COMPOUND SUMMATION AND ATTENUATION OF CONDITIONED SUPPRESSION

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By

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In six conditioned suppression experiments with rats, two conditioned stimuli (CSs) were individually trained and then tested as a compound. In one set of experiments, the suppressing effect of the compound was greater than that of either CS presented alone. This result is referred to as compound summation. In a second set of experiments, the suppressing effect of the compound was less than that of the "stronger" suppressing individual CS. This result is referred to as compound attenuation. The combination of summation and attenuation makes it possible to determine whether CSs with unknown properties are weakly excitatory (i.e., weak suppressors) or inhibitory (i.e., conditioned characteristics that are opposite the excitatory suppressing effect). If an unknown CS is tested in compound with a second CS known to be excitatory, summation indicates that the unknown stimulus is excitatory, while attenuation indicates that the unknown stimulus is inhibitory. In a final set of experiments, this compound test procedure was used to examine extinction and differential conditioning as inhibitory training procedures. Extensive extinction of a previously trained CS, even far beyond the point at which suppression vanished, was found to be an ineffective inhibitory training procedure. Rather, compound tests showed that the stimulus retained excitatory properties. Differential conditioning was found to be a very effective inhibitory training procedure, regardless of whether presentations of a previously trained CS and shock, shock alone, or the previously trained CS - alone accompanied the unreinforced CS undergoing inhibitory conditioning. These findings are discussed in terms of current theories of conditioning and unresolved issues surrounding the acquisition and maintenance of inhibitory properties.

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CHAPTER I

GENERAL INTRODUCTION

One of the forms of learning most commonly studied in the laboratory is Pavlovian, or classical conditioning. In Pavlovian procedures, a signal (called a conditioned stimulus or CS) regularly precedes the delivery of a reinforcing stimulus (also called an unconditioned stimulus, or US). At the beginning of the procedure, the CS is functionally "neutral", in the sense that it is not observed to have special response-eliciting properties. After a number of pairings of CS and US, however, an "anticipatory" response (called the conditioned response, or CR) comes to be elicited by the CS.

Conditioning of the salivation response in dogs is a familiar example of a Pavlovian procedure. When a dog is first exposed to a stimulus, such as a flashing light, there is little chance that marked salivation will occur. However, if the light regularly signals the occurrence of food, so that it functions as a CS regularly preceding the delivery of a reinforcing stimulus, it is highly likely that the CR of salivation will be reliably observed.

Procedurally, then, _Pavlovian_ conditioning situations are those in which presentations of a reinforcing stimulus are scheduled according to the occurrence of a signal.

Frequently, Pavlovian conditioning is distinguished from operant conditioning, in which the presentation of a reinforcing stimulus is scheduled according to the occurence of a response (cf Reynolds, 1969). The familiar laboratory procedure of training rats to press a bar for food reward is an example of operant conditioning.[1]

Operant and Pavlovian conditioning paradigms are frequently combined in experimental procedures. The experiments to be reported in this thesis made use of such a procedure, first developed by Estes and Skinner (1941), which has come to be called "conditioned suppression". In conditioned suppression, the results of Pavlovian pairings of CS and shock are examined by measuring the extent to which presentations of the CS suppress food-rewarded behaviour.

In the conditioned suppression procedure used in these experiments, rats were first operantly conditioned to press a bar for food reward. At first, each bar press

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[1] Note that the distinction being made between Pavlovian and operant conditioning is in terms of the experimental operations involved in each. For our purposes in this thesis, the distinction is a very useful one. It should be noted, however, that a number of authors (e.g., Hutchinson and Emley, 1970; Brown and Jenkins, 1968; Staddon and Simmelhag, 1971) have introduced data which suggests that there are many situations which require a more subtle analysis than the simple procedural dichotomy.

was rewarded, then reinforcement came intermittently (every three minutes, on the average). When the food-reinforced baseline of bar pressing had stabilized, Pavlovian conditioning was carried out while subjects (Ss) responded for food. In this Pavlovian conditioning, a CS (either darkness or white noise), was presented for 90 seconds. During the last .5 seconds of the CS, an electric shock US was administered. The direct result of these pairings of CS and shock US, was that the CS came to suppress bar pressing. That suppression of bar pressing is referred to as "conditioned suppression".

Experiments in Pavlovian conditioning normally study the development of a CR to an individual CS. Recently, however, interest has grown in experiments where more than one CS is presented simultaneously. The simultaneous presentation of more than one CS is frequently called a <u>compound stimulus</u>, with individual CSs labeled <u>components</u>. For example, a light/tone compound stimulus would be programmed by simultaneously presenting the component stimuli, light and tone.

Compound stimuli have attracted interest because, as Wickens (1965) has noted, they permit "controlled complications of the environment" with access to more complex phenomena than those revealed by experiments using only individual CSs. For example, Pavlov (1927, p. 141) reported that when a compound CS, composed of a "tactile" and a "thermal" component, was paired with a weak acid US, subsequent tests of the component stimuli revealed no apparent conditioning to the thermal stimulus, although the tactile stimulus produced strong salivation. The absence of conditioned responding to the thermal stimulus was unexpected because such CSs were frequently used with success in other experiments in Pavlov's laboratory. Thus, the failure of conditioning seemed clearly to be attributable to the fact that pairings with the US occurred while the thermal CS was presented in compound with the tactile CS. Findings such as these, in which one CS is apparently "selected" over another, have suggested to some investigators that attentional mechanisms may be involved in determining how components are conditioned in compound presentations. Recently, a good deal of experimental and theoretical effort has been devoted to the study of such mechanisms of selection (Kamin, 1969; Vom saal and Jenkins, 1970; Wagner, 1969; Rescorla, 1969a; Rescorla and Wagner, in press).

In this thesis, compound stimuli were studied in a different manner by first conditioning individual components and then testing them as a compound. Subjects were trained in conditioned suppression situations so that each of two individual CSs produced a certain level of suppression. The individual CSs were then tested as a compound to see how the resulting level of compound suppression differed from that associated with the components. In some instances, response-suppressing properties of the compound were greater than even the "stronger" suppressing components. The effect was as if the response-suppressing effects of the components added together to produce the greater combined effect; consequently, this general result will be referred to here as compound summation. In other instances, the response-suppressing properties of the compound proved to be less than those of the "stronger" suppressing component. When this occurred, the effect was as if the "weaker" component reduced the suppressing effectiveness of the "stronger" component; consequently, this general result will be referred to here as compound attenuation.

Summation and attenuation were the object of study in this thesis because it was hoped that they would combine to form an analytic tool for the study of Pavlovian "excitation" and "inhibition". "Excitation" and "inhibition" are both terms that may be used to describe the response-eliciting characteristics acquired by a CS as a result of a conditioning procedure.

The term "excitation" is, by far, the easier one to define. When a CS comes to produce a CR as a result of some training procedure with a particular US, the CS may be described as "excitatory" with respect to that CR. In conditioned suppression, for example, a CS that has acquired response-suppressing properties as a result of pairings with shock might be described as excitatory with respect to the

CR of suppression.

"Inhibition" is more difficult to define. In some conditioning procedures, a CS may acquire response-producing characteristics that appear to be opposite, or at least antagonistic to, excitatory effects. In conditioned suppression situations, for example, arrangements may be made so that a CS reliably signals an interval that is free from shock. It may be useful to think of such an inhibitory CS as being associated with "safety" in contrast to a "dangerous, fear-producing" excitatory CS. In a more general sense, the word "inhibition" will be used in this thesis to describe a CS that has been presented in such a relationship with a specific US that the resulting response-producing characteristics of CS are in apparent opposition to those excitatory effects that might have been anticipated from simple pairings with the US.

It is important to note that the terms "excitation" and "inhibition" are both used to describe behaviour with respect to stimuli. In this thesis, both are relative terms: "excitatory" will always be defined in terms of some acquired response with respect to a specific reinforcing stimulus, while "inhibitory" will always be defined relative to some excitatory condition. It should also be made clear that no particular classes of neurophysiological events are implied as distinguishing inhibitory from excitatory stimuli.

In some conditioning experiments, a CS may be identified as excitatory simply because when it is presented a CR occurs. Identification of stimulus properties is much more difficult when presentations of the stimulus do not produce clearcut observable effects. In several of the experiments to be described in later chapters of this thesis, tests of a CS produced no observable suppression of food-rewarded bar pressing. One obvious explanation for this is that the CS was "neutral". A second possible reason for the lack of observable effects is that the CS was weakly excitatory, but so weak that no suppression resulted. Finally, the CS may not have had a suppressing effect because it acquired inhibitory properties.

In the experiments in this thesis, compound tests were used to distinguish among these three possibilities of excitation, inhibition, and neutrality. CSs with unknown properties were presented in compound with comparison CSs known to be excitatory. If the results of the compound tests showed summation, the indication was that the effects of the unknown CS "added" with the effects of the excitatory comparison CS. The unknown CS could then also be described as "excitatory". If the results of the compound tests showed attenuation, the indication was that the effects of the unknown CS were in apparent opposition to the effects of the excitatory comparison CS. The unknown CS could then be identified as "inhibitory".

If the results of the compound test did not differ from those of the comparison CS, the indication was that the effects of the unknown CS neither added nor interfered with the effects of the excitatory comparison CS. The unknown CS then could be described as "neutral".

The following two chapters of this thesis trace the research that made it possible to employ the combined summation and attenuation indexes of excitation and inhibition. Chapter Two reviews much of the previous summation research, and describes in detail two experiments which studied summation phenomena in conditioned suppression. Chapter Three summarizes relevant attenuation findings, and also describes two attenuation experiments which were designed to determine the sensitivity of the attenuation index to weak inhibitory effects. Then in Chapters Four and Five, two experiments will be described in which compound tests were used to study the effectiveness of extinction and differential conditioning as inhibitory training procedures in conditioned suppression. Finally, in Chapter Six, the data from these experiments will be discussed with emphasis on features of conditioning situations that appear to contribute to the acquisition of inhibitory properties.

CHAPTER II

EXPERIMENTS ON COMPOUND SUMMATION

I. Experiments Prior to 1960

The experiments of interest in this chapter are demonstrations of summation; where CSs were first individually conditioned, then their combined effect was shown to be greater than that of invividual presentations. It is interesting that unequivocal demonstrations of summation are relatively rare--particularly interesting when one considers the status summation principles have had in some theoretical contexts.

In his introductory lectures, Pavlov (1927) cited a summation demonstration by Leporsky, in which dogs were trained with three CSs (rotating object, tone, and flash) all of which were paired with food. When salivation was established to all three individually, Leporsky tested them as a compound. According to Pavlov, the level of salivation recorded to the three-stimulus compound was greater than that observed to the components.

A similar demonstration by Leporsky was described by Razran (1939), in which "several" CSs were used. When all CSs were combined, summation was observed. Moreover, Razran noted, the compound of all CSs was more powerful in evoking salivation than compounds of fewer CSs. Razran also reported that similar results were obtained by Yakovleva.

Finally, Kimble (1961) described a summation demonstration by an anonymous "Pavlovian". In this study, CS1 (oil of camphor) elicited a conditioned response of 60 drops of saliva. CS2 (a mild shock) produced a conditioned response of 30 drops. The CS1/CS2 compound reportedly produced a net response of 90 drops.

Appraisal of early Pavlovian experiments is often made more difficult by the rather sketchy accounts that are available in English. Frequently, however, original reports from Pavlov's laboratories were also very brief, so even if manuscripts were available, there is little certainty that we would know more about the conditions under which the data were collected, or the reliability of the results.

This lack of detailed information has produced certain levels of skepticism about such "fundamental" processes as summation. In the case of the experiment by the anonymous Pavlovian cited by Kimble, and the experiments by Leporsky and Yakovleva, one might wonder what effect the "novel" features of the compound might have had on the Ss' responding. It is known that prior exposure to the US may occasionally result in enhancement of responses to a novel CS that are not attributable to any programmed pairings of CS and US. It is as though the US "sensitizes" the subject, so that responding occurs to any novel stimulus that is presented subsequently. These instances of sensitization are usually classified as nonassociative effects, because they do not require the pairing of CS and US (Gormezano, 1966). It is possible that in the early Pavlovian summation demonstrations, sensitization may have played a role in producing compound responding. As a result, the greater level of responding may not have reflected a combined associative effect of the CSs. Any relatively intense novel stimulus might have had the same effect. At the very least, the simple arithmetic summation obtained in Kimble's example is called into question.

Consequently, one can only speculate on the empirical basis of the following statement by Hull in which he strongly affirmed the principle of summation and described the level of summation to be predicted in most situations.

> "...if two distinct stimuli which have been individually conditioned to a given response be presented together, the intensity of the resulting response is likely to approach closely the arithmetical sum of the response to the two stimuli presented separately. (Hull, 1929, p. 502)

Subsequently, in 1940, Hull published a series of "exploratory studies in patterning of stimuli". which included a summation demonstration reported somewhat incidentally. In that experiment, in which the galvanic skin response (GSR) was studied, Hull found CS1 (light) to produce a response of 2.5 units[2] while CS2 (vibrator) produced a response of 2.9 units. Tests of the CS1/CS2 compound produced a response of 3.3 units. The indication was that the response associated with the compound was, indeed, greater than that observed with either of the components.

There were no control groups in this study, which can perhaps be explained by the fact that one of Hull's major goals in the paper was to examine the properties of a "quantitative" index he had devised for describing responding to a compound relative to its elements.

Hull defined the index as $\frac{R1 + R2}{R1/2}$, where R1 = responses to CS1, R2 = responses to CS2, R1/2 = responses to CS1/CS2. Presumably, equal responding to all three stimulus conditions was designated by an index value of 2.00. Values of 1.00 indicated those situations in which R1/2 responding precisely equalled the sum of individual R1 + R2. Values less than 1.00 indicated "patterning", in Hull's terminology, in which the compound response exceeded the simple sum of the elements.

The utility of this index may be questioned for a number of reasons. For example, when responses were associated with CS1 and CS2, but not with the compound, index

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[2] The actual measurement used, as well as the scale, is unspecified.

values approached infinity. Moreover, values less than 2.00 but greater than 1.00 could be obtained in several ways. Such values could indicate that compound responding exceeded responding to at least one of the elements. However, there would be no way of knowing from the index value whether compound responding exceeded responding to both elements.[3] Consequently, in later experiments in the series where Hull presented the data only in terms of index values, there is no way of knowing whether summation, in fact, occurred. Finally, it was impossible to distinguish between instances in which there was some responding to the compound and none to the elements, and instances in which no responding was observed to either the compound or the elements, since both conditions resulted in an index value of zero. It is an interesting historical note that Hull proposed this index as an improvement over what he described as the "qualitative level" of Pavlov's experiments.

In 1943, the first formal version of Hull's behavior system appeared. In contrast to his 1929 views on summation, Hull noted that "adequate empirical investigations are largely lacking" and went on to provide two additional demonstrations of summation effects in the GSR. In the first demonstration, CS1 (light) produced an average

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[3] For example, if CS1 and CS2 both produced a response of 10 units while CS1/CS2 produced 15 units, summation should have occurred and would be represented by an index value of 1.3. But if CS1 produced a response of 19 units, CS2 1 unit, while CS1/CS2 produced 15 units, this non-summative relationship would also be represented by an index value of 1.3.

response of 3.5 mm. and CS2 (vibrator) a mean response of 3.6 mm. The CS1/CS2 response was recorded as 4.4 mm. In a second demonstration, the respective values for CS1, CS2, and CS1/CS2 were 2.2, 3.7, and 3.91. Hull's index made a re-appearance here in an inverted form:

$$\frac{R1/2}{R1 + R2}$$

This version was subject to essentially the same difficulties as the earlier index. Summation was indicated by values greater than one, while a total absence of compound responding produced a value of zero. The significance of values ranging between .5 and 1.0 was ambiguous. Hull's revised formulation was that the combined effect of CSs was to produce that level of responding that would be produced by the total number of reinforcements to the elements. Since the acquisition function is negatively accelerated, one would anticipate greater summation with stimuli in the early stages of conditioning than with stimuli nearing asymptote, an intriguing prediction never specified by Hull, and consequently, never tested.

When Hull's theory appeared in its final form in 1952, his treatment of summation was largely limited to discussions of situations in which response tendencies were assumed to summate as a result of generalization between CSs.[4] By this time, however, an experiment had been

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[4] For a recent experiment investigating summation of generalization, see Blough (1969).

reported by Konorski (1948), which suggested that compound summation might be much more complicated than previously supposed.

In Konorski's experiment, dogs were trained in a salivation conditioning paradigm with a lamp, metronome, and a brief touch serving as CSs. In most cases, the effect of combining the individual CSs was summation. However, a very dramatic feature of Konorski's data was that stimuli that were made very weak continued to show marked summation in compound tests. In one condition, a dog was fed before the experiment and tested with a "very dim lamp" and "continuous touch". Presumably as a result of the feeding and the departures from original training values, both stimuli produced very little salivation. In fact, Konorski emphasized that the little secretion produced by presentation of individual stimuli was, for all practical purposes, equivalent to zero. When the stimuli were combined, however, substantial salivation resulted. Similar summation effects with weak stimuli will be encountered frequently in this thesis.

An experiment by Grings and O'Donnell (1956; later replicated by Grings, Tadao, and Fiebiger, 1965) has received rather frequent citation as a summation demonstration in Pavlovian conditioning. In the original experiment, Grings and O'Donnell studied the GSR in 32 humans, using four coloured dots as CSs. Two of the dots served as positive stimuli (CS+).[5] Shock was programmed for the last .5 sec of each 1.0 sec CS+ trial. One of the coloured dots served as CS-. On CS- trials, no shock was programmed. The remaining dot was defined as "neutral" and did not figure prominently in the conditioning sequence. When the conditioning sequence was completed, unreinforced compound tests were administered to all Ss. Tests of the CS+/CS+ compound showed a significantly greater GSR than any of the other three compound conditions, which ranked (in decreasing order) CS+/CS^{o}, CS^{o}/CS-, and CS+/CS-.

Unfortunately, it is not clear whether responding to the CS+/CS+ compound consistently exceeded responding to the individual components. This crucial information was presented by Grings and O'Donnell only in terms of Hull's (1943) patterning index. The index values for CS+/CS+, CS+/CS^{o}, and CS+/CS- were .75, .50, and .36 respectively. It has been noted earlier (p.14) that values in this range do not permit one to conclude whether CS+/CS+ responding exceeded levels associated with both, or only one, of the individual components. Consequently, although the results of the experiments by Grings and O'Donnell (1956) and

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[5] It is a convention in discrimination experiments to identify a CS according to whether the "reinforcing" stimulus occurs on those trials in which it is presented. No qualitative evaluation is implied, as in this instance in which shock was scheduled on CS+ trials.

Grings, Tadao, and Fiebiger (1968) suggest that excitatory effects may have combined in CS+/CS+ presentations, it is not clear whether their data provide a demonstration of summation as the phenomenon has been defined here.

It is clear, then, that prior to 1960 evidence in support of summation in Pavlovian conditioning was not extensive. There was also only limited evidence for summation in operant conditioning.

One operant conditioning experiment that received a summation interpretation was conducted by Eninger (1952). Three groups of rats were run in T-maze discrimination tasks. One group was trained to obtain food by turning right when the stem of the maze was black, left when the stem was white. A second group was trained to turn right when a tone was presented, left when no tone was presented. A third group was trained to turn right when the stem of the maze was black <u>and</u> a tone was sounded, left when the stem was white and not accompanied by a tone. Thus, the first group was to learn the discrimination on the basis of visual cues, the second on the basis of auditory cues, and the third on the basis of visual <u>and</u> auditory cues.

The results of the experiment showed quite clearly that the group trained with both auditory and visual cues learned the discrimination fastest. Eninger interpreted this result to mean that each rewarded trial separately increased the associative strength of the components of the black/tone and white/no-tone stimulus conditions. The strengths were assumed to summate, producing a greater net response tendency than that which could be maintained by components individually conditioned.

Eninger's interpretation was not entirely convincing. The assumption that reward had the function of increasing the strength of all stimuli present at the time of reward had been seriously questioned much earlier (Lashley, 1942). This point had been the basis of a controversy between "continuity" and "non-continuity" theorists which had continued for some 10 years prior to the publication of Eninger's paper. An equally plausible interpretation might be that the presence of both auditory and visual cues simply produced a more "intense" stimulus combination, which could also account for the faster acquisition.

II. Recent Summation Experiments

After 1960 a number of more convincing demonstrations of summation appeared. Several of those sought to extend summation to operant conditioning. Others sought to extend the phenomenon to new Pavlovian Conditioning Paradigms. In this section we shall first review recent Pavlovian conditioning experiments showing summation in conditioned suppression. Among the conditioned suppression experiments will be included detailed descriptions of two experiments conducted in the course of this thesis research.[6]

A. Operant Conditioning Experiments on Summation

Wolf (1963) made the first attempt to examine summation of individually trained components in a operant conditioning situation. In his first procedure, four rats with somewhat varied conditioning histories were run on a 3 component multiple schedule. In the presence of two stimuli, $S+_1$ and $S+_2$,[7] bar pressing was reinforced on a VI 1 min schedule. When a third stimulus (S-) was presented, bar pressing was not reinforced. For three Ss, the S+s were illumination of different portions of a display of lights, while S- was darkness. For the remaining S, $S+_1$ was part of the light display while $S+_2$ was a tone. During S- neither light nor tone was programmed. The S+s alternated with S- throughout training which continued until responding stabilized.

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[6] In this section, only summation demonstrations in compound tests will be described. Certain procedural modifications have resulted in compound tests in which summation was not observed. These experiments are reviewed in Appendix A.

[7] In experiments conducted in operant conditioning paradigms, the discriminative stimuli will be designated either S+ (stimulus associated with reinforcement) or S- (stimulus not associated with reinforcement). CS+ and CS- will be reserved for classical conditioning experiments.

The two S+s and $S+_1/S+_2$ were tested in extinction. S- was interpolated between the test trials, which continued until the components and compound had all been presented 20 times.

Cumulative response curves for the components and the compound for all four Ss indicated greater responding to $S+_1/S+_2$ during extinction than to either of the components. This result, of course, is very much in line with the results anticipated from a summation mechanism. However, two interesting effects were minimized by the cumulative plot presentations. The first is that on the first trial, $S+_1/S+_2$ produced greater responding in only two of the four subjects. In one of the remaining Ss, $S+_1/S+_2$ produced slightly greater responding than either component on trial two, in the other it did not appear until trial four. The rates controlled by the individual stimuli were moderate, on the order of 20 per minute, so it is highly unlikely that responding had reached an asymptote that the Ss were incapable of exceeding. It seems curious, in many respects, that the additive effect of two S+s should be a phenomenon that <u>develops</u>, but that clearly seems to be the case in half of Wolf's subjects.

The other interesting effect, is that at some point in each of the four Ss, the single stimulus cumulative plots were flat (indicating no responding) while the compound curve continued to rise. This suggests that at those points in the test, the individual S+s produced no bar pressing, while the compound continued to maintain responding. This effect provides an interesting parallel to Knonorski's (1948) observations in salivary conditioning (c.f. p.15).

Wolf also reported data from a second experiment in which a single S was studied. Three S+s, each individually associated with a VI 1 min schedule, were tested as a compound while the schedule of reinforcement remained in effect. The three components were different portions of a light display. Over three days of testing greater responding was observed to the compound than to the components on days one and two, with little difference on day three. This, of course, is at least partially in line with the anticipated effects of a summation mechanism, although it is not entirely clear why the effect disappeared after two days.

While Wolf's experiment suggested that summation may be observed in operant conditioning situations, there was a lack of comparison groups permitting one to assess the importance of nonassociative features of the compound. For example, when the stimuli were different portions of the light display, simply presenting a more intense light might have had the same effect. This possibility presents particularly serious problems for the data from the main experiment, which were collected while the barpressing extinguished. Very recently, Brimer (in press) has reported that a novel stimulus superimposed on an extinguished barpress baseline could momentarily restore responding. Consequently, it is not clear that the results obtained in Wolf's compound tests were, in fact, limited to the compound of $S+_1/S+_2$. Any novel stimulus condition might have exerted a similar effect.

An experiment by Weiss (1964, Experiment I) reported summation effects when the components exerted "weak" or "strong" control over barpressing. These demonstrations also included an effort to control for "novelty" in compound tests of appetitively-reinforced stimuli.

Weiss' strategy was to first train four rats on a multiple VI 30 sec VI 75 sec schedule, with S+s either a light or a tone. S- was defined as the absence of both S+s, and was interpolated between all S+ trials. When responding had stabilized, generalization tests were conducted with two weaker intensities of tone, and two weaker intensities of light, in order to find stimuli that produced approximately half the responding associated with the original stimulus value. We shall designate the stimuli in the original conditioning procedure that were associated with the VI 30 sec and VI 75 sec schedules as S+30TRG and S+75TRG respectively. The weaker values on each stimulus continuum will be called S+30GEN and S+75GEN.

At the end of the generalization test, four levels of bar pressing were controlled by the four stimuli. In decreasing order they ranked S+30TRG, S+75TRG, S+30GEN, S+75GEN. After four more training sessions, the four possible compounds made up of an S+30 and an S+75 value were tested for each S, as well as the four individual stimuli. While these tests were administered, no bar presses were reinforced. Total responses over four Ss showed that the S+30TRG/S+75GEN compound produced the greatest level of bar pressing, followed in decreasing order by S+30TRG/S+75GEN, S+30GEN/S+75TRG, and S+30GEN/S+75GEN. It is interesting that the compound rankings were not directly related to the strengths of individual components. The totals of the four Ss showed that S+30GEN produced the most responding in tests, followed by S+75TRG, S+30TRG, and S+75GEN. On the basis of the single-stimulus rankings one might have anticipated greatest responding to S+30GEN/S+75TRG, a combination that ranked third in terms of overall responding.

In a second experiment by Weiss (1964, Experiment 2) essentially the same procedure was employed, with two modifications. The first was that the generalization tests were omitted, (the same four stimulus intensities were tested however). The second modification was the inclusion of a novel stimulus control which consisted of programming a buzzer at various points in the test sequence.

The main results of the first experiment were duplicated, since compounds nearly always produced more responding than components. Weiss also reported that no appreciable responding occurred to the buzzer. It is interesting, however, that the buzzer did produce more responding than the weakest component stimulus in all Ss.

The fact that some responding was observed to the buzzer raises two questions: 1) If a more intense novel stimulus, or a novel compound had been presented, would more responding have resulted than the level observed in response to the buzzer? 2) If the buzzer had been presented in compound with either of the light values that maintained responding, would summation have resulted? We cannot be absolutely certain that the effects observed to the variety of compounds in Weiss' experiment are all independent of unconditioned stimulus effects. In fact, the observations of responding to the buzzer tend to confirm some of the apprehensions raised earlier over Wolf's data.

An apparent lack of concern over possible non-associative artifacts in summation has persisted through more recent demonstrations. However, these experiments have uniformly provided support for the phenomenon. In an experiment involving six rats, Cornell and Strub (1965) reported as an incidental finding that two S+s, consisting of different parts of a light display, which were individually correlated with a VI 1 min schedule, showed summation when tested as a compound.

Weiss (1969) ran five rats on a multiple VI 30 sec VI 70 sec schedule. During S- periods (interpolated between each S+), a tone was presented and a bright light turned on. $S+_1$ consisted of turning off the light (leaving a dim houselight), $S+_2$ consisted of turning off the tone. The compound consisted of turning off both stimuli. Tests of the compound and components were carried out in extinction. The results showed quite clearly that the compound produced greater responding than either of the components maintained separately, lending further support to the summation mechanism and extending it to "off" stimuli as well as "on".

Weiss' demonstration is particularly valuable, since it shows that summation effects are not limited to compounds "more intense" than component values. The immediate implication is that since the effects of two "off" stimuli appear to summate, stimulus intensity factors may not be substantial contributors to summation findings. However, non-associative effects may be involved other than those produced by increases in stimulus intensity. Brimer (in press) has found that when darkness is presented as a novel stimulus, a previously suppressed barpress response may be momentarily facilitated. Thus, although an important control, the use of "off" stimuli does not appear to guarantee the complete elimination of non-associative stimulus effects.

A recent experiment by Miller and Ackley (1970) is notable for demonstrating summation of food-reinforced bar pressing using schedules other than VI. Two S+s (light and tone) were individually associated with identical fixed-interval (FI) schedules. One rat was run on FI 1 min, two on FI 2 min, and one on FI 3 min. Test trials of the compound and components were conducted with reinforcement maintained, in contrast to the extinction tests used in nearly all the earlier operant demonstrations. Over four test sessions, the compound did, in fact, maintain the highest response rates in all Ss.

However, it should be noted that the practice of rewarding trials in such compound tests may be questionable. If a higher rate of responding is obtained to the compound over the first few trials, it could be argued that the high rate is maintained in later trials, not because of a summation mechanism, but because of superstitious reinforcement of the higher rate (Morse and Skinner, 1957). Consequently, although Miller and Ackley report that the compound in their experiment maintained the highest responding over four test sessions, it is uncertain whether all four sessions reflect a summation mechanism.

Miller and Ackley also re-opened examination of the "additive" nature of summation. The authors divided each FI interval into six "bins", six ten-second bins for the FI 1 min S, six 20 second bins for the FI 2 min Ss, and six 30 second bins for the FI 3 min S. In this way, the distribution of responses across consecutive portions of each stimulus presentation could be measured.

Miller and Ackley totaled the average number of responses made in each of the six bins when the S+s were presented individually, and compared that total with the number of responses made when the compound was presented. They then plotted the comparison between the individual totals and compound responding. They were interested in how the average number of responses recorded in any one bin of the compound was related to the average total number of responses recorded in the corresponding bins of $S+_1$ and $S+_2$. An additive summation model would predict that each compound bin would be a simple sum of the corresponding single stimulus bins.

Since there were six bins and four Ss, a total of 24 data points were generated by these comparisons. One complicating factor in this analysis is that the 24 data points represent different time bases, since the bins varied in duration for the different FI schedules studied. Normalized data, perhaps in the form of response rates, might have presented a more representative picture. The data are summarized by Miller and Ackley in terms of a line of "best fit" ($y=1.02x + .46$), where y = the mean number of compound responses and x = the mean of the sum of component responses. While this is a reasonably close approximation of the summation hypothesis that $y = x$, the fit is helped considerably by a cluster of points generated in the first bins (with the shortest time bases) with very few responses and very low variability. In later bins, where there is more substantial responding to compare, the approximation of the perfect additive relationship is less convincing. The safest conclusion to draw from Miller and Ackley's experiment is that they have shown that under some training and test conditions, the level of compound responding may be at least ordinally related to component strength. Whether this result was entirely due to the summation of conditioned effects, or whether additive summation is an accurate representation of the results, awaits a more thorough analysis.

Finally, there is one operant summation paper involving avoidance behaviour. Miller (1969b) trained rats in a shuttle box to avoid shock whenever a light or a buzzer was presented. After eight sessions with 20 trials of each stimulus, the Ss were tested with the components and with the compound over seven days. Five compound trials occurred each day. The remaining trials were light and buzzer-alone. Apparently, the avoidance contingency was maintained for both the component and the compound trials, although Miller is not specific on that point.

Three of the four Ss readily acquired the avoidance response, and showed a consistently lower latency of responding to the compound than to the buzzer or light presented alone. The fourth S did not attain a high level of avoidance (25% to the light, 35% to the buzzer), nor did it show any consistent summation effects when light and buzzer were compounded. The results suggested to Miller that when the avoidance response is acquired, the net effect of two stimuli presented in compound may be greater than the individual effects. While this may be a reasonable position, the lack of control groups again makes it difficult to know the extent to which this apparent summation is produced only by stimuli with similar conditioning histories.

In overview, because many of the experiments reviewed in this section were designed only to extend summation to operant paradigms, we are lacking a good deal of relevant information on the extent to which unconditioned or non-associative stimulus effects may have been involved in most of the demonstrations. Only Weiss(1964, 1969) seems to have been concerned with these effects. However, individual deficits in these experiments tend to be outweighed by the fact that they have succeeded in demonstrating compound summation in a wide range of situations. The result is a fairly strong case for including summation as a working principle of operant conditioning.

B. Recent Experiments on Summation in Pavlovian Conditioning

Since 1960 a number of investigators have reported summation effects in Pavlovian conditioning. One way in which the summation mechanism has been studied is by means of transfer designs. In these experiments, Ss are trained in an operant conditioning situation in which behaviour is maintained by some reinforcing stimulus. In a separate phase of the experiment, a CS is paired with the same reinforcing stimulus, often in a different situation from the one in which the operant behaviour was trained. Finally, the CS is presented while S is once again permitted to perform the operant response. The assumption is often made (e.g., Rescorla and Solomon, 1967) that an important feature of the operant situation is the association of certain situational cues with the reinforcing stimulus; a process which causes those situational cues to acquire conditioned excitatory properties. Consequently, if presentations of the separately conditioned CS cause responding to increase, it could be argued that this effect is due to a summation of excitatory effects.

Rescorla and LoLordo (1965) and Rescorla (1966) trained dogs to perform an avoidance response in order to postpone the delivery of shock. It is often assumed that an important aspect of this "Sidman Avoidance" behaviour is conditioned fear resulting from acquired excitatory properties of situational cues. Thus, since these authors demonstrated that a stimulus separately paired with shock could increase the rate of avoidance behaviour, it could be argued that this result was due to a summation of fear-producing excitatory stimuli. Bull and Overmier (1968) emphasized the additive characteristics of excitation in a duplication of Rescorla and LoLordo's (1965) findings in a discrete-trial situation. Rescorla and Solomon (1967) noted that such an interaction was in accord with what might be anticipated on the basis of laws of Pavlovian conditioning.

A summation interpretation of these experiments requires assumptions both about the underlying Pavlovian process and about the stimuli that maintain such a process. While such assumptions may be very valuable in the analysis of operant behaviour (Rescorla and Solomon, 1967; but see also Trapold and Overmier, in press), one might wish for more fundamental demonstrations of summation effects with well-defined Pavlovian CSs, before the phenomenon is invoked as a mechanism to account for complex interactions among behaviours.

A number of experiments have recently provided such fundamental demonstrations of summation in the context of conditioned suppression. It has been previously noted that this thesis emphasizes those features of the conditioned suppression paradigm that link it with Pavlovian conditioning. That is, in conditioned suppression, CS and US are presented in succession, and S's behaviour in the presence of CS is observed. Moreover, as Kamin (1965) has effectively argued and demonstrated:

> The fact is that parametric control over the CER more closely resembles that reported for salivary conditioning than is the case with most experimental situations which have been identified with Pavlovian conditioning. (Kamin, 1965, p. 119)

These Pavlovian features of conditioned suppression have, of course, been the subject of thorough discussion (c.f. Lyon, 1968; Davis, 1968; Millenson and de Villiers, 1970, for reviews). Frequently these discussions have centered about various operant mechanisms that could contribute to the acquisition and maintenance of suppression. However, recent tendencies (e.g., Rescorla and Solomon, 1967) have been to emphasize that the ingredients of operant conditioning are implicit in virtually all Pavlovian conditioning procedures. In that respect, at least, conditioned suppression seems to fit very well into the mainstream of Pavlovian research.

As with most complex phenomena, it seems highly unlikely that only one interpretation will generate a thorough understanding of the results subsumed under conditioned suppression. In the experiments to be reported here, the experimental situations were simplified, with baseline schedules of reinforcement, intensity and duration of the CS and US all selected so that suppression was a readily obtained response. The precise mechanisms producing suppression are less important in the experiments in this thesis, than the fact that the observable relationship between CSs and suppression was a sensitive dependent variable.

The first two reports of summation in conditioned suppression were published within a few months of each other: first Miller (1969), followed by Reberg and Black (1969). Since then, two others have appeared (VanHouten, O'Leary, and Weiss, 1970; Weiss and Emurian, 1970). The experiment by Reberg and Black and a related experiment will be described in some detail and Experiment 1 and 2 of this thesis. Other reports of summation in conditioned suppression will then be reviewed.

1. Experiment 1: A Demonstration of Summation In Conditioned Suppression

The purpose of this experiment was to demonstrate summation in conditioned suppression. Two CSs were individually paired with shock. Compound tests were conducted both in early acquisition and extinction.

The apparatus and barpress training procedures used in this experiment will be described in detail here. Only departures from that basic format will be referred to in later experiments.

METHOD

Subjects

The Ss used in these experiments were male, hooded rats, supplied by Quebec Breeding Farms. Eighteen Ss served in Experiment 1. The animals weighed between 250 and 300 grams when deprivation procedures began.

Ss were maintained on *ad lib* food (Purina Lab Chow) and water for several days. Ss were weighed on three successive days to establish a baseline weight.

During deprivation, each S was weighed daily, and fed 3 to 5 grams of food. Water was always available. When Ss' weights reached 75% of their baseline weights, their daily ration was increased to 10-12 grams. Most Ss were exposed to the deprivation schedule between seven and ten days before training began. During training, all Ss were weighed daily, and fed 8-10 grams to maintain 75% weights.

Apparatus

All experiments involved standard Skinner Boxes, which, while not identical, were fairly uniform in design. Five boxes were used in the first experiment. The boxes had stainless steel walls at the front and the rear, while the sides and top were plexiglas. The floor was composed of 18 3/16 in. stainless steel grids, through which shock could be programmed. The stainless steel walls and the response lever were also included in the shock circuit.

In the center of the "front" wall was a response lever, calibrated before each experiment with a pressure gauge to operate with approximately 25 grams force. In the lower left corner of the front wall was a small protruding food cup into which Noyes 45 mg. food pellets were delivered. At the rear of the box, mounted outside the plexiglas wall, was an AC lamp socket and a 10 watt bulb which served as a houselight.

The Skinner Boxes were enclosed in larger chambers, which were light-tight and also served to reduce noise transfer among boxes. Each chamber was equipped with a blower to provide ventilation and, in the process, a slight masking noise. Mounted flush with the ceiling of each chamber was a four inch speaker, positioned over the center of the Skinner Box.

The CSs in all these experiments were white noise and darkness. The white noise was produced by a Grason-Stadler Model 901B noise generator, transferred to the various boxes. In the first experiment, the noise intensity was 70 db. Noise levels were adjusted in each box daily, using a General Radio Model 1551-C noise meter. The adjustments were made with the doors closed and the fans off. Regular checks with the fans running indicated that their presence affected the measured noise level only marginally.

Darkness, effectively total, was produced by extinguishing the house light.

Scrambled shock was supplied to each box by individual Grason-Stadler Model 1064GS or Model 700 shock generators. In the first experiment, the shock intensity used was that obtained at the 1.0 ma setting of each shock generator. Before each session in which shock was to be employed, the grids were thoroughly cleaned and a shock check was run with a voltmeter.

All experimental conditions were programmed by relay equipment in another room. Responses and reinforcements were continually monitored on Gerbrands Cumulative

Recorders, and when appropriate, selectively monitored on Sodeco counters and Grason-Stadler Model E46000 printout counters.

Procedure

Bar press Training. On the first day of training, Ss were placed in the boxes and given a few moments to adapt to the apparatus. Food pellets were then delivered noncontingently on a VI 1 min schedule. At the same time, all bar presses resulted in reinforcement with a single 45 mg. Noyes Rat Pellet. Using this procedure, it was rare for rats not to begin responding within 30 minutes. When about 10 responses had been recorded, free reinforcement for bar pressing remained in effect. The Ss remained in boxes until at least 60 responses had occurred, or until about one hour had elapsed. Ss failing to respond on the first day were usually given a second session on the succeeding day. Ss not learning on the second day were ordinarily discarded from the experiment.

VI Training. After the bar press response had been acquired, Ss were placed on a VI 3 min schedule of reinforcement. In the early experiments, transition to the VI 3 min schedule took place gradually on the first day, beginning with ten continuously reinforced responses, followed by about one hour of VI 1 min, and VI 3 min thereafter. In the final three experiments, VI 1 min training was discontinued, and Ss began with the VI 3 min schedule.

Occasionally, if Ss bar pressed infrequently in early VI training, they were briefly placed on a VI 1 min or a VI 30 sec schedule, and then returned to VI 3 min. The result in most cases was rates averaging between 500 and 1000 responses/hour, although rates much higher than that were observed and, occasionally, responding stabilized at lower rates. Throughout the experiments, baselines were checked very carefully. In the accounts to be included here, baselines will be referred to only in rare instances in which they appeared to influence major results.

<u>Pretest</u>. After preliminary barpress training was completed, Ss were exposed to a pretest of the stimulus conditions to be used. Two trials each of noise (N), dark (D), and the N/D compound were scheduled. For half the Ss in Experiment 1, the sequence was N, D, N/D, N/D, D, N. The sequence for the other half was D, N, N/D, N/D, N, D.

Pretest trials were scheduled in the following way: First, barpresses were recorded for 90 seconds in order to provide a measure of baseline responding. This interval will be referred to as the <u>Pre-CS interval</u>. At the end of the Pre-CS interval, N, D, or N/D was presented for 90 sec, during which responses were also tabulated. This will be called the <u>CS-interval</u>.

The effect of the CS was described in terms of a suppression ratio, developed by Annau and Kamin (1961) according to the formula $\frac{B}{A + B}$. A = the number of responses recorded in the pre-CS interval, and B = the number of responses recorded in the CS-interval. This ratio takes a value of zero when the CS suppresses responding completely, and a value of .50 when the CS exerts no suppressing effect. On those occasions when acceleration is observed to the CS, the ratio is greater than .50 with 1.00 as a limit.[8]

<u>Conditioning and Early Acquisition Summation Test</u>. On the day following pretest, noise and dark were both paired twice with shock. Each CS was presented for 90 seconds, terminating with a .5 sec shock. CS and shock terminated simultaneously. The sequence of trials for half the Ss was N,D,D,N. The other half received D,N,N,D.

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[8] The Annau-Kamin ratio is only one of a number of ratios available for the description of relative responding in various stimulus conditions. Many of the alternatives have been described by Lyon (1968). Some form of ratio is appropriate, because of between-subject and within-subject baseline variability, which tends to be considerable in the absence of "pacing procedures" (Blackman, 1967). The adherence to the Annau-Kamin ratio here stemmed primarily from the fact that it was used in the early procedures to establish criterion levels important in testing. In general, however, the effects to be described here are very clear, and it is likely that other measures would have proven equally satisfactory.

The fifth trial at the end of the first conditioning day was an unreinforced test trial for all 18 Ss. For six Ss (Group N), noise was tested, for another group of six (Group D), dark was tested. The remaining six (Group C), received tests of the N/D compound. The purpose of this test was to determine whether two CSs in the early stages of conditioning would summate to produce greater suppression than either presented alone.

On the second conditioning day, Ss again received two noise and two dark trials, all reinforced with shock. Half received an N,D,N,D sequence. In the remainder the sequence was reversed.

Extinction and Summation Tests. On the following day, all Ss received two unreinforced presentations of noise and two of dark, followed by a test of the same stimulus that was tested at the end of the first conditioning session. Twelve Ss continued testing beyond that point on the next day.[9] This group received a test procedure that included repeated exposure to the individual stimuli and their compound in a single extended session. N and D were repeatedly presented in irregular sequence, at five-minute intervals, until either one satisfied an extinction criterion. This criterion was defined as an

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[9] One of the original 18 Ss was discarded because of an apparatus failure. Five other Ss received an alternate test procedure not comparable with the other twelve.

Annau-Kamin suppression ratio of .20 or above. The other CS was then extinguished to criterion, whereupon the first was again tested to insure that it still equalled or exceeded .20. Then the compound was tested. Following this test, the N,D,N/D compound sequence was repeated until all Ss received three compound tests.

RESULTS AND DISCUSSION

The pretest presentations of D, N, and N/D produced no appreciable response suppression, and no consistent differences were observed among the stimuli. Averaged over both trials, the median N ratio was .45, the median D ratio was .44, and the median N/D ratio was .47.

The results of the first two acquisition trials of N and of D, and the unreinforced test trial of either N,D, or N/D are shown for the three groups in Figure 1. In the reinforced acquisition trials, the only difference among the groups was that Group D showed significantly greater suppression to the final D acquisition trial than either Groups N or C (Kruskal-Wallis one-way nonparametric analysis of variance: $H = 8.41$, $p < .02$). Since all groups received identical treatment up to that trial, the difference was quite unexpected. However, observations of over

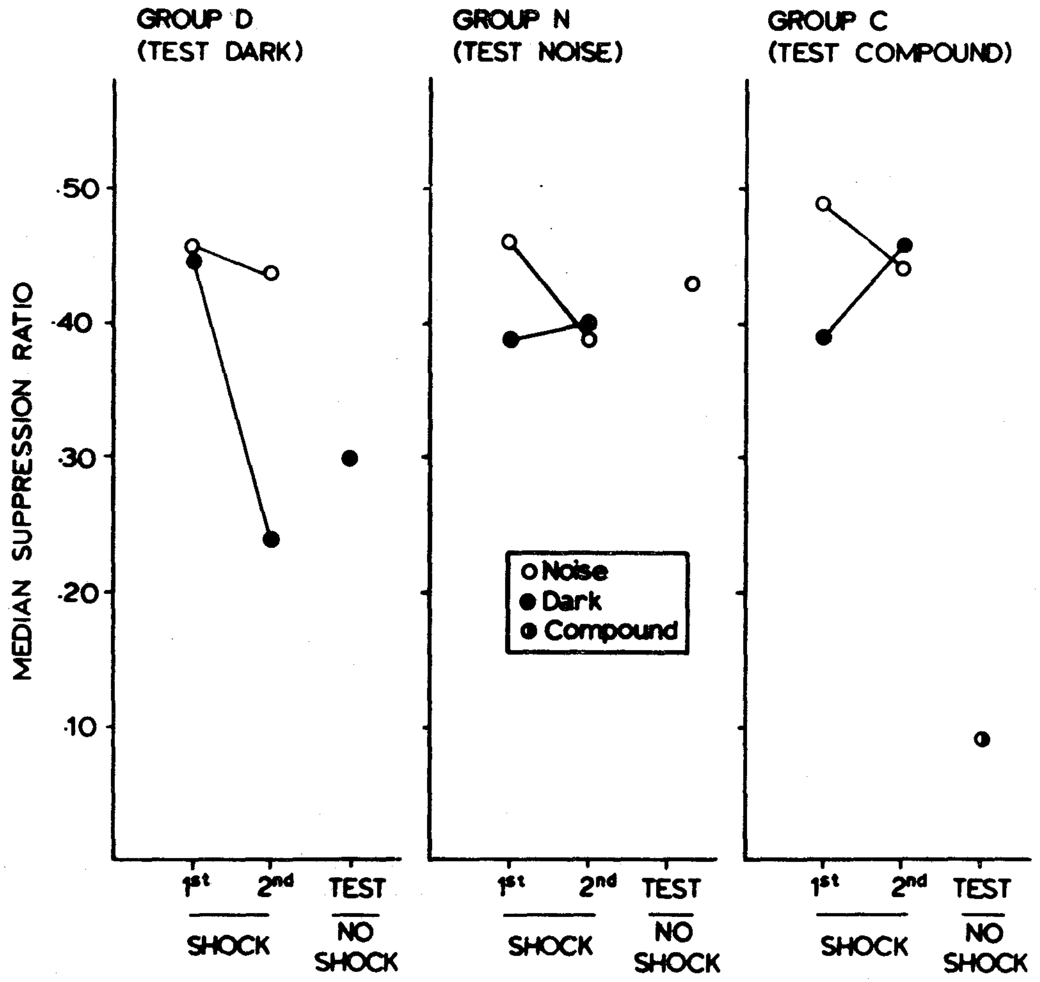


Figure 1. Median suppression ratios for acquisition trials and first test trial (Experiment 1). The points joined by lines represent the suppression observed on the first and second shock-reinforced acquisition trials with either 70 db white noise or darkness. The independently presented points in each section represent the suppression observed on the unreinforced test trial of either Noise, Darkness, or the Noise/Dark compound.

200 rats in conditioned suppression situations have indicated that data on the first acquisition day is highly variable. It seems likely that this difference among the groups was a result of sampling error, rather than a systematic bias.

It is clear from Figure 1 that the median suppression associated with the compound was substantially greater than comparable test trials with N and D alone. The results of the stimulus tests were assessed by comparing the level of suppression on test trials, for each S, with the most suppressed of the four preceding acquisition trials. All six Ss tested with the compound showed greater suppression on the test trial than to any of the previous single-stimulus trials. This pattern was duplicated by only two Ss in Group N and two in Group D. The differences between the compound test and the most suppressed of the four acquisition trials, were significantly greater than the corresponding differences for each of the single stimulus test groups [Whitney's extension of the Mann-Whitney U-test (Mosteller and Bush, 1954) $p(h = 2.40, 2.64) < .01$]. This index indicated quite clearly that after each component had been paired with shock twice, the N/D compound exerted a greater relative suppressing effect in test trials than either N or D presented alone.

On the following day, acquisition to N and D was essentially complete in all Ss (last D trial median = .02; last N trial median = .00). The second tests scheduled for all Ss on the first extinction day provided minimal information since virtually no extinction occurred to the components over four unreinforced trials (D median = .00; N median = .04; N/D median = .00). Thus, the results of those tests served only to demonstrate that when the components produce complete suppression, a compound test does not result in a loss of suppression.

The results of the second extinction tests in the sub-Group of 12 Ss are shown in Figure 2. In all three blocks, the N/D compound produced much more suppression than either N or D presented alone. Ten of the twelve Ss tested in extinction duplicated this pattern in Block 1, eleven of twelve in Block 2, and nine of twelve in Block 3. Wilcoxon's matched-pair signed-ranks test (Siegel, 1956) showed these results to be highly significant (Block 1 $T = 1$ $p < .01$; Block 2 $T = 0$, $p < .01$; Block 3 $T = 10$, $p < .05$).

Detailed examination of test protocols for individual Ss showed inconsistent relationships among the degree of suppression observed to components and the results of compound tests. This inconsistency is illustrated by the results for three Ss shown in Figure 3. Each portion of the figure shows the results of the test session for an

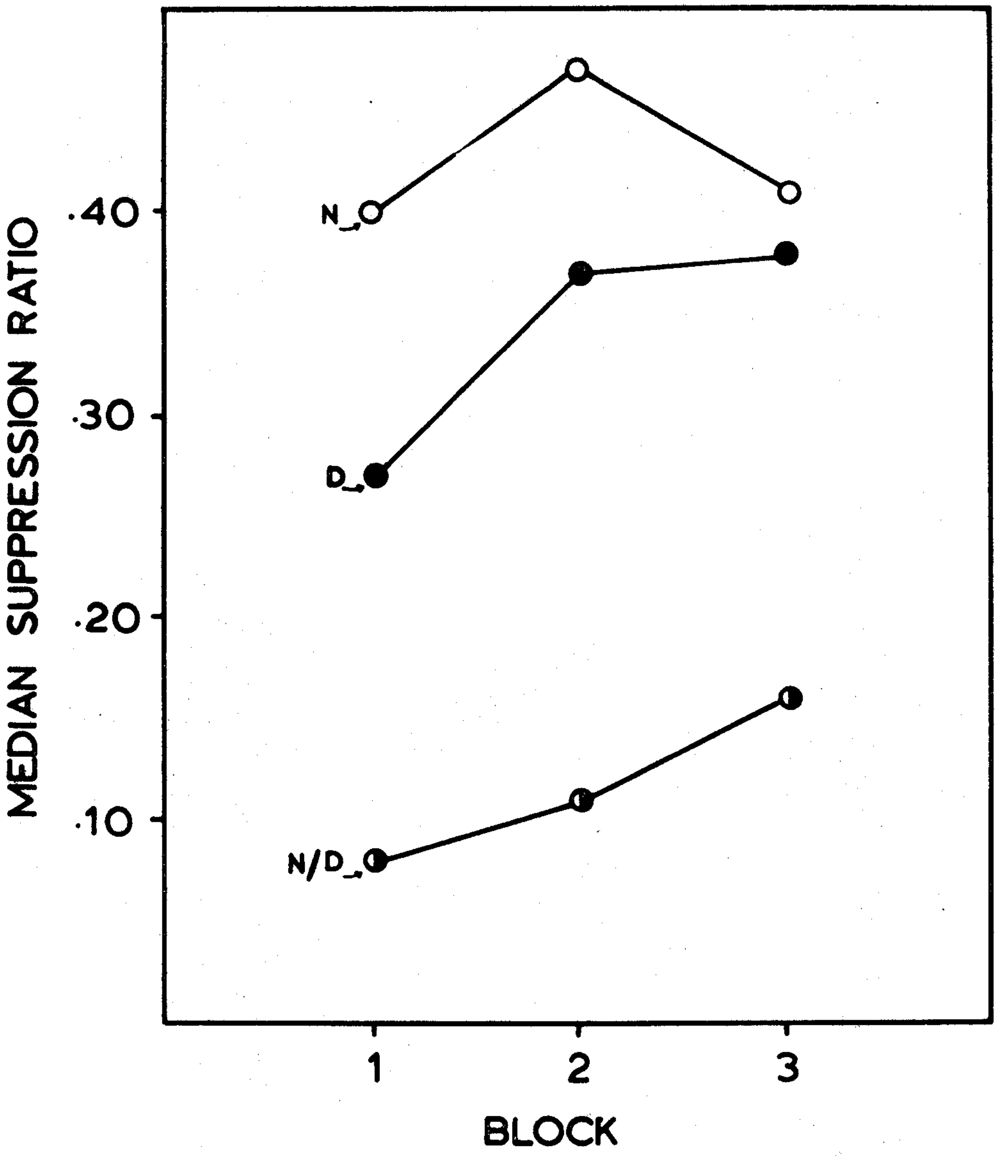


Figure 2. Extinction test suppression ratios for subgroup of 12 Ss. Each point represents the median suppression ratio observed to unreinforced presentations of either Noise, Darkness, or the Noise/Dark compound in each of three consecutive test blocks.

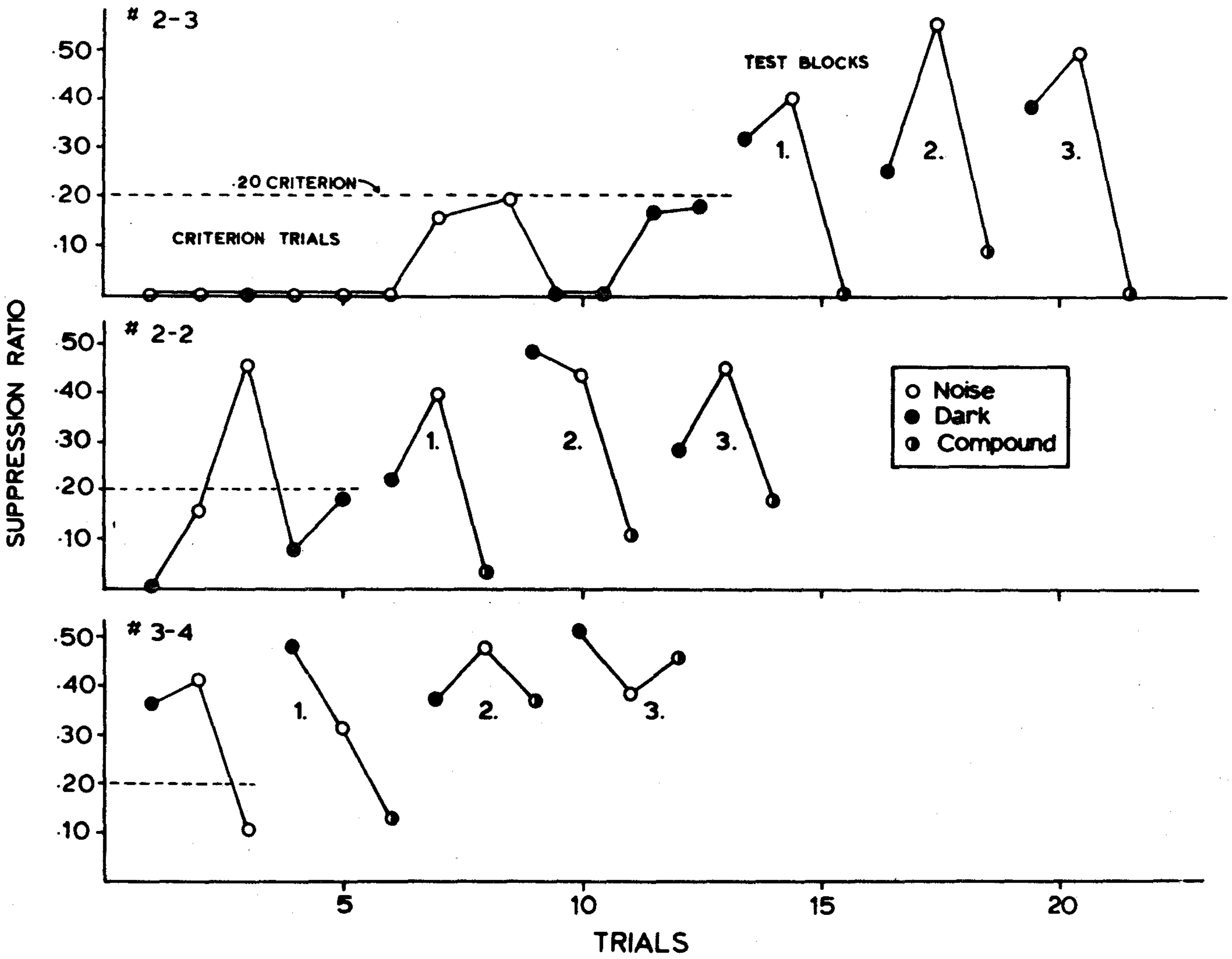


Figure 3. Extinction test results for three individual Ss. The first block of joined points under the broken line shows suppression ratios on the trials preceeding the satisfaction of the .20 criterion. The groups of three points not included under the broken line show suppression ratios recorded in test blocks.

individual S. The first block of connected points represents the results of those trials on which N and D were individually extinguished to the .20 criterion. The three groups of points following, labeled 1, 2, and 3, represent the outcomes of the respective test blocks.

Three distinct relationships between compound and component suppression are shown in these examples. All three Ss showed some extinction to the components over the test blocks. S #2-3 retained total compound suppression and summation throughout. S #2-2 also retained summation throughout, but in a decreasing pattern that parallelled component extinction. S #3-4, however, showed summation only on the first block with the compound producing the same level of suppression as D on Block 2, and less compound suppression than that observed to N on Block 3. On the second test block, #3-4 showed compound suppression equalling that observed to D alone. On the third test block, N was the most suppressed stimulus. Of the twelve Ss, five showed patterns in testing resembling #2-3, four resembled #2-2, and the remaining three resembled #3-4. Obviously, since three different relationships were observed between component and compound suppression, this summation was not even "ordinal" to say nothing of a simple "additive" combination of effects.

There is, of course, the possibility that unconditioned effects such as "novelty" could have contributed to compound suppression. However, in the experiment to follow, data from a "novel CS" control group indicate quite clearly that the contribution of such effects to summation is negligible.

The results of this experiment provide strong support for the summation phenomenon in conditioned suppression. There were also some preliminary indications in these data that the summation phenomenon might be sensitive to relatively weak excitatory effects. For example, on the first acquisition day, fifth-trial tests with N produced very little suppression (see Figure 1) but compound tests of N and D resulted in marked summation. Although one might conclude on the basis of single stimulus presentations that there was little conditioning to N, the compound tests provide a different indication. Also encouraging were individual instances such as Block 2 with S #2-3 (see Figure 3) where slight acceleration (ratio = .55) was recorded to N, and nearly complete suppression was obtained to the N/D compound.

However, since much of the research in this thesis was concerned with weak excitatory effects, sensitivity of compound summation was required. The following experiment was designed to provide information about summation with weak CSs.

Experiment 2: Compound Summation II: Effects of Minimal Training with One CS

Three groups were included in this experiment. The first group was designed primarily to duplicate the results of Experiment 1. The second group was designed to determine whether a CS paired only once with shock and a second CS with a more extensive conditioning history would summate. The third group was designed to provide information on the extent to which unconditioned (or non-associative) stimulus effects resulting from "novel" properties of the compound contribute to summation.

METHOD

Subjects

Thirty-two hooded rats were used. The death of two Ss before completion of the experiment forced elimination of their data from all analyses.

Apparatus

Eight Skinner Boxes were used in this experiment. The major features of the boxes and programming equipment were as in Experiment 1. The CSs were darkness and 75 db white noise. US intensity was set at 1.3 ma, with a duration of .5 sec.

Procedure

Magazine and bar press training, and establishment of VI 3 min baselines proceeded in essentially the same sequence as Experiment 1. Preliminary VI 3 min training continued for five two-hour sessions. During the sixth session, two pretest presentations each of CS_1, CS_2, and CS_1/CS_2 were programmed. For half the Ss, CS_1 was darkness, CS_2 was noise. The roles of the stimuli were reversed for the other half.

The design of the experiment is shown in Figure 4. Each of the three groups was run in three phases: conditioning, extinction, and test.

Conditioning. The three conditioning sessions were designated C_1, C_2, and C_3. During these three sessions, all **Ss** received four CS_1-shock pairings. The groups differed on the basis of CS_2 treatments. Group 2 - CS_{2+} received two pairings of CS_2 and shock; Group 1 - CS_{2+} received one pairing of CS_2 and shock, and Group CS_2o received no pairings of CS_2 and shock.

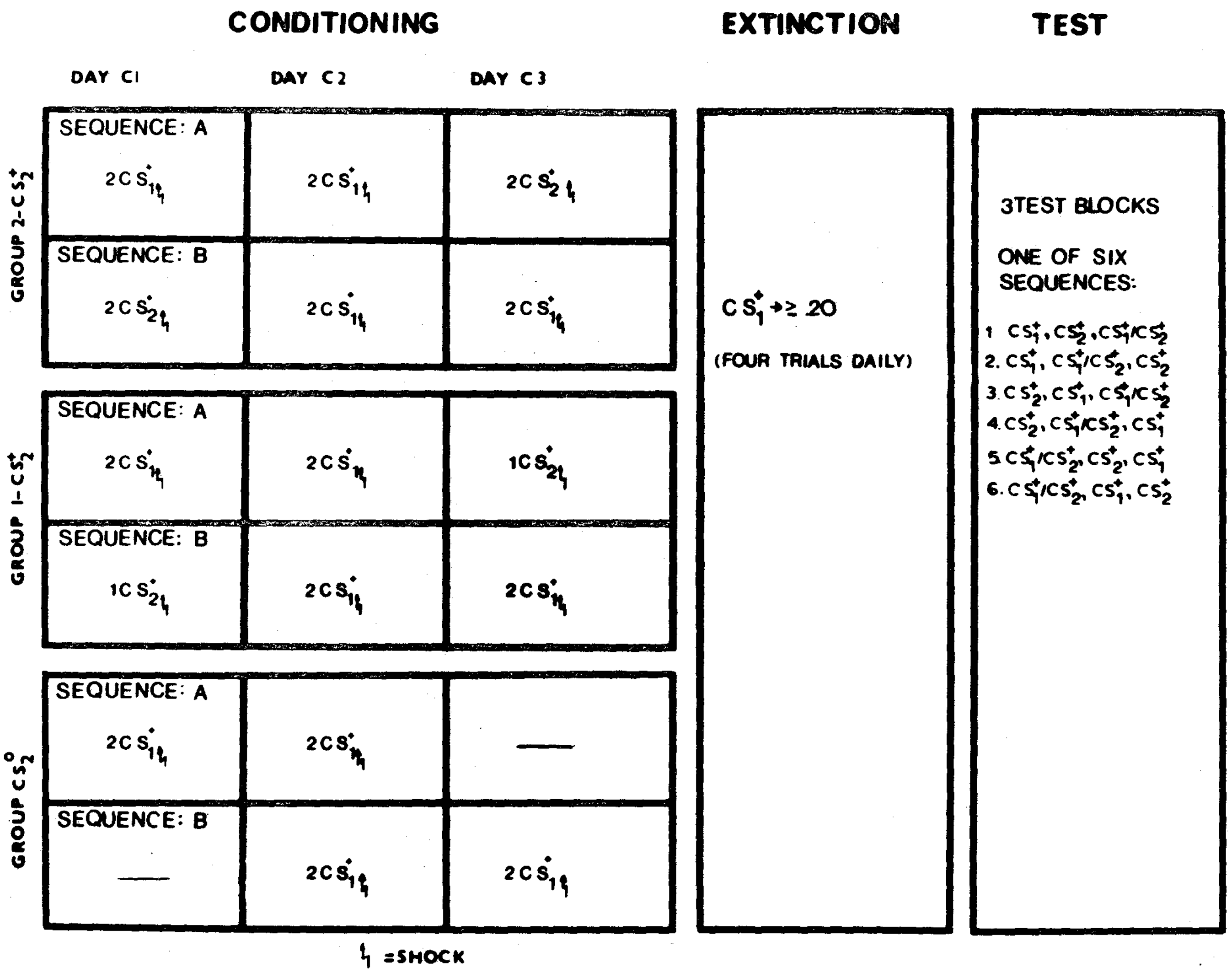
Conditioning in each group was scheduled in two sequences. Ss assigned to sequence "A" received two CS_1-shock trials on each of days C_1 and C_2, while day C_3 was reserved for the CS_2 treatment. Ss assigned to sequence "B" were scheduled to receive the CS_2 treatment on day C_1.

Two CS_1- shock trials were then scheduled during each of days C_2 and C_3. All conditioning trials included a 90 second CS presentation terminated with a .5 sec 1.3 ma shock, programmed as in Experiment 1.

<u>CS_1 Extinction</u>. After conditioning was completed, CS_1 was extinguished to the criterion level, defined as an Annau-Kamin suppression ratio of .20 or greater. Extinction was scheduled at the rate of four trials daily. During the session in which the .20 criterion was satisfied, the first test block was scheduled with presentations of CS_1, CS_2, and CS_1/CS_2. Trials were scheduled at random points in the session, and no more than seven trials were included in any single session.

<u>Testing</u>. The test sequences used in test blocks were made up of the six possible orders of CS_1, CS_2, and CS_1/CS_2, shown in Figure 4. The same test sequence was programmed for each S on consecutive days until three blocks had been observed.

Occasionally, the CS_1 criterion was not satisfied within four trials on the second test day. When this occurred, testing was not scheduled and the second test block was observed on the next day of testing.



		CONDITIONING		
		DAY C1	DAY C2	DAY C3
GROUP 2-CS_2^+	SEQUENCE: A	2 CS_1^+ ϟ	2 CS_1^+ ϟ	2 CS_2^+ ϟ
	SEQUENCE: B	2 CS_2^+ ϟ	2 CS_1^+ ϟ	2 CS_1^+ ϟ
GROUP 1-CS_2^+	SEQUENCE: A	2 CS_1^+ ϟ	2 CS_1^+ ϟ	1 CS_2^+ ϟ
	SEQUENCE: B	1 CS_2^+ ϟ	2 CS_1^+ ϟ	2 CS_1^+ ϟ
GROUP CS_2^0	SEQUENCE: A	2 CS_1^+ ϟ	2 CS_1^+ ϟ	—
	SEQUENCE: B	—	2 CS_1^+ ϟ	2 CS_1^+ ϟ

ϟ =SHOCK

EXTINCTION

$CS_1^+ \rightarrow \geq 20$

(FOUR TRIALS DAILY)

TEST

3TEST BLOCKS

ONE OF SIX SEQUENCES:

1. CS_1^+, CS_2^+, CS_1^+/CS_2^+
2. CS_1^+, CS_1^+/CS_2^+, CS_2^+
3. CS_2^+, CS_1^+, CS_1^+/CS_2^+
4. CS_2^+, CS_1^+/CS_2^+, CS_1^+
5. CS_1^+/CS_2^+, CS_2^+, CS_1^+
6. CS_1^+/CS_2^+, CS_1^+, CS_2^+

Figure 4. Diagram of procedure for Experiment 2, including events programmed on conditioning, extinction, and test days.

RESULTS

Pretest trials resembled Experiment 1. Median suppression to N was .45, D was .38, and N/D was .44. The differences among these stimuli were not significant.

The acquisition phase provided an opportunity to examine the extent to which previous conditioning with one CS facilitated acquisition with a second CS. The relevant data are summarized in Figure 5, which shows CS_1 and CS_2 acquisition under sequences "A" and "B" for all three groups. The filled squares in the center panels show CS_1 acquisition under sequence "A" (CS_1 followed by CS_2), while the open squares show CS_1 acquisition under sequence "B" (CS_2 followed by CS_1). The open and filled circles in the left and right panels show CS_2 acquisition under the respective sequences. Comparison of open and filled squares then permits evaluation of different levels of CS_2 pretraining on CS_1 acquisition.

It is clear that two trials of CS_2 training exerted only a marginal effect on subsequent CS_1 acquisition. Trial 2 for Group 2 - CS_2+ showed "A" sequence Ss significantly more suppressed than "B" Ss, but all other similar comparisons failed to approach significance.

Comparison of open and filled circles permits evaluation of the effect of CS_1 pretraining on CS_2 acquisition. Pooling the first "A" trials and the first

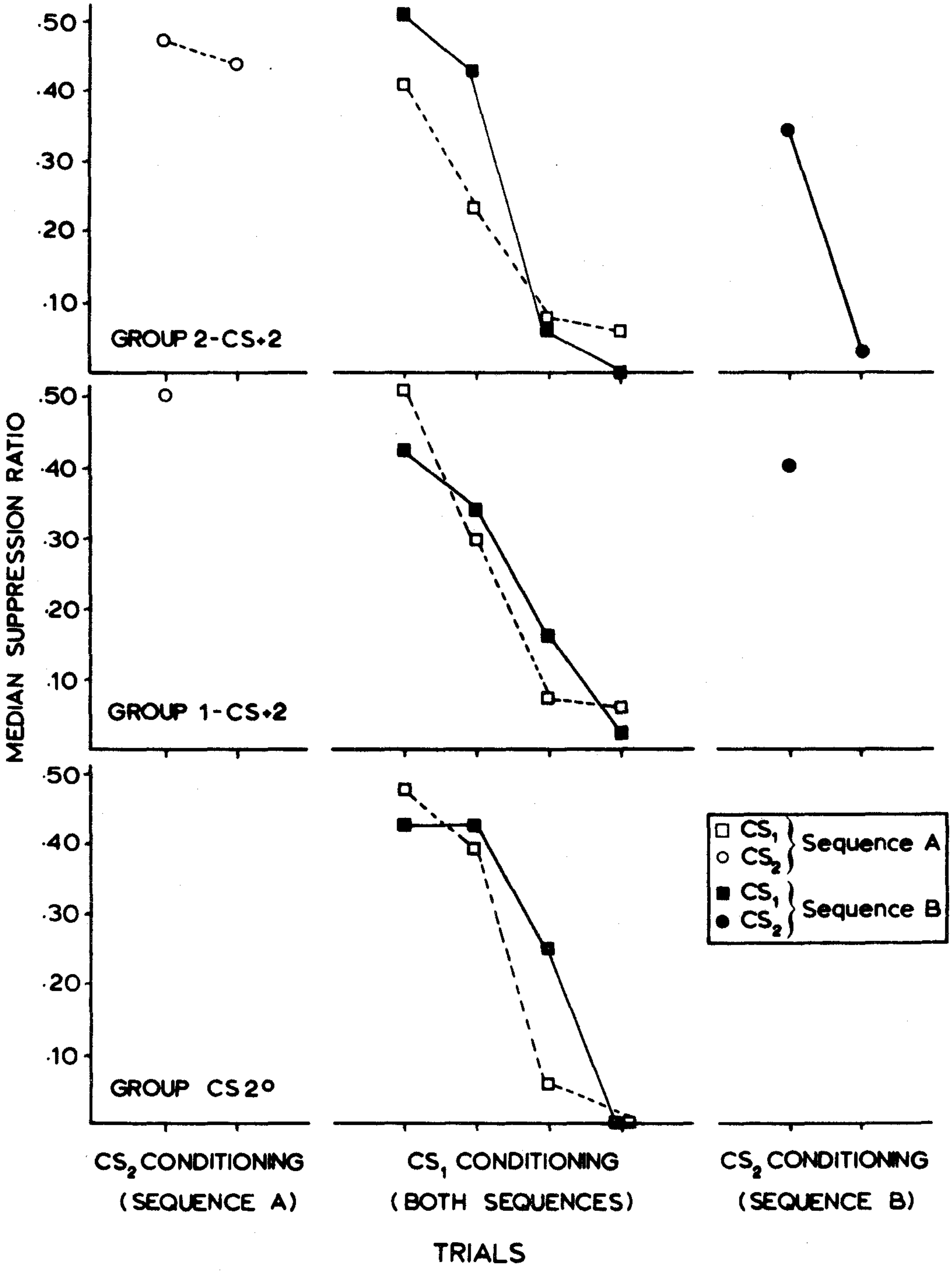


Figure 5. Acquisition results for Experiment 2. The left and right portions of the figure show median CS2 suppression ratios recorded for Ss conditioned under sequence A (CS2, CS1) or B (CS1, CS2), respectively. The number of CS2 points displayed for each group varies according to the number of trials programmed. The middle portions show median CS1 suppression ratios for both conditioning sequences.

"B" trials with CS_2 for Groups 1 - CS_2+ and 2 - CS_2+ showed "B" sequence suppression to be significantly greater than "A" sequence ($U = 22.5$, $p < .05$). The most marked effect of CS_1 pretraining on CS_2 acquisition was revealed in the second CS_2 trial in Group 2 - CS_2+, where "B" suppression was consistently greater than "A" suppression ($U = 0$, $p < .01$). Four conditioning trials with CS_1 clearly facilitated subsequent CS_2 acquisition.

Figure 6 shows acquisition data for the three groups when N and D served as $CS_1$and CS_2. Table 1 shows median trials to CS_1 criterion when N or D served as CS_1. Examination the these data revealed no reliable stimulus or group effects.

The results of the test blocks are shown in Figure 7. For each group the median suppression ratios for CS_1, CS_2, and CS_1/CS_2 are shown for each of three test blocks. The mean suppression ratios for each S to each stimulus condition are displayed in the right panels, labeled "Three-Block means".

The results of the test presentations of CS_1 and CS_2 differed considerably across the three groups. Group 2 - CS_2+ retained substantial suppression to CS_1 and especially CS_2 over all three blocks, while Groups 1 - CS_2+ and CS_2o showed marked extinction. Kruskall-Wallis

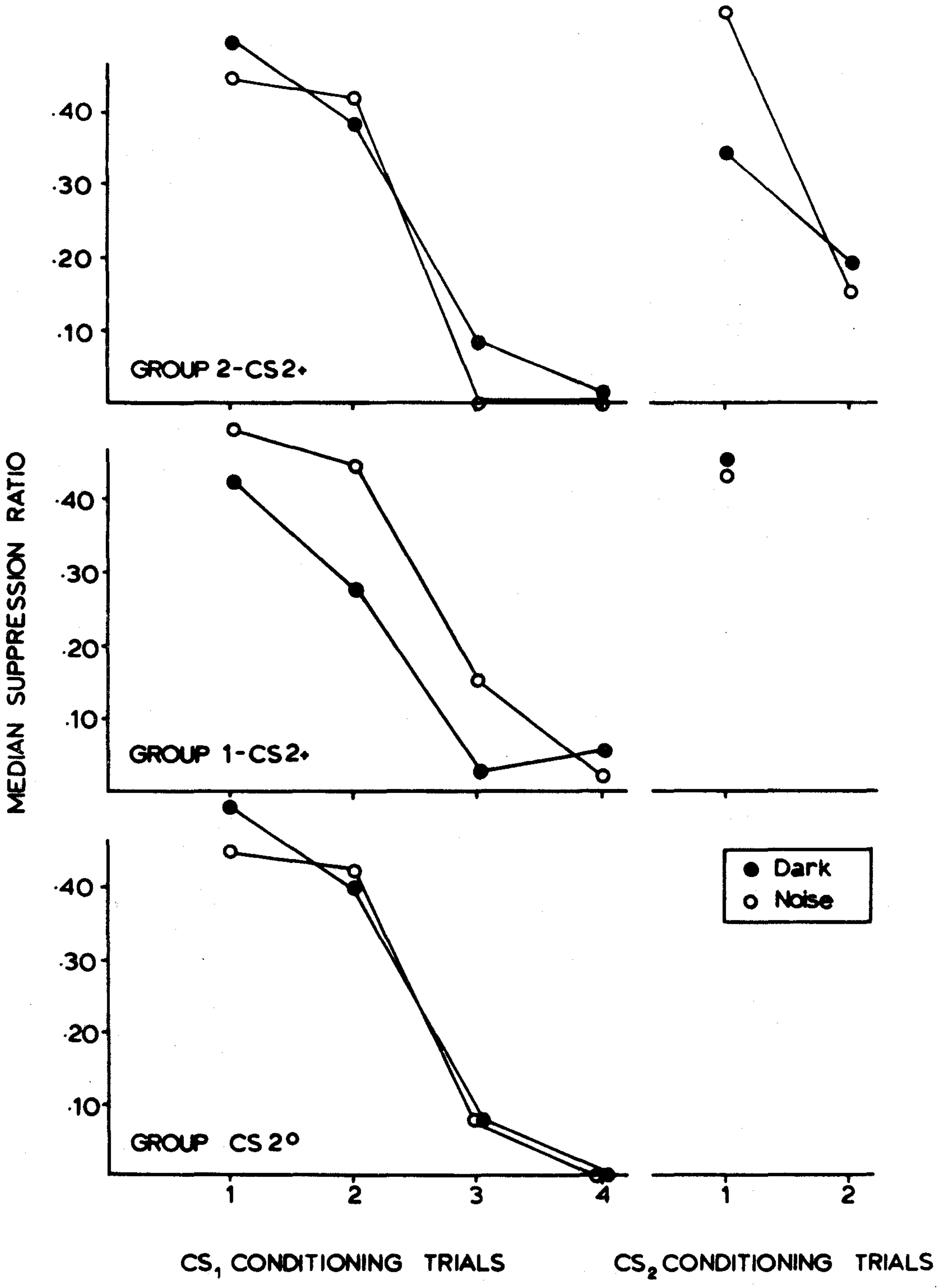


Figure 6. Acquisition results for Darkness and 75 db white noise for Experiment 2. The left portions show acquisition data for CS1, the right portions for CS2. The number of CS2 points displayed for each group varies according to the number of trials programmed.

Table 1 Experiment 2

Median Trials to $CS_1 \geq .20$ Criterion

for 75 db Noise and Darkness

		Noise	Darkness
Group 2 - $CS+^2$	Median:	42	30
	Range:	6 - 48	6 - 60
Group 1 - $CS+^2$		16	21
		6 - 42	6 - 42
Group CS_2^o		24	36
		18 - 36	24 - 36

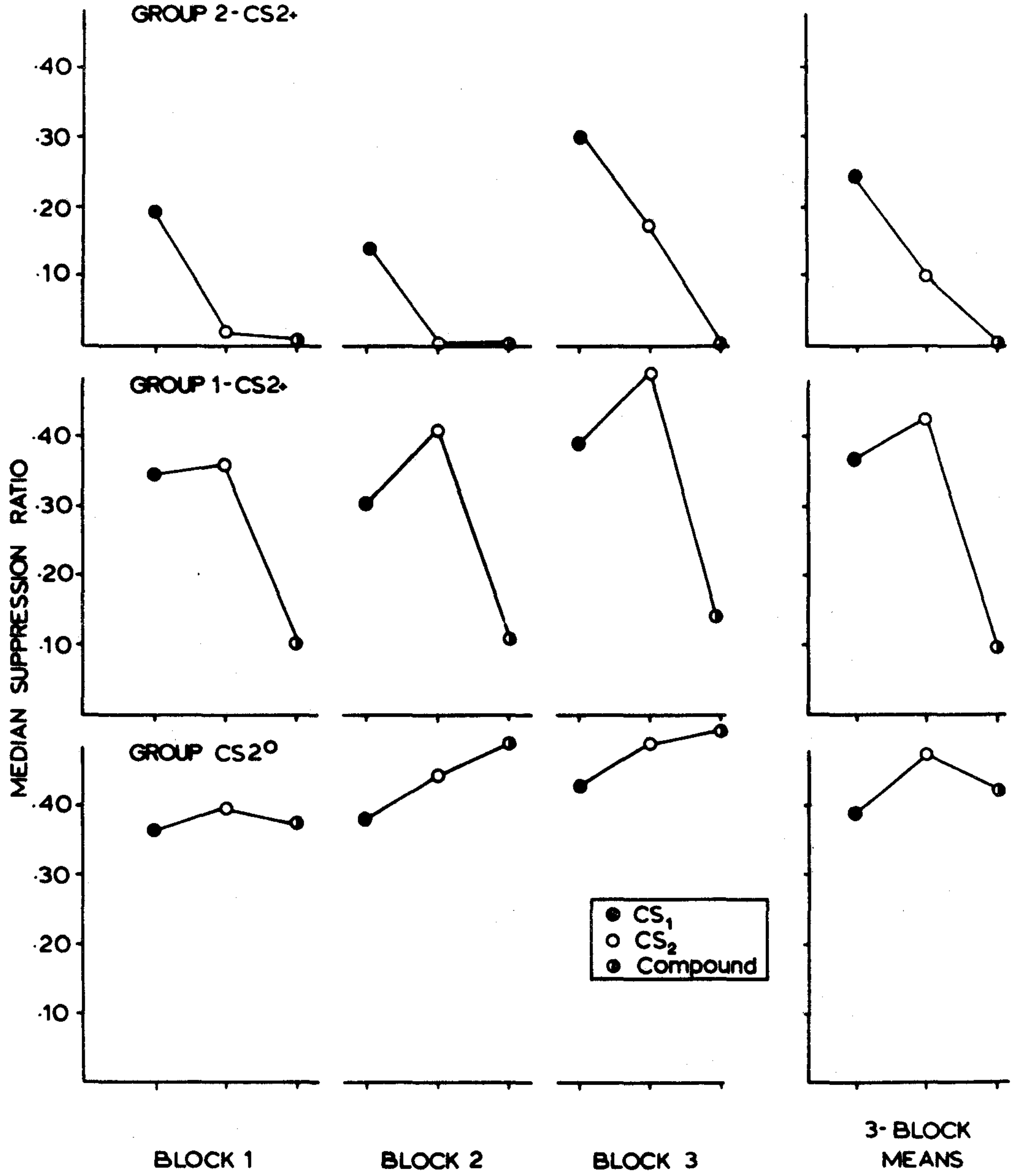


Figure 7. Test results for Experiment 2. Each group of three points in the left portions represents the median suppression ratios recorded in a single test block. The group of three points displayed in each of the right portions represents the median of the mean suppression ratios recorded over all three blocks.

Analyses of Variance confirmed that these differences in the three-block means were highly significant (CS_1 H = 12.74, $p < .05$; CS_2 H = 9.64, $p < .01$).

For our immediate purposes the most important result was that summation was observed in both groups. When three-block means were examined, Whitney's extension of the U test confirmed for both Groups 2 - CS_2+ and 1 - CS_2+, that the compound tests were significantly more suppressed than either of the component tests (Group 2 - CS_2+: $p(h = 2.76, h = 3.15) < .01$; Group 1 - CS_2+: $p(h = 2.53, h = 2.59) < .01$).

The results of the CS^o "novelty" group showed no significant differences among the components and the compound. In fact, within-subject comparisons over three day averages showed that the $CS+/CS^o$ compound was slightly, but consistently less suppressed than the CS_1+ - alone test (Wilcoxon's $T = 2$, $p < .05$). Further examination of average CS_1/CS_2 suppression in the three-block averages for all groups showed three distinct levels of compound suppression. Group 2 - CS_2+ compound suppression exceeded Group 1 - CS_2+, which in turn, exceeded Group CS_2o (Whitney's extension of the U - Test, $p(h = +2.80, h =-3.90)$ $< .01$).

The average results of the test blocks were also examined for stimulus effects. The results of this

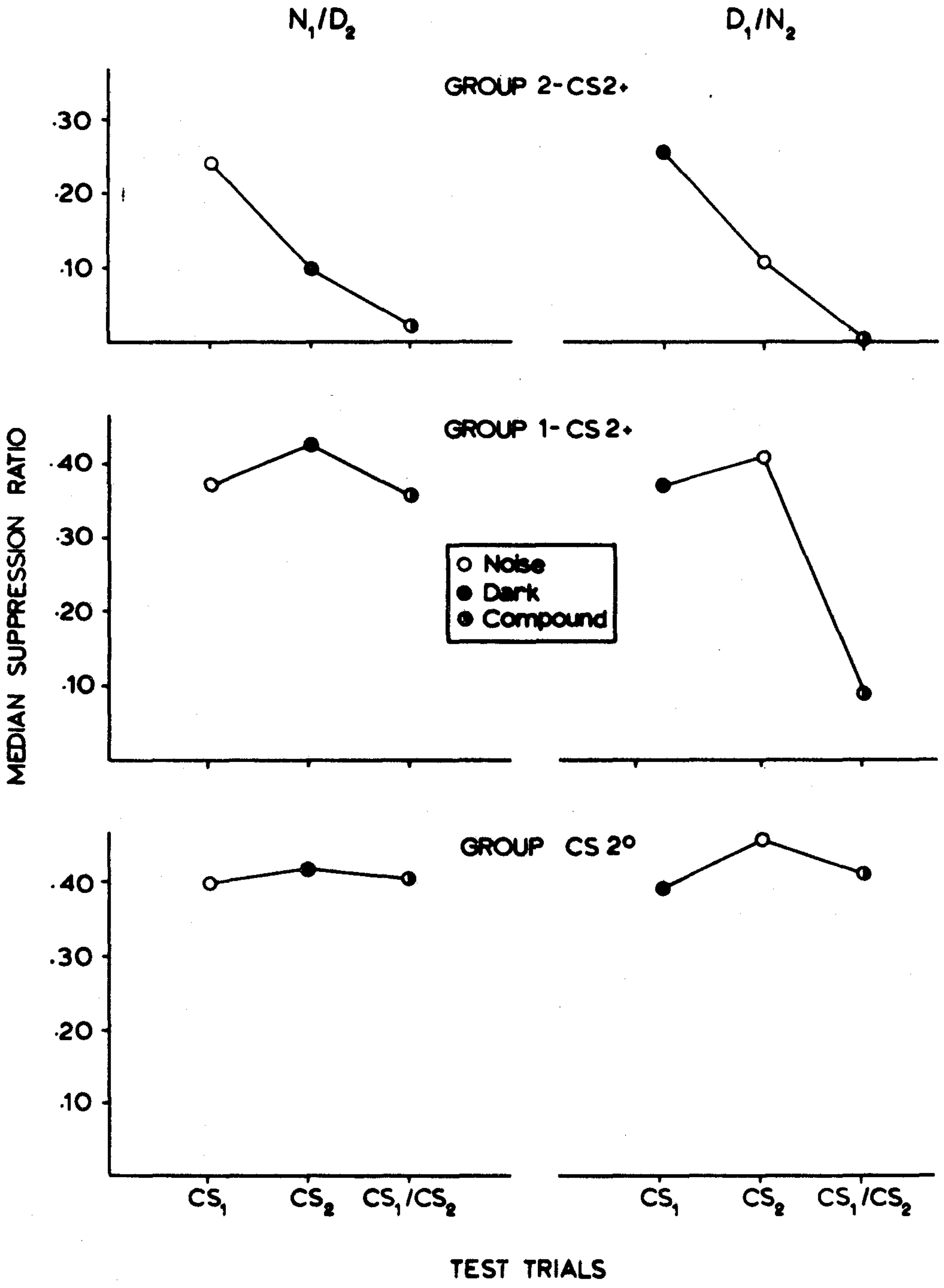


Figure 8. Median three-block mean test results for Experiment 2, when 75 db white noise or darkness served as CS1 or CS2.

analysis are shown in Figure 8, which includes component and compound suppression for each group when N served as CS_1, D as CS_2 (designated N_1/D_2 in the figure) and when D served as CS_1, N as CS_2 (D_1/N_2).

One instance of a significant stimulus effect was observed, illustrated in the center panel of Figure 8. In Group 1 - CS_2+, significantly greater compound suppression was recorded when D was CS_1 and N was CS_2 than when N was CS_1 and D was CS_2. No differences between N and D were observed when the stimuli were presented individually, nor were any stimulus effects observed in the other groups.

DISCUSSION

The results of Experiment 2 provide further support for summation as a phenomenon of conditioned suppression. Moreover, since no summation was observed to the compound including a novel stimulus (Group CS_2o), the indication is that nonassociative "novel" features of the compound do not greatly influence summation results. This "CS^o" control procedure has been repeated in a number of experiments (see Experiments 3, 4, 6 and 7, below), both when CS^o was a novel stimulus and when Ss received extensive pre-exposure to CS^o prior to testing. None of these groups have shown summation effects approaching the magnitude or reliability of the present data. In short, it seems extremely unlikely that nonassociative factors could be substantial contributors to these data.

It is particularly significant that three distinct levels of compound suppression were observed. The combination of two "strong" components (Group 2-CS_2+) produced reliably greater suppression than the combination of a "weak" and a "strong" component (Group 1-CS_2+), which in turn produced more suppression than the compound including the "novel" stimulus (Group CS_2o). The results of Groups 1-CS_2+ and CS_2o deserve special emphasis, since tests of both CS_1 and CS_2 in those groups were virtually indistinguishable. Only the results of the compound tests provide an indication that the single conditioning trial in Group 1-CS_2+ exerted some effect.

The significant stimulus effect observed in Group 1-CS_2+ may be a further indication of the sensitivity of the summation index. The differences in compound suppression appear to reflect a more substantial effect of the single conditioning trial on N than on D. However, this effect was not observed in the form of stimulus effects in compound tests for the other groups, nor in stimulus differences in acquisition or extinction.

At this point it is not possible to say conclusively whether the stimulus effect represents a systematic difference between N and D that is only revealed by the compound test. More important for our present purposes is that the first and second experiments have made it perfectly clear that summation is a powerful effect in conditioned suppression. Equally significant is the fact that compound tests of summation appear to be sufficiently sensitive to distinguish between a "neutral" CS^o and a CS+ that has been paired once with shock, in spite of the fact that there were no detectable differences in trials on which those stimuli were presented alone.

C. Other Summation Demonstrations in Conditioned Suppression

Following the completion of Experiments 1 and 2, three additional demonstrations of summation in conditioned suppression were published. The first demonstration was by Miller (1969a). In his experiment, rats were trained to barpress for food reinforcement on a VI 40 sec schedule. Conditioned suppression training was then carried out with a tone and a light CS. The CS-US interval was 4 minutes. Shock intensity and duration were individually adjusted for each S so that both CSs produced moderate suppression. When the suppression stabilized, training was continued with the individual CSs for several additional days. On each of these days, a compound test was scheduled without shock.

In practically every test, the compound produced greater suppression than the average of either component. In later experimental procedures, Miller reported that compound presentations of two "weak" suppressing stimuli produced summation, but less net suppression than when the two stimuli were "strong" suppressors. Miller also found that in extinction, the compound continued to maintain suppression after the components had extinguished. Finally, Miller examined a novelty control similar to Group CS_2o described in Experiment 2. There were no indications that unconditioned stimulus effects were responsible for summation. Furthermore, when CS^o later was paired with shock so that it became a suppressing stimulus, compound tests revealed normal summation.

Van Houten, O'Leary, and Weiss (1970) trained rats on a VI 30 sec schedule, then carried out conditioning trials with tone and light individually paired with a .5 ma shock. At first the CS was 3 min, later increased to 6 min. In several sessions, all Ss received shock on only 50% of the trials in order to achieve moderate suppression levels.

Van Houten, et al, used two test procedures to show summation effects. The first test procedure used a "probe" technique, in which six-minute test trials were divided into three consecutive two-minute segments. In the first segment, either light or tone was presented alone. Then the second stimulus was added to the first for two minutes. In the final segment, the first stimulus was again presented alone.

The second test procedure tested components and compound in separate extinction trials. During each of five sessions, each component and the compound was tested ten times.

Van Houten, *et al*, reported that summation was obtained with both test procedures over several days, although the magnitude of the effects decreased over sessions.

The most recent demonstration of summation in conditioned suppression was reported by Weiss and Emurian (1970), with stimulus conditions that parallelled those used in the operant summation demonstration of Weiss (1969). Five rats were first trained to barpress on a VI 60 sec schedule. During the preliminary training sessions, both a tone and a light (T/L) were continuously present. The CSs were produced by either turning off the tone ($\overline{T}$) or turning off the light ($\overline{L}$). Conditioned suppression training began with a .5 ma, .3 sec shock. Shock intensity and duration, as well as the CS-US interval, were subsequently manipulated for each S so that moderate levels of suppression resulted.

When suppression had stabilized, a test session was scheduled that included 16 3-stimulus blocks of $\overline{L}$, $\overline{T}$, and $\overline{L}/\overline{T}$. The test session began with a 30 min "warm up" during which one $\overline{L}$ and one $\overline{T}$ trial were scheduled. During actual testing, each stimulus was presented for one-minute intervals, with two minutes of T/L intervening between trials. All Ss showed much more substantial suppression to the $\overline{T}/\overline{L}$ compound than to either of the components. Weiss and Emurian also reported that the compound maintained suppressive effects when the individual stimuli were substantially extinguished. These data clearly demonstrate the summation effect, and also confirm that summation results are not limited to conditioned suppression situations in which the stimulus compound may be described as "more intense" than the individual components.[10]

When the results of all these experiments are conbined, they indicate that summation is a powerful

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[10] Weiss' experimental demonstrations of summation in conditioned suppression and in food-reinforced bar-pressing have resulted in an analysis of the phenomenon which has been labeled Stimulus Composit Continuum Attentional Analysis. This analysis, and two experiments designed to support the analysis (Weiss, 1968; in press), are reviewed in Appendix A.

effect in conditioned suppression. The phenomenon has been shown with both components in early stages of acquisition (Experiment 1) one component in early stages of acquisition (Experiment 2), as well as components which have undergone extinction (Experiment 1, Miller, 1969; Van Houten, et al, 1970; Weiss and Emurian, 1970; also see Experiment 5 below). The training conditions range from relatively consistent CS and US treatments (Experiment 1, Experiment 2) to situations involving a good deal of variability in procedures. Weiss and Emurian adjusted the CS-US interval for each S; Miller, as well as Weiss and Emurian, adjusted US intensity and duration for each S; and Van Houten et al, varied the percentage of trials reinforced with shock. Finally, it is apparent that summation results are not dependent upon novel features of the compound (Experiment 2; Miller, 1969a) or limited in any way to combinations of stimuli "more intense" than the components. (Experiment 1 and 2, and especially Weiss and Emurian, 1970). In short, all of the experiments indicate that in conditioned suppression procedures involving rats, summation is a robust phenomenon, easily duplicated in a wide variety of experiment situations.

CHAPTER III

EXPERIMENTS ON COMPOUND ATTENUATION

In some instances, a compound of two individually conditioned stimuli may produce less conditioned responding than the level that would have been expected from a presentation of the "stronger" component alone. These results, in which the weaker stimulus appears to reduce the effectiveness of the stronger, are examples of what is referred to in this thesis as compound attenuation.

It has been noted previously (Chapter 1, p.6) that compound attenuation is very closely related to the Pavlovian concept of inhibition. In fact, since inhibition was defined in terms of acquired effects that are in apparent opposition to conditioned excitation, it has been emphasized here that compound attenuation may be an effective means of identifying inhibitory stimuli.

The use of the attenuation function to define inhibitory stimuli began in Pavlov's laboratory. For example, Pavlov found in his experiments that the presence of a novel stimulus could very easily disrupt established conditioned responding to a CS. This disrupting effect of novel stimuli was termed by Pavlov "external inhibition".

For a more complete description of external inhibition, we can turn directly to Pavlov:

> The following is a very simple case, and one of common occurrence in our earlier experiments. The dog and the experimentor would be isolated in the experimental room, all the conditions remaining for a while constant. Suddenly, some disturbing factor would arise--a sound would penetrate into the room; some quick change in illumination would occur, the sun going behind a cloud; or a draught would get in underneath the door, and maybe bring some odour with it. If any one of these extra stimuli happened to be introduced just at the time of application of the conditioned stimulus, it would inevitably bring about a more or less pronounced weakening or even a complete disappearance of the reflex response, depending on the strength of the extra stimulus. The interpretation of this simple case does not present much difficulty. The appearance of any new stimulus immediately evokes the investigatory reflex, and the animal fixes all its appropriate receptor organs upon the source of disturbance, pricking up its ears, fastening its gaze upon the disturbing agency, and sniffing the air. The investigatory reflex is excited and the conditioned reflex is in consequence inhibited.
> (1927, p.44)

Subsequent reaction to the use of the word "inhibition" in connection with this phenomenon is interesting. Diamond, Balvin, and Diamond (1958) have suggested that at the time Pavlov introduced the notion of external inhibition, almost no one outside of Russia was prepared to admit that external inhibition represented evidence for a special inhibition process. But Skinner, who has no fondness for the "inhibition" concept, admitted that this description of behaviour had "some historical right to the term 'inhibition'", (1938, p. 17).

Apparently at least one of Pavlov's contemporaries had more substantial doubts than Skinner about the appropriateness of the term "external inhibition". Konorski expressed this uncertainty in a later review of Pavlovian theory by noting, "It is obvious that external inhibition can be completely explained from the view point of the general laws governing reflex activity, and that it is nothing but one of the numerous manifestations of interference between antagonistic reflexes." (1948, p. 114)

Our concern in this thesis will be with stimuli that acquire inhibitory properties as measured by attenuation, rather than those that exert an effect in the absence of any particular conditioning procedure. Indeed, we shall examine a number of control groups to help rule out contributions to attenuation effects by "novel" features of stimulus compounds. Although external inhibition may have the "historical right" alluded to by Skinner, the term "inhibition" will be reserved here for attenuation results that are attributable to certain specified conditioning procedures.

A. Early Pavlovian Experiments on Compound Attenuation

In Pavlov's system, acquired properties of attenuation were described as "internal inhibition". Most of the observations made by Pavlov in this context made use of a conditioning paradigm that he labeled "conditioned inhibition". In the basic conditioned inhibition procedure, two CSs (CS+ and CS-) were used. CS+ trials were followed by a US, while CS+/CS- trials were not. Consequently, CS+ came to elicit a CR, while CS+/CS- produced no CR.

Pavlov emphasized that this demonstration with CS+ and CS+/CS- did not in itself provide proof that CS- exerted an active "inhibitory" influence in the compound. He noted one possible alternative that responding to the compound may have "passively extinguished" as a result of nonreinforcement. However, the identification of CS- characteristics was difficult, because individual presentations of that stimulus produced no measureable response.

One solution of the problem was to present CS- in compound with another positive conditioned stimulus, CS_2+. Prior to that compound test, CS- had never been associated with CS_2+. When such a test was performed, Pavlov reported, "The inhibitory properties of the additional stimulus became clearly revealed, the result being an immediate diminution in the positive reflex response associated with CS+2". (1927, p.75)

As an example of this general procedure, Pavlov described an experiment by Leporsky. In a somewhat complicated situation, a dog was trained with three CS+s (CS_1+ = lamp flash; CS_2+ = rotating object; CS_3+ = tone of C sharp), such that all three elicited salivation. Two other stimuli (CS_4- = tactile stimulation to the skin; CS_5- = metronome) were then paired with CS_2+ in nonreinforced presentations. Thus, at the end of the pre-training phase of the experiment, CS_1+, CS_2+, and CS_3+ produced about the same level of salivation while both CS_2+/CS_4- and CS_2+/CS_5- produced no salivation.

In two separate sessions, Leporsky then examined the effects of CS_4- and CS_5- in compound with other CS+s. It was apparent that adding a CS- for the first time to another CS+ produced a dramatic drop in conditioned responding.

Pavlov also illustrated the compound test for inhibition by referring to an experiment by Babkin. In this experiment, CS- was established as a conditioned inhibitor by presenting it in unreinforced compound trials with a CS+ that was separately paired with food. Subsequent tests of CS- showed that it could also exert an attenuating influence on the level of salivation produced by a second CS+ that had been paired with a weak acid solution. In Pavlov's laboratory, conditioned salivation responses established with acid and food USs were regarded as different or "heterogenous" reflexes. Thus, Pavlov maintained that conditioned inhibitors had very powerful effects that extended across response systems.[11]

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[11] It should be noted that this feature of Pavlov's work received considerable criticism from Konorski (1948). Konorski argued that the "heterogenous" responses chosen by Pavlov's group for examination were almost invariably acid-salivation and food-salivation, which was scarcely the most convincing pair of responses for making the point. In fact, Konorski rather reversed Pavlov's formulation to imply that the degree to which summation and attenuation are produced in compound tests of stimuli controlling different responses might be an index of the extent to which the responses overlap, or are <u>not</u> heterogenous.

Pavlov also cited a second experiment by Leporsky designed to show that the extent to which responding is attenuated by a conditioned inhibitor is dependent on the magnitude of the response which is to be attenuated. Three stimuli were first established as positive conditioned stimuli (CS_1+ = rotating object; CS_2+ = tone; CS_3+ = flash). In the next phase of the experiment, CS_4- (tactile stimulation) was established as a conditioned inhibitor in unreinforced compound trials with each of the three CS+s, so that any individual CS+ combined with CS_4- produced no salivation.

One result of the experiment has been previously described. When the three CS+s were presented simultaneously, they showed much more salivation than any one presented alone. Leporsky went on to test the compound of 3 CS+s and the CS-. The compound tests showed that although the CS- could completely eliminate salivation to any one of the CS+s, when they were all presented in compound only partial attenuation was obtained.

It is perfectly clear that Pavlov wished to distinguish between these examples of attenuation produced by a CS- as a result of inhibitory conditioning procedures, and external inhibition produced by a novel CS^o. Although he presented no data, he emphasized that the stimuli chosen to serve as CS- in experiments such as Leporsky's had been shown not to produce external inhibition. Clearly, he wished to emphasize that any inhibitory properties that were present in CS- were acquired in the conditioning sequence.[12]

The attenuation effect was often replicated in Pavlov's laboratory. Following the English translation of his Conditioned Reflexes (1927), some investigators sought to duplicate his paradigms using other responses and subjects. For example, Shipley (1934) trained human subjects in an eyelid conditioning situation to discriminate between a light flash as a CS+ and a compound of flash and buzzer as CS-. While the discrimination was readily acquired, Shipley did not demonstrate that the attenuating function of CS- transferred to a second

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[12] Pavlov may have had more substantial doubts about the inhibitory function of CS- after he presented these arguments. Syrenskii (1958) says that in 1925 (one year after the lectures in the 1927 volume were actually delivered), Pavlov advanced the possibility that "inhibition" in the conditioned inhibition procedure actually developed to CS+/CS- acting as a unit, rather than exclusively to CS-. Actually, Syrenskii included data in his paper to support that position, but his experiment involved sequential, rather than simultaneous presentations of CS + and CS - , and it is not entirely clear how that modification relates to Pavlov's original paradigm. Pavlov apparently never voiced his misgivings about the inhibitory function of CS- in print, and Syrenskii is not specific about why Pavlov may have found his earlier position less convincing.

CS+. Consequently, it is not possible to specifically attribute inhibitory properties to CS-. It could also be argued, for example, that the Ss responded to S+/S- as a unit, without S- acquiring special characteristics in the process.[13] In general, there are relatively few instances prior to 1960 in which compound tests for attenuation were actually used to identify inhibitory stimuli.[14]

Rodnick (1937) used compound tests in an attempt to confirm Pavlov's contention that the early portion of a long CS may acquire inhibitory properties ("inhibition of delay"). This experiment was complicated by the fact

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[13] There were also some parallel efforts to show the effectiveness of Pavlovian paradigms in operant conditioning situations. Woodbury (1943) trained dogs to lift a bar for food reinforcement when either one of two buzzers was present, but responses made when both buzzers were present were unreinforced. Kimble (1961) cited this experiment as an example of a conditioned inhibition study with operant conditioning, but Woodbury's study was considerably more complicated than Pavlov's basic paradigm and he did not show transfer of S- inhibitory function. In short, Kimble was again premature in entending the Pavlovian phenomenon to the operant case.

[14] Pavlov reported more frequent use of a related strategy, in which the "inhibitory after-effect" persisting after the termination of an inhibitory stimulus, was measured. In one experiment by Beliakov (cited by Pavlov, 1927, p. 125), a dog was differentially conditioned with a "definite tone of an organ-pipe" serving as CS+ while "an interval of 1/8 lower" served as CS-. The inhibitory properties of CS- were revealed in the test sequence. When CS+ closely followed CS-, a dramatic reduction of salivation over earlier and later CS+ trials was observed. Apparently, this strategy is still favoured in Russian laboratories (e.g., Soventov and Chernigovskii, 1959).

that it involved an effort to use the early portion of a long CS+ for GSR conditioning to attenuate the effect of a shorter CS+ for conditioned eyeblink. Although the results are somewhat difficult to interpret, Rodnick's experiment is significant as a rare early example of the attenuation phenomenon being used as an analytic tool.

A later example was provided by Szwejkowska (1957) with salivary conditioning in dogs. Two dogs were trained in a four-stimulus differential conditioning situation. CS_1+ and CS_2+ were the sound of a bell and "bubbling", respectively; CS_3- and CS_4- were the sound of a metronome and a whistle. Szwejkowska emphasized these stimuli had no prior training. Conditioning proceeded at a rate of 5-6 CS+ trials and 1-3 CS- trials daily until performance had stabilized. Then while conditioning continued, compounds of either a positive and a negative conditioned stimulus, two positives, or two negatives were tested at widely spaced intervals. The results showed that compounds of CS+ and CS- produced less salivation than comparison CS+ presentations. Tests of CS+/CS+ produced salivation that did not differ from individual CS+ trials.[15] The tests of CS-/CS- produced no saliva-

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[15] This result may have been due to the fact that the individual CS+s were at asymptote when compound tests were scheduled.

tion. Szwejkowska concluded on the basis of the tests that CS- acquired inhibitory properties in the differential conditioning procedure.

B. Operant Conditioning Experiments

The first demonstration of attenuation in an operant paradigm was by Cornell and Strub (1965). A total of six rats were trained in a food-reinforced discriminated barpress. Two signal lights served as positive stimuli (S_1+ and S_2+), in the presence of which barpressing was rewarded on a VI 1 min schedule. Presentation of a third light served as a negative stimulus (S_3-), during which no barpresses were reinforced. When responding had stabilized, Cornell and Strub tested the individual stimuli, and the compounds of S_1+/S_3-, S_2+/S_3-, S_1+/S_2+, and S_1+/S_2+/S_3-. No responses were reinforced during the test.

As noted in the previous chapter, Cornell and Strub found that tests of S_1+/S_2+ showed a clear summation effect. Tests of the other compounds showed an equally clear attenuation effect. Presentations of S_1+/S_3- and S_2+/S_3- produced less barpressing than individual presentations of S_1+ or S_2+. Furthermore, tests of S_1+/S_2+/S_3-

produced less responding than tests of S_1+/S_3+, but more than either S_1+/S_3- or S_2+/S_3-.

Note that the test comparisons and the results of Cornell and Strub parallelled those of Leporsky's, which were reported by Pavlov (1927). Unlike the Pavlovians, however, Cornell and Strub did not deal with the possibility that attenuation functions might be due to nonassociative mechanisms that should be classified as "external inhibition".

An experiment by Brown and Jenkins (1967) demonstrated operant attenuation and also included a group to control for possible novel effects. Three pigeons were first trained to peck the right half of a split key when the key was red, and to peck the left half when the key was green. When that response had stabilized, training progressed to a second discrimination involving the presence and absence of a tone. Using just one of the key colours, pecks to the appropriate side were rewarded whenever the tone _was_ _not_ present. When the tone _was_ present, pecks were _not_ reinforced. This phase of the experiment was an operant reconstruction of Pavlov's conditioned inhibition paradigm. In the final phase the attenuating function of tone was tested in extinction with both of the key colours. The results showed a clear tendency for the tone to reduce responding in both the key colour in which auditory training had been carried out, as well as in compound tests with the second key colour. Similar tests conducted with a novel stimulus showed no marked attenuation. Because of its role in the conditioned inhibition paradigm, the tone acquired an attenuating function that could be demonstrated with a second CS+. Moreover, the novel stimulus control showed this result to be independent of external inhibition effects.

A final example of operant attenuation has been reported by Weiss (1967). Four rats were given training on a "multiple schedule" in which either a VI 30 sec or a DRL 20 sec schedule was in effect. During those intervals in which the DRL was in effect, all responses separated by a minimum of 20 seconds were reinforced. Responses separated by less than 20 seconds were not reinforced. The VI and DRL components of the Multiple schedule were signalled by either a tone or a light. The result was high rates of barpressing in the VI 30 component, and low rates in the DRL component.

Tests of the components and the compound were conducted in extinction. The compound uniformly showed rates of barpressing that were lower than those observed in the VI component, higher than those observed in the

DRL component. Although no control data were reported by Weiss, it seems that in operant procedures, a stimulus need not be correlated with non-reinforcement for it to produce attenuation in compound tests.

C. Recent Pavlovian Experiments on Compound Attenuation

Recently, there has been renewed interest in attenuation phenomena in Pavlovian conditioning situations. In large part, this renewed interest has been due to efforts such as those of Rescorla and his collaborators (e.g. Rescorla and Solomon, 1967; Rescorla, 1967a, 1967b, 1969c, Rescorla and Wagner, in press) to point out an unjustified lack of interest in inhibitory effects in North American conditioning experiments.

A number of experiments have studied inhibitory effects in transfer designs, following the general experimental strategies that were described in Chapter 2 (p. 30) for the study of summation effects. For example, Rescorla and LoLordo (1965) found that a CS- established as a conditioned inhibitor could reduce the rate of a Sidman Avoidance response. If the assumption is made that conditioned fear is an important factor in maintaining the avoidance response, the reduced avoidance response rate suggests that the presence of CS- served to actively reduce the level of fear. Bull and Overmier (1968) duplicated this finding in a discrete-trial avoidance procedure. Rescorla (1967a) used a similar procedure to examine the properties of the various portions of a relatively long CS in a study of inhibition of delay.

Other investigators have sought to study attenuation phenomena in situations in which the sources of conditioned excitation were more clearly specified. As with the recent Pavlovian summation experiments reviewed in Chapter 2, a great many of these experiments have been conducted in conditioned suppression situations.

Hendry (1967) made the first effort to extend the conditioned inhibition paradigm to conditioned suppression. Six rats were first trained to barpress for food on a VI 1 min schedule. Conditioned suppression training was then carried out. Ss received 16 two-min trials daily, including eight shock-reinforced trials with white noise (CS+), and eight unreinforced trials with a white noise/light compound (CS+/CS-). Over twelve sessions, it was apparent that the Ss did acquire the discrimination, showing marked suppression to CS+ and no suppression to CS+/CS-. Unfortunately, Hendry did not provide a second CS+ with which it might be determined if the attenuating function of CS- extended beyond the original CS+/CS-compound. Thus, although Hendry showed that rats could learn a discrimination based on the conditioned inhibition paradigm, it is by no means certain that the lack of suppression to the CS+/CS- compound was due to any "inhibitory" characteristics of CS-.

Hammond (1967) made the first effort to provide a convincing demonstration of attenuation in conditioned suppression. Twenty rats were divided into a differential conditioning group and a "random" control (see Rescorla, 1967b). All Ss were first trained to bar press for water reinforcement on a VI 1 min schedule. When the baselines stabilized, conditioned suppression training was initiated. On each of ten conditioning days, both groups received three trials daily of three-min tone (CS+) terminated with a .72 ma .5 sec shock; and three trials of three-min light (CS-), never paired with shock. The groups differed in the constraints imposed on the scheduling of CS- trials. For the differential group, CS- never occurred during CS+ or during the three minutes preceding CS+. For the random group, CS- could occur at any point in the session. Presumably, then, on occasion CS- immediately preceded or overlapped CS+ for the random group and consequently was a relatively poorer indicator of intervals free from shock.

When the conditioning phase was completed, the compound of CS+/CS- was extinguished in all Ss for five days at three trials daily. No presentations of CS+ were scheduled during these sessions.

The results of the tests showed that the CS+/CS- compound produced significantly less suppression in the differential group than for the random group. These results are in accord with what might be anticipated from CS- acquiring inhibitory properties in the differential conditioning procedure. However, both groups showed a dramatic reduction in suppression on the first block of three unreinforced compound tests (from nearly complete suppression in both groups to about .24 for the random group, .30 for the differential group). Since there are no data from CS+ - alone trials on the test days, it is not entirely clear if this reduced suppression is less than that which might have been expected from CS+ - alone at the same point in extinction. Lacking that information, it is not really possible to say if either or both groups showed a significant attenuation effect, or if CS- acquired inhibitory properties as a result of either conditioning procedure.

A more convincing demonstration of attenuation in conditioned suppression was provided by Cappell, Herring, and Webster (1970). These investigators first trained four rats to barpress on a VI 60 sec schedule of food reinforcement. Differential conditioned suppression was then scheduled for 14 days. During barpress sessions, three trials of CS+ and three of CS- were programmed. CS+ trials were terminated with a .5 sec shock of 1.1 ma. The stimuli were a 65 dB 3,000 Hz tone, and two flashing lights, one red, one white.

The three CS+ and CS- presentations continued in each of 30 test sessions. Using a "probe" technique, the attenuating effect of CS- was examined in compound presentations with CS+, which were scheduled during either the first or second minute of each CS+ trial. Cappell, _et al_, presented data from the last ten compound sessions, five of which had CS- tests during the first minute of CS+ trials, five during the second minute. The results clearly showed that CS- presentations in the first minute produced a disruption of suppression. Substantial suppression resumed when the CS- was terminated. However, attenuation in the second minute tests was dependent on a stimulus effect. In the two Ss for which CS- was light, second-minute probes resulted in attenuation of suppression. But when CS- was tone, no attenuation was observed in second-minute tests. It is also interesting that when light was CS-, both Ss showed marked acceleration on CS-trials, an effect that was not observed when tone served as CS-.

It seems unlikely that the difference may be attributed to light being "more intense" than tone, since acquisition was more rapid when tone served as CS+ than when light served as CS+. The data of Cappell, et al, are useful since they point to the possibility of unanticipated stimulus effects in compound tests. The lack of comparison groups, however, makes it difficult to assess the extent to which these results may reflect the influence of nonassociative effects.

Extensive attenuation data, as well as data from a control group for external inhibition, have been reported by Rescorla (1969b). Four groups of eight rats were first trained to bar press on a VI 2 min schedule for food reinforcement. Sessions were then conducted in a conditioning box which provided no opportunity for bar pressing or food reward. In each of five two-hour "inhibitory" conditioning sessions, Ss were exposed 12 times to a two-min tone (CS-). Shock never occurred in the presence of the tone. Rescorla was concerned with demonstrating that the degree to which tone functioned as an inhibitor in each of four groups was related to the relative frequency of shock occurring in its absence (the degree of "negative contingency"). Group 0-8 received shock frequency of .8 per 2-min non-CS- ($\overline{\text{CS-}}$) interval; Group 0-4 received .4 per 2-min $\overline{\text{CS-}}$ interval; Group 0-1, .1 per 2-min $\overline{\text{CS-}}$ interval; while Group 0-0 never received shock in the absence of CS-. Group 0-0 served to control for "novel" features of the compound.

After the CS- conditioning, a flashing light CS+ was prepared in a conditioned suppression procedure to serve as a comparison stimulus in tests. In each of three barpress sessions, four two-min trials of CS+ were programmed, two of which terminated with 2.5 sec 1 ma shock.

Two test sessions followed CS+ conditioning. In each of these, CS+ and CS+/CS- were each tested twice in counterbalanced sequence. The results of these tests indicated that Group 0-8 showed the greatest attenuation followed in decreasing order by Groups 0-4 and 0-1. No marked attenuation resulted in the control Group 0-0. The indication was that the effectiveness of the various inhibitory training procedures was related to the degree of negative contingency. Equally important for our purposes, the effectiveness of the various inhibitory training procedures was revealed in the attenuation results, and those results were separable from unconditioned stimulus effects.

The sensitivity of attenuation to different inhibitory training procedures has also been documented by Rescorla and Wagner (in press). One experiment they report was conducted by Wagner and Saavedra in an eyelid conditioned inhibition paradigm, with rabbits serving as Ss. The authors wished to demonstrate that the inhibitory strength of CS- in a conditioned inhibition paradigm is dependent on the excitatory response-eliciting strength of the accompanying CS+. All Ss were first trained with two stimuli, CS_1+ and CS_2+ so that CS_1+ was a "strong" elicitor of eyeblink while CS_2+ was "weak". This was accomplished by reinforcing CS_1+ 240 times, CS_2+ only 8 times. In the same conditioning sequence, a third stimulus (CS_3+) was reinforced 548 times. CS_3+ served as a comparison stimulus in later compound tests. In the conditioned inhibition phase of training, CS- was presented in unreinforced compound trials with either CS_1+ or CS_2+. Reinforced trials of either CS_1+ or CS_2+ continued, depending on which stimulus appeared in the compound. Finally, the inhibitory properties of CS- were assessed for all Ss by presenting it in compound with CS_3+. The results of the tests showed strong attenuation for the groups trained with the $CS_1+/CS-$ combination.

Finally, Rescorla and Wagner (in press) describe an experiment conducted by Rescorla in the conditioned suppression paradigm. As in the Wagner and Saavedra experiment, Rescorla was also concerned with demonstrating that the inhibitory strength acquired by CS- in a conditioned inhibition paradigm depended on the excitatory strength of the accompanying CS+.

Three groups of eight rats were first trained to bar press for food delivered on a VI schedule. Then a tone (CS_1+) and a flashing light (CS-) were presented in a conditioned inhibition paradigm. The excitatory strength of CS_1+ was varied in the three groups by reinforcing CS_1+ trials with shocks of either 0, .5, or 1.0 ma. CS_1+/CS- trials were never reinforced with shock. This procedure was programmed while Ss bar pressed. Over 30 days of training, Ss received 45 CS_1+ trials and 75 CS_1+/CS- trials. When this training was completed, CS_2+ (a second tone) was trained as a comparison stimulus for compound tests. While Ss bar pressed, CS_2+ trials were reinforced with a .5 ma shock on a 50% schedule. Subsequent compound tests showed that there was substantial attenuation in the 1 ma group, little in the .5 ma group, while the 0 ma group showed no substantial signs of attenuation.

The experiments reviewed in this section provide a good deal of evidence that attenuation results when CS+ and CS- are tested in compound following CS- training in procedures defined as inhibitory. These findings support the notion that inhibitory stimuli may be identified by means of compound tests. However, since all the experiments involved testing after extended training sequences, there remains some question of the sensitivity of the attenuation index when inhibitory stimuli are in early stages of acquisition.

This extended training feature is particularly characteristic of the conditioned suppression experiments. Hammond's (1967) experiment involved 30 CS+ - shock and 30 CS- trials over ten days; Cappell, et al, (1970), administered 42 CS+ - shock trials and 42 CS- trials over 14 days; Rescorla employed 60 CS- trials, no distinct CS+ and an unspecified number of shocks over 5 days in his 1969 experiment; 45 CS+ - shock trials and 75 CS+/CS- trials over 30 days in the experiment reported by Rescorla and Wagner (in press).

Attenuation is of interest in this thesis because there are some circumstances in which one may wish to identify very weak inhibitory effects. If attenuation provided a relatively sensitive index of weak effects, the combined summation/attenuation analysis proposed earlier (Chapter I, p. 7) might be used to examine stimuli with unknown properties. Thus, the two experiments to be described in the next sections were conducted to provide some necessary information about the outcomes of compound tests administered after limited exposure to differential conditioning.

Experiment 3: Compound Tests Following Differential Conditioned Suppression Training: I. Induction-like Effects.

Two groups of rats were examined in this experiment. The first group received differential training with three trials of CS+-shock, and three of CS- on each of four conditioning days. Later, extinction tests were conducted with CS+, CS-, and CS+/CS-, in order to assess attenuating properties of CS-.

In the second group, three CS+-shock trials were programmed on each of four conditioning days, while a second stimulus (CS^o) was reserved as a "neutral" stimulus. Later, CS+, CS^o and $CS+/CS^o$ were tested in extinction, in order to evaluate the possible importance of nonassociative effects in compound attenuation.

METHOD

Subjects

Twenty hooded rats were divided into two groups of ten.

Apparatus

The apparatus was unchanged from Experiment 1. The CSs were darkness and 80 dB white noise. US intensity was set at 1.3 ma, with a duration of .5 sec. The CS-US interval was 90 sec.

Procedure

Magazine and bar press training proceeded in the same sequence as Experiment 1. Preliminary VI 3 min training continued for five two-hour sessions. During the sixth session, N, D, and N/D were each pretested twice in 90 sec presentations.

All conditioning took place during four consecutive VI 3 min sessions. In each session, Ss in Group 3/3/A received three CS+ trials terminated by shock, and three CS- trials which never terminated by shock. The order of presentation of CS+ and CS- was determined with the aid of a random numbers table. Pairings of CS+ and US were programmed as in the earlier experiments.

Ss in Group 3/0/A received 3 CS+-shock pairings in each session. These trials were presented at the same intervals in each conditioning session as the CS+

trials for Group 3/3/A. The stimulus designated as CS^o was never presented during conditioning.

Extinction tests of the three stimuli were conducted in the course of the next five VI 3 min sessions. On each test day, Ss in Group 3/3/A received four consecutive blocks of three stimuli. Two block sequences were used: (1) CS+, CS-, CS+/CS- and (2) CS+, CS-, CS+. Stimulus duration during tests remained at 90 sec. Half the Ss received the blocks in a (1), (2), (1), (2) sequence, which was reversed for the other half. Testing was conducted in the same way for Group 3/0/A, with CS^o substituting for CS-.

RESULTS

Median pretest ratios for N, D, and N/D were .47, .40, and .46 respectively. These differences did not approach significance.

The acquisition data for both groups are summarized in Figure 9. In Group 3/3/A a clear differentiation between CS+ and CS- suppression appeared on trial 3 ($U = 13$, $p < .02$), and the differences continued over subsequent conditioning trials. Although previous reports (Hammond, 1966) have indicated that acceleration

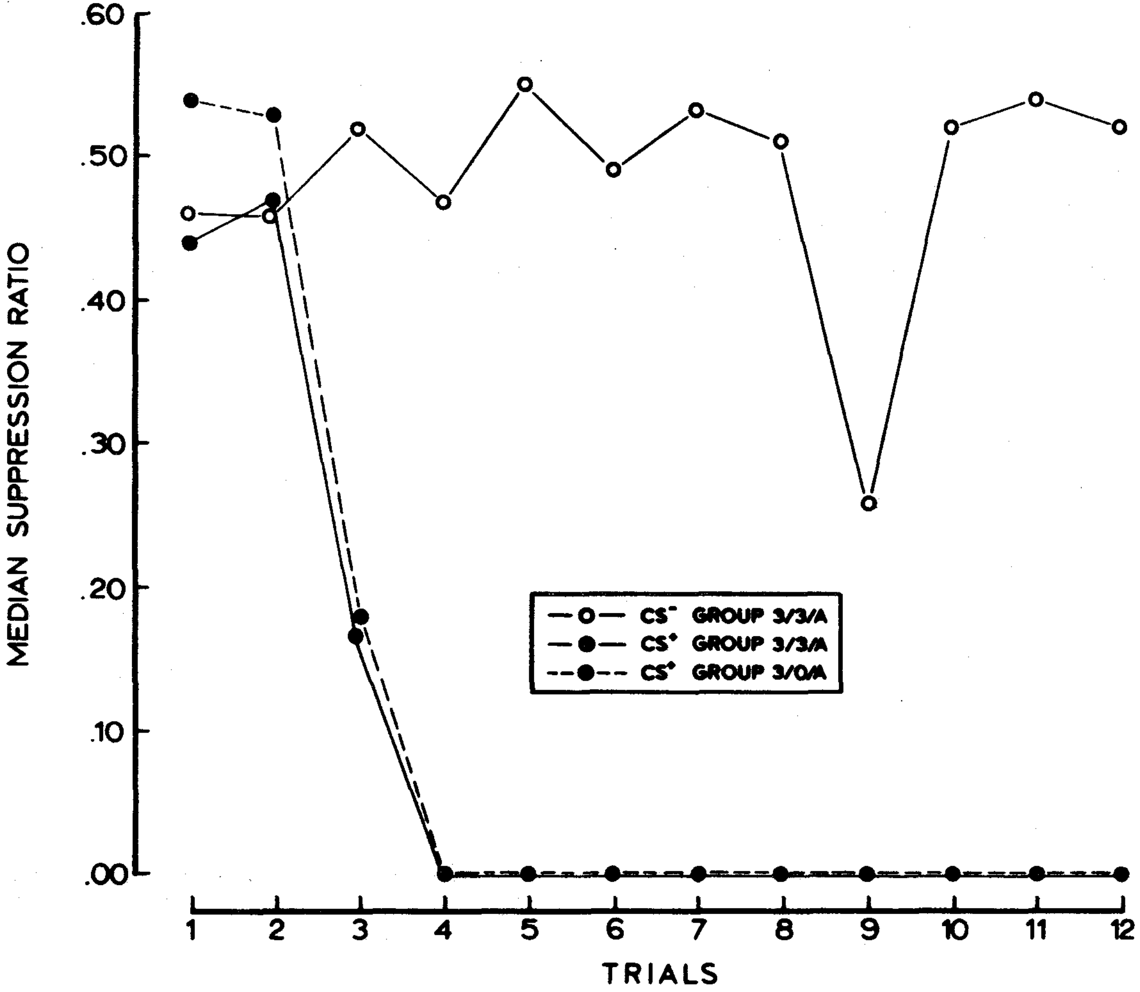

Figure 9. Experiment 3 acquisition data, showing median suppression ratios for CS+ and CS- for Groups 3/3/A, and CS+ for Group 3/0/A.

may be observed to CS- in a differential conditioned suppression paradigm, no consistent indications of CS- acceleration were found in these data.

CS+ acquisition functions for the two groups were virtually indistinguishable, and no significant effects were found when the acquisition data were examined for systematic effects of N or D serving as CS+ or CS-.

In extinction tests, the mean suppression ratios recorded for each stimulus on each day were defined as daily suppression ratios. The median daily ratios for each stimulus recorded over all five test days are shown for both groups in Figure 10. It is clear from the figure that in both groups less suppression was observed to the compound than to the CS+-alone, particularly in later test days. The attenuation data were summarized in the form of attenuation scores, calculated daily for each S by subtracting the daily CS+ ratio from the corresponding daily compound ratio. The mean daily attenuation scores for each group are shown in Figure 11, with the positive scores indicating the attenuation tendencies in both groups. Analysis of variance (summarized in Table 2) confirmed that the "days" effect was significant, indicating progressively larger attenuation scores over test days in both groups.

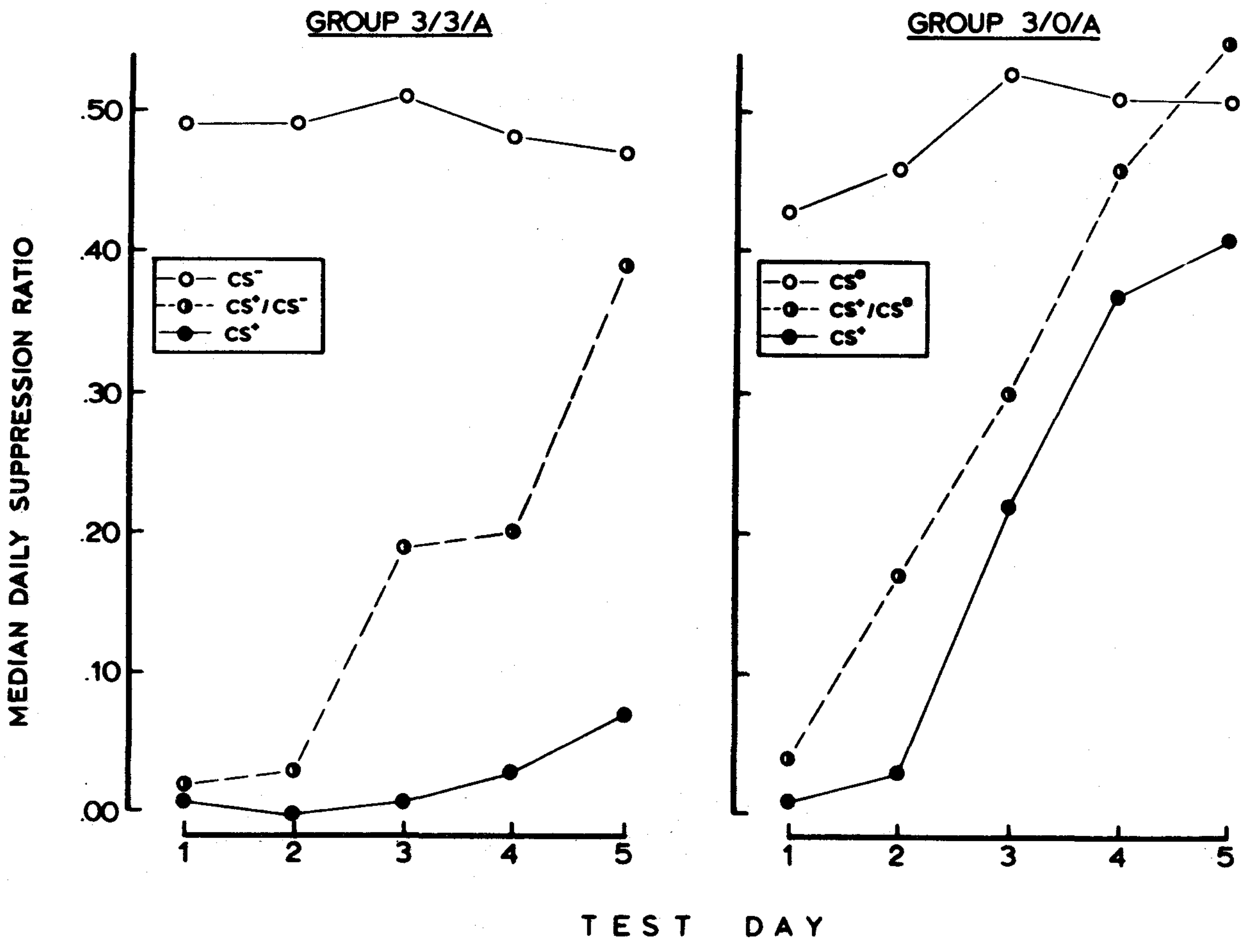

Figure 10. Experiment 3 extinction test data. The median daily suppression ratios for each stimulus condition are shown for five consecutive test days. Daily suppression ratios were defined as the mean suppression ratio recorded on four unreinforced presentations of the appropriate stimulus.

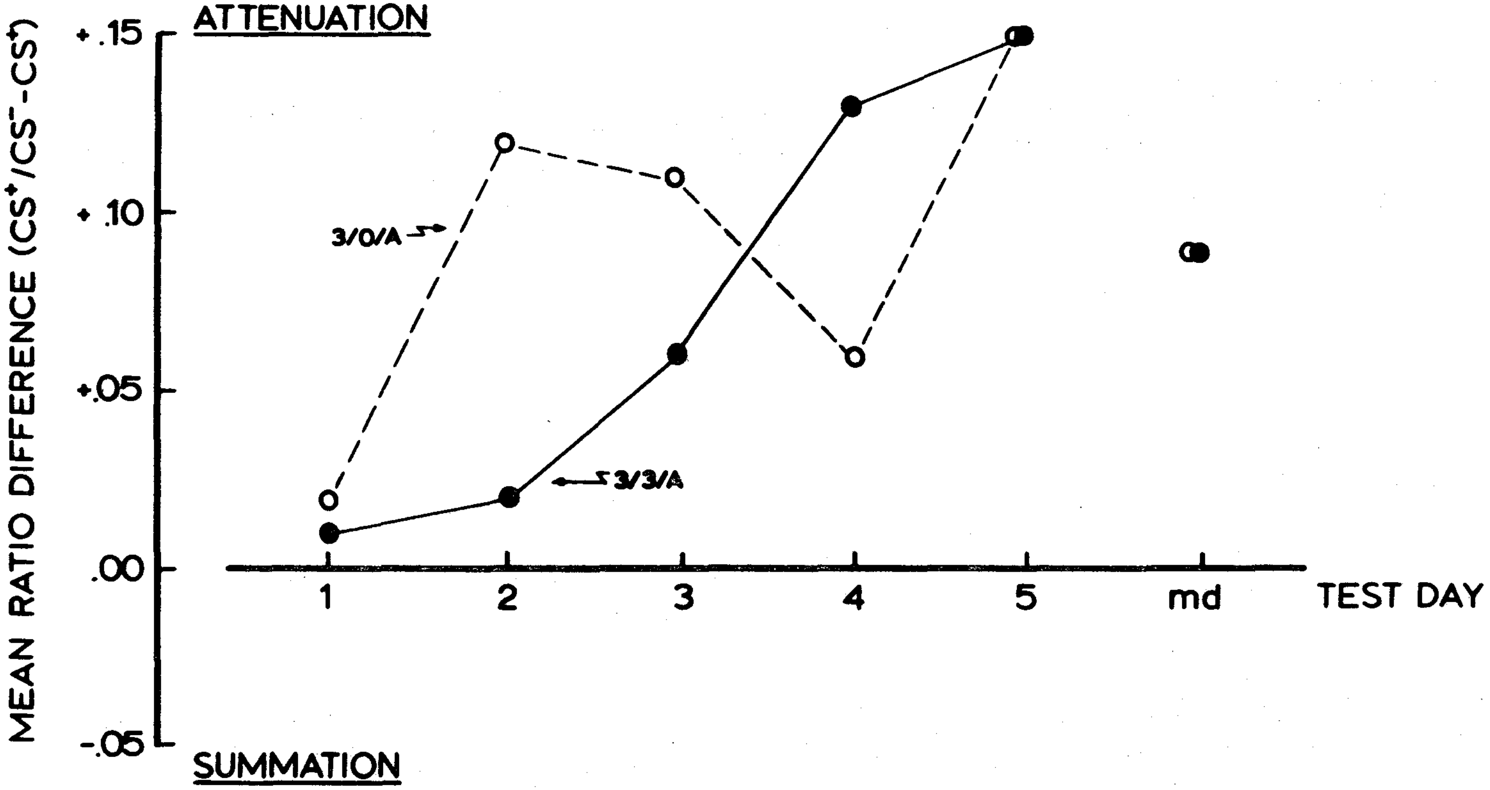

Figure 11. Mean ratio difference test scores for Experiment 3, recorded over all test days. Ratio difference scores were computed daily for each S by subtracting the mean CS+ daily ratio from the mean compound daily ratio. Positive scores indicate an attenuation tendency, while negative scores indicate a summation tendency.

Table 2 Analysis of Variance Summary: Experiment 3 Test Difference Scores

Source	SS	df	MS	F	P
Between Variables					
Groups	.64	1	.64	.002	
Subjects	3892.84	9	432.538		
Subjects x Groups	1276.36	9	141.818		
Subjects within Groups	5169.20	18	287.17		
Within Variables					
Days	1360.84	4	340.21	4.15	< .01
Groups x Days	174.76	4	43.69	.53	
Subjects x Days	1611.56	36	44.76		
Subjects x Days x Groups	4295.24	36	119.31		
Days x Subjects within Groups	5906.80	72	82.03		

In terms of the overall ability of CS- or CS^o to reduce CS+ suppression, there were no significant differences between the groups.

One difference that was obtained between the groups, however, is clearly shown in Figure 10. CS+ was much slower to extinguish in Group 3/3/A than in Group 3/0/A. However, closer examination of these data revealed that the CS+ extinction effect was dependent on whether N or D served as CS+. The relevant data are summarized in Figure 12, showing CS+ extinction for both groups when N and D served as CS+.

Analysis of variance (summarized in Table 3) confirmed the result shown in Figure 12. In addition to a significant trials effect (which reflects the general extinction of CS+ over 5 days of unreinforced trials), both the trials X stimuli and trials X groups interactions were significant.

DISCUSSION

Contrary to expectations, the attenuation index did not show significant differences between the two groups. Compound test results showed an attenuation

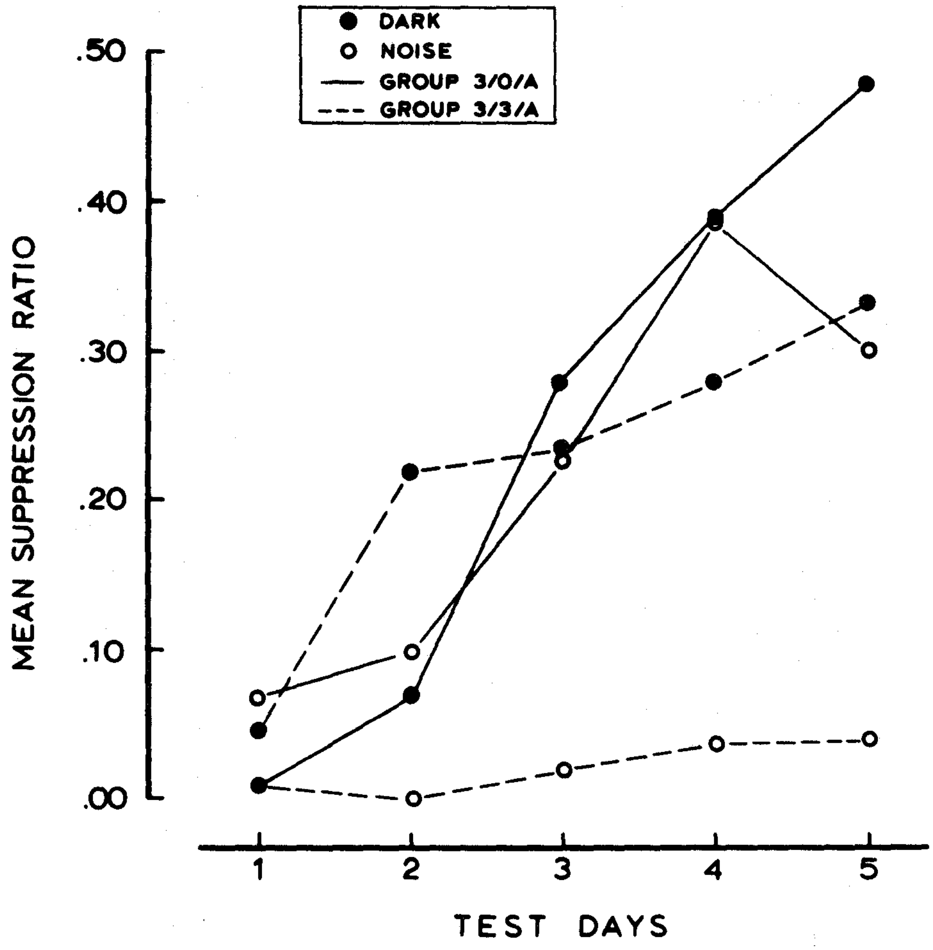

Figure 12. Mean CS+ suppression ratios recorded in extinction test blocks in Experiment 3, when 75 db white noise or darkness served as CS+.

Table 3 Analysis of Variance
CS^+ Extinction for N and D
Groups 3/3A and 3/0/A

Experiment 3

Source	SS	df	MS	F.	D
Between Variables					
Groups	.312	1	.312	3.74	> .05
Stimuli	.298	1	.298	3.33	>.05
Groups x Stim.	.174	1	.174	1.74	>.05
Error	1.335	16	.083		
Within Variables					
Trials	.991	4	.248	35.78	<.001
Trials x Groups	.215	4	.054	7.76	<.001
Trials x Stim.	.143	4	.036	5.15	<.001
Trials x Groups x Stim.	.016	4	.004	.57	
Error	.443	64	.007		

effect in both groups that increased over days of testing.

Based on the test results, one might be tempted to conclude that the differential conditioning procedure did not exert a substantial influence on conditioned properties of CS-. However, CS+ was much slower to extinguish in Group 3/3/A than in Group 3/0/A, an outcome which suggests that the differential conditioning procedure may have exerted an effect.

The resistance to CS+ extinction in Group 3/3/A bears a marked resemblance to observations reported by Pavlov (1927). Under some circumstances, Pavlov asserted, presentations of CS- could result in a facilitation of responding to CS+. This phenomenon, which he labeled "positive induction" was identified as one manifestation of inhibitory properties of CS-.[16]

In describing positive induction, Pavlov referred to an experiment by Foursikov. A dog was trained

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[16] There is a paradox in the positive induction effect (in which a CS- trial yields an increased effectiveness of subsequent CS+ trials) in that Pavlov also described inhibitory after-effects (in which a CS- trial yields a decreased effectiveness of subsequent CS+ trials). Pavlov indicated at one point that induction was associated with "maximal development of cortial inhibition" and that it "disappears after the inhibition has been finally stabilized". However, he went on to note that there were exceptions to that general rule, and the conditions under which inhibitory after-effects and positive induction could be expected were apparently never worked out in detail.

in a salivary conditioning situation using tactile stimulation to the forepaw as CS+, tactile stimulation to the hindpaw as CS-. CS- was conditioned until, in Pavlov's words, "not a single drop of saliva appeared in response to stimulation of the inhibitory place" (1927, p. 189). Foursikov then compared CS+ presentations closely following CS- with those preceding it, and others following it by longer intervals. When a CS+ trial closely followed CS- (by 30 sec), salivation was increased by as much as 50% over control levels.

A closer parallel to the present data has been provided by Senf and Miller (1967, Experiment 1) in a conditioning situation involving rats, a food US, and a "general activity" CR. They found that when CS- trials intervened between unreinforced CS+ trials, extinction was much slower than when CS+ trials were not accompanied by CS-. Equally important, the intertrial interval in Senf and Miller's experiment was 10 min, which suggests that very short intervals between CS- and CS+ such as those used in Pavlov's laboratory are not a necessary condition for induction-like effects.

Although there are parallels between these data and positive induction demonstrations, it is by no means certain that the resistance to CS+ extinction in Group 3/3/A is an example of positive induction. In the absence of appropriate comparison groups, for example, it is not clear that the presence of CS- was necessary for the effect. Nor is it clear why attenuation was most prominent when N served as CS+, although the stimulus effect is less surprising when compared with similar examples in this thesis (Experiment 2; also Cappell, Herring, and Webster, 1970). It does not seem that this stimulus effect may be attributed to 80 dB white noise being somehow "more intense" than darkness. If that were the case, faster acquisition to N as CS+ would also have been anticipated, but no significant effects were observed in acquisition in either group. Moreover, if the effect were attributable to implicit characteristics of N, similar attenuation results would have been expected in Group 3/0/A. However, no stimulus effects were observed in that group at any point.

For the purposes of this thesis, it is of less immediate importance to identify the precise causes of these effects than to recognize their potential implications on compound test procedures. First, the data show very clearly that in the later stages of an experiment, stimulus effects may appear that would be completely unexpected on the basis of data from earlier stages. Second, CS+ comparison levels may vary in extinction tests because of sequential "induction-like" effects that differ between procedures.

The stimulus effects that have been observed here and by Cappell, et al, (1970), raise questions about those attenuation demonstrations reviewed earlier in which counterbalancing procedures were not observed. Fortunately, the extent of those influences can be assessed relatively easily by making counterbalancing a routine precaution.

However, the possibility of CS+ comparison levels varying is more serious, since these systematic effects could introduce substantial biases in test data. This possibility is illustrated in the present results. CS+ produced complete suppression in most subjects on the first two test days, but attenuation was observed only in Group 3/0/A. If CS- trials in Group 3/3/A had the by-product of enhancing CS+ strength in early test trials in Group 3/3/A, attenuation demonstrations would have been more difficult to obtain. The direct implication of these data is that compound test procedures would be much more easily interpreted if CS+ has some moderate suppressing strength. It is also clear that comparisons should be made when both CS+ and CS+/CS- follow CS- trials, so that both measurements are influenced similarly by any existing sequential effects.

Of course, it is by no means certain that the failure of these attenuation data to distinguish between "conditioned inhibitory properties" of CS- and "unconditioned inhibitory properties" of CS^o is entirely due to induction-like effects. The failure could also be due to the 3/3/A conditioning paradigm being an inefficient inhibitory conditioning procedure.

In this experiment, conditioning began with trials of CS- and CS+-shock in the first session. This runs counter to the custom in Pavlov's laboratory, however, where it was the practice to introduce CS- only after CS+ was rather well-established as an excitatory stimulus. Although many of the previously reviewed examples of compound attenuation also began conditioning with both CS+ and CS- (Szwejkowska, 1957; Cornell and Strub, 1965; Hammond, 1967; Cappell, et al, 1970), these all involved extended training sequences. Little enough is known about the acquisition function of inhibitory properties to make it interesting to speculate that the stage of CS+ conditioning at which CS- is introduced could well make a difference, particularly when inhibitory conditioning is not carried out over a long period of time.

In summary, although this experiment failed to demonstrate the utility of compound attenuation tests as a means of distinguishing between weak inhibitory stimuli and neutral stimuli, it served to point out potentially complicating features of conditioning and test procedures. These considerations resulted in several modifications of the conditioning and test procedures in the next experiment, in which a second effort was made to demonstrate attenuation following limited exposure to differential conditioning.

2. Experiment 4: Compound Tests Following Differential Conditioned Suppression: II. Attenuation.

As in Experiment 3, this experiment studied a 3/3 Differential Group and a 3/0 Nondifferential Group. A number of changes were introduced in conditioning and test procedures in an effort to demonstrate attenuation effects that could be attributed to the differential conditioning paradigm.

METHOD

Subjects

Originally, 24 hooded rats were formed into two groups of 12. Illness and procedural irregularities forced the elimination of four Ss, two from each group.

Apparatus

The apparatus consisted of six Skinner Boxes and associated programming equipment. The stimuli used as CSs were darkness (D) and 80 dB white noise (N). US intensity was set at 1.3 ma, with a duration of .5 sec. CS duration was 90 sec in all trials. Conditioning trials were programmed with shock as previously described.

Procedure

Magazine and bar press training proceeded in essentially the same way as earlier experiments. Preliminary VI 3 min training continued for five two-hour sessions. During the sixth session, two pretest presentations each of N, D, and N/D were programmed. For four Ss in Group 3/3/B, D was CS+, N was CS-. The functions were reversed for the remaining six. For five Ss in Group 3/0/B, D was CS+ while N was reserved as a "neutral" stimulus (CS^o). The functions were reversed for the remaining five.

Figure 13 shows the design of the acquisition phase of the experiment, and the details of the test procedure for both groups. The conditioning phase lasted four days, designated C1 through C4. The conditioning sequence was changed from the previous experiment, so that CS+ was established before the introduction of CS-. On days C1 and C2, all Ss in both groups received three CS+trials which terminated with shock. On days C3 and C4, Group 3/3/B received three CS+-shock trials, terminated with shock, and three trials of CS- that did not terminate with shock. On days C3 and C4, Group 3/0/B continued to receive only three CS+-shock trials, while the second stimulus, CS^o, was reserved as a neu-

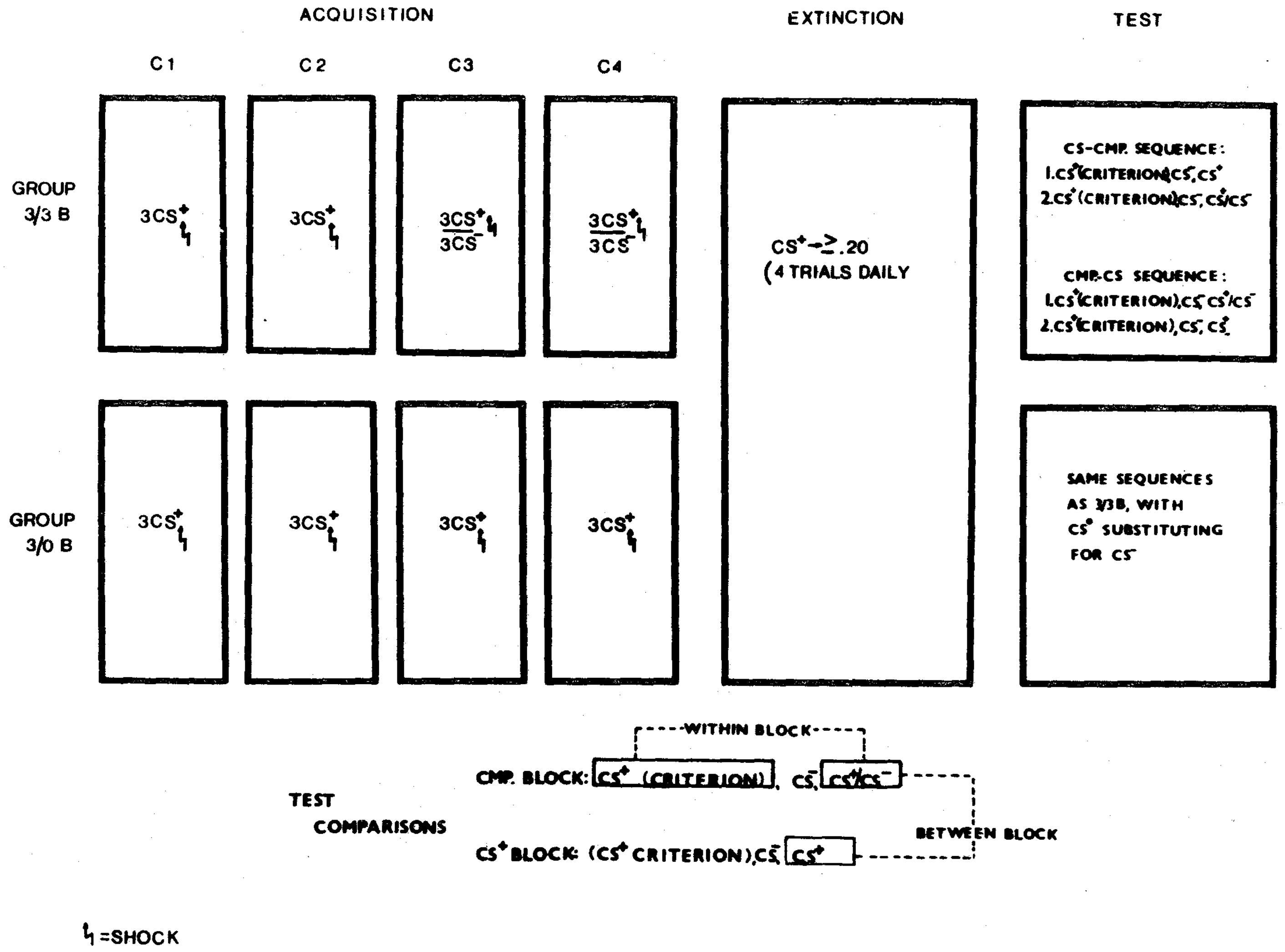

Figure 13. Diagram of Experiment 4 procedure, showing events programmed in acquisition, extinction, and test phases.

tral stimulus. CS+-shock trials in Group 3/0/B occurred at the same points in each session as CS+-shock trials in Group 3/3/B.

Trial sequences and intertrial intervals were selected with the aid of a table of random numbers. During the bar press session following day C4, no stimulus presentations were made in order to insure stable bar press baselines in the test phase.

The compound test procedure was arranged so that the suppressing strength of the comparison CS+ could be observed. In order to accomplish this, a series of unreinforced CS+ trials was administered to each S until an extinction criterion was reached, defined as a single trial on which CS+ suppression was equal to or greater than .20. After the .20 criterion was reached, compound tests were programmed.

Test sessions for Ss in Group 3/3/B were scheduled as follows: first, CS+ was presented without shock four times in the first 90 minutes of a two-hour bar press session. Trial-by-trial suppression ratios were monitored for each S throughout the session. If S did not reach the .20 criterion by the fourth trial, no further stimulus presentations were made in that session. If criterion was reached by trial 4, the next trial programmed was CS-, followed by CS+ for half the Ss, CS+/CS- for the other half. On the following day, CS+ was again presented for a maximum of four trials. When the .20 criterion was reached, a CS- trial followed, succeeded in turn by either CS+ or CS+/CS-, whichever had not been tested on the previous day. On those occasions on which CS+ criterion was not met until the third or fourth trial, one or two additional trials were programmed in the last 30 minutes of the session to complete the test block.

Testing continued until all Ss received four test blocks, two designated as CS+ Blocks (CS+ criterion trial, CS-, CS+) and two designated as Compound Blocks (CS+ criterion trial, CS-, CS+/CS-). Extinction and testing proceeded in the same way for Group 3/O/B, except that CS^{o} substituted for CS-.

RESULTS

Median pretest ratios for N, D, N/D were .39, .42, and .48, respectively. These differences did not approach significance.

The acquisition data for both groups are shown in Figure 14. CS+ acquisition curves showed only slight, nonsignificant differences between the groups, and no significant stimulus effects were detected.

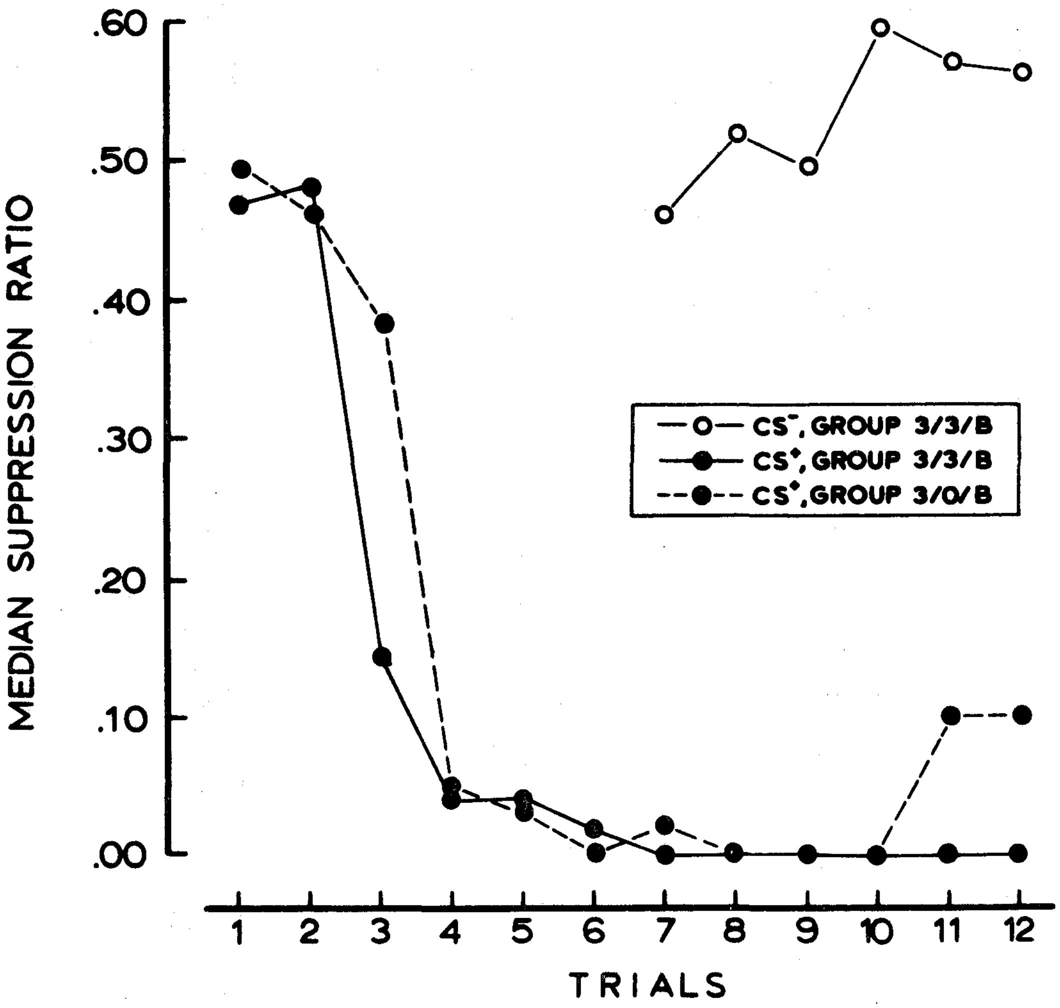

Figure 14. Experiment 4 acquisition data showing median suppression ratios for CS+ and CS- for Group 3/3/B, and CS+ for Group 3/0/B, over consecutive test trials.

In contrast with Experiment 3, the present differential conditioning procedure resulted in significant acceleration to CS-. On day C4, Group 3/3/B showed CS- suppression ratios that were reliably greater than .50 (median daily ratio = .58; Wilcoxon $T = 3.5$; $p < .01$). The development of acceleration in CS- training sessions was associated with a reliable decrease in baseline response rates over those observed at the beginning of conditioning. Average pre-CS- rates on days C3 and C4 compared with average pre-CS+ rates on days C1 and C2 showed a median decrease of 19% in Group 3/3/B. This depression of bar press baselines on CS- conditioning was highly significant (Wilcoxon $T = 0$; $p < .01$).

The median number of trials required to reach the CS+$\geq$.20 criterion are shown in Table 4. No consistent differences were found, either between groups or between stimuli.

Results of the test phase are shown in Figure 15. The results of the first CS+ and compound blocks are superimposed for each group, as well as the second CS+ and compound blocks. The final set of data shows the averages of both CS+ and both compound blocks.

Two major comparisons of compound and CS+-alone suppression were examined in the test results.

Table 4

Experiment 4: Trials to CS1 $\geq$ .20 Extinction Criterion

		N^+	D^+
Group 3/3 B	median:	14	16
	range:	(8-15)	(3-22)
Group 3/0 B		16	11
		(4-25)	(3-32)

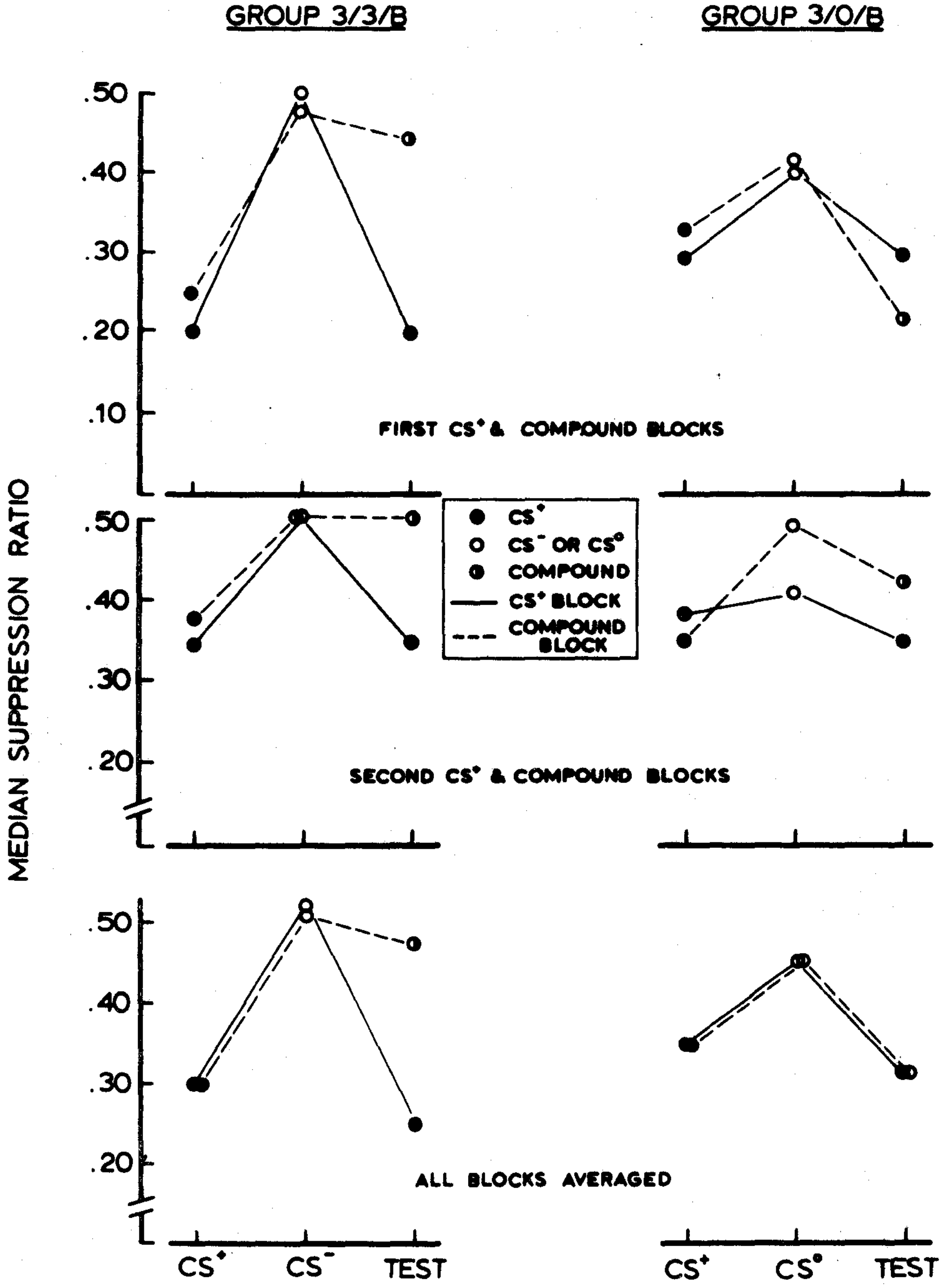

Figure 15. Extinction test results for Experiment 4. The upper portions of the figure summarize the results of Blocks 1 and 2, while Blocks 3 and 4 are represented in the middle portions. The results of all blocks are averaged in the lower portions. Blocks containing the compound in test position are represented by broken lines, while blocks with CS+ in the test position are represented by solid lines.

(see Figure 13). Within-block comparisons were made of suppression on the compound trial with suppression observed on the presentation of CS+ that formed the first criterion trial of the compound block. Between-block comparisons were made of suppression on the compound trial with suppression observed to CS+ when it was also in the third position of a CS+ block. Compound suppression in the first compound block was compared with CS+ suppression in the first CS+ block, while compound suppression in the second compound block was compared with CS+ suppression in the second CS+block.

Both comparisons showed a strong attenuation effect in Group 3/3/B. When all tests were combined, CS+/CS- produced reliably less suppression than CS+-alone in either the between or the within-blocks position [Whitney's extension of the T-test: $p(H = 2.1, 2.9) < .01$] .

Group 3/0/B showed no comparable signs of attenuation. In the first set of test blocks, slightly greater suppression was recorded to CS+/CS^{0} than to CS+. In the second set, slightly less compound suppression was observed than to CS+. Neither of these results approached significance, and the overall effect for Group 3/0/B was that compound test blocks were indistinguishable from CS+ test blocks.

Examination of CS+-alone suppression revealed no reliable differences between groups, indicating that induction-like effects were not present in these data. The attenuation effect received further support when comparisons of compound suppression averaged over all blocks showed that CS+/CS- in Groups 3/3/B produced reliably less suppression than CS+/CS^{o} in Group 3/0/B ($U = 26$, $p = .05$).

Since the order of presentation of test blocks was counterbalanced, there were actually two sequences of between-block comparisons. Ss tested under the compound-CS+ sequence (CMP-CS) received compound blocks on days 1 and 3, CS+ blocks on days 2 and 4. Ss tested under the CS+-compound sequence (CS-CMP) received CS+ blocks on days 1 and 3, compound blocks on days 2 and 4. Since Ss tested under the CS-CMP sequence received compound blocks on the day following CS+ comparison blocks, between-block comparisons under that sequence could have been made with a compound that was more extinguished than the comparison CS+. One might, therefore, anticipate greater apparent attenuation under the CS-CMP sequence than under the CMP-CS sequence, where the extinction bias was reversed.

The test results were in accord with that prediction. The left portion of Figure 16 shows the

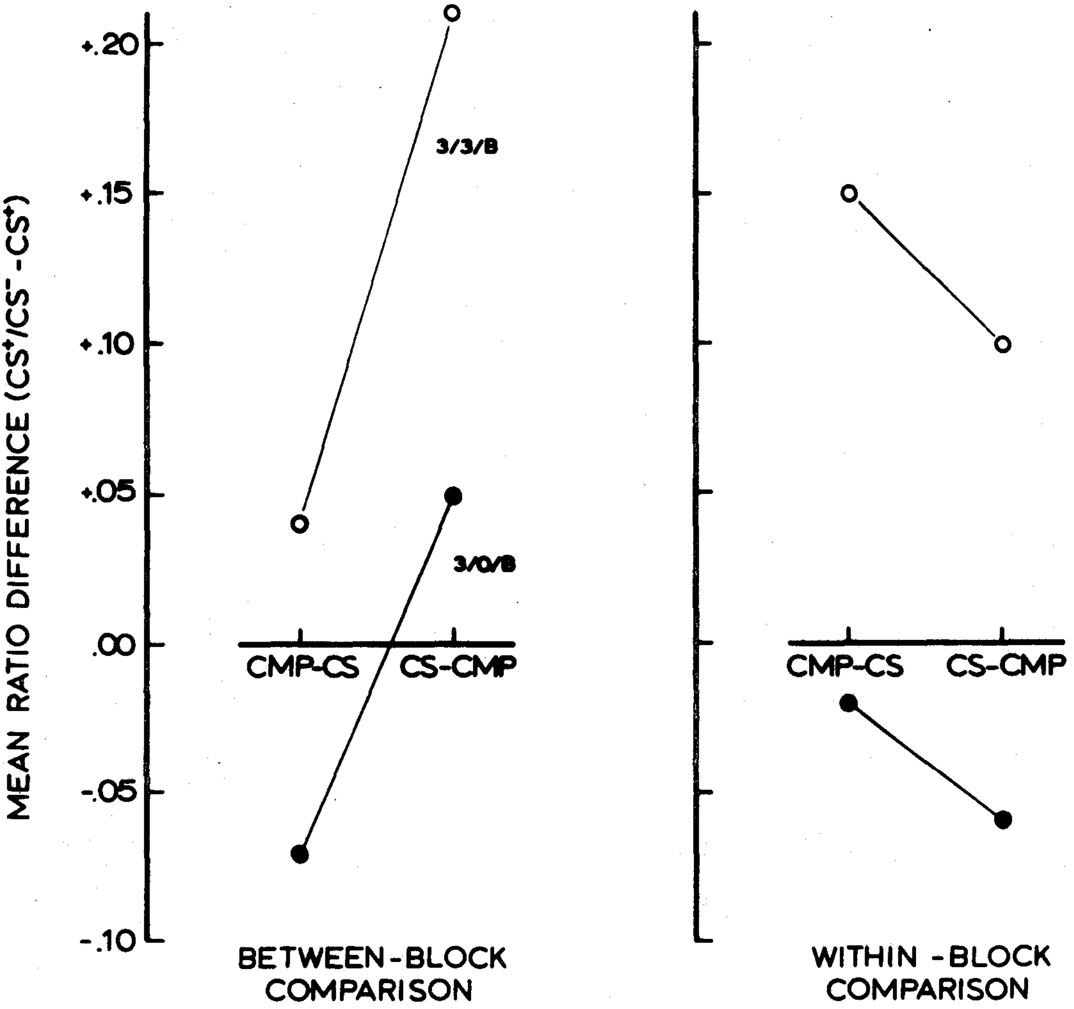

Figure 16. Mean ratio difference for both test sequences in Experiment 4, for between-block and within-block comparisons. Ratio differences were computed for each S by subtracting the appropriate mean CS+ test ratio from the compound test ratio. See text for further details.

Table 5A

Summary: Groups x Test Sequence Analysis of Variance

Between-Block Comparisons

Source	SS	df	MS	F	P
Total	368.28	19			
Groups	154.13	1	154.13	7.29	< .025
Sequence	200.64	1	200.64	9.50	< .01
Groups x Seq.	8.50	1	8.50	.40	ns
Error	338.8	16	21.13		

Table 5B

Summary: Groups x Test Sequence Analysis of Variance

Within-Block Comparisons

Source	SS	df	MS	F	P
Total	243.07	19			
Groups	199.52	1	199.52	6.96	p< .025
Sequence	41.67	1	41.67	1.45	ns
Groups x Seq.	1.89	1	1.89	.07	ns
Errors	458.4	16			

mean difference between average compound and CS+ ratios for both groups under both sequences. A 2 X 2 unequal-N analysis of variance (summarized in Table 5 A) confirmed that both the "sequence" and "Groups" effects were significant.

Since within-block comparisons of CS+ and compound were scheduled on the same day, one might expect that the test sequence would not exert a systematic effect. Maintaining the same group divisions, a similar analysis was performed on the results of within-block comparisons, as diagrammed in Figure 16. No significant sequence effects emerged, and analysis of variance (Table 5 B) confirmed that only the "Groups" effect was significant.

The data were also examined for effects attributable to functions of N and D. The results of the analysis are diagrammed for between-block comparisons in the left protion of Figure 17. It is clear that a more substantial attenuation tendency was recorded in between-block comparisons when D was CS+, N CS-. Analysis of variance confirmed that both stimuli and group effects were significant (Table 6 A).

When stimulus effects were examined in within-block comparisons, however, a very different picture

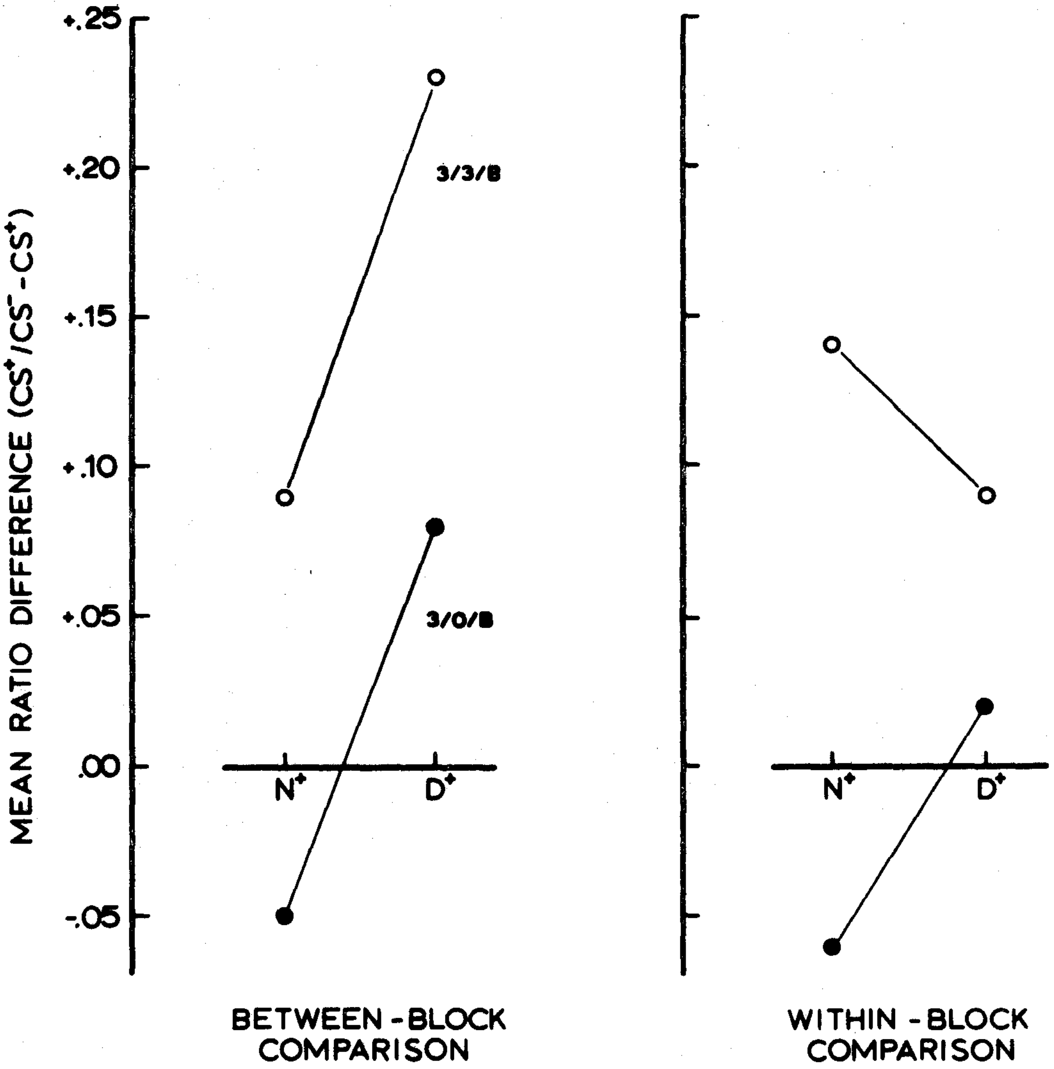

Figure 17. Mean ratio difference for Experiment 4 when 80 db white noise or darkness served as CS+, for between-block and within-block comparisons. Ratio differences were computed for each S by subtracting the appropriate CS+ mean test ratio from the compound test ratio. See text for further details.

Table 6A

Summary: Groups x Stimuli Analysis of Variance

Between-Block Comparisons

Source	SS	df	MS	F	P
Total	373.71	19			
Groups	205.49	1	205.49	9.31	<.01
Stimulus	168.09	1	168.09	7.62	<.025
Groups x Stim.	.13	1	.13	.01	ns
Error	352.96	16	22.06		

Table 6B

Summary: Groups x Stimuli Analysis of Variance

Within-Block Comparisons

Source	SS	df	MS	F	P
Total	241.23	19			
Groups	195.02	1	195.02	7.07	<.025
Stimulus	1.78	1	1.78	.06	ns
Groups x Stim.	44.42	1	44.42	1.61	ns
Error	440.64	16	27.54		

emerged. These data are displayed in the right portion of Figure 17. When within-block comparisons were made, no systematic stimulus effects were revealed. Analysis of variance (summarized in Table 6 B) indicated that only the groups effect was significant.

DISCUSSION

The most important result of this experiment was that attenuation resulted in compound tests of CS+ and CS- following differential training in Group 3/3/B. Compound tests in Group 3/0/B produced very different results: average CS+/CS^o suppression did not differ from the suppression observed to CS+-alone. Moreover, between-group comparisons showed that average levels of CS+/CS- suppression were reliably lower than corresponding levels of CS+/CS^o suppression, while corresponding levels of CS+-alone suppression did not differ. In short, compound tests differentiated clearly between the attenuating effects of CS- and the non-attenuating effects of CS^o.

In contrast with Experiment 3, there were no significant indications of positive induction in Group 3/3/B. Because of the many modifications of conditioning and test procedures in this experiment, it is not clear why the induction effect was not observed. At this point is is best to again make note of the fact that such effects were observed in Experiment 3, and continue to take precautions against sequential effects surrounding CS- trials that may bias the outcome of compound tests.

One feature of earlier experiments that is shared by Experiment 4, however, is that stimulus effects were observed in compound tests although no stimulus effects were observed in earlier stages of the experiment. Although no reliable differences could be detected between N and D during pretest, acquisition, or in the number of trials to the .20 extinction criterion, between-block comparisons in compound tests showed that greater attenuation resulted when N served as CS- than when D served as CS-. However, this effect did not reach significance when examined in within-block comparisons.

Similar stimulus effects have been encountered in Experiments 2 and 3. In Experiment 2, no differences in pretest ratios, speed of acquisition, or resistance to extinction were observed between 75 dB N and D. Yet, when compound tests were conducted after CS_2+ had been paired once with shock, summation was much more prominent when CS_2 was N than when CS_2 was D. In Experiment 3, induction-like effects were more prominent when CS+ was 80 dB N than when CS+ was D, in spite of the fact that no corresponding differences were observed in either pretest, acquisition, extinction, or attenuation.

It is perfectly clear from these data that demonstrating similar conditioning properties of N and D at one stage of an experiment does not offer any assurance that the stimuli will also prove to be equivalent at a later stage. This problem of stimulus equivalence is both intriguing and troublesome.

Fortunately, the attenuation phenomenon which was of primary interest in this experiment cannot be attributed to stimulus effects or to sequential effects surrounding CS+. The major importance of this experiment is that attenuation was observed in compound tests following limited exposure to a differential conditioning procedure. This observation suggests that attenuation might be used to identify weak inhibitory stimuli, when inhibitory properties are defined in terms of effects antagonistic to excitation.

Recently, Rescorla (1969c) has addressed the question of using compound tests to identify CSs that have acquired inhibitory properties. In particular, he has pointed to the importance of distinguishing between inhibitory mechanisms of attenuation and "attentional" mechanisms of attenuation.

Investigators have frequently used compound tests to draw inferences about the "attention" of Ss to certain stimuli. For example, Szwejkowska (1957) contended that his demonstration of attenuation, which was described earlier in this chapter, showed that CS- acquired active properties in conditioning, rather than being "unattended to". If the animal had not detected the presence of CS- in the CS+/CS- compound, he argued, the level of CS+ responding could scarcely have been affected.

Rescorla (1969c), however, has used a version of Szwejkowska's argument as a possible non-inhibitory mechanism of attenuation. Under some circumstances, Rescorla has noted, compounding CS+ with CS- may result in a "shift" of attention away from CS+. As a result, CS+ might well be expected to lose effectiveness in controlling behaviour. However, rather than being due to an associative inhibitory mechanism, the diminished effectiveness of CS+ could be due to the fact that CS- was somehow a more salient stimulus that "commanded the attention".

It should be noted immediately that Rescorla does not argue that all attenuation is attributable to attentional factors. On the contrary, he very strongly maintains that under a wide range of experimental conditions, attenuation may be attributed to inhibition; that is, response tendencies that are opposite conditioned excitation. The important point of Rescorla's formulation is that under some conditions, attenuation may also possibly result from attentional factors. The problem is to make an empirical, as well as a conceptual, distinction between these two mechanisms.

To accomplish this, Rescorla has pointed to a second technique for measuring inhibitory properties. If a stimulus acquires inhibitory characteristics, it would be expected that subsequent excitatory conditioning with that stimulus would be slower than with a neutral stimulus. Hammond (1968), for example, interpreted slower acquisition of conditioned suppression to a former CS- for shock as evidence that the CS- was inhibitory.

Rescorla has suggested that if both the compound and retardation test techniques are used, the distinction between attentional and inhibitory mechanisms may be made. If attenuation results from CS- "capturing the attention", excitatory conditioning with CS- should proceed at least at a normal rate. But if the attenuation is the result of inhibitory factors, excitatory conditioning with CS- should be retarded.

The attenuation and retardation of acquisition measures are seen by Rescorla as being complimentary in one other respect. If one shows that acquisition is retarded to a CS-, it could be argued that the conditioning was slower because the animal did not attend to the stimulus. However, if the same stimulus shows attenuation, using Szwejkowska's argument, one could say that CS- must have been detected, and consequently attended to.

Taken together, these two test procedures could provide an elegant analysis. But before Rescorla's argument may be thoroughly assessed, a good deal of fundamental information about the sensitivity of the two measures must be obtained. The matter of sensitivity seems particularly important when relatively weak inhibitory stimuli are being studied. Experiment 4 indicates that the compound test procedure detects inhibitory effects after only two differential conditioning sessions. A similar test of the sensitivity of retardation of acquisition tests remains to be performed. Until such information is available, a failure to confirm compound results with the retardation of acquisition procedure could be attributed to differential sensitivities of the techniques.

One final point should be made about the selection of compound tests for the experiments in this thesis. In Experiment 2 and the experiment to be described in the following chapter, compound tests were conducted with a comparison CS_1 and a very weak excitatory CS_2. In these situations, the excitatory properties of CS_2 were indicated by rather dramatic summation effects. It seems possible that reacquisition tests could also have been conducted with CS_2, showing faster conditioning than would have been anticipated with a neutral stimulus.

Of the two test procedures for excitatory effects, compound tests seem less susceptible to contamination from attentional factors. For example, if CS_2+ did command more attention than CS_1+, one would still not expect greater suppression to the compound than to either CS_1+ or CS_2+ presented alone. The prediction that might be generated under those circumstances would be that the compound would produce a level of suppression approaching that associated with CS_2+ alone.

Reacquisition tests are quite different in that respect. If faster acquisition were observed to CS_2+ than to a neutral stimulus, it could easily be argued that it did so simply because it was "better attended to". Rescorla (1969c) has raised this possibility in connection with the faster acquisition that is frequently reported with extinguished stimuli. In short, if there is a possibility of weak excitatory effects being revealed in a test procedure, as in the following experiment, compound tests would seem to provide more definitive information.

CHAPTER IV

Experiment 5: Extinction As an Inhibitory Training Procedure

Extinction is a fundamental process in learning; consequently, theoretical interpretations of extinction are many and varied. In this thesis, extinction is of interest because it has been identified by traditional Pavlovian theory as the prototype of inhibitory training procedures. Four major observations led Pavlov (1927) to that view of extinction.

The first was that extinction of one CS very frequently had similar effects on other CSs. In experiments in which several CSs were conditioned concurrently, extinction of one often had the effect of weakening responding to the others. Pavlov labeled that phenomenon "secondary extinction".

The second observation was the very interesting fact that extinction rarely produced permanent elimination of the CR. If an extinguished CS was not presented for a period of time, a marked recovery of response strength was frequently observed when presentations resumed. Since the renewed response strength followed an interval in which no reinforced trials occurred, and since it occurred on the very first renewed presentation, the effect was termed "spontaneous recovery".

The spontaneous recovery phenomenon gave rise to a third set of observations termed by Pavlov "extinction below zero", in which the effects of extinction appeared to continue even if nonreinforced trials were scheduled after the observable CR had disappeared. The "deepening" effect of these additional extinction trials was revealed by a substantial decrement in spontaneous recovery.

Finally, Pavlov found that extinguished CRs could momentarily be restored by superimposing a novel stimulus on the extinguished CS. The effect was as if the novel stimulus temporarily counteracted a restraining or inhibiting tendency. Consequently, this phenomenon was labeled "disinhibition".

The fact that extinguished CRs showed spontaneous recovery indicated that the weakening of the response could not be attributed to permanent damage of associative connections. Moreover, since extinction could be continued beyond the zero point, and since the extinguished response could be momentarily restored by the disinhibiting action of a novel stimulus, it could not be reasonably argued that extinction was due to a "fatigue mechanism" which rendered the S physically incapable of further exercising the response. After summarizing these observations, Pavlov concluded:

> By a process of elimination, we are forced to the conclusion that experimental extinction is based on inhibition, and if we look at the facts which have been described in the light of this conclusion, nearly all of them become perfectly intelligible. (1927, p. 60)

Extinction thus became the basis of inhibitory training procedures in Pavlov's theory.

In retrospect, it is not entirely obvious that Pavlov should have been "forced" to the conclusion that extinction necessarily involves inhibition. Under many conditions, the absence of responding to a CS may be more parsimoniously described as a relative lack of excitation, rather than being due to an active inhibitory mechanism. Descriptions of weakened response tendencies in terms of inhibition are compelling only if one offers some independent measure of the inhibition (cf. Jenkins, 1965; Brown and Jenkins, 1967).

Rather than being independent sources of evidence, Pavlov's observations were ultimately converted into properties of inhibition. Secondary extinction served as an evidence that extinction was inhibitory but it was also regarded as evidence that inhibition spread to other associative connections. Spontaneous recovery served as evidence that extinction was inhibitory, but it also was cited as evidence that inhibition decayed over time. In short, a circular arrangement resulted in which extinction was regarded as an example of inhibition; and characteristics of extinguished stimuli then became principles of inhibition.

Although Pavlov later introduced the compound test as a demonstration of acquired inhibitory properties, there is no indication that he attempted to show attenuating functions of a CS that had undergone simple experimental extinction. Rescorla (1969c) has recently called attention to this oversight. As noted earlier (Chapter 3) Rescorla has emphasized that the negative contingency between CS- and US may be a very important factor in producing an inhibitory stimulus. Since the US is not present in the typical extinction procedure, no negative contingency can exist. Rescorla has consequently argued that if reacquisition or compound tests are used to assess characteristics of extinguished

CSs, no signs of inhibition should be revealed.

Actually, Pavlov himself (1927, p. 59) reported rapid reqcquisition with extinguished CSs, rather than the retarded acquisition that might be expected with inhibitory stimuli. In describing his results, Pavlov suggested that the unanticipated reappearance of the CR was due to a "disinhibition" effect produced by the reintroduction of the US. Of course, this account was weakened considerably by the fact that disinhibition was typically a short-term phenomenon, and the effects of reinforced trials in the reacquisition procedure were much more enduring. Pavlov dealt with this apparent discrepancy only briefly, noting that the long-term effects of reconditioning indicated that disinhibition was a complicated phenomenon indeed, and that further research was necessary to understand those effects. Although this strategy left the inhibition account of extinction momentarily intact, the effect was to obscure indications of a very interesting aspect of extinguished stimuli: rather than "converting" excitatory stimuli to active inhibitors, extinction may leave a "residue" of excitation.

Subsequent to Pavlov's observations, evidence was made available which confirmed that reacquisition with extinguished stimuli proceeds at a very rapid rate (e.g., Konorski and Szejkowska; 1950, 1952). Thus, reacquisition observations support the notion that extinguished excitatory stimuli might retain excitatory properties.

As noted earlier, however (Chapter 3, p. 131), reacquisition tests appear to be particularly inconclusive when weak excitatory properties are in question. In the compound summation experiments reviewed in Chapter 2, a number of examples were cited (cf. especially Experiments 1 and 2) in which stimuli that no longer produced suppression individually produced marked suppression when compounded. Although these experiments support the general position that inhibition may not necessarily be a by-product of extinction procedures, a more systematic investigation involving prolonged extinction is clearly required. In this experiment, then, information was sought on characteristics of thoroughly extinguished CSs in compound tests.

METHOD

Subjects

Twenty-four male hooded rats were assigned to two groups of twelve. The test data from one S were discarded because it failed to extinguish in the last phase of the experiment.

Apparatus

The apparatus consisted of eight Skinner Boxes and related programming equipment. The stimuli used as CSs were darkness (D), and a 75 dB white noise (N). The US intensity was set at 1.3 ma, with a duration of .5 sec. The CS duration in all trials was 90 sec. Conditioning trials were programmed during VI 3 min bar press sessions, as in previous experiments.

Procedure

Magazine and bar press training proceeded in essentially the same sequence as earlier experiments. Preliminary VI 3 min training continued for five two-hour sessions. During the sixth session, all Ss received pretest presentations of N, D, and N/D. For half the Ss in each group, N was designated CS_1, D as CS_2. The functions were reversed for the remaining Ss.

Subsequent stages of the procedure are diagrammed in Figure 18. On days C1, C2, and C3, CS_1 and CS_2 were individually paired with shock so that

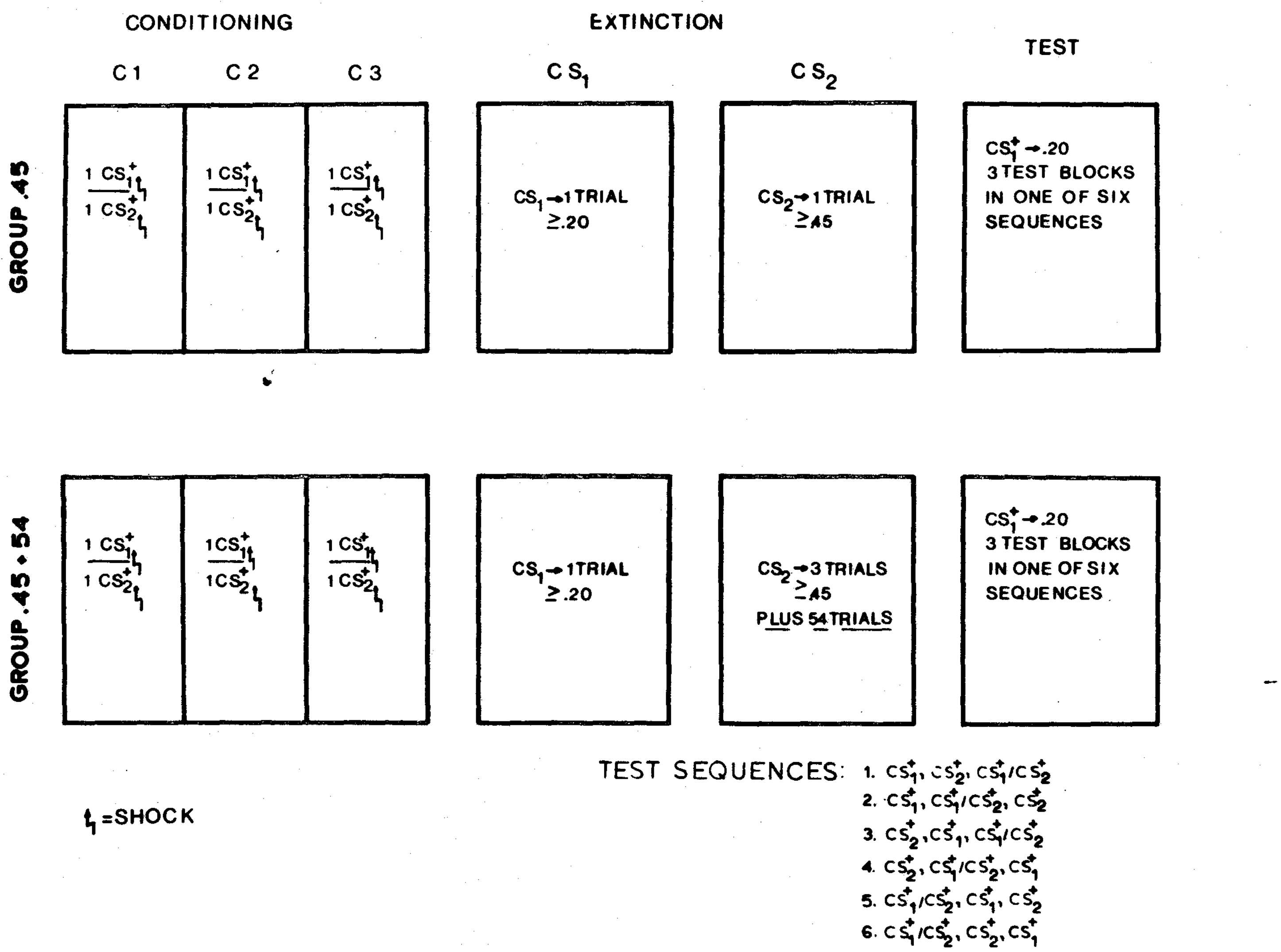

Figure 18. Experiment 5 procedure diagram, showing events programmed in acquisition, extinction, and test phases.

both produced complete suppression. One trial with each stimulus was programmed on each conditioning day, at points in the sessions selected with the aid of a table of random numbers.

In the next two phases of the experiment, CS_1 and CS_2 were extinguished to preselected criteria. First CS_1 was extinguished for six trials daily until a criterion was reached defined as one trial with a suppression ratio equal to or greater than .20. When criterion was satisfied, no further CS_1 trials were scheduled in that session. CS_1 was then reserved for use as a comparison stimulus in compound tests.

On the next day, extinction with CS_2 began. In one group of 12 Ss (Group .45), the extinction continued with six daily trials until the CS_2 no longer produced suppression. This point was defined as three consecutive trials in which the suppression ratio equalled or exceeded .45. In a second group (Group .45 + 54), CS_2 extinction also continued until the .45 criterion was reached. Extinction was then continued for an additional nine days with six daily trials, for a total of 54 trials beyond the .45 criterion.

In summary, both groups first received moderate extinction with CS_1 followed by CS_2 extinction. Group .45 received CS_2 extinction just to the point where very little suppression was observed. Group .45 + 54 received CS_2 extinction for many trials after that point was reached. In Pavlov's terminology, Group .45 + 54 received extinction "below zero".

As each S completed the extinction phases, testing was initiated on the following day. First, CS_1 was presented and, when necessary, re-extinguished to the .20 level. When criterion was satisfied, each S received one of the six possible sequences of CS_1, CS_2, and CS_1/CS_2 shown in Figure 18. Testing continued on consecutive days until all Ss received three blocks.

RESULTS

No significant differences were observed among N, D, and N/D in pretest presentations. Median suppression ratios were .38, .31, and .34, respectively.

The acquisition data are summarized in Figure 19, showing conditioning for N and D averaged over all Ss. Neither stimulus nor groups effects approached significance, and complete suppression was recorded in virtually all Ss by the third trial with each stimulus.

The extinction phase provided an opportunity to examine the effect of extinguishing one CS on sub-

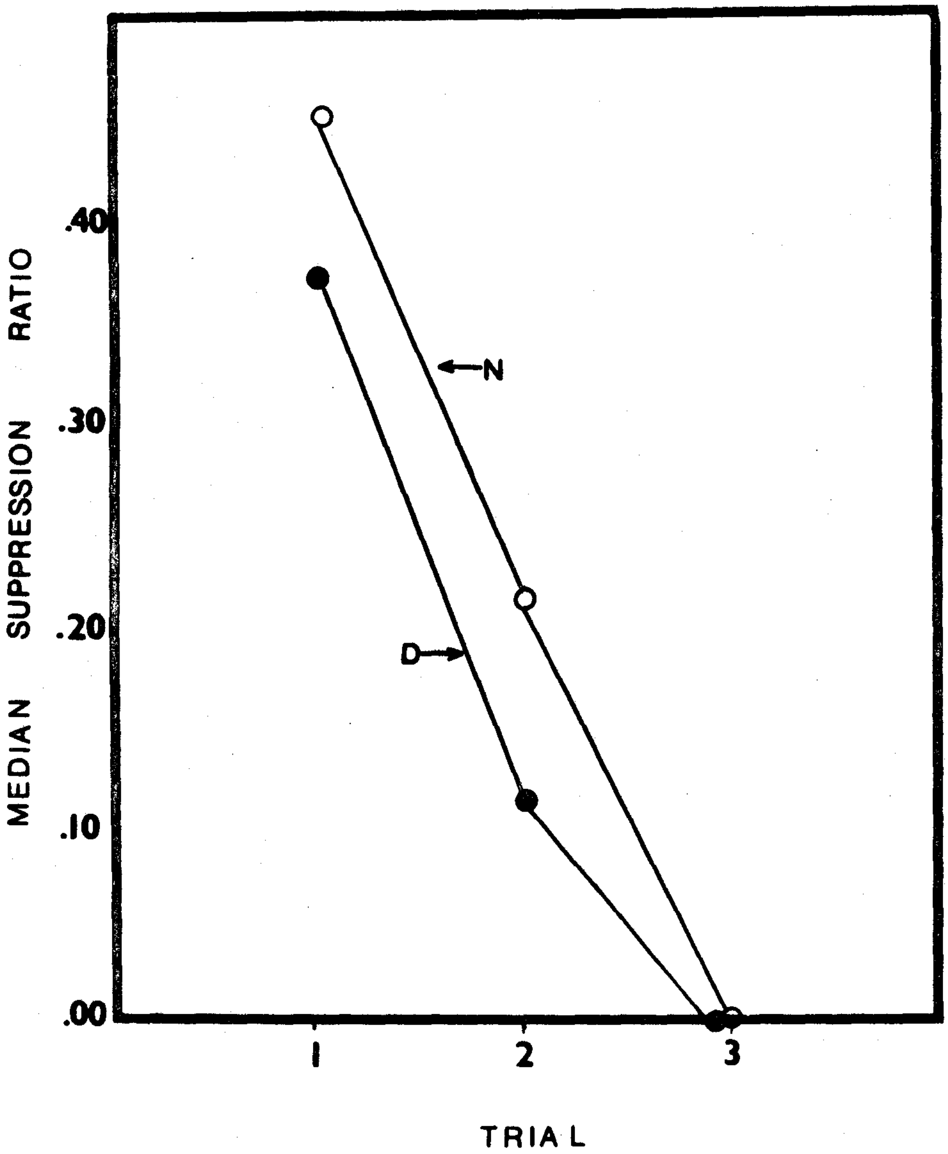

Figure 19. Experiment 5 acquisition data, showing median suppression ratios recorded over all Ss on each shock-reinforced conditioning trial when 75 db white noise or darkness served as CS+.

sequent extinction with a second CS. The results of this analysis are shown in Figure 20. The two curves indicate the median trial on which various extinction criteria were satisfied by CS_1 and CS_2 when N served as CS_1, D as CS_2 (solid lines); and when D served as CS_1, N as CS_2 (broken lines). The first points indicate the median trial on which the .20 criterion was satisfied by CS_1. Although the .20 criterion had no programmed consequences in CS_2 extinction, the trial on which that level was exceeded was recorded for each S. Those data are represented by the second point in each curve. Comparison of the first and second points in each curve permits evaluation of the effect of extinguishing one CS to the .20 criterion on subsequent extinction to the same criterion with a second CS. The final data points in each curve indicate the median number of trials required for CS_2 to reach the .45 extinction criterion.

The data clearly indicated that previous CS_1 extinction facilitated CS_2 extinction. Over all Ss the .20 criterion was consistently reached in fewer trials for CS_2 extinction than for CS_1 extinction ($T = 47.5$ $p < .01$). Although the effect was substantially stronger when N served as CS_2, the difference between the stimuli did not reach significance when examined at either .20

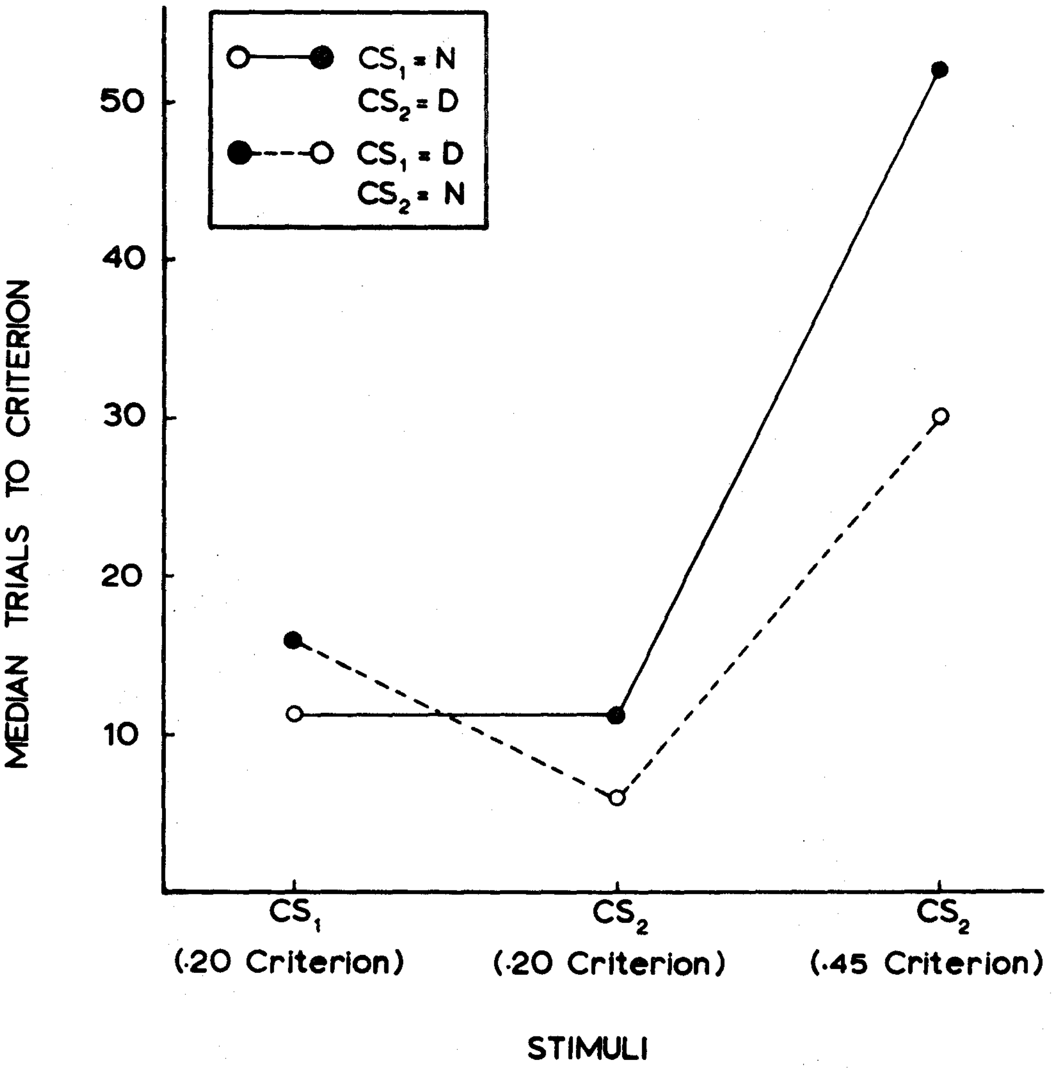

Figure 20. Median trials to extinction criteria for all Ss in Experiment 5 when darkness or white noise served as CS1 or CS2.

criterion. Extinction to the .45 criterion, however, proceeded significantly faster when N served as CS_2 (Mann-Whitney $U = 13.5$; $p < .002$).

The 54 additional extinction trials administered to Group .45+54 showed no systematic departures from approximate daily ratios of .50. No significant effects were detected that were attributable to N or D serving as CS_2.

The test results for both groups are summarized in Figure 21. The data points in the left portions of the figure represent median suppression ratios recorded for CS_1, CS_2, CS_1/CS_2 on each of the three test blocks. Overall test results were computed for each S in the form of mean responding to each stimulus condition, over the three test blocks. The medians of these three-block means are indicated in the right portion of the figure.

Both groups showed summation in compound tests; however, a stronger effect was observed in Group .45. For those Ss, although individual CSs showed marked extinction, the compound produced nearly complete suppression throughout the test sequence. These results were duplicated by virtually every S in the group.

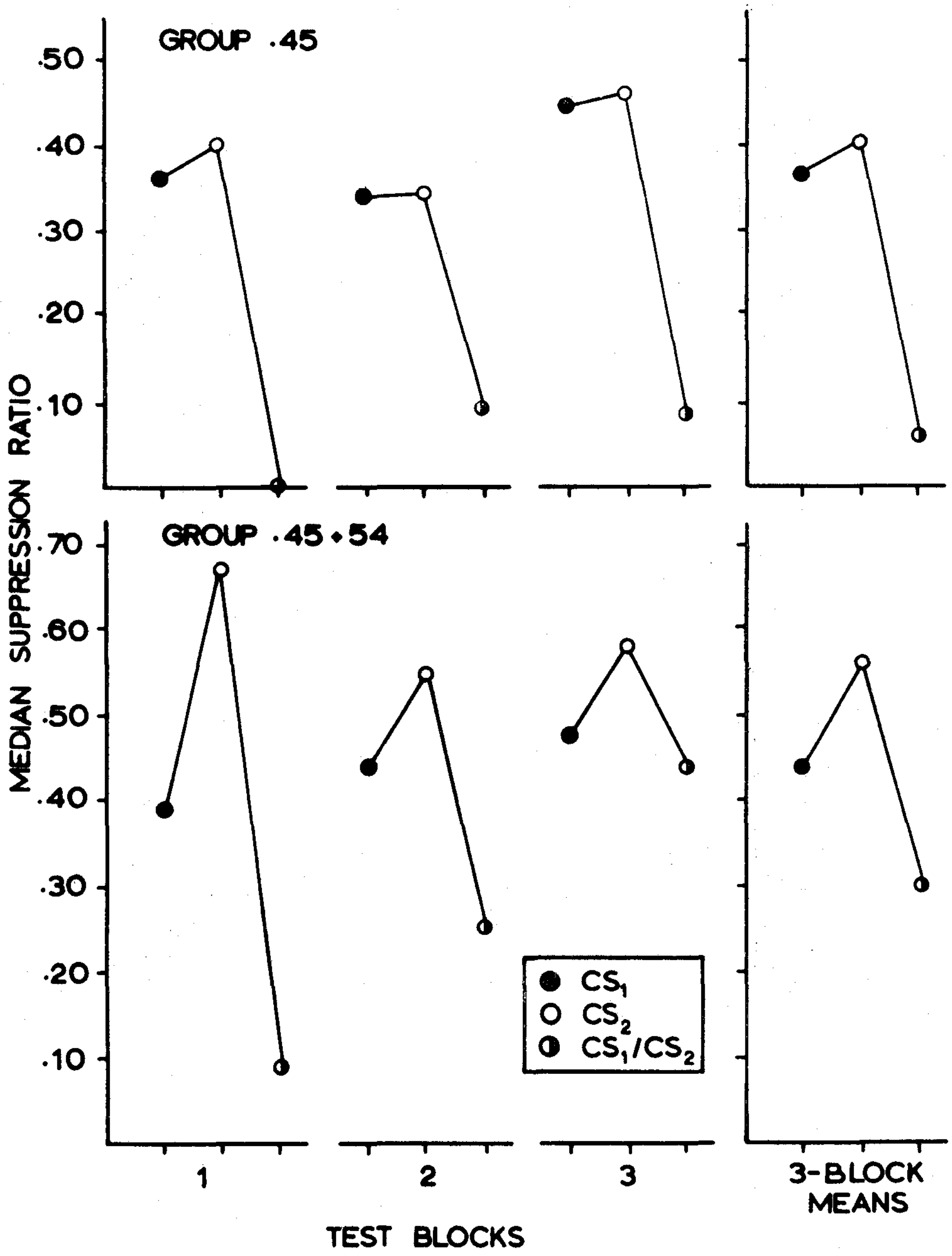

Figure 21. Median test suppression ratios for Experiment 5. The groups of three points in the left portions represent the outcomes of test blocks administered on three consecutive days. The groups of three points in the right portions represent medians for each group based on mean suppression ratios calculated over all three blocks.

Group .45+54 also showed summation, but the effect was less consistent over the three test blocks. Significant summation was obtained in Block 1 (Wilcoxon $T = 0$, $p < .01$) and Block 2 ($T = 7$, $p < .02$), while in Block 3 compound suppression did not reliably differ from levels associated with the individual components. There was no significant difference in compound suppression between the two groups in Block 1. However, in both Blocks 2 and 3, Group .45+54 showed reliably less compound suppression than Group .45 (Block 1 $U = 21.5$, $p < .02$; Block 3 $U = 8$, $p < .01$). No differences in summation were detected in either group that could be attributed to N or D serving as CS_1 or CS_2.

The two groups also differed in response to CS_2. Group .45+54 displayed significantly less CS_2 suppression than Group .45 in Blocks 1 and 2 (Block 1 $U = 14.5$, $p < .05$; Block 2 $U = 29$, $p < .05$), but not in Block 3. The difference was most dramatic in Block 1, in which Group .45+54 showed *acceleration* to CS_2, as evidenced by suppression ratios consistently greater than .50 (median = .65; $T = 7.5$, $p < .05$). Examination of pre-CS baselines, however, revealed that this acceleration to CS_2 was accompanied by a slight depression of VI baselines. Nine of 11 Ss in Group .45+54 displayed their lowest pre-CS rates in Block 1 on the CS_2 trial. Of these nine Ss, only one failed to show acceleration to CS_2. Both Ss not showing the depression of VI rate failed to exhibit CS_2 acceleration. In Blocks 2 and 3, neither consistent baseline depression nor CS_2 acceleration was observed.

DISCUSSION

It is very clear that neither extinction procedure resulted in a conversion of excitatory stimuli to inhibitory stimuli as measured by compound tests. Summation, rather than attenuation, was observed in every S in both groups. Although a companion CS^o control procedure was not examined in this experiment, the results of earlier CS^o groups in Experiments 2 and 4, as well as additional data to be presented in the next chapter, provide ample evidence that summation effects of the present magnitude and reliability may not be attributed to nonassociative effects. In short, the data indicate that even when CS_2 extinction was carried out far beyond the point at which suppression was no longer observed, excitatory properties were retained.

It is also obvious, however, that the additional nine days of extinction in Group .45+54 exerted a substantial effect. Results over all three test blocks showed that both CS_2 and compound suppression in Group .45+54 were much weaker than comparable suppression for Group .45. There were clear indications in the test blocks that both CS_2 and compound suppression were weaker in Group .45+54 than in Group .45. One could argue, of course, that both the additional extinction trials and a "forgetting" effect extending over the additional nine days of training could have contributed to this weakening. The significant point is that even with these features of the situation potentially contributing to a weakening of CS_2 in Group .45+54, "below zero" extinction did not result in an elimination of excitatory properties.

One particular feature of the test results in Group .45+54 deserving special mention is that the most substantial and reliable compound summation was observed in connection with significant acceleration to CS_2. The reasons for this acceleration are not entirely clear. Since slightly depressed baseline rates preceded the acceleration trials, and since neither CS_2 acceleration nor depressed pre-CS_2 rates were observed in subsequent test blocks, it may be most reasonable to attribute the effect to operant "disinhibition" of depressed barpress baselines similar to that reported by Brimer (in press; cf. also Chapter 2, p.22). Nevertheless, the observation of CS_2 acceleration is of interest because it has been suggested by Hammond (1966, cf. also Rescorla and Solomon, 1967) that acceleration associated with CS- in differential conditioned suppression may be associated with inhibitory effects. If one assumes that depressed baseline response rates could be due to fear of situational cues, acceleration to CS- could be attributed to inhibition of that fear. However, since the present data show compound summation in the same test block as CS_2 acceleration, the indications are that acceleration per se is not a reliable index of inhibition in conditioned suppression.

These data certainly do not provide encouragement for the view that extinction of an excitatory CS results in an acquisition of inhibitory properties. At the same time, of course, they do not eliminate the possibility that an inhibitory mechanism may be involved. For example, it could be argued that other extinction procedures (perhaps involving more extinction trials, or a massing of extinction trials) might have produced very different results in compound tests.

One could also argue that introducing the 24-hour interval between the satisfaction of the CS_2 extinction criterion and the compound test might have provided ample opportunity for spontaneous recovery of weak excitatory properties. Similar compound tests performed immediately after the satisfaction of criterion might have produced different results.

Alternatively, it may be that the classification of CSs as *either* inhibitory *or* excitatory is a misleading dichotomy. Konorski (1948), for example, argued that extinction essentially involves the counteracting of excitatory properties associated with a CS by concurrently conditioned inhibitory properties. According to this formulation, then, extinguished CSs emerge as *both* excitatory *and* inhibitory. Given such a mechanism, it is at least plausible that excitatory properties of CS_1 and CS_2 could summate, resulting in a net level of excitation too great to be attenuated by any inhibition that also might be present in the situation.

These speculations are of less immediate interest, however, than the fact that compound test results in the present experiment revealed no indications of attenuation, even after very extensive extinction training. Although on the basis of these data we cannot rule out the logical possibility of an inhibitory mechanism being involved in extinction, it seems clear that demonstrating attenuating properties of an extinguished CS is likely to prove a very difficult undertaking.

The results of differential conditioning procedures, on the other hand, have presented a very different picture. In Experiment 4, CS- from a differential conditioned suppression situation produced consistent attenuation even after very limited training. In the next chapter, a final experiment will be described that was directed at learning more about the features of the differential conditioning procedure that were important in producing the apparent inhibitory effects.

CHAPTER V

Experiment 6: The Role of Accompanying Events in Differential Conditioning

The results of Experiment 4 clearly indicated that differential conditioning can be an effective inhibitory training procedure, when inhibition is defined in terms of the attenuation function. Marked and consistent attenuation was observed in compound tests in Experiment 4 after only two differential conditioning sessions.

Experiment 5, however, indicated that extinction of an excitatory CS+ was not an effective inhibitory training procedure when inhibition was measured by compound tests. Even after very prolonged extinction, compound summation, rather than attenuation, was the rule. These results indicate that the extinguished CS+s did not acquire inhibitory strength, but retained excitatory properties.

There are several features of the differential paradigm used in Experiment 4 that could have contributed to its effectiveness as an inhibitory training procedure. One major feature is that CS- presentations were accompanied by trials of a previously conditioned (ie. "established") CS+ and shock. Although it seems likely that presentations of CS+ and shock in the accompanying role contributed to the effectiveness of the differential procedure, it is not clear how CS+ and shock individually contributed to that effectiveness. For example, it may not be necessary that both an established CS+ and shock accompany unreinforced CS- trials. Rescorla (1966, 1969b) has presented data indicating that unreinforced CS- trials accompanied only by shock result in inhibitory characteristics being acquired by CS-. Unreinforced CS- trials accompanied only by presentations of an established excitatory CS+ may also be an effective inhibitory training procedure.

It is also possible that presentations of CS- accompanied by neither CS+ nor shock could result in inhibitory/attenuating functions. Although the results of Experiment 4 were not encouraging for inhibitory interpretations of simple extinction procedure, the extinguished stimuli in that experiment had a previous history of excitatory conditioning. Perhaps similar extinction trials with a "neutral" CS would have a different effect.

There is ample evidence that unreinforced pre-exposures of a neutral CS may result in substantial retardation of subsequent acquisition of conditioned suppression with that CS (Carlton and Vogel, 1967; Anderson, Merrill, Dexter, and Alleman, 1968; Anderson, Wolf, and Sullivan, 1969; May and Tolman, 1967; Siegel and Domjan, in press). Thus far, however, demonstrations of this "latent inhibition" phenomenon have been limited to retardation of acquisition tests (cf. Chapter 3, p. 129; Rescorla, 1969c). It is not known whether unreinforced CS- presentations unaccompanied by CS+ or shock also produce attenuation in compound tests.

These considerations prompted the examination of the six training conditions studied in this experiment. Three differential conditioning procedures included unreinforced CS- trials, accompanied by presentations of either an established CS+, shock, or both CS+ and shock. In three nondifferential procedures, the effects of presenting CS- in unaccompanied "extinction trials" were studied. The properties of CS- resulting from all six training procedures were evaluated in compound tests of CS+ and CS-.

METHOD

Subjects

A total of 64 rats were run under six experimental conditions. Death and procedural irregularities forced the elimination of five Ss.

Apparatus

The apparatus consisted of eight Skinner Boxes and programming equipment. Darkness and 75 dB white noise served as the CSs. US intensity was set at 1.3 ma, with a duration of .5 sec. CS duration on all trials was 90 sec.

Procedure

Preliminary VI training and pretests were identical for all Ss. Following magazine and barpress training, all Ss received five two-hour sessions with responding reinforced on a VI 3 min schedule. In the course of the sixth session, all Ss received two pretest trials with each of N, D, and the N/D compound.

The subsequent conditioning days are summarized in Figure 22. A total of six experimental conditions

3/3 DIFFERENTIAL GROUPS	C 1	C2	C 3	C 4	C5	C6
1.- CS^+/SHOCK N=8 1-A (REPLICATION) (N=11)	—	—	3CS^+↯	3CS^+↯	3CS^- 3CS^+↯	3CS^- 3CS^+↯
2.- SHOCK-ONLY N=8	—	—	3CS^+↯	3CS^+↯	3CS^- 3↯	3CS^- 3↯
3.- CS^+ONLY N=8	3CS^+↯	3CS^+↯	3CS^+↯	3CS^+↯	3CS^- 3CS^+	3CS^- 3CS^+

0/3 NONDIFFERENTIAL GROUPS						
4.- 6-SHOCK N=11	—	—	3CS^+↯	3CS^+↯	3CS^-	3CS^-
5.- 12-SHOCK N=7	3CS^+↯	3CS^+↯	3CS^+↯	3CS^+↯	3CS^-	3CS^-
6.- PREX. N= 8	3CS^-	3CS^-	3CS^+↯	3CS^+↯	3CS^+↯	3CS^+↯

↯ = SHOCK

Figure 22. Experiment 6 conditioning procedure diagram, showing events programmed on each of six conditioning days.

were examined, classified in Figure 22 as either "3/3 Differential" or "0/3 Nondifferential" conditions.

All 3/3 Differential Groups received CS+-shock pairings on at least two of the first four conditioning days, and three CS- presentations on the last two conditioning days. These groups differed in the events that accompanied the CS- presentations on days C5 and C6.

Group 1 and Replication Group 1A received three CS+-shock trials on days C3 and C4. On days C5 and C6, three CS- trials were accompanied by three CS+-shock trials. This differential conditioning procedure was essentially the same as that employed in Experiment 4.

Group 2 also received two CS+-shock trials on days C3 and C4. On each of days C5 and C6, three CS- trials were accompanied by three unsignalled shocks.

Group 3 received three CS+-shock trials on days C1 through C4. On days C5 and C6, three CS- trials were accompanied by three CS+ trials. In Group 3, shock was never programmed in the same session as CS-.

In the 0/3 Nondifferential groups, CS- was never accompanied by CS+ or shock. Groups 4 and 5 both received CS+-shock pairings preceding the introduction of CS-. Group 4 (parallelling Groups 1 and 2) received three CS+-shock pairings on days C3 and C4 for a total of six shocks. Group 5 (parallelling Group 3) received three CS+-shock pairings on days C1 through C4, for a total of 12 shocks. Finally, Group 6 received three CS- presentations on days C1 and C2, followed by three CS+-shock pairings on each of days C3 through C6.

Taken together, the six conditioning procedures represent a dissection of the major features of the 3/3 Differential conditioning procedure. Groups 1 and 1A both received unreinforced CS- trials accompanied by both the previously conditioned CS+ and shock. In Group 2, CS- was accompanied by shock alone, while in Group 3, CS- was accompanied by only the previously conditioned CS+.

CS- training in Groups 4, 5, and 6 included no accompanying trials. Groups 4 and 5 received only unreinforced CS- trials after 6 and 12 CS+-shock pairings, respectively. Group 6 provided an opportunity to examine the role of unreinforced CS- trials scheduled with no previous conditioning to CS+.

Beginning on the day following session C6, all Ss received a series of unreinforced CS+ trials over the course of a 2½ hour session. CS+ extinction terminated for each individual S when one trial was recorded with an

Annau-Kamin suppression ratio of .20 or greater. A maximum of 15 CS+ trials was programmed in the session, with a constant inter-trial interval of 7 min. On the infrequent occasions in which criterion was not met within those 15 trials, an additional CS+ extinction session was scheduled on the following day.

The first test session was scheduled on the day following the satisfaction of CS+ extinction criterion. Test sessions were also 2½ hours. In the first 45 minutes, a maximum of six unreinforced CS+ trials was scheduled for each S until satisfaction of the .20 extinction criterion. These preliminary CS+ trials were terminated for each S when criterion was satisfied. In the remaining 1 hour 45 min., all Ss satisfying criterion received one of two test blocks: either CS+, CS+/CS-, CS+, CS+/CS-, CS-; or CS+/CS-, CS+, CS+/CS-, CS+, CS-. On the following day, the CS+ was again extinguished to .20 for each S, followed by the test block not scheduled on the previous day.

RESULTS

Over all Ss, the daily pretest ratios for N, D, and N/D were .42, .42, and .49 respectively. These differences were not significant.

Figures 23 and 24 summarize daily suppression ratios for each acquisition day for 3/3 Differential and 0/3 Nondifferential Groups. Daily suppression ratios consisted of the mean of the three individual suppression ratios recorded with each stimulus on the appropriate conditioning day.

Acquisition of suppression on the first two CS+ conditioning days was very similar in all groups. CS+ suppression was essentially complete by the second conditioning day, and was maintained at near-zero levels over all subsequent presentations. It should be emphasized that nearly complete CS+ suppression was also maintained in Group 3 on sessions C5 and C6, although no shock was presented on those days.

CS- ratios differed considerably between 3/3 Differential and 0/3 Nondifferential Groups. On the first day of CS- training (day 5 for every group but Group 6), ratios showed no significant departures from .50 in any group. Ratios on the second day of CS- training, however, showed consistent acceleration in 3/3 Differential groups. When all the 3/3 Differential Ss were combined, second day CS- ratios were found to be reliably greater than .50 (Wilcoxon T = 172.5; $n = 35$, $p < .02$). Within individual 3/3 Differential groups, CS- acceleration

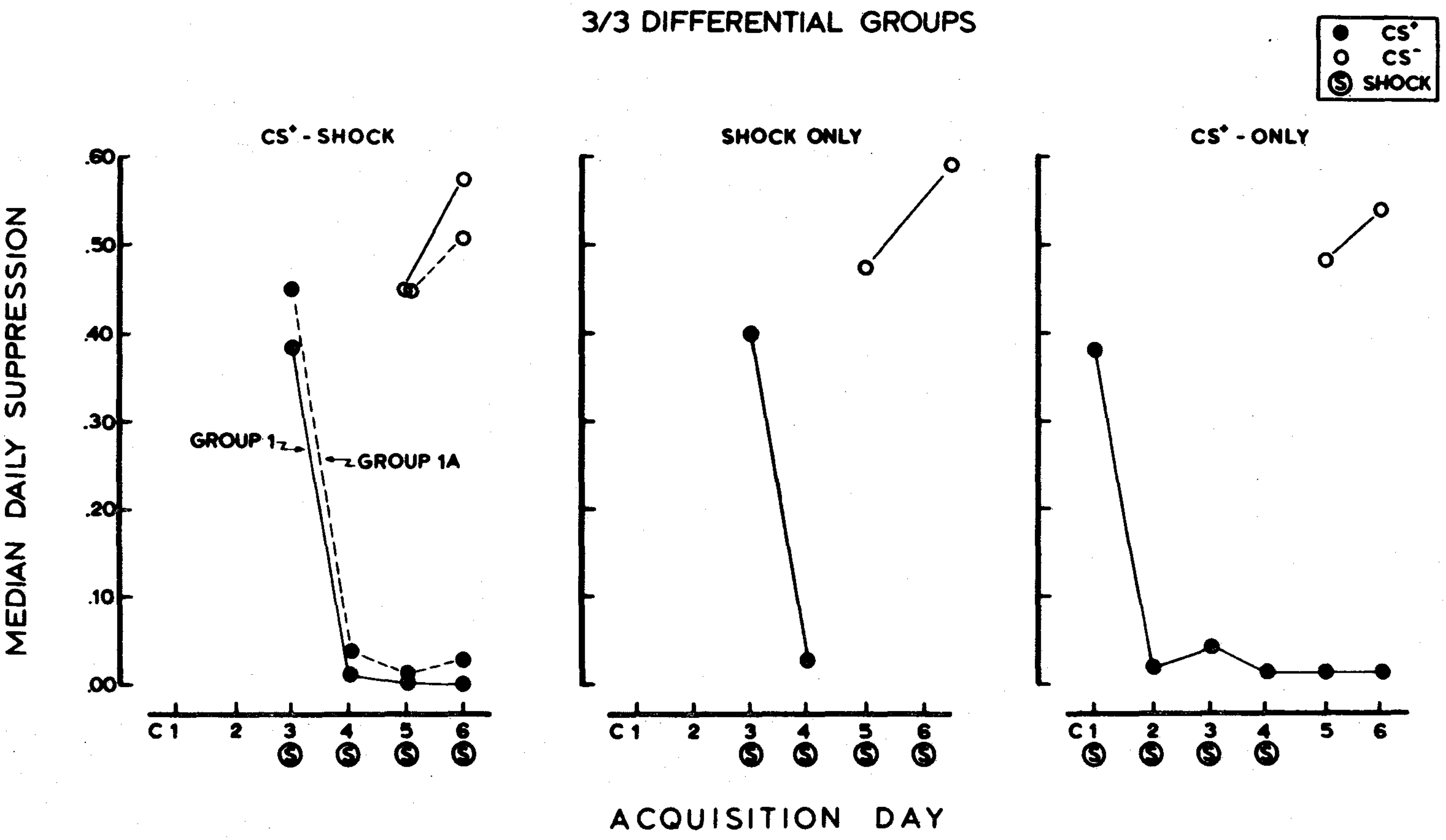

Figure 23. Median daily suppression ratios for CS+ and CS- on each of six conditioning days for 3/3 Differential groups in Experiment 6. Daily suppression ratios were defined for each S as the mean suppression ratio recorded over three conditioning trials on each day with the appropriate stimulus.

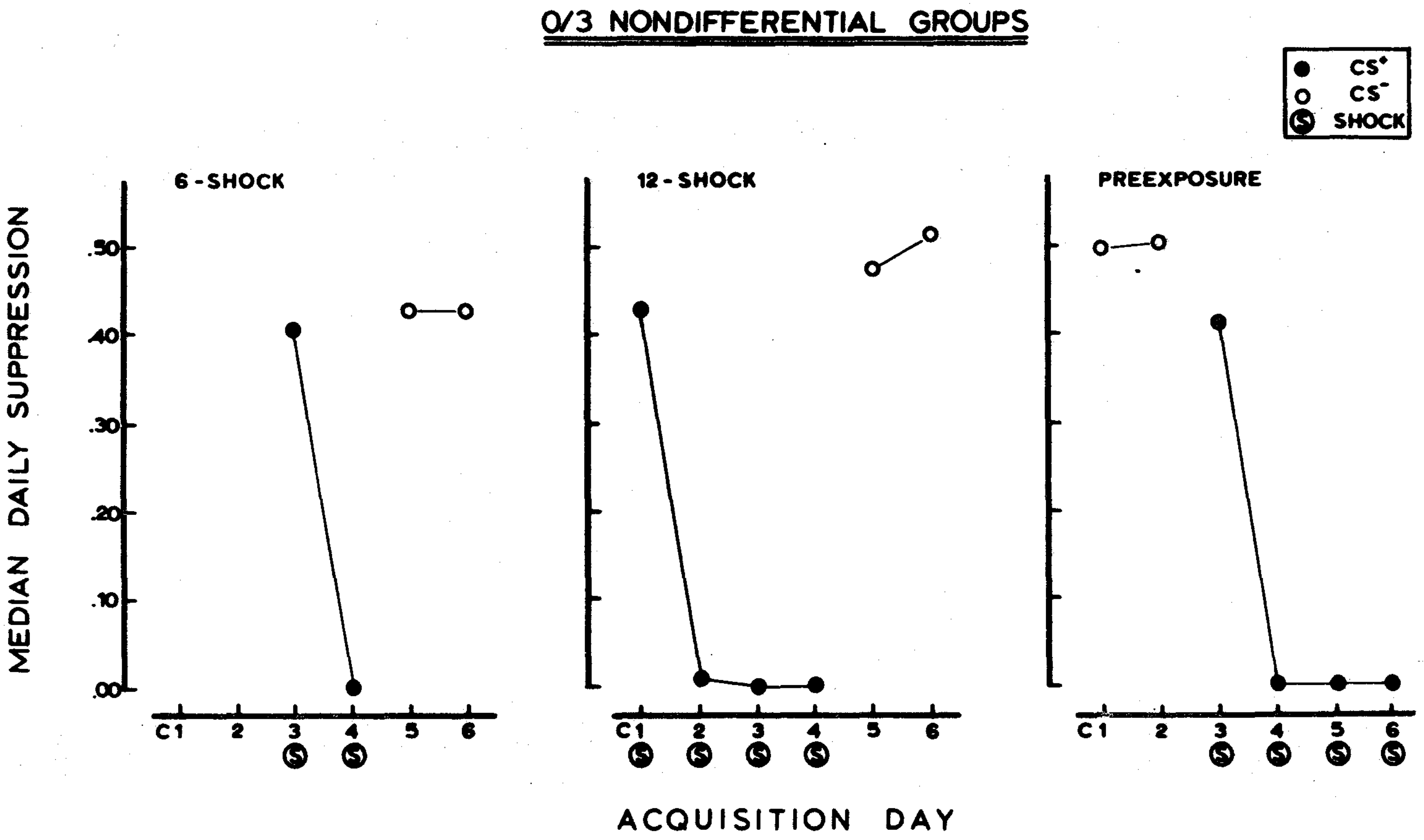

Figure 24. Median daily suppression ratios for CS+ and CS^{o} on each of six conditioning days. for 0/3 Nondifferential groups in Experiment 6. Daily suppression ratios were defined for each S as the mean suppression ratio recorded over three conditioning trials on each day with the appropriate stimulus.

was most prominent in Group 2, in which CS- trials were contrasted with unsignalled shocks. No comparable CS- acceleration was observed on the second days of CS- training in any of the 0/3 Nondifferential groups.

Examination of baselines on CS- conditioning days revealed that the acceleration observed in 3/3 Differential groups was accompanied by a prominent decrease in bar press rates. An estimate of CS- baselines was provided by computing the mean pre-CS- rates for each S on both CS- conditioning days. In each group, these rates were compared with similar estimates on the first two days of CS+ conditioning.

The differences between CS+ and CS- baselines, expressed as a percentage of CS+ baseline, are shown in Figure 25. Negative values indicate that CS+ baselines were higher, on the average, than CS- baselines.

It is very clear from the figure that CS- baselines were depressed in all 3/3 Differential Groups. When all 3/3 Differential Ss were combined, the depression was statistically reliable ($T = 68$, $n = 35$, $p < .02$). 0/3 Nondifferential Groups, on the other hand, displayed CS- baselines that, overall, were slightly higher than CS+ baselines. It should be noted that the large increase shown for Group 6 Ss is attributable to the fact

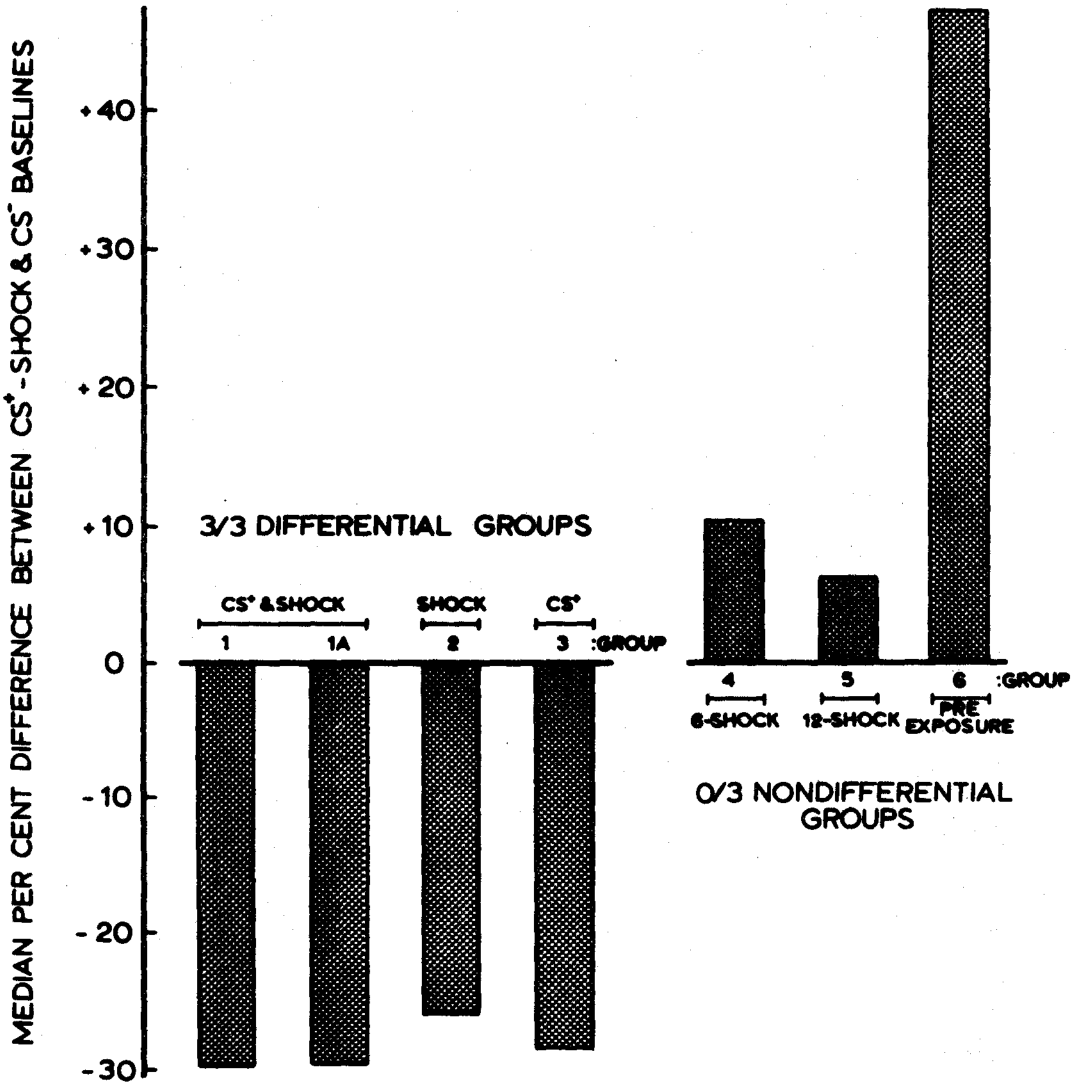

Figure 25. Median percent difference between CS+ and CS- conditioning baselines for all groups in Experiment 6.

that CS+, and the introduction of shock, followed CS- training, rather than preceding it as in the other groups.

In compound test sessions, the depressed baselines in 3/3 Differential groups showed marked recovery. Test baselines did not differ significantly from CS+ conditioning baselines in those groups.

The median number of trials required for CS+ to reach the .20 extinction criterion is shown for each group in Table 7. As in previous experiments, the extinction functions tended to be highly variable, showing no significant stimulus effects. The fact that Group 3 extinguished to criterion very rapidly is to be anticipated, since nonreinforced CS+ trials had been presented for that group on conditioning days C5 and C6. However, the unusually rapid extinction in Group 5 was not anticipated. Because of the overall variability, it is not clear if this represents a systematic effect of the conditioning procedure.

The results of both test blocks for each S were summarized by computing the mean of all four CS+ presentations, and the mean of all four CS+/CS- presentations. The means were converted to difference scores, with positive values indicating compound attenuation of CS+ suppression. The results for all groups are summarized in Figure 26.

Experiment 6: Median Trials and Range to $CS_1 \geq .20$ Extinction Criterion

Table 7

3/3 Differential Groups

	CS+/Shock		Shock Only	CS+ Only
	Group 1	Group 1A	Group 2	Group 3
Md =	16	13	10	2
R =	2-39	6-35	1-23	2-16

Overall D Median = 10 Overall N Median = 11

3/0 Nondifferential Groups

	6-shock	12-shock	Pre-exposure
	Group 4	Group 5	Group 6
Md =	20	5	13
R =	10-35	5-24	9 - 30

Overall D Median = 18 Overall N Median = 19

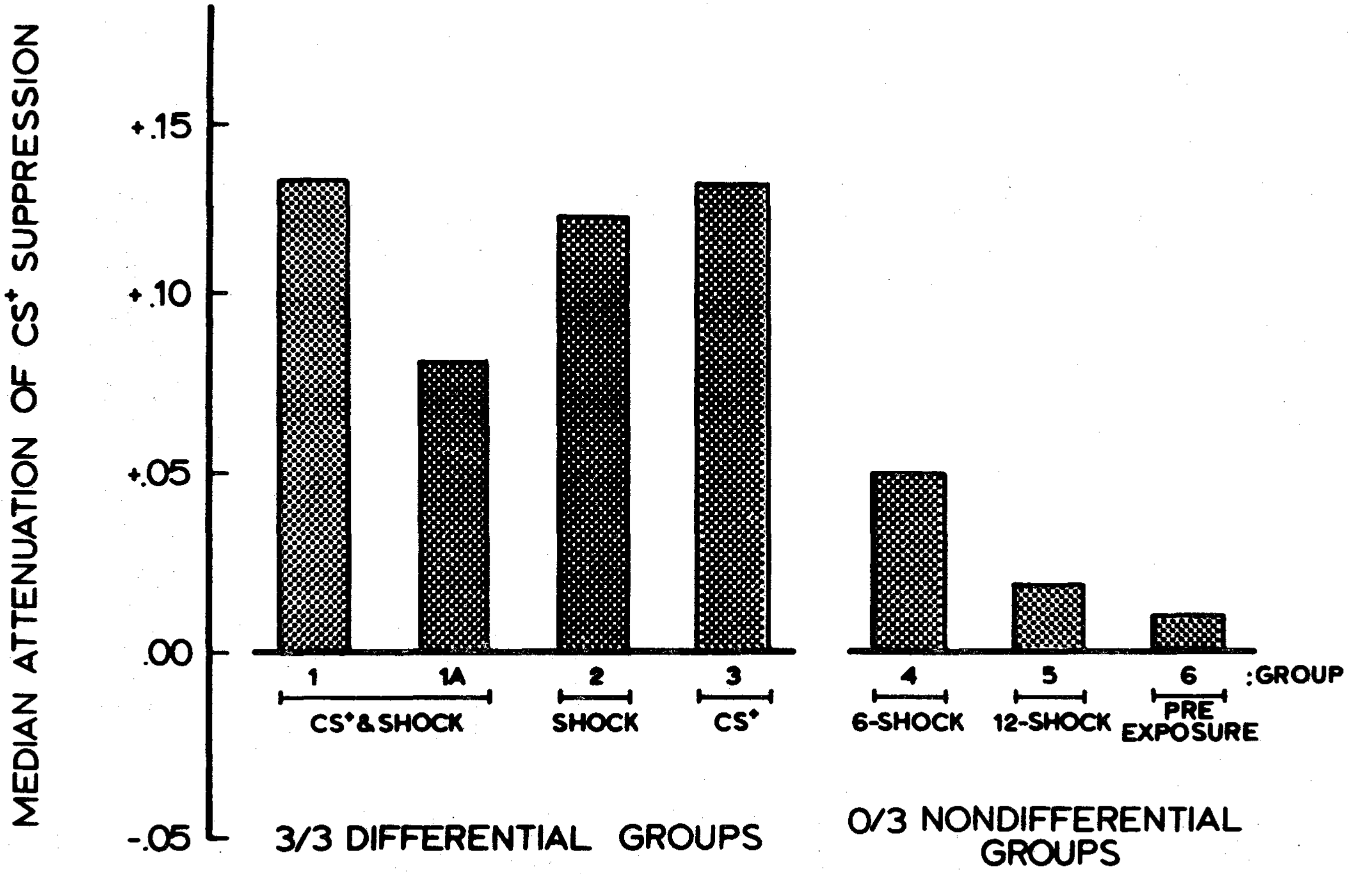

Figure 26. Median test attenuation scores for Experiment 6. Attenuation scores were computed for each S by subtracting the mean suppression ratios obtained over all compound test presentations from the mean suppression ratio obtained over all CS+ test presentations.

The attenuation of CS+ suppression was reliable in all 3/3 Differential Groups (Wilcoxon T's; Group 1 = 1 (n = 8), Group 1A = 11 (n = 11), Group 2 = 0 (n = 8), Group 3 = 3 (n = 8), all P's $< .05$). Reliable attenuation effects were not observed in any 0/3 Nondifferential Groups. Moreover, the overall levels of attenuation observed in 3/3 Differential Ss were significantly greater than levels observed for 0/3 Nondifferential Ss ($U = 208$; $n1 = 35$, $n2 = 25$; $z = 3.4$, $p < .01$). No significant effects were detected that were attributable to either stimuli or test sequences.

Figures 27 and 28 summarize the results of all four CS+ and all four CS+/CS- presentations for 3/3 Differential and 0/3 Nondifferential Groups. With one exception (Trial 1 in Group 1A) CS+/CS- suppression for all 3/3 Differential Groups was maintained well above CS+ suppression. Groups receiving 0/3 Nondifferential training showed compound suppression ratios that did not differ reliably from CS+-alone trials. The slight attenuation tendency indicated for 0/3 Nondifferential Groups on test trial 4 did not approach significance.

Examination of CS+ ratios in the test sequence showed a prominent effect in Groups 1 and 1A, reminis-

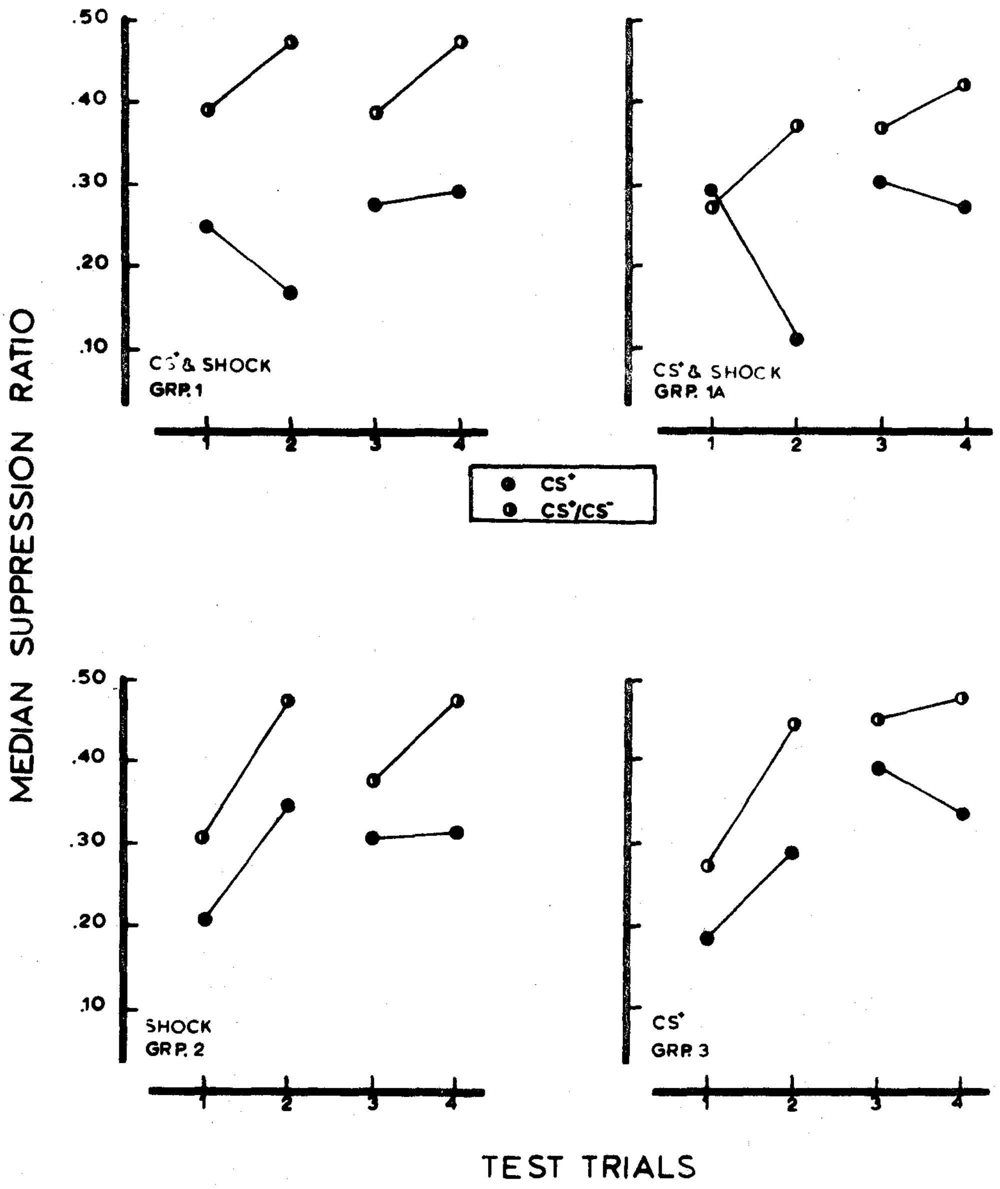

Figure 27. Median test ~~trial~~ suppression ratios for CS+ and CS+/CS- for Experiment 6 3/3 Differential groups.

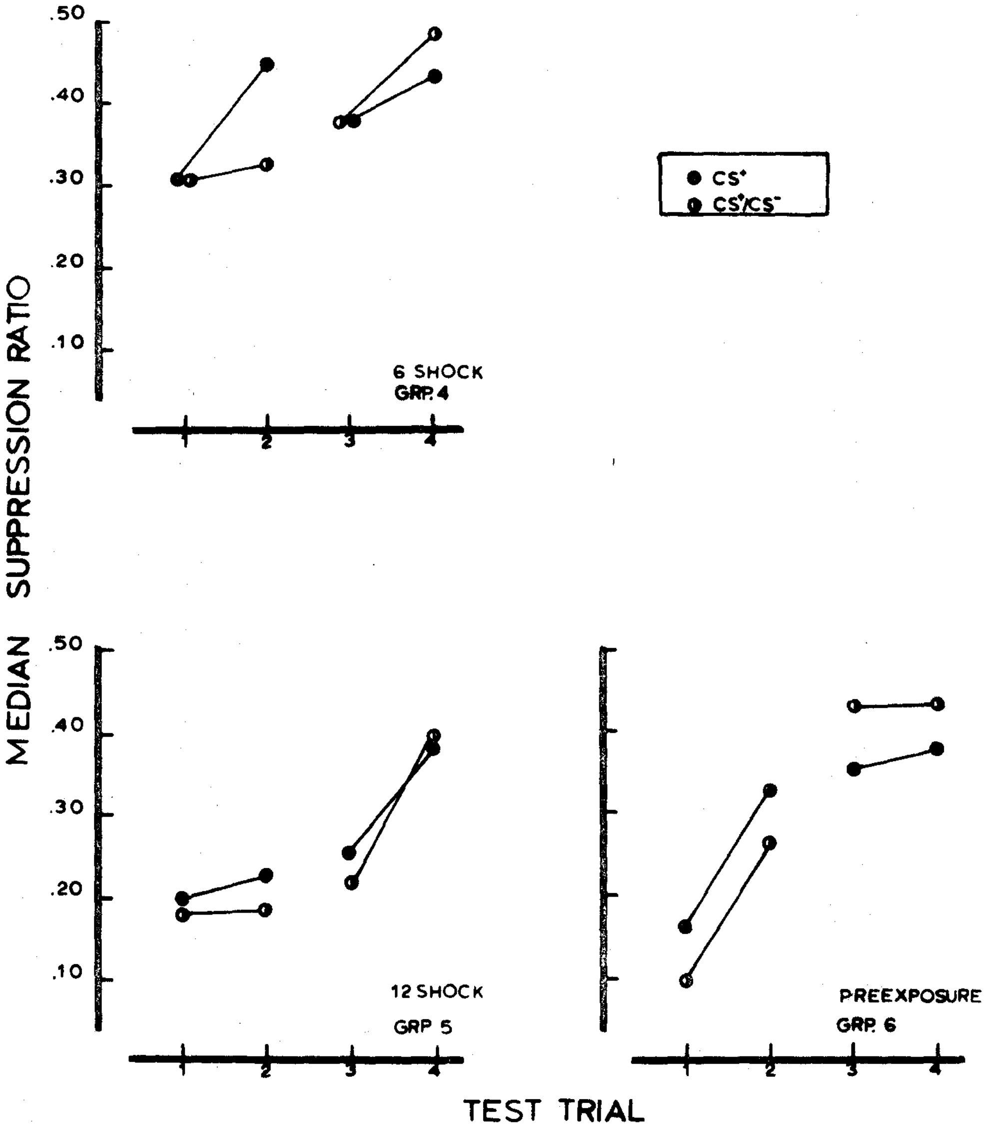

Figure 28. Median test trial suppression ratios for CS+ and CS+/CSo for Experiment 6 0/3 Nondifferential groups.

cient of "positive induction". Second trial CS+ ratios in those groups consistently showed increased suppression over first trial levels. The remaining 3/3 Differential Groups and all 0/3 Nondifferential Groups followed the anticipated extinction pattern of less CS+ suppression on trial 2 than on trial 1. When the differences between first and second CS+ trials were calculated for each group, Groups 1 and 1A showed significantly greater decrements in trial 2 suppression than Groups 2 and 3 combined. ($U = 62$; $n1 = 16$, $n2 = 19$; $z = 2.05$; $p < .05$). Similarly, Groups 1 and 1A combined showed significantly greater decrements in Trial 2 suppression than all 0/3 Nondifferential groups combined ($U = 85$; $n1 = 25$, $n2 = 19$; $z = 2.01$; $p < .05$). No significant differences in CS+ suppression were found over groups in Block 2.

DISCUSSION

The most prominent result of this experiment was that all 3/3 Differential Groups exhibited attenuation of CS+ suppression in compound tests, while no 0/3 Nondifferential Groups showed attenuation. In terms of the attenuation definition of inhibition that has been stressed in this thesis, the results indicate that all 3/3 Differential training procedures resulted in the acquisition of inhibitory properties by CS-, regardless of whether an established CS+, shock, or both CS+ and shock served as accompanying events. Unaccompanied, unreinforced CS- trials did not result in the acquisition of inhibitory properties.

Although no significant differences were detected among 3/3 Differential Groups with the attenuation tests, there is some indication that the use of both CS+ and shock as accompanying events (in Groups 1 and 1A) may have results that differ from those obtained when either CS+ or shock is used alone. Suppression on the second CS+ test trial in Groups 1 and 1A showed a substantial and reliable decrement over corresponding levels in other Differential and Nondifferential Groups. Since the second CS+ trial followed a CS+/CS- trial in each instance, it might be argued that differential training with CS+ and shock as accompanying events resulted in a slight "positive induction" effect, similar to that observed in Experiment 3.

However, in order to seriously consider positive induction as the mechanism underlying the second trial suppression increment, it is necessary to suppose that CS- presentations in compound with CS+ could exert an effect on subsequent CS+ presentations. In addition, although there is evidence that induction-like effects decrease with repeated trials (Terrace, 1966), it is not clear why the prominent effects in the present data were limited to the first test block. Rather than supplying a label for the effect, it will best suit our present purposes to note that these apparent sequential effects in Groups 1 and 1A may indicate properties of CS- that differed from those in the other 3/3 Differential Groups, and that were not reflected in attenuation functions.

It is of greater immediate interest that attenuation results were obtained in 3/3 Differential Groups regardless of whether nonreinforced trials were accompanied by an established CS+, shock, or both CS+ and shock. Accompanying events were clearly important, since unaccompanied CS- presentations in 0/3 Nondifferential Groups did not produce attenuation.

The demonstration of attenuation following differential conditioning with CS+ as an accompanying event is particularly significant, since inhibitory training procedures have been frequently characterized as involving some interval relatively free from the occurrence of US (eg.Rescorla, 1967b). These data, however, clearly suggest that accounts of inhibitory conditioning that emphasize the relationship between CS- and US may be incomplete. Rather, the need for a mechanism is indicated in which conditioned *or* unconditioned stimuli may exert an influence in the acquisition of inhibitory properties. In the next chapter, a theory recently proposed by Rescorla and Wagner (in press) that includes such a mechanism will be considered.

CHAPTER VI

CONCLUDING DISCUSSION

INHIBITION IN DIFFERENTIAL CONDITIONING, AND SOME UNRESOLVED ISSUES

Research reported in this thesis was conducted in two phases. In the first phase, summation and attenuation were demonstrated to be phenomena of conditioned suppression. In the second phase, the summation and attenuation phenomena were used to identify inhibitory training procedures. These latter experiments have raised an issue that remains open to discussion: How does a CS- acquire inhibitory properties, particularly in differential conditioning procedures?

Experiment 5 showed clearly that extinction of excitatory CS+s did not result in a "conversion" of excitatory to inhibitory stimuli. Even when the extinction was carried out far beyond the point at which suppression disappeared, compound tests showed summation. Nor were there indications of inhibition when extinction trials were programmed with a CS that had not been previously conditioned. That point was demonstrated by the compound tests for 0/3 Nondifferential groups in Experiment 6, in which reliable attenuation was not observed.

Although the extinction paradigms that have been examined in these experiments scarcely represent an exhaustive inventory of possible procedures, all indications point to differential conditioning being at least a much more effective inhibitory training procedure than extinction. Compound tests in both Experiments 4 and 6 indicated that after only two sessions of exposure to the 3/3 Differential paradigm, attenuation resulted when CS- was compounded with CS+.

It is particularly interesting that in Experiment 6, differential conditioning proved to be effective regardless of whether a previously conditioned CS+, shock, or both CS+ and shock accompanied CS- trials. As noted earlier, Rescorla's (1966, 1969b) "negative contingency" experiments have provided ample evidence that when shock serves as an accompanying stimulus in differential conditioned suppression, CS- may acquire inhibitory/attenuating properties. Similarly, experiments by Hammond (1967) and by Herring, Cappell, and Webster (1970) provide precedent for CS- acquiring inhibitory/attenuating properties when both CS+ and shock serve as accompanying stimuli. However, there seems to be no experimental precedent for the finding that CS- may acquire inhibitory/attenuating properties when only an established CS+ serves as the accompanying stimulus.

There is little room for doubt that the accompanying events in these differential conditioning procedures did serve a crucial function in the acquisition of inhibitory/attenuating properties by CS-. However, the precise nature of that function is not clear. Rescorla and Wagner (in press) have recently presented a joint formalization of their earlier theories (Rescorla, 1969a; Wagner, 1969a, 1969b) which includes an account of inhibitory conditioning that may prove useful in understanding the role of accompanying stimuli in differential procedures. Since the inhibitory mechanism they propose is most clear in the context of their discussion of excitation, both the excitatory and inhibitory aspects of their theory will be discussed in some detail before turning to implications for the present data.

The Rescorla-Wagner Theory

The Rescorla-Wagner theory is based on a nunber of experiments which studied conditioning of components in reinforced and unreinforced compound trials. One related series of experiments concerns the "blocking effect", studied in conditioned suppression by Kamin (1969). Kamin first demonstrated that if conditioned suppression training began with pairings of a CS_1/CS_2 compound and shock, subsequent tests of CS_2 showed substantial suppression. However, if the same compound conditioning was preceded by a series of reinforced CS_1 trials, subsequent CS_2 tests showed very little suppression. In discussing Kamin's experiments, Rescorla and Wagner suggested that as a result of CS_1 pretraining, the total strength of CS_1/CS_2 at the beginning of compound conditioning was nearly at the asymptote that could be maintained by the particular shock level employed. Consequently, subsequent pairings of CS_1/CS_2 and shock could exert only a limited effect on the excitatory strength of the component stimuli.

A general description of the blocking paradigm as it relates to the Rescorla-Wagner theory is as follows: When the combined strength of both stimuli was low (ie., when there was no CS_1 pretraining), reinforcements were very effective in increasing the strength of the components. When the combined strength of both stimuli was high, however, (ie., when CS_1 had received pretraining), reinforcements were relatively ineffective in increasing component strength.

In formalizing this relationship, Rescorla and Wagner proposed that individual changes in the strength of component stimuli CS_1 and CS_2 on a reinforced trial of the compound CS_1/CS_2 be represented as a function of $\lambda -(V_1 + V_2)$. λ is the asymptote of conditioning that the US will sustain.V_1 and V_2 are the "associative strengths" of CS_1 and CS_2 prior to that reinforced trial.

Note that the Rescorla-Wagner theory treats associative strengths, rather than probabilities of occurrence of specific responses. In conditioned suppression, for example, theoretical statements are made about positive (excitatory) and negative (inhibitory) associations between CS and shock, without specifying how those associations might be manifested in a particular response measure. Rescorla and Wagner have not specified the relationships between associative strengths and response probabilities, other than to state that positive non-zero V's designate excitatory stimuli, negative non-zero V's designate inhibitory stimuli, while V's of zero are associated with neutral stimuli. It should be pointed out that the transformations between associative strengths and response probabilities are likely to prove difficult. The summation results of Experiments 2 and 5 indicate that CSs may have excitatory properties that may not be manifested in individual presentations, but exert very strong effects in compound tests. In short, the relationship between associative strengths and response probability is likely to be dependent on the sensitivity of the particular response measure being studied.

We have reviewed in Chapter 3 an experiment in inhibitory conditioning conducted by Wagner and Saavedra (reported in Rescorla and Wagner, in press) that parallels the excitatory conditioning principle of the Rescorla-Wagner theory. This eyelid conditioning experiment, in which rabbits served as Ss, studied the effects of unreinforced trials of CS-, when CS- was presented in compound with either a strong CS_1+ or a weak CS_2+. The strong CS_1+ had earlier been paired 240 times with US, while the weak CS_2+ had been paired only 8 times with US. A third stimulus, CS_3+, paired with US 548 times, served as a comparison stimulus in later compound tests. In the first phase of the experiment all Ss received conditioning trials with all three stimuli.

In the subsequent conditioned inhibition phase, CS-was presented in unreinforced compound trials with the strong CS_1+ for the half the Ss, the weak CS_2+ for the other half. In both conditioning situations, unreinforced compound trials were accompanied by reinforced presentations of CS_1+ or CS_2+, whichever stimulus appeared in the compound. When the conditioned inhibition phase was completed, all Ss received compound tests of $CS_3+/CS-$.

The results of the compound tests indicated that the attenuation of CS_3+ responding was related to whether nonreinforced CS- trials had been programmed in compound with the strong $CS_1+/CS-$ compound. When conditioned inhibition training was carried out with the weak $CS_2+/CS-$ compound, however, a much weaker attenuation effect was observed. In summary, when the initial strength of the compound was high, unreinforced trials of $CS_1+/CS-$ resulted in the apparent acquisition of strong inhibitory properties by CS-. When the initial strength of the compound was low, however, unreinforced trials of $CS_2+/CS-$ resulted in CS- acquiring weak inhibitory properties.

The Rescorla-Wagner theory incorporates the Wagner-Saavedra data by assuming the decrements in CS- associative strength on each unreinforced CS+/CS-trial to be dependent on $\lambda -(V_1 + V_i)$. The asymptote (λ) associated with nonreinforcement is assumed to be zero. V1 and Vi designate the associative strengths of CS_1 and CS-, respectively. Similarly, decrements in component V's on each unreinforced CS_2+/CS- trial are dependent on $\lambda -(V_2 + V_i)$. Because V1+Vi is large, Vi should undergo a large decrement over a number of unreinforced compound trials. Because V2+Vi is small, the Vi decrement over nonreinforced trials should also be small. The general principle that emerges is that a sequence of unreinforced trials with a compound consisting of a strong CS+ and a CS- should be an optimal condition for Vi to assume a large negative value, and as a result, for CS- to acquire substantial inhibitory properties.

This general relationship is also supported by an experiment by Rescorla (reported in Rescorla and Wagner, in press). Three groups of rats were trained in a conditioned inhibition paradigm in which unreinforced CS1$^+$/CS- trials were accompanied by trials of CS_1+. The groups differed according to whether CS1+ trials terminated with shocks of 0 ma (unreinforced), .5 ma, or 1.0 ma. Subsequent to the conditioned inhibition training, a third stimulus, CS_2+ was paired with shock in order to serve as a comparison stimulus in tests. Compound tests of CS_2+/CS- showed that the amount by which CS- attenuated CS_2+ suppression was related to the level of shock presented on CS_1+ trials, with the 0 ma group showing the least and the 1.0 ma group showing the most attenuation. In the terminology of the Rescorla-Wagner theory, reinforcement of CS_1+ with the more powerful shock acted to increase the value of Vl, making it possible for Vi to assume a larger negative value as a result of the nonreinforced compound trials.

Note that the reinforced CS+ trials that accompanied the unreinforced compound trials in both the Wagner and Saavedra and the Rescorla experiments were of particular importance. Because of these accompanying trials, Vl was presumably maintained at a high positive level throughout conditioned inhibition training. Under these conditions, Vi would continue to gain in negative strength until an asymptote of inhibitory conditioning is reached, defined as that point at which (Vl + Vi) $= \lambda = 0$. The stronger that Vl is maintained throughout conditioned inhibition training by accompanying reinforced trials, the more negative it is possible for Vi to become.

The Role of Background Stimuli

In extending their basic theory, Rescorla and Wagner have raised a point that seems particularly applicable to the results of the experiments in this thesis. They have stressed that the analysis described above in connection with compound excitatory and inhibitory conditioning is also applicable to situations in which CSs are not explicitly programmed as part of a compound. Although CS- was not compounded with a specific second stimulus in the present experiments, it may be appropriate to consider the possible role of "background stimuli" (CSb).

CSb, for present purposes, incorporates a wide range of usually unspecified contributors, such as cues from the Skinner Box, food, feedback from bar-pressing, and incidental noise. In terms of the Rescorla-Wagner analysis, it is most important that representations of differential conditioning situations should include such background stimuli, with CS- trials represented as CS-/CSb, CS+ trials as CS+/CSb, and the intertrial interval as CSb.

In view of the conditioning principles suggested by Rescorla and Wagner, the fact that CS- acquired inhibitory properties in the 3/3 Differential groups but not in the 0/3 Nondifferential groups may be related to different characteristics of CSb in each of those conditioning procedures. In their notation, the inhibitory effect of any nonreinforced CS- trial in a differential conditioning procedure emerges as being dependent on $\lambda - (V_b + V_i)$ where λ = the asymptote associated with nonreinforcement (assumed to be zero), Vi the associative strength of CS-, and Vb the associative strength of background stimuli (CSb). With larger positive values of Vb, a larger decrement of Vi would result from each nonreinforced trial of CS-/CSb. In general, then, the Rescorla-Wagner theory suggests that when compound trials are not specifically programmed, inhibitory properties should be acquired by CS- only in those situations in which CSb maintains excitatory properties.

The implication on the present data is clear. In the 3/3 Differential groups, the accompanying events may have acted to maintain excitatory fear-evoking properties of CSb. In 0/3 Nondifferential groups, on the other hand, CSb may have maintained much weaker excitatory properties, because no accompanying events were programmed.

Assessing the characteristics of background stimuli in the present experiments is difficult, since no special provisions were made for those measurements. The single index that is available is in the form of rates of baseline responding in each of the experimental sessions. If 3/3 Differential procedures did result in excitatory fear-evoking properties of CSb, it might be anticipated that baseline reates in those groups would be depressed in the presence of accompanying events. If background stimuli in 0/3 Nondifferential groups exerted weaker excitatory effects, one would not anticipate a pronounced depression in baseline response rates.

The data from these experiments conform to those expectations. In Experiment 6, all 3/3 Differential groups exhibited lower baselines in CS- conditioning sessions than those observed when conditioning began (Figure 28). A similar pattern of baseline responding was recorded for Ss in the 3/3 Differential group examined in Experiment 4 (p.115). Equally important, none of the 0/3 Nondifferentaial groups in Experiment 6 showed a baseline decrement on CS- conditioning days.

It seems clear that when shock served as an accompanying event, excitatory conditioning of CSb could easily have resulted. Accompanying presentations of the previously conditioned CS+ could have exerted a similar effect through a conditioning paradigm Pavlov

(1927) labeled "higher order conditioning". If a previously conditioned stimulus (CS+) regularly followed presentations of a neutral stimulus (CS_1), CS_1 may come to evoke the response that previously was associated only with CS+. Davenport (1966) has reported that higher order conditioning may occur in conditioned suppression. It should be stressed that in such a conditioning procedure, US is never presented. Consequently, when the established CS+ served as the accompanying event in Experiment 6, excitatory effects on CSb may have resulted even though shock was not present. Finally, when both CS+ and shock accompanied CS- trials, either or both of the accompanying stimuli might have been expected to contribute to the excitatory conditioning of CSb.

The role of background stimuli suggested by the Rescorla-Wagner theory provides a very intriguing mechanism for consideration. In many respects, the theoretical contribution might be regarded as of greater immediate importance than the precise accuracy of the present analysis; since, as it stands, this application of the theory is far from completely convincing. One of the major shortcomings should be discussed in some detail because it relates to a major point of this thesis.

The data supporting the proposed "excitatory properties" of CSb are confined in these experiments to baseline response rates. Unfortunately, when response rates are reinforced on a schedule of reinforcement, a wide range of subtle influences may be introduced that are difficult to interpret.

For example, the 3/3 Differential Ss may initially have exhibited a decrease in baseline response rate because of one of the conditioning mechanisms outlined above. However, since food reinforcement was continued throughout differential conditioning, the reduced response rate may have been maintained in subsequent sessions simply because it was reinforced on a VI schedule. The major point is that a reduced rate of bar pressing is encouraging, but not convincing, evidence for fear-evoking properties of CSb. Ideally, experiments in which the conditioned properties of background stimuli play an important role should include provisions for independently assessing such properties.

Although assessing the properties of "background stimuli" may seem difficult, careful experimental design could make such measurements possible. For example, the 3/3 Differential and the 0/3 Nondifferential conditioned suppression procedures could be conducted in darkness (analogous to CSb) where CS+ and CS- were two different tones. Tests could be conducted in the course of bar press sessions held in a well-lit box in which a white noise was conditioned for use as a comparison stimulus. It would be most encouraging for an analysis based on the Rescorla-Wagner theory if it could be shown that subsequent compound tests of darkness and white noise resulted in summation in 3/3 Differential groups but not in 0/3 Nondifferential groups.

Unconducted experiments are rarely interesting, but the above example serves to illustrate a central point of this thesis. The distinction between CSs that are weakly excitatory and those that are neutral requires independent confirmation in much the same way as the identification of inhibitory properties. It has been argued here (Chapter 3, p. 131) that compound tests with a CS+ known to be excitatory are particularly effective procedures for making that distinction.

Concluding note: Outstanding Issues in Inhibition

Rescorla has pointed out on a number of occasions (Rescorla, 1967; Rescorla and Solomon, 1967; Rescorla, 1969) that North American psychologists have traditionally demonstrated a certain "excitatory bias" in Pavlovian conditioning studies, with the result that questions of inhibition have been virtually ignored.

In recent years, however, a number of experiments have been conducted to study inhibitory phenomena. As evidenced in the studies reviewed in this thesis, many of these experiments were designed primarily to demonstrate inhibition in a variety of conditioning situations. More recently, studies on inhibitory conditioning have become more precise in focus, examining some of the more important features of conditioning situations that are responsible for CSs acquiring inhibitory properties. The Rescorla-Wagner theory is certain to generate many more.

Although these experiments have approached relatively complicated and intriguing mechanisms, a number of very fundamental questions about inhibitory conditioning have not been examined. For example, very little is known about the acquisition function of inhibition. The results of the experiments in this thesis indicate that inhibitory effects may be observed after only two sessions with three CS- presentations. However, it is not immediately clear if those results represent an asymptotic level, or how many trials might be required to reach an asymptote of inhibition.

Nor is it clear how the acquisition of inhibitory properties might be affected by traditional Pavlovian parametric variables. The experiment by Rescorla (in Rescorla and Wagner, in press) described earlier in this chapter, provides a very interesting indication that the intensity of the US on which accompanying excitatory conditioning is based may be an important determiner of the strength of inhibitory conditioning. Only two actual shock intensities were studied in that experiment, however, and more extensive experimentation is necessary. There is also little information available on the importance of CS- intensity in inhibitory conditioning. When more intense stimuli act as CS-, should faster acquistion of inhibitory properties result than with less intense stimuli? Kamin (1965) has carefully mapped out the importance of CS and US intensity in a variety of excitatory conditioned suppression situations, and it seems important for a similarly thoroughgoing study be conducted in the inhibitory case.

Questions regarding the removal of inhibitory effects are similarly unexplored. It is known that a CS- that has acquired inhibitory properties in a conditioned suppression paradigm may subsequently acquire excitatory properties when paired with a US (Hammond, 1968). However, does this observation mean that the inhibitory properties are "replaced" by excitatory properties? Or, as in the case of the extinction data in Experiment 5, should we again give careful consideration to Konorski's (1948) contention that a single CS may be both excitatory and inhibitory? The dichotomization of CSs into excitators or inhibitors is, at this point an assumption; and that assumption may prove to be inaccurate.

It is also not known whether inhibitory effects may be "extinguished". If a CS is established as an inhibitor in a differential conditioning situation, and is subsequently presented in a series of unaccompanied, unreinforced trials, should one anticipate extinction of inhibitory properties? Although a substantial amount of evidence has been presented here which indicates that nonreinforcement *per se* is not a sufficient condition for acquisition of inhibitory/attenuating properties it would be crucial for that argument to demonstrate that under some circumstances, nonreinforced presentations may actually weaken inhibitory effects. Finally, in all situations in which inhibitory effects are weakened, confirmation is badly needed of Konorski's (1948) contention that inhibition may show spontaneous recovery.

These questions seem particularly important for theories such as Rescorla and Wagner's. One reason for this importance is that in its current form, their theory generates predictions regarding at least two of the outstanding issues: the importance of US intensity, and the extinction of inhibitory effects. We have reviewed some important contributions by Rescorla to the question of US intensity in the conditioned inhibition paradigm. On the basis of the conditioning mechanisms proposed by Rescoral and Wagner, it would also be anticipated that in differential conditioning, increasing the intensity of accompanying US presentations would increase inhibitory properties of CS-. Stronger USs as accompanying events would be expected to result in greater excitatory properties of background stimuli (larger Vb's). Consequently, each nonreinforced CS-/CSb trial should result in a larger negative change in Vi, and greater inhibitory effects associated with CS-.

Similarly, the Rescorla-Wagner theory clearly implies that continued nonreinforcement of CS- in the absence of accompanying events should result in an extinction of inhibitory properties. To illustrate this prediction, assume that inhibitory conditioning has reached an asymptote such that $(Vb + Vi) = \lambda = 0$. Recall that the changes in strength for each component on a nonreinforced trial is dependent on $\lambda - (V_b + V_i)$. If Vb becomes smaller as a result of the removal of accompanying stimuli, subsequent nonreinforced trials of Vi should result in a weakening of negative strength until such time as Vi = 0.

Note that this "weakening" of negative strength actually translates as a relative positive increase in strength as Vi moves from some negative value to zero. The prediction of increased excitatory strength as a result of unreinforced trials is a particularly interesting feature of the Rescorla-Wagner theory. Such predictions are made on the basis of the assumption that excitatory and inhibitory conditioning are fundamentally symmetrical processes, determined by the existing strength of a compound on any reinforced or nonreinforced trial relative to the strength that may be maintained by the unconditioned stimulus value present on the trial. As a result, these unexplored issues assume particular importance for the theory. If the assumption of symmetry is accurate, it would be anticipated that excitatory and inhibitory conditioning would show similar sensitivity to the same fundamental parametric variables.

Even more crucial than the basic parametric variables such as CS and US intensity, however, are those manipulations that have been widely regarded as exerting different effects according to whether responses are reinforced or nonreinforced. For example, it is a common observation in excitatory conditioning (c.f. Kimble, 1961) that if reinforced trials are presented at short intervals (massed), acquisition proceeds at a slower rate than if such trials are separated by longer intervals (spaced). Conversely, if nonreinforced trials are massed, extinction may proceed more quickly than if such trials are spaced.

Such variables seem worthy of careful consideration. If spaced trials proved to be optimal for excitatory conditioning, while inhibitory conditioning prospered under massed trials, it would seem that two very different associative processes might be involved. In the face of such an outcome, assumptions of symmetry between excitatory and inhibitory conditioning would seem to require extensive revision.

Finally, mention should be made of the excitatory/ inhibitory dichotomy. Rescorla and Wagner do not have provisions in their theory for dual properties of stimuli; it is evident that a V value may not be both positive and negative. All theories begin with a set of assumptions, and the excitatory/inhibitory dichotomy seems to be particularly popular. Such a dichotomy is certainly implicit in many of the interpretations advanced in this thesis. Nevertheless, it is an assumption that has not received extensive experimental attention, and the issue should certainly be resolved empirically.

The experiments in this thesis have shown that both excitatory and inhibitory effects may make unexpected appearances when appropriate measurement techniques are used. In view of those observations, it is perhaps appropriate that this concluding note has dealt with outstanding issues.

It is becoming increasingly evident that Pavlovian conditioning may involve subtle and intricate mechanisms, and further refinements in experimental design and measurement are likely to result in the emergence of even more complex mechanisms. In any case, it seems unlikely that the characterization of Pavlovian conditioning as being based on learning processes that are either simple, or well-understood, is likely to be perpetuated.

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APPENDIX A

WEISS' ANALYSIS OF SUMMATION

APPENDIX A

Weiss' Analysis of Summation

In Chapter 2, a series of experiments by Weiss and his associates was outlined, concerning summation in food-reinforced barpressing (Weiss, 1964; 1969), and in conditioned suppression (VanHouten, O'Leary, and Weiss, 1970; Weiss and Emurian, 1970). In both experimental situations, the Weiss group demonstrated summation when the component stimuli were (T) and light (L), (Weiss, 1964; VanHouten, *et*. *al*., 1970), and when the stimuli were no-tone ($\bar{T}$) and no-light ($\bar{L}$). (Weiss, 1969; Weiss and Emurian, 1970).

Throughout this series of experiments, and in additional papers that will be reviewed here, Weiss has developed and extended an analysis of summation experiments that has been labeled "Stimulus Composite Continuum Attentional Analysis" (SCCAA).

Although based on a continuum, SCCAA is most easily presented if we begin with a 2 X 2 table. Table 8A shows the stimulus elements involved in the

		LIGHT	
		L	$\bar{L}$
A TONE	T	T L CS_1^+/CS_2^+	T $\bar{L}$ CS_1^+
	$\bar{T}$	$\bar{T}$ L CS_2^+	$\bar{T}$ $\bar{L}$ ITI

		LIGHT	
		L	$\bar{L}$
B TONE	T	T L ITI	T $\bar{L}$ CS_1^+
	$\bar{T}$	$\bar{T}$ L CS_2^+	$\bar{T}$ $\bar{L}$ CS_1^+/CS_2^+

Table 8. 2 X 2 Tables describing stimulus composites in Weiss' analysis. (A) Composites and stimulus conditions in Van Houten, O'Leary, and Weiss (1970) and Weiss (1964). (B) Composites and stimulus conditions in Weiss (1969) and Weiss and Emurian (1970).

experiments of VanHouten, et. al., (1970) and of Weiss (1964), representing Weiss' suggestion that the stimuli serving as components, compound, and intertrial interval (ITI) may be represented as "composites" of T, $\bar{T}$, L, and $\bar{L}$. For example, when T is presented as a CS, Weiss contends that the appropriate representation of the stimulus should be $T\bar{L}$.

Table 8B provides a similar representation of the experiments of Weiss (1969) and of Weiss and Emurian (1970). It is important to note that in terms of Weiss' analysis, the experimental conditions diagrammed in Tables 8A and 8B differ only in that different stimulus composites were defined as the compound and the ITI.

The "stimulus composite continuum" essentially involves "stretching" the 2 X 2 table. Figure 29A shows the continuum based on Table 8A. The continuum extends from the condition in which neither tone nor light is present ($\bar{T}\bar{L}$), through the two conditions in which one element is present ($T\bar{L}$, $\bar{T}L$), to the condition in which both elements are present (TL). For convenience, Weiss' (1964) demonstration of summation with stimuli that individually controlled barpressing, and the VanHouten, et. al., (1970) demonstration of summation

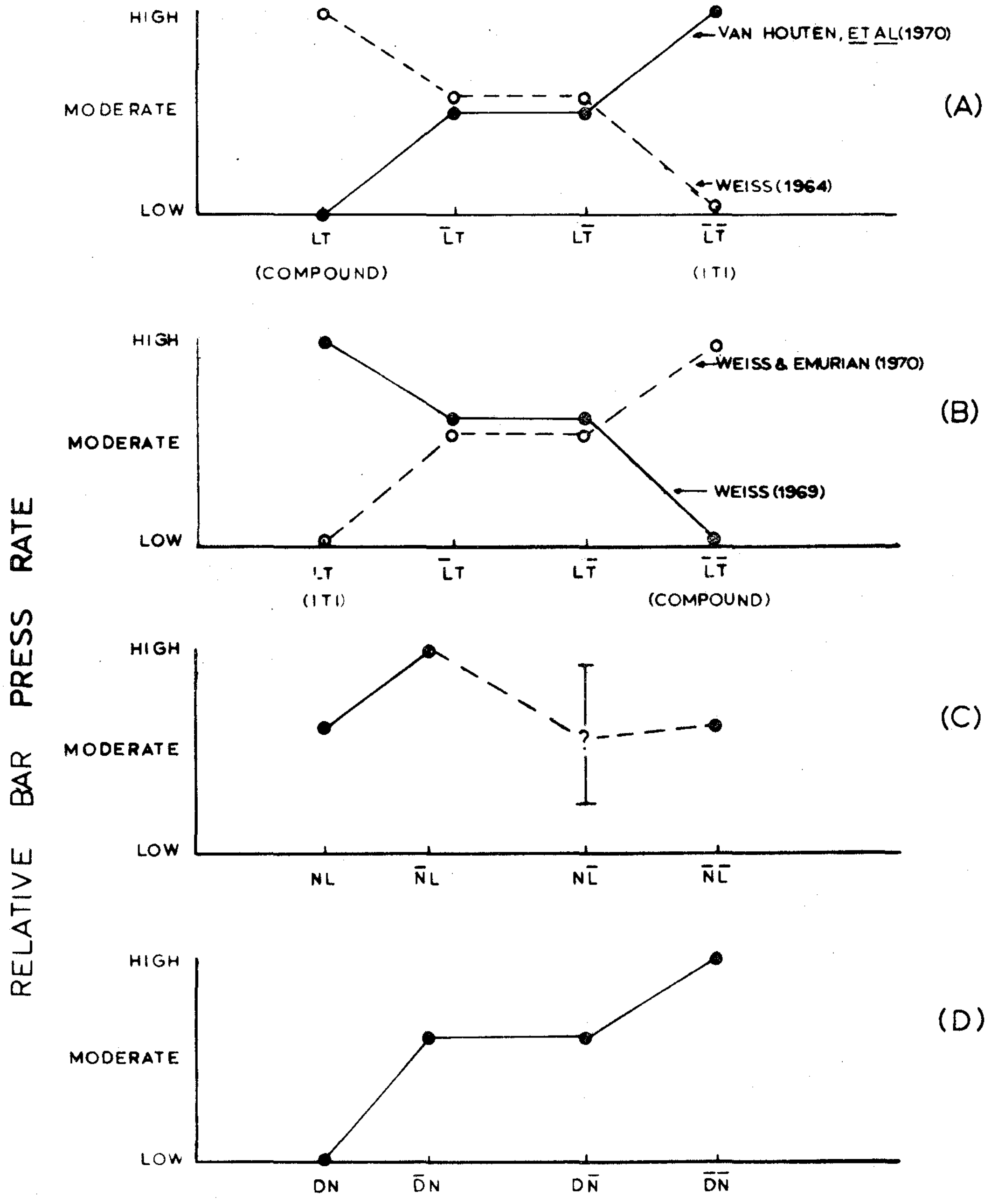

Figure 29. Theoretical stimulus composite continua generated by Weiss' analysis: (A) Composites describing experiments of Van Houten, O'Leary, and Weiss (1970) and Weiss (1964). (B) Composites describing experiments of Weiss (1969) and Weiss and Emurian (1970). (C) Stimulus composite continuum describing Experiment 1. (D) Alternative composite continuum describing Experiment 1. See text for details.

in conditioned suppression have been diagrammed above the continuum, in terms of the relative response levels associated with the various components.

A similar continuum representation of Table is shown in Figure 29 B. The food-reinforced bar press summation demonstration by Weiss (1969) and the conditioned suppression summation by Weiss and Emurian (1970) are diagrammed above the continuum.

One interesting feature of Weiss' analysis is illustrated by the conditioned suppression experiments of VanHouten, <u>et</u>. <u>al</u>., (1970) and Weiss and Emurian (1970). We have described the CSs in those two experiments as L and T, and as $\bar{L}$ and $\bar{T}$, respectively. Weiss' analysis, however, has raised the intriguing point that in both experiments the CSs were actually composites of $L\bar{T}$ and $\bar{L}T$.

Weiss (1969) has suggested that when conditioning takes place in the presence of a $T\bar{L}$ or $\bar{T}L$ composite, it is uncertain which feature of the composite S may be attending to. He has argued that compound tests may provide necessary information in this regard. For example, if summation is observed to the TL compound rather than the $\bar{T}\bar{L}$ compound, an indication is provided that T and L were "selectively attended to". Summation to the $\bar{T}\bar{L}$ compound, on the other hand, provides that $\bar{T}$ and $\bar{L}$ were attended to. Weiss has stressed that in the absence of compound tests one could not make that conclusion. In this respect, SCCAA is similar to the applications of compound summation that have been emphasized in this thesis. While we have been concerned with the possible use of compound tests to identify stimuli with "excitatory properties", Weiss has stressed their use to determine the controlling elements of a stimulus composite to which S is "selectively attending", Although the terminologies differ, the rationales seem similar.

Weiss has extended the continuum analysis to propose a schema that generates predictions of summation. Specifically he has suggested that the relationship between response rates at one extreme of the continuum and the rates observed to the composites that occupy the intermediate positions is a crucial factor in determining the response rates at the opposite extreme. In summarizing this point, Weiss and Emurian argued:

> What might be the necessary conditions for summation, whether additive or suppressive, is the differential rates controlled by extreme and intermediate composite stimuli in training. The relation of these rates to each other, other variables held constant,

> could determine the direction of summation to the composite extreme opposite to that employed in training.
>
> Weiss and Emurian (1970, p. 209)

Low rates of responding at one extreme of the continuum, coupled with moderate levels at the intermediate composites, should be accompanied by high levels of responding at the opposite extreme. Conversely, high rates at one extreme, coupled with moderate levels at intermediate composites, should be accompanied by low rates at the opposite extreme. In short, the implication of Weiss and Emurian's analysis would seem to be that summation is somehow a "rate-dependent" mechanism.

Note that Weiss and Emurian have specified that the relative rates of responding *during training* are the critical features. This feature permits SCCAA to incorporate the many instances described in Chapter 2, in which "extinguished" components exhibited very strong summation effects. Those demonstrations were clearly instances in which the rate of responding to at least one of the intermediate composites did not differ from the extreme composite identified as ITI.

However, occasional instances have also been recorded in which summation was observed, although one component did not produce suppression in training. In Group 1 - CS_2 in Experiment 2, three Ss showed prominent suppression on initial tests of CS_1/CS_2, in spite of the fact that corresponding test trials of CS_2 produced acceleration rather than suppression. Although there was no indication that the single pairing of CS_2 and shock produced any effect on the response rate, in those three Ss, summation still resulted in compound tests. It seems very likely that diligent experimental design and careful selection of shock intensities could produce similar summation demonstrations in which most Ss would display no observable suppression to CS_2+ in training.

In summary, the indications of summation experiments to date is that the extent to which summation may be predicted on the basis of observable rate relationships among stimuli is limited. A second difficulty with SCCAA seems even more fundamental, however: the appropriateness of the composite "continuum" is very much open to question.

One of the major problems with SCCAA is that the composite continuum possesses a degree of flexibility that is not associated with conventional continua such as wavelength of light. For example, stimuli with wavelengths of 540, 550, 560, and 570 NM have a fixed order that remains constant in any analysis. In the composite continuum however, the sequence is much more arbitrary. It is not clear, for example, whether $T\bar{L}$ should be regarded as adjacent to TL or to $\bar{T}\bar{L}$; the positions of intermediate components are entirely interchangable. Moreover, the status of composites as either "extreme" or "intermediate" may also be arbitrary. This feature is particularly damaging, since in its present form SCCAA predicts summation on the basis of relative response rates in extreme and intermediate components.

The arrangement shown in Figure 29C illustrates this point. White noise and light were stimuli used in the experiment that is represented in the continuum. Note that both extreme composites LN and $\bar{L}\bar{N}$ produce moderate levels of responding while one intermediate composite (LN) produces a high level. What result should be anticipated from a test of LN?

When the experimental situation is presented in this way, it is difficult to generate a prediction from SCCAA. But it is highly likely that very little responding would be observed to the NL composite, because the continuum describes the stimuli used in

Experiment 1 of this thesis. In terms of SCCAA, the experiment is recognizable only if the continuum is redrawn with D substituted for $\bar{L}$, as in Figure 19D, in which case the positions of extreme composites and intermediate composites are interchanged.

It is evident from this exercise that the relationships proposed in SCCAA are applicable only if one knows which composites served as CSs and the ITI, and which composite defined the compound. Weiss' analysis, then, is based on a convenient representation of the stimuli involved in the experiments, rather than being based on an implicit ordering that may properly be called a continuum.[17]

Although serious questions may be raised about the assumptions underlying SCCAA, the theory has generated two very interesting experiments as supporting evidence. In the first experiment (Weiss, 1968), two groups of four rats were trained in a multiple VI 30

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[17] In one major extension of SCCAA, Weiss (1970, in press) has drawn parallels betwen summation and the "peak shift" observed in some post-discrimination generalization gradients in well-defined continua such as light wavelength. Since it is highly questionable whether the composite "continuum" is related to the physical continua on which peak shift is observed, this extension of SCCAA seems particularly hazardous.

VI 75 sec schedule with tone (T) and light (L) counterbalanced as S+s. The ITI in both groups was identified by a no-tone/ light-out ($\bar{T}/\bar{L}$) condition. In one group, ITI was always 5 sec. In the second group, a no-response requirement ranging from 20 to 60 sec was enforced during ITI before the next component was presented.

Compound tests of the stimuli indicated that ITI treatment was important. When the ITI was prolonged, with the no-response requirement enforced, the summation effect was strong and consistent in all Ss. However, when only a brief ITI was introduced between trials, very different results were obtained. Only two of the four Ss showed any indication of summation, while the remaining two showed less compound responding than to the VI 30 stimulus. Furthermore, the results of compound tests in the short ITI groups were closely related to ITI performance. Those Ss that did *not* respond to the ITI in tests showed clear summation, paralleling the results of the long ITI group. Those Ss that *did* respond appreciably to the long ITI, however, showed less compound responding than to the VI 30 stimulus.

To extend these results, Weiss (in press, Experiment 1) examined a group of four rats trained on a Mult VI 30 VI 75 sec schedule, in which the components were programmed consecutively, with no intervening ITI.

In Weiss' notation, the stimuli signalling the components were $T\bar{L}$ and $\bar{T}L$, counterbalanced. In extinction tests, 45 sec presentations of $T\bar{L}$, $\bar{T}L$, and TL alternated with 15 sec periods of $\bar{T}\bar{L}$. Thus, Weiss was able to examine the compounds of TL and $\bar{T}\bar{L}$, both of which included one element from the composite associated with VI 30 and one from the composite associated with VI 75 sec. The results of these tests were clear. Both the TL and the $\bar{T}\bar{L}$ compounds produced rates of responding that were lower than those associated withthe VI 30 stimulus. In fact, overall test results indicated that the TL and $\bar{T}\bar{L}$ conditions were indistinguishable.

In a related experiment, Weiss (in press, Experiment 2) attempted to assess the relative effects of response cessation and non-reinforcement during ITI. Two groups of 5 rats were examined. Both were trained on a Mult VI 30 sec VI 90 sec schedule. L and T were counterbalanced as S+s. Following each component, a no-light no-tone ITI was scheduled. The groups differed primarily in the treatments received during the ITI.

In the first group, no reinforcement was programmed during ITI, and Ss were required to cease responding for between 30 and 90 sec before the subsequent S+ appeared. In the second group, the ITI no-response requirement was 15 sec, at the end of which food was delivered. Ss in the second group were yoked to Ss in the first group so that total exposure to ITI was the same. Contrasting these ITI treatments permitted evaluation of the relative importance of response and reinforcement cessation on summation demonstrations. Both groups showed prolonged periods of non-responding in the ITI, but one group received food reinforcement for non-responding. Weiss argued that if response cessation were the critical variable, both groups should show summation in compound tests of LT. If reinforcement cessation were critical, only the group receiving no food in ITI should show summation. Test results showed that both groups displayed summation on compound trials, although the group receiving no reinforcement in ITI showed a stronger effect than the reinforced ITI group. While response cessation during ITI is important for summation demonstrations, there were indications that nonreinforcement also contributes.

Since Weiss' theory is fundamentally a theory about summation, his discussion of these data emphasized the occurrence or non-occurrence of summation. However, it is evident that the "failures to obtain summation" may constitute very interesting findings in themselves. The tests of the two non-summation subjects reported in Weiss' (1968) limited-ITI experiment, and the compound tests of subjects in Weiss' (in press) no-ITI experiment all showed compound levels of responding that were less than those associated with the VI 30 sec component and greater than the VI 75 sec component. This pattern of responding suggests that stimulus elements associated with the VI 75 sec schedule may have exerted an attenuating effect in compound tests. If this is the case, the very interesting possibility is introduced that a stimulus associated with a relatively "poor" VI 75 sec schedule in Mult VI 30 VI 75 training may become functionally excitatory or inhibitory, depending on the treatment administered during the ITI. The potential importance of ITI treatments in such experiments would seem worthy of serious investigation.[18]

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[18] There is indirect confirmation of this possibility in experiments by Guttman (1959) and Terrace (1968, Experiment 1) showing "behaviour contrast" and "peak shift" in multiple schedules including relatively "good" and relatively "poor" VI components. Guttman's experiment included a 10 sec ITI that was presented only three times in early 20 min session. Terrace's experiment featured a two-second ITI. Since behaviour contrast and peak shift have been identified as adjuctive indexes of inhibition (Terrace, 1966; 1968), these results suggest that the stimuli signalling the "poorer" component may have exerted inhibitory control. Further research is obviously necessary to confirm that possibility, but when the results of Guttman (1959) and Terrace (1968) are combined with the above interpretation of Weiss' (1968, in press) findings the interesting possibility is raised that ITI treatment may prove to be an important variable in observations of peak shift and behaviour contrast in such situations.

In overview, it is evident that Weiss' experiments (1968, in press) reported in support of SCCAA have much broader implications. Those implications are only apparent, however, when the experiments are considered outside the emphasis on excitatory summation effects; that is an unfortunate by-product of SCCAA. Although SCCAA has generated some very interesting experimental designs and data, the overall impact of the theory seems to be one of obscuring, rather than clarifying, potential importance of compound tests.

APPENDIX B

EXPERIMENTAL DATA

Experiment 1: Acquisition and first test suppression ratios

	Session:	Pretest						Conditioning 1						Conditioning 2			
	Stimulus:	N		D		N/D		N		D			Test 1	N		D	
	Trial:	1	2	1	2	1	2	1	2	1	2			1	2	1	2
	S#																
	1	.33	.53	.45	.48	.33	.56	.46	.12	.27	.10		.12	.00	.00	.00	.00
Group D	2	.41	1.0	.64	.59	.28	.61	.53	.47	.40	.33		.62	.00	.00	.10	.00
	3	.31	.33	.24	.67	.22	.49	.37	.40	.50	.10	Dark	.00	.35	.00	.00	.08
	4	.38	.47	.46	.67	.25	.65	.52	.50	.56	.23		.50	.48	.25	.24	.04
	5	.43	.48	.47	.40	.45	.40	.27	.36	.33	.25		.33	.17	.11	.08	.57
	6	.40	.58	.41	.67	.48	.56	.47	.50	.62	.42		.27	.25	.14	.20	.00
	7	.26	.66	.21	.36	.61	.66	.41	.37	.26	.40		.42	.45	.13	.00	.00
Group N	8	.44	.50	.21	.27	.24	.04	.32	.63	.33	.40		.15	.00	.08	.03	.09
	9	.35	.45	.19	.33	.17	.35	.48	.40	.39	.50	Noise	.45	.09	.00	.36	.07
	10	.41	.40	.40	.55	.59	.50	.50	.33	.64	.56		.59	.15	.00	.07	1.0
	11	.45	.51	.35	.44	.40	.38	.53	.48	.62	.33		.64	.68	.47	.04	.10
	12	.38	.37	.13	.49	.33	.73	.69	.36	.38	.40		.43	.04	.00	.00	.00
	13	.43	.53	.33	.43	.55	.59	.51	.50	.30	.43	Noise/Dark	.14	.50	.00	.02	.11
Group C	14	.36	.52	.26	.30	.52	.51	.53	.43	.51	.47		.31	.30	.29	.35	.30
	15	.21	.50	.22	.40	.49	.50	.48	.41	.39	.46		.00	.13	.00	.00	.00
	16	.50	.55	.39	.36	.62	.53	.47	.51	.41	.45		.29	.12	.00	.05	.00
	17	.47	.60	.47	.50	.37	.69	.46	.39	.26	.45		.00	.00	.00	.00	.00
	18.	.29	.60	.24	.31	.57	.60	.49	.41	.39	.26		.04	.00	.00	.33	.00

Experiment 1 Extinction and Test Suppression Ratios

		EXTINCTION 1								EXTINCTION 2								
							Test 2	Trials to .20 crit		Test Block 1			Test Block 2			Test Block 3		
	S#	N		D				N	D	N	D	N/D	N	D	N/D	N	D	N/D
		1	2	1	2													
	1	.00	.00	.00	.00		.00			**								
Group D	2	.00	.00	.00	.00		.00			**								
	3	.00	.03	.05	.03	Dark	.03			**								
	4	.00	.00	.17	.00		.04			**								
	5	.00	.00	.33	1.0		.00			**								
	6	.00	.00	.00	.00		.00	2	6	.50	.31	.17	.50	.50	.20	.45	.28	.17
	7	.00	.00	.00	.00		.00	2	4	.40	.21	.03	.43	.49	.10	.49	.38	.00
Group N	8	.00	.00	.00	.00	Noise	.03	5	6	.40	.32	.00	.55	.25	.08	.23	.31	.00
	9	.00	.00	.00	.00		.06	2	2	.23	.31	.00	.26	.26	.00	.53	.45	.43
	10	.00	.00	.00	.00		.00			**								
	11	.03	.24	.00	.00		.45	2	2	.47	.23	.31	.65	.39	.34	.00	.25	.00
	12	.02	.04	.10	.05		.00	3	10	.40	.26	.00	.37	.35	.03	.44	.30	.14
	13	.03	.18	.02	.02		*	2	2	.49	.43	.18	.49	.40	.27	.47	.43	.61
Group C	14	.00	.04	.04	.12	Noise/Dark	.10	1	2	.47	.48	.22	.46	.59	.31	.36	.46	.05
	15	.00	.00	.00	.00		.00	4	4	.35	.30	.00	.42	.29	.00	.38	.51	.46
	16	.00	.27	.04	.17		.04	1	1	.31	.49	.13	.47	.37	.37	.35	.48	.00
	17	.00	.00	.00	.00		.00	3	1	.32	.39	.00	.33	.37	.00	.30	.38	.26
	18	.00	.05	.20	.22		.00	2	2	.37	.27	.29	.38	.23	.12	.57	.21	.31

* received noise test by error. Ratio = .45

** No tests

Experiment 2 Acquisition Suppression Ratios

		Stimuli		Session: Pretest						Conditioning 1				Conditioning 2		Conditioning 3			
		CS_1	CS_2	Stimuli: N		D		N/D		CS_1		CS_2		CS_1		CS_1		CS_2	
	S#			Trial: 1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Group 1-CS_2	1	D*	N**	.41	.53	.39	.42	.65	.43	.11	.37			.00	.12			.32	
	2	N	D	.30	.48	.40	.39	.61	.39	.50	.45			.21	.00			.32	
	3	D	N	.39	.47	.23	.40	.46	.40	.43	.34			.33	.14			.40	
	4	D	N	.17	.44	.16	.40	.32	.26			.45		.34	.19	.04	.07		
	5	N	D	.33	.62	.43	.35	.25	.48			.50		.30	.61	.16	.05		
	6	D	N	.49	.57	.38	.50	.58	.43			.58		.53	.15	.00	.00		
	7	N	D	.51	.38	.41	.53	.49	.41			.52		.52	.49	.56	.41		
	8	D	N	.44	.87	.55	.50	.36	.28			.68		.55	.00	.09	1.0		
	9	N	D	.36	.52	.44	.46	.43	.58			.40		.53	.41	.00	.03		
	10	D	N	.40	.49	.48	.43	.40	.43	.43	.45			.00	.02			.46	
	11	N	D	.42	.40	.31	.42	.30	.46	.46	.32			.00	.00			.50	
Group 2-CS_2	1	N	D	.48	.49	.31	.33	.27	.58	.45	.45			.05	.00			.26	.04
	2	D	N	.44	.46	.38	.30	.33	.54	.39	.35			.08	.02			.35	.00
	3	N	D	.25	.68	.09	.30	.27	.08	.49	.62			.00	.00			.25	.00
	4	D	N	.23	.52	.36	.38	.54	.41	.65	.58			.35	.00			.75	.16
	5	N	D	.30	.55	.29	.47	.68	.47			.53	.38	.42	.00	.00	.00		
	6	D	N	.50	.37	.55	.44	.42	.71			.55	.64	.27	.24	.14	.02		
	7	N	D	.49	.47	.33	.36	.48	.49			.34	.34	.52	.24	.07	.06		
	8	N	D	.30	.72	.55	.36	.33	.36	.60	.41			.00	.00			.35	.09
	9	D	N	.19	.61	.33	.34	.23	.45	.54	.39			.00	.00			.32	.00
	10	N	D	.09	.30	.31	.45	.26	.44			.45	.43	.21	.01	.00	.00		
	11	D	N	.49	.44	.26	.41	.36	.52	.71	.51			.50	.45	.13	.07		
Group CS_2^{o}	1	N	D	.76	.57	.25	t	.48	t	.43	.48			.25	.08				
	2	D	N	.52	t	.41	.53	.56	t	.57	.43			.27	.00				
	3	N	D	.16	.18	.23	t	.78	t	.51	.52			.07	.00				
	4	D	N	.19	t	.26	.34	.25	t					.65	.49	.02	.00		
	5	N	D	.39	.33	.49	.39	.32	.52					.48	.38	.06	.00		
	6	D	N	.37	.37	.23	.18	.44	.53					.53	.39	.13	.02		
	7	N	D	.45	.41	.09	.63	.48	.58					.34	.38	.08	.00		
	8	D	N	.54	.57	.10	.20	.31	.51					.29	.08	.00	.00		

* D = Darkness

** N = 75 db White Noise

t: lost data

Experiment 2 Extinction and Test Block Suppression Ratios

		Stimuli		Trials to Extinction Crit.	Test Block 1			Test Block 2			Test Block 3		
	S#	CS$_1$	CS$_2$	CS$_1 \geq$.20	CS$_1$	CS$_2$	CS$_1$/CS$_2$	CS$_1$	CS$_2$	CS$_1$/CS$_2$	CS$_1$	CS$_2$	CS$_1$/CS$_2$
	1	D	N	12	.39	.00	.00	.13	.00	.11	.35	.17	.15
	2	N	D	7	.35	.20	.30	.36	.36	.39	.40	.56	.45
Group 1-CS$_2$	3	D	N	10	.13	.08	.10	.31	.26	.09	.38	.32	.10
	4	D	N	26	.21	.11	.00	.20	.45	.03	.33	.55	.23
	5	N	D	7	.50	.30	.30	.51	.42	.34	.47	.52	.45
	6	D	N	19	.00	.50	.00	.89	.84	.14	.44	.64	.00
	7	N	D	2	.21	.88	.56	.44	.87	.59	.39	.50	.68
	8	D	N	2	.05	.36	.17	.05	.67	.00	.28	.54	.15
	9	N	D	24	.35	.36	.00	.30	.34	.11	.27	.50	.21
	10	D	N	16	.37	.52	.00	.31	.48	.02	.57	.05	.28
	11	N	D	10	.39	.59	.42	.59	.40	.22	.54	.33	.13
	1	N	D	14	.18	.03	.04	.34	.00	.00	.42	.18	.00
	2	D	N	37	.50	.00	.00	.24	.00	.00	.20	.08	.00
Group 2-CS$_2$	3	N	D	27	.38	.15	.00	.19	.20	.01	.06	.02	.03
	4	D	N	34	.27	.00	.00	.14	.00	.00	.40	.33	.00
	5	N	D	26	.05	.14	.00	.00	.06	.00	.21	.18	.00
	6	D	N	19	.07	.00	.00	.07	.00	.00	.23	.37	.00
	7	N	D	4	.15	.09	.17	.25	.32	.38	.36	.37	.40
	8	N	D	24	.22	.00	.00	.00	.00	.00	.30	.05	.00
	9	D	N	13	.19	.00	.00	.14	.00	.00	.35	.00	.00
	10	N	D	29	.19	.05	.00	.26	.35	.00	.31	.12	.00
	11	D	N	1	.17	.13	.12	.14	.31	.17	.77	.55	.35
Group CS$_2^{o}$	1	N	D	10	.41	.18	.38	.16	.13	.66	.75	.37	.61
	2	D	N	24	.43	.48	.36	.38	.53	.47	.44	.37	.45
	3	N	D	8	.42	.35	.19	.46	.39	.59	.26	.40	.50
	4	D	N	14	.18	.42	.45	.26	.39	.36	.44	.47	.52
	5	N	D	18	.26	.41	.38	.44	.44	.38	.48	.51	.35
	6	D	N	22	.52	.39	.59	.37	.46	.30	.28	.58	.82
	7	N	D	22	.32	.38	.40	.54	.56	.55	.38	.47	.34
	8	D	N	23	.30	.60	.25	.26	.44	.51	.44	.48	.62

Experiment 3: Group 3/3/A Pretest and Acquisition Suppression Ratios

	Stimuli		Pretest						Conditioning 1						Conditioning 2					
	CS+	CS-	N		D		N/D		CS+			CS-			CS+			CS-		
S#			1	2	1	2	1	2	1	2	3	1	2	3	1	2	3	1	2	3
1	D	N	.76	.67	.32	.35	.42	.50	.44	.42	.51	.69	.30	.48	.15	.00	.13	.49	.54	.45
2	D	N	.31	.59	.36	.44	.36	.40	.20	.36	.24	.51	.55	.36	.00	.00	.00	.07	.55	.39
3	N	D	.38	.65	.40	.55	.46	.53	.53	.60	.00	.41	.59	.67	.00	.00	.00	1.0	.59	.58
4	N	D	.44	.50	.16	.40	.34	.40	.36	.64	.14	.19	.39	.68	.00	.00	.00	.09	.29	.33
5	N	D	.26	.55	.43	.56	.50	.63	.55	.54	.00	.55	.52	1.0	.00	.00	.20	.33	.55	.66
6	N	D	.29	.53	.25	.48	.41	.42	.52	.19	.55	.44	.39	.55	.01	.00	.00	.31	.00	.92
7	N	D	.38	.64	.25	.33	.63	.48	.41	.42	.19	.38	.40	.49	.00	.00	.00	.50	.48	.00
8	D	N	.26	.45	.21	.58	.47	.44	.22	.05	.00	.47	.57	.50	+.00	.00	.00	1.0	1.0	1.0
9	D	N	.37	.30	.28	.37	.23	.46	.43	.51	.43	.40	.39	.54	.02	.13	.00	.45	.62	.53
10	D	N	.50	.53	.36	.55	.75	.61	.57	.57	.00	.50	.57	.00	+.00	.00	.00	.00	.00	.00

	Conditioning 3						Conditioning 4					
	CS+			CS-			CS+			CS-		
	1	2	3	1	2	3	1	2	3	1	2	3
1	+.00	.00	.00	.57	.00	.00	.00	.00	.09	.50	.55	.50
2	.03	.03	.00	.52	.51	.51	.04	.00	.00	.76	.68	.70
3	.00	.00	.00	.48	.66	.20	.00	.00	.00	.65	.60	.53
4	.00	.07	.07	.56	1.0	.31	.00	.00	.00	.32	.47	.35
5	+.00	.14	.00	.53	.00	.00	.00	.00	.00	.53	.53	.76
6	.00	.08	.00	.27	.30	1.0	.00	.00	.00	.33	.45	.29
7	+.00	.00	.00	.69	.50	.00	.00	.00	.03	.53	.00	.43
8	+.00	.00	.00	1.0	1.0	1.0	.00	.00	.00	.54	.61	.82
9	.00	.09	.03	.52	.52	.41	.10	.07	.08	.42	.48	.55
10	+.00	.00	.00	.00	.00	.00	+1.0	.75	.00	.43	1.0	.25

+ Session in which S "froze" with little bar-pressing

Experiment 3: Group 3/0/A Pretest & Acquisition Suppression ratios

	Stimuli			Pretest						Conditioning 1			Conditioning 2		
	S#	CS+	CS^{o}	N		D		N/D		CS+			CS+		
				1	2	1	2	1	2	1	2	3	1	2	3
Group 3/0/A	1	N	D	.35	.53	.29	.55	.37	.33	.77	.45	.38	.06	.00	.00
	2	N	D	.49	.63	.31	.43	.48	.41	.58	.63	.70	.25	.14	.16
	3	D	N	.27	.53	.46	.57	.41	.55	.30	.55	.17	.00	.20	.00
	4	D	N	.48	.68	.66	1.0	.81	.94	.42	.63	.00	.00	.09	.00
	5	D	N	.50	.55	.44	.33	.69	1.0	.77	.54	.43	.00	.00	.00
	6	D	N	.27	.38	.23	.25	.57	.46	.55	.03	.19	.00	.00	.00
	7	D	N	.09	1.0	.21	.40	.22	.49	.43	.36	.56	.34	.00	.03
	8	N	D	.30	.65	.43	.32	.28	1.0	.63	.57	.13	.00	.00	.00
	9	N	D	.48	.39	.40	.46	.44	.37	.51	.52	.00	.00	.00	.00
	10	N	D	.34	.56	.23	.50	.35	.32	.52	.34	.00	.00	.00	.00

	Conditioning 3			Conditioning 4		
	CS+			CS+		
	1	2	3	1	2	3
1	.00	.00	.00	.00	.00	.00
2	.22	.00	.00	.00	.14	.00
3	.00	.00	.00	.00	.00	.00
4	.00	.00	.00	.00	1.0	.00
5	.00	.07	.11	.00	.00	.05
6	+.00	.00	.11	.00	.00	.00
7	.00	.00	.00	.03	.00	.00
8	+.00	.00	.00	.00	.00	.00
9	.00	.00	.07	.00	.02	.05
10	.00	.00	.00	.00	.00	.02

+ session in which *S* "froze" with little bar-pressing.

Experiment 3: Groups 3/3/A and 3/0/A. Daily Test Suppression Ratios

	S#	Stimuli		Test 1			Test 2			Test 3			Test 4			Test 5		
		CS+	CS-	CS+	CS-	CS+/CS-	CS+	CS-	CS+/CS+	CS+	CS-	CS+/CS+	CS+	CS-	CS+/CS+	CS+	CS-	CS+/CS-
Group 3/3/A	1	D	N	.00	.74	.31	.32	.68	.60	.24	.55	.53	.34	.59	.50	.40	.46	.66
	2	D	N	.14	.55	.18	.47	.47	.46	.42	.44	.51	.49	.51	.54	.58	.70	.65
	3	N	D	.02	.43	.03	.00	.49	.03	.06	.53	.09	.4	.45	.25	.07	.42	.40
	4	N	D	.00	.39	.05	.00	.44	.00	.00	.45	.00	.00	.45	.04	.00	.29	.03
	5	N	D	.02	.76	.00	.00	.50	.00	.00	.59	.00	.00	.58	.03	.04	.46	.12
	6	N	D	.01	.46	.01	.00	.48	.00	.01	.49	.06	.14	.47	.29	.00	.48	.38
	7	N	D	.00	.46	.01	.00	.46	.01	.01	.21	.12	.03	.43	.28	.05	.42	.35
	8	D	N	.00	.75	.00	.00	.48	.00	.00	.52	.02	.01	.49	.03	.00	.49	.11
	9	D	N	.12	.51	.22	.31	.50	.40	.50	.47	.52	.53	.48	.63	.60	.50	.58
	10	D	N	.00	.32	.00	.00	.49	.12	.00	.53	.29	.03	.40	.30	.08	.52	.26

		CS+	CS^o	CS+	CS^o	CS+/CS^o	CS+	CS^o	CS+/CS^o	CS+	CS^o	CS+/CS^o	CS+	CS^o	CS+/CS^o	CS+	CS^o	CS+/CS^o
Group 3/0/A	1	N	D	.03	.45	.04	.00	.60	.18	.16	.53	.43	.14	.42	.63	.03	.40	.45
	2	N	D	.32	.41	.43	.43	.56	.61	.48	.58	.35	.65	.66	.71	.41	.75	.76
	3	D	N	.00	.41	.00	.00	.55	.00	.11	.46	.25	.29	.51	.42	.62	.50	.55
	4	D	N	.01	.48	.07	.00	.59	.04	.32	.81	.27	.33	.66	.47	.33	.61	.58
	5	D	N	.02	.59	.26	.27	.45	.42	.44	.56	.58	.65	.67	.73	.40	.30	.57
	6	D	N	.01	.41	.05	.04	.46	.16	.33	.53	.40	.40	.50	.33	.53	.59	.55
	7	D	N	.01	.35	.00	.05	.45	.27	.21	.40	.32	.27	.41	.29	.40	.45	.45
	8	N	D	.00	.45	.01	.02	.40	.03	.23	.37	.28	.46	.45	.45	.44	.51	.57
	9	N	D	.00	.33	.00	.06	.35	.17	.17	.43	.27	.43	.44	.48	.42	.48	.52
	10	N	D	.00	.43	.03	.00	.22	.00	.12	.48	.25	.29	.32	.34	.20	.41	.40

Experiment 4: Group 3/0/B Pretest and Acquisition Suppression Ratios

	Stimuli		Pretest						Conditioning 1			Conditioning 2		
	CS+	CS^o	N		D		N/D		CS+			CS+		
Subject #			1	2	1	2	1	2	1	2	3	1	2	3
1	N	D	.32	.27	.21	.22	.20	.28	.49	.45	.41	.11	.08	.03
2	N	D	.29	.58	.23	.34	.23	.33	.46	.53	.40	.01	.02	.00
3	N	D	.43	.47	.33	.48	.63	.61	.51	.47	.50	.00	.00	.00
4	N	D	.37	.52	.21	.63	.63	.82	.51	.36	.29	.00	.00	.00
5	N	D	.30	.52	.50	.47	.37	.61	.49	.39	.08	.04	.00	.00
6	D	N	.35	.39	.42	.50	.53	.52	.48	.56	.28	.03	.03	.00
7	D	N	.29	.46	.45	.56	.31	.39	.59	.63	.50	.33	.00	.36
8	D	N	.53	.55	.39	.45	.41	.37	.36	.24	.00	.05	.13	.14
9	D	N	.35	.45	.29	.48	.42	.53	.42	.25	.46	.21	.03	.00
10	D	N	.32	.46	.34	.43	.52	.48	.46	.66	.35	.13	.57	.25

	Conditioning 3			Conditioning 4		
	CS+			CS+		
	1	2	3	1	2	3
1	.03	.00	.28	.00	.70	.11
2	.00	.03	.05	.02	.14	.18
3	.00	.00	.00	.00	.00	.00
4	.00	.01	.00	.00	.04	.00
5	.00	.00	.00	.00	.00	.00
6	.00	.00	.00	.00	.00	.00
7	.08	.28	.17	.00	.15	.13
8	.03	.00	.00	.08	.29	.33
9	.08	.11	.09	.00	.00	.08
10	.26	.00	.00	.11	.33	.17

Experiment 4 Group 3/3/B Pretest and Acquisition Data

	Stimuli		Pretest						Conditioning 1			Conditioning 2		
	CS+	CS-	N		D		N/D		CS+			CS+		
Subject #			1	2	1	2	1	2	1	2	3	1	2	3
1	D	N	.18	.00	.35	.44	.48	.36	.47	.32	.37	.35	.11	.00
2	D	N	.21	.49	.37	.45	.33	.68	.47	.39	.41	.06	.29	.07
3	D	N	.33	.91	.50	.45	.64	.95	.49	.35	.44	.00	.00	.00
4	D	N	.44	.47	.53	.47	.55	.41	.54	.49	.43	.25	.17	.00
5	N	D	.34	.41	.44	.56	.48	.51	.50	.46	.15	.05	.07	.03
6	N	D	.28	.44	.41	.43	.48	.35	.46	.43	.13	.00	.00	.06
7	N	D	.21	.54	.27	.41	.36	.36	.52	.49	.19	.00	.00	.06
8	N	D	.25	.43	.23	.39	.40	.47	.43	.50	.13	.03	.03	.00
9	N	D	.26	.48	.43	.46	.37	.30	.48	.47	.10	.05	.00	.00
10	N	D	.49	.49	.41	.49	.53	.49	.44	.61	.47	.00	.04	.15

	Conditioning 3						Conditioning 4					
	CS+			CS-			CS+			CS-		
	1	2	3	1	2	3	1	2	3	1	2	3
1	+ .30	.00	.00	.30	1.0	.00	+ 1.0	1.0	1.0	.00	1.0	1.0
2	.59	.46	.59	.00	.03	.00	.43	.58	.68	.00	.18	.13
3	.54	.37	.88	.06	.00	.00	.60	.56	.56	.00	.09	.13
4	.00	.00	.45	.00	.00	.00	.56	.59	.55	.00	.00	.00
5	.46	.62	.55	.17	.00	.20	.60	.69	.68	.00	.20	.38
6	.35	.59	.37	.00	.00	.00	.52	.52	.64	.00	.00	.00
7	.50	.35	.32	.00	.05	.04	.63	.62	.52	.00	.00	.00
8	.48	.55	.56	.00	.03	.00	.60	.31	.56	.00	.00	.00
9	.55	.52	.50	.00	.00	.00	.58	.52	.43	.00	.00	.00
10	.42	.38	.48	.00	.00	.00	.75	.38	.48	.00	.00	.00

+ = session in which S "froze" with
little bar-pressing

Experiment 4: Average Conditioning Pre-CS Baseline

Group 3/0/B

Subject #	Cond'g 1	Cond'g 2	Cond'g 3	Cond'g 4
1	39.3	40	32.7	28.0
2	54.6	84.3	51.0	39.7
3	13.3	9.7	8.0	6.3
4	57.0	40.0	76.3	51.7
5	31.0	25.0	12.7	15.7
6	14.3	23.7	18.7	21.0
7	12.0	11.0	10.7	17.0
8	24.3	10.7	11.7	6.0
9	41.3	49.3	16.3	29.3
10	24.6	19.3	17.7	20.3

Group 3/3/B

Subject #				
2	46.3	25.3	47.8	18.0
3	16.3	21.3	14.5	12.0
4	16.3	14.7	16.5	11.8
5	17.0	19.7	16.7	18.0
6	25.7	19.6	13.0	11.7
7	36.0	38.3	32.7	26.7
8	37.6	29.3	24.0	17.8
9	10.6	16.3	10.7	9.2
10	20.0	20.3	20.5	13.8

Experiment 4 Trials to CS+ $\geq$ .20 Extinction Criterion

Group 3/0/B			Group 3/3/B		
Subject #	CS+	CS+ $\geq$ .20	Subject #	CS+	CS+ $\geq$ .20
1	N	25	1	N	12
2	N	9	2	N	4
3	N	16	3	N	16
4	N	14	4	N	16
5	N	18	5	N	25
6	D	32	6	N	18
7	D	12	7	D	3
8	D	3	8	D	32
9	D	11	9	D	10
10	D	11	10	D	12

Experiment 4 Test Block Suppression Ratios

	S#	Stimuli		Test Sequence	First CS+ Block			First CMP Block			Second CS+ Block			Second CMP Block		
		CS+	CS^{o}		CS+	CS^{o}	CS+	CS+	CS^{o}	CS+/CS^{o}	CS+	CS^{o}	CS+	CS+	CS^{o}	CS+/CS^{o}
Group 3/0/B	1	N	D	CS-CMP	.45	.24	.42	.42	.27	.30	.40	.56	.50	.47	.37	.32
	2	N	D	CS-CMP	.20	.49	.27	.25	.27	.19	.29	.41	.57	.31	.31	.42
	3	N	D	CMP-CS	.30	.19	.13	.32	.45	.17	.36	.37	.37	.45	.44	.58
	4	N	D	CMP-CS	.23	.34	.61	.30	.33	.44	.20	.41	.23	.41	.49	.45
	5	N	D	CMP-CS	.30	.31	.00	.44	.41	.09	.39	.78	.60	.39	.64	.34
	6	D	N	CMP-CS	.27	.40	.19	.50	.16	.20	.36	.42	.17	.19	.60	.19
	7	D	N	CMP-CS	.30	.50	.31	.42	.48	.37	.68	.61	.07	.24	.47	.29
	8	D	N	CM -CS	.53	.41	.14	.32	.38	.00	.21	.46	.05	.22	.50	.46
	9	D	N	CS-CMP	.58	.45	.36	.20	.43	.25	.50	.54	.46	.44	.55	.49
	10	D	N	CS-CMP	.24	.08	.34	.29	.69	.53	.42	.30	.34	.28	.48	.43
					CS+	CS-	CS+	CS+	CS-	CS+/CS-	CS+	CS-	CS+	CS+	CS-	CS+/CS-
Group 3/3/B	1	N	D	CMP-CS	.22	.56	.10	.27	.46	.42	.24	.39	.42	.55	.48	.52
	2	N	D	CMP-CS	.22	.56	.00	.22	.63	.07	.29	.44	.33	.20	.59	.46
	3	N	D	CMP-CS	.36	.51	.21	.29	.49	.50	.38	.51	.29	.41	.38	.76
	4	N	D	CS-CMP	.29	.48	.35	.20	.39	.40	.47	.52	.62	.23	.63	.53
	5	N	D	CS-CMP	.22	.31	.19	.28	.26	.19	.32	.61	.33	.31	.39	.41
	6	N	D	CS-CMP	.20	.48	.30	.23	.46	.31	.38	.69	.53	.20	.42	.41
	7	D	N	CS-CMP	.20	.57	.14	.29	.75	.44	.39	.63	.42	.50	.55	.54
	8	D	N	CMP-CS	.27	.59	.44	.39	.57	.36	.39	.57	.36	.69	.63	.71
	9	D	N	CMP-CS	.22	.45	.25	.23	.35	.36	.28	.70	.25	.31	.14	.53
	10	D	N	CMP-CS	.50	.47	.06	.75	.47	.45	.21	.59	.32	.32	.53	.44

Experiment 5: Pretest and Acquisition Suppression Ratios

		Stimuli		Pretest						Cond'g 1		Cond'g 2		Cond'g 3	
		CS$^+$1	CS$^+$2	N		D		N/D		CS$^+$1	CS$^+$2	CS$^+$1	CS$^+$2	CS$^+$1	CS$^+$2
	Subject #			1	2	1	2	1	2						
Group .45	1	N	D	.41	.55	.06	.29	.11	.29	.52	.31	.06	.10	.00	.08
	2	N	D	.40	.36	.26	.51	.45	.36	.34	.41	.26	.11	.00	.06
	3	D	N	.39	.42	.24	.39	.43	.25	.30	.43	.00	.27	.00	.00
	4	D	N	.30	.39	.32	.40	.49	.53	.44	.37	.00	.00	.00	.00
	5	N	D	.35	.49	.26	.59	.30	.22	.49	.34	.02	.17	.00	.00
	6	N	D	.28	.43	.37	.55	.46	.59	.54	.35	.00	.02	.00	.00
	7	D	N	.44	.37	.09	.32	.18	.28	.37	.67	.12	.50	.00	.02
	8	D	N	.26	.41	.33	.42	.30	.26	.44	.60	.02	.00	.00	.00
	9	N	D	.40	.38	.34	.27	.33	.29	.38	.27	.37	.05	.01	.02
	10	N	D	.31	.38	.28	.39	.26	.41	.47	.43	.38	.19	.00	.00
	11	D	N	1.0	.33	.50	.22	.04	.00	.75	.08	.13	.04	.00	.00
	12	D	N	.43	.56	.22	.30	.55	.46	.28	.57	.12	.32	.00	.03
Group .45 + 54	1	N	D	.27	.38	.29	.48	.43	.53	.42	.48	.00	.00	.00	.00
	2	N	D	.27	.46	.20	.58	.21	.29	.53	.34	.41	.29	.00	.00
	3	D	N	.39	.37	.39	.26	.53	.33	.23	.39	.32	.42	.00	.05
	4	D	N	.15	.53	.33	.36	.36	.41	.47	.49	.09	.51	.00	.00
	5	D	N	.39	.38	.12	.10	.29	.49	.13	.49	.02	.38	.24	.00
	6	D	N	.33	.41	.09	.15	.24	.32	.31	.48	.00	.00	.02	.03
	7	N	D	.32	.39	.10	.49	.39	.38	.48	.39	.26	.45	.00	.02
	8	N	D	.34	.48	.32	.55	.22	.40	.52	.61	.25	.00	.00	.00
	9	D	N	.14	.33	.32	.41	.32	.55	.40	.33	.01	.05	.01	.00
	10	D	N	.35	.35	.17	.39	.48	.11	.19	.43	.06	.17	.00	.00
	11	N	D	.23	.52	.31	.44	.33	.54	.00	.50	.00	.43	.00	.00
	12	N	D	.49	.52	.15	.57	.38	.50	.38	.37	.61	.12	.00	.00

Experiment 5: Trials to Extinction Criteria

		Stimuli		Trials to	Trials to	Trials to
	Subject #	CS_1^+	CS_2^+	$CS_1^+ \geq .20$	$CS_2^+ \geq .20$	$CS_2^+ \geq .45$
	1	N	D	10	17	57
	2	N	D	53	31	57
	3	D	N	4	2	15
Group .45	4	D	N	19	20	30
	5	N	D	20	16	51
	6	N	D	20	9	60
	7	D	N	15	9	24
	8	D	N	16	2	6
	9	D	N	10	15	47
	10	D	N	11	6	17
	11	N	D	46	10	54
	12	N	D	10	11	45
	1	D	N	31	2	16
	2	D	N	12	4	35
Group .45 + 54	3	N	D	8	4	24
	4	N	D	11	9	45
	5	D	N	20	4	33
	6	D	N	21	4	51
	7	N	D	9	5	54
	8	N	D	10	11	52
	9	N	D	23	17	46
	10	N	D	9	26	35
	11	D	N	26	13	21

Experiment 5 Test Blocks

		Stimuli		Test Sequence	Block 1			Block 2			Block 3		
		CS_1	CS_2		CS_1	CS_2	CS/CS	CS_1	CS_2	CS/CS	CS_1	CS_2	CS/CS
	1	N	D	3	.43	.44	.00	.00	.34	.07	.57	.44	.17
	2	N	D	3	.27	.37	.00	.27	.17	.00	.30	.43	.00
	3	D	N	4	.19	.49	.11	.22	.32	.11	.32	.45	.21
Group .45	4	D	N	4	.45	.42	.00	.48	.43	.00	.52	.46	.00
	5	N	D	5	.42	.47	.00	.37	.36	.00	.50	.30	.01
	6	N	D	5	.67	.33	.00	.46	.47	.27	.36	.59	.02
	7	D	N	6	.46	.54	.00	.48	.23	.14	.56	.41	.04
	8	D	N	6	.32	.33	.07	.32	.49	.12	.57	.66	.13
	9	D	N	1	.28	.28	.02	.13	.45	.03	.45	.47	.20
	10	D	N	1	.39	.38	.00	.40	.17	.00	.44	.33	.12
	11	N	D	2	.21	.35	.00	.38	.32	.02	.35	.52	.17
	12	N	D	2	.19	.51	.00	.36	.63	.17	.42	.61	.27
	1												
	2	D	N	3	.37	.55	.23	.36	.58	.11	.39	.50	.22
Group .45 + 54	3	N	D	4	.46	.71	.09	.47	.54	.51	.43	.80	.45
	4	N	D	4	.41	.70	.00	.55	.56	.55	.32	.63	.66
	5	D	N	5	.45	.65	.30	.34	.48	.45	.57	.46	.53
	6	D	N	5	.33	.47	.05	.36	.63	.05	.48	.74	.37
	7	N	D	6	.35	.70	.32	.57	.43	.30	.70	.70	.68
	8	N	D	6	.61	.76	.23	.58	.54	.32	.55	.57	.35
	9	N	D	1	.30	.57	.00	.43	.15	.00	.38	.27	.07
	10	N	D	1	.48	.35	.02	.48	.38	.25	.58	.51	.44
	11	D	N	2	.31	.44	.00	.23	.55	.15	.45	.41	.40
	12	D	N	2	.39	.67	.32	.22	.55	.24	.48	.47	.51

Experiment 5 Test Block Pre-CS Baselines

		Block 1			Block 2			Block 3		
	Subject #	CS_1	CS_2	CS_1/CS_2	CS_1	CS_2	CS_1/CS_2	CS_1	CS_2	CS_1/CS_2
Group .45	1	41	57	70	29	51	49	23	49	20
	2	88	62	33	67	40	14	78	135	108
	3	72	46	74	43	40	40	42	77	57
	4	86	98	49	114	94	90	47	87	40
	5	101	59	109	86	63	54	85	102	73
	6	7	16	16	22	27	27	47	13	41
	7	7	11	32	13	24	6	11	17	23
	8	40	39	38	17	20	15	16	11	20
	9	102	68	60	78	41	68	91	50	69
	10	31	44	39	6	20	20	32	33	22
	11	62	54	41	42	52	40	47	11	45
	12	46	34	46	30	25	15	36	14	30
Group .45 + 54	2	101	79	108	77	90	70	88	113	116
	3	13	8	20	9	21	18	17	7	16
	4	19	11	9	13	23	13	17	21	13
	5	47	37	56	80	68	76	72	71	64
	6	46	32	51	45	32	41	43	19	47
	7	26	15	21	23	37	44	13	18	15
	8	13	10	27	15	35	38	22	26	34
	9	37	26	46	34	51	36	48	55	57
	10	30	44	49	37	48	32	27	30	31
	11	29	39	34	51	36	60	36	50	49
	12	55	73	98	114	90	113	84	150	91

Experiment 6 3/3 Differential Groups Pretest Suppression Ratios

Group 1 CS+ and shock

	N		D		N/D	
S#	1	2	1	2	1	2
1	.52	.70	.47	.48	.64	.73
2	.51	.69	.29	.42	.49	.50
3	.30	.53	.37	.35	.53	.56
4	.33	.46	.32	.27	.61	.49
5	.00	.06	.38	.41	.41	.42
6	.40	.31	.20	.00	.25	.61
7	.12	.57	.27	.57	.44	.77
8	.45	.42	.14	.50	.28	.34

Group 1A CS+ and shock

	N		D		N/D	
S#	1	2	1	2	1	2
1	.78	.26	.17	.70	.09	.47
2	.45	.26	.32	.42	.48	.33
3	.53	.48	.72	.55	.60	.55
4	.41	.56	.47	.50	.32	.63
5	.61	.59	.43	.43	.57	.43
6	.55	.36	.41	.35	.31	.42
7	.32	.48	.41	.53	.71	.47
8	.37	.41	.36	.48	.44	.64
9	.41	.67	.28	.41	.63	.48
10	.35	.46	.29	.31	.46	.37
11	.40	.41	.26	.21	.37	.34

Group 2: Shock only

	N		D		N/D	
S#	1	2	1	2	1	2
1	.48	.61	.20	.50	.47	.39
2	.43	.48	.26	.44	.43	.42
3	.38	.44	.45	1.0	.60	.65
4	.39	.37	.50	.65	.48	.57
5	.63	.84	.40	.58	.00	.67
6	.33	.44	.35	.39	.46	.42
7	.39	.35	.48	.48	.35	.60
8	.31	.33	.21	.37	.33	.28

Group 3: CS+ only

	N		D		N/D	
S#	1	2	1	2	1	2
1	.48	.46	.29	.49	.29	.35
2	.35	.57	.39	.44	.52	.56
3	.40	.47	.26	.29	.44	.59
4	.49	.51	.28	.46	.38	.53
5	.21	.44	.32	.64	.36	.50
6	.39	.45	.37	.31	.48	.39
7	.23	.69	.41	1.0	.49	.69
8	.12	.49	.22	.23	.49	.63

Experiment 6 0/3 Nondifferential Pretest Suppression Ratios

	S#	N		D		N/D			S#	N		D		N/D			S#	N		D		N/D	
		1	2	1	2	1	2			1	2	1	2	1	2			1	2	1	2	1	2
	1	.12	.69	.29	.26	.52	.48		1	.35	.52	.30	.61	.67	.71		1	.18	.41	.26	.00	.06	.75
Group 5 12-shock	2	.48	.58	.19	.38	.51	.58		2	.41	.65	.39	.25	.35	.21	Group 7 Pre-exposure	2	.36	.48	.37	.53	.48	.56
	3	.48	.55	.39	.53	.45	.52		3	.37	.50	.70	.50	.53	.61		3	.03	.26	.43	.55	.40	.42
	4	.51	.55	.33	.45	.55	.48	Group 6 6-shock	4	.09	.47	.11	.26	.47	.36		4	.03	.24	.37	.48	.62	.43
	5	.03	.58	.62	.45	.36	.57		5	.19	.35	.27	.57	.36	.31		5	.33	.48	.30	.41	.34	.49
	6	.12	.51	.43	.46	.49	.61		6	.37	.71	.58	.42	.92	.83		6	.34	.43	.47	.46	.59	.58
	7	.41	.41	.49	.57	.50	.59		7	.26	.50	.56	.59	.51	.47		7	.36	.33	.36	.38	.91	.51
	8	.22	.43	.47	.43	.43	.45		8	.37	.38	.29	1.0	.36	.49								
									9	.24	.49	.14	.19	.31	.34								
									10	.40	.53	.40	.35	.28	.39								
									11	.37	.39	.30	.13	.38	.38								

Experiment 6 Groups 1 & 1A Acquisition Daily Suppression Ratios

		Stimuli		Day:	C1		C2		C3		C4		C5		C6	
	Subject #	CS_1^+	CS_2^-		CS_1^+	CS_2^-	CS_1^+	CS_2^-	CS_1^+	CS_2^-	CS_1^+	CS_2^-	CS_1^+	CS_2^-	CS_1^+	CS_2^-
Group 1	1	N	D						.32		.00		.00	.46	.00	.57
	2	N	D						.47		.01		.00	.50	.02	.63
	3	D	N						.38		.25		.02	.43	.04	.43
	4	D	N						.37		.14		.07	.58	.05	.57
	5	N	D						.22		.00		.00	.40	.00	.58
	6	N	D						.42		.00		.00	.32	.00	.57
	7	D	N						.28		.00		.00	.75	.00	.52
	8	D	N						.51		.03		.05	.33	.00	.40
Group 1A	1	D	N						.58		.02		.00	.58	.04	.52
	2	D	N						.12		.00		.00	.53	.00	.49
	3	N	D						.41		.05		.00	.65	.03	.56
	4	D	N						.47		.00		.00	.54	.00	.56
	5	D	N						.51		.21		.00	.45	.00	.52
	6	N	D						.43		.04		.11	.35	.04	.54
	7	N	D						.43		.01		.07	.37	.00	.49
	8	N	D						.60		.04		.00	.41	.04	.40
	9	N	D						.45		.14		.32	.33	.03	.42
	10	D	N						.49		.07		.02	.37	.00	.45
	11	D	N						.43		.18		.14	.64	.15	.56

Experiment 6 Groups 2 & 3 Acquisition Daily Suppression Ratios

		Stimuli		Day:	C1		C2		C3		C4		C5		C6	
		CS_1^+	CS_2^-		CS_1^+	CS_2^-	CS_1^+	CS_2^-	CS_1^+	CS_2^-	CS_1^+	CS_2^-	CS_1^+	CS_2^-	CS_1^+	CS_2^-
	Subject #															
Group 2	1	D	N						.23		.05			.59		.57
	2	D	N						.40		.06			.67		.70
	3	N	D						.21		.00			.61		.62
	4	N	D						.24		.01			.41		.55
	5	D	N						.66		.18			.54		.60
	6	D	N						.40		.01			.40		.74
	7	N	D						.33		.00			.32		.88
	8	N	D						.43		.02			.26		.51
Group 3	1	N	D		.49		.00		.01		.02		.02	.39	.06	.29
	2	N	D		.51		.02		.09		.02		.09	.41	.07	.54
	3	D	N		.31		.00		.03		.00		.03	.49	.03	.46
	4	D	N		.39		.02		.04		.07		.03	.59	.10	.53
	5	N	D		.37		.00		.00		.00		.00	.59	.00	.63
	6	N	D		.31		.04		.00		.00		.00	.51	.00	.45
	7	D	N		.34		.06		.07		.03		.17	.47	.04	.57
	8	D	N		.43		.07		.11		.83		.00	.46	.00	.57

Experiment 6 Group 4 Acquisition Daily Suppression Ratios

	Subject #	Stimuli		Day	C1		C2		C3		C4		C5		C6	
		CS_1^+	CS_2^o		CS_1^+	CS_2^o	CS_1^+	CS_2^o	CS_1^+	CS_2^o	CS_1^+	CS_2^o	CS_1^+	CS_2^o	CS_1^+	CS_2^o
	1	N	D						.44		.00			.36		.27
	2	N	D						.42		.00			.34		.26
Group 4 6-shocks	3	D	N						.47		.02			.35		.31
	4	D	N						.35		.00			.71		.54
	5	N	D						.39		.00			.24		.51
	6	N	D						.36		.00			.23		.23
	7	D	N						.35		.00			.50		.43
	8	D	N						.31		.00			.55		.42
	9	D	N						.51		.04			.51		.46
	10	D	N						.46		.02			.51		.47
	11	N	D						.44		.01			.65		.53

Experiment 6 Group 5 & 6 Acquisition Daily Suppression Ratios

	Subject #	Stimuli		Day	C1		C2		C3		C4		C5		C6	
		CS_1^+	CS_2^o		CS_1^+	CS_2^o	CS_1^+	CS_2^o	CS_1^+	CS_2^o	CS_1^+	CS_2^o	CS_1^+	CS_2^o	CS_1^+	CS_2^o
Group 5: 12 shock	1	N	D		.22		.00		.00		.00			.37		.49
	2	N	D		.53		.12		.00		.00			.42		.55
	3	D	N		.34		.00		.00		.00			.50		.57
	4	N	D		.47		.01		.00		.00			.46		.27
	5	N	D		.43		.00		.00		.00			.45		.34
	6	D	N		.47		.03		.00		.00			.51		.61
	7	D	N		.27		.13		.10		.00			.58		.54
Group 6: Preexposure	1	D	N			.52		.49	.26		.00		.00		.00	
	2	D	N			.58		.58	.36		.00		.00		.00	
	3	N	D			.53		.53	.39		.00		.00		.02	
	4	N	D			.41		.40	.49		.06		.00		.00	
	5	D	N			.46		.51	.44		.00		.00		.00	
	6	D	N			.51		.50	.47		.25		.00		.00	
	7	N	D			.47		.45	.60		.05		.00		.00	
	8	N	D			.49		.49	.21		.00		.02		.00	

Experiment 6: Mean Pre-CS bar presses 3/3 Differential Groups

Subject #	1st & 2nd CS$^+$ Sess.	1st & 2nd CS- Sess.		1st & 2nd CS$^+$ Sess.	1st & 2nd CS- Sess.		1st & 2nd CS$^+$ Sess.	1st & 2nd CS- Sess.		1st & 2nd CS$^+$ Sess.	1st & 2nd CS- Sess.
Group 1			Group 1A			Group 2			Group 3		
1	17.2	15.5	1	33.3	25.5	1	17.4	13	1	21.5	24.7
2	27.5	18.8	2	39.9	43.0	2	7.9	4.8	2	15.5	14.2
3	11.0	12.4	3	21.4	11.9	3	7.8	8.6	3	13.7	7.5
4	15.7	4.9	4	18.0	7.7	4	31.3	25.2	4	17.15	7.1
5	25.3	19.0	5	9.6	6.9	5	6.5	4.9	5	29.2	26.4
6	22.7	36.5	6	25.2	17.0	6	31.2	23.5	6	33.8	22.7
7	12.9	6.2	7	36.7	32.5	7	15.2	7.4	7	21.9	20.2
8	23.9	2.3	8	19.9	27.2	8	43.2	32.5	8	18.0	10.7
			9	24.5	23.5						
			10	30.9	23.0						
			11	32.0	14.8						

Experiment 6: Mean Pre-CS Bar Presses 0/3 Nondifferential Groups

	Subject #	1st & 2nd CS$^+$ Sessions	1st & 2nd CS$^-$ Sessions			3rd & 4th CS$^+$ Sessions	1st & 2nd CS$^-$ Sessions			3rd & 4th CS$^+$ Sessions	1st & 2nd CS$^-$ Sessions
	1	18.5	20.5		1	35.3	46.3		1	35.7	51
	2	12.7	36.2	Group 5: 12-Shocks	2	21	22.2	Group 6: Preexposure	2	25	18.8
	3	21.5	23.7		3	32.7	22.5		3	12.7	14
Group 4: 6-Shocks	4	12.3	16.2		4	49.1	71.3		4	28.4	43.1
	5	13.7	25.5		5	55.1	79.0		5	19.9	33.8
	6	40.4	39.7		6	22.1	7.0		6	58	81.5
	7	32.2	31.7		7	22.7	16.0		7	20.2	22
	8	63.2	70.9						8	20	9.5
	9	29	28.4								
	10	34	19.5								
	11	35	21.5								

Experiment 6 3/3 Differential Groups Trials to CS+ ≥ .20 Extinction Criterion

	Subject #	CS+	Trial ≥ .20		Subject #	CS+	Trial ≥ .20
Group 1	1	N	13	Group 1A	1	D	2
	2	N	7		2	D	23
	3	D	5		3	N	16
	4	D	6		4	D	39
	5	N	21		5	D	24
	6	N	35		6	N	27
	7	D	13		7	N	11
	8	D	33		8	N	20
					9	N	5
					10	D	16
					11	D	4
Group 2	1	D	1	Group 3	1	N	2
	2	D	1		2	N	2
	3	N	11		3	D	2
	4	N	8		4	D	2
	5	D	13		5	N	2
	6	D	23		6	N	9
	7	N	19		7	D	1
	8	N	7		8	D	16

Experiment 6: 0/3 Nondifferential Groups,
Trials to CS+ $\geq$ .20 Extinction Criterion

	Subject #	CS+	Trial $\geq$ .20		Subject #	CS+	Trial $\geq$ .20
	1	N	20		1	N	24
	2	N	20		2	N	5
	3	D	11	Group 5	3	D	24
	4	D	16		4	N	5
Group 4	5	N	41		5	N	5
	6	N	29		6	D	5
	7	D	20		7	D	24
	8	D	10				
	9	D	35				
	10	D	50				
	11	N	24				
	1	D	30				
	2	D	11				
Group 6	3	N	11				
	4	N	9				
	5	D	30				
	6	D	7				
	7	N	14				
	8	N	19				

Experiment 6 Groups 1 & 1A Test Block Suppression Ratios

		Stimuli			Block 1					Block 2				
		CS+	CS-		CS+		CS+/CS-		CS-	CS+		CS+/CS-		CS-
	Subject #			Test Sequence	1	2	1	2		1	2	1	2	
Group 1	1	N	D	A	.22	.43	.28	.48	.38	.41	.47	.33	.67	.44
	2	N	D	B	.33	.23	.44	.57	.49	.54	.28	.56	.56	.51
	3	D	N	A	.27	.38	.46	.46	.47	.33	.35	.45	.50	.44
	4	D	N	B	.20	.04	.50	.53	.68	.20	.07	.36	.69	.56
	5	N	D	A	.33	.10	.47	.46	.47	.16	.29	.45	.45	.55
	6	N	D	B	.00	.00	.17	.22	.67	.00	.00	.00	.41	.38
	7	D	N	A	.31	.35	.33	.50	.43	.45	.61	.40	.38	.62
	8	D	N	B	.00	.00	.23	.06	.75	.03	.07	.05	.22	.53
Group 1A	1	D	N	A	.36	.19	.39	.60	.45	.23	.24	.45	.48	.71
	2	D	N	B	.36	.35	.24	.42	.49	.32	.44	.27	.33	.56
	3	N	D	A	.00	.00	.44	.64	.73	.16	.29	.41	.42	.48
	4	D	N	B	.00	.00	.00	.00	.48	.25	.19	.32	.24	.70
	5	D	N	A	.40	.43	.31	.41	.85	.44	.27	.24	.32	.31
	6	N	D	A	.32	.00	.17	.09	.25	.28	.25	.27	.21	.30
	7	N	D	B	.00	.00	.28	.25	.81	.42	.23	.47	.43	.56
	8	N	D	A	.16	.04	.17	.28	.35	.52	.60	.34	.58	.46
	9	N	D	B	.32	.31	.17	.33	.37	.29	.00	.32	.41	.48
	10	D	N	A	.17	.00	.00	.11	.51	.23	.40	.39	.68	.54
	11	D	N	B	.29	.28	.56	.52	.63	.32	.45	.63	.48	.54

	Block 1	Block 2
Sequence A:	CS+, CS+/CS-, CS+, CS+/CS-, CS-	CS+/CS-, CS+, CS+/CS-, CS+, CS-
Sequence B:	CS+/CS-, CS+, CS+/CS-, CS+, CS-	CS+, CS+/CS-, CS+, CS+/CS-, CS+

Experiment 6 Groups 2 & 3 Test Block Suppression Ratios

	Subject #	Stimuli		Test Sequence	Block 1					Block 2				
		CS+	CS-		CS+		CS+/CS-		CS-	CS+		CS+/CS-		CS-
					1	2	1	2		1	2	1	2	
Group 2	1	D	N	B	.08	.38	.32	.25	.55	.14	.25	.39	.50	.57
	2	D	N	A	.31	.00	.58	.60	.34	.00	.22	.33	.64	.65
	3	N	D	B	.30	.35	.31	.60	.53	.31	.36	.73	.57	.71
	4	N	D	A	.28	.46	.27	.47	.53	.37	.44	.41	.40	.70
	5	D	N	B	.60	.47	.60	.47	.63	.50	.45	.63	.55	.61
	6	D	N	A	.03	.33	.30	.42	.40	.33	.44	.39	.44	.45
	7	N	D	B	.08	.31	.22	.63	.55	.00	.23	.47	.41	.61
	8	N	D	A	.15	.35	.28	.24	.37	.40	.29	.49	.40	.41
Group 3	1	N	D	A	.17	.20	.25	.53	.50	.41	.41	.45	.45	.74
	2	N	D	B	.19	.45	.29	.53	.37	.36	.50	.48	.49	.63
	3	D	N	A	.00	.00	.41	.38	.44	.55	.56	.64	.50	.31
	4	D	N	B	.12	.42	.37	.67	.40	.41	.30	.43	.42	.61
	5	N	D	A	.18	.22	.25	.33	.62	.20	.23	.26	.48	.81
	6	N	D	B	.28	.54	.09	.36	.53	.20	.37	.20	.33	.33
	7	D	N	A	.15	.17	.18	.30	.63	.37	.23	.45	.42	.58
	8	D	N	B	.27	.37	.46	.53	.62	.43	.28	.56	.35	.41

Sequence A	CS+, CS+/CS-, CS+, CS+/CS-, CS-	CS+/CS-, CS+, CS±/CS-, CS+, CS-
Sequence B	CS+/CS-, CS+, CS+/CS-, CS+, CS-	CS+, CS+/CS-, CS+, CS+/CS-, CS-

Experiment 6 Group 4 Test Block Suppression Ratios

		Stimuli			Block 1					Block 2				
		CS+	CS-	Test Sequence	CS+		CS+/CS-		CS-	CS+		CS+/CS-		CS-
	Subject #				1	2	1	2		1	2	1	2	
Group 4	1	N	D	A	.03	.46	.15	.17	.36	.32	.30	.65	.52	.43
	2	N	D	B	.33	.26	.17	.14	.43	.40	.54	.27	.55	.71
	3	D	N	A	.29	.23	.10	.34	.55	.17	.18	.22	.20	.37
	4	D	N	A	.14	.52	.36	.30	.51	.27	.42	.40	.76	.79
	5	N	D	B	.49	.38	.26	.34	.39	.36	.54	.29	.39	.43
	6	N	D	A	.43	.06	.14	.17	.40	.42	.08	.09	.13	.05
	7	D	N	B	.27	.44	.38	.54	.58	.47	.43	.45	.41	.52
	8	D	N	B	.50	.27	.34	.19	.54	.64	.74	.39	.70	.61
	9	D	N	B	.19	.07	.36	.32	.46	NO BLOCK 2				
	10	D	N	B	.20	.50	.41	.38	.60	.30	.47	.35	.51	.51
	11	N	D	A	.33	.44	.50	.51	.51	.38	.39	.51	.45	.52

	Block 1	Block 2
Sequence A	CS+, CS+/CS-, CS+, CS+/CS-, CS-	CS+/CS-, CS+, CS+/CS-, CS+, CS-
Sequence B	CS+/CS-, CS+, CS+/CS-, CS+, CS-	CS+/CS-, CS+, CS+/CS-, CS+, CS-

Experiment 6 Groups 5 & 6

		Stimuli			Block 1					Block 2				
		CS+	CS -	Test	CS+		CS+/CS -		CS -	CS+		CS+/CS -		CS -
	Subject #			Sequence	1	2	1	2		1	2	1	2	
Group 5	1	N	D	A	.09	.22	.24	.46	.49	.26	.37	.21	.27	.34
	2	N	D	B	.08	.15	.21	.23	.53	.21	.37	.17	.55	.59
	3	D	N	B	.34	.29	.08	.11	.48	.10	.05	.19	.06	.36
	4	N	D	A	.25	.28	.38	.37	.39	.30	.32	.44	.55	.33
	5	N	D	B	.00	.23	.17	.18	.42	.33	.37	.24	.39	.35
	6	D	N	A	.32	.04	.17	.00	.39	.00	.00	.00	.27	.53
	7	D	N	B	.19	.20	.04	.18	.56	.25	.41	.30	.46	.52
Group 6	1	D	N	B	.00	.18	.00	.11	.65	.35	.42	.63	.40	.44
	2	D	N	A	.16	.17	.09	.13	.64	.28	.31	.25	.29	.52
	3	N	D	B	.14	.33	.20	.37	.40	.35	.11	.57	.33	.51
	4	N	D	A	.16	.43	.18	.26	.52	.41	.56	.25	.41	.33
	5	D	N	B	.00	.42	.00	.06	.47	.00	.00	.00	.06	.41
	6	D	N	A	.42	.36	.09	.30	.44	.37	.47	.44	.52	.39
	7	N	D	B	.03	.00	.00	.25	.55	.63	.50	.66	.56	.47
	8	N	D	A	.18	.21	.27	.44	.41	.23	.15	.41	.27	.27

	Block 1	Block 2
Sequence A	CS+, CS+/CS -, CS+, CS+/CS -, CS -	CS+/CS -, CS+, CS+/CS -, CS+, CS -
Sequence B	CS+/CS -, CS+, CS+/CS -, CS+, CS -	CS+, CS+/CS -, CS+, CS+/CS -, CS -