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Interactions between Pavlovian first- and second-order conditioning.

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INTERACTIONS BETWEEN PAVLOVIAN FIRST- AND SECOND-ORDER CONDITIONING

A Dissertation Presented

By

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ABSTRACT

Interactions Between Pavlovian
First- and Second-Order Conditioning
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Four experiments investigated the interactions between Pavlovian first- and second-order conditioned stimuli in the rat CER preparation. The first three experiments examined the interactions of these kinds of stimuli with the Kamin two stage blocking procedure. The fourth experiment examined these interactions with Pavlov's summation technique. Experiment 1 showed that second-order conditioning to an added cue was attenuated if such conditioning took place in the presence of a pretrained second-order conditioned stimulus (CS). Experiment 2 failed to produce evidence for "super" second-order conditioning, i.e., rapid conditioning when a first-order conditioned inhibitor was compounded with a new cue during second-order conditioning. Experiment 3 showed that first-order conditioning to an added cue was attenuated if such conditioning took place in the presence of a pretrained second-order CS.

This experiment also replicated the results of Experiment 1. Experiment 4 showed that 1) compounding a stimulus trained as a first-order inhibitor with a stimulus trained as a second-order excitor resulted in less suppression to the compound than to the second-order excitor alone and less suppression than that controlled by the excitor and a neutral cue that were compounded in a control group, 2) compounding two stimuli trained as second-order excitors resulted in greater suppression to the compound than to either stimulus alone and greater suppression than a compound of one of the excitors and a neutral cue in a control group. Experiment 4 failed to show summation when a second-order excitor was compounded with a first-order excitor. This failure was probably due to a conditioning floor effect. Results were discussed in terms of what assumptions would have to be made by the Rescorla and Wagner (1972) model in order to account for across-order interactions. An alternative interpretation suggested that across-order interactions did not necessarily account for the results.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Pavlov (1927) was the first to study the phenomenon of higher-order conditioning. Higher-order conditioning is said to occur when the conditioned strength of a stimulus comes from the reinforcing action of a conditioned, as opposed to an unconditioned, stimulus. For example, in second-order conditioning, a first-order conditioned stimulus (S_1) is initially established by pairing it with an unconditioned stimulus (US). Then, the S_1 stimulus is used to reinforce another stimulus S_2. As a result of the $S_2 \rightarrow S_1$ relationship, S_2 comes to exhibit conditioned strength. This second-order conditioning of S_2 occurs in the absence of the US, (Third-order conditioning is a case in which S_2 is used to reinforce S_3 and so forth for other orders of conditioning).

After Pavlov's (1927) initial empirical demonstration, many theorists used higher-order conditioning as an explanation for the conditioned strength exhibited by stimuli when no primary reinforcers (USs) were immediately available in the learning situation. For example, Hull

(1952), Konorski (1967) and Spence (1956) suggested that, through the operations of higher-order conditioning, stimuli that are present during instrumental response sequences come to exhibit motivational and rewarding properties. In addition, Bandura (1969) used the operation of higher-order conditioning to explain certain types of phobic behaviors.

Although theorists have used higher-order conditioning as an explanation, researchers have not empirically examined the phenomenon to any great extent. Rather, the focus has been on first-order conditioning, despite the possibility that an organism may have more opportunities for higher-order conditioning than for first-order conditioning. That is, the opportunities seem greater for a stimulus to be paired with other conditioned stimuli rather than to be paired with a primary reinforcer as in a first-order conditioning pairing. Nevertheless, researchers have only recently begun to demonstrate or study the phenomenon of higher-order conditioning. Even those studies that have been done do not in fact examine conditioning beyond the second-order.

It has been suggested that the reason for the lack of experimental interest in higher-order conditioning has been its reputation as being difficult to demonstrate and to maintain even a rigorous laboratory setting (e.g., Pavlov, 1927; Rescorla, 1973a; Skinner, 1933). However, evidence has recently accumulated suggesting that second-order conditioning is both powerful and reliable. It has been demonstrated in studies employing several different conditioning preparations and several different species, e.g., with rats in both aversive and appetitive preparations (e.g., Davenport, 1966; Holland & Rescorla, 1975; Kamil, 1969; Rescorla, 1973a, 1973b, 1974, 1977; Rizley & Rescorla, 1972), in conditioned odor-aversion in neonatal rats and in the terrestial mollusc, Limax Maximus (e.g., Cheatle & Rudy, 1978; Sahley, Gelperin & Rudy, 1980) in appetitive conditioning in goldfish (e.g., Amiro & Bitterman, 1980), in autoshaped keypecking in pigeons (e.g., Leyland, 1977; Leyland & Mackintosh, 1978; Rashotte, Griffin & Sisk, 1977), and with eyelid conditioning in rabbits (e.g., Sears, Baker & Frey, 1979).

These recent, rather robust demonstrations of second-order conditioning suggest that we should examine the phenomenon with as much vigor as we examine first-order conditioning. It is hoped that such endeavors will allow us to understand more about conditioning and learning in general. It would seem a reasonable strategy to pose the same kind of questions that are posed when asking questions about the nature of first-order conditioning. It also seems reasonable to examine the outcomes of various combinations (excitatory and inhibitory) of second-order stimuli and combinations of first- and second-order stimuli. This would allow us to compare the combination rules of second-order stimuli with those of first-order stimuli. This strategy will help us to understand if the underlying learning is similar for the operations of first- and second-order conditioning as well as providing us with answers to questions about learning in general.

The present paper contains a brief review of some of the literature on second-order conditioning and describes a group of studies that provide information on the interactions between Pavlovian first- and second-order conditioning. In addition, the question of whether second-order conditioning can be described in terms of the same rules that are used to describe first-order conditioning is examined. This question is cast in terms of a leading conditioning model (Rescorla & Wagner, 1972).

Second-order Conditioning

Rizley and Rescorla's (1972) experiment provides a basic demonstration of second-order conditioning with the proper control procedures. That experiment used the conditioned emotional response (CER) technique with rats. With the CER technique an aversive US (shock) is paired with a neutral stimuls (S_1). This pairing is superimposed on an appetitive barpress baseline. Evidence of the conditioned emotional response is indexed by suppression of the barpressing response during S_1 presentations relative to baseline responding during a comparable time period.

The experiment by Rizley and Rescorla (1972) consisted of three conditions and is outlined in Table 1. Group PP (paired-paired) received pairings of S_1 and shock during Phase I and pairings of S_2 followed by S_1 during Phase II. Phase I for Group PP was designed to establish first-order fear conditioning to S_1. Phase II was designed to establish second-order fear conditioning to S_2.

Groups PU (paired-unpaired) and UP (unpaired-paired) were included as controls for "nonassociative" response changes. Nonassociative response changes are dependent only upon separate event presentations. Therefore, Group PU, which received pairings (S_1 shock) during Phase I and unpaired presentations of S_2 and S_1 during Phase II, was included to determine that the Phase II pairings were necessary. Group UP, which received unpaired (S_1/shock) presentations during Phase I and S_2 S_1 pairings during Phase II, was included to determine that Phase I pairings were necessary.

The findings of the study by Rizley and Rescorla (1972) were that Group PP exhibited greater levels of response suppression to S_2 relative to Groups PU and UP. This finding is taken as evidence for the second-order conditioning of fear in Group PP. It should be pointed out, however, that Group UP was more suppressed than Group PU. This outcome suggests that the S_2 stimulus was probably mildly excitatory even though it had never been paired with a reinforcer or a stimulus that has acquired the status of a reinforcer (S_1). Rizley and Rescorla (1972) suggested that this latter observation points up the importance of including adequate control conditions. Nevertheless, the outcomes of this experiment can be taken as demonstrating robust second-order conditioning since suppression in Group PP was significantly different from that in Groups UP and PU.

Other evidence for robust second-order conditioning has been found using a food US. Holland and Rescorla (1975) have conducted such an experiment. In their experiment activity to a signal for food was the conditioned response. Their experiment employed the same design as the Rizley and Rescorla (1972) experiment and similarly found strong second-order conditioning.

Second-order Conditioning Literature

Having clearly demonstrated that second-order conditioning was a reliable phenomenon, Rizley and Rescorla (1972) and Rescorla (1973a) set out to determine the types of associative connections that are formed in second-order conditioning. They asked: Does the organism learn to associate S_2 with S_1, S_2 with some representation of the US, or S_2 with the emotional response evoked by S_1? The strategy used to attempt to answer this question consisted of somehow modifying (e.g., by habituation, satiation, etc.) the reinforcer following second-order conditioning. Then, during a test session, it was determined whether the second-order stimulus would continue to elicit the conditioned response despite the modifications. For example, if the second-order reinforcer, S_1, was devalued and no longer elicited a conditioned response, whereas S_2 after the manipulation continued to elicit a conditioned response, then it was inferred that either 1) an S-R association was formed between S_2 and the response that had been elicited by S_1 during second-order trials or 2) that an S-S association had been formed between S_2 and some internal representation of the US. A third conceptualization would be suggested if S_2 lost its conditioned strength after S_1 devaluation. This third idea suggests that the association is between S_2 and S_1. If S_2 and S_1 are associated, then this reasoning suggests that S_2 elicits a response only because S_1 has elicited a response. Therefore, if S_1 is devalued and is no longer capable of eliciting a response then S_2 should also fail to do so.

Rescorla (1973a) and his associates have conducted several experiments that test the above conceptualizations. In order to determine whether S_2-US associations are importantly involved in second-order conditioning, Rescorla (1973a) has conducted the following CER experiment. After initial barpress training, rats received first-order conditioning trials designed to establish an effective S_1 with an aversive loud noise US. Animals then received S_2 followed by S_1 in order to establish second-order conditioning to S_2. After the second-order conditioning phase, one half of the animals (the experimental group), received several sessions of many trials with the noise US alone. This phase was intended to habituate the aversiveness of the noise. The other half of the animals (the control group), received no habituation. Animals next received test presentations of S_1 and S_2. It was found that although the habituation manipulation was effective (the experimental group after the manipulation exhibited fewer conditioned responses to S_1 than did the control group), habituation to the US did not interfere with S_2's continued ability to elicit a conditioned response.

Other evidence has revealed that inflating the value (e.g., by increasing shock level or amount of food) of the reinforcer for a first-order stimulus results in an increased first-order response; but inflating the value of the second-order reinforcer, S_1, does not affect the magnitude of the second-order conditioned response (Rescorla, 1974).

These results have been taken as evidence against the S_2-US conceptualization. If second-order conditioning involved an S_2-US association, then the degrading and inflating manipulations should have affected the magnitude of the second-order conditioned response. In addition, these results also bear on the question of whether S_2-S_1 associations are importantly involved. If S_2-S_1 associations are involved, the reasoning suggests that habituating or inflating the US should have attenuated or enhanced S_1's ability to produce a response that in turn should have affected responding to S_2. But it did not (Rescorla, 1973, 1974).

Other evidence that bears on the question of whether an S_2-S_1 association is involved in second-order conditioning comes from the following CER experiment. In this experiment (Rescorla, 1973a) rats were given first-order conditioning trials with a tone S_1 and a foot shock US after baseline bar press training had been established. Then the rats received second-order conditioning trials that consisted of a light (S_2) followed by the tone (S_1). After the second-order conditioning phase, the rats were divided into two groups: an extinction group and a control group. The extinction group received non-reinforced test presentations of S_1 on the bar press baseline, whereas, the control group received only continued bar-press experience. During the first test day rats received a light-alone test designed to detect any differences in second-order conditioning. During the second test day rats received a tone-alone test designed to confirm that the extinction that had been carried out with the extinction group had indeed produced a difference between the two groups in responding to S_1.

The light test revealed that there was no difference between the extinction group and the control group in the magnitude of second-order responding. The tone test provided evidence that the extinction procedure was successful in producing a significant difference between the two groups in responding to the tone. These results were taken as evidence against the S_2-S_1 conceptualization.

To summarize, then, these results suggest that a S_2-S_1 association is not involved in second-order conditioning, since changing the value of S_1 failed to produce a change in S_2. It seems that if one either inflates or defalates the reinforcer after first-order conditioning, only the responses to the first-order stimulus change. Second-order responding remains relatively unchanged. The results of the preceding experiments have been held to be consistent only with the S-R conceptualization. But, the fact that the response to S_2 seems to be "independent" of S_1 manipulations has led Rescorla (1973b) to suggest that:

> in first-order conditioning the animal may learn that he will receive a US following the CS; after second-order conditioning he may remember that he was afraid following the CS, without remembering the sources of that fear (p. 137).

These findings suggest then that perhaps first-order conditioning involves an association between S_1 and the US, whereas second-order conditioning involves an association between S_2 and the response evoked by S_1. Therefore, they suggest that the associative connections differ with the operations of first- and second-order conditioning.

The finding that changing the value of S_1 fails to produce a corresponding change in S_2 has been confirmed in preparations other than in the CER preparation. This finding has been obtained with rats in an appetitive activity situation (e.g., Holland & Rescorla, 1975), with rats in the odor aversion preparation (e.g., Cheatle &

Rudy, 1978), and with goldfish in an appetitive conditioning situation (Amiro & Bitterman, 1980).

However, some recent studies with a pigeon second-order autoshaping preparation have found that extinguishing the second-order reinforcer, S_1 diminished the response-eliciting effectiveness of S_2 (e.g., Leyland, 1977; Rashotte, Griffin & Sisk, 1977). Given the alternatives suggested by Rescorla, (1979), these results of course imply that an S_2-S_1 associative connection was important in these experiments. The discrepancy between the results of these studies and those done with the rat CER technique have been attributed to a number of factors. In the standard autoshaping preparation (e.g., Leyland, 1977; Rashotte, <u>et al</u>, 1977; Rescorla, 1979) a pigeon comes to peck a lighted key (S_1) when the key is paired with a food US. After the Pavlovian first-order key peck has been established, another visual stimulus, S_2, is paired with S_1. These pairings ($S_2 \rightarrow S_1$) result in the second-order key peck conditioning of S_2. Two factors that may account for the discrepancy are 1) there may be a special relationship between the visual stimuli (keylights) and food and 2) there might be a special relationship between the visual stimuli and the keypeck response. These special relationships might exist for the highly visually sensitive pigeon and be absent in the less visually sensitive rat. Or it may be that particular experimental preparations especially encourage the detection of or the learning about one or the other associations (S-S or S-R). That is, a variety of events may be learned about.

Rescorla (1979) in a recent series of studies has demonstrated that pigeons do seem to associate a CS with "a rich representation of the reinforcer" since when a particular S_1 is extinguished, its particular S_2 will lose some of its conditioned strength. In one study pigeons were given second-order autoshaping to two stimuli each based upon a different second-order reinforcer. Subsequently, one of the second-order reinforcers was extinguished. It was found that there was a loss in conditioned strength only to the S_2 that had had its reinforcer extinguished. This finding indicated to Rescorla (1979) that pigeons do seem to learn about specific features of the reinforcer. However, it was found that complete response extinction to S_1 failed to produce a complete loss of behavior to S_2. This finding suggested to Rescorla (1979) that at least some of the pigeon's second-order conditioning is independent of the subsequent state of its particular reinforcer.

In a more recent series of studies Nairne and Rescorla (1981) present data suggesting that certain features of the autoshaping paradigm may importantly determine what is associated (S-S, S-R or both) in the pigeon autoshaping preparation.

In one study they compared the effects of extinguishing either an auditory or a visual S_1 upon a second-order autoshaped visual S_2. They found (as have Leyland, 1977; Rashotte, et al., 1977) that extinguishing a visual S_1 will reduce responding to its visual S_2. However, their experiment showed that extinguishing an auditory S_1 did not reduce responding to its visual S_2. Thus, it seems that when S_1 and S_2 are from different sensory modalities, in the pigeon autoshaping preparation, the extinction of S_1 after second-order conditioning has little impact upon responding to S_2. It may be that preparations that use stimuli from the same sensory modality especially encourage the organism to learn about specific stimulus features of the second-order reinforcing stimulus. However, when stimuli are from different sensory modalities or when, perhaps, features of the response topographies differ, then features such as the "affective response evoked by the reinforcing stimuli" (Nairne & Rescorla, 1981) may importantly enter into the learned associations.

It may of course be true that there is no such thing as a "pure" example of second-order conditioning, all second-order conditioned stimuli may contain from the point of view of the organism the elements of first-order conditioning (e.g., $S_2 \rightarrow S_1 \rightarrow$ US memory) contrariwise, insofar as the stimuli that are conditioned early in a sequence have an opportunity to act as reinforcers to stimuli occurring later in a sequence, all first-order conditioning may contain from the point of view of the organism elements of second-order conditioning (e.g., $S_2 \rightarrow S_1 \rightarrow US$).

It may also be the case that the assessment techniques (changing the value of S_1 then assessing the impact on S_2) encourage the dismissal of the relative contributions that both kinds of associations contribute to every learning situation. There do not seem to be any logical or evolutionary reasons why an organism can't form associations between many events in a given situation.

The resolution of the issue of what is learned in second-order conditioning, e.g., S-S or S-R, seemingly is meeting with the same kind of problems that such phrasing of the questions met with in the 1950s during the old S-S S-R controversy (Rescorla, 1973a). It seems that both kinds of learning are produced in every conditioning operation. Perhaps the question should be asked in another way. It is possible that even if different events are associated, the underlying associative processes are similar. Zimmer-Hart (1974) has suggested such a strategy. He has argued that if underlying associative processes are similar in first- and second-order conditioning, then the principles that describe one process should adequately describe the other.

The present idea is to examine the possibility that the associative processes are similar enough so that the cross functions of second-order excitatory and inhibitory stimuli can be described in a manner that is similar to first-order conditioning functions. That is, the principles derived for first-order conditioning from a model like that of Rescorla and Wagner (1972) should be able, at least in principle, to handle the outcomes of, for example, a first-order stimulus blocking second-order conditioning or a second-order stimulus blocking first-order conditioning.

Second-order Conditioning and the Rescorla-Wagner Model

Zimmer-Hart (1974) has already offered some evidence that second-order conditioning involves some of the same associative processes as first-order conditioning. As mentioned above he also suggests that second-order conditioning processes can be handled by the Rescorla-Wagner (1972) model, which very adequately accounts for first-order conditioning.

In his first two experiments he attempted to vary the strength of the reinforcer. In one case S_1 was paired with different intensities of shock for different groups. In another case the loudness of S_1 was increased during second-order conditioning. It was found that changing the value of S_1 resulted in a similar change in the amount of second-order conditioning. These results were accounted for by the Rescorla-Wagner model, which describes first-order conditioning. The Rescorla-Wagner model, which has been called the discrepancy model, assumes that the stimuli in a conditioning situation compete for a limited amount of conditioned strength (λ) that is determined by the US that is used. According to the discrepancy model conditioning on a trial is proportional to the discrepancy between some fixed, asymptotic level of conditioned strength, , that the US will support and the level of conditioned strength that has already been obtained by all the stimuli present on that trial (V_{AX}). Formally,

$$\Delta \; V_A = \alpha_A \beta, \; (\lambda - V_{AX}).$$

Here ΔVA refers to the change in conditioned strength of stimulus A on a trial: α_A is a salience parameter for the stimulus A; β is a learning rate parameter that is dependent on the US that is used; λ represents the asymptotic level of conditioning that the US will support; V_{AX} is the amount of conditioning that the stimuli present on the trial have already accrued; and $V_{AX} = V_A + V_X$. The model contends that conditioning is a function of the discrepancy between the current level of conditioning and the maximum that the reinforcer will support.

The discrepancy account can adequately describe the above second-order conditioning findings. That is, it can predict that reinforcers of different strength can produce the different levels of second-order conditioning that were observed in the above studies. Moreover, it has been observed that blocking has been produced with the second-order conditioning paradigm (Leyland & Mackintosh, 1978; Zimmer-Hart, 1974) and it was on the basis of the first-order blocking phenomenon that the discrepancy model was developed. Blocking is the observation that a neutral cue fails to condition if it is compounded with a pretrained cue. Blocking is thought to arise because the reinforcer fails to "surprise" the organism (Kamin, 1969), since it has already been signaled by the pretrained cue. Surprise or a discrepancy between what is expected and what actually occurs as a trail outcome is seen as being necessary for learning. More formally, the discrepancy model contends that the pretrained cue (A) has a large amount of associative strength at the start of compounding ($V_A \cong \lambda$). Therefore, reinforced trials consisting of A and the added neutral cue (X) will result in very little increase in conditioning to the added X cue ($\lambda - V_{AX} \cong 0$).

In addition, the model can predict overshadowing. Overshadowing is the observation that the presence of an intense stimulus reduces conditioning to a stimulus that is less intense. Zimmer-Hart (1974) was able to observe overshadowing with the second-order conditioning preparation. He found a reduction in the second-order conditioning of a stimulus that was conditioned in the presence of a more intense stimulus. The discrepancy model predicts overshadowing by indicating that the conditioned strength of the elements of a compound (AX) will always be less than the conditioned strength of either A or X when they are conditioned alone.

Further, other observations reveal that second-order conditioning seems to obey other first-order conditioning laws. Second-order conditioning like first-order conditioning: 1) is best when forward rather than backward pairing procedures are used, 2) is sensitive to the effects of latent inhibition, 3) is best when delayed rather than trace procedures are used (Rescorla, 1973a), and 4) is sensitive to temporal variables (Kehoe, Gibbs, Garcia, & Gormezano, 1979; Rescorla, 1973a).

The intention of the last two sections has been to provide an overview of the literature on second-order conditioning and to point up the success of the discrepancy model in handling the results of both first- and second-order conditioning. Further it has been indicated that it might be advantageous to attempt to discover if we can apply the rules that have been developed for first-order conditioning to combinations of first- and second-order stimuli. The next section describes a series of studies that were intended to provide information on the interactions between Pavlovian first- and second-order conditioning. They sought to determine how stimuli that gain their conditioned strength through the operations of first-order conditioning combine with stimuli that have gained their conditioned strength through the operations of second-order conditioning. They also examined the effects of combining two second-order stimuli. As will be seen, some of these studies provide information on the question of what associations are formed in the two orders of conditioning.

CHAPTER II

EXPERIMENT 1

Experiment 1 was designed to see whether a second-order conditioned stimulus would block second-order conditioning to an added cue. This experiment sought to replicate the unpublished data of Zimmer-Hart (1974) and the published data of Leyland and Mackintosh (1978). Zimmer-Hart (1974), using the CER technique with rats, and Leyland and Mackintosh (1978), using the pigeon autoshaping technique, were both able to demonstrate such blocking.

Their findings are in agreement with both the surprise idea of Kamin (1969) and the discrepancy model of Rescorla and Wagner (1972). According to Kamin (1969) only events that are "unexpected" or "surprising" promote conditioning. Accordingly, if reinforcement is signaled by a pretrained stimulus, then introducing a new stimulus along with the pretrained stimulus should not "surprise" the organism. If the organism is not "surprised" when a new stimulus is added to a pretrained stimulus, then Kamin (1969) predicts blocking or attenuated conditioning to the added stimulus. If second-order conditioning follows the same rules as first-order conditioning, then second-order conditioning to an added stimulus should be blocked by the presence of a pretrained second-order stimulus since the pretrained stimulus would preclude "surprise."

Similarly, the discrepancy model would suggest that second-order conditioning should be influenced by the level of associative strength that the pretrained stimulus has already attained. As discussed in the introduction, the presence of a previously trained stimulus should block conditioning to an added stimulus. In the present experiment a cue, N, was second-order conditioned and was later compounded with a novel cue, L, while second-order conditioning was continued. According to the model, blocking of second-order conditioning to L would be expected because little or no "discrepancy" would exist between the level of conditioning controlled by the compound, NL, and the maximum level of conditioning that the reinforcer will support. Rats in a control group received no pretraining on N; they simply received the second-order compound training along with an equal number of N and second-order reinforcer, T, presentations. Since the control group rats did not receive pretraining with N, both the N and the L stimuli were predicted to condition on second-order compound trials. The model contends that conditioning should result when a discrepancy exists between the current level of conditioning and the maximum that the reinforcer will support; therefore, conditioning should accrue to both the N and the L elements of the compound. The control group was included to measure N's ability to reduce conditioning to L without prior training of the N element.

Method

Subjects and apparatus. The subjects were 16 Yale bred male rats about 90 days old at the start of the experiment. They were maintained at 80% of normal body weight during the experiment and were allowed ad lib access to water.

The experimental chambers consisted of eight identical Skinner boxes, 22.9 x 20.3 x 20.3 cm. Each Skinner box was constructed with two aluminum end walls; the top and side walls were clear Plexiglas. Each Skinner box had a recessed food magazine mounted in the center of one end wall. To the left of the food tray was a response bar. The floor of the Skinner boxes consisted of 13, .48-cm stainless steel rods spaced 1.9 cm apart. The grid could be electrified through a high-voltage, high-resistance, relay sequence scrambler. The Skinner boxes were enclosed in sound- and light-resistant shells. Mounted on the back wall of each of these shells were a 6½-W bulb and two speakers. These permitted delivery of a houselight, L, an

1800-Hz tone, T, at an intensity of 76-dB (re 20,u N/m^2) or a white noise, N, of 80-dB. Background sound pressure level was 62-dB. All experimental events were recorded and controlled automatically by relay equipment located in an adjacent room.

Procedure. In the initial session, all rats were automatically magazine trained with 45-mg Noyes food pellets delivered on a variable time (VT) 1-min schedule. During the delivery of the free scheduled food pellets, each bar-press produced a food pellet. The first session was continued for each rat until the animal had emitted about 50 bar-presses; shaping was used if necessary. Starting with the second experimental day all sessions were 2 h long, and the rats were placed on a variable interval (VI) schedule of reinforcement. For the first 20 min of the experimental day there was a VI 1-min schedule in effect; thereafter and for all subsequent days the schedule was VI 2-min. After five VI sessions, pretesting and conditioning sessions were begun.

An outline of the pretesting and conditioning procedures are shown in Table 2. All animals were initially pretested for unconditioned suppression to L. During each of two pretest sessions animals received four 30-sec flashing (2/sec) L presentations, superimposed on the bar-press baseline. Next, all animals received differentiation training to the N and T stimuli. Evidence of generalization of conditioned responding to the N and T stimuli had been shown in previous experiments. The purpose of this stage was to reduce the level of generalized responding between N and T and to first-order condition T so that it could later serve as a second-order reinforcer.

On the 1st day of differentiation training, all the rats received, four 10-sec T presentations, which terminated with the onset of a .5-sec .5-mA footshock. For the next 13 days the rats received four 30-sec N stimuli nonreinforced and one 10-sec T presentation that terminated with the onset of the shock. This training continued until suppression to N was eliminated and there was complete response suppression to T. After the differentiation stage and before the element pretraining stage, rats were assigned to two groups of eight.

During the element pretraining stage the group labeled SOE (second-order experimental) received a treatment designed to second-order condition N and to maintain first-order conditioning to T. During each of six element pretraining sessions the rats received four 30-sec N stimuli that terminated with the onset of the 10-sec T stimulus ($N \rightarrow T$) and one 10-sec T stimulus that terminated with the onset of the shock (T+).

During the element pretraining stage the group labeled SOC (second-order control) received a treatment designed to leave N relatively neutral (when compared to N in Group SOE) and T first-order conditioned. During each of the element pretraining sessions, the rats in Group SOC received one T stimulus that terminated with the onset of shock (T+) and four unpaired presentations of N alone and T alone (N/T). These treatments permitted rats in both the experimental and control groups to receive the same number of stimulus presentations.

After element pretraining, all the rats received one further pretest session. They received four 30-sec nonreinforced light (L-) presentations to be sure that the conditioning had not generalized to the light. Next, all rats received three second-order compounding sessions. During the second-order compound conditioning stage each session consisted of four 30-sec noise-light compounds that terminated with the onset of the 10-sec tone (NL→T). In addition, each session contained one tone refresher trail, i.e., T terminating with the onset of shock (T+).

Finally, both groups were given two extinction test sessions in order to assess conditioning to the light. The test contained four 30-sec light presentations and no other programmed event (L-). All training and testing was conducted while the rats were bar-pressing. The measure of conditioning used in this and all of the following experiments was a suppression ration of the form *A*/(*A*+*B*), where *A* was the rate of responding during the stimulus presentation and *B* was the rate in a comparable period prior to the stimulus presentations. Complete suppression of baseline responding (strong excitatory conditioning) is indicated by a ratio of 0, while no change in baseline responding is indicated by a ratio of .5.

Results and Discussion

The results of the initial pretest session indicated there were no differences between groups in the level of unconditioned suppression controlled by the light, stimulus L. Figure 1 shows the change in suppression to the non-reinforced noise stimulus, N, during differentiation training. The results are plotted in blocks of two trials. The figure shows that the differentiation stage was successful in removing much of the generalized suppression to N. Not depicted in the figure is the suppression to the reinforced tone trials, stimulus T. The suppression ratios for T were 0 in both groups following the second conditioning day.

The left panel of Figure 2 depicts the course of second-order conditioning to N during the element pre-training stage. It shows that the noise acquired suppressive properties in Group SOE, for which N was paired with the pretreated T, but remained relatively neutral in the control group (SOC), for which the T and N stimuli were explicitly unpaired. Not depicted in the figure are the results of the final light pretest that was given prior to the compounding stage. The results of the final light pretest indicated that there were no differences between groups in the level of unconditioned suppression controlled by L. The compounding stage is represented in the middle panel of Figure 2. During this stage, rats in both groups received the compound of noise and light followed by the tone (NL→ T). The figure shows that, initially the compound controls little suppression in Group SOC, the group that did not receive pretreatment to N, and that the compound did control considerable suppression in Group SOE, the group that received pretreatment to N. It can be seen that by the end of the compound stage, both groups exhibited comparable levels of suppression to the compound stimulus, (NL).

The results of most interest are those from the light extinction stage, shown in the right portion of Figure 2. Comparisons of suppression during L presentations in Groups SOE and SOC indicated that blocking was produced. The suppression controlled by L in Group SOE was significantly less than in Group SOC on trial blocks 1-4 of extinction

($\underline{U}$ = 10, $\underline{p} < .05$).

During the test sessions, the pre-CS rates for Groups SOE and SOC did not differ reliably ($\underline{U}$ = 28, $\underline{p} > .05$). Thus, group differences in suppression ratios were not complicated by differences in baseline rates. (The raw pre-CS data over trial blocks, 1-2: 3-4 and 1-4 are presented in Table 6 of the Appendix.)

We may conclude from this study, that when the light was conditioned in the presence of the pretrained second-order conditioned noise, the amount of conditioning the light received was diminished. These results replicate the findings of Zimmer-Hart (1974) and those of Leyland and Mackintosh (1978) and are in agreement with the discrepancy model and with Kamin's (1969) surprise account of blocking.

CHAPTER III

EXPERIMENT 2

Experiment 2 was designed to assess the ability of first-order excitors and inhibitors to modulate second-order conditioning to a new cue. This study was designed to address the following two questions: 1) Does a stimulus (N) that has gained its conditioned strength through the operations of first-order excitatory conditioning block second-order conditioning to an added stimulus (L)? 2) Does a stimulus (N) that has gained its conditioned strength through the operations of first-order inhibitory conditioning produce second-order super-conditioning to an added stimulus (L)?

In order to make predictions from the discrepancy model for the above two cases, certain assumptions must be made concerning the model's associative strength variable (V). What the model predicts depends upon what assumptions are made concerning what V reflects. For example, if it is assumed that V reflects the strength of an S-S association in first-order conditioning and an S-R association in second-order conditioning, then when N and L are compounded during a second-order conditioning stage, V_{NL}, the quantity reflecting the strength of the S-R association, would equal zero regardless of whether the element N was a first-order excitor or a first-order inhibitor. Under these assumptions, a first-order excitor should not produce blocking, and a first-order inhibitor should not produce super-conditioning.

On the other hand, it can be assumed that V reflects the strength of an association regardless of its nature (S-S or S-R). Or similarly, it can be assumed that V reflects the ability of a CS to elicit some affective state regardless of the type of learning that elicitation reflects. With the latter assumption, the crucial discrepancy would be between the strength of the state aroused by the CS and that aroused by the reinforcer. Under these assumptions, V_{NL}, going into the second-order stage would indeed depend upon the past conditioning history of element N, and both blocking and super-conditioning would be predicted. That is, blocking of conditioning to an added cue would be produced when little or no discrepancy exists at the start of compound conditioning (as would be the case if N was a first-order excitor) whereas, super-conditioning (exceptionally strong) would be produced if a large negative discrepancy (as would be the case if N was inhibitory at the start of compound conditioning) existed (Rescorla & Wagner, 1972).

In the present experiment, N was given first-order excitatory conditioning in one group and first-order inhibitory conditioning in a second group. Then, a novel cue (L) was added to the pretrained cue during a second-order conditioning stage. These groups were compared with a so-called overshadowing control group. The control group received no pretraining on N. Rats in the control group received a treatment known to leave the N element relatively neutral (Rescorla, 1980). The control group was included to measure N's ability to reduce conditioning to L without prior training.

Method

Subjects and apparatus. The subjects were 24 Yale bred male rats about 90 days old at the start of the experiment. The rats were maintained as in Experiment 1. The apparatus and stimuli were unchanged.

Procedure. Magazine and bar-press training were identical to those in the previous experiment. The rats were randomly assigned to three groups. Each group contained eight rats. An outline of the procedure for Experiment 2 is shown in Table 3. The pretesting sessions were identical to those in Experiment 1.

On the first day of the element pretraining stage, all the rats received four T presentations that terminated with the onset of shock. For the next 13 days, the rats in Group Control (C), received four 30-sec N stimuli non-reinforced (N-), and one 10-sec T presentation that terminated with the onset of the shock (T+). As in Experiment 1, this differentiation procedure was adopted so as to reduce the level of generalized responding between N and T. During these same 13 days, element pretraining with N was being conducted with rats in the experimental groups. Rats in Group First-order experimental (FOE) received one T+ presentation and four N presentations that terminated with the shock (N+). Rats in Group First-order inhibition (FOI) received one T+ presentation and four 30-sec presentations of a compound of the T and N stimuli nonreinforced (TN-). The T stimulus was conditioned so that it could be used as a second-order reinforcer in a later stage of the experiment, while the N treatments were given so that their ability to modulate conditioning to stimulus L, during compound conditioning could be assessed. For Group FOE the N was given first-order excitatory strength in order to see if it would block second-order excitatory conditioning to L. For Group FOI the N was given first-order inhibitory strength to see if it would enhance second-order excitatory conditioning to L. For Group C the N was left relatively neutral so as to provide a baseline against which the possible blocking and enhancing effects could be assessed.

As in Experiment 1, after the element pretraining stage, all the rats received one further pretest session of four L- presentations to be sure that the conditioning had not generalized to L. Next, all rats received three second-order compounding sessions. Each session consisted of four 30-sec NL compounds that terminated as T, the second-order reinforcer, began. In addition, each session contained on T+ refresher trial. Finally, all groups were given two extinction test sessions in order to assess conditioning to the L stimulus. Each test session contained four L- presentations.

Results and Discussion

The results of the initial pretest session indicated there were no differences between groups in the level of unconditioned suppression controlled by the L stimulus. Figure 3 shows the changes in suppression of bar-pressing during presentations of the N element for Groups FOE and C, and during presentations of the NT compound for Group FOI. The results are plotted in blocks of two trials. The figure shows that this stage was successful in removing much of the generalized suppression to N and NT in Groups

C and FOI, the groups that had the N element and the NT compound nonreinforced. It can be seen that Groups C and FOI showed a progressive loss of responding to the N and NT stimuli, respectively. Figure 3 also shows that N in Group FOE, the group that had received noise-shock pairings during this stage, came to control more suppression than the N in Group C. Not depicted in this figure is the suppression on the reinforced T trials. The suppression ratios for T were 0 in all groups following the second conditioning day. Also not depicted on the figure are the results of the final light pretest. The results of the final pretest session indicated that L was relatively neutral (mean suppression ratios above .44) during this stage.

Figure 4 depicts the results of the compounding stage. The data again are represented in two-trial blocks. The left portion of Figure 4 shows that there was little suppression to the noise-light (NL) compound in Groups C and FOI at the start of second-order conditioning in the compounding stage. However, Group FOE, which had received first-order preconditioning to the N element prior to this stage, remained suppressed throughout this stage. By the end of this stage all groups were equally suppressed.

The right panel of Figure 4 shows the results of the light (L-) extinction test. It can be seen that the suppression to L was greater in Group C than in Group FOE. Group C was significantly more suppressed than Group FOE on Trial Blocks 1-4 ($\underline{U} = 10$, $\underline{p} < .05$). There were no significant differences between Group FOI and Group C on Trial 1, Trial Blocks 1, 2 and 1-4 ($\underline{U}$s = 23, 18, 26, 23; $\underline{p}$s $> .05$).

The results of Groups FOE and C indicate that a stimulus that had gained its conditioned strength through the operations of Pavlovian first-order conditioning blocked the development of second-order conditioned suppression to an added stimulus. However, the comparison between Groups FOI and C indicated that a first-order inhibitor did not produce super-conditioning to an added cue in a subsequent second-order conditioning stage. This result is at odds with results that are reported for super-conditioning with first-order reinforcers (Rescorla & Wagner, 1972). A close examination of L extinction trials in Group FOI reveals a nonsignificant blocking tendency. That is, on all trials Group FOI was always less suppressed than Group C. This, of course is, in the direction opposite to what would be predicted if super-conditioning were to occur.

During the 2 test days (trial blocks 1-4), the pre-CS rates for Groups C and FOE and FOI did not differ reliably ($\underline{H} = .21$, $\underline{p} > .05$). Thus, group differences in suppression ratios were not complicated by differences in baseline rates. (The pre-CS data for these groups are presented on Table 7 in the Appendix.)

The finding of a blocking effect in Group FOE contradicts several theories of blocking. One of these is Kamin's (1969) surprise theory. According to the theory, surprise is produced by some change in the significance of the reinforcing event. Kamin (1969) argues that the conditioning of an added stimulus (one reinforced in compound with a preconditioned stimulus) is blocked when the organism is not surprised by the reinforcer. He suggests that if the organism is surprised, it is somehow forced to examine the significance of such a trial; therefore conditioning accrues to the added stimulus. Thus conditioning occurs according to the theory only to the extent that the reinforcer is not already heralded by the aggregate of cues present on the compounding trials. Blocking occurs when the reinforcer is already heralded by such cues.

Kamin (1969) supports his surprise theory with several experiments. For example, he found that conditioning accrued to an added stimulus if the magnitude of reinforcement was raised from the preconditioning stage to the added cue stage. If however, reinforcement remained unchanged, i.e., if it remained unsurprising, he observed no conditioning to the added stimulus. In another experiment, he showed that the addition of an extra shock five seconds after the end of each added stimulus trial was sufficient to produce unblocking (excitatory conditioning) to the added cue. Kamin (1969) argued that the conditioning occurred because the new reinforcer intensity or the addition of the extra reinforcer was surprising.

The finding of a blocking effect across-orders of conditioning would not be predicted by Kamin's (1969) theory. No blocking should have been evidenced in Group FOE because the switch of reinforcers across orders of conditioning should have constituted a surprise. Thus, when Group FOE was switched from the shock reinforcer (during the preconditioning stage) to the second-order reinforcer, T, (during the compounding stage) conditioning to the added stimulus should have been evidenced.

The finding of a blocking effect in Group FOE also contradicts Mackintosh's (1973; 1975) theory. According to this theory, stimuli that signal a change in the predictiveness of the reinforcement should gain conditioned strength. Like Kamin's (1969) theory the Mackintosh theory would have predicted excitatory conditioning (unblocking) to the added cue (L) in Group FOE. Both theories are similar in that they rely on surprise as a necessary condition for learning. A study conducted by Dickinson, Hall, and Mackintosh (1976) has been interpreted as supporting the surprise notions. In this experiment, rats were pretrained with either a single or a double shock beginning at the termination of a stimulus element. Then, half the rats from each condition received a compound (consisting of the pretrained element and a new cue) signaling a single shock, while the compound signaled a double shock for the remaining rats. It was found that if the rats received either a single or a double shock throughout learning, then conditioning to the added cue was blocked. But, if either an unexpected shock or the omission of an expected shock occurred during compound training, then excitatory conditioning (unblocking) to an added cue was observed.

If in the present study the switch of reinforcers (shock to T) from the pretraining stage to the compounding stage was similar to the Dickinson et al. (1976) study in which an expected shock was omitted, then the added cue should have conditioned in Group FOE according to Mackintosh's (1973, 1975) theory. The blocking results in Group FOE speak against the Dickinson et al. (1976) surprise interpretation of their reinforcer omission findings.

Other evidence against a surprise interpretation has accumulated. For example Kohler and Ayres (1979) found no evidence of unblocking when they studied the surprise manipulation of "uncertainty" about the moment of reinforcer occurence. In their experiment the duration of the pretreated stimulus and/or the compound was varied from trial to trial. When the duration of the stimulus was varied it did not predict the time of the reinforcer's occurence yet blocking was observed even though the reinforcer's onset was "surprising." Similarly, Maleske and Frey (1979) found that a change in the stimulus-reinforcer interval from the pretraining stage to the compounding stage failed to produce unblocking. The Maleske and Frey (1979) study examined the uncertainty notion using the rabbit eyeblink response system, while the Kohler and Ayres (1979) study used the rat CER, and both failed to find results that were consistent with an interpretation of blocking in terms of the reinforcer's surprisingness. In addition, Ayres and Bombace (1980) failed to find evidence for unblocking when they studied extending the pretrained stimulus beyond the moment of the reinforcement of the compound as a "surprise" manipulation. Also, Donegan, Whitlow, and Wagner (1977) in a series of studies, that used the rat CER preparation, failed to produce evidence of unblocking when they studied the effects of a post compound surprising event such as the addition of an auditory or a visual event. However, Feldman (1971) has obtained results that are consistent with the surprise idea and the Mackintosh et al. (1976) data. In this experiment, which used an appetitive instrumental paradigm with rat subjects, he either reduced or maintained the percentage of reinforced trials between the pretraining stage and the added cue stage. Feldman (1971) found relatively more excitatory conditioning to the added cue when the percentage of reinforced trials was reduced during the added cue stage. The results and interpretation of this experiment should be taken with some caution, because the experiment was not designed to rule out the involvement of a generalization decrement due to changes in the background context that would permit additional learning. Neely and Wagner (1974) have argued that events that change the background context (such as changes in the size of the reinforcer at the beginning of compound conditioning) should reduce the value of associative strength to all of the cues present on that trial (through generalization decrement). To the extent that the associative strength has been reduced below the level that the reinforcer can support, then, to that extent conditioning should accrue to the added cue.

It is interesting to notice that no one other than Feldman (1971) has ever demonstrated unblocking using the obvious "surprise" strategy of lowering the reinforcer's intensity from the pretraining stage to the compounding stage. Instead, when Wagner, Mazur, Donegan and Pfautz (1980) were able to control for generalization decrement, they found that, when the reinforcer (shock) intensity was lowered from the pretraining stage to the compounding stage (in a rat CER preparation) the target cue developed inhibitory tendencies. Evidence for the development of inhibitory tendencies to the target cue was assessed through periodic summation tests. (It is possible that the lack of suppression to the target cue in Group FOE was actually evidence that the cue had gained inhibitory strength. Further discussion of this possibility will be taken up at a later point in this section.)

The blocking results of Group FOE also speak against the interpretation of the discrepancy model that makes the assumption that the model's associative strength variable (V) reflects the strength of an S-S association in first-order conditioning and S-R association in second-order conditioning. Using these assumptions, a first-order excitor should not have produced blocking. The blocking result of Group FOE is consistent with the interpretation of the discrepancy model that makes the assumption that V reflects the ability of the CS to arouse an affective state. According to this assumption the crucial discrepancy is the discrepancy between the strength of the state aroused by the CS and that aroused by the reinforcer. In the case of Group FOE the sum of V_{NL} would exceed λ, thus, the blocking effect would be predicted with these assumptions.

The problem with accepting this interpretation is that the Dickinson et al. (1976) data on reinforcer omission is at first glance not consistent with this affective state interpretation. The problem is that it is assumed that omitting a shock produces a weaker affective state than presenting a shock does. Thus, it is not understood how unblocking occurred unless a concept like surprise is invoked. The finding of unblocking is problematic even for the discrepancy model. If the omitting of a shock did indeed produce a weaker affective state, as the model would have to assume, then the model would have to predict that inhibition should have developed to the added cue, not the excitatory unblocking that was actually observed. However, the model would be salvaged and the affective state interpretation would be given support if the assumption that omitting a shock produces a weaker affective state, was proven to be unwarranted. It may be the case that the omission of an expected shock produces a stronger affective state than does the presentation of that shock. Ayres and Vigorito (1981) have offered indirect evidence that suggests this possibility. In their study, which used the conditioned suppression technique, they found that there was more post-CS suppression (an index of greater aversiveness) when the usually appearing shock was omitted as compared with when it was presented.

Other data that support the affective state assumption come from a first-order blocking study conducted by Bakal, Johnson and Rescorla (1974). Bakal et al. found that when the quality of the reinforcer was changed from a shock during preconditioning, to a klaxon during compounding, blocking was not disrupted insofar as the potencies of the reinforcer were accounted for. The switch from a shock to a klaxon US may be seen as being similar to the switch in USs for Group FOE. Thus, both the findings of Bakal et al. (1974) and the findings for Group FOE may be interpreted as indicating that it was the affective state of the reinforcers and their relationship to the pretrained stimulus that was responsible for the observed blocking effects. The Bakal et al. (1974) findings also seem to contradict the surprise theory. The surprise theory would have promoted the argument that the change in the quality of the reinforcer should have produced unblocking.

On the other hand, a study conducted by Stickney and Donahoe (1979) implicates the importance of the US-elicited response rather than the importance of the affective state for the blocking effect. In a first-order blocking study using the rabbit nicitating membrane response, they found that if they held the physical intensity of the shock (and presumably the affective state) constant from the pretraining stage to the compounding stage but changed the locus of the US, unblocking was observed. Since the shock intensity remained the same and only the location of the shock application (left or right paraorbital region) differed between stages, it would be difficult on one level to suggest that the shocks elicited different affective states, but it would not be difficult to suggest that the shocks elicited different affective state strengths. Since the unblocking animals had never received shock at the "switched" paraorbital region, perhaps shock there elicited a greater affective state as compared to the affective state elicited at the end of element pretraining in the opposite paraorbital region. This may be the case especially if there were any US habituation during element pretraining. If this were true, then the change in the strength of the affective state could have produced the unblocking-effect that was observed.

It may also be the case that some conditioning preparations especially encourage the dominance of US-elicited response learning. Under such conditions the discrepancy critical for learning is primarily between US and elicited response events while in other preparations the critical discrepancy primarily involves the affective state.

Another interpretation that was alluded to earlier may be given to the results of Group FOE. Perhaps what has been called blocking in the present study (the lack of suppression to the target, L, cue in Group FOE) was actually evidence that L had gained inhibitory strength. That is, the lack of suppression to the L cue could indicate that inhibition developed. Perhaps the switch of reinforcers (from shock to T) constituted a decrement in the magnitude of reinforcement during the added cue stage and thus allowed for the development of inhibition to the L cue. It is interesting to note that a finding of inhibition in the above case would be in agreement with the Wagner _et al_. (1980) study and with one interpretation of the discrepancy model. According to the model, if the discrepancy ($\lambda - V_{NL}$) becomes negative, for example, by lowering the magnitude of reinforcement (e.g., switching from shock to T) then, the model predicts that inhibition (not blocking or not the excitation found in the Dickinson _et al_. [1976] study) should have accrued to the L cue. It is clear that such an inhibition interpretation does not account for the data from the Dickinson _et al_. (1976) study although it can account for the data in Group FOE. However, all of the findings if taken together suggest that a more parsimonious explanation is necessary. The affective state assumption seems capable of accounting for all of the data thus far presented. Of course the matter of whether the target cue L, in Group FOE was inhibitory or not will have to be answered empirically. Unfortuantely there are a limited number of stimuli available with the CER technique so that it is difficult to propose a study with the traditional transfer tests of inhibition within an across-order blocking paradigm.

It is difficult to know how seriously to take Group FOI's failure to demonstrate super-conditioning. Perhaps the blocker cue (N) was not inhibitory. The data in fact suggested that perhaps the N cue was still slightly excitatory by the end of training. Further comment on this outcome awaits a replication of the FOI Group and an appropriate control group.

CHAPTER IV

EXPERIMENT 3

The purpose of Experiment 3 was to see if a second-order conditioned stimulus blocks first-order conditioning to a new cue. Besides allowing an examination of this particular second-order and first-order interaction, this experiment should indirectly bear on the question of whether the attenuation of conditioning that occured in Experiment 2 (when the first-order excitor was compounded with a neutral cue for second-order conditioning) was due to the development of inhibition. Whereas Experiment 2 examined a case in which the value of the reinforcer was presumably decreased during the compounding stage, Experiment 3 sought to examine a case where the value of the reinforcer was increased during the compounding stage. That is, in Experiment 3 the second-order reinforcer (T), the presumed weaker reinforcer, was used to condition the pretrained cue (N). Then during the compounding stage the first-order reinforcer (shock), the stronger reinforcer, was used to condition the compound of N and a new cue (e.g., NL shock). A finding of attenuated conditioning to L under these conditions might suggest that blocking, not inhibition was observed in Experiment 2, Group FOE. A finding of blocking when the reinforcer is switched from T to shock might suggest that the asymptotic level of the reinforcer is left relatively unaffected by such a manipulation. If the asymptote were greatly changed by such a manipulation, then conditioning to L (unblocking) would be expected when the reinforcer value is raised (T- to shock) and inhibition (which gives the appearance of blocking) would be predicted when the reinforcer value is lowered (shock to T-).

In order to make predictions from the discrepancy model for this experiment, as was the case for Experiment 2, certain assumptions must be made concerning the model's associative strength variable (V). Again, if it is assumed that V reflects and S-S association in first-order conditioning and a S-R association in second-order conditioning, then a second-order conditioned stimulus would not be expected to block first-order conditioning. However, if it is assumed that V reflects the ability of a CS to elicit some affective state regardless of the type of learning (S-S or S-R) that elicitation reflects, then a second-order conditioned stimulus would be expected to block first-order conditioning, provided that the second- and first-order reinforcers elicit similar affective states with similar strengths.

A preliminary experiment suggested that if blocking were to be observed with the above conditions, then it would be necessary to attempt to equate the strengths of the first- and second-order reinforcers. In this experiment an attempt was made to make the strength as well as the affective state of the reinforcers similar by using a weak shock as the first-order reinforcer and basing the strength of the second-order reinforcer on a strong shock.

The Rescorla - Wagner (1972) model suggests that only reinforcer potency should affect blocking. Changes that modify the qualitative properties of the reinforcer, but leave the reinforcer's asymptote unaffected should not interfere with blocking.

This study is similar to the Bakal et al. (1974) study, of first-order conditioning and blocking. Bakal et al. found that qualitative properties other than those of reinforcer potency are not important in producing blocking or unblocking.

This experiment also included groups that assessed whether a second-order conditioned stimulus could block second-order conditioning to an added cue. The latter groups were included to be sure that blocking could be observed with the procedures used and to serve as a basis of comparison for first- and second-order blocking.

Method

Subjects and apparatus. The subjects were 32 Yale bred male rats about 90 days old at the start of the experiment. The apparatus and stimuli were unchanged. The shock intensities were .5-sec .5-mA footshock or a .5-sec 1-mA footshock. These shocks are hereafter referred to as the weak shock (WS) and the strong shock (SS) respectively.

Procedure. The rats were magazine trained, bar press trained, and pretested as in Experiment 1. The procedure is outlined in Table 4.

Differentiation training was identical to that of Experiment 1, except that it took 10 days (not including the initial differentiation day). After differentiation training, the subjects were assigned to four groups of eight rats each.

During the element preconditioning stage the groups labeled SSE (second-order blocking/second-order-Experimental) and SFE (second-order blocking/first-order-Experimental) received a treatment designed to second-order condition N and to maintain first-order conditioning to T with the strong shock (SS). They received a single T trial that terminated with the onset of SS and four N presentations followed by the T stimulus on each of three element preconditioning days. During element preconditioning the groups labeled FC (first-order blocking control group) and SC (second-order blocking control group) received a treatment designed to leave N relatively neutral and to maintain strong excitatory conditioning to T. During each session these rats received a single T trial that terminated with the onset of SS and four T presentations that were not followed with any programmed event (T-). The purpose of the T- trials was to keep the number of stimulus presentations and the number of nonreinforced T trials equal in the experimental and control groups. In addition, these rats received four N presentations non-reinforced.

Following the element pretraining stage, all groups received one final pretest day consisting of four L presentations without any other programmed event. This stage, as in Experiment 1, was included to insure that the L cue remained neutral. Then, in the compound conditioning stage, Groups SFE and FC received one T presentation followed by the strong shock (T→SS) and four NL compounds that terminated with the onset of the weak shock (NL→WS) on each of 2 days. During this same time, Groups SSE and SC received one T presentation followed by the strong shock (T→SS) and four NL compounds that terminated with the onset of the second-order reinforcer, the T stimulus (NL T) during each session.

Finally, all groups received 4 days of an extinction test to the light (L-). On each day they received four L presentations while bar-pressing on the VI schedule.

Results and Discussion

The results of the initial and final pretest sessions indicated there were no differences between groups in the level of unconditioned suppression controlled by L.

The differentiation stage removed most of the generalized suppression to N. At the end of this stage there were no differences between the groups in responding to N or in suppression to T. The course of this differentiation was similar to that of Experiments 1 and 2. The data of most interest are presented in two-trial blocks in Figure 5. The left panel of Figure 5 depicts the course of second-order conditioning (element pretraining stage) to N in Groups SFE and SSE. This panel shows that at the start of this stage all the groups were responding to N at about the same level. This figure shows that the N cue remained relatively neutral in Groups FC and SC but developed suppressive tendencies in Groups SFE and SSE during the course of second-order conditioning. Not depicted in any of the figures are the tone, stimulus T, trials. The suppression ratios for T did not differ between groups.

They remained between 0 and .1 following the second conditioning day.

The compounding stage is represented on Figure 5 in the middle panel. Just as would be expected, the middle panel shows that the pretreated Groups (SFE and SSE) were more suppressed at the start of the compounding stage than were the nonpretreated Groups (FC and SC). An examination of trial blocks shows that by the end of the compound stage rats in Groups SFE and FC (that received the NL compound terminating in WS) had suppression ratios of 0 and did not differ from each other. Similarly, by the end of this stage rats in Groups SSE and SC (that received the NL compound terminating in T) did not differ from each other ($\underline{U}$ = 25.5, $\underline{p}$ >.05). In addition, comparisons between Groups SFE and SSE revealed that there were no significant differences in the level of conditioned suppression obtained when the two reinforcers (WS or T) were used to condition the compound ($\underline{U}$ = 25.5, $\underline{p}$ >.05). The results of the compounding stage revealed that all groups exhibited comparable levels of conditioned suppression to the NL compound.

The results of the light (L) extinction test are shown in the right portion of Figure 5. Comparisons of suppression during L presentations in Groups SFE and FC indicated that a blocking effect was observed. The suppression controlled by L in Group SFE was significantly less than in Group FC on Trial Block 5 ($\underline{U}$ = 13, $\underline{p} < .05$) and over Trial Blocks 7-8 ($\underline{U}$ = 15.5, $\underline{p} < .05$). Thus, when L was reinforced with shock in the presence of the pretrained second-order conditioned N cue, blocking was observed.

The suppression controlled by L in Group SSE was significantly less than in Group SC on Trial Block 1 ($\underline{U}$ = 7, $\underline{p}$ .05); over Trial Blocks 1 and 2 ($\underline{U}$ = 10.5, $\underline{p} < .05$); and over Trial Blocks 4-5 and 6-7 ($\underline{U}$s = 6.5, 6; $\underline{p}$s $< .05$). Thus, when L was reinforced with the second-order reinforcer, T, in the presence of the pretrained second-order conditioned N cue, blocking was observed. This result replicates the results of Experiment 1. That is, a second-order conditioned stimulus blocks second-order conditioning to an added cue.

It appears that this experiment was not successful in equating the potencies of the affective state of the first- and second-order reinforcers since the levels of suppression controlled by L in the control groups (FC and SC) clearly differed (see the right panel of Figure 5). The suppression controlled by L in the group that received the WS to condition the NL compound (Group FC) was greater than the suppression that was controlled by L in Group SC that received the second-order reinforcer, T. The fact that these levels of suppression differed makes it difficult to compare the magnitudes of the blocking effects with the particular second- and first-order reinforcers used in this experiment, i.e., to compare Groups SFE and SSE.

During the 4 test days, the pre-CS rates between Groups SSE and SC and between SFE and FC did not differ reliably (Us = 26.5, 25; ps $>$.05). Thus, group differences in suppression ratios were not complicated by differences in baseline rates. (The raw pre-CS data for the various groups are presented in Table 8 of the Appendix.)

The right panel of Figure 5 shows that the suppression controlled by L, for Group SFE, at the start of extinction testing was complete. During the course of extinction the impact that the second-order conditioned N cue had on subsequent first-order conditioning to L was revealed by the fact that L appears to extinguish more rapidly in Group SFE than in Group FC. It may be that the differences in US potency (T to WS) can account for the relatively attenuated blocking effect that was observed since blocking was observed late in extinction in the group that had its reinforcer switched. One interpretation of these data can be that the differences that are observed between Groups SFE and FC are attributable to the second-order conditioned stimulus blocking the development of first-order conditioning to a new cue.

A blocking interpretation for the results of Groups SFE and FC would be consistent with the Bakal et al. (1974) data that suggested that changes in the qualitative properties of the reinforcers did not preclude the observation of first-order blocking if changes in US potencies were accounted for. That is, it may be argued that if the potency of the reinforcer was greater during compounding, than during pretraining, then to that extent incomplete blocking (as was the case for Group SFE) would be observed (Rescorla & Wagner, 1972) not the absence of blocking. The absence of a blocking effect would have been predicted by an informal interpretation of the Kamin surprise idea because changing the quality as well as the potency of the reinforcer during compounding should have led to surprise and the absence of blocking.

An interpretation of blocking for the results of Groups SFE and FC would also be consistent with the idea that the crucial discrepancy (for the observation of blocking) is one between the magnitude of the affective states elicited by the pretrained stimulus and the current reinforcer.

An alternative interpretation to the idea that first- and second-order conditioning interact in the same way that a first-order stimulus interacts with another first-order stimulus to produce blocking-attenuated conditioning to L, is that the attenuation of conditioning may not have been due to the actions of a second-order stimulus blocking first-order conditioning but may have been due to the second-order stimulus blocking subsequent second-order conditioning. It is probably true that some second-order conditioning takes place every time first-order conditioning is conducted. It might be that the early segments of a stimulus may be second-order conditioned by the later segments that stand in a direct relation to the first-order reinforcer. Nevertheless, whatever interpretation is left standing, the operations of combining second- and first-order stimuli yield similar behavioral results.

Taken together, the results of these experiments suggest (at least with the rat CER preparation) that combinations of first- and second-order conditioning seem to obey some of the same rules that have been established for first-order conditioning. That is, a second-order conditioned stimulus not only blocks the development of second-order conditioning to an added cue, as a first-order conditioned stimulus blocks the development of first-order conditioning, but a second-order conditioned stimulus also seems to attenuate subsequent conditioning when it is compounded with a new cue during first-order conditioning. In addition, a first-order conditioned stimulus attenuates subsequent second-order excitatory conditioning to a new cue.

Thus far, all of the experiments have examined the interactions between first- and second-order conditioning within the blocking paradigm. Experiment 4 examines such interactions using the summation technique (Pavlov, 1927).

CHAPTER V

EXPERIMENT 4

This experiment was designed to see if 1) a first-order inhibitory stimulus suppresses the responding that is elicited by a second-order excitatory stimulus; 2) a first-order excitatory stimulus summates with a second-order excitatory stimulus and 3) two second-order excitatory stimuli summate. Thus far, all of the experiments that have been presented have examined the interactions between first- and second-order conditioning within the blocking paradigm. The present experiment examines such interactions using the summation technique developed by Pavlov (1927) for first-order conditioning. He found that there was an increase in responding when two excitors are combined, and a decrease in responding if an inhibitor is combined with an excitor relative to the level of responding that is observed when the excitor is presented alone. The present experiment examines the summation of some first-order and second-order stimuli.

Answers to the questions about what the discrepancy model predicts for the present experiment depend upon what assumptions are made for what the model's associative strength variable (V) reflects. If V reflects two types of learning (S-S or S-R), then the model predicts that no response suppression would be observed when a first-order inhibitor is combined with a second-order excitor. According to Rescorla (1977) a first-order inhibitor exerts its influence on the arousal of US memory while a second-order excitor does not involve US (a first-order reinforcer) memory. If the US memory is not involved in second-order excitatory conditioning, then it may be reasoned that there should be no response suppression when a first-order inhibitor is combined with a second-order excitor and further that a first-order excitatory stimulus will not summate with a second-order excitatory stimulus. However, it may be that V reflects the ability of the CS to arouse an affective state. If this assumption is true, then the compound of a first-order inhibitor and a second-order excitor would be expected to evoke less of a response than the second-order excitatory stimulus alone. This suppression would occur regardless of what type of second-order associations are involved. Similarly, it would be expected that a compound of two second-order excitatory stimuli or a compound of a first-order excitor and a second-order excitor would tend to evoke a greater response than the second-order excitatory stimulus alone. The following CER study examined the effects of compounding a first-order excitor or inhibitor with a second-order excitatory stimulus.

Method

Subjects and apparatus. The subjects were 32 Yale bred male rats about 90 days old at the start of the experiment. The apparatus and stimuli were unchanged.

Procedure. The rats were magazine trained, bar-press trained, and pretested as in Experiment 1. The various conditioning stages are outlined in Table 5.

Differentiation training was identical to that of Experiment 1, except that it took 2 days not including the initial differentiation day) and that eight of the animals (those in Group I) received a TN compound, (30-sec) nonreinforced instead of the N alone. The purpose of this stage was to leave N relatively neutral for 24 of the rats, leave T excitatory for all of the rats, and to begin first-order inhibitory conditioning with eight of the rats (those in Group I).

The rats were assigned to four groups of eight. During the conditioning stage, rats in Group I received four additional sessions of conditioned inhibition training consisting of four NT compound trials nonreinforced along with one T trial that terminated with the onset of shock (+). This treatment was designed to leave N controlling conditioned inhibitory tendencies and T controlling conditioned excitatory tendencies.

During the conditioning stage, rats in Group E received a treatment designed to leave both N and T controlling conditioned excitatory tendencies. These rats received four N stimuli and one T stimulus all reinforced with shock during each of the sessions. Rats in Group C received a treatment designed to leave N, relative to N in the other groups, neutral. These rats received four N stimuli nonreinforced and one T stimulus reinforced with shock during these sessions.

During the conditioning stage, rats in Group S received four sessions of second-order excitatory conditioning to N. During these sessions the rats received four trials of N followed by T (N→T) and one T presentation that terminated with the onset of shock. This treatment was designed to produce second-order excitatory conditioning to N and first-order excitatory conditioning to T.

In addition, during the conditioning stage, rats in Groups E and C received four T alone presentations. The T alone presentations were included so as to keep the number of their presentations equal across groups.

After Days 2 and 4 of the conditioning stage, all groups received 1 day of T conditioning. This session consisted of four T presentations that terminated with the onset of the shock. These T "refresher trials" were included to insure that T remained excitatory.

After the conditioning stage, all the rats received one further pretest session of four L- presentations to be sure that the conditioning had not generalized to L.

Next, all rats received two second-order conditioning (L→T) sessions designed to leave L controlling excitatory tendencies. Each session consisted of four L stimuli followed by T as the second-order reinforcer. In addition, each session contained one refresher trial (T→shock).

Finally, all groups were given six extinction test sessions. The test contained two presentations each of L, N, LN, and TN compounds (all 30-sec) nonreinforced. The order of test stimulus presentations was varied daily. All training and testing was conducted while the rats were bar pressing.

Results and Discussion

The results of the pretest sessions indicated that there were no differences between groups in the level of unconditioned suppression controlled by L.

The differentiation stage removed most of the generalized suppression to N. The course of differentiation training was similar to such training in Experiment 2.

The left panel of Figure 6 depicts the course of conditioning to N during the conditioning stage. The data are presented in two-trial blocks. Not presented in this figure are the T conditioning trials since they mostly yielded suppression ratios of zero. It can be seen from the figure that at the start of this stage Groups E, C, and S were responding to N at about the same level. Group I, the group that received the NT compound during this stage, was more suppressed. The figure shows, as expected, that by the end of this stage N remained relatively neutral in Group C but developed strong suppressive tendencies in Groups E and S while NT lost much of its suppressive tendencies.

The second-order conditioning stage is represented on Figure 6 in the right panel. The figure shows that by the end of this stage (during which all groups received second-order conditioning to L) all of the groups exhibited equal levels of suppression.

The results of the extinction test session are shown in Figure 7. The data are averaged over six-trial blocks. Since Groups I and C both received the same second-order conditioning to stimulus L, the two groups should suppress similarly to L. However, since N was established as a first-order inhibitor only in Group I, we might expect less suppression to the NL compound in Group I than in Group C. These expectations were confirmed, the two groups suppressed similarly to L ($\underline{U}$ = 40, $\underline{p} > .05$) but suppression to the NL compound was greater in Group C than in Group I ($\underline{U}$ = 16, $\underline{p} < .05$). In addition, since N was established as a first-order inhibitor in Group I, it would be expected that the NL compound in Group I would be less suppressed than L in both Groups I and C. These expectations were also confirmed. A within group comparison revealed that suppression to the NL compound in Group I was less than the suppression to L ($\underline{T}$ = 1.5, $\underline{p} < .05$) and a between groups comparison revealed that Group I suppressed less to the NL compound ($\underline{U}$ = 11.5, $\underline{p} < .05$) than Group C suppressed to L. These results reveal that when a stimulus (N) that was given first-order inhibitory training was compounded with a stimulus (L) that was given second-order excitatory training, greater suppression resulted relative to the level of suppression observed when a neutral stimulus was compounded with a second-order excitatory stimulus.

Figure 7 also depicts the results of Group S, the group that received second-order excitatory conditioning to both N and L before they were combined. It was expected that a compound of two second-order conditioned stimuli would control more suppression than either stimulus alone and would control more suppression than a compound of a neutral cue and a second-order excitatory cue (Group C). These expectations were confirmed. The figure shows that the NL compound was more suppressed in Group S than either N ($T = 0$, $p < .05$) or L ($T = 1$, $p < .05$) and more suppressed than the NL compound in Group C ($U = 9.5$, $p < .05$) and either N ($U = 0$, $p < .05$) or L ($U = 7.5$, $p < .05$) in Group C. In addition, a within group comparison of L and N in Group S revealed that there were no differences in the level of suppression to L or N ($T = 10.5$, $p > .05$). This comparison suggests that any differences that might be seen, (i.e., when the stimuli are compounded) cannot be attributed to differences in the level of conditioning achieved with each stimulus. The results indicate that when two stimuli that have been given second-order excitatory training are compounded, they produce greater response suppression than either stimulus alone and greater response suppression than a compound of a second-order trained stimulus and a neutral stimulus.

Figure 7 also shows that there were no differences in the level of suppression controlled by N and NL in Group E but that both of these stimuli produced more suppression than did L ($Ts = 0, 0$; $ps < .05$). The results of these data indicate that perhaps the first-order excitatory conditioning of N resulted in a floor effect that made it difficult to observe summation of N with the second-order excitor, L.

Based on all of the other results it is presumed that if an intermediate level of conditioning to N had been achieved then this summation effect would have been observed.

Not depicted on the figure are the results for NT testing. The results of this test confirmed that N in Group I maintained its inhibitory status throughout testing, i.e., the NT compound controlled the least amount of suppression in this group (mean suppression ratios above .40).

An analysis on the pre-CS data during the extinction test (over the six trial blocks) was conducted for each stimulus separately and revealed that the groups did not differ reliably ($\underline{H}$s = .93, 1.6, 2.0, 1.3; $\underline{p}$s $>$ .05) for L, N, NL, and NT respectively. Thus, group differences in suppression ratios were not complicated by differences in baseline rates. (The raw pre-CS data for the various groups are presented in Tables 9 - 11 in the Appendix.)

The results of the summation data were consistent with the results of the blocking data in suggesting that the discrepancy model variable V reflects the ability of the CS to arouse an affective state. Based on this assumption, it was predicted that the compound of a first-order inhibitor and second-order excitor would control less response suppression than the second order excitatory stimulus alone. In addition, it was predicted that a compound of two second-order excitatory stimuli would control greater response suppression than either second-order stimulus alone.

Taken as a whole, the results of Experiments 1-4 are consistent with the idea that second-order conditioning seems to obey some of the same rules that first-order conditioning obeys at least with the preparations used in the present experiments. Furthermore, these rules also seem to operate across the two orders of conditioning. Unfortunately, the combination (of first- and second-order or second- and first-order) experiments did not directly assess which order of conditioning was actually producing the observed effects. However, it seems clear at the operational level that such combinations produce behavioral outcomes that are consistent with or similar to the behavioral outcomes for combinations of first-order conditioned stimuli.

CHAPTER VI

GENERAL DISCUSSION

The present set of experiments clearly demonstrated that attenuated conditioning occurred within an across-order blocking paradigm and that across-order summation occurs.

These across-order blocking results therefore join the same-order blocking results of Kamin (1969) in showing that attenuated conditioning to an added cue was dependent upon the preconditioning of one element of a to-be-conditioned compound. These across-order results are also consistent with the first-order results of Bakal _et al_. (1974). The results of the present set of studies and the studies of Bakal _et al_. (1974) may be interpreted as suggesting that qualitative changes in the reinforcer do not interfere with blocking. In addition, the present results disagree with an interpretation of the surprise idea of blocking by showing that qualitative changes in the reinforcer (from a first-order reinforcer to a second-order reinforcer and from second-order reinforcers to first-order reinforcers) do not eliminate the attenuated conditioning effect. The results of these experiments were also seen as being consistent with predictions that were made from the Rescorla and conditioning are present in every conditioning preparation and that the sum of the behavior observed is the combination of both orders of conditioning.

Unfortunately, the matter of whether the attenuated conditioning was a result of across-order blocking or blocking of like-order conditioning would be difficult to separate given the relatively limited techniques at our disposal for separating first- and second-order conditioning. However it is clear that these experiments have identified the fact that, at least at the operational level, combinations of first- and second-order stimuli yield the same behavioral outcomes as combinations of first-order conditioned stimuli. Further examination of across-order combinations seems warranted even though at the present time it is difficult to discern whether the two orders of conditioning actually interact or whether the two orders of conditioning act in parallel to produce their effects (i.e., blocking of same-order conditioning in the across-order paradigm). If the two orders of conditioning do interact, then it would be convenient to maintain the assumption that the discrepancy model variable, V, reflects the affective state of the reinforcer. However, if it turns out that the two orders of conditioning act in parallel, then there would be no need to adopt such an assumption.

R E F E R E N C E S

Amiro, T.W., & Bitterman, M.E. Second-order appetitive conditioning in goldfish. Journal of Experimental Psychology: Animal Behavior Processes, 1980, 6, 41-48.

Ayres, J.J.B., & Bombace, J.C. A Surprising extension of A beyond the moment of a reinforced AX trial does not alleviate blocking., 1980, Manuscript in preparation.

Ayres, J.J. B., & Vigorito, M. Blocking, surprise, and Post US suppression in the conditioned suppression procedure. Manuscript in preparation, 1981.

Bakal, C.W., Johnson, R.D., & Rescorla, R.A. The effect of change in US quality on the blocking effect. The Pavlovian Journal, 1974, 2, 97-103.

Bandura, A. Principles of behavior modification. New York: Holt, Rinehart, and Winston, 1969.

Cheatle, M.D., & Rudy, J.W. Analysis of second-order odor-aversion conditioning in nenatal rats. Implications for Kamin's blocking effect. Journal of Experimental Psychology: Animal Behavior Processes, 1978, 4, 237-249.

Davenport, J.W. Higher-order conditioning of fear (CER). Psychonomic Science, 1966, 13, 5-6.

Donegan, N.H., Whitlow, J.W. & Wagner, A.R. Posttrial reinstatement of the CS in Pavlovian conditioning. Facilitation or impairment of acquisition as a function of individual differences in responsiveness to the CS. Journal of Experimental Psychology: Animal Behavior Processes, 1977, 3, 357-376.

Dickinson, A., Hall, G., & Mackintosh, N.J. Surprise and the attenuation of blocking. Journal of Experimental Psychology: Animal Behavior Processes, 1976, 2, 313-322.

Feldman, J.M. Added cue control as a function of reinforcement predictability. Journal of Experimental Psychology, 1971, 91, 318-325.

Holland, P.C., & Rescorla, R.A. The effect of two ways of devaluing the unconditioned stimulus after first- and second-order appetitive conditioning. Journal of Experimental Psychology: Animal Behavior Processes, 1975, 1, 355-363. (a)

Holland, P.C. & Rescorla, R.A. Second-order conditioning with food unconditioned stimulus. Journal of Comparative and Physiological Psychology, 1975, 88, 459-467. (b)

Hull, C.L. A behavior system. New Haven: Yale University Press, 1952.

Kamil, A.C. Some parameters of the second-order conditioning of fear in rats. Journal of Comparative Physiological Psychology, 1969, 67, 364-369.

Kamin, L.J. Predictability, surprise, attention and conditioning. In B.A. Campbell and R.M. Church (Eds.), Punishment and aversive behavior. New York: Appleton-Century-Crofts, 1969.

Kehoe, E.J., Gibbs, C.M., Garcia, E. & Gormezano, L. Associative transfer and stimulus selection in classical conditioning of the rabbits' nictitating membrane response to serial compound CSS. Journal of Experimental Psychology: Animal Behavior Processes, 1979, 5, 1-18.

Kohler, E.A., & Ayres, J.J.B. The Kamin blocking effect with variable-duration CSs. Animal Learning and Behavior, 1979, 7, 347-350.

Konorski, J. Integrative activity of the brain. Chicago: University of Chicago Press, 1967.

Leyland, C.M. Higher-order autoshaping. Quarterly Journal of Experimental Psychology, 1977, 29, 607-619.

Leyland, C.M., & Mackintosh, N.J. Blocking of first- and second-order autoshaping in pigeons. Animal Learning and Behavior, 1978, 6, 391-394.

Mackintosh, N.J. Stimulus selection: Learning to ignore stimuli that predict no change in reinforcement. In

R.A. Hinde & J. Stevenson-Hinde (Eds.), Constraints on learning. London: Academic Press, 1973.

Mackintosh, N.J. A theory of attention: Variations in the associability of stimuli with reinforcement. Psychological Review, 1975, 82, 276-298.

Maleske, R.T., & Frey, P.W. Blocking in eyelid conditioning: Effect of changing the CS-US interval and introducing an intertrial stimulus. Animal Learning and Behavior, 1979, 7, 452-456.

Nairne, J.S. & Rescorla, R.A. Second-order conditioning with diffuse auditory reinforcers in the pigeon. Learning and Motivation, 1981, 12, 65-91.

Neely, J.H., & Wagner, A.R. Attenuation of blocking with shifts in reward. The involvement of schedule-generated contextual cues. Journal of Experimental Psychology, 1974, 102, 751-763.

Pavlov, I.P. Conditioned reflexes. (Translated by G.V. Anrep). London: Oxford University Press, 1927.

Rashotte, M.E., Griffin, R.W., & Sisk, C.L. Second-order conditioning of the pigeon's keypeck. Animal Learning and Behavior, 1977, 5, 25-38.

Rescorla, R.A. Second-order conditioning: Implications for theories of learning. In F.J. McGuigan and D.B. Lumsden (Eds.), Contemporary approaches to conditioning and learning. Washington, D.C.: V.H. Winston, 1973.(a)

Rescorla, R.A. Effect of US habituation following conditioning. Journal of Comparative and Physiological Psychology, 1973, 82, 137-143. (b)

Rescorla, R.A. Effect of inflation of the unconditioned stimulus value following conditioning. Journal of Comparative and Physiological Psychology, 1974, 86, 101-106.

Rescorla, R.A. Pavlovian second-order conditioning: Some implications for instrumental behavior. In H. Davis & H.M.B. Hurwitz (Eds.), Operant-Pavlovian interactions. Hillsdale, New Jersey: Erlbaum, 1977.

Rescorla, R.A. Aspects of the reinforcer learned in second-order Pavlovian conditioning. Journal of Experimental Psychology: Animal Behavior Processes, 1979, 5, 79-95.

Rescorla, R.A. Pavlovian second-order conditioning: Studies in associative learning. Hillsdale, New Jersey: Erlbaum, 1980.

Rescorla, R.A., & Wagner, A.R. A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and nonreinforcement. In A.H. Black & W.F. Prokasy (Eds.), Classical conditioning II: Current research and theory. New York: Appleton-Century-Crofts, 1972.

Rizley, R.C., & Rescorla, R.A. Associations in second-order conditioning and sensory preconditioning. Journal of Comparative and Physiological Psychology, 1972, 81, 1-11.

Sahley, C., Gelperin, A., & Rudy, J.W. First- and second-order Associative Learning in the Terrestial Mollusc, Limax Maximus. Neuroscience Abstract, 1980, 200.3, 589.

Sears, R.J., Baker, J.S., & Frey, P.W. The eye blink as a time-locked response: Implications for serial and second-order conditioning. Journal of Experimental Psychology: Animal Behavior Processes, 1979, 5, 43-64.

Skinner, B.F. Science and human behavior. New York: Macmillan, 1933.

Spence, K.W. Behavior theory and conditioning. New Haven: Yale University Press, 1956.

Stickney, K. & Donahoe, J.W. Classical Conditioning: Role of the elicited response. Unpublished Manuscript, 1981.

Wagner, A.R., Mazur, J.E., Donegan, N.H., & Pfautz, P.L. Evaluation of blocking and conditioned inhibition to a CS signaling a decrease in US intensity. Journal of Experimental Psychology: Animal Behavior Processes, 1980, 6, 376-385.

Zimmer-Hart, C.L. An investigation of first-order principles in second-order conditioning. Unpublished doctoral dissertation, Yale University, 1974.

A P P E N D I X

Tables 1 - 5

These tables display an outline of experimental procedures. Table 1 shows the outline of the Rizley and Rescorla (1972) experiment. Tables 2, 3, 4, and 5 show an outline of the procedures for Experiments 1, 2, and 3 respectively.

TABLE 1

Outline of second-order conditioning control procedure used by Rizley and Rescorla (1972)

Group	Phase I	Phase II
PP	$S_1 \rightarrow$ shock	$S_2 \rightarrow S_1$
PU	$S_1 \rightarrow$ shock	S_2/S_1
UP	S_1/shock	$S_2 \rightarrow S_1$

TABLE 2

Outline of Procedure
Experiment 1

Group	Initial Pretest	Differentiation Stage	Element Preconditioning	Final Pretest	Compound Conditioning	Extinction Test
SOE	L-	T+, N-	T+, N → T	L-	T+, NL → T	L-
SOC	L-	T+, N-	T+, N/T	L-	T+, NL → T	L-

TABLE 3

Outline of Procedure
Experiment 2

Group	Initial Pretest	Element Preconditioning	Final Pretest	Compound Conditioning	Extinction Test
C	L-	T+, N-	L-	T+, NL→ T	L-
FOE	L-	T+, N+	L-	T+, NL→ T	L-
FOI	L-	T+, NT-	L-	T+, NL→ T	L-

TABLE 4

Outline of Procedure
Experiment 3

Group	Initial Pretest	Differentiation Stage	Element Preconditioning	Final Pretest	Compound Conditioning	Extinction Test
FC	L-	T_{ss} N-	T_{ss} N/T	L-	T_{ss}, NL → ws	L-
SFE	L-	T_{ss} N-	T_{ss} N → T	L-	T_{ss}, NL → ws	L-
SSE	L-	T_{ss} N-	T_{ss} N → T	L-	T_{ss}, NL → T	L-
SC	L-	T_{ss} N-	T_{ss} N/T	L-	T_{ss}, NL → T	L-

ss = strong shock .5-sec 1-mA
ws = weak shock .5-sec .5-mA

TABLE 5

Outline of Procedure
Experiment 4

Group	Initial Pretest	Differentiation Stage	Element Preconditioning	Final Pretest	Second-order Conditioning	Test
I	L-	T+, TN-	T+, TN-	L-	T+, L → T	L-, N-, NL-, TN-
E	L-	T+, N-	T+, T-, N+	L-	T+, L → T	L-, N-, NL-, TN-
C	L-	T+, N-	T+, T-, N-	L-	T+, L → T	L-, N-, NL-, TN-
S	L-	T+, N-	T+, N T	L-	T+, L → T	L-, N-, NL-, TN-

<u>Tables 6-12</u>.

These tables display the pre-CS data during test days for Experiments 1, 2, 3, and 4. Tables 6, 7, and 8 show the pre-CS response rates for Experiments 1, 2, and 3 respectively. Tables 9, 10, 11, and 12 show the pre-CS response rates during L, N, NL, and NT testing, respectively.

TABLE 6

Pre-CS (2-min) Data for L- Test
Experiment 1

Subjects		Trial Blocks 1 - 2	Trial Blocks 3 - 4	Trial Blocks 1 - 4
Group SOE	101	41	44	85
	102	50	18	68
	103	79	38	117
	104	22	16	38
	105	57	49	106
	106	62	58	120
	107	43	36	79
	108	69	78	147
Group SOC	109	33	13	46
	110	49	64	113
	111	41	51	92
	112	52	58	110
	113	38	12	50
	114	47	50	97
	115	129	97	226
	116	88	67	155

TABLE 7

Pre-CS (2-min) Data for L- Test
Experiment 2

Subjects		Trial Blocks 1 - 2	Trial Blocks 3 - 4	Trial Blocks 1 - 4
Group C	201	84	119	203
	202	55	97	152
	203	36	49	85
	204	52	31	83
	205	28	55	83
	206	66	71	137
	207	86	76	162
	208	30	39	69
Group FOE	209	54	71	125
	210	29	31	60
	211	41	49	90
	212	34	35	69
	213	77	109	186
	214	27	34	61
	215	75	76	151
	216	114	116	230
Group FOI	217	60	49	109
	218	34	42	76
	219	64	121	185
	220	79	96	175
	221	73	56	129
	222	38	44	82
	223	76	79	155
	224	37	45	82

TABLE 8

Pre-CS (2-min) Data for L- Test
Experiment 3

Subjects		Day 1 Trials 1-4	Day 2 Trials 1-4	Day 3 Trials 1-4	Day 4 Trials 1-4	Days 1-4 Total
		Trial Blocks				
		1-2	3-4	5-6	7-8	1-8
Group FC	301	57	62	40	38	197
	302	26	34	39	33	132
	303	0	16	43	34	93
	304	54	61	40	50	205
	305	117	170	119	118	524
	306	70	121	121	115	427
	307	49	45	43	42	179
	308	52	61	62	60	235
SFE	309	39	36	41	44	160
	310	37	31	44	48	160
	311	46	80	87	100	313
	312	31	58	82	87	258
	313	47	46	59	43	195
	314	43	49	57	68	217
	315	129	114	107	139	489
	316	103	115	116	103	437
SC	317	56	46	42	44	188
	318	13	32	40	34	119
	319	58	56	61	51	226
	320	41	64	43	60	208
	321	76	104	81	98	359
	322	113	115	105	128	461
	323	95	100	96	68	359
	324	69	85	89	59	302
SSE	325	83	88	46	52	269
	326	62	50	47	49	208
	327	51	50	33	43	177
	328	41	53	51	56	201
	329	27	26	23	27	103
	330	87	87	89	83	346
	331	150	159	138	152	599
	332	54	61	58	41	214

TABLE 9

Pre-CS (2-min) Data for L- Test
Experiment 4

Subjects	L Trial 1	L 2	L 3	L 4	L 5	L 6	Trials 1-6
Group I 401	15	14	21	18	11	18	97
402	17	18	8	24	16	10	93
403	16	12	13	13	11	13	78
404	44	29	38	41	16	34	202
405	23	15	19	18	15	16	106
406	11	10	12	15	18	14	80
407	22	12	20	22	13	11	100
408	8	1	14	25	20	19	87
Group E 409	50	16	27	41	30	13	177
410	28	8	8	15	9	6	74
411	27	7	5	14	10	6	69
412	21	21	9	20	9	5	85
413	43	11	29	37	22	16	158
414	25	12	21	16	22	14	110
415	18	10	10	14	14	13	79
416	53	13	9	22	17	16	130
Group C 417	26	23	18	23	15	24	129
418	31	22	20	29	24	22	148
419	18	10	13	9	13	10	73
420	11	17	13	17	13	21	92
421	26	21	15	14	12	10	98
422	16	12	12	10	13	14	77
423	20	22	11	14	16	10	93
424	21	25	25	21	26	30	148
Group S 425	9	13	23	22	13	8	88
426	23	15	13	15	18	12	96
427	18	15	8	8	12	6	67
428	17	15	18	25	15	13	103
429	36	23	26	18	18	13	134
430	21	32	25	30	24	12	144
431	16	25	23	30	28	26	148
432	82	67	71	69	96	16	401

TABLE 10

Pre-CS (2-min) Data for N- Test
Experiment 4

Subjects		N Trial 1	N 2	N 3	N 4	N 5	N 6	Trials 1-6
Group I	401	22	11	11	26	21	25	116
	402	17	19	19	18	15	14	102
	403	6	13	15	8	13	16	71
	404	23	26	46	12	40	47	194
	405	16	15	14	14	19	18	96
	406	14	10	8	17	21	12	82
	407	25	11	15	20	18	10	99
	408	12	0	14	26	13	22	87
Group E	409	27	24	29	38	60	35	213
	410	19	7	7	11	12	13	69
	411	16	12	15	15	29	21	108
	412	21	12	11	15	16	16	91
	413	33	11	48	31	46	30	199
	414	19	16	19	21	25	26	126
	415	6	10	7	17	17	15	72
	416	31	6	22	35	36	20	150
Group C	417	25	19	23	38	21	27	153
	418	28	25	23	30	27	26	159
	419	13	9	11	8	9	17	67
	420	20	14	12	20	13	15	94
	421	24	3	19	30	16	15	107
	422	12	14	19	6	10	14	75
	423	18	10	14	18	20	12	92
	424	34	19	18	39	19	32	161
Group S	425	18	10	7	42	24	20	121
	426	12	11	5	13	22	18	81
	427	10	9	3	17	14	7	60
	428	29	18	12	23	18	23	123
	429	19	20	11	29	45	33	157
	430	20	33	15	13	38	17	136
	431	36	26	16	39	33	30	180
	432	62	59	23	44	87	69	344

TABLE 11

Pre-CS (2-min) Data for NL- Test
Experiment 4

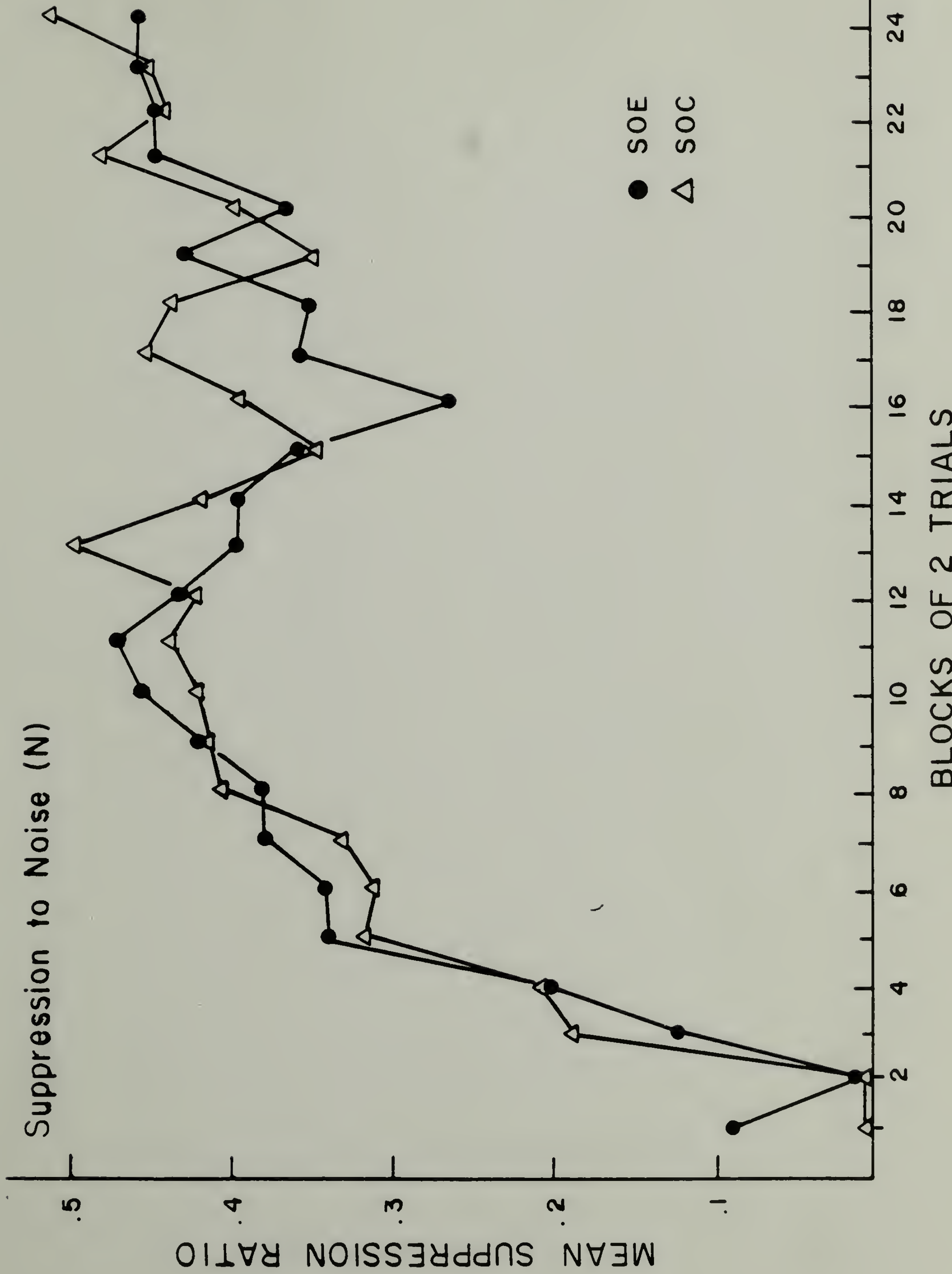
Subjects		NL Trial 1	NL 2	NL 3	NL 4	NL 5	NL 6	Trials 1-6
Group I	401	9	29	21	18	28	15	120
	402	13	17	13	17	22	8	90
	403	19	18	13	8	12	15	85
	404	32	48	57	20	44	46	247
	405	9	23	13	8	17	21	91
	406	8	13	11	12	16	10	70
	407	20	28	9	9	22	15	103
	408	9	7	29	24	24	15	108
Group E	409	28	40	34	28	41	45	216
	410	13	20	11	8	18	13	83
	411	11	18	15	18	11	26	99
	412	21	30	14	14	22	16	117
	413	24	27	34	26	35	47	193
	414	14	22	23	15	19	24	117
	415	15	17	14	11	28	14	99
	416	21	27	15	26	27	36	152
Group C	417	15	24	34	13	31	24	141
	418	13	30	30	25	26	41	165
	419	9	21	17	12	17	11	87
	420	10	22	22	12	18	24	108
	421	10	15	24	9	20	14	92
	422	7	11	16	16	17	20	87
	423	12	18	14	9	23	19	95
	424	11	24	36	19	27	22	139
Group S	425	12	17	18	20	8	19	94
	426	17	15	15	9	23	11	90
	427	7	9	11	11	5	16	59
	428	16	20	35	18	24	24	137
	429	15	43	38	18	25	22	161
	430	26	27	37	5	12	34	141
	431	19	33	35	18	31	39	175
	432	25	8	76	55	75	23	262

TABLE 12

Pre-CS (2-min) Data for NT- Test
Experiment 4

Subjects		NT Trial 1	NT 2	NT 3	NT 4	NT 5	NT 6	Trials 1-6
Group I	401	15	11	14	10	7	11	68
	402	15	5	22	12	16	10	80
	403	13	13	12	17	8	13	76
	404	37	41	44	37	20	18	197
	405	21	23	16	12	13	21	106
	406	8	12	13	8	13	9	63
	407	12	19	23	9	14	7	84
	408	8	3	3	15	12	11	52
Group E	409	27	37	40	34	27	19	184
	410	13	12	11	5	4	12	57
	411	13	20	14	16	10	7	80
	412	14	30	30	12	7	11	104
	413	30	37	46	28	12	27	180
	414	17	24	25	10	14	19	109
	415	12	6	12	12	17	11	70
	416	31	38	29	21	19	28	166
Group C	417	13	32	28	19	14	13	119
	418	22	27	28	15	23	11	126
	419	11	20	14	7	13	9	74
	420	16	22	9	19	13	9	88
	421	24	33	20	26	17	7	127
	422	10	17	15	8	6	12	68
	423	22	23	13	15	16	19	108
	424	17	35	31	22	15	18	138
Group S	425	17	16	24	13	13	8	91
	426	15	7	18	10	11	13	74
	427	14	12	10	10	9	6	61
	428	13	12	27	15	21	21	109
	429	27	41	36	24	12	12	152
	430	29	31	33	7	24	26	150
	431	29	31	21	22	17	14	134
	432	83	76	50	45	14	24	292

Fig. 1. Suppression of bar-pressing during presentations of the noise (N) during differentiation training.



Suppression to Noise (N)
MEAN SUPPRESSION RATIO
.1
.2
.3
.4
.5
BLOCKS OF 2 TRIALS
2
4
6
8
10
12
14
16
18
20
22
24
SOE
SOC

Fig. 2. The suppression of bar-pressing to stimuli receiving second-order conditioning and extinction respectively. In the element pretraining stage (left panel) Group SOE received paired presentations of noise (N) and the second-order reinforcer, tone (T). Group SOC received explicitly unpaired presentations of N and T. During compound conditioning (middle panel) both groups received a Noise + light (NL) compound followed by T. During the Extinction test (right panel) both groups received presentations of L alone in order to determine if the presence of the pretrained N, would interfere with conditioning to L relative to the conditioning that is achieved when N is not pretrained.

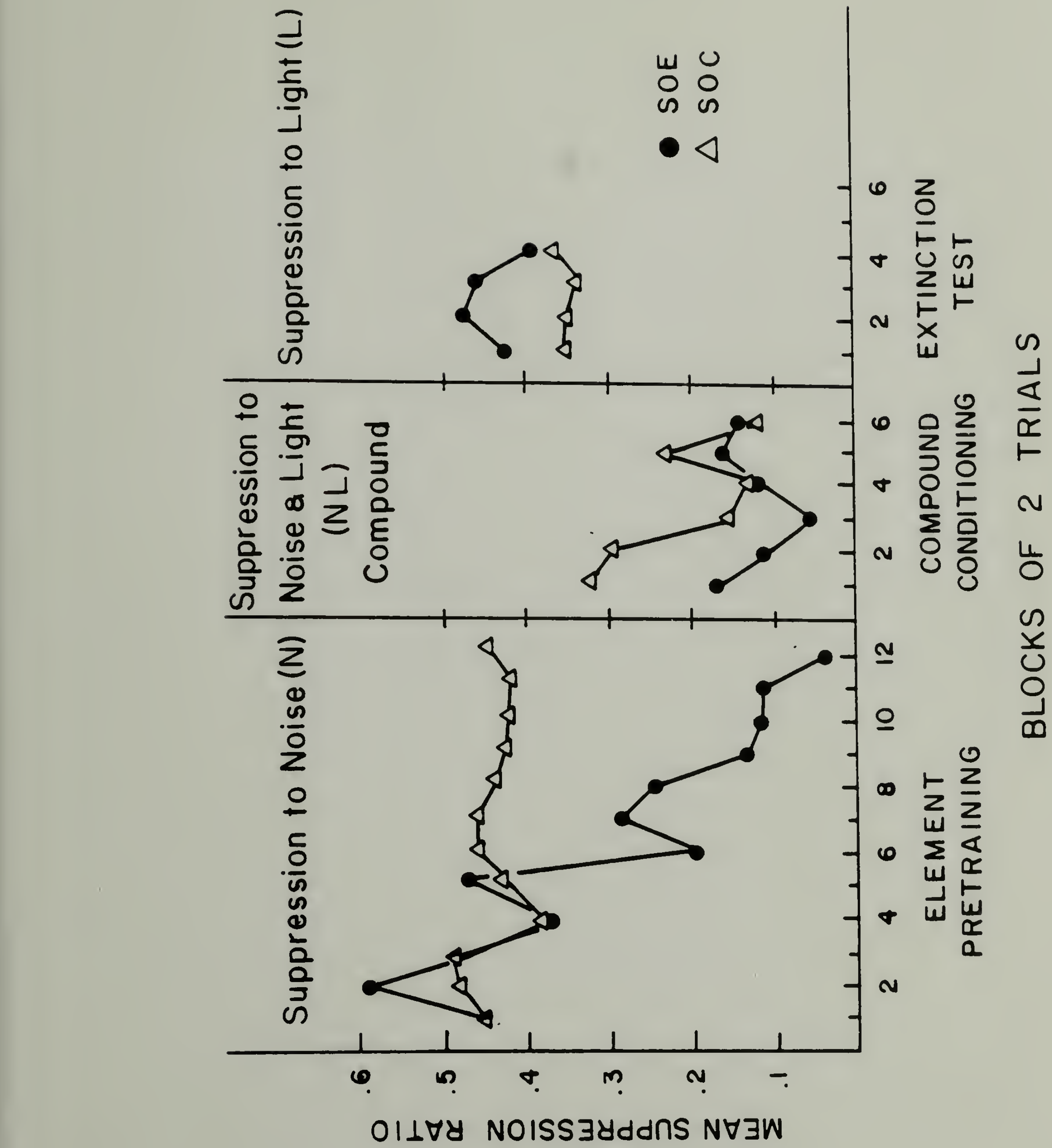

Suppression to Noise (N)
Suppression to Noise & Light (NL) Compound
Suppression to Light (L)
● SOE
△ SOC
MEAN SUPPRESSION RATIO
.6
.5
.4
.3
.2
.1
2
4
6
8
10
12
2
4
6
2
4
6
ELEMENT PRETRAINING
COMPOUND CONDITIONING
EXTINCTION TEST
BLOCKS OF 2 TRIALS

Fig. 3. Suppression of bar-pressing during presentations of the noise (N) element for Group FOE and C and during presentations of the noise + tone (NT) compound for Group FOI.

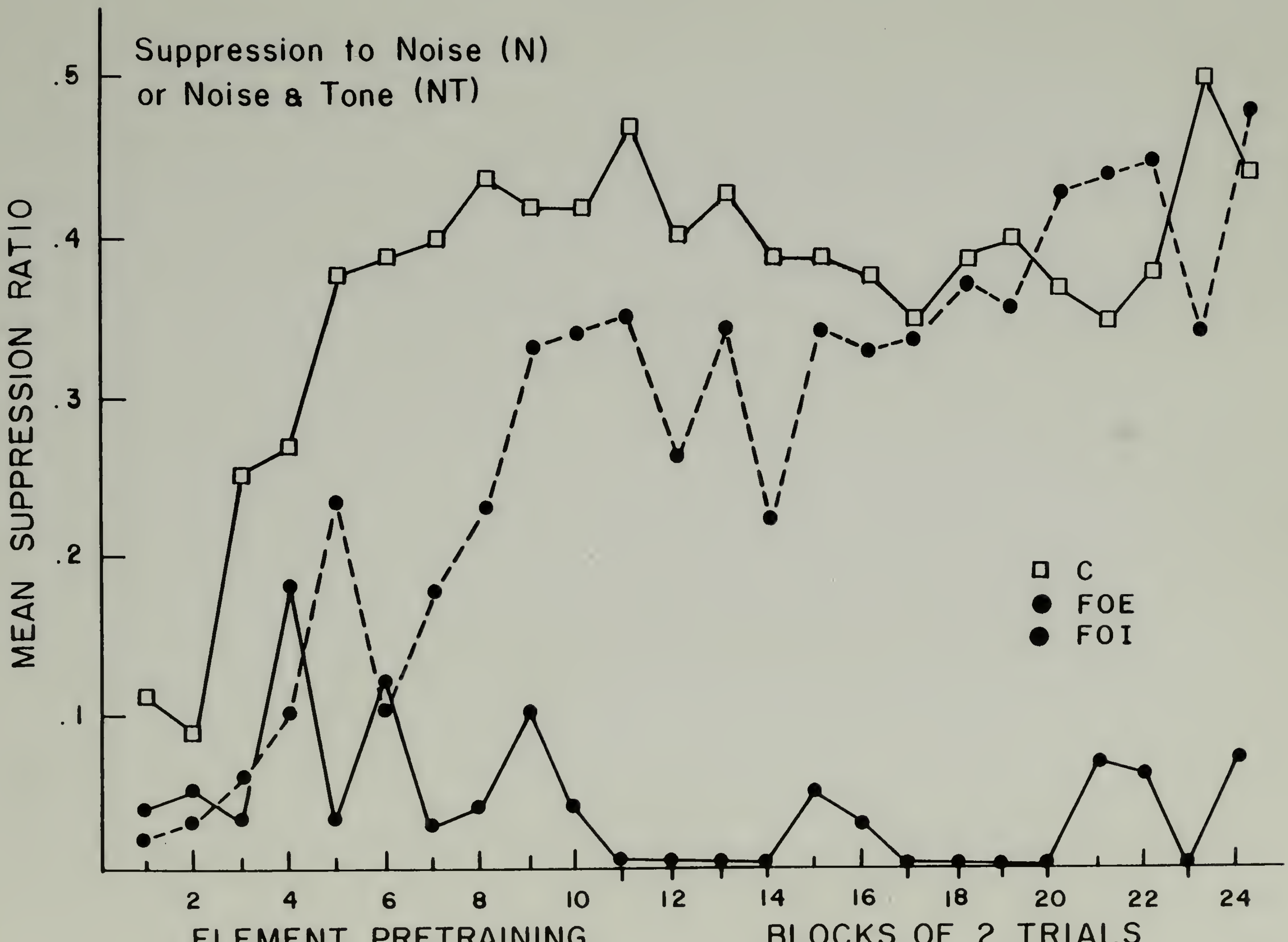

Suppression to Noise (N)
or Noise & Tone (NT)
MEAN SUPPRESSION RATIO
.5
.4
.3
.2
.1
C
FOE
FOI
2
4
6
8
10
12
14
16
18
20
22
24
ELEMENT PRETRAINING
BLOCKS OF 2 TRIALS

Fig. 4. The suppression of bar-pressing to a noise + light (NL) compound during second-order conditioning (left panel). In the compound conditioning stage all rats received the NL compound followed by the second-order reinforcer, tone (T). The right panel depicts the suppression of bar pressing to L during extinction. During the extinction test stage all rats received presentations of L superimposed on VI-supported bar-press baseline.

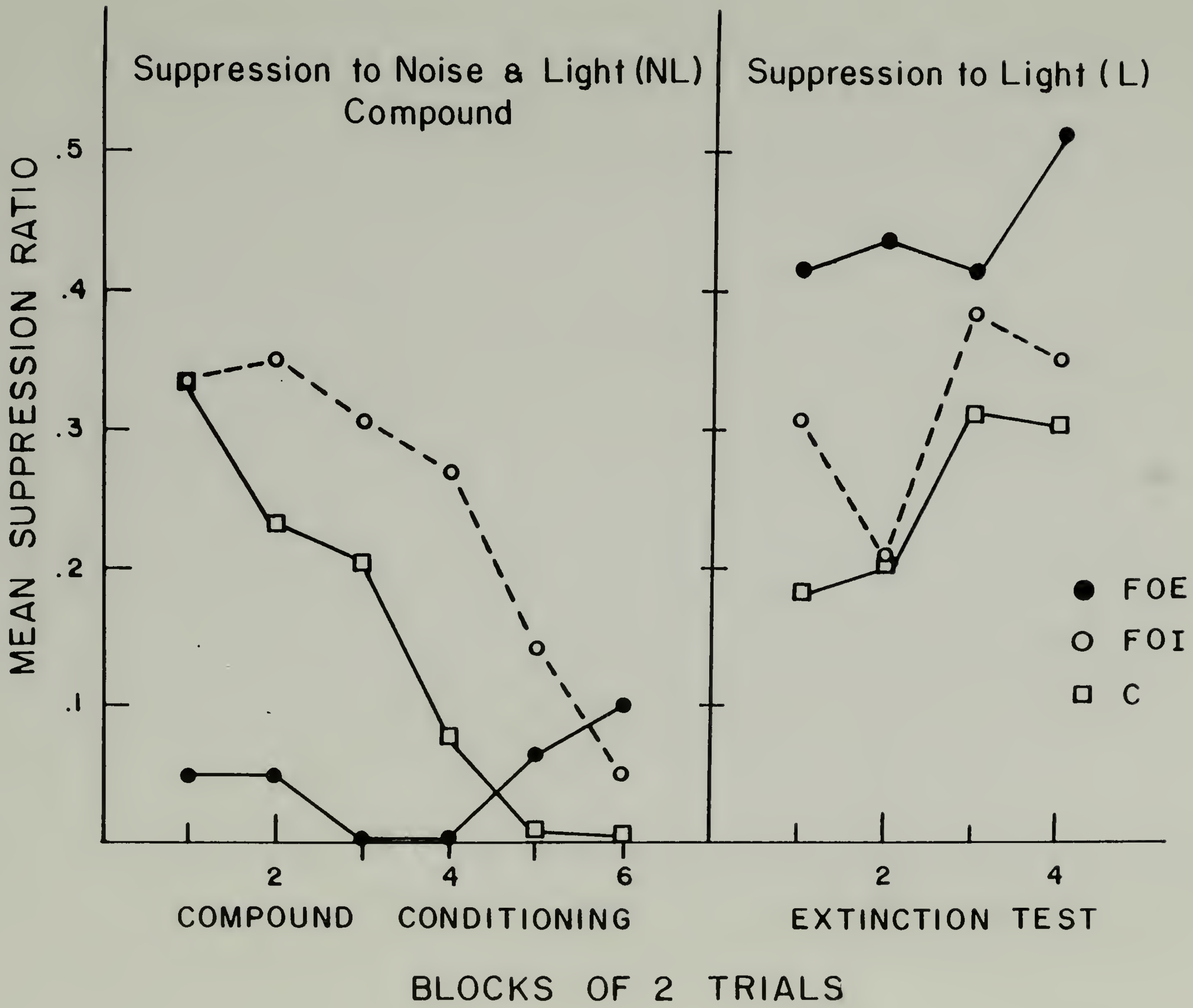

Suppression to Noise & Light (NL) Compound
Suppression to Light (L)
MEAN SUPPRESSION RATIO
.5
.4
.3
.2
.1
2
4
6
COMPOUND CONDITIONING
2
4
EXTINCTION TEST
BLOCKS OF 2 TRIALS
FOE
FOI
C

Fig. 5. The suppression of bar-pressing to a noise (N) during second-order conditioning is presented in the left panel. In the element pretraining stage rats in Group SFE and SSE received N followed by the (tone) second-order reinforcer (T). Rats in Groups FC and SC received explicitly unpaired presentations of N + T. The middle panel depicts suppression to the noise + light (NL) compound. During compound conditioning all rats were given an NL compound followed by reinforcement. Rats in Group FC and SFE received a weak shock as the reinforcement while rats in Groups SSE and SC received T as the reinforcement (second-order reinforcer). The right panel depicts suppression of bar-pressing to L during an extinction test. During the extinction test stage all rats received presentations of L alone.

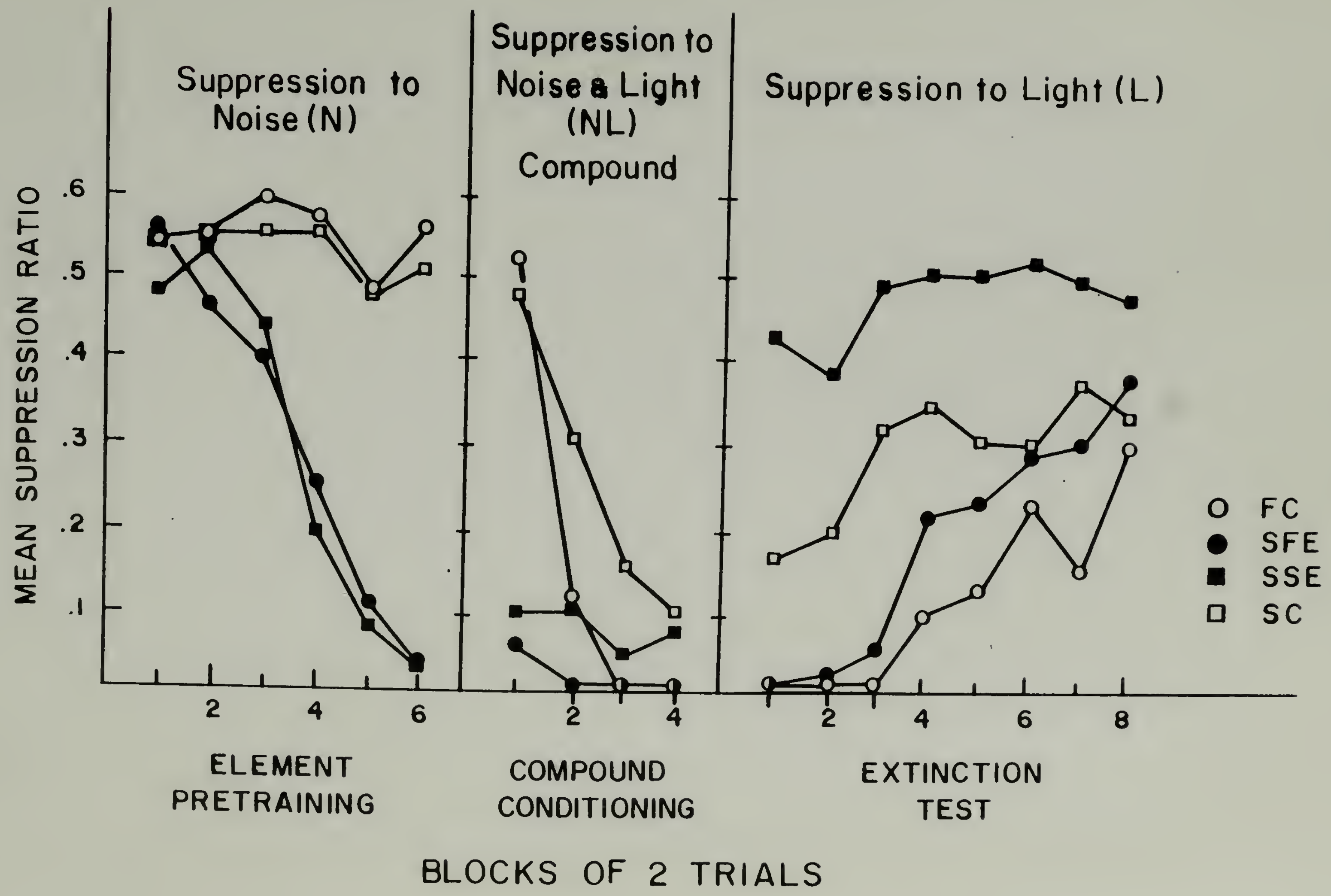

Suppression to Noise (N)
Suppression to Noise & Light (NL) Compound
Suppression to Light (L)
MEAN SUPPRESSION RATIO
.6
.5
.4
.3
.2
.1
2
4
6
2
4
2
4
6
8
ELEMENT PRETRAINING
COMPOUND CONDITIONING
EXTINCTION TEST
BLOCKS OF 2 TRIALS
FC
SFE
SSE
SC

Fig. 6. Suppression of bar-pressing during the conditioning stage (left panel) and during the second-order conditioning stage (right panel). During the conditioning stage Group I received first-order inhibitory conditioning to a tone + noise (TN) compound. Group E received first-order excitatory conditioning to the noise (N), Group C received N alone and Group S received second-order excitatory conditioning to N. During the second-order conditioning stage all groups received the light (L) followed by tone (T).

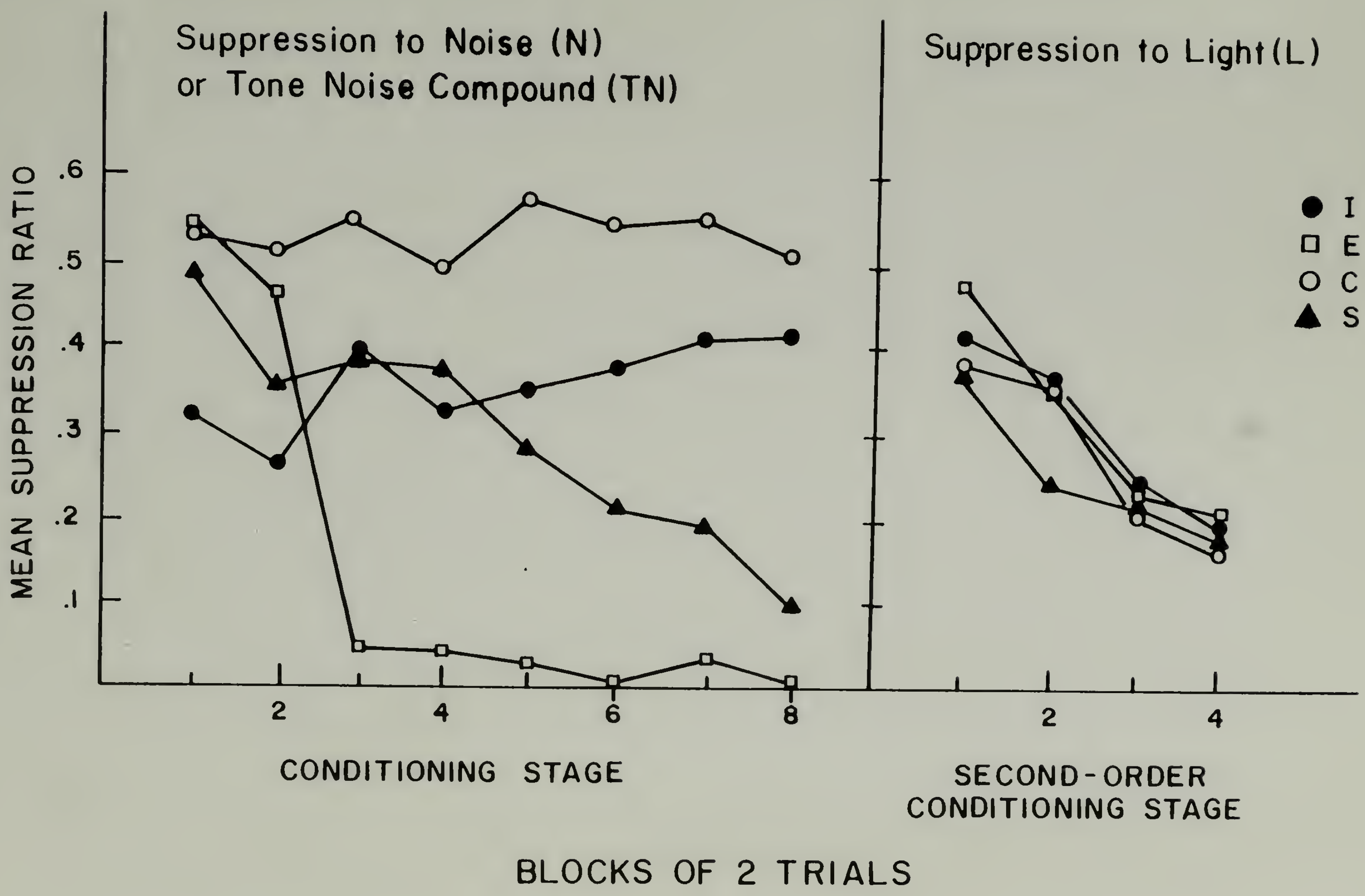
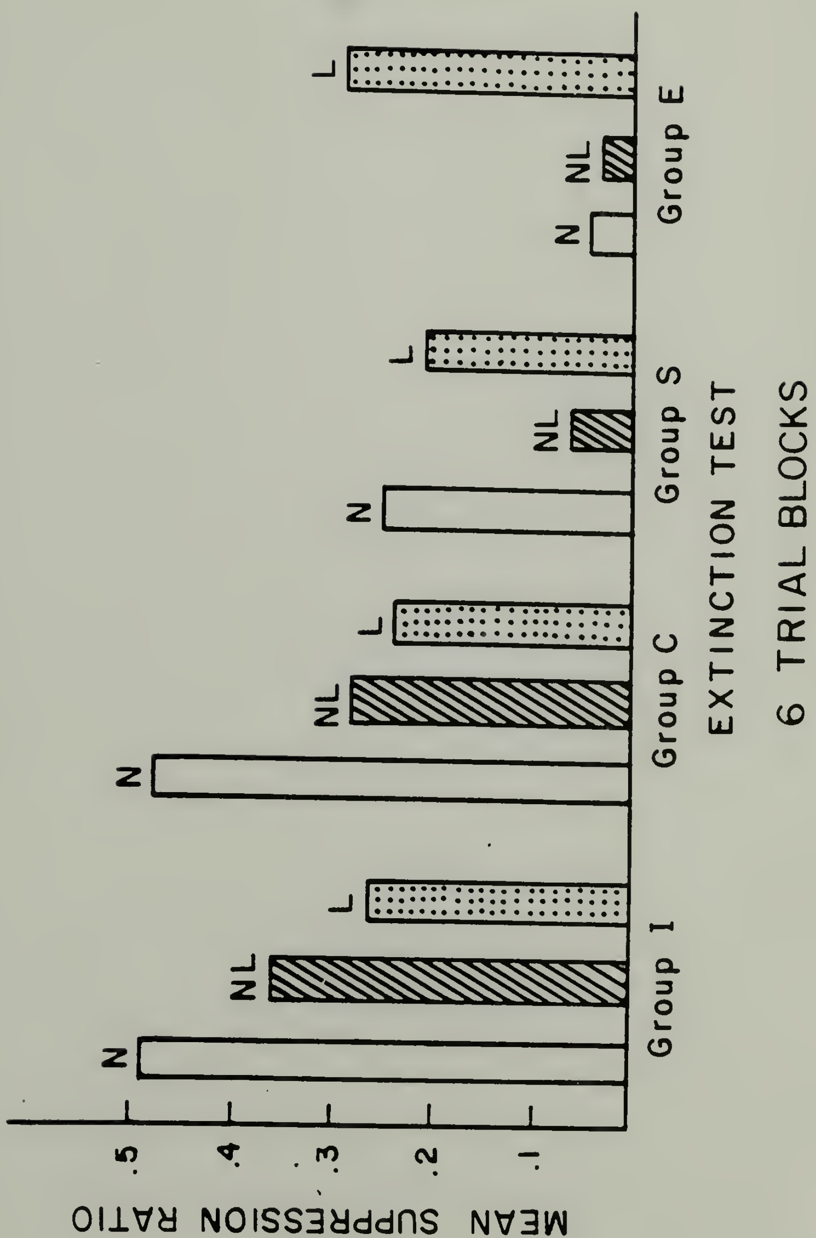

Suppression to Noise (N)
or Tone Noise Compound (TN)
Suppression to Light (L)
MEAN SUPPRESSION RATIO
.6
.5
.4
.3
.2
.1
I
E
C
S
2
4
6
8
CONDITIONING STAGE
2
4
SECOND-ORDER
CONDITIONING STAGE
BLOCKS OF 2 TRIALS

Fig. 7. Suppression of bar-pressing to the noise (N), noise + light compound (NL) and the light (L) during extinction tests.


MEAN SUPPRESSION RATIO
.5
.4
.3
.2
.1
N
NL
L
Group I
Group C
Group S
Group E
EXTINCTION TEST
6 TRIAL BLOCKS