THE IMPAIRMENT OF CONDITIONING PRODUCED BY PRE-TRIAL SHOCKS

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ABSTRACT

The first experiment of the present thesis replicated the observation made by many investigators that inter-trial interval (ITI) shocks interfere with conditioning. Experiment 1 extended this observation, however, by demonstrating that all ITI shocks are not equally disruptive of conditioning--the closer an ITI shock occurs prior to a trial, the greater the interference with conditioning.

Two broad classes of theory can explain this temporal location effect. The first class, competition theory, states that a pre-trial shock diminishes the effectiveness of a subsequent CS-US pairing because it, directly or indirectly, functions to signal the same shock that is later signalled by the CS. Furthermore, since competition theory postulates that a US can support only a fixed amount of signal value, the more signal value that is acquired by the competing stimuli, the less is available for the CS to acquire. The second class, interference theory, states that the failure of CS-US pairings to produce strong conditioning when preceded by pre-trial shocks is not due to the acquisition of conditioned strength by other stimuli, but rather that less total conditioning occurs.

One kind of competition theory is the Rescorla-Wagner model of

classical conditioning. This model suggests that the temporal location effect is due to the conditioning of background cues. Experiment 3 tested this hypothesis by comparing the performances of two groups of rats. Each group received a pre-trial shock prior to each CS-US pairing--but in one group this shock was itself signalled by a salient CS. According to the model, this signalling should reduce the conditioning of background stimuli and hence should increase conditioning. Although the results suggested a small effect in the predicted direction, the important fact was that the temporal location effect was not eliminated, or even substantially reduced, when the pre-CS shock was itself signalled. Conditioning to the background cues does not appear to be the mechanism by which the pre-CS shock reduces the amount of suppression controlled by the CS.

Experiment 4 tested the predictions of two other forms of competition theory--the overshadowing and the Information Hypothesis. The results of Experiment 4 suggested that the temporal location effect does not occur because pre-trial shocks overshadow the CS or because they make the CS "uninformative" or redundant.

In conclusion, the results of the present thesis suggest that pre-trial shocks do not diminish the effectiveness of CS-US pairings because of some form of stimulus competition. Rather, pre-trial shocks interfere with conditioning because they reduce the total amount of suppression controlled by all of the cues in the situation--not just the amount controlled by the CS.

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CHAPTER 1

INTRODUCTION

From its earliest beginnings, the study of classical conditioning has been dominated by a contiguity theory of learning. Pavlov (1927), for example, maintained that a sufficient condition for the development of conditioned responding was the contiguous pairing of an external stimulus (a conditioned stimulus or CS) with a biologically more potent event (an unconditioned stimulus or US). This forward-pairing, in which the CS precedes and overlaps with the US, was taken to be sufficient for conditioning. As long as the CS precedes in time the presentation of the US, it should, according to Pavlov, begin to elicit conditioned responses that are similar in form to the responses that are unconditionally or innately elicited by the US.

Many lines of recent research suggest that Pavlov's contiguity theory of classical conditioning is inadequate. These inadequacies are of two types. First, recent experiments show that whether a CS-US pairing results in conditioning depends critically on what other stimuli are present and on their status as signals of the US. In Pavlov's theory, the role of the context provided by other signals was not adequately represented. The second failure of Pavlov's contiguity theory also involves context, but of a different kind. In a typical Pavlovian conditioning experiment, the CS-US trials occupy only a small portion of the experimental session. Although the vast majority of a subject's time is spent in this between-trial-period, Pavlov did not consider that what happens during this inter-trial-interval (ITI) might affect conditioning. Recent research has shown, however, that unsignalled USs delivered in the interval between trials reduce, and may even prevent, conditioning to the CS. Clearly, the significance of a US-free ITI is outside the scope of Pavlov's trial-centered contiguity theory. Let us review the developments that show that both trial and inter-trial context are important factors in conditioning.

Trial context

In an extensive and beautifully designed series of experiments, Kamin (1968, 1969) has shown that if two stimuli are followed by a US, but one of the stimuli has previously been paired with that US, conditioning to the other stimulus will be prevented or "blocked." In a blocking experiment, the blocked group is given an initial series of trials on which, say, a noise, is paired with shock. Subsequently, both the blocked group and a control group, which has not received the initial trials, receive pairings of a light-noise compound CS with a shock US. The important outcome of a blocking experiment is that, while both the light and the noise become strongly conditioned in the control group, little or no conditioning develops to the light in the blocked group. Despite the fact that the light is followed by reinforcement an equal number of times in both groups, the prior conditioning of the noise in the blocked group attenuates or "blocks" the conditioning of the light.

Kamin has interpreted this effect in terms of predictability or surprise. That is, perhaps the pairing of a CS and a US is effective only to the extent that the US is surprising or unexpected. In the first phase of the blocking experiment, noise becomes a reliable signal of shock in the blocked group. By the time light is added in the second phase, the shock no longer has surprise value since it is fully predicted by the noise. Therefore, no learning about the added stimulus occurs. In the control group, on the other hand, shock does have surprise value since there has been no prior training to establish the noise as a signal of shock. Consequently, both the light and the noise become signals of shock as the result of the compound CS-US pairings in the control group.

The phenomenon of blocking nicely illustrates the importance of trial context in conditioning. The knowledge that a CS has been repeatedly paired with a US does not permit one to predict that the CS will condition since a CS becomes a signal only if no other CS fully predicts that US.

During the course of some experiments that were designed to elucidate this concept of surprise, Rescorla and Wagner (Rescorla and Wagner, 1972; Wagner and Rescorla, 1972) have obtained additional evidence that CS-US pairings, in and of themselves, may not produce strong conditioning. Their experiments demonstrate that not only can conditioning be prevented by giving one of the elements of a compound CS a history of reinforcement with a US, but a "blocking-like" effect can also be obtained if one of the elements is *currently* better correlated than another with the US. A representative experiment is as follows. Three groups of subjects all receive a compound stimulus, AX, which is always followed by a shock US. Two of the groups also receive additional presentations of A interspersed with those of AX. For one group, these presentations of A are reinforced; for the other, they are nonreinforced. In all groups, X is always followed by shock and would therefore be expected to show excitatory conditioning. Although X was treated identically in all groups, Rescorla and Wagner found that X conditioned most strongly in the group that received nonreinforced A-trials and conditioned hardly at all in the group that received reinforced A-trials. Rescorla and Wagner reasoned that the group that received the nonreinforced A-trials conditioned the most to X because the US was not fully predicted by A when an AX trial occurred. Conversely, the group that received the A-reinforced trials conditioned the least to X because A alone was a perfectly reliable predictor of shock.

Rescorla and Wagner have examined many other cases in which the context of the CS-US pairing proves important to conditioning. These cases all demonstrate that pairing a CS and US is effective in producing conditioning only if the US is unexpected on the basis of all of the cues concurrently present--the more unexpected, the greater the conditioning.

<u>Inter-trial context</u>

Some recent research by Rescorla (1966, 1968, 1969, 1972) clearly demonstrated that the effectiveness of CS-US pairings cannot be evaluated independently of the events in the ITI that surround or provide the context for those pairings. The results of this research led Rescorla to develop a new theory of classical conditioning in terms of contingency. The theory differs from that of a pairing or contiguity theory in that it stresses not only what is paired with the CS but also what occurs when the CS is not present. Rescorla (1967) has suggested that excitatory conditioning occurs not simply by pairing CS and US, but by establishing a positive correlation between the CS and US. In other words, Rescorla argues that an animal will learn a CS-US association only if the CS increases the probability of the US.

In a preliminary test of this correlational or contingency theory of conditioning, Rescorla (1966, 1968) compared the performances of two groups of subjects. In the positive contingency group, shock could occur only in the CS. The no contingency group received these same CS-US pairings, but, in addition, they received shock in the absence of the CS so that the probability of shock at any moment was the same in the presence of the CS as in its absence. A contiguity theory would, of course, provide no basis for expecting a difference between these two groups. Rescorla found, however, that even though the groups were equated for number of CS-US pairings, the CS conditioned in the former group but not in the latter. This experiment has become the classic demonstration of the importance of context in conditioning.

Subsequent research has confirmed that contingency is an important determinant of Pavlovian conditioning. For example, Rescorla (1968) trained a variety of groups under many different contingencies between CS and US. When the probability of shock was higher in the presence of the CS than in its absence (a positive correlation), excitatory conditioning occurred. The greater the difference between the two probabilities, the stronger the conditioning. When the two probabilities were equal, no conditioning occurred (see Benedict and Ayres, 1972; Kremer, 1971, 1974; Kremer and Kamin, 1971; and Quinsey, 1971; for evidence that some excitatory conditioning may occur even though the probability of shock in the ITI is equal to the probability of shock in the CS). Other experiments have shown the application of contingency to inhibitory conditioning. If the probability of shock in the non-CS or ITI is greater than the probability of shock in the CS (a negative correlation), the CS acquires inhibitory properties (Rescorla, 1966, 1968).

Is contingency the effective variable?

The present thesis is concerned with the effects of the inter-trial context on amount of conditioning that occurs on the trial. It is an attempt to improve our understanding of the process by which unsignalled USs attenuate conditioning. Although the questions center on the sequential or inter-trial context, a consideration of the context provided by concurrent or trial stimuli will prove relevant. As will become apparent, it is possible that the effects of inter-trial USs are mediated by conditioning to prevailing stimuli which provide a concurrent context within which the trial itself occurs.

Although contingency appears to be a good predictor of the degree of conditioning, it is not clear that the concept of contingency accurately reflects the process by which unsignalled USs interfere with conditioning. In calculating contingency, Rescorla compares the probability of shock in the CS to the average probability of shock in the ITI. According to Rescorla, if the probability of shock in the CS is higher than the probability of shock in the ITI, excitatory conditioning will occur; if it is lower, inhibitory conditioning occurs; if the two probabilities are equal, no conditioning will occur. Thus, the factor that determines the degree and the kind of conditioning is the average probability of shock in the ITI relative to the average probability of shock in the CS.

The calculation of contingency based on average probabilities of shock implies that each shock in the ITI has an equal weight. There are reasons, however, to think that shocks occurring immediately before a CS-US pairing would interfere more strongly with excitatory conditioning than those more remote from the CS. For example, it is a commonplace that under a variety of conditions the effectiveness of a stimulus decays in time.

This thesis concerns the following questions. Do unsignalled shocks that occur immediately prior to a CS-US trial interfere with conditioning more than do shocks that are temporally remote from the trial? If so, can the effects of contingency be understood more precisely in terms of local interference than in terms of averaged probabilities of shock? Most important, assuming local interference, what is the mechanism that transmits the effect of the inter-trial shock to the trial itself?

GENERAL METHOD

The four experiments in this thesis are all conditioned suppression or conditioned emotional response (CER) experiments. The experiments typically involved four phases of training. During the first phase, naive hooded-rats were reduced to 75% or 80% of their free-feeding body weights and were maintained on a 24-hour feeding rhythm. The rats were trained to press a bar for food reward in one of four identical operant conditioning chambers or "Skinner boxes". They were initially trained to respond on a continuous reinforcement schedule and were gradually shifted to variable-interval (VI) schedules of reward. During the last two sessions of bar-pressing on the VI schedule, the rats received several nonreinforced presentations of the CS to allow any unconditioned responses to the CS to habituate. At the end of phase one, the rats were divided into groups that were matched for response rates and Skinner boxes. In the second phase, the bar was retracted and no food was delivered. It was during this phase that the rats received Pavlovian conditioning treatments. The CS was usually an illumination of the houselight (the normal condition of the box was complete darkness). The US was a scrambled-electric shock delivered through the grid floor. Following the Pavlovian conditioning phase, the bar was reinserted into the box and the animals were given three to five sessions on their

VI schedule of reinforcement to re-establish their response rates. In the fourth and final phase, the CS was presented to the animals while they were pressing for food reward. With the exception of Experiment 4, shock was never delivered during this phase. Conditioning to the CS was therefore being extinguished during this phase. For each CS presentation, a suppression ratio was calculated. The ratio was B/A+B, where B represents the number of responses during the two-minute CS, and A the number of responses during the two-minute period immediately preceding the CS. When the CS has no effect on the rat's tendency to respond, the ratio is .50; when the CS completely suppresses the animal's responding, the ratio is .00. The learned suppression produced by the CS is commonly regarded as an index of association between CS and US--much as Pavlov used conditioned salivation to a metronome as an index of conditioning.

CHAPTER 2

EXPERIMENT 1

The Temporal Location Study

The purpose of the first experiment was to learn whether the interference with conditioning produced by ITI shocks increases as the shocks occur closer and closer to the onset of a CS-US trial. The design of the experiment was as follows. Each of four groups received one ITI shock prior to each CS-US trial. The only difference between the groups was in the length of time between their ITI shock and the onset of each CS-US trial. One group had an ITI shock occur 3 seconds before each CS-US pairing. The remaining three groups had an ITI shock occur 18, 108, or 648 seconds prior to the start of every trial.

METHOD

Subjects

The Ss were 32 experimentally naive Long-Evans male hooded-rats, obtained from Canadian Breeding Farms, Quebec, Canada. They were housed in individual cages. Water was freely available in the cages and in the Skinner boxes. The rats were reduced to 80% of their free-feeding weights and were maintained at this level throughout the experiment.

Apparatus

Individual animals were run in one of four identical Lehigh Valley Model 1316 operant chambers. Each box was equipped with two retractable levers. The right bar was retracted throughout the experiment. During the Pavlovian conditioning sessions, both bars were retracted. The end walls of the chamber were aluminum; the side walls and the top were clear Plexiglas. The floor of the chamber was a grid composed of 4.8 mm stainless-steel rods spaced 19 mm apart (measured center to center). A ventilating fan raised the ambient level of the noise in the box to 59 dbA. The CS, which consisted of a two-minute presentation of a 1.4 KHz tone, interrupted approximately four times per second (on 30 ms., off 200 ms.), raised the sound level to 78 dbA. The cue lights over each bar pulsated on and off in syncrony with the interrupted tone. The US, a 4.0 mA, 0.5 second scrambled-electric shock delivered through the grid floor, was generated by a Lehigh Valley constant current shock generator (Model 113-04).

Procedure

The experiment consisted of four phases: 1. preliminary bar-press training. 2. five Pavlovian conditioning sessions (bars retracted). 3. three additional VI 2' re-establishment sessions. 4. superimposition of the CS on the VI 2' baseline. Subjects differed only in their treatment during the Pavlovian conditioning sessions. Phase 1. During the first two experimental sessions, Ss were magazine trained automatically with food delivered on a variable-time 1' schedule of non-contingent reinforcement. In addition, each bar-press yielded a food pellet (45 mg). The Ss were then given a 1 1/2 hour session on VI 30" and two 1 1/2 hour sessions on VI 1'. Starting with the seventh experimental day, Ss were placed on VI 2' for six 120 minute sessions. On the fifth and sixth days of VI 2', each S received four two-minute presentations of the CS. These presentations allowed any unconditioned responses to the CS to habituate. At the end of Day 6, Ss were divided into four groups of eight Ss each. These groups were matched for response rates and Skinner boxes. Phase 2. Ss were given five Pavlovian "fear" conditioning sessions. During these sessions both bars were retracted and each group received seven two-minute CSs with a fixed-inter-CS interval (i.e., ITI) of 16 minutes. On each day, twelve minutes of ITI preceded the first CS presentation and four minutes of ITI followed the last CS presentation. Each of the four groups received an average of 0.83 shocks in each CS. Since only one shock was allowed to occur in any CS, this means that

29 out of the 35 CSs contained a shock. Shock delivery and CS presentation were controlled by a tape reader that was stepped every 3 seconds. The temporal location of a shock in a CS was random. That is, if a particular CS contained a shock, each of the 40 three-second samplings of the tape (40 x 3 sec. = CS duration), except the first, had an equal probability of producing that shock. A different sequence of CS shocks was used in each of the five Pavlovian sessions. As previously indicated, each of the four groups received one unsignalled shock in each fixed ITI. For any one group, this shock always preceded CS onset by a constant number of seconds: either 3, 18, 108, or 648 seconds before the onset of each CS. *Phase 3.* Following the five sessions in Phase 2, three two-hour VI 2' sessions were given to re-establish a stable bar-pressing rate. *Phase 4.* During each of four two-hour test sessions, the VI 2' schedule of reinforcement remained in effect; superimposed on this baseline were three two-minute presentations of the CS. No shocks were delivered during these four sessions.

RESULTS

A Kruskal-Wallis *H* test on the individual response rates on the last day of VI 2' re-acquisition found no group differences ($H = 0.83$, $p > .05$). Consequently, the amount of suppression produced by the CS during the subsequent extinction test trials was not confounded by group differences in VI 2' response rates.

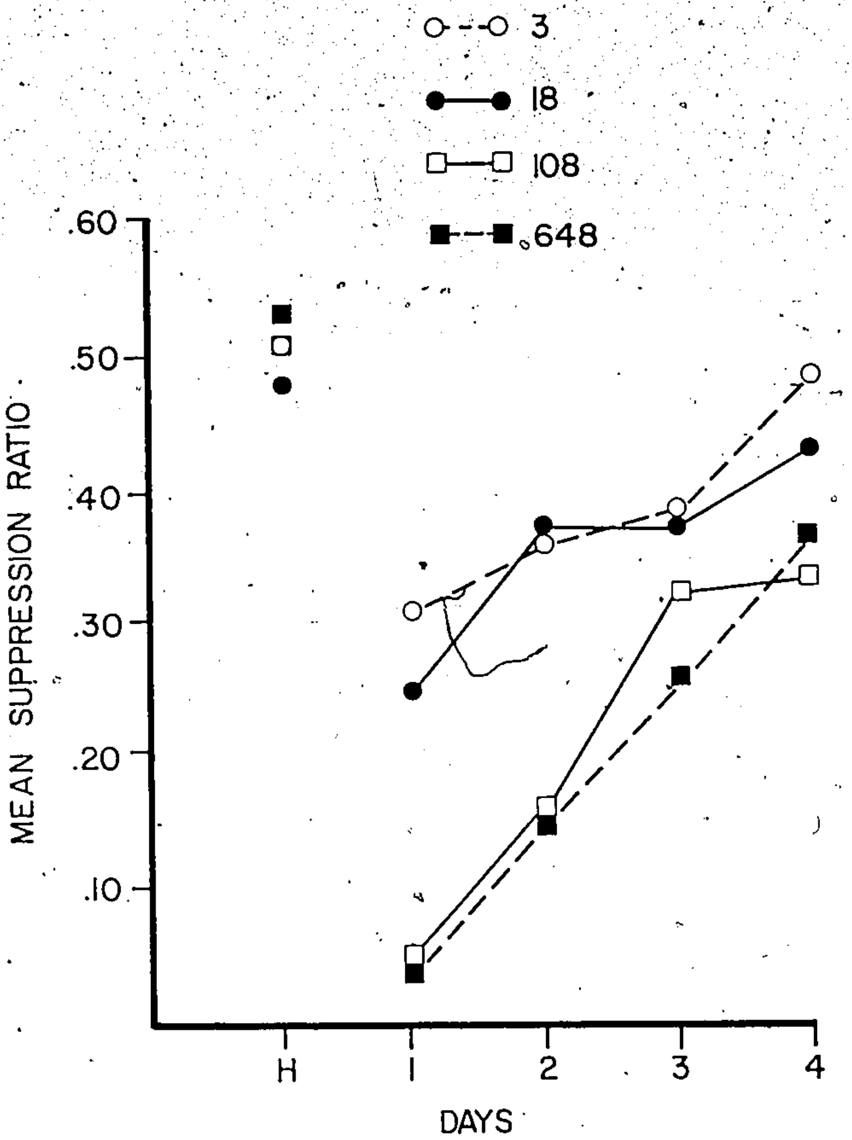
Figure 1 shows the mean suppression ratio for each group for the last day of habituation and for each of the four extinction sessions. A Kruskal-Wallis *H* test on the means of the individual suppression ratios across the four test sessions showed that group differences were highly significant ($H = 13.84$, $p < .01$). Mann-Whitney *U* tests confirmed that on Days 1 and 2, groups 3 and 18 suppressed less than groups 108 and 648 (Day 1, 3 vs 108 and 648 ($Us = 5$ and 4 1/2, $ps < .01$), 18 vs 108 and 648 ($Us = 8$ 1/2 and 8, $ps < .01$); Day 2, 3 vs 108 and 648 ($Us = 10$ and 8 1/2, $ps < .05$), 18 vs 108 and 648 ($Us = 10$ and 9, $ps < .05$). Additional Mann-Whitney *U* tests confirmed that groups 3 and 18, as groups 108 and 648, never differed significantly from each other on any of the four extinction days.

DISCUSSION

The results of Experiment 1 demonstrate that the temporal location of ITI shocks is a strong determinant of conditioned suppression. Those shocks in the ITI that occur within a brief time period immediately preceding CS onset produce a greater disruption of conditioning than do shocks more temporally removed from CS onset.

Figure 1

Experiment 1: The mean suppression ratios for each group for the last day of habituation and the four days of extinction.


3
18
108
648
MEAN SUPPRESSION RATIO
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.50
.40
.30
.20
.10
H
1
2
3
4
DAYS

What is the bearing of the present results on the concept that conditioning is determined by contingency? In experiments on the role of contingency in CER conditioning, the variables are the average rate of shock in the absence of the CS (during the ITI) and the average rate during the CS. The extent (and kind) of conditioning has been shown to be an orderly function of the difference between these rates of shock. The present results raise the possibility that a part, or even all, of the effect of changing the average rate of shock in the ITI is due to the relation between average rate and the probability that a shock will occur within a brief period prior to CS onset. If that were so, contingency would be an indirect and artifactual variable since the effective variable would be the occurrence of shocks within a critical period prior to CS onset.

The possibility is worth serious consideration because the present data show that the "critical period" (time range within which time is still important) extends to somewhere between 18 and 108 seconds. It must be recognized, however, that although the present evidence raises the possibility that one could improve on the concept of contingency by replacing it with a temporal weighting function for the amount of interference produced by ITI shocks, the present evidence does not demonstrate conclusively that such a reformulation is necessary. The present evidence is restricted to a single shock in a fixed location in the ITI. It is not certain that temporal location would remain effective when multiple shocks of variable location occur, as they do in the experiments on which the concept of contingency is based. Further, the power of the contingency concept is that it handles directly the demonstrated fact that the relation between shock rate in and out of the CS is predictive of the amount of conditioning. It is not clear that the more molecular analysis involving a temporal weighting function on ITI shocks would be able to rationalize the apparent dependence of conditioning on relative shock rates. Finally, some of Rescorla's data on the effects of ITI shocks suggests that shocks outside of a critical period have some effect on conditioning during the trial. In his experiments in which he varied the contingency between CS and US, Rescorla (1968) ran several groups that received probabilities of shock in the one-minute period that preceded CS onset that were quite low. For example, an ITI shock might occur in the one-minute interval, on the average, of only 1 out of 10 times. Despite the fact that the probability of shock in what we may take to be a critical period was so low, Rescorla found poor conditioning in these groups. Thus, shocks outside of the critical period appear to play a role in conditioning.

The results of the first experiment suggest two avenues for further exploration. One is to find out whether the already existing data on the effects of contingency when there are multiple shocks of variable location in the ITI, and in the CS, can be more precisely understood by taking into account the role of temporal location in producing interference. The other is to find the reason why a single shock received prior to the CS interferes with conditioning more profoundly when it is close to CS onset than when it is further removed. It was decided to follow the second avenue of exploration. We begin with a consideration of alternative hypotheses about how the interference is mediated. We refer to these alternatives as theories although it must be admitted that in some instances they are simply guesses about what might be important and are not well worked-out accounts of general applicability outside of the immediate problem.

COMPETITION THEORIES

The first class of theories of the differential disruptive effects of ITI shocks is based on the concept of stimulus competition. These theories state that the CS fails to condition strongly because the prior shock, directly or indirectly, functions to signal the same shock that will later be signalled by the CS. Competition theories postulate that the event being signalled supports a certain total amount of signal value. The total is fixed and does not depend on how many separate stimuli are predicting the event. Since the total is fixed, the more signal value one stimulus acquires, the less is available for the remaining stimuli to acquire. Thus, to the extent that the prior shock directly serves as a signal of forthcoming shock, or establishes some other stimulus as a signal (see below), there will be less signal value available for the experimental or nominal CS to acquire.

By far the best worked out example of a competition theory is the Rescorla-Wagner model of classical conditioning. In that model, the prior shock itself is not viewed as the competing signal. Rather, the prior shock conditions prevailing or background stimuli, and they serve as a competing signal of shock. In two other theories, Egger and Miller's Information Hypothesis and the overshadowing hypothesis, the trace or the transient-after-effects of the pre-CS shock are given hypothetical stimulus properties. In effect, the pre-CS shock itself becomes the other signal. We now turn to a discussion of each of these varieties of a competition theory.

Rescorla-Wagner Model of Classical Conditioning

Rescorla and Wagner's (Rescorla and Wagner, 1972; Wagner and Rescorla, 1972) model of classical conditioning is stated in terms of increments and decrements in the associative strength of component stimuli as a result of reinforcement and nonreinforcement of compound stimuli. Although a CER experiment that has shocks occurring in the ITI is not an experiment which obviously involves the presentation of compound stimuli, Rescorla and Wagner have argued that their model is applicable to this type of experiment (Rescorla and Wagner, 1972, p. 87). In order to understand how the model correctly predicts that group 3 will suppress less than group 648 in Experiment I, for example, it is necessary to be familiar with several key assumptions of this Rescorla-Wagner model of classical conditioning. First, any particular reinforcer can support only a certain maximum or asymptote of conditioning. In the equations of the model this maximum is represented by λ. Secondly, and the most important assumption of the model, the effect of reinforcement in changing the conditioned strength of a stimulus on a trial depends not only on the conditioned strength of that stimulus, but also on the strength of <u>all</u> of the stimuli concurrently present. This change in strength, ΔV_I, is proportional to the quantity ($\lambda - \bar{V}$) where λ is the asymptote of strength supported by the reinforcer and $\bar{V}$ is the current conditioned strength of all of the stimuli concurrently present on that trial. If none of the stimuli have previously been paired with the US, the quantity ($\lambda - \bar{V}$) will be large; therefore, the increase in conditioned strength to each stimulus will also be large. If one or more concurrent stimuli have conditioned strength then the quantity ($\lambda - \bar{V}$) will be small and the pairing will produce little or no increment in conditioned strength. Thirdly, in any situation in which a single element CS, say, a light, is being reinforced, Rescorla and Wagner hypothesize that there are actually two stimuli present--the situational or constant background considered as a single stimulus (e. g., walls, houselight, grid-floor, noise of ventilating fan, etc.) and the experimentally-manipulated stimulus of the light. These stimuli compete for the increase in conditioned strength that results from the pairing on that trial. Thus, what at first glance appears to be the reinforcement of a single CS, is, in actuality, the pairing of a compound CS, light and background stimuli, with the US.

Finally, in order to account for the disruptive effects on conditioning of ITI shocks, Rescorla and Wagner make an additional assumption. They assume that the experimental session can be divided into segments that are equal to the duration of the CS. Each segment containing the CS is treated as a compound stimulus and as an AX "trial"; each segment not containing the CS (i.e., the ITI) is treated as an A "trial". Furthermore, both A and AX segments can be reinforced and nonreinforced. For example, a shock-free ITI that is 5 times as long as the duration of the CS is treated as 5 consecutive A extinction trials. According to Rescorla and Wagner's model, then, a group that receives a shock 3 seconds before CS onset will suppress less than a group that receives a shock farther away from CS onset because the value of ($\lambda - V_{AX}$) will be smaller the closer an ITI shock occurs to CS onset. This has to be the case since any increment in the associative strength of the A or common stimuli that results because of a distal shock will be diminished by the long series of A extinction trials that occur after the increment. Consequently, this model predicts that group 3 will suppress less than group 648 because the associative strength of the common or background cues at each trial onset is higher in the former group than in the latter. Thus, the quantity (λ - V_{AX}) is smaller in group 3 than in group 648; therefore, less excitatory conditioning of the trial stimulus occurs in group 3.

In sum, Rescorla and Wagner's model accounts for the effects of ITI shocks on conditioning (i. e., inter-trial context) by postulating that the conditioning of background cues necessarily leads to a lesser conditioning of the CS. Moreover, the greater the conditioned strength of the common cues at trial onset, the poorer the conditioning.

It will be apparent that one of the strong assets of the theory is to treat the effects of sequential or ITI context in the same way as it treats concurrent context provided by additional, or compound, stimuli.

Egger and Miller's Information Hypothesis

Egger and Miller (Egger and Miller, 1962, 1963) hypothesized that when two or more stimuli predict primary reinforcement, the more informative stimulus will become the stronger secondary reinforcer. Although Egger and Miller did not completely specify what variables determine the informativeness of a stimulus, one important determinant was taken to be temporal priority. That is, they argued that if two stimuli are equally correlated with a US, but one of the stimuli precedes the other in time, the temporally prior stimulus will condition more than the subsequent stimulus In order to test the Information Hypothesis, Egger and Miller gave a group of subjects a considerable number of S_1-S_2-food sequences. S_1 came on prior to S_2 and both stimuli terminated together. Food was delivered one-half second prior to their co-termination. Egger and Miller argued that, since S_1 always precedes S_2, S_2 should be a non-informative, redundant predictor of food; therefore, S_1 should be a stronger conditioned reinforcer than S_2. In agreement with their predictions, Egger and Miller found that S_1 was a stronger conditioned reinforcer than S_2. Subsequent experiments have partially confirmed the superiority of informative over redundant stimuli (Allaway, 1971, Experiment 2; Davis and Oliphant, 1968; Seligman, 1966; Thomas, Berman, Serednesky, and Lyons, 1968).

The application of the Information Hypothesis to the results of Experiment 1 is relatively straightforward. Since, in group 3, an ITI shock always immediately precedes the occurrence of each CS-US pairing, the CS might be a redundant stimulus. That is, an

Information Hypothesis interpretation states that, since the CS provides little or no additional information about the occurrence of CS shocks other than that already provided by the pre-CS shock, the CS fails to condition strongly.

Overshadowing

Pavlov (1927, pp. 141-144) was the first investigator to discover that simply pairing a stimulus with a reinforcer is not a guarantee that an association between the two will be learned. For example, he often found that when the components of a previously conditioned compound CS were tested individually, one component might elicit as much salivation as the compound itself would, while the other component might elicit little or no salivation. This would happen even though the "ineffective" component was quite capable of eliciting salivation if it alone was paired with the US. When a stimulus elicits a smaller response after being reinforced in compound with another stimulus than after being reinforced alone, the stimulus is said to be overshadowed. Pavlov did not regard overshadowing as an important exception to his contiguity theory of classical conditioning. He considered it as merely an interesting instance of the importance of stimulus salience in conditioning.

An overshadowing account of the results of Experiment 1 could be developed as follows: Let us assume, as have other investigators (e.g., Mowrer, 1960, pp. 130-131), that the occurrence of a shock produces transient stimulus-after-effects. Furthermore, assume that these stimulus-after-effects, although short-lived, can, nonetheless, be quite salient. Since the degree of overshadowing is known to vary as a function of stimulus salience, it is possible that the stimulus-after-effects of shock overshadow the less salient experimenter-introduced CS.

INTERFERENCE THEORIES

Unlike competition theories, interference theories do not state that the failure of pairings to produce strong conditioning is due to the acquisition of conditioned strength by other stimuli. Furthermore, interference theories do not maintain that proximal ITI shocks merely cause a different distribution of the available conditioned strength, but rather that less conditioning occurs. In interference theories, CS-US pairings are seen to be ineffective because the occurrence of a proximal ITI shock disrupts processes that are deemed to be essential to the occurrence of strong excitatory conditioning. Interference theories differ only in respect to their identification of the essential process(es) that must not be disrupted if good conditioning is to occur. In sum, interference theories assume that proximal ITI shocks cause a lesser amount of conditioning, rather than a different distribution of conditioning among available signals.

It should be emphasized that the following interference hypotheses are largely ad hoc. These "theories" have been developed by the present author to account for the immediate problem so their general applicability is unknown.

Anterograde Interference

Wagner, Rudy, and Whitlow (1973) have recently demonstrated that the conditioned responding produced by a series of CS-US trials is diminished if each trial is followed by a surprising or incongruent event. Moreover, they also found that this retroactive interference effect decreases as the time interval between the CS-US trial and the surprising event increases.

The findings of Wagner et al suggest a different interpretation of the results of Experiment I. Since surprising post-trial events have been shown to disrupt conditioning, perhaps surprising pre-trial events can also interfere with conditioning. Although Wagner et als surprising events were not shock, it seems plausible to view unsignalled shocks as surprising. The anterograde interference hypothesis states that proximal ITI shocks interfere with excitatory conditioning to the extent that they are surprising or unexpected.

The unexpectedness produced by the ITI shock is seen to cause the animal to begin a kind of processing of the events of the recent past. This prior processing of a surprising event is assumed to decrease the animal's probability of processing subsequent surprising events (i.e., CS shocks). Consequently, since the animal fails to process the CS shock for a sufficient period of time, the rehearsal that is necessary for a good association does not occur.

Relative Fear

The relative fear hypothesis holds that not only must a CS be paired with fear producing stimuli for conditioning to occur, but that the CS must be associated with an increase in fear if excitatory conditioning is to result. Consider a standard CER experiment in which shocks only occur in the presence of the CS. The subject is relatively unafraid during the ITI because any fear that resulted from the previous CS shock has had sufficient time to dissipate. Suddenly, the CS comes on and a shock is presently delivered. Is it possible that fear conditioning occurs in this situation, not because fear producing stimuli are paired with the CS, but because the CS is an interval that is associated with an increase in the subject's fear? In other words, perhaps an increase in fear is an absolute prerequisite for excitatory fear conditioning. Thus, the CS might have failed to condition strongly in groups 3 and 18 because the pre-CS or ITI shock had increased the subject's fear to such a high level that the CS shock could not increase it much further. Consequently, little conditioning resulted.

UCR Diminution

The occurrence of a pre-CS shock might make an animal temporarily "unresponsive" to a closely following second shock for reasons other than those demanded by the relative fear theory. The second shock of a two-shock sequence might be ineffective in producing strong conditioning because the occurrence of the first shock initiates an inhibitory or refractory process. This inhibition, which dissipates with the passage of time, decreases the magnitude of the unconditioned response (UCR) produced by the second shock. Since the strength of a conditioned response is undoubtedly affected by the magnitude of the UCR, lesser conditioning results.

GENERALIZATION DECREMENT

It is a well-established fact that changes in the stimulus conditions of an experiment can produce a decrease in responding. For example, if after training a pigeon to peck a red-key light for reward, the key-light is suddenly changed to blue, the pigeon will continue to respond, but at a lower rate. A reduction or decrement in performance that is attributable to a change in the stimulus conditions of an experiment is called a generalization decrement. A generalization decrement interpretation of the results of Experiment 1 states that the differences in suppression that were obtained are artifacts of the testing procedure. On this interpretation the suppression differences occurred during the extinction phase rather than the Pavlovian conditioning phase of the experiment. During the Pavlovian conditioning phase the CS in group 3 was always closely preceded by a shock. A shock did not, of course, closely precede the occurrence of the CS in group 648. In the extinction phase the CS in group 3 was, for the first time, no longer preceded by a shock. Consequently, a large generalization decrement might be expected in group 3. This decrement would be observed as a "loss" or a decrease in conditioned suppression. No generalization decrement would, however, be expected in group 648. On the generalization decrement interpretation, then, the four groups of Experiment 1 formed identical associations between CS and US in the Pavlovian conditioning phase of the experiment. In attempting to assess the magnitude of these associations, however, we introduced such a great contrast between the training and testing phases of the experiment that groups 3 and 18 suffered large generalization decrements. Thus, the differences in suppression do not reflect a real difference in the association between CS and shock.

SIMPLE ADDITIVITY OF EXCITATION AND INHIBITION

The subjects of groups 3 and 18 were prevented from forming a strong association between CS and US by closely preceding each CS-US pairing with a shock. In these groups, the sequence was, therefore, shock, then CS and shock, then a long ITI free of any further shock. A sequence of this kind can be viewed as containing the essentials of both excitatory and inhibitory conditioning. The cornerstone of excitatory conditioning is a forward-pairing between CS and US, while, that of inhibitory conditioning is the occurrence of a US followed by a CS and then a long ITI. The US-CS-US-long ITI sequences of Experiment 1 contained each of these elements. Consequently, one possible interpretation of the results of Experiment 1 is that the excitatory and inhibitory components of each US-CS-US-long ITI sequence function independently of each other. That is, the inhibitory components are assumed not to affect or interact with the excitatory components, and vice versa. If this assumption were correct, the performances of groups 3 and 18 might simply reflect a summation of the excitatory tendencies due to the CS-US pairing in each sequence and the inhibitory tendencies due to the backward-pairing component of each sequence.

The plausibility of this account rests upon the assumption that the "inhibition" in groups 3 and 18 is greater than the "inhibition" in groups 108 and 648. Stronger inhibition in the former than in the latter groups might be expected for two reasons: 1. CS offset in groups 3 and 18 predicts a greater shock-free interval than in groups 108 and 648. 2. In inhibitory conditioning experiments, it seems possible that the shorter the interval between shock presentation and CS onset, the greater the inhibition.

The remaining experiments of this thesis were designed to narrow down the possible accounts of the effects of prior shock on conditioning and if possible to identify the kind of interference involved.

CHAPTER 3

EXPERIMENT 2

The Excitation and Inhibition Study

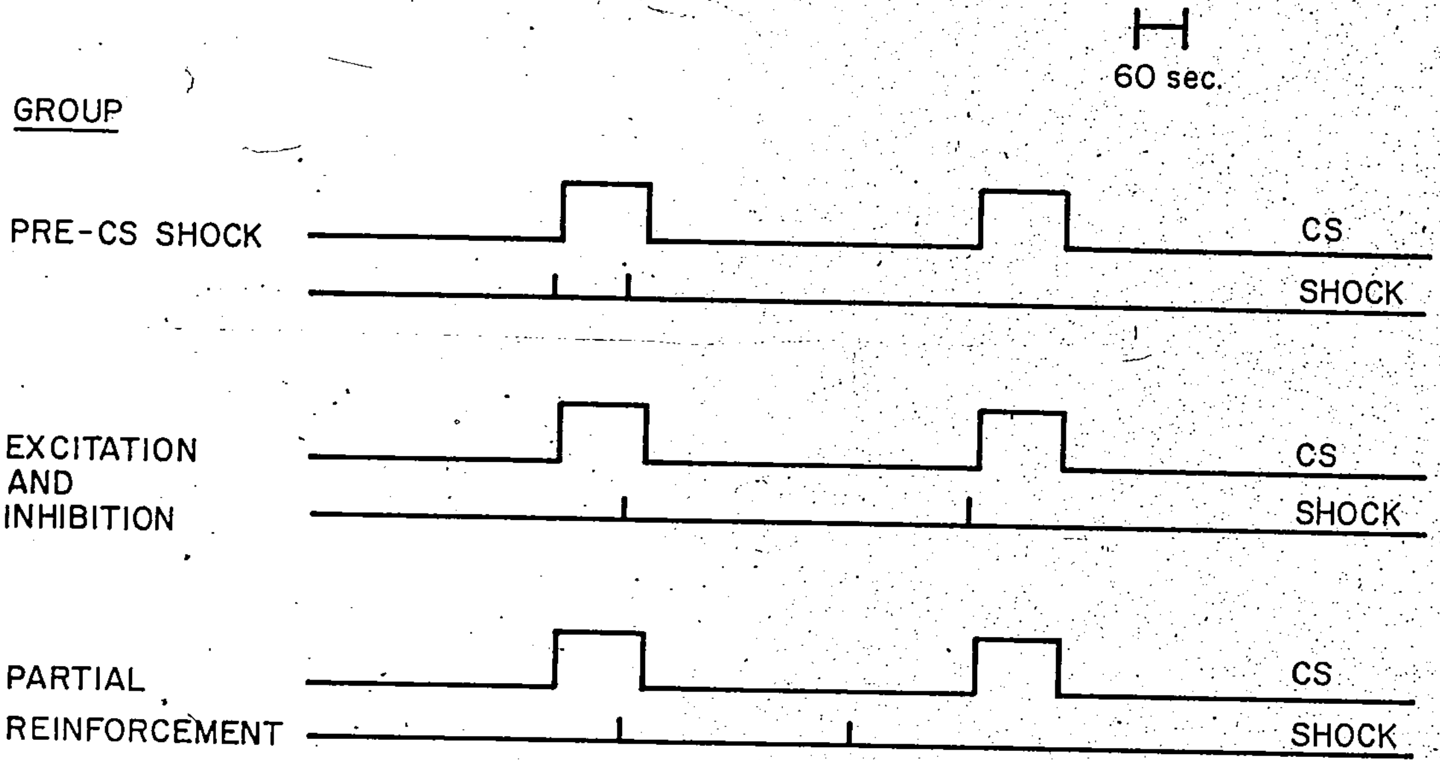
The additivity of excitation and inhibition account of the interference with conditioning produced by an unsignalled shock close to the trial is distinguished from all the other accounts on a very fundamental point. In all the other accounts the time interval between the unsignalled pre-trial shock and the shock within the CS (trial shock) is essential to the interference, whereas if the excitation-inhibition account were correct, that interval would not be essential to the interference. According to the excitation-inhibition account, the interference is due to the fact that the interval between the unsignalled shock and the CS (not the CS shock) is short in relation to the shock-free period predicted by the CS. Although the presumptive evidence in favor of the excitation-inhibition account is not strong, it is useful to examine the implications of this account at the outset. In so doing, we learn whether the interval between the successive shocks is a critical condition of the interference.

If separate inhibitory and excitatory conditioning were taking place, it ought to be possible to separate these opposed processes and still obtain the same effect. Experiment 2 tested this possibility by comparing the performance of a group of subjects similar to group 3 of Experiment 1 to a group that received its excitatory conditioning on one type of trial and its "inhibitory" conditioning on another type of trial. Figure 2 shows a schematic representation of Experiment 2. All three groups received an equal number of CS-US trials and CS alone trials. The only difference between the groups was in the location of their ITI shocks. Group pre-CS shock had an ITI shock occur 3 seconds prior to the onset of each CS-US pairing, while, group excitation and inhibition received an ITI shock 3 seconds before each CS alone trial, while, the partial reinforcement group always received an ITI shock 5 minutes after the termination of each CS-US trial.

The key group is the excitation and inhibition group. If additivity theory is correct, group pre-CS shock's performance should be identical to that of group excitation and inhibition. Additivity theory must predict this result because the only difference between these two groups is that the processes of excitation and inhibition that determine group pre-CS shock's performance have been separated in group excitation and inhibition. But, since additivity theory assumes that the timing of the pre-CS shock and the conditioning shock is not an effective variable in group pre-CS shock, their performances must be equal.

Figure 2

Experiment 2: A schematic representation of the design of Experiment 2.


60 sec.
GROUP
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CS
SHOCK
EXCITATION
AND
INHIBITION
CS
SHOCK
PARTIAL
REINFORCEMENT
CS
SHOCK

The partial reinforcement group was included in this experiment in order to provide a control group against which to assess the effect of the temporal location of the ITI shock, and therefore to make possible a replication of the effect obtained in Experiment 1.

METHOD

Subjects

The Ss were 32 experimentally naive male hooded-rats, obtained from Blue Spruce Farms, Altamont, New York. Ss were housed in individual cages, with water freely available in the cages and Skinner boxes. The rats were reduced to 75% of their free-feeding weights and were maintained at this level throughout the experiment.

Apparatus

Apparatus was the same as was used in the previous experiment. The CS in Experiment 2 was a two-minute illumination of the house-light (bulb #304, 28 vDC).

Procedure

The experiment consisted of four phases: 1. preliminary bar-press training. 2. five Pavlovian conditioning sessions (bar retracted). 3. five additional VI 2' re-establishment sessions. 4. superimposition of the CS on the VI 2' baseline. Subjects differed only in their treatment during the Pavlovian conditioning sessions. Phase 1.

Pre-training of the bar-press was carried out as it was in the first experiment. On the sixth and seventh days of VI 2', each S received four two-minute presentations of the CS. These presentations allowed any unconditioned responses to the CS to habituate. At the end of Day 7, Ss were divided into three groups--the pre-CS shock group and the excitation and inhibition groups had 12 Ss each, while, 8 Ss were assigned to the partial reinforcement group. These groups were matched for response rates and Skinner boxes. Phase 2. Ss were given five, 115-minute Pavlovian conditioning sessions. In each of these sessions, each S received 4 CS-US and 4 CS alone trials. The sequence of these CS-US and CS alone trials was random. There were 3 ITIs each of 8, 11, and 14 minutes so that the average ITI was 11 minutes. The only difference among the groups was the temporal location of the ITI shocks (see Fig. 2). Group pre-CS shock received an ITI shock 3 seconds prior to the onset of each CS-US pairing, while, the excitation and inhibition group received its ITI shocks 3 seconds before the onset of each CS alone trial. The partial reinforcement group received their ITI shocks 5 minutes after the termination of each CS-US trial. Since the ITI was either 8, 11, or 14 minutes, an ITI shock in this group occurred 3, 6, or 9 minutes prior to the start of a new trial. Shock delivery and CS presentation were controlled by a tape reader. This reader was stepped every 3 seconds. The temporal location of a shock within a CS-US trial was random since during a CS-US trial, each of the forty (40 x 3 seconds = CS duration) 3-second samplings of the tape, except the first, had an equal probability of producing that CS shock. A different sequence of CS shocks and ITIs was used in each of the five Pavlovian conditioning sessions. Phase 3. Five two-hour VI 2' sessions were given to re-establish a stable bar-pressing rate. Phase 4. During each of three two-hour test sessions, the VI 2' schedule remained in effect; superimposed on this baseline were four two-minute presentations of the CS. No shocks were delivered during this phase.

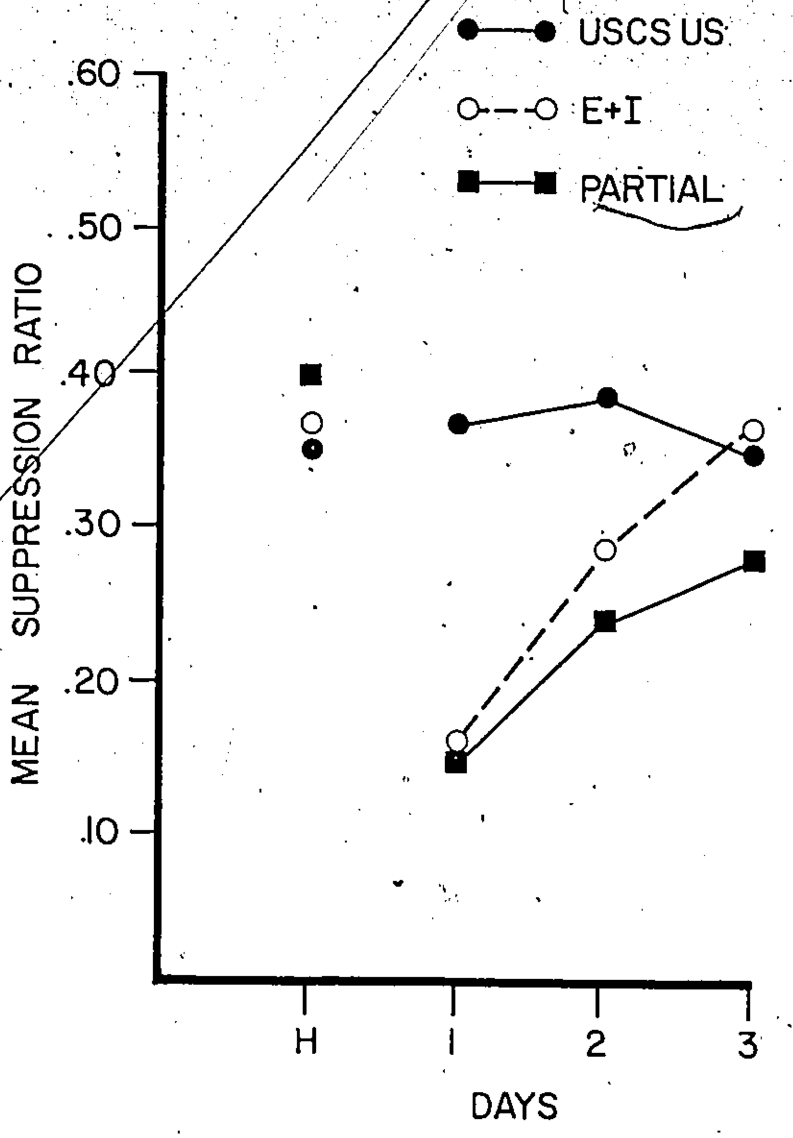
RESULTS

A Kruskal-Wallis H test on the individual response rates on the last day of VI 2' re-acquisition found no significant group differences ($H = 0.25$, $p > .05$). Thus, the amount of suppression produced by the CS during the subsequent extinction test trials was not confounded by group differences in VI 2' response rates.

Figure 3 shows the mean suppression ratio for each group for the last day of habituation and for each of the three extinction sessions. A Kruskal-Wallis H test on the means of the individual suppression ratios across the three test sessions showed that group differences were highly significant ($H = 13.55$, $p < .01$). Mann-Whitney U tests

Figure 3

Experiment 2: The mean suppression ratios for each group for the last day of habituation and the three days of extinction.


●—● USCS US
○--○ E+I
■—■ PARTIAL
.60
.50
.40
.30
.20
.10
MEAN SUPPRESSION RATIO
H
1
2
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DAYS

confirmed that on Days 1 and 2 group pre-CS shock suppressed less than group excitation and inhibition (Us=4 and 28, ps < .05) and less than the partial reinforcement control group on all three days (Us= 7, 13 1/2, and 29, ps < .05). Although the differences between the partial reinforcement and the excitation and inhibition group were suggestive, they failed to reach conventional levels of significance (Us= 31 1/2 and 23 1/2 on Days 2 and 3, a U of 22 or less is needed to reach the .05 level of significance).

DISCUSSION

The implication of the hypothesis that the loss of fear conditioning was caused by a combination of excitatory and inhibitory conditioning was that the effect could be decomposed into a separate effect of the timing of the pre-CS shock with respect to the CS alone (inhibition) and the effect of the pairing of CS with shock (excitation). Contrary to this implication, the results of Experiment 2 show clearly that the temporal interval between the pre-CS shock and the CS shock is necessary to the loss of conditioning. When the sequence of pre-CS shock followed by CS with shock was broken into pre-CS shock followed by CS alone and, separately, CS with shock, fear conditioning was not severely attenuated by the pre-CS shock.

Although the results allow us to reject the excitation-inhibition hypothesis as a sufficient account of the loss of fear conditioning, the results nevertheless do suggest that close timing of the pre-CS shock with respect to the CS alone was responsible for some lessening of fear conditioning to the CS. The excitation-inhibition group did show less suppression than the partial reinforcement control on the second and third days of testing although these differences fell short of conventional levels of significance.

A second important result of Experiment 2 is that the pre-CS shock group suppressed significantly less than the partial reinforcement group on all three days of testing. This finding replicates the results of Experiment 1 and it suggests that the temporal location effect is a reliable phenomenon.

In any case, the major result of Experiment 2 is the demonstration that the interval between the pre-CS shock and the CS shock is critical to the temporal location effect.

CHAPTER 4

EXPERIMENT 3

The Rescorla-Wagner Model Study

According to the Rescorla-Wagner model of classical conditioning, ITI shocks reduce the amount of conditioning to a CS by the extent to which they condition the common or background stimuli. Since the increment to a CS on a CS-US trial is said to depend upon the associative strength of both the background and the trial stimuli, the greater the associative strength of the common stimuli at trial onset, the less the conditioning of the CS. Background stimuli play a crucial role in the Rescorla-Wagner model because they mediate the effects of ITI shocks.

The above analysis suggests that the temporal location effect occurs because of differential conditioning of background cues. For example, the Rescorla-Wagner model predicted that group 3 in Experiment 1 would suppress less than group 648 because the associative strength of the common stimuli at each trial onset was higher in group 3. The value of $(\lambda - V_{AX})$ was therefore lower in group 3, so less conditioning occurred to the CS.

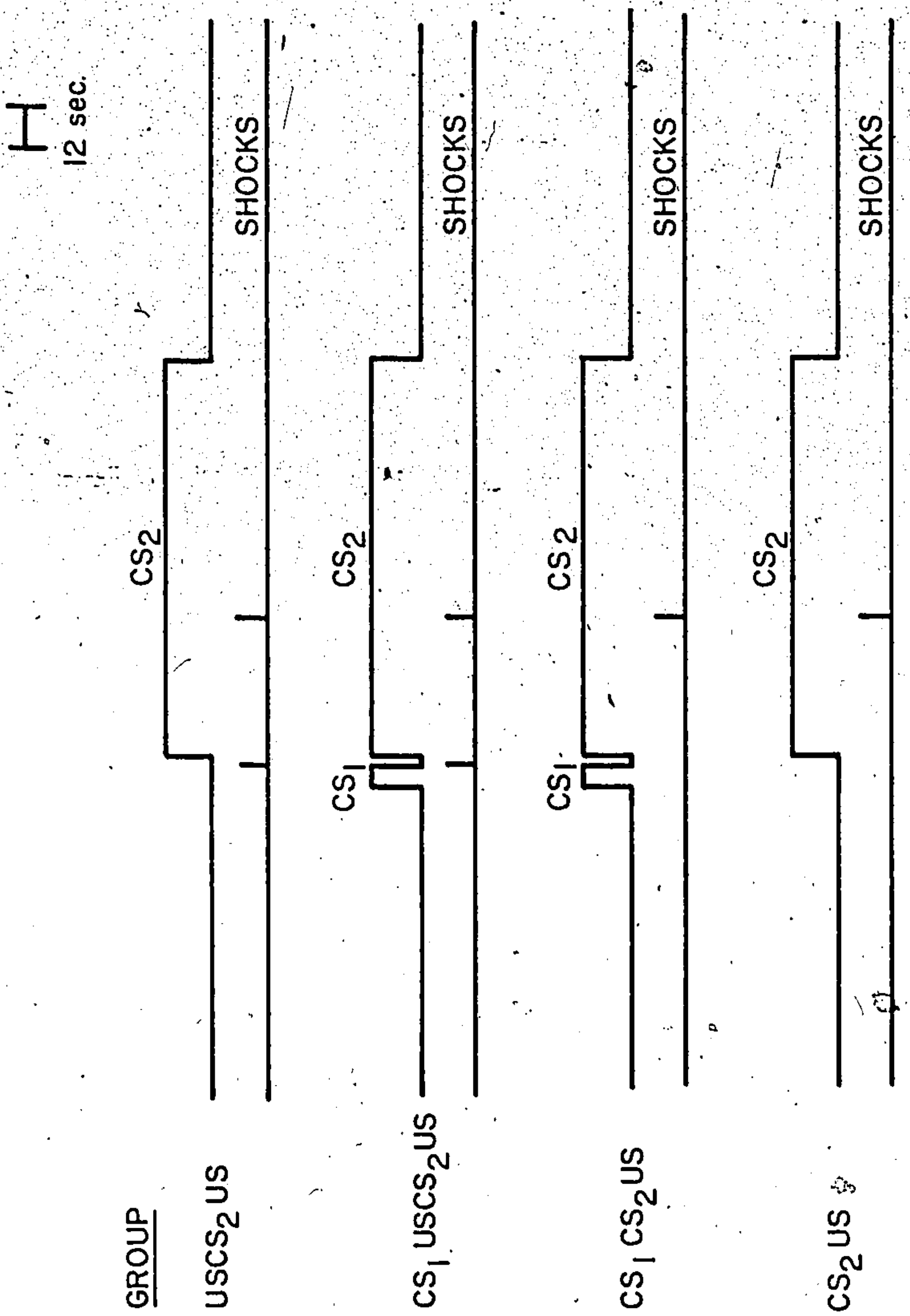
If the Rescorla-Wagner model provides a correct explanation of the temporal location effect, it should be possible to produce strong excitatory conditioning of a CS--even though each CS-US pairing is preceded by a shock. To achieve this strong conditioning, one would have to ensure that pre-CS shocks did not cause excitatory conditioning to the common or background cues. A technique that should be adequate to accomplish this, according to the Rescorla-Wagner model, is to condition the pre-CS shock to a salient stimulus. The model implies that if the pre-CS shock is fully signalled, the background stimuli will not acquire much excitatory strength. When compared with an unsignalled pre-CS shock, a signalled pre-CS shock should interfere much less, if at all, with conditioning to a subsequent CS.

The present experiment was a test of this implication of the Rescorla-Wagner model. The plan of the experiment, in outline, was as follows. Rats were trained to bar-press for food pellets. After a stable rate of responding had been established, the bar was retracted and the first of two phases of Pavlovian conditioning was begun. In the first phase, sixty pairings of a salient, 102 db white noise (GS_1) with an intense shock were given. The purpose of these pairings was to produce asymptotic excitatory conditioning to CS_1 (i.e., $V_A = 0$ and $V_X = \lambda$). In the second phase of the Pavlovian conditioning (see Figure 4), two groups received an intense shock 3 seconds prior to the onset of a new CS (CS_2). For group CS_1USCS_2US, the shock was signalled by CS_1; for group $USCS_2US$, the shock was unsignalled. According to the Rescorla-Wagner model, the group that received the signalled pre-CS_2 shocks should condition much more strongly than the group whose pre-CS_2 shocks are unsignalled. Indeed, suppression in group CS_1USCS_2US should approach closely suppression in group CS_2US. The predictions follow from the model because the first phase of Pavlovian conditioning fully conditioned CS_1, hence driving the excitatory value of the common stimuli close to zero. Consequently, the CS_1US pairings in phase two in group CS_1USCS_2US should not interfere with the excitatory conditioning of CS_2.

It is important to note that the anterograde interference hypothesis also predicts that group $USCS_2US$ will suppress less than group CS_1USCS_2US and that group CS_1USCS_2US will be equivalent in magnitude of suppression to group CS_2US. The anterograde interference hypothesis predicts these results because group $USCS_2US$ has a surprising event (i.e., an unsignalled shock) occur before each CS_2-US pairing, whereas, group CS_2US and group CS_1USCS_2US do not (the pre-CS_2 shock in group CS_1USCS_2US is no longer surprising because of the prior CS_1-US pairings in the first phase of Pavlovian conditioning.)

Figure 4

Experiment 3: A schematic representation of the design of Phase 3 of Experiment 3.


12 sec.
GROUP
USCS2US
CS2
SHOCKS
CS1 USCS2US
CS1
CS2
SHOCKS
CS1 CS2US
CS1
CS2
SHOCKS
CS2US
CS2
SHOCKS

METHOD

Subjects

The Ss were 32 experimentally naive Long-Evans male hooded-rats, obtained from Canadian Breeding Farms, Quebec, Canada. Ss were housed in individual cages, with water freely available in the cages and Skinner boxes. The rats were reduced to 80% of their free-feeding weights, and were maintained at this level throughout the experiment.

Apparatus

Apparatus was the same as was used in the first experiment. CS_1 was a six second presentation of a 102 db white noise (the noise level was measured by a General Radio Sound-Level Meter, Model #1551-C, weighting A). The white noise was produced by a Grason-Stadler White-Noise Generator (901B). The output of this generator was amplified by a Realistic Amplifier (AF-15D). CS_2 was a two minute illumination of the houselight (#304, 24 vDC). The US, a 4.0 mA, 0.5 second scrambled electric shock delivered through the grid floor, was produced by a Lehigh Valley constant current shock generator (Model 113-04).

Procedure

The experiment consisted of six phases: 1. preliminary bar-press training. 2. stage one of Pavlovian conditioning (both bars retracted) in order to condition CS_1. 3. stage two of Pavlovian conditioning (both bars retracted) in which the several groups received differential treatment. 4. re-establishment of the VI 2' baseline. 5. test of conditioning to CS_2 by superimposition of CS_2 on the VI 2' baseline. 6. test of conditioning to CS_1 by superimposition of CS_1 on the VI 2' baseline.

Phase 1.

Pretraining of the bar-press was carried out as it was in the first experiment. Starting with the sixth experimental day, Ss were placed on VI 2' for six 120 minute sessions. On the fifth and sixth days of VI 2', each S received four 2 minute presentations of CS_2 and four 1 minute presentations of CS_1. These presentations allowed any unconditioned responses to CS_1 and CS_2 to habituate. At the end of Day 6, Ss were divided into 4 groups of 8 Ss each. These groups were matched for response rate and Skinner box.

Phase 2.

This phase consisted of six, 126 minute sessions. Throughout this phase, both bars were retracted. On four of these days (days 1, 2, 4, and 6), each S received 15 pairings of a 6 second, 102 db white noise (CS_1) with a 0.5 second, 4.0 mA shock. The ITI averaged 8 minutes. There were 3 ITIs of 2, 5, 8, 11, and 14 minutes on each of the four pairing days. On Days 3 and 5, the Ss were put into the boxes but no CSs or USs were given. The purpose of these two sessions was to extinguish any fear that may have been conditioned to the common cues on Days 1, 2, and 4. There is evidence (Dweck and Wagner, 1970) that if extinction sessions are interspersed with pairing sessions, increased fear conditioning to the CS will occur.

Phase 3.

This phase consisted of four Pavlovian conditioning sessions. During these sessions the bars continued to be retracted and each group received seven 2 minute illuminations of the houselight (CS_2). The ITI was fixed at 16 minutes. On each day of phase three, 12 minutes of ITI preceded the first CS_2 presentation and four minutes of ITI followed the last CS_2 presentation. Each group received an average of 0.89 shocks per CS_2. Since only one shock was allowed to occur in any CS_2, this means that 25 out of the 28 CS_2 presentations contained a shock Shock delivery and CS_2 presentation were controlled by a tape reader that was stepped every 3 seconds. Except for the restriction that a shock could not occur at the onset of CS_2, the temporal location of shocks in CS_2 was random. That is, if a particular CS_2 was scheduled to contain a shock, each of the 40 (40 x 3 seconds = CS duration) samplings of CS_2, except the first, had an equal probability of containing the shock. A different sequence of CS_2 shocks was used in each of the four sessions.

Group $USCS_2US$ received a shock 3 seconds prior to each CS_2 onset. Group CS_1USCS_2US also received these pre-CS_2 shocks, but their occurrence was signalled by CS_1. Each presentation of CS_2 in group CS_2US was neither preceded by a shock or CS_1, while, group CS_1CS_2US was treated identically to group CS_1USCS_2US except that the pre-CS_2 shocks were omitted.

Phase 4.

Following the four sessions in Phase 3, three two-hour sessions of VI 2' were given to re-establish a stable bar-pressing rate.

Phase 5.

During each of these four two-hour test sessions, the VI 2' schedule of reinforcement remained in effect; superimposed on this VI 2' baseline were four two-minute presentations of CS_2. No shocks were delivered during these four sessions.

Phase 6.

During this two-hour session, the VI 2' remained in effect; superimposed on this baseline were four two-minute presentations of CS_1.

RESULTS

Re-acquisition of VI 2' response rates

A Kruskal-Wallis H test on the individual response rates on the last day of VI 2' re-acquisition showed that there were no significant group differences ($\underline{H} = 1.73$, $\underline{p} > .05$). Consequently, the subsequent tests of suppression to CS_1 and CS_2 during extinction test trials were not confounded by between-group differences in baseline rates.

Suppression to CS_2

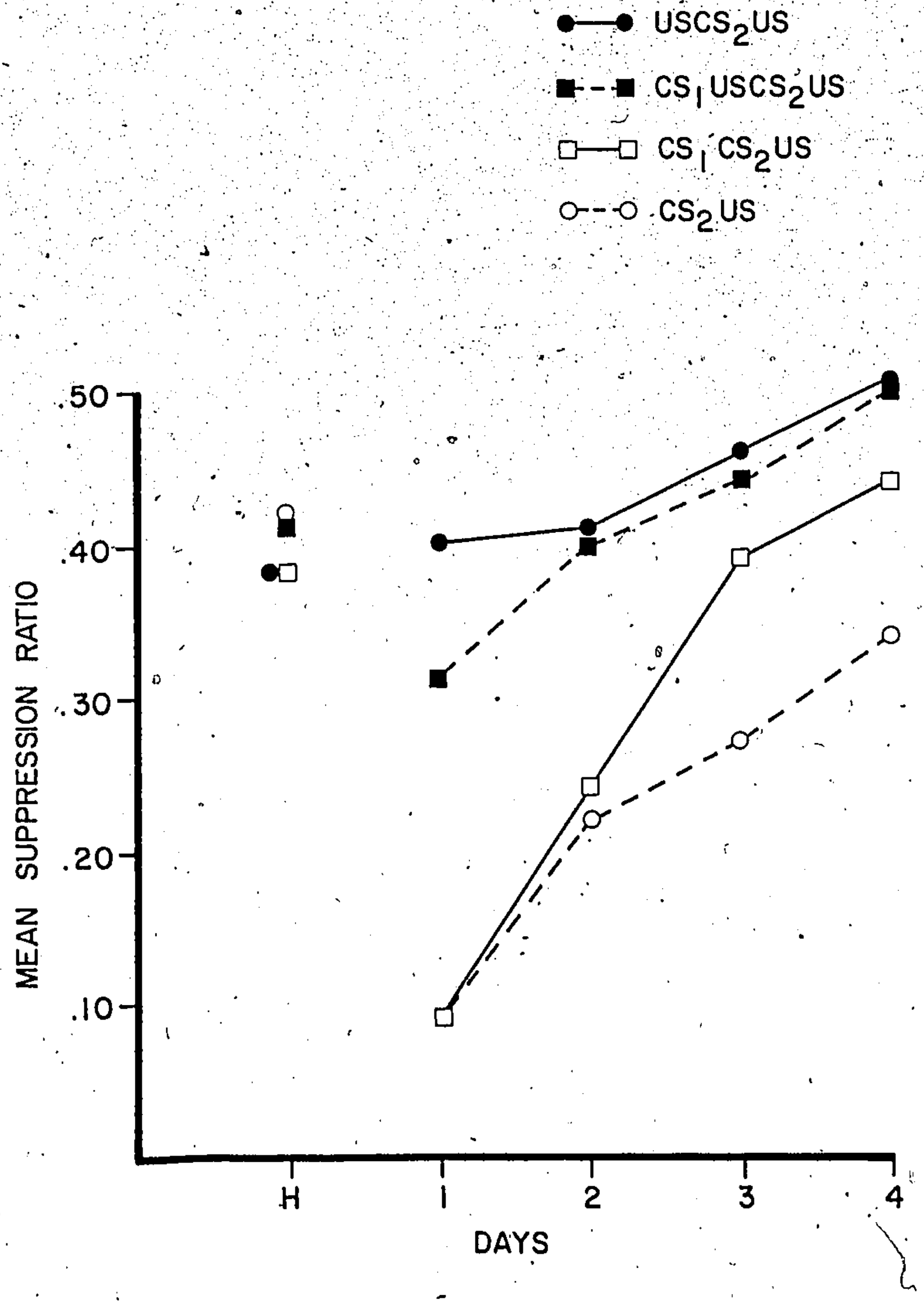
Figure 5 shows the mean suppression ratios to CS_2 for each group for the last day of habituation training and for the four days of extinction testing. A Kruskal-Wallis $\underline{H}$ test revealed that there were significant group differences ($\underline{H} = 19.66$, $\underline{p} < .001$). Individual Mann-Whitney $\underline{U}$ tests confirm the impression that groups $USCS_2US$ and CS_1USCS_2US suppressed less than group CS_2US on all four days of extinction testing (group $USCS_2US$ vs CS_2US on Days 1-4, $\underline{Us} = 0$, 9, 6 and 7; group CS_1USCS_2US vs CS_2US on Days 1-4, $\underline{Us} = 3\ 1/2$, 11, 8 1/2, and 11) and less than group CS_1CS_2US on the first two days of extinction (group $USCS_2US$ vs CS_1CS_2US, $\underline{Us} = 0$ and 8 1/2; CS_1USCS_2US vs CS_1CS_2US, $\underline{Us} = 3\ 1/2$ and 12). Additional Mann-Whitney $\underline{U}$ tests showed that groups CS_2US and CS_1CS_2US did not differ significantly from each other on any of the four testing days, while, groups $USCS_2US$ and CS_1USCS_2US differed only on Day 1 ($\underline{U} = 8$).

Suppression to CS_1

In phase 2 of the present experiment all groups received a

Figure 5

Experiment 3: The mean suppression ratios for each group for the last day of habituation and the four days of extinction.


USCS$_2$US
CS$_1$USCS$_2$US
CS$_1$CS$_2$US
CS$_2$US
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substantial amount of fear conditioning to CS_1 (60 trials) under conditions that could confidently be expected to produce strong conditioning. Nevertheless, in phase 6 it was thought desirable to test for suppression to CS_1 to verify that CS_1 had functioned as an effective signal of shock. The test was complicated by the fact that CS_1 was only 6 seconds in duration during conditioning; a duration too short for reliable measurement of suppression ratios. For the purpose of testing, CS_1 was extended to 120 seconds. The CS_1 extinction suppression ratios, however, were based only on the first 60 seconds of each 120 second trial. Since the CS_1 habituation ratios of phase 1 were 60 seconds in length, in order to ensure comparability, responding during the second minute of each 120 second trial was ignored.

In order to determine whether "fear" conditioning had occurred to CS_1 during Pavlovian conditioning, each rat's suppression ratio on its first extinction test trial was compared to its suppression ratio on its first CS_1 habituation trial. The same comparison was made between the second, third and fourth habituation trials and the corresponding extinction test trials. A sign test (Siegel, 1956) was run on each of the four comparisons. These tests showed that the rats suppressed significantly more on each of the four extinction trials than they did on the corresponding habituation trials (trials 1-4, $\underline{zs} = 4.77$, 5.12, 3.36, and 4.06, $\underline{ps} < .001$). Further evidence that CS_1 had become an effective signal of shock is gained by comparing the last four CS_1 habituation suppression ratios (.54, .60, .55 and .53) with the four

CS_1 extinction ratios (.04, .17, .30, and .34). There seems little doubt that the CS_1-US pairings of phase 2 made CS_1 into a good signal of shock.

Finally, the differential treatments in phase 3 did not significantly affect the level of conditioning to CS_1. Mann-Whitney U tests between pairs of groups in no case reached significance.

DISCUSSION

The results of the present experiment force one to reject the possibility of explaining the temporal location effect by the application of the Rescorla-Wagner model. Signalling the pre-trial shock did not prevent, nor did it markedly lessen, the effect of the pre-trial shock on conditioning to the subsequent CS. The theory could fail for either, or both, of the following reasons. The temporal location effect may not be due to conditioning of prevailing or background stimuli. Or, signalling the pre-CS shock may not prevent the background stimuli from becoming excitatory. The last is unlikely for several reasons. The design of Experiment 3 tried to minimize the possibility of the conditioning of background cues by making CS_1 a very salient stimulus, by interspersing CS_1-US pairing sessions with background cue extinction sessions and by giving a large number of CS_1-US trials. In view of these precautions, and in view of the fact that CS_1 produced a substantial amount of suppression during tests in extinction, the most likely reason for the failure of the Rescorla-Wagner formulation to explain the temporal location effect is that the effect is not mediated by conditioning to background cues.

The results of Experiment 3 are quite similar to the results of an experiment by Rescorla (Rescorla, 1972, pp. 25-26). Rescorla was also interested in the question of whether ITI shocks reduce the conditioning of a CS by conditioning of background cues. He compared the performances of three groups of subjects--a positive contingency group which received shocks only during the trial, a no contingency group which received shocks at the same average rate in the ITI as in the trial, and a no contingency group that had the shocks in the ITI signalled by a CS that was different from the CS that signalled the trial shocks. Although Rescorla found that the group with ITI shocks signalled suppressed significantly more than the unsignalled group (mean suppression ratio of .37 compared to .48), he also found that the positive contingency group suppressed much more than the signalled "ITI" group (.08 versus .37). These results are, of course, very similar to the results of the present experiment. Both experiments obtained a significant effect that could be attributed to conditioning of background cues. Yet, both experiments also revealed that this factor is not as effective as the Rescorla-Wagner model demands. In other words, the conditioning of background cues is probably one factor that can reduce a CS's tendency to produce suppression when unsignalled shocks are delivered in the ITI. However, it does not appear to be either the only or the most important factor.

Mention should also be made of the fact that the results of Experiment 3 eliminate the anterograde interference hypothesis as an account of the temporal location effect. This hypothesis predicted that signalling the pre-CS_2 shocks, and thereby removing their surprise value, should allow the subsequent CS_2-US pairings to be effective. Although there was an effect of signalling, it was small. The failure of the CS_2-US pairings to produce strong conditioning, then, does not appear to be a result of the occurrence of a surprising event before each CS_2-US trial.

The following experiment tried to ascertain whether the overshadowing, the Information Hypothesis, or the generalization decrement interpretations can account for the temporal location effect.

CHAPTER 5

EXPERIMENT 4

The Overshadowing and Information Hypothesis Study

Both an overshadowing and an "information" interpretation of the results of the first three experiments state that the CS fails to condition strongly in groups that receive an ITI shock immediately preceding each CS-US pairing because the ITI shock, itself, introduces a second signal into the stimulus situation. This second signal, the trace or the stimulus-after-effects of shock presentation, is assumed to compete with the nominal CS for the conditioned strength that results from the pairing on each CS-US trial. Moreover, since a particular reinforcer can maintain only a certain maximum or asymptote of conditioning, any conditioned strength that the trace stimulus acquires will necessarily be subtracted from the conditioned strength that the nominal CS would have acquired had an ITI shock preceded each CS-US trial. According to the Information and the overshadowing hypothesis, then, when a proximal ITI shock precedes each CS-US pairing, there is not less conditioning of the concurrently present stimuli, but a different distribution of the conditioned strength.

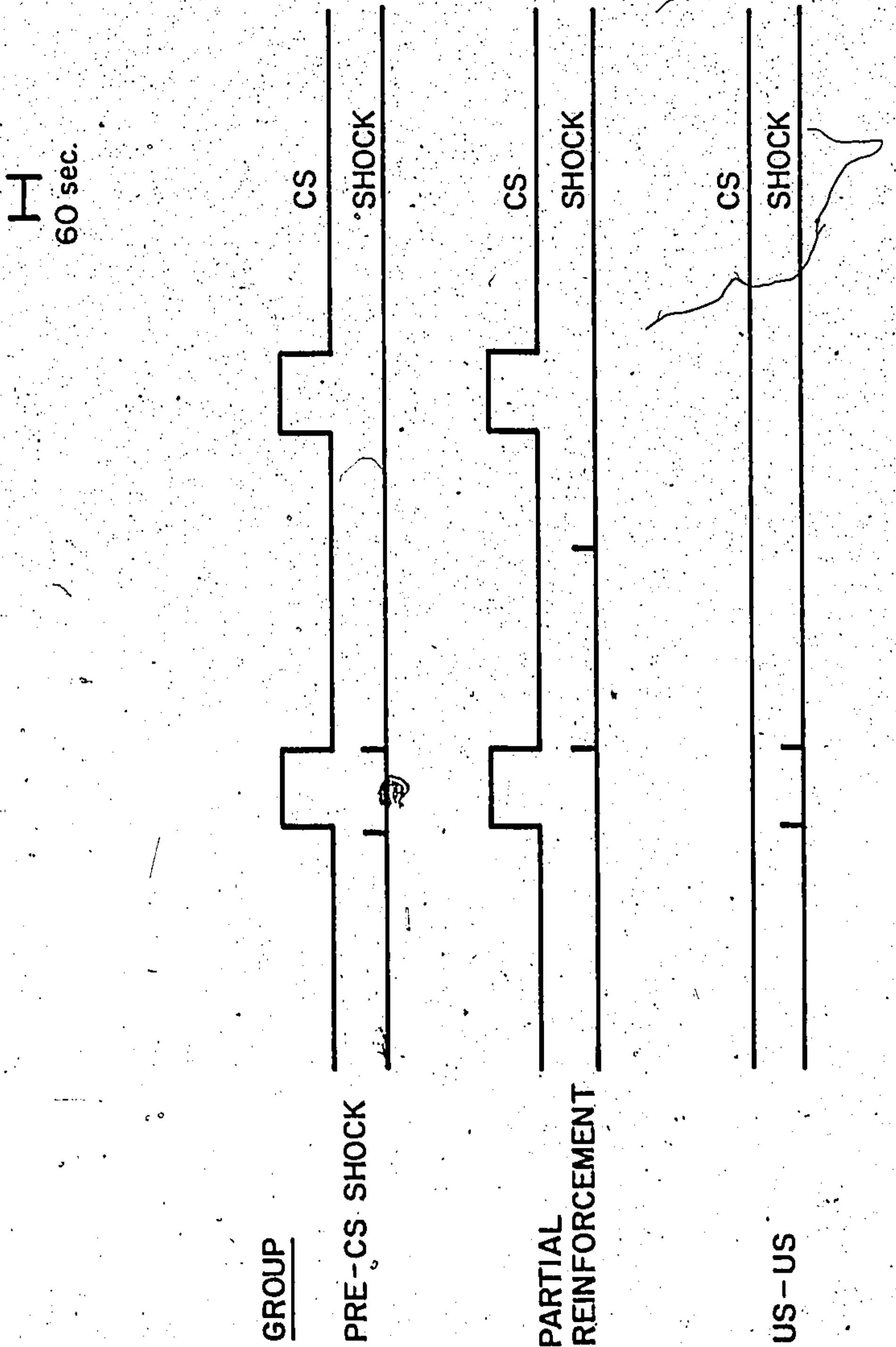
That is, two stimuli, the trace of shock presentation and the nominal CS, share the conditioned strength that would normally accrue solely to the nominal CS.

The design of Experiment 4 tested three implications of the overshadowing and the Information Hypothesis. First of all, the above analysis suggests that the conditioned strength acquired by the trace and the nominal CS in a group whose CS-US pairings are always preceded by an ITI shock should be equal to the conditioned strength that is acquired by the CS in a group whose CS-US pairings are not so preceded. Experiment 4 tested this prediction by comparing the amount of suppression in two such groups. If competition theories are correct, the pre-CS shock group (see Figure 6) should suppress on CS-US trials as much as a group whose CS-US trials are never preceded by a shock (see the partial reinforcement group in Figure 6).

Secondly, if shock can, indeed, serve a signalling function, it should be possible to make rats learn a discrimination on the basis of the presence of this cue. Experiment 4 tested this prediction of the Information Hypothesis and the overshadowing account by ascertaining whether a group of rats (see Figure 6, group pre-CS shock) could form a within-subject discrimination between the following two types of trials. The CS on both trial types is always an illumination of the houselight. However, on one type of trial, this CS is preceded

Figure 6

Experiment 4: A schematic representation of the design of Phase 2 of Experiment 4. During this phase, the Pavlovian conditioning was done with the bar retracted (i.e., off the baseline). In a subsequent phase, these Pavlovian conditioning trials were given to each subject while it was bar-pressing for food. This "on the baseline" training allowed the calculation of separate suppression ratios for CS alone and US-CS-US trials in group pre-CS shock. Group US-US never received any CSs. A suppression ratio was obtained, however, for this group. This ratio was identical in method of calculation to the one obtained from group pre-CS shock on US-CS-US trials except that the houselight (i.e., the CS) was not illuminated in group US-US.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GROUP
PRE-CS SHOCK
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PARTIAL REINFORCEMENT
CS
SHOCK
US-US
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SHOCK

and terminated by a shock. On the other type of trial, shock occurs neither before nor during the CS. The only basis for a discrimination between these two kinds of trials is the stimulus-after-effects of shock. Thus, if rats can learn to suppress during a CS that is preceded by a shock and learn not to suppress when that same CS is not so preceded, it would demonstrate that shock can have an important signalling function. The absence of such a discrimination, however, would provide strong evidence against an interpretation of the temporal location effect in terms of either the Information Hypothesis or the overshadowing hypothesis.

Thirdly, the design of Experiment 4 included one other group whose results would be relevant to the question of whether rats can use the trace of a shock as a signal. In this group (see group US-US in Figure 6), the animals were given pairs of shocks that were separated by the same time interval as in the pre-CS shock group--but with no CS. The conditions in this group are optimal for the development of a signalling function since there is no other basis for predicting the occurrence of the second shock. If the suppression in this group, when compared to the suppression produced by single shock in a group that has never received two ITI shocks closely in succession, is strong, it would provide additional evidence that rats can use the occurrence of a shock as a signal for subsequent shock.

The results of Experiment 4 will also bear on the generalization decrement interpretation. Recall that this account states that all of the groups in each of the preceding experiments learned identical CS-US associations. This interpretation argues that our failure to observe such an equivalence was due to the fact that the groups that ostensibly learned a weaker association between CS and US experienced a sharp contrast between the training and testing phases of the experiment. That is, these "weaker-association" groups always had an ITI shock immediately precede their CS-US trials in training, but, in testing, USs did not precede their extinction trials. As a result of this change in stimulus conditions, the "weaker-association" groups showed a smaller association than they had learned.

The design of Experiment 4 permitted an assessment of the validity of this generalization decrement account because group pre-CS shock received both CS alone and US-CS-US trials. If this interpretation is correct, the rats in the pre-CS shock group should show much more suppression on US-CS-US than on CS alone trials because there should be a large generalization decrement on the CS alone trials. Conversely, if the rats fail to discriminate between these trial types, a generalization decrement account can be rejected.

METHOD

Subjects

The Ss were 32 experimentally naive Long-Evans male hooded-rats, obtained from Canadian Breeding Farms, Quebec, Canada. The rats were reduced to 75% of their free-feeding weights, and were maintained at this level throughout the experiment. Ss were housed in individual cages, with water freely available. Unlike the first three experiments, water was not available in the Skinner boxes.

Apparatus

Individual animals were run in one of four roughly identical Skinner boxes (23.5 cm long by 21 cm wide by 19 cm high). Each box was equipped with a Lehigh Valley rat lever. During Phase 2, this bar was retracted. The end walls of the chamber were aluminum; the side walls and the top were clear Plexiglas. The floor was a grid composed of 2 mm stainless-steel rods spaced 12.7 mm apart. A ventilating fan raised the ambient level of the noise in the box to 49 dbA. The CS was a two-minute illumination of the houselight (bulb #302, 24 vDC). The US, a 3/4 second, 1 mA scrambled electric shock delivered through the grid floor, was produced by a Grason-Stadler Shock Generator (Model E1064).

Procedure

The experiment consisted of four phases: I. preliminary bar-press training. 2. Pavlovian conditioning with the bar retracted. 3. re-establishment of the VI 30 second baseline. 4. Pavlovian conditioning trials superimposed over the VI 30 second baseline.

Phase 1.

During the first two sessions, Ss were magazine-trained automatically with food delivered on a variable-time 1' schedule of reinforcement. In addition, each bar-press yielded a food pellet (45 mg). Both sessions continued until each S had received 100-150 pellets. On Days 3 and 4, each S was allowed to produce 100-150 pellets on continuous reinforcement (i.e., Fixed Ratio 1). The Ss were then given seven, 2-hour sessions on VI 30". On the sixth and seventh day of VI 30", each S received four 2-minute presentations of the CS. These presentations allowed any unconditioned responses to the CS to habituate. At the end of Day 7, Ss were divided into three groups. The partial reinforcement and the pre-CS shock groups were given 12 Ss each, while, the US-US group was given 8 Ss. These groups were matched for response rates and Skinner boxes.

Phase 2.

This phase consisted of six, 125-minute Pavlovian conditioning sessions Throughout this phase, no food was delivered and the lever was retracted. On each of these six days, each S in the pre-CS shock group received six non-reinforced presentations of the CS and three trials in which a CS-US pairing was preceded by an ITI shock. This pre-CS or ITI shock occurred three seconds prior to the onset of each of the three CS-US trials. Thus, the rats in the pre-CS shock group received nine CSs per day--six CS extinction trials and three CS-US pairing trials that were each preceded by a shock. The partial reinforcement control group was treated identically to the pre-CS shock group except that their ITI shocks occurred, not immediately preceding each CS-US trial, but five minutes after the termination of each CS-US trial. Finally, group US-US was treated identically to the pre-CS shock group except that group US-US never received any CSs.

Shock delivery, CS presentation and ITI duration were controlled by a tape reader which was stepped every three seconds. The ITI averaged 11 minutes. On each day of phase 2, there were three ITIs each of 8, 11, and 14 minutes. Except for the restriction that a shock could not occur at CS onset, the temporal location of CS shocks was random. That is, if a particular CS contained a shock, each of the 40 (40 x 3 seconds = CS duration) three-second samplings of the CS had an equal probability of containing that shock. A different sequence of ITIs, CS shocks and nonreinforced and reinforced trials was used in each of the six sessions.

Phase 3.

Following the six sessions in phase 2, four 2-hour sessions of

VI 30" were given to re-establish stable bar-pressing rates.

Phase 4.

In each of the 31 sessions of this phase, the VI 30" schedule remained in effect. During Sessions 1-3 and 5-30 (on Session 4, no USs or CSs were given), the rats in the pre-CS shock and the partial reinforcement group received two CS alone or extinction trials and one CS-US pairing trial per day. As in phase 2, the CS-US pairing trial had a shock occur three seconds prior to CS onset in the pre-CS shock group and five minutes after CS offset in the partial reinforcement group. Group US-US was treated identically to group pre-CS shock except that this group did not receive any CSs. Thus, the Pavlovian conditioning trials that were characteristic of phase 2 were superimposed on each animal's VI 30" baseline in phase 4.

In 10 out of the above 29 sessions, the CS shock on the CS-US pairing trial in each session occurred at CS termination. In the other 19 sessions, the CS shock on a CS-US trial occurred randomly during CS presentation. That is, except for the restriction that the shock on a CS-US trial could not occur at CS onset, the CS shocks on those 19 trials could occur anywhere during the CS. A different sequence of extinction and pairing trials and ITIs was used in each of the 29 sessions.

The suppression ratios of Experiment 4 were calculated by comparing the number of responses in a 2-minute interval that commenced 123 seconds prior to CS onset to the number of responses made in the 2-minute CS. The pre-CS response-count or measurement interval was terminated three seconds prior to CS onset, rather than at CS onset, because this prevented the responses in the three second period after the ITI shock on pairing trials in group pre-CS shock from entering into the calculation of suppression ratios. A suppression ratio was also calculated for group US-US on US-US trials. This ratio was identical in method of calculation to those mentioned above. That is, the number of responses in the 2-minute interval immediately preceding the first ITI shock was compared to the number of responses in the 2-minute interval that commenced three seconds after the onset of this ITI shock.

On the last day of the experiment (Day 31), each group received two unsignalled ITI shocks and no CSs--the first shock occurred 50 minutes after the start of the session and the second occurred 64 minutes later. A suppression ratio was calculated for each of these trials. These ratios were identical in method of calculation to those obtained from group US-US on US-US trials.

The purpose of the US alone trials was to attempt to determine whether the suppression that followed an ITI shock in the pre-CS shock or the US-US group was a conditioned or unconditioned effect of shock presentation. That is, either of these groups might decrease their rates of responding following the delivery of an ITI shock because: 1. shock has unconditioned suppressive properties. 2. animals can learn that an ITI shock is a signal for subsequent shock. This second kind of suppression would, of course, be an example of a conditioned suppression that is controlled by the stimulus-after-effects of shock. In order to determine whether the suppression that might follow shock delivery in either of these groups is unconditioned rather than conditioned, a control group is needed. The partial reinforcement group can serve as this control because the occurrence of an ITI shock in this group was never closely followed by another shock. Thus, the suppression produced by US alone trials in this group should be a fair estimate of the unconditioned suppressive effects of shock presentation. Therefore, if the animals in the pre-CS shock or the US-US group have learned to use the delivery of an ITI shock as a signal for subsequent shock, their US alone suppression ratios should be significantly lower than the ratios of the partial reinforcement group. Conversely, if their ratios are not lower, any suppression that occurred was presumably unconditioned in origin.

RESULTS

Table 1 shows the mean suppression ratios for each group for each kind of trial for each of the 29 days of testing. A quick glance

TABLE I

Mean Suppression Ratios

Group		pre-CS shock		partial reinforcement		US-US
	Temporal location of CS shock in # of sec. from CS onset (120 = max.)	Trial		Trial		Trial
Session #		CS alone	US-CS-US	CS alone	CS-US	US-US
1	120	.25	.14	.03	.10	.16
2	120	.20	.11	.04	.08	.19
3	24	.20	.13	.05	.10	.13
5	45	.31	.09	.06	.03	.11
6	75	.26	.18	.03	.05	.12
7	12	.33	.09	.05	.04	.16
8	120	.31	.27	.04	.02	.23
9	90	.25	.13	.06	.06	.19
10	60	.22	.16	.06	.06	.16
11	120	.24	.24	.04	.06	.29
12	18	.31	.14	.04	.05	.09
13	36	.28	.19	.04	.06	.09
14	120	.30	.20	.05	.03	.15
15	96	.21	.19	.05	.06	.12
16	120	.26	.20	.04	.06	.27
17	6	.22	.15	.04	.09	.07
18	72	.26	.16	.04	.09	.13
19	54	.22	.19	.03	.06	.10
20	120	.24	.17	.03	.03	.17

TABLE 1 con't

Mean Suppression Ratios

Group		pre-CS shock		partial reinforcement		US-US
		Trial		Trial		Trial
Session #	Temporal location of CS shock in # of sec. from CS onset (120=max.)	CS alone	US-CS-US	CS alone	CS-US	US-US
21	84	.22	.18	.02	.05	.09
22	48	.21	.12	.07	.06	.11
23	21	.28	.12	.05	.06	.13
24	42	.24	.18	.06	.09	.15
25	120	.27	.21	.05	.05	.32
26	81	.23	.14	.06	.08	.20
27	51	.19	.10	.07	.08	.17
28	120	.20	.15	.05	.04	.20
29	93	.23	.16	.04	.09	.23
30	120	.17	.10	.04	.03	.16
		$\bar{X}=.25$	$\bar{X}=.16$	$\bar{X}=.05$	$\bar{X}=.06$	$\bar{X}=.16$

at this table reveals three principal findings: 1. group pre-CS shock suppressed less than the partial reinforcement group both on CS alone and CS-US trials. 2. the pre-CS shock group suppressed somewhat more on CS-US than on CS alone trials. 3. group US-US showed a moderate level of suppression following the first shock of a shock-shock sequence.

Table 2 shows suppression ratios that are representative of each animal's terminal performance. A Kruskal-Wallis H test on the pre-CS response rates that were used in the calculation of these ratios failed to find a significant difference ($H = .004$, $p > .05$). Thus, the suppression ratios in Table 2 are not confounded by large differences in pre-CS response rates (the mean pre-CS response rates of the partial reinforcement, the pre-CS shock and group US-US were 27.09, 28.08 and 27.39 responses per minute).

The overshadowing and the Information Hypothesis make three principal predictions about the results of Experiment 4, and the results have been organized around these predictions. One of the predictions was that the pre-CS shock group would suppress as much as the partial reinforcement group on CS-US trials. This prediction followed from competition theories because they assume that proximal ITI shocks do not cause less conditioning, but a different distribution of the conditioned strength. A Mann-Whitney U test on the CS alone and the CS-US

TABLE 2

Individual Suppression Ratios

Group	pre-CS shock				partial reinforcement			US-US	
	Trial				Trial			Trial	
CS alone	US-CS-US	Diff.	US alone	CS alone	CS-US	US alone	US-US	US alone
.20	.14	.06	.37	.16	.12	.27	.35	.35
.32	.02	.30	.14	.04	.08	.39	.26	.23
.27	.18	.09	.49	.01	.00	.47	.13	.28
.55	.45	.10	.43	.00	.01	.34	.34	.30
.21	.21	.00	.45	.02	.00	.32	.22	.34
.39	.27	.12	.33	.02	.01	.40	.20	.27
.14	.12	.02	.46	.00	.00	.14	.04	.03
.02	.05	-.03	.37	.02	.02	.23	.28	.28
.07	.09	-.02	.45	.05	.05	.52		
.12	.01	.11	.16	.08	.06	.37		
.12	.11	.01	.42	.01	.01	.09		
.25	.21	.04	.42	.12	.11	.37		
$\overline{X}$=.22	$\overline{X}$=.16	$\overline{X}$=.07	$\overline{X}$=.37	$\overline{X}$=.04	$\overline{X}$=.04	$\overline{X}$ = .33	$\overline{X}$=.23	$\overline{X}$=.26

Note. The CS alone, CS-US, and US-US ratios were based on each animal's performance during Sessions 25, 28, and 30; the US alone ratios were obtained from Session 31. Each ratio was calculated by comparing the number of responses in the pre-CS response interval for that kind of trial across all test sessions to the number of responses made in the CS during these same trials.

suppression ratios in Table 2 found that the pre-CS shock group suppressed less than the partial reinforcement group on both kinds of trials ($\underline{Us}$ = 14 1/2 and 21 1/2, $\underline{ps}$ < .01). This result, even if taken by itself, is sufficient to eliminate competition theories as potential explanations of the temporal location effect.

A second prediction of the overshadowing and the Information Hypothesis was that group US-US would learn to use the first shock of a shock-shock sequence as a cue for the second shock. If this prediction were correct, the magnitude of suppression produced by the delivery of an unsignalled shock should be greater in the US-US group than in the partial reinforcement group. A Mann-Whitney $\underline{U}$ test on the US alone suppression ratios of these two groups, although in the right direction, did not find a significant difference ($\underline{U}$ = 29 1/2, $\underline{p}$ < .20). Group US-US did, however, suppress more on US alone trials than did the pre-CS shock group ($\underline{U}$ = 16, $\underline{p}$ < .05).

The third prediction of the overshadowing and the Information Hypothesis was that the animals in the pre-CS shock group would form a good discrimination between CS alone and CS-US trials. That is, these animals would show strong suppression on CS-US trials, but little or no suppression on CS alone trials. Table 2 shows that, on the average, the pre-CS shock group did not form a good discrimination between CS-US and CS alone trials. This group can, nonetheless, be somewhat arbitrarily divided into two subgroups--discriminators and nondiscriminators. That is, if one defines a discriminator as an animal that suppressed .06 or more on CS-US than on CS alone trials, half of the Ss in the pre-CS shock group would be discriminators; half, nondiscriminators. Table 3 shows that there are important differences between these subgroups other than the discrimination difference. However, before these other differences are examined, mention should be made that Mann-Whitney U tests found that both subgroups suppressed significantly less on CS alone trials than did Ss in the partial reinforcement group (discriminators, $U = 1\ 1/2$, $p < .001$; nondiscriminators, $U = 13$, $p < .05$). Thus, contrary to the expectations of the overshadowing and the Information Hypothesis, the animals in the pre-CS shock group that showed no evidence of an ability to use the trace of shock presentation as a cue (i.e., the nondiscriminators) suppressed less on CS alone trials than did animals in the partial reinforcement group.

Table 3 compares the terminal performances of the discriminators and the nondiscriminators. The differences between these two subgroups that will be noted below are probably due to the greater unconditioned suppressive effects of shock presentation on the discriminators. Table 3 shows that the discriminators suppressed, on the average, .13 more on CS-US trials than on CS alone trials, while, the nondiscriminators suppressed as much on CS alone trials as CS-US trials.

TABLE 3

A Comparison of the Suppression Ratios of Discriminators and Nondiscriminators

Subgroup	Discriminators				Nondiscriminators			
	Trial				Trial			
	CS alone	US-CS-US	Diff.	US alone	CS alone	US-CS-US	Diff.	US alone
	.20	.14	.06	.37	.21	.21	.00	.45
	.32	.02	.30	.14	.14	.12	.02	.46
	.27	.18	.09	.49	.02	.05	-.03	.37
	.55	.45	.10	.43	.07	.09	-.02	.45
	.39	.27	.12	.33	.12	.11	.01	.42
	.12	.01	.11	.16	.25	.21	.04	.42
	$\bar{X}$ = .31	$\bar{X}$ = .18	$\bar{X}$ = .13	$\bar{X}$ = .32	$\bar{X}$ = .14	$\bar{X}$ = .13	$\bar{X}$ = .00	$\bar{X}$ = .43

Note. The figures in this table are taken from Table 2.

US alone trials also tended to produce more suppression in the discriminators than in the nondiscriminators, although the difference was not significant ($\underline{U}=9\ 1/2$, $\underline{p} > .20$). Similarly, although the nondiscriminators came very close to suppressing significantly less than the partial reinforcement group on US alone trials ($\underline{U}=15$, $\underline{p} < .10$), the discriminators did not ($\underline{U}=35\ 1/2$, $\underline{p} > .05$). Finally, it should be noted that the discriminators suppressed much less on CS alone trials than did the nondiscriminators ($\underline{U}=5\ 1/2$, $\underline{p} < .06$; a $\underline{U}$ of 5 or less is needed at the .05 level).

DISCUSSION

The most important result of the present experiment is that the pre-CS shock group suppressed less than the partial reinforcement group on CS-US trials. This finding is contrary to the expectations of competition theories because such theories imply that the pre-CS shock, directly or indirectly, serves to introduce a second signal into the situation. This other signal, the pre-CS shock itself in the overshadowing and "information" accounts, or the prevailing or background cues in the Rescorla-Wagner model, is hypothesised to acquire some of the conditioned strength that would normally accrue solely to the nominal CS. If this account in terms of a different distribution of conditioned strengths were correct, the conditioned strength that is shared by the nominal CS and the other signal in the pre-CS shock group should have been equal to the conditioned strength of the CS in the partial reinforcement group. Since this was not the case, the result is incompatible with competition theories. The result is, however, congruent with theories, such as interference theories, that stress that proximal ITI shocks disrupt the conditioning process, and thereby produce a smaller total amount of conditioning.

The above result shows that the temporal location effect is not produced because the trace of the pre-CS shock has served a signalling function. A second important result of the present experiment further reinforces this conclusion. The nondiscriminators of the pre-CS shock group suppressed less than the partial reinforcement group on CS alone trials--even though the animals in this subgroup showed no evidence of using the trace of shock presentation as a cue for subsequent shock. This result replicates the temporal location effect and it shows that interpretations of the effect in terms of overshadowing, "information", and generalization decrement are incorrect. All three of these accounts stressed that Ss in the pre-CS shock group must discriminate between extinction and pairing trials if they are to suppress less than the partial reinforcement group. Clearly, however, the effect can be obtained when these factors are not affecting the performances of animals in the pre-CS shock group.

Although the results of Experiment 4 demonstrate that the temporal location effect can occur when overshadowing, "information", and generalization decrement are not operating, the finding that the discriminators suppressed less than the nondiscriminators on CS alone trials might suggest to some that the effect is larger when those factors are influencing some animals in the pre-CS shock group. Much caution, however, should be used when interpreting the CS alone suppression difference in this manner. If the discriminators suppressed less than the nondiscriminators on CS alone trials because they learned to use the pre-CS shock as a signal for subsequent shock, the discriminators should suppress more on US alone trials than a group that never had the opportunity to learn that an ITI shock is immediately followed by a second shock. The partial reinforcement group was, of course, such a group. Since the discriminators did not suppress more on US alone trials than did the partial reinforcement group, it would appear that most of the suppression caused by US alone trials in the pre-CS shock group can be attributed to the unconditioned suppressive effects of shock presentation. Furthermore, it would appear that the most likely explanation of the difference between discriminators and nondiscriminators on CS alone trials is that the former subgroup is more sensitive to the unconditioned suppressive properties of US presentation.

This heightened sensitivity produced greater unconditioned suppression on US alone and CS-US trials and interfered with the learning of a CS-US association when a US immediately preceded that pairing.

Finally, the results of the US alone trials are also quite consistent with the main conclusion that the temporal-location effect is not due to the acquisition of signalling value by the pre-CS shock. The observation that on US alone trials group US-US suppressed significantly more than the pre-CS shock group and tended to suppress more than the partial reinforcement group suggests that under optimal conditions the trace of shock presentation might be used as a cue. However, the finding that on US alone trials the partial reinforcement group did not differ significantly from the pre-CS shock group makes it clear that animals in the pre-CS shock group were not able to use the pre-CS shock as a signal. Furthermore, the finding that the US alone trials produced less suppression in the pre-CS shock group than in group US-US suggests that the CS in the pre-CS shock group overshadowed the trace of shock presentation, and thereby prevented the subjects in the pre-CS shock group from using this event as a cue.

CHAPTER 6

GENERAL DISCUSSION

The principal findings of the present series of experiments can be summarized as follows:

1. The amount of suppression to a CS resulting from repeated trials in which a CS is paired with shock is reduced when the conditioning trials are preceded by a single shock. The closer the preceding shock is to the beginning of the trial (CS onset), the greater the loss of suppression to the CS. We refer to this as the temporal location effect.

2. The results of Experiment 2 showed that the temporal location effect is only obtained when the entire sequence: shock preceding the CS paired with shock, is intact. The effect is not obtained when the sequence is decomposed into a shock preceding a CS-alone trial and a separate trial consisting of CS paired with shock. In other words, the interval between the pre-CS shock and the conditioning shock on the trial itself is critical. This result led to the rejection of the hypothesis that the temporal location effect was due to inhibition arising from the timing of the pre-CS shock, the CS, and the long inter-trial interval.

3. The Rescorla-Wagner theory of classical conditioning suggests the hypothesis that the pre-CS shock results in the conditioning of signal value to the background or prevailing stimuli and this reduces the amount of signal value that can be acquired by the CS. In Experiment 3 this hypothesis was tested by providing a definite signal of the pre-CS shock. According to the Wagner-Rescorla theory, the signal should reduce the conditioning of background stimuli and hence should increase conditioning to the CS. Although the results suggested a small effect in the predicted direction, the important fact was that the temporal location effect was not eliminated, or even substantially reduced, when the pre-CS shock was itself signalled. Conditioning to the background stimuli does not appear to be the mechanism by which the pre-CS shock reduces the amount of suppression conditioned by the CS.

4. The pre-CS shock could itself serve as a signal for the shock that subsequently occurs on the trial. In that case, the CS would be redundant. There are empirical and theoretical grounds for expecting that a redundant CS acquires less signal value than does a CS that is the sole basis for predicting the occurrence of shock. The hypothesis that the temporal location effect occurs because the pre-CS shock serves as a signal of the later shock was examined in Experiment 4. The hypothesis implies that a discrimination will form between two

types of trials: 1. trials on which the CS is preceded and accompanied by shock should produce strong suppression. 2. trials on which the CS is neither preceded nor accompanied by shock should eventually result in little or no suppression. The hypothesis also implies that suppression to the CS when tested in the context of a preceding shock (the first type of trial) should not be less than suppression to the CS resulting from the usual conditioning procedure in which no pre-CS shock occurs. In other words, the combined signal value of the pre-CS shock and the CS should not be less than the signal value of a CS after conditioning without pre-CS shocks.

The results of Experiment 4 were contrary to the hypothesis that the temporal location effect results from a competition between the signalling functions of the pre-CS shock and the CS. The most definitive result was that less suppression was obtained to a CS preceded by a pre-CS shock even when suppression was tested in the context of a preceding shock. Further, the results provided no clear evidence for the development of a discrimination based on the pre-CS shock. The means by which the pre-CS shock reduces suppression to the CS is therefore not through a competition between the signalling functions of the pre-CS shock and the CS itself. The pre-CS shock in some way reduces the amount of suppression controlled by all of the cues in the situation; not just the amount of suppression controlled by the CS.

Implications

At the outset, the most promising approach to the explanation of the temporal location effect appeared to be some form of competition theory. There are two versions of this theory. The Rescorla-Wagner version stresses that the background or prevailing stimuli become signals, while, the information and overshadowing versions emphasize that the pre-CS shock itself becomes the signal. The results of Experiment 3 ruled out the Rescorla-Wagner model and the results of Experiment 4 eliminated competition from the signalling function of the pre-CS shock as an account of the effect.

Although we have not provided a definitive account of the temporal location effect, we have narrowed the search. The single result with the clearest implication for the explanation of the effect is that when suppression was tested during the CS with the pre-CS shock present as an immediate context, the level of suppression was still less than obtained after CER conditioning without a pre-CS shock. As previously indicated, this means that the pre-CS shock reduces the total amount of conditioning rather than causing a different distribution of a constant amount of conditioning.

How could the pre-CS shock cause less conditioning? We have identified several possibilities under the general heading of interference theories. What can be said about them?

Anterograde Interference

The likelihood of this hypothesis providing an explanation of the temporal location effect seems remote. Signalling the pre-CS shock in group CS_1USCS_2US in Experiment 3 (and thereby reducing the surprise produced by that shock) did not substantially increase the conditioning to the subsequent CS. Furthermore, the group (CS_1CS_2US) that received a surprising CS_1 extinction trial prior to each CS_2-US trial did not suppress significantly less than group CS_2US. Thus, the surprise produced by the pre-trial event does not appear to be the critical factor.

UCR Diminution

This hypothesis maintains that the pre-CS shock initiates an inhibitory-like process that decreases the magnitude of the UCR when a US occurs during the refractory period. Although this kind of interpretation can not be ruled out, it seems doubtful that the inhibitory period produced by a shock could last as long as is necessary to account for the temporal location effect.

Relative-Fear

Perhaps the most likely candidate for an explanation of the temporal location effect is the relative-fear hypothesis. This hypothesis is like a contingency theory of conditioning in its reliance on comparison, but it is unlike contingency theory in that it is based, not on averaged probabilities of shock, but on temporally dependent emotional states. Thus, this hypothesis holds that strong fear-conditioning occurs to the extent that a stimulus change is paired with a large change in the fear-pain level. Any factor that increases or decreases the relative change in fear-pain produced by a trial will have a corresponding effect on the fear conditioning that occurs as a result of the trial.

The relative-fear hypothesis correctly predicted, unlike the Rescorla-Wagner model, that the signal value maintained by a CS shock in the pre-CS shock group in Experiment 4 would be less than the signal value that was maintained by the CS shock in the partial reinforcement group. The relative-fear hypothesis predicted this result because, contrary to the Rescorla-Wagner theory, the hypothesis does not state that the loss of conditioning to the CS that is produced by a pre-CS shock will necessarily be compensated by a complementary increase in conditioning to the background cues. In other words, one of the reasons the relative-fear hypothesis predicted this result is because it does not assume that background or common stimuli can be effective signals of shock. The relative-fear hypothesis does not make this assumption for two reasons. One, prevailing stimuli are continuously present. Thus, they are of long duration when compared to more typical CSs. The relative-fear theory argues that the continuous nature of these stimuli makes them less salient than briefer stimuli and therefore less conditionable. Two, in a standard CER conditioning experiment, the animals are often quite familiar with (i.e., have had extensive pre-exposure to) the background stimuli before fear conditioning is commenced. This familiarity could lead to habituation and therefore make the background stimuli even less conditionable. Thus, the relative-fear hypothesis states that the pre-CS shock in Experiments 3 and 4 did not produce strong conditioning to the prevailing stimuli because they were familiar and continuous.

Relative-fear theory departs from the Rescorla-Wagner model on at least one additional basic assumption. The Rescorla-Wagner theory is a contiguity theory of conditioning. When a stimulus gains signal value, it does so because of simple joint occurrence--not because of a comparison between relative probabilities of shock. How much signal value is gained depends on the presence and status of other signals, but when increments occur, they do so because of contiguity.

The relative-fear hypothesis is not only consistent with all of the results of the present thesis, but is also consistent with many other fear-conditioning phenomena. For example, the theory predicts that as the contingency between CS and US is decreased, less conditioning of the CS should occur. The relative-fear theory makes this prediction because as the rate or probability of shock in the ITI is increased, the amount of fear or emotion that is associated with the ITI also increases. Therefore, there is less of an opportunity for CS shocks to produce conditioning.

Relative-fear theory might also explain the results of a recent experiment by Heth and Rescorla (1973). They varied the temporal relationship between a 4-second US and a 2-second CS. In different groups, the CS preceded the occurrence of the US, commenced simultaneously with US presentation, or followed US onset. Heth and Rescorla found that the magnitude of excitatory conditioning decreased in a regular manner as the delay between US onset and CS onset was increased. Most importantly, they observed a moderate level of excitation when the US preceded CS onset by two seconds. Although these results are contradictory to conceptions of conditioning that are based on the notion of "information", they are easily explained by a relative-fear theory. Because as the delay between US and CS is increased, the contrast between the fear that is associated with the ITI and the fear that is paired with the CS is less; therefore, less excitatory conditioning of the CS should occur.

Although the relative-fear hypothesis is able to predict a wide range of fear-conditioning phenomena, some additional tests of the theory are needed. One possible way to test the validity of the relative-fear theory would be to try to increase the amount of fear-pain produced by a CS-US pairing. For example, one could precede each CS-US pairing with a conditioned inhibitor of fear. If the degree of conditioning is indeed a function of the change in the fear-pain level, a group that receives such a safety signal should condition more strongly than a group whose CS-US pairings are not so preceded.

In conclusion, it is hoped that these speculations, if further developed, will provide an adequate account of the process by which the introduction of USs outside of the CS reduce conditioning to that CS.

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