the aversive tactile stimulus (US_s), also to be used in this study, consisted of a 1 sec 1 mA foot shock. The two CSs used in this study were light (CS_L), as in Study 7, and a 78 db SPL 1 KHz tone (CS_T). The CS was 1 min in duration. Groups of four subjects each were assigned to each of the four CS-US combinations. As can be seen in Figure vii Groups CS_L/US_s, CS_T/US_s and CS_L/US_n acquired the conditioned suppression response at essentially similar rates. Group CS_T/US_n, however, did not acquire the response. This basic pattern was repeated several times in other unreported studies under a variety of CS_T intensity and frequency parameters. However, in each case where the frequency of the auditory CS was greater than 1 KHz, the auditory CS failed to become conditioned to the auditory US.

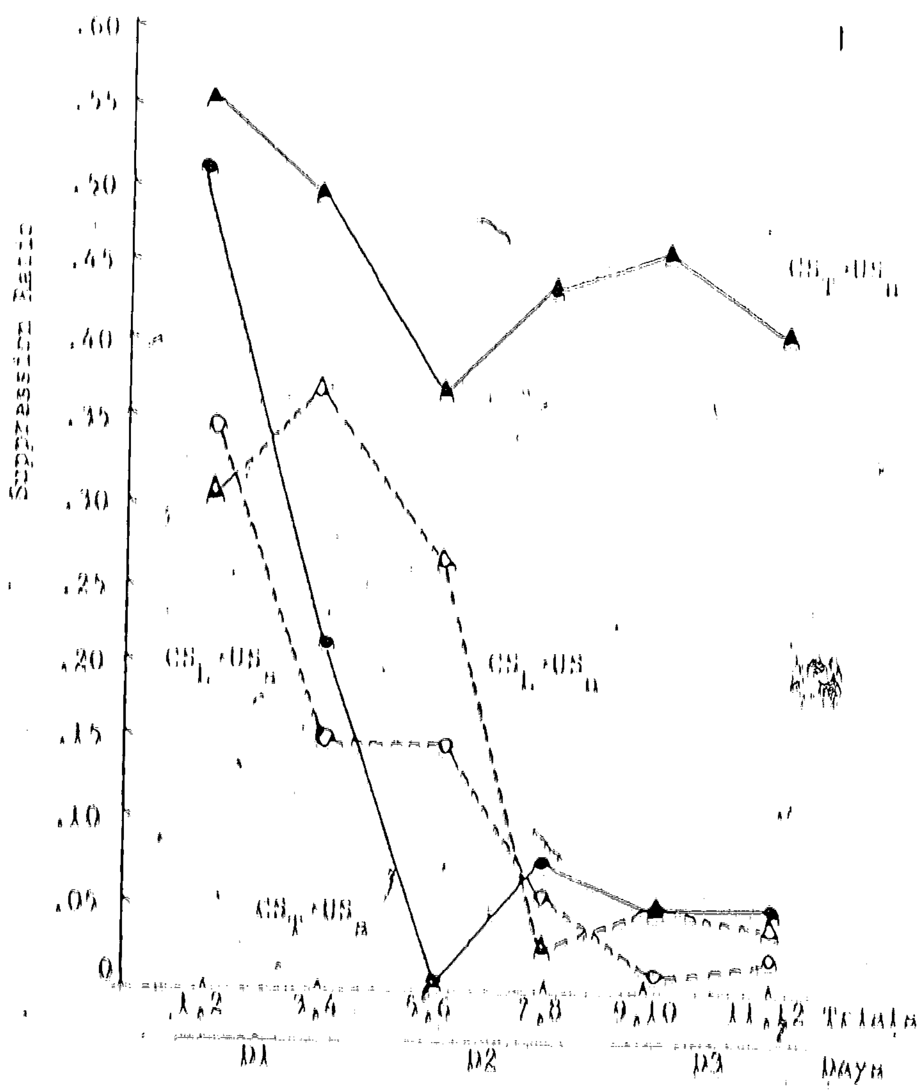

FIGURE VII. MEAN SUPPRESSION RATIOS OBTAINED DURING ACQUISITION IN PILOT STUDY 8 (n=4 per group).

APPENDIX I

PILOT STUDY 9

As a result of Study 8, the frequency characteristics of the aversive auditory US were examined and it was found that a band of noise from 1 KHz to approximately 10 KHz was being presented in the conditioning apparatus. Moreover, all auditory CSs used to date had been 4 KHz or above. As a consequence Study 9 was designed to compare the conditionability of an auditory CS (CS_I) whose frequency (.52 KHz) fell outside the range of US_n and a second ($CS_{I'}$) whose frequency (5.2 KHz) fell well within the range of US_n. CS_I and $CS_{I'}$ were each presented for 1 min and were set at an intensity of 76 db SPL. Three subjects were given four CS presentations per session with CS_I and $CS_{I'}$ preceding the US on two occasions each in random order. Figure VIII shows the rate of acquisition to the two CSs. CS_I was found to acquire the conditioned suppression response whereas $CS_{I'}$ was not.

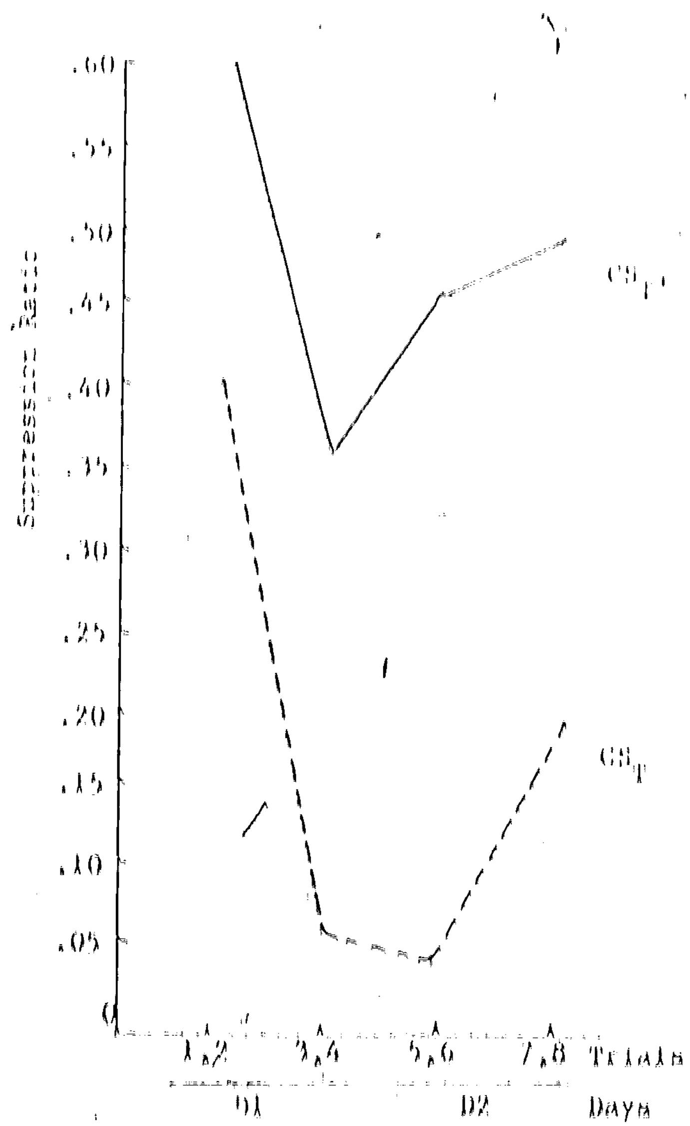

FIGURE VIII. MEAN SUPPRESSION RATIOS OBTAINED DURING ACQUISITION IN PILOT STUDY 9 (n=3 per group).

APPENDIX L

PILOT STUDY 10

Following some additional pilot investigations, an auditory stimulus of 240 Hz was selected to serve as CS_T. Secondly, it was decided to present this stimulus intermittently at 1 CPS. The following study was aimed at determining what intensity CS_T should be set at in order to make it similar in saliency to CS_L. In Group I, four subjects received 8 compound-CS conditioning trials in which CS_T was set at 74-76 db SPL; US_n served as the aversive stimulus for this group. In Group II, the intensity of CS_T was set at 76-80 db SPL for four additional subjects; US_n served as the aversive stimulus for this group. In Group III, eight subjects received compound-CS conditioning with CS_T set at 83-84 db SPL; US_n served as the aversive stimulus for this group.

As can be seen in Figure 18, CS_T was found to be overshadowed by CS_L at the two lowest intensities. On the other hand, the same stimulus tended to slightly overshadow CS_L at the highest intensity. As a consequence, an intensity of 80-83 db SPL was selected for use in Experiment 1.

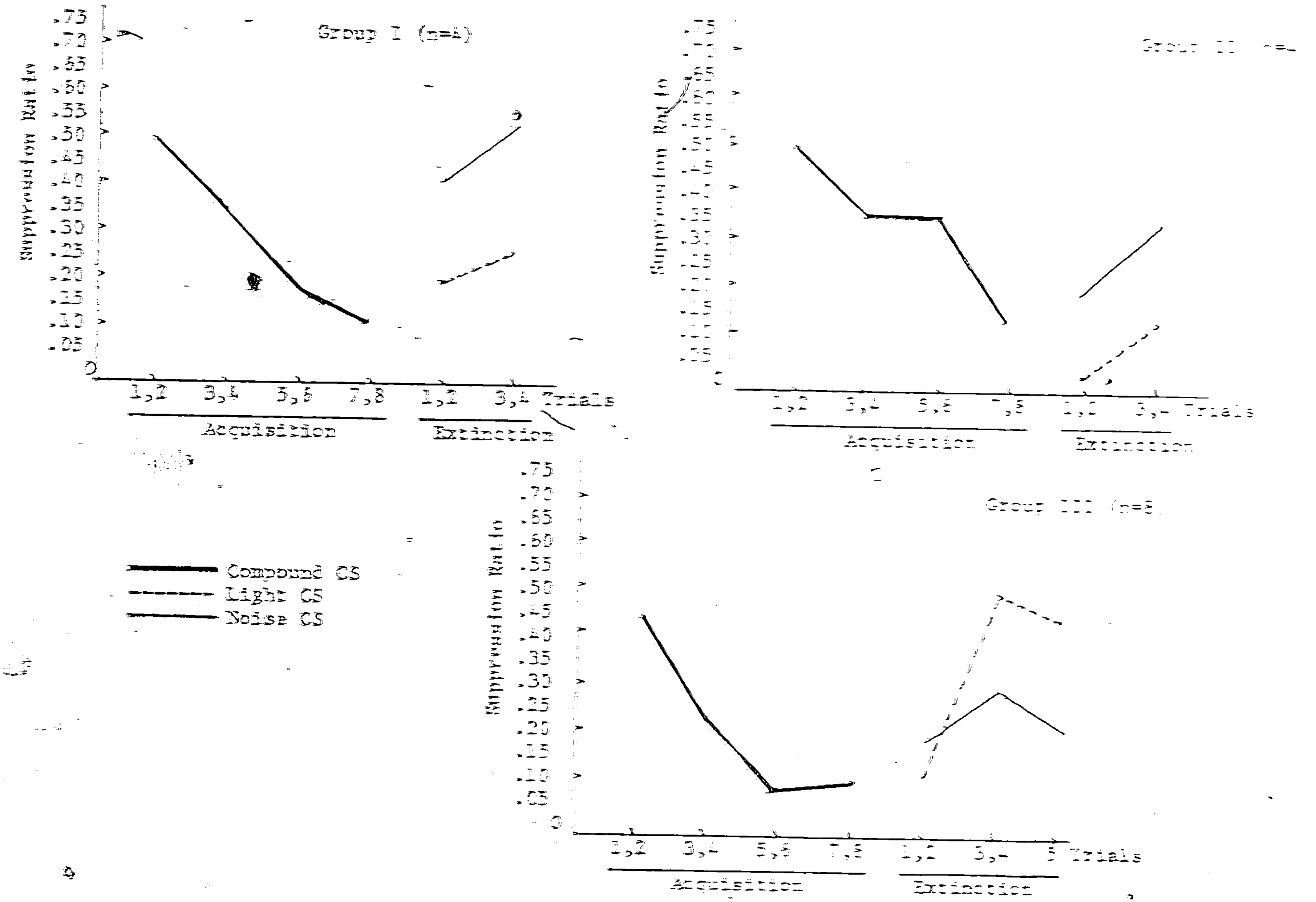

FIGURE ix. MEAN SUPPRESSION RATIOS OBTAINED DURING ACQUISITION AND EXTINCTION IN PILOT STUDY 10.

APPENDIX M

DISCUSSION OF PILOT STUDIES 7-10

Although the loud burst of pure tone used in Pilot Study 7 was not found to support a conditioned suppression response, a loud burst of noise was found to serve this function (see Pilot Studies 8-10). Interestingly enough, Pilot Studies 8 and 9 suggest that an auditory CS is only able to acquire a conditioned suppression response involving an auditory US when the frequency of the CS falls outside the band width of the auditory US. Research is presently being designed to investigate further this observation.

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