MOTIVATIONAL INTERACTIONS IN PAVLOVIAN TRANSFER

MOTIVATIONAL INTERACTIONS: THE ROLE OF INHIBITION IN PAVLOVIAN AVERSIVE TO APPETITIVE TRANSFER

BY

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ABSTRACT

The nature of motivational interactions between appetitive and aversive response systems was assessed in four Pavlovian transfer studies where the two conditional responses are peripherally independent. The theory of reciprocal inhibition postulates that excitatory aversive conditioning would inhibit appetitive conditioning. Furthermore, inhibitory aversive conditioning would enhance appetitive conditioning. According to recent formulations of reciprocal inhibition, several transfer effects are predicted on the basis of results found within a single motivational system. Some of these were tested here for Pavlovian motivational transfer.

In each transfer study, four aversive pretraining conditions were used. Excitatory aversive conditioning was conducted by forward pairings of the tone CS with shock. Inhibitory aversive pretraining was conducted by backward pairings, where the shock preceded the tone. In addition, two control conditions were included: a random control, where the tone CS and shock were presented in an uncorrelated manner; and a naive control condition, where no tones or shocks were presented. THe four transfer studies differed only in their treatment in the transfer phase.

Experiment 1 transferred aversive pretraining onto an aversive conditional inhibition discrimination to the pretrained tone. This transfer design is sensitive to inhibitory pretraining and was used to demonstrate clearly that backward pretraining effectively produces an inhibitory aversive CS and that random pretraining does not. The

results showed that backward pretraining with the shock and tone enhanced the acquisition of a conditional inhibition discrimination to the backward tone CS. Random pretraining, on the other hand, interferred with the acquisition of conditional inhibition to the random tone CS.

Experimental 2 transferred aversive pretraining onto the simple acquisition of appetitive responding to the tone CS. Excitatory aversive pretraining profoundly retarded acquisition to the tone CS. Inhibitory aversive pretraining enhanced appetitive responding to the tone CS compared to the naive control condition, but not compared to the random control condition which also showed enhanced acquisition compared to the naive control condition. With the exception of performance in the random control condition, Experiment 2 confirmed the predictions of reciprocal inhibition.

Experimental 3 transferred aversive pretraining onto the acquisition of an appetitive conditional inhibition discrimination to the tone CS. The excitatory aversive tone suppressed appetitive responding from the outset of discrimination training. Although the inhibitory aversive and random control conditions enhanced responding on negative trials initially, this enhancement was short-lived compared to the naive control condition. The results of Experiment 3 confirmed the inhibitory nature of excitatory aversive transfer to the appetitive system, but are inconclusive with respect to the predicted facilitative nature of inhibitory aversive transfer for the appetitive system.

Experiment 4 transferred aversive pretraining onto compound appetitive conditioning. Excitatory aversive pretraining suppressed

responding during compound acquisition, but showed enhanced responding to the previously neutral light CS ("superconditioning") compared to naive control condition which received appetitive conditioning to the light alone. Inhibitory aversive pretraining enhanced responding during compound conditioning compared to the naive control conditions but not more than the random control condition. Both the inhibitory aversive and random control conditions responded more to the light CS than the naive control condition, but were not different from the naive control condition which received light alone acquisition. This apparent reduction in overshadowing is inconsistent with the predictions of reciprocal inhibition for inhibitory aversive transfer.

Taken together, the results suggest that aversive excitation is inhibitory, but aversive inhibition is not facilitative, for the appetitive conditioning system. A model is proposed which incorporates this asymmetry in motivational interactions. In addition, analysis of control group performance suggests that greater attention be paid to contextual conditioning and pseudoconditioning in assessing motivational interactions.

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CHAPTER 1: Introduction

1.1 Motivation and Learning

When an animal senses danger, its behaviour immediately changes from whatever activity it is engaged in to a radically different behaviour, such as fleeing or attack. Similarly, an animal who goes without water or food will gradually shift its activities increasingly to a diversified class of water or food seeking behaviours which share the common goal of reducing thirst or hunger respectively. A somewhat different case occurs when an animal enters a state of sexual readiness. Here the hormonal state and the presence of a potential mate occasions the tendency to engage in mating or courtship behaviours for reproductive purposes. In sexual behaviours, as in defensive or water and food seeking behaviours, the prevalent condition of the animal controls the likelihood of a range of related activities. Each of these conditions describe an important facet of animal behaviour: motivational states arising from specific internal or external antecedant conditions play a crucial role in selecting the tendencies revealed in an animal's behaviour.

Motivation as used here refers to the presence of an inferred condition in the central nervous system which controls specific behavioural tendencies and occurs under definite and observable antecedent conditions. Sometimes a motivational state may be inferred by the presence of certain defining behavioural characteristics or physiological indices, but often such central mediation may not be

directly or uniquely observable. Nevertheless, motivational mediators are assumed to be linked directly to certain antecedent conditions. For example, water motivation is potentiated by thirst activation and is operationally tied to the independent variable of the amount of water deprivation (e.g. hours since last drink or total water consumption/ day). In contrast, fear motivation may be tied primarily to the actual occurrence of a dangerous, painful or novel event. Despite this difference in antecedent conditions, both water and the fear producing event are treated as activating underlying motivational states because they select certain behavioural tendencies. These motivational states are defined by the operations that produce them and are important as mediators in theoretical discussions of animal learning (see Mackintosh, 1974; pp. 81-84, for a discussion). Ethologists use a similar concept of motivational control systems as mediators in describing animal behaviour (see, for example, McFarland, 1976). Since Thorndike (1911) introduced the law of effect, motivational variables have been studied extensively in the history of research on behavioural changes resulting from learning. Motivation has been given prominent consideration in the study of how learning may control animal behaviour because empirically much learned behaviour is tied directly to motivational variables such as the presence of danger or pain, water or food deprivation, or sexual readiness.

Traditional learning theorists refer to the acquisition of behaviour or behavioural tendencies as a result of a contingency between the occurrence of two events. Following the lead of Skinner (1938), the procedures used to modify behaviour can be classified into two

categories: a contingency between a response emitted by the animal (an operant response) and a reinforcing stimulus (one which results in a change in the probability of the response) is called operant or instrumental conditioning; whereas, a contingency between a stimulus presented to the animal (a conditional stimulus, CS) and an unconditional stimulus (one which elicits a response without specific training, US) is called Pavlovian (after Pavlov, 1927), or respondent, conditioning. In operant conditioning, learning is indicated by a change in the frequency or probability of the operant response. In Pavlovian conditioning, learning is indicated by the CS eliciting a new response, called the conditional response (CR). One way motivational variables are known to influence the effectiveness of learning in both operant and Pavlovian conditioning is by acting through the reinforcing stimuli or USs respectively (see for example, Mackintosh, 1974).

In addition to direct motivational effects of reinforcers or USs, a number of theorists have suggested that during Pavlovian training a central motivational state, corresponding to the US, is conditioned as a preparatory response to the CS (Estes & Skinner, 1941; Konorski, 1967; Mowrer, 1960; Rescorla & Solomon, 1967). This conditioning can be described as emotional or affective conditioning, and is invoked theoretically as a central mediator for classically conditioned behaviour controlled by stimuli associated with motivational events. Although these conditional central motivational states may not be directly observable, they may be inferred either by their influence on other learned behaviours or by the presence of discrete peripheral indicants (Rescorla & Solomon, 1967). That is, they are inferred just

as unconditional motivational states are inferred, by their control of certain behavioural tendencies.

Konorski (1967) argued that one important indicator of conditional motivation is the presence of a discrete measurable CR. He proposed that CRs could be divided into two classes: preparatory and consummatory. Preparatory CRs are proposed as a diffuse, non-directed class of response tendencies which can be viewed an indication of direct conditioning of the motivational state activated by the US. Most direct measures of preparatory CRs as indices of motivational activities would be subjected to problems of response interactions with the context of conditioning: for example, the available response opportunities. Consummatory CRs, on the other hand, are specific responses directed at interacting with the US and are often easily and reliably measured. Moreover, according to Konorski's distinction, consummatory CRs are based on the presence of a conditional motivational state (i.e. preparatory CR). Consummatory conditioning, consequently, serves as an easily located and measurable index of conditional motivational mediators.

Konorski's (1967) analysis of consummatory conditioning as a reliable indicator of conditional motivational activation reveals an obvious method for the study of motivational interactions. Essentially, this approach would suggest monitering the transfer of consummatory conditioning from one motivational system to another (e.g. Konorski & Swejkowska, 1956). Motivational interactions would be expected whenever two central mediational states are activated together. Since the level of activation of the underlying motivational state is reflected in the

level of consummatory responding, transfer of conditioning across motivational systems would provide both the basis for simultaneous activation of two motivational states and an easily measured index of the effects of interactions. The method of the present thesis is to use transfer of training from conditioning based on an aversive US (electric shock) to various forms of consummatory conditioning with an appetitive US (water).

The application of transfer of training techniques, in addition to providing a direct method for studying motivational interactions, allows comparison with empirical findings and theoretical models which have been developed within a single motivational system. The purpose of the work described here is to test the predictions of theories of motivational interactions by using the same transfer training methods which have been used to test similar predictions within a single motivational system. In particular, interactions between fear-induced (aversive) motivational states and water-induced (appetitive) motivational states have often been characterized as inhibitory (see 1.4 Inhibition in Appetitive-Aversive Transfer, for a detailed discussion). Although much theoretical and empirical research has been done on the effects of inhibition on conditioning within a single motivational system, little rigorous research has been applied to assessing the nature of inhibition in motivational interactions. This thesis focuses on the role of inhibition in appetitive-aversive motivational interactions as revealed in the transfer of Pavlovian aversive to Pavlovian appetitive conditioning.

1.2 Appetitive and Aversive Events

It is important before discussing motivational interactions and learning to separate motivational events into two categories, appetitive and aversive events. Many of the events which can be effectively used to alter behaviour have a biological significance for the animal that depends on the animal's motivational condition. These events, which are effective reinforcers or USs, often serve to maintain natural biological functions (e.g. food, water, or a receptive sexual partner) and under the appropriate motivational condition will elicit consummatory behaviours such as eating, drinking, and mating. Alternatively, reinforcers may threaten the organism (e.g. painful or noxious stimulation) and elicit defensive behaviours such as withdrawal, rejection, and aggression. Here the motivator, fear, is induced by the stimulus itself. These observations suggest a basis for dividing reinforcing or unconditional stimuli into two classes according to their functional significance: events which elicit consumatory behavioral tendencies to preserve natural biological functions will be referred to as appetitive events, whereas events which elicit defensive or protective behavioral tendencies to prevent or lessen biological assaults will be referred to as aversive events (Konorski, 1967).

In practice, the definition of appetitive and aversive events by their motivational significance may seem arbitrary. An empirical definition is necessary. It is easy to assign the appetitive-aversive label to the events commonly used in psychological investigations, but how can such labels be applied to events with no apparent preservative or protective implications and, perhaps, no directly observable defining

behaviours. Intracranial electrical or chemical stimulation of various regions of the brain presents an example of this problem. When a particular site is first stimulated there may be no overt behavior elicited to allow classification into one of the two motivational classes. In fact, in an intuitive sense, consumatory or defensive behaviour towards a stimulus acting only in the CNS would be hard to understand. Not withstanding these difficulties, we may wish to characterize various forms of intracranial stimuli and other potential reinforcers, such as drugs, as appetitive or aversive events with the corresponding motivational attributes. Thorndike (1911) proposed that assessing the approach-avoidance tendencies to a stimulus event was an independent and empirical way of classifying the stimulus as a reward or punishment. Although the approach-avoidance dimension is obviously important for many stimulus events, it does not solve the problem of classifying internal stimuli. Another course to follow is to compare the reinforcing actions of unclassified events with the reinforcing actions of known appetitive and aversive events.

Perhaps the most consistent and defining characteristic of appetitive and aversive events, which are easily classified according to their biological implications, is found in their reinforcing effects on the establishment and maintenance of operant behaviour. Procedurally, operant behaviors are modified by the presentation of a reinforcer contingent on the occurrence of a designated response emitted by the animal. Generally, appetitive stimuli made contingent on the occurrence of an operant response will increase the probability of that response in the experimental situation, whereas aversive stimuli made contingent on

an operant response will decrease the probability of that response in the experimental situation. The former experimental outcome is called reward and the latter experimental outcome is called punishment. Because appetitive and aversive events have these polar opposite effects on contingent operant behaviours as a defining characteristic, the distinction between the two underlying motivational states has taken on a good-bad affective connotation. This good-bad hedonic dimension also reflected in the approach-avoidance tendencies suggested by Thorndike (1911).

In Pavlovian conditioning, where the occurrence of an US is contingent on the presentation of a CS and is programmed independently of the organism's responses, no distinction exists between the response strengthening properties of appetitve and aversive USs. Both appetitive and aversive USs will increase the probability of a CR to the CS previously paired with the US. Nevertheless, we may still refer to Pavlovian appetitive conditioning as reward conditioning and Pavlovian aversive conditioning as defense conditioning (Gormezano, 1972; Konorski, 1967). As indicated earlier, both appetitive and aversive consumatory conditioning are thought to be mediated by the presence of a conditional affective state which corresponds to the US used in conditioning. Thus, in appetitive-aversive transfer studies, the effects of motivational interactions are revealed by the influence of prior training with one US on the rate or level of acquisition of conditioning with the other US.

1.3 Appetitive-Aversive Transfer

A substantial literature has already accumulated addressing the question of appetitive-aversive transfer effects (see reviews by Rescorla & Solomon, 1967; Trapold & Overmier, 1972; Dickenson & Pearce, 1977). For the most part, however, these studies involve Pavlovian transfer onto the performance or acquisition of an operant task, and consequently introduce the additional complication of operant-Pavlovian interactions into the assessment of central motivational interactions. Although operant-Pavlovian interaction is an interesting and important issue in its own right, it renders the task of assigning transfer effects to central Pavlovian interactions very difficult. This is not to say that conclusions concerning the central mediation of these transfer effects should be discarded, but rather that alternative interpretations other than the interaction between appetitive and aversive classically conditioned states cannot be eliminated (Trapold and Overmier, 1972). As indicated in Section 1.1, studies directed toward assessing motivational interactions in explicit Pavlovian consummatory conditioning procedures simplify the inferences that can be drawn.

We investigated motivational interactions between appetitive and aversive affective systems using a modification of the rabbit eyelid closure and jaw movement conditioning preparations described by Gormezano (1972). There are several reasons for choosing these conditioning preparations. Although some differences in the rate of acquisition of the two response measures are present, the effective parameters for conditioning with the appetitive and the aversive USs,

water and shock, can be arranged to overlap considerably (Gormezano, 1972). As a result, the motivational significance of the USs can be isolated as the major difference between the two conditioning procedures.

In the aversive eyelid conditioning preparation, the US is a brief shock, delivered to one of the lower eyelids of the rabbit, which elicits an unconditioned closure of the shocked eyelid (as well as the corresponding nictitating membrane). A CS of short duration (e.g., a one sec tone) paired with the pariorbital shock will come to elicit an easily measured eyelid closure CR in anticipation of the US presentation. In the appetitive conditioning procedure, the US is a delivery of a pulse of water directly into the oral cavity of a water-deprived rabbit which elicits an unconditioned sinusoidal jaw movement response (chewing and/or swallowing). The pairing of the same one sec tone CS with the oral injection of water will result in a jaw movement CR to the CS prior to US delivery. That the same CS can be used to establish a different and discrete CR when paired with either the aversive US or the appetitive US is an important procedural advantage of using the jaw movement and eyelid conditioning preparations to assess cross-motivational transfer.

The obvious operational advantage of jaw movement and eyelid conditioning is the ease of measuring the respective CRs: both arrangements result in discrete skeletal movements as CRs when conditioning is complete. From a theoretical point of view, however, a more important outcome is derived. Since both CRs are consummatory, the level of responding can be used as an index of motivational activation.

Given that jaw movment and eyelid closure CRs represent similar consummatory conditioning situations which may be ideally suited to the study of Pavlovian transfer effects, any conclusions concerning central motivational interactions require additional justification. In particular, response interactions between the simultaneous occurrence of appetitive and aversive CRs could occur outside the central nervous system and must be reasonably eliminated as an explanation of the observed transfer effects. Such peripheral response interactions might be eliminated as a reasonable alternative by establishing preexperimentally that reflexive elicitation of one of the two measured responses does not influence elicitation of the other. Unfortunately, unconditioned response independence does not necessarily imply conditional response independence. Scavio (1974; 1975) provides a more rigorous alternative for jaw movement and nictitating membrane response classical conditioning transfer studies. Briefly, during transfer conditioning the conditional probabilities of the two responses were analyzed and assessed for response independence. The absence of a correlation between the two responses is taken as an indication that no peripheral response interaction is present. There are some conceptual difficulties associated with this approach since the motivational analysis does not require CR independence (see discussion of Experiment 2). Nevertheless, this technique may be a valuable tool for ruling out peripheral response interpretations of interactive effects and will be employed where applicable in the transfer studies reported here.

A second problem in justifying a central motivational interaction is the demonstration of a dependence of conditional

responding on motivational variables. The assumption of the foregoing discussion of appetitive-aversive transfer is that the Pavlovian conditioning procedures to be used provide measurable indicants of central motivational states. The evidence for this supposition is somewhat indirect but nevertheless adequate. Both eyelid and jaw movement conditioning respond systematically to manipulations which would be expected to affect the strength of a conditional motivational state. The rate of acquisition of eyelid conditioning varies directly as a function of US intensity (Spence, Haggard & Ross, 1958 and Trapold & Spence, 1960). Similarly, the magnitude of the water US in jaw movement conditioning influences directly the rate and asymptote of CR acquisition (Sheafor & Gormezano, 1972). Furthermore, alterations in water deprivation levels change the rate and asymptote of jaw movement conditioning directly as expected by a motivational analysis (Mitchell & Gormezano, 1970). The effects of motivational variables are consistent with interpretations of classical jaw movement and eyelid conditional responding as controlled, in part, by the activation of central motivational mediators. Central interactions between motivational states activated by appetitive and aversive stimuli in transfer studies should be observable in the acquisition of eyelid closure and jaw movement conditional responding.

1.4 Inhibition in Appetitive-Aversive Transfer

Motivational interactions between appetitive and aversive stimuli have frequently been characterized as inhibitory (Rescorla & Solomon, 1967; Konorski, 1967; Stein, 1964). Before discussing the

nature of these inhibitory interactions, it will be helpful to clarify the meaning of inhibition implied in these theories and to contrast its general meaning with the more specific term, conditional inhibition. Up to this point conditioning has meant excitatory conditioning whereby a CS is established as a signal for a US and come to elicit a CR. In contrast Pavlovian conditional, inhibition is a process that reduces or diminishes the strength of conditional responding which is established by the contingency between a CS and a US. Rescorla (1969a) refers to inhibition as a response tendency opposite to that of the CR. An antagonistic response tendency need not be observed directly, but rather such inhibition is determined by the conditional response suppression observed when inhibition is active.

In order to conclude that a stimulus produces inhibition as an opposite response tendency, at least one alternative explanation of conditional response suppression must be discarded. The stimulus could reduce the strength of the CR by simply distracting the animal. Pavlov (1927) referred to the ability of a strong or novel stimulus to depress the level of conditional responding as a special kind of inhibition, called external inhibition. External inhibition by distraction, however, is not a specific response tendency antagonistic to the CR. Consequently, another test of the inhibitory properties of a stimulus is required to rule out this alternative.

An inhibitory stimulus with an antagonistic response tendency would be expected to acquire an excitatory CR only after lengthy training. In contrast, a strong distracting stimulus would be expected to be very salient and acquire an excitatory CR very rapidly.

Consequently, a retardation of CR acquisition test has been adopted as a necessary criteria for demonstrating that a stimulus has inhibitory properties (Rescorla, 1969a; Hearst, 1972). In this test, the putative inhibitory stimulus is compared against other stimuli for its ability to acquire a CR. A positive (inhibitory) result is the reduced rate of CR acquisition. Retarded response acquisition alone, however, does not replace the suppression of excitatory CRs as a criteria for inhibitory properties. Non-inhibitory phenomena are capable of reducing the ability of a stimulus to elicit a CR acquired by Pavlovian conditioning (see Mackintosh, 1975). Some form of summation test whereby the inhibitory stimulus is presented in compound with a CS that elicits a CR is also necessary to demonstrate active response suppression. Here an inhibitory stimulus would be expected to reduce the ability of another CS to elicit a CR. Positive results (i.e. consistent with inhibition) on both of these tests are generally regarded as necessary and sufficient criteria for claiming that a stimulus has inhibitory properties (Rescorla, 1971a, Hearst, 1972).

In the studies that follow, inhibition is used in two contexts. Conditional inhibition will refer to the result of a specific class of procedures which produce (or may produce) an inhibitory stimulus by virtue of a negative relationship with the US used to establish excitatory conditioning. For example, a tone stimulus that procedurally predicts the omission of an expected shock may become inhibitory for conditional responding established to a light that predicts (is paired with) the shock. Inhibition will also be used here more generally to refer to the outcome of any procedure that produces a response tendency

antagonistic to conditional responding established by a US. It is important to note that a conditional inhibitor for CRs established with one US will not necessarily be inhibitory with respect to the CRs established with another US. In fact, theories of inhibitory motivational interactions predict a conditional inhibitor for the US of one motivational state should be excitatory for the US of the alternative, opposing, motivational state (see discussion of reciprocal inhibition, Section 1.5).

Assessing empirically the role of conditional inhibition in theories of motivational interactions is one primary objective of the present thesis. The prediction that a conditional inhibitor will affect motivational interactions depends partly on the assumption that an inhibitory stimulus is a motivationally significant stimulus. Since no direct response is often associated with the presence of conditional inhibition, the motivational properties of inhibition must be inferred less directly than in the case of excitation where the presence of a consummatory response may be taken as indicating the activation of the US-associated motivational state.

Demonstrating motivational significance for an inhibitory stimulus is a two part process. First, the stimulus must prove positive results on both the summation and retardation of acquisition tests for inhibition. Second, once confirmation of an inhibitory condition is obtained, the additional assumption of opposite motivational significance also requires justification. The assumption that an inhibitory stimulus has a motivational significance opposite to that of an excitatory stimulus can be argued from an approach-avoidance

distinction between appetitve and aversive states and on the operant effects of these stimuli presented contingently on the animal's behaviour (pp. 6-7). Generally, when an established inhibitory stimulus is tested for approach-avoidance properties, the tendency is to behave opposite to the behaviour supported by an excitatory stimulus. Thus, organisms will avoid a signal for an impending aversive event and approach a signal for the absence of that event. Similarly, organisms will approach a signal for an impending appetitive event and avoid a signal for the absense of that event (Wasserman, Franklin & Hearst, 1974; Hearst & Franklin, 1977).

Unfortunately it must be noted that this phenomenon has an alternative interpretation. Tests for inhibitory approach-avoidance tendencies are uniformly conducted in the presence of an excitatory background: that is, in an environment, such as an experimental apparatus, which signals that the US may be delivered. Consequently, inhibition may act simply by reducing the excitatory context in the vicinity of the stimulus. Approach to an inhibitory aversive CS may be nothing more than avoidance of the aversive background. Avoidance of an inhibitory appetitive CS may be approach towards a more excitatory background. From an operational point of view, however, the operant effects of inhibitory stimuli are also opposite to those of their respective excitation. Since this criterion seems to be a defining characteristic of the affective state, the opposite approach-avoidance tendencies toward excitatory and inhibitory CSs appear to provide initial support for the claim that opposite motivational states are activated by excitatory and inhibitory stimuli.

1.5 Theoretical Basis of Appetitive-Aversive Transfer Studies

Although transfer studies have almost limitless potential variations, the basic procedure is easily described as a two phase experiment. During the initial or preconditioning phase, animals are given some form of experience with a CS or CSs and/or either the appetitive or aversive US. For example, we might initially train different groups with CS and US presentations designed to produce conditional excitation, conditional inhibition, or control effects. During the second phase a US from the motivational system not pretrained is used to asses the transfer of the pretraining experience from one system to the other. Probably the simplest form of transfer testing is to present the preconditioned CS paired with the new US in a manner known to produce reliable conditional response acquisition with an associatively neutral stimulus. The exact form of the transfer test allows extensive variation with a little imagination, but in practice the type of transfer test is determined by predictions made from an underlying theoretical framework. The theoretical assumptions generating the present series of studies are based on the notion of reciprocal inhibition of motivational interactions (Konorski, 1967) combined with another current theory of Pavlovian conditioning, the Rescorla-Wagner model (Rescorla & Wagner, 1972; Wagner & Rescorla, 1972; see Fowler, 1978).

This model of appetitive-aversive interactions, which combines Konorski's notion of reciprocal inhibition with the Rescorla-Wagner model, begins by postulating the existence of two affective motivational states, reward (appetitive) and punishment (aversive), with

strong reciprocal inhibition (Konorski, 1967; Stein, 1964). Activation of one system diminishes or compete with activation of the other. Further, the reciprocal nature of the model postulates that the conditions which produce conditional inhibition would also activate the alternative affective state (Fowler, 1978). For example, an aversive conditional inhibitor would produce a conditional activation of the reward system which effectively competes with the punishment system. Similarly, an appetitive conditional inhibitor would produce a conditional activation of the punishment system. Thus, it would be expected that an explicit conditional inhibitory stimulus for one reinforcer would be functionally equivalent in its motivational properties to a conditional excitatory stimulus established with a reinforcer from the other affective system. Fowler and his colleagues (see Fowler, 1978) have proposed just such an account for some of the motivational transfer effects they have found in operant tasks.

Several predictions follow directly from an analysis based on the premise of motivational equivalence of conditional excitation and inhibition of the opposite motivational state. An excitatory CS should behave like an inhibitory CS for conditional responding established by pairings with a US from the alternative motivational system. For example, according to the widely accepted criteria for demonstrating an inhibitory stimulus (Rescorla, 1971; Hearst, 1972), an excitatory aversive CS should demonstrate both a retardation of reward conditioning and a decrease in conditioned responding on a summation test with an excitatory appetitive CS. Further, without going into the details here, several other predictions concerning the effects of inhibition based on

the Rescorla-Wagner model should also prove true. These would include the expectations that 1) an excitatory aversive CS would enhance the development of appetitive inhibition to the CS (cf Rescorla, 1971a) and 2) appetitive acquisition to a novel stimulus reinforced in compound with an aversive excitatory pretrained stimulus would occur more rapidly than if the novel stimulus were reinforced alone (superconditioning, Wagner & Rescorla, 1972).

Another set of predictions arises from studies transfering an inhibitory stimulus trained with the US from one motivational system to conditioning supported by the other motivational system. Since our theoretical formulation claims a functional equivalence of inhibition in one system and motivational activation of the other, these transfer tasks should reveal positive or facilitative effects. Thus, preconditioning inhibitory training with a US from the opposite motivational system of the to be conditioned response would be expected to 1) facilitate acquisition to the preconditioned CS, 2) reduce acquisition to a stimulus reinforced in compound with the preconditioned stimulus (blocking, Kamin, 1969), and 3) retard the acquisition of explicit conditional inhibition to the preconditioned stimulus.

These predictions are based on a straightforward adaptation of the Rescorla-Wagner model for the acquisition of associative strength, V. In the Rescorla-Wagner model the rate of acquisition to any CS-US pairing is given by Equation 1:

$$\Delta V_A = \theta(\lambda - V_T) \qquad (1)$$

where ΔV_A is the change in associative strength to CS_A; θ is a rate parameter determined by both the specific conditional stimulus, CS_A and the specific US; λ is the assymptotic level of associative strength supported by the particular US; and V_T is the total associative strength of all stimuli present during the CS_A-US trial. V_T is calculated by a simple summation of all individual V values; i.e., $\sum_{i \epsilon S} V_i$. In addition to specifying the change in associative strength, a simple response rule is assumed: the strength of the CR is monotonically and directly determined by the value of V_T. Although the model does not have a precise rule for response mapping, the simple monotonic relationship to CR measurement does provide testable comparative predictions.

The model is a form of the linear-operator-model (Bush & Mosteller, 1955). Rescorla-Wagner's major advance is in the assertion that the discrepancy between a US determined asymptote, λ, and total associative strength, V_T, is an important variable for predicting acquisition in the presence of stimuli with associative strength. For example, the model accurately predicts the low level of acquisition to a stimulus reinforced in compound with a previously reinforced stimulus -- the phenomenon of "blocking" (Kamin, 1969). The previously reinforced, CS_B, already predicts US delivery (i.e., V_B is close to λ), thus, $V_T = V_A + V_B$ is close to λ and very little change occurs to CS_A's associative strength, V_A. The successful prediction of the outcome of several forms of compound conditioning is one main advatange of the model (Rescorla & Wagner, 1972). Another positive feature of the model is its simple representation of inhibitory phenomena.

Inhibition is represented by negative values of V. Suppose CS_A were a conditional inhibitor, V_A would be negative and, on a compound trial with an excitatory CS_B, V_T would be equal to $V_B - |V_A|$. The presence of the conditional inhibitor (CS_A) would, thus, reduce the level of CR seen to CS_B compared to when CS_B was presented alone (summation test) because the negative value of V_A would reduce the total value of associative strength on the compound trial. This direct subtractive relationship is merely a formalization of the definition which says that "inhibition is antagonistic to excitation". Nevertheless, the discrepancy formulations (i.e., $\lambda - V_T$) of change in associative strength yields interesting predictions for compound conditioning with a conditional inhibitor.

The presence of a conditional inhibitor on a compound trial will have two effects. First, inhibition will reduce responding by subtracting from V_T. Notice, in addition, that the reduction of V_T on the trial implies a corollary effect. From equation (1) the change in associative strength is inversely related the value of V_T. The presence of a conditional inhibitor on a compound acquisition trial will enhance the acquisition of associative strength to the other stimulus by increasing the value of $\lambda - V_T$. Inhibitory-induced facilitation of compound acquisition to a novel stimulus, "superconditioning", is a novel prediction derived directly from the model and confirmed in subsequent studies (Rescorla, 1971b; Wagner & Rescorla, 1972). Enhanced acquisition to the novel CS reinforced with an inhibitor is good evidence that the discrepancy between combined associative strength and

the level of conditioning supported by the US is an important determinant of CR acquisition.

The application of the Rescorla-Wagner model to appetitive-aversive interactions would assume two values of associative strength: one value for each motivational system. The associative strength of a specific stimulus, CS_X, for an aversive US would be given by $V_{X,AV}$ and the associative strength of a specific stimulus, CS_Z, for an appetitive US would be given by $V_{Z,AP}$. Conditional inhibition within each motivational system would be represented by negative values of associative strength for that system. Reciprocal inhibition, however, is represented by a rule for combining associative strength across motivational systems. To preserve the inhibitory quality of appetitive-aversive interactions, this rule must be subtractive. Specifically, if CS_X had aversive associative strength and CS_Z had appetitive associative strength, then the combined aversive associative strength would be given by:

$$V_{T,AV} = V_{X,AV} - V_{Z,AP} \tag{2}$$

and combined appetitive associative strength by:

$$V_{T,AP} = V_{Z,AP} - V_{X,AV}. \tag{3}$$

These rates imply the functional equivalence of excitation in one motivational system and inhibition in the other motivational system. When applied to Equation (1) they generate the predictions outlined at

the beginning of this section. A failure to confirm the predictions of excitatory and inhibitory transfer derived from the Rescorla-Wagner model with a subtractive rule for combining appeititve and aversive associative strength would require modification of the current reciprocal inhibition approach to appetitive-aversive interactions (e.g. Dickenson & Pearce, 1977; Fowler, 1978).

The program of research suggested by the predictions of reciprocal inhibition outlined above differs from most previous studies of appetitive-aversive transfer studies in its treatment of conditional inhibition. Although inhibition as a functional construct has been used freely in theoretical discussions of appetitive-aversive interactions, conditional inhibition in transfer studies has rarely been given the careful attention it deserves. It is not yet clear, for example, whether the inhibition induced by an excitatory stimulus from an aversive motivational system means anything more than retardation of appetitive acquisition to that stimulus (Scavio, 1974). Conditional inhibition in current theoretical accounts of Pavlovian conditioning means much more than simple interference with acquisition. Cross-motivational interference with acquisition could be due to a number of factors other than inhibition (e.g. salience, Mackintosh, 1975).

Although considerable evidence exists to support an inhibitory role for an aversive excitatory CS in appetitive conditioning procedures (see Dickinson & Pearce, 1977), the conclusion of centrally mediated inhibitory transfer can be criticised in two ways. First, many of the experiments claiming inhibitory transfer are conducted with operant response measures. This does not decrease their interest, but it raises

the significant possibility that alternative accounts may be developed that do not depend on central Pavlovian inhibition (Trapold & Overmier, 1972). The most significant of these is response competition (Dinsmoor, 1954) whereby the aversive response physically competes with the appetitive response. The second criticism is that, even when care is taken to eliminate peripheral competing response alternatives, the usual criteria for establishing a stimulus as inhibitory have not been satisfied. Of the minimum two tests suggested (Rescorla, 1971a; Hearst, 1972), only the retardation of acquisition test (Scavio, 1974) has been satisfactorily demonstrated in a well controlled Pavlovian aversive to appetitive transfer study. The present studies will assess whether or not an excitatory aversive CS behaves predictibly as an appetitive inhibitory stimulus would in a variety of conditioning situations.

A second problem with previous studies which purport to test the predictions of reciprocal inhibition is that many studies lack good control procedures for inhibitory transfer, such as for the mere exposure to the elements of conditioning: the CS and US (see Aversive Control Conditions, Section 1.6). This problem is by no means universal; but the lack of controls for effects other than conditional inhibition has been most notable in those studies where care has been taken to rule out peripheral response interactions as an alternative to motivational accounts (e.g. Bromage & Scavio, 1978 and Scavio & Gormezano, 1980). Without control procedures it is difficult to determine whether an effect is caused by conditional inhibition. More important, without exception, these previous transfer studies have not

demonstrated independently that any putative inhibitory aversive stimulus used for transfer was, in fact, inhibitory. Without such evidence the case for inhibitory transfer facilitating activation of the alternative motivational state remains largely speculative. The present series of studies has the second goal to clearly assess the effects of inhibitory aversive transfer on the acquisition of appetitive conditioning against the predictions of the reciprocal inhibition model described above.

1.6 Aversive Control Conditions

The current studies of appetitive-aversive interactions test claims concerning both excitatory and inhibitory transfer. In order to assess the contribution of conditional excitation and inhibition to transfer effects, at least two control conditions should be included in the design. The first is a non-preexposed group, which receives none of the CS or US presentations prior to being assessed in the transfer task. Instead, this group is merely exposed to the experimental context during the preexposure phase of the transfer study. The purpose of this condition is to provide a baseline of performance on the transfer task in the absence of any influence from the US of the alternative motivational state. It is against this background that facilitation and retardation must be assessed. Surprisingly, the early work on Pavlovian transfer effects lacks this simple, but essential control (see Konorski, 1967).

A second control condition must be included to assess the influence of mere preexposure to the elements used to establish

excitation and inhibition in the preconditioning phase (see Siegel & Domjan, 1971). Rescorla (1967) has suggested the truly random control (TRC) procedure as a method for assessing the contribution of non-excitatory and non-inhibitory expousre to both the CS and US. The selection of random CS/US presentations as a non-associative control is based more on the lack of an acceptable alternative, rather than on the conviction that random presentations do not have any associative effects. Several experimenters (Kremer & Kamin, 1971; Benedict & Ayers, 1972; Mackintosh, 1973; 1974; 1975) have challenged the non-associative nature of random CS/US presentations under certain conditions. On the one hand, Mackintosh (1975) has emphasized the residual retardation effects of random training on subsequent excitatory acquisition and has suggested that CS salience is markedly reduced by such non-contingent arrangements (learned irrelevance). On the other hand, Kremer and Kamin (1971) and Benedict and Ayers (1972) have emphasized the dependence of random presentation effects on the density of US presentations. They suggest the possibility that with a high density of US presentation the randomly presented CS may actually acquire excitatory strength. Nevertheless, in the eyelid conditioning preparation, which will be used in the studies reported here, Siegel and Domjan (1971) have argued that TRC transfer effects may be interpreted as the combined contribution of simple exposure to the two elements of preexposure (Siegel & Domjan, 1971). In any event, the TRC or an alternative control for simple exposure to the elements of the preconditioning phase is necessary as a baseline for comparison with the

transfer effects attributed to the excitatory or inhibitory signal value of the CS.

Although TRC controls have been included in many transfer studies involving Pavlovian transfer onto an operant task, this comparison is conspicuously absent from the recently reported Pavlovian to Pavlovian transfer studies of appetitive-aversive interactions (Scavio, 1974; 1975; Bromage & Scavio, 1979; Scavio & Gormezano, 1980). In these studies, an explicitly unpaired control condition was employed. In this procedure, CSs and USs are presented such that no temporal conjunctions between the two occur. Rescorla (1967), however, argues convincingly that explicitly unpaired presentations is a procedure with a negative correlation between the CS and US and, thus, would allow the development of conditional inhibition to the CS.

A similar inhibitory interpretation of the TRC procedure could be made in the eyelid conditioning preparation where both the CS and the US occur very infrequently and occupy only a small fraction of the total session time (e.g. Siegel & Domjan, 1971). It is conceivable that in sparse reinforcement conditions with short duration CSs that a randomly presented CS may become a signal for US absence and produce inhibitory effects. This suggestion is encouraged by the observation that CS-US pairings in such random pretreatment phase are highly unlikely with the temporal parameters used in these studies. Such pairings virtually never occur in the random pretreatment phase. Thus, although the CS is not a better predictor of US absence than any other non-contingent stimulus present in the situation, it may still acquire inhibitory properties.

Siegel and Domjan (1971; 1974) did not rule out the possibility that random CS/US presentations produce inhibition in their demonstration that backward shock-tone pairings are inhibitory. Instead, their claim is based on the observation that backward pretraining interferes more with subsequent CR acquisition than random pretraining does. Such results could reflect different degrees of inhibition in the two treatments rather than qualitatively different sources of interference with CR formation. More recently, however, Hinson and Siegel (1980) report a summation test with CSs pretrained with random US presentations. They found no decrement in responding to an excitatory CS when the excitatory CS was presented in compound with the random CS. An inhibitory CS should oppose excitatory, conditional responding. The failure of the random CS to suppress CRs in a summation test strongly indicates that the random CS is not inhibitory and suggests the need for an alternative account of random CS-produced retardation of acquisition. Because of the importance of the TRC as a control for non-associative effects, Experiment 1 was designed, in part, to demonstrate conclusively that the specific random pretraining procedure used in later transfer studies does not have any excitatory or inhibitory effects.

Experiment 1 in the present series tests the potential excitatory and inhibitory properties of the various aversive preexposure conditions to be used throughout the appetitive-aversive transfer studies, and, thus permits confirmation that the inhibitory procedure does, in fact, produce conditional inhibition. Acquisition of a conditional inhibition discrimination to the preexposed CS between the

two control and the inhibitory conditions is compared. Clearly, any pretreatment producing an inhibitory CS should facilitate learning the inhibitory discrimination over control conditions. If the putative inhibitory condition demonstrated superiority in this test, then using a comparison of transfer performance of the inhibitory pretreatment against control conditions in transfer to appetitive tasks would provide an unambiguous test of inhibitory transfer effects in aversive to appetitive interactions.

1.7 Design of Aversive to Appetitive Transfer Studies

Table 1 shows the design and theoretical predictions of reciprocal inhibition for three appetitive-aversive transfer studies. These studies are derived from the reciprocal inhibition model described in section 1.5. In each, there is an aversive preexposure phase with a tone CS to establish the experimental and control conditions. The effects of these conditions are then tested in a specific appetitive transfer task. The predictions in these tests are briefly outlined here, to give an overview before considering the individual studies in detail.

In the first study, the transfer to simple appetitive acquisition (Experiment 2; Chapter 3) replicates (in part) and extends the design of an earlier study by Scavio (1974). Reciprocal inhibition predicts that preexposure to a condition producing an excitatory aversive CS (AV CS+) will substantially retard appetitive acquisition to that stimulus compared to a truly random control stimulus (AVCSo) or a non-preexposed stimulus (NPx). Preexposure to a condition producing an

TABLE 1: Aversive to Appetitive Transfer Studies

	Experiment	Aversive[1] Pretraining	Appetitive[2] Conditioning	Reciprocal Inhibition Prediction
Ex. 2:	Appetitive Acquisition	AV CS+	T-Water	Retardation
		AV CS-		Facilitation
		AV CSo		Preexposure control
		NPx		Control
Ex. 3:	Appetitive Discrimination	AV CS+	L-Water; L+T-No Water	Facilitation
		AV CS-		Retardation
		AV CSo		Preexposure control
		NPx		Control
Ex. 4:	Compound Appetitive Acquisition	AV CS+	L+T-Water	Superconditioning[3]
		AV CS-		Blocking
		AV CSo		Random Control
		NPx-LT		Overshadowing Control
		NPx-L	L-Water	Light Alone Control

[1]Type of pretraining with tone CS and aversive US (shock):
AV CS+ - Excitatory aversive CS
AV CS- - Inhibitory aversive CS
AV CS^0 - Random control CS
NPx - No Pretraining

[2]Specific pairings of tone CS (T) and light CS (L) with appetitive US (water).

[3]Predictions for aquisition to the light.

inhibitory aversive CS (AV CS-) on the other hand, should facilitate acquisition to that stimulus compared to the two control conditions.

The second appetitive-aversive transfer study (Experiment 3; Chapter 4) tests the transfer of the aversive stimuli to an appetitive conditional inhibition discrimination. By comparing acquisition of appetitive conditional inhibition to the aversive preconditioned stimulus, a second test of the inhibitory nature of excitatory aversive transfer to the appetitive system is achieved. Not only would an AV CS+ be expected to facilitate acquisition of appetitive conditional inhibition, but also, an AV CS+ as an appetitive inhibitor should be capable of some suppression of appetitive responding at the outset of acquisition (similar to a summation test of inhibition; Rescorla, 1971a; Hearst, 1972). In contrast, an AV CS- as an activator of the appetitive system would be expected to interfer with the acquisition of appetitive conditional inhibition to that stimulus. Moreover, such appetitive-activation would be expected to enhance appetitive conditional responding at the start of conditional responding.

Finally, the third study (Experiment 4; Chapter 5) tests several unique predictions of reciprocal inhibition for acquisition to a compound stimulus. To apply reciprocal inhibition to compound stimulus acquisition, the theory has been combined with the Rescorla-Wagner model and the known effects of preconditioning on compound stimuli (see Dickenson & Pearce, 1977; Fowler, 1978). According to the Rescorla-Wagner model, the amount of conditioning during compound acquisition is inversely related to the associative strength of the stimulus elements present on the conditioning trials. Thus, the presence of an inhibitory

CS in the compound CS will enhance acquisition to the other element (superconditioning, Rescorla, 1971b) and the presence of an excitatory CS in the compound CS will reduce or block acquisition to the other element (blocking, Kamin, 1969). In the present context, support for reciprocal inhibition would be found if a novel CS appetitively reinforced in compound with an AVCS+ acquired more conditional responding than a novel CS appetitively reinforced by itself. Similarly, support for the facilitative effect of aversive inhibition facilitative effect of aversive inhibition in appetitive acquisition would be shown by a reduced acquisition of conditional responding to the novel CS reinforced in compound with the AV CS- compared to acquisition to the novel CS reinforced in compound with an associatively neutral CS (either NPx or AV CSo).

These predictions are based on an application of reciprocal inhibition to known excitatory and inhibitory transfer phenomena in Pavlovian conditioning, derived from the adaptation of the Rescorla-Wagner model described above. They are also based on the assumption that the various preexposure operations do what was intended. Although the presence of aversive excitation may be inferred from conditional responding, aversive inhibition is more difficult to demonstrate. Moreover, appropriate comparisons against control conditions assume that the control conditions do not produce excitation or inhibition themselves. Random control presentations are especially vulnerable to such suspicion of associative contamination. Experiment 1 addresses the issue of what properties are actually developed to the CS in the various conditions during the aversive preconditioning phase to be used

throughout the appetitive-aversive transfer studies. Provided these conditions are appropriate, consistent positive results on the appetitive-aversive transfer tests outlined here would strongly support reciprocal inhibition in a preparation where peripheral response interactions are not a factor.

CHAPTER 2: Properties of Aversive Transfer Conditions

The logic of appetitive-aversive transfer experiments outlined in the first chapter suggests various predictions made by current theories of motivational interactions. As is the case in many experimental designs, these theoretical predictions are grounded on the validity of their assumptions. In a transfer study, we assume that, in the initial preconditioning phase, a designated stimulus acquires a particular motivational significance. In the excitatory instance, it can be argued effectively that the conditional response provides at least a crude index of motivational activation. In the inhibitory instance, however, no such index is readily available; instead, a more indirect measure of conditional inhibition must be taken.

2.1 Experiment 1: Aversive transfer to aversive discrimination training

The conditioned inhibition discrimination design described by Pavlov (1927) is an ideal procedure not only for producing an inhibitory CS, but also for differentiating excitatory and inhibitory transfer effects. During discrimination training a single positive stimulus is reinforced, A+, and a compound negative stimulus is not reinforced, AB-. These compound trials provide a robust measurement of prior conditioning to the B element. Prior excitatory conditioning to the B element should enhance AB- responding and interfere with learning the discrimination, whereas inhibitory pretraining should suppress AB-responding and

facilitate learning the discrimination. A non-associative pretraining experience should have no effect on AB responding when compared to A+ responding. These simple predictions of excitatory and inhibitory transfer were assessed here with backward, random, and no exposure preconditioning experiences with the B element prior to subsequent discrimination training.

This experiment provides test of the associative effects the random control procedure eyelid conditioning. If present, either excitatory or inhibitory effects in the random training procedure would be revealed in this transfer design. Moreover, the design permits a confirmation of the suggestion that backward US-CS pairings do produce an inhibitory CS (Siegel & Domjan, 1971; 1974, and Moscovitch & LoLordo, 1969).

2.2 Backward Conditioning as Inhibitory Preexposure

The ideal inhibitory transfer procedure for control purposes would be one that established an inhibitory CS using only that stimulus and the US. Under the best circumstances, the inhibitory preconditioning procedure would differ from the TRC control procedure only with respect to the temporal relationship between the CS and US. Since both conditions would use the same frequency of CS and US presentations, the TRC would provide a reasonable baseline for the effects of mere exposure to the CS and US to compare against inhibitory transfer effects. For this reason, in the studies conducted here, backward conditioning trials, where the US termination is coincident with CS onset, were used to establish an inhibitory aversive CS.

Several investigators have reported data indicating that backward pairings of a stimlus with shock (i.e. CS following shock termination) produce a powerful inhibitory stimulus in eyelid conditioning with rabbits (Siegel & Domjan, 1971; 1974), conditioned suppression with rats, (Siegel & Domjan, 1971; 1974) and fear conditioning with dogs (Moscovitch & LoLordo, 1969). These findings have been interpreted as indicating that inhibition develops under circumstances where the CS is paired with a relative safety period free from shock (Moscovitch & LoLordo, 1969) or with the inhibitory after-reaction to the shock (e.g. the opponent process; Solomon, 1979).

More recently, however, Heth (Heth & Rescorla, 1973; Heth, 1976) reported a failure to find consistent inhibitory conditioning with backward pairings of a US and CS in the conditioned suppression paradigm with rats. Instead, they report excitatory conditioning with a small number of conditioning trials and the gradual development of inhibition with larger numbers of conditioning trials. Similarly, Varga and Pressman (1963) report some conditioned responding to a backward CS in both leg flexion and salivary conditioning in dogs. Although, in this case, the conditional responding did not exceed the baseline level shown by a random control condition, these findings raise suspicions on the effectiveness of backward conditioning as an inhibitory procedure.

Siegel and Domjan (1974) point out a number of procedural differences, other than the number of training trials, between their demonstration of inhibitory conditioning and Heth's demonstration of excitatory conditioning which might be important for the descrepant results. For our present purposes, the backward conditioning procedure for eyelid conditioning followed closely the successful parameters used

by Siegel and Domjan (1971). Experiment 1 was designed primarily to confirm inhibitory backward conditioning under these parameters and to differentiate this inhibition from the TRC effects.

A clear qualitative difference between backward and random preconditioning effects on the acquisition of the A+;AB- discrimination task is necessary to permit a reasonable interpretation of the role of inhibition in later appetitive-aversive transfer studies comparing these two conditions.

2.3 Excitatory and Inhibitory Transfer to Discrimination Learning

The Rescorla-Wagner theory may be applied to discrimination learning to predict the directions of excitatory and inhibitory transfer. According to this approach, transfer effects may operate on either of two components of the discrimination task: 1) acquisition of excitatory strength during presentation of the positive element or 2) acquisition of inhibitory strength to the negative element. In the A+;AB- design, the negative compound trials provide the basis for interaction between these two stimuli, which further complicates the analysis. However, the direction of interactive effects of excitatory and inhibitory transfer are predicted by the Rescorla-Wagner model and supported by an extensive literature on compound stimulus effects. Application of the model to the A+;AB- design makes clear differential predictions for the aversive preexposure conditions proposed above.

2.3.1 Positive Element Acquisition:

Aversive transfer should have predictable effects on acquisition to the positive component of the discrimination. First, it is well documented that once a conditional response is established to

one CS acquisition to a second CS is enhanced (Pavlov,, 1927). Thus, excitatory conditioning prior to discrimination training would be expected to facilitate conditioned responding to the new excitatory CS, a positive element. By an analogous argument, inhibitory conditioning prior to discrimination training should be expected to retard acquisition to the positive element of the discrimination. Moreover, both the TRC and inhibitory procedures involve the presentation of unpredicted shock. The usual finding is that unpredicted US presentations, occurring prior to paired presentations, result in a subsequent retardation of conditional response acquisition (Dweck & Wagner, 1970; Mis & Moore, 1973; Hinson, 1982). Consequently, both the TRC and backward conditioning procedures would be expected to interfere with acquisition to the positive, or A, element of the discrimination compared to the naive control condition.

2.3.2 Negative Element Acquisition:

The effects of prior aversive experience on the negative element of a Pavlovian discrimination are even more straightforward. Excitatory pretreatment should directly oppose the development of inhibition to the negative CS and would enhance responding to the AB- compound. Inhibitory pretreatment, on the other hand, should facilitate the development of inhibition to the negative CS. Both of these effects should be observable at least during the early stages of conditioning when compared to a naive control condition. Initially, an excitatory effect would demonstrate a higher rate of response to the negative stimulus than to the positive stimulus. An inhibitory effect would evidence response suppression on negative trials at the outset of acquisition to the positive stimulus. Indeed, the early stages of

conditioning in an A+;AB- discrimination design would provide a sensitive summation test for associative strength.

Backward conditioning, if inhibitory, should suppress compound responding at the outset of responding on positive trials. In constrast, the TRC condition, if associatively neutral with respect to excitation and inhibition, would not have any initial effects on negative trial response. In fact, a reduction in stimulus salience to the random CS would predict that the eventual acquisition of response suppression on negative trials would be delayed in comparison to the non-preexposed control group (cf. Bates & Mackintosh, 1977).

2.4 Method

2.4.1 Subjects and Apparatus

Fifteen, experimentally naive, male, New Zealand white rabbits, weighing 3-5 kg at the start of the experiment, served as subjects. Each rabbit was individually housed and given free access to Purina rabbit chow and water throughout the duration of the experiment.

During each experimental session, the rabbits were placed in one of six 18 x 14 x 41 cm Plexiglas restraining boxes. Conditioning was carried out in six identical, sound attenuated, ventilated chambers (Scientific Prototype Model SPO 300), with illumination by a 7.5-W bulb located in the ceiling of each chamber. The outer eyelid response was recorded with a modification of the technique described by Gormezano (1966). Briefly, movement of the rabbit's left outer eyelid response was conducted, via a string and pulley arrangement, to the shaft of a microtorque potentiometer. Voltage changes through the potentiometer

were graphically recorded by a Grass Model 7 Polygraph and provided a record of conditional and unconditional eyelid activity.

Two CSs were used in the present experiment, one visual and one auditory. The visual CS consisted of a 1000 msec termination of the overhead illumination. The auditory CS consisted of a 1000 msec 2000-Hz tone at 76 dB above 20 uN/m emanating from a speaker in the rear of the chamber. The US consisted of a 100 msec, 2.0 mAmp, 200-V ac shock, delivered through a pair of chronically implanted tantalum wire electrodes, mounted approximately 1 cm apart and 1 cm below the left eye.

2.4.2 Procedure

The experiment consisted of three phases: 1) habituation to the conditioning chamber, restraining box, and eyelid recording apparatus; 2) preconditioning with the aversive transfer conditions; and 3) acquisition of the conditional inhibition discrimination. Subjects differed only in their treatment during the preconditioning phase of the experiment. Independent groups of rabbits (all N=5) were assigned to one of three preexposure conditions. Group BKD animals received all CSs immediately following US termination. Group RDM animals received the same number of USs and CSs presented in a random manner. Group NPx received neither the CS nor the US during the preconditioning phase, but were simply restrained in the conditioning chambers during these sessions.

In Phase 1, all subjects received three days of adaptation prior to the preconditioning phase. On Day 1, each rabbit was placed for approximately 30 minutes in a restraining box in the animal colony room. On Day 2, each rabbit received exposure to the restraint box and

conditioning chamber for a full one-hr session. On Day 3, the rabbit was placed in the restraining box, the shock electrodes were implanted, and a wound clip (for attaching the strings to the potentiometer) was fastened to the rabbit's left upper eyelid. The animal then was placed in the conditioning chamber for the rest of the one hr session.

Following habituation to the conditioning apparatus, each subject participated in 10 preconditioning sessions. During these sessions, subjects in Group NPx were simply restrained in the conditioning chambers. Subjects in Groups BKD and RDM each received 40 CS and 40 US presentations in each session. For both groups, presentations of the tone CS occurred at intervals of 1.0, 1.5, and 2.0 min with the intervals scheduled to occur in a semi-random order derived from a random numbers table. For Group BKD subjects, tone CS presentations were always preceded immediately by presentation of a shock US. For Group RDM subjects, the 40 US presentations were scheduled to occur with equal probability in any 100 msec segment of the 60 min session. Although coincidental occurances of CSs and USs are possible on this random schedule, with these temporal parameters such events are unlikely and did not occur in the Group RDM sessions.

The 15 session conditional inhibition discrimination phase followed completion of the preconditioning phase. All subjects received 40 trials presented at intervals of 1.0, 1.5 and 2.0 min scheduled semi randomly. Half of the trials were positive trials and the other half were negative trials. A positive trial consisted of the light CS followed by the US. The time between CS onset and US onset, the interstimulus interval (ISI), was 1 sec, so the US presentation was coincident with the CS termination. The negative trial consisted of a

simultaneous compound presentation of both the light CS and the tone CS followed only by the next intertrial interval. The order of positive and negative trials was random with the constraint that no more than three presentations of one trial-type occur consecutively. This was done to reduce the potential influence of response sets (e.g. Prokasy & Gormezano, 1980).

Throughout both the preconditioning and discrimination phases of the experiment, eyeblinks were recorded for a 2 sec prestimulus interval (in order to establish a stable baseline for eyelid activity), each US presentation (in order to ensure US delivery had occurred), and each CS presentation (in order to measure conditional eyelid activity). An eyelid response was defined as a 1 mm deflection of the recording pen in the direction of eyelid closure during the 1 sec CS and only if the prior 1 sec prestimulus interval were free of spontaneous eyelid activity.

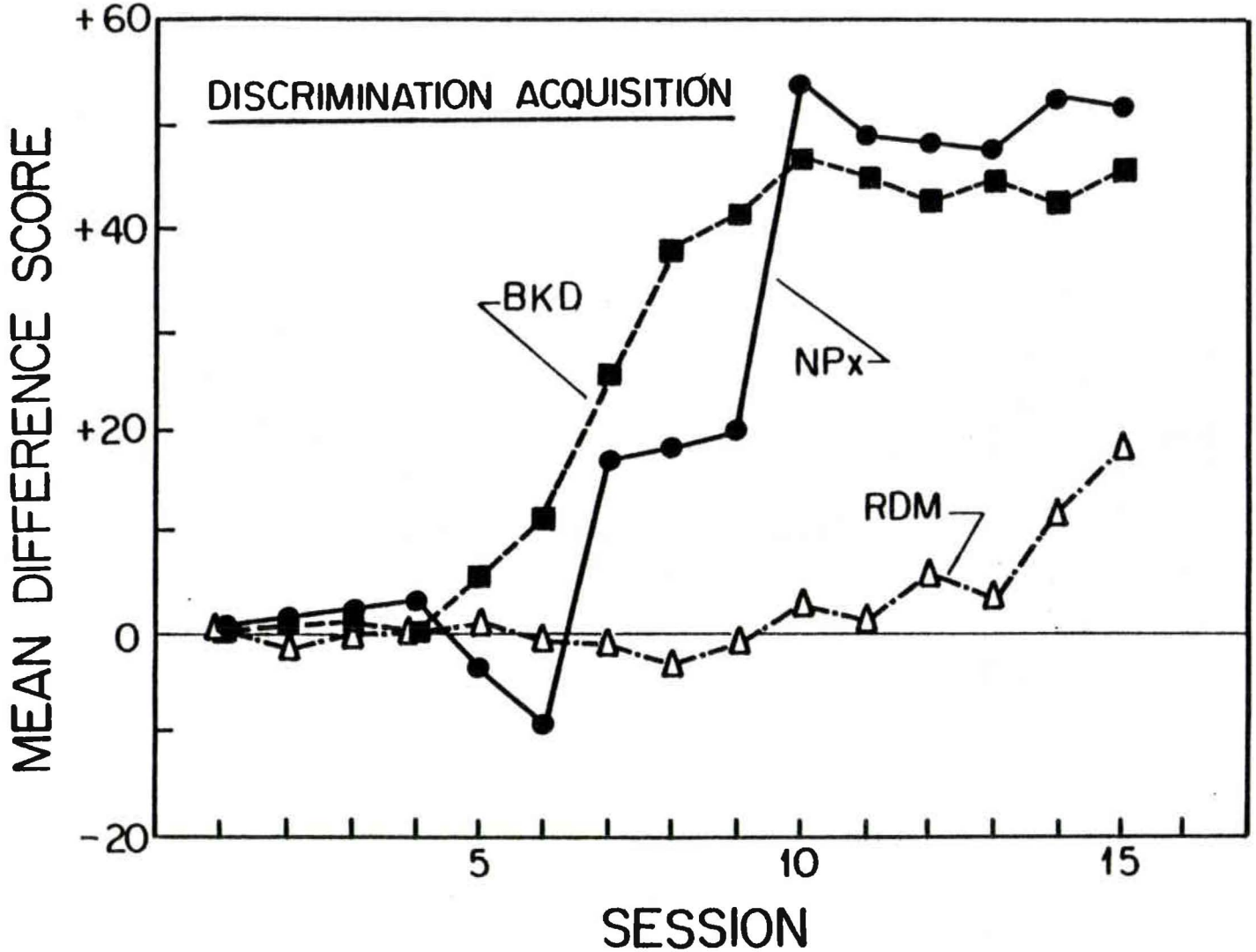
In order to analyze discrimination performance two measures of discrimination accuracy were calculated: 1) a difference score obtained by subtacting response rates on negative trials from response rates on positive trials where higher difference scores indicate greater accuracy on the discrimination, and 2) a discrimination ratio obtained by dividing the response rate on positive trials by the total response rate on all trials, where larger ratios indicate greater accuracy on the discrimination. The first measure is more sensitive to the magnitude of conditioning on the positive trials and may not provide an accurate indication of relative responding on early discrimination trials. The second measure is more sensitive to the relative rates of response and should provide an accurate detection of early inhibitory tendencies.

2.5 Results

Figure 1 depicts the difference score (positive percent response - negative percent response) measure showing the acquisition of the conditional inhibition discrimination over the fifteen sessions of training. Clear acquisition of the discrimination is shown only for groups BKD and NPx. In addition, initial acquisition is more rapid in the BKD preconditioning group than in the naive control group. A two-way mixed design ANOVA revealed a significant effect of preexposure condition ($F_{2,12}=6.34$; $p < .025$) and of training sessions ($F_{14,168}=16.53$; $p < .001$). The condition x sessions interaction was also significant ($F_{23,168}=3.37$; $p < .001$). Post hoc comparisons between conditions with Newman-Keul's comparisons showed that both the BKD and NPx groups perform the discrimination better than the RDM group ($p < .001$). This comparison, however, failed to reveal a significant difference in the performance of the BKD and NPx groups.

Support for enhanced conditional inhibition in the BKD group with the difference score measure is found by an analysis of individual performance in the early stages of positive trial acquisition. Setting a criterion for the initial session of positive trial CR acquisition at 25 percent response on positive trials allows comparison of the BKD and NPx groups performance of the difference score measure during the initial stages CR acquisition. The effects of inhibitory transfer should be revealed at the start of conditional responding since the negative element should already have inhibitory properties. As anticipated, all BKD subjects showed an initial suppression of responding on the compound negative trials. In contrast, only one subject of the NPx group showed an initial suppression of responding on

Figure 1: Difference score measure of aversive transfer to aversive discrimination training.


DISCRIMINATION ACQUISITION
+60
+40
+20
0
-20
MEAN DIFFERENCE SCORE
BKD
NPx
RDM
5
10
15
SESSION

the compound trials. A Student's t-Test of the difference scores obtained from the session in which the 25% criterion was first achieved was significant ($t_{1,8}=3.1$; $p < .02$).

Further support for inhibitory transfer in the BKD group is found in the discrimination ratio measure. Figure 2 shows the mean discrimination ratio for successive five session blocks of the discrimination training phase. Because the use of a ratio measure prohibits an accurate analysis with the usual ANOVA statistics, an individual Kruskal-Wallis non-parametric ANOVA was applied to each trimester of discrimination training. Significant differences between groups were found only in the second and third trimesters of training. Individual Mann-Whitney U-Tests indicated superior discrimination performance by the BKD group over both the NPx and RDM groups in the second trimester (both $U's_{5,5} \leq 2$, $p < .05$). In the third trimester, the BKD and NPx groups did not differ from each other, but both groups were superior to the RDM group ($U's_{5,5} = 0$, $p < .05$).

Finally, Figure 3 shows acquisition to the positive element of the discrimination. A two-way mixed design ANOVA demonstrates significant condition ($F_{2,12}=9.95$; $p < .005$), sessions ($F_{14,168}=51.93$; $p < .001$), and condition x sessions ($F_{28,168}=3.39$; $p < .001$) effects. Newman-Keul's comparisons based on separate one-way analyses of each trimester demonstrate a retardation of acquisition in the RDM group compared to both the BKD and NPx groups (ps $< .01$), which do not differ from one another. These statistics indicate that CR performance is retarded in group RDM compared to both NPX and BKD groups during both the second and third trimesters of acquisition.

Figure 2: Discrimination ratio measure of aversive transfer to aversive discrimination training.

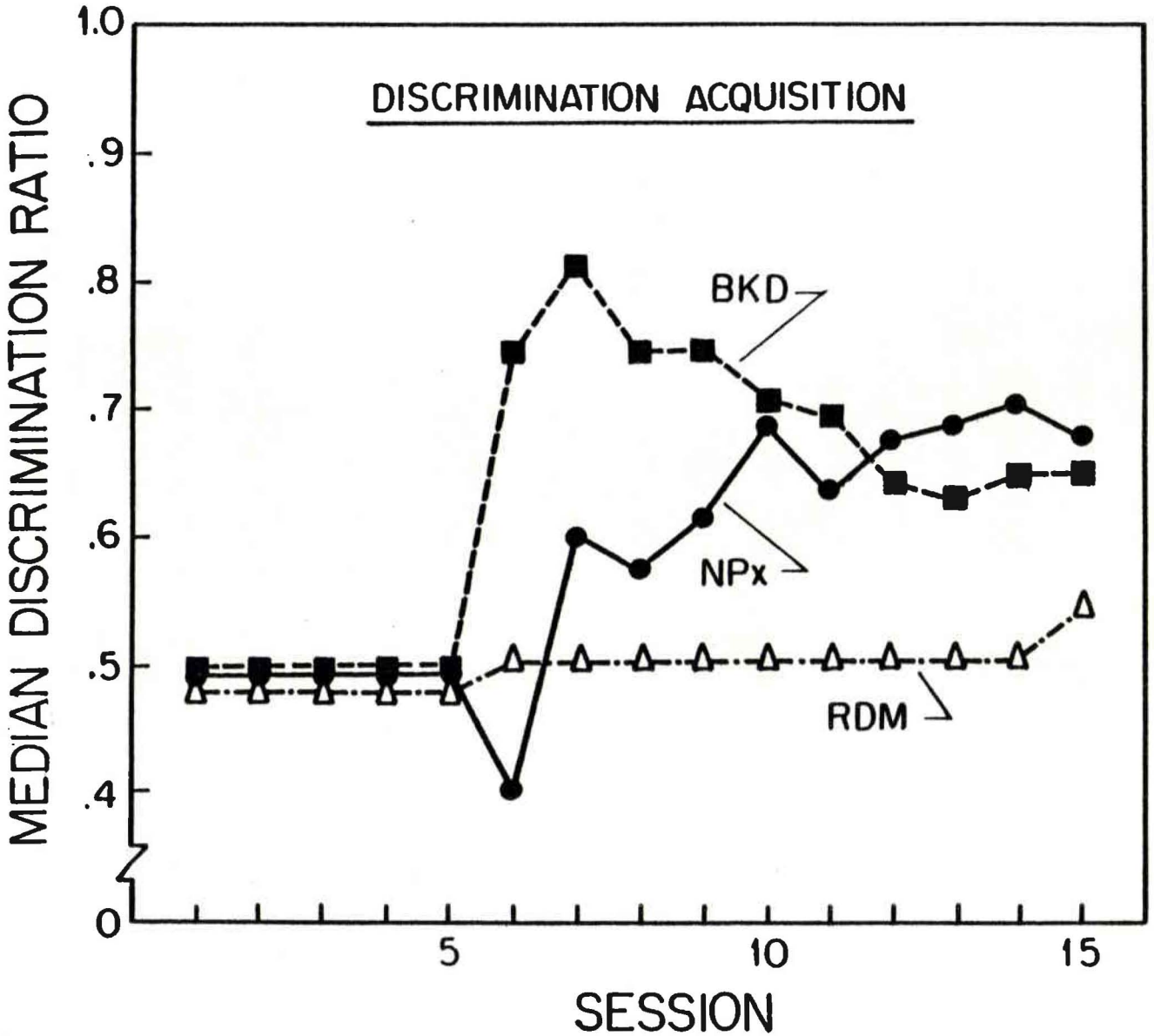
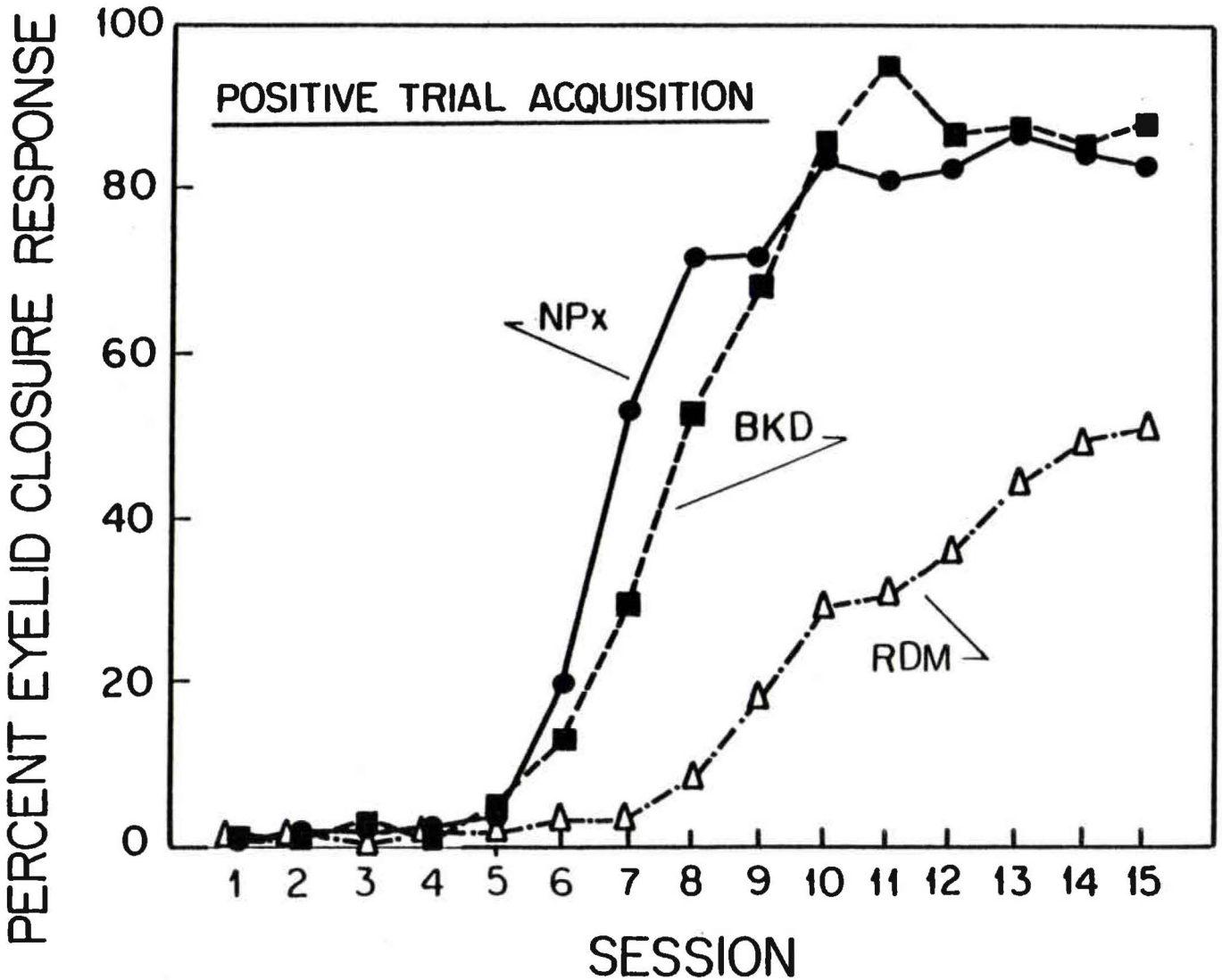

DISCRIMINATION ACQUISITION
MEDIAN DISCRIMINATION RATIO
1.0
.9
.8
.7
.6
.5
.4
0
5
10
15
SESSION
BKD
NPx
RDM

Figure 3: Acquisition of eyelid CRs on positive trials during aversive discrimination training in Experiment 1.


POSITIVE TRIAL ACQUISITION
PERCENT EYELID CLOSURE RESPONSE
100
80
60
40
20
0
NPx
BKD
RDM
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
SESSION

2.6 Discussion

2.6.1 Aversive Inhibitory Transfer

The results of Experiment 1 confirm Siegel and Domjan's (1971) suggestion that backward pairings of a CS and US are capable of producing an inhibitory CS in the eyelid conditioning preparation. The early suppression of responding found to the backward CS in the acquisition of a conditional inhibition discrimination compared to both the random and naive control conditions provides positive confirmation of the summation test suggested by Rescorla (1969a). This test effectively rules out a salience decrement account of the previously reported retardation of acquisition of an eyelid CR to a CS backwardly paired with a US (Siegel & Domjan, 1971; 1974). Together these tests provide strong evidence that, with the parameters used in these studies, backward conditioning is an inhibitory procedure.

2.6.2 Random Control Transfer

In contrast to the associative inhibitory transfer shown in the backward group, the performance of the random preconditioning group is consistent with a salience decrement account. Both the acquisition of an excitatory CR (Siegel & Domjan, 1971) and the acquisition of conditional inhibition, (Figures 1 and 2) are retarded by random CS/US training compared to the naive control condition. Moreover, Hinson and Siegel (1980) report a standard summation test with a similar, randomly preexposed CS. Consistent with the present study, no evidence of any suppression of conditional responding is found. Together, these data suggest that, at least in part, random preexposure produces effects through a reduction in salience to the CS. This conclusion would concur with both the learned irrelevance account (Mackintosh, 1973; 1975) and

the latent inhibition account (Siegel & Domjan, 1971) of CS preexposure effects derived from a random control procedure. In contrast, the present findings clearly argue against any inhibitory or excitatory acquisition during random control presentations. Either of these two associative tendencies should have been revealed on the discrimination measures taken early in training. The expectations for the random control condition in appetitive-aversive transfer can not be projected directly from these findings. Clearly, the randomly preexposed CS looses salience for the acquisition of both excitatory and inhibitory aversive associations. Mackintosh (1973; 1975) however, suggests that this salience decrement may be specific only to the US with which the CS was randomly presented. The acquisition of an appetitive CR would not necessarily be affected. On the other hand, a latent inhibition interpretation of the salience decrement found with random preexposure (Siegel & Domjan, 1971) would predict a general decrement in associability that would transfer to appetitive CR acquisition. Comparisons between the random and naive control conditions in the following transfer studies will provide some information towards resolving this issue.

Notwithstanding this unresolved issue, the random control procedure is a necessary comparison condition for equivalent total exposure to the CS and US during preconditioning. In particular, unpredicted US presentations are equivalent in both the random control and inhibitory aversive groups. Experiment 1 clearly distinguishes the associative effects of backward and random preexposure to a CS and US and strongly suggests inhibitory aversive transfer effects on appetitive

conditioning may be revealed in the comparison of these conditions when transferred to any one of several appetitive transfer tasks.

2.6.3 Positive Element Acquisition

Comparison of acquisition to the positive element of the discrimination reveals some interesting results that may indirectly support the analysis that backward pretreatment is inhibitory and are consistant with the analysis that random pretreatment reduces stimulus salience.

Because of unsignalled US presentations in the preconditioning phase, both the random and backward groups were expected to be slow in acquiring the conditional response to the novel positive stimulus (US preexposure effect; e.g. Dweck & Wagner, 1970; Hinson, 1982). However, only the random group was retarded in acquisition shown on positive trials. The backward, inhibitory group was not retarded on positive trial acquisition compared to the naive control group.

What accounts for the failure to find a US preexposure effect in the backward group? Two main explanations are possible. First, it is possible that something about the backward preexposure procedure disrupts the US transfer effect. For example, CS presentation following US presentation could disrupt US processing and consequently US habituation (c.f. Wagner, 1977). Such disruption might be enhanced by the inhibitory backward CS providing a safety signal following each US occurrence. This reduced US impact approach would predict that the retardation of novel CS acquisition would occur in simple acquisition as well as the discrimination task.

The second explanation of the lack of a US preexposure effect following backward conditioning is specific to the discrimination task

used in this study. Reinforcement of the positive element occurs only on 50% of the trials. On the other 50% of the trials (negative compound trials), the positive element occurs without reinforcement (partial reinforcement) and would be expected to lose part of its excitatory strength and would be slower to acquire than if these trials were omitted. However, according to current theoretical accounts, the presence of an inhibitory stimulus on negative compound trials in the backward group would be expected to lessen the impact of non-reinforcement and thus introduce an offsetting tendency on positive stimulus acquisition to counteract any US preexposure effect.

The inhibitory CS is expected to lessen the impact of non-reinforcement on the basis of the Rescorla-Wagner model. Simply put, the presence of an inhibitory CS predicts the occurrence of non-reinforcement on compound trials. Consequently, no discrepancy occurs on the negative compound trials and the positive stimulus is protected from losing any excitatory strength. Protection from extinction by the simultaneous presentation of an inhibitory CS with the excitatory CS on extinction trials is a similar phenomena which has received considerably empirical support in the work of Soltysik (1960, 1963, 1979).

This second explanation of the lack of a US preexposure effect relies on the assumption that the negative stimulus is inhibitory at the onset of discrimination training and could be taken as indirect evidence of the effectiveness of inhibitory pretreatment. This tangential line of evidence is weak because we can not rule out the possibility that the backward preconditioning procedure reduces the US preexposure effect directly by influencing US processing. Nevertheless, a reduced US preexposure effect on positive trial acquisition would be expected when

an inhibitory CS is presented on the negative compound trials of an A^{+}; AB^{-} discrimination.

The results of positive trial acquisition require a more complex theoretical analysis than the discrimination measures in this experiment. Acquisition of conditional responding differentiated the backward and random conditions, however, in a manner consistent with the interpretations of pretreatment effects based on the discrimination measures. In particular, backward preconditioning evidenced clear inhibitory learning on the discrimination measures which may aid in the interpretation of a relatively rapid positive trial acquisition. Random preconditioning evidenced a salience decrement on the discrimination measure which is consistent with slower positive trial acquisition. These findings effectively show that the two preconditions produce markedly different CSs for transfer studies. On the critical dimension, the backward-trained CS is inhibitory, whereas the randomly trained CS is not.

CHAPTER 3: Experiment 2: Aversive Transfer to Appetitive Excitatory Conditioning

One prediction of an antagonistic relationship between appetitive and aversive motivational states is the retardation of acquisition of conditioning by prior conditioning with the US of the antagonistic motivational state. Equally as important, according to the reciprocal nature of the motivational interaction, is the prediction that an explicit conditional inhibitor would not retard and, in fact, should enhance subsequent conditioning in the opposite motivational system. The present study examines these predictions for the transfer of preconditioning experience with an aversive US to the acquisition of an appetitive-based CR (see Table 1).

Three previous studies have reported data on the classical transfer of aversive conditioning to an appetitive excitatory conditioning procedure. Konorski and Szwejkowska (1956) report data indicating that prior leg flexion conditioning retards salivary conditioning to the excitatory CS but not to an inhibitory CS. Unfortunately, a comparison between these two conditions does not permit any conclusion regarding retardation or facilitation of acquisition because there is no baseline control comparison. Moreover, the general lack of control procedures (e.g. non-naive, previously conditioned subjects) inherent in the design of most of these investigations further complicates analysis. More recently, Scavio (1974; Bromage & Scavio, 1978) demonstrated a similar finding using transfer from nictitating membrane conditioning to jaw movement conditioning. Animals receiving forward pairings of pariorbital shock and a CS were retarded in

acquisition of anticipatory jaw movement activity to that CS compared to naive animals or animals pretrained with unpaired CS-shock presentations.

Scavio's (1974) demonstration that forward pretraining with a shock US retards appetitive acquisition compared to naive control animals confirms the prediction that an excitatory aversive stimulus should be slow to acquire response properties controlled by appetitive USs. On the other hand, a facilitatory transfer effect of inhibitory aversive pretraining is not shown by the comparison of an explicitly unpaired condition against the naive control condition. Since the unpaired CS-shock pretraining may be sufficient to endow the stimulus with inhibitory properties (e.g. Rescorla & LoLordo, 1965), facilitated acquistion to the CS might be expected by reciprocal inhibition. There are several reasons why this failure to facilitate is not too damaging to theoretical predictions. First, it is not necessarily the case that the CS was made inhibitory by unpaired pretraining. Independent verification, as provided in Experiment 1 here, is necessary to confirm the success of inhibitory pretreatment. Secondly, Scavio (1974) used a high deprivation condition that not only guaranteed rapid acquisition in the naive control animals, but also provided a ceiling effect against which facilitation would be difficult to demonstrate. Some support for facilitation in the unpaired condition of Scavio's (1974) study is indirectly indicated. Simple preexposure to the CS prior to conditioning with the appetitive US should retard acquisition of a response to that CS (latent inhibition; Lubow & Moore, 1959; see also Siegel, 1972). Preliminary research, not reported here, revealed a latent inhibition effect with the jaw movement preparation. The

suggestion, therefore, is that something about the unpaired condition prevented latent inhibition from occurring. Reciprocal inhibition is one of several mechanisms which might account for reduced latent inhibition by this procedure.

Evidence for an aversive inhibitory transfer effect is presented by Bromage and Scavio (1978). Under moderate deprivation conditions where acquisition was less rapid than the earlier study (Scavio, 1974), unpaired CS/US presentations actually enhanced jaw movement acquisition compared to a non-preexposed condition. This finding is consistent with the inhibitory facilitation expected by reciprocal inhibition. However, again there is no independent evidence that unpaired CS/US presentations produce an inhibitory CS in the nictitating membrane preparation with the particular parameters used. The unpaired condition with these parameters differs only in the regularity of CS and US presentations from the random control condition, which was used as a non-associative control in Experiment 1. As Experiment 1 has shown, random CS and US presentations do not produce an inhibitory CS (see also Hinson & Siegel, 1980). At the very least, the effects of any inhibitory condition must be differentiated from the effects of the random condition in order to attribute any transfer effects to the presence of inhibition.

Experiment 2 addresses the shortcomings of these previous transfer studies with respect to inhibitory transfer. First, the aversive backward conditioning procedure is inhibitory (Experiment 1), thus, comparison of jaw movement acquisition following backward and random presentations of the CS will assess the effect of aversive inhibition against a non-inhibitory aversive control as well as against

a naive control comparison in this straightforward transfer test. Aversive inhibitory facilitation of appetitive acquisition should be evident against both these control comparisons in order to derive clear support for reciprocal inhibition.

Experiment 2 will also serve to replicate Scavio's (1974; Bromage & Scavio, 1978) reports that excitatory aversive conditioning retards acquisition of an appetitive CR to that CS compared to a naive control condition. Moreover, the experiment will compare acquisition of the random control condition against the naive control condition. Since there is evidence that random CS/US presentations reduce CS salience (Mackintosh, 1974; Siegel & Domjan, 1971; Hinson & Siegel, 1980; Experiment 1), this comparison will reveal the extent to which loss of salience will be transferred from one motivational system to another (c.f. Mackintosh, 1974). Finally, comparisons of the excitatory condition to the random condition should show the relative effect of reciprocal inhibition to that expected by mere exposure to the elements of pretreatment.

3.1 Method

3.1.1 Subjects

Twenty, experimentally naive, male, New Zealand white rabbits weighing 3-7 kg at the start of the experiment served as subjects. Each rabbit was individually housed and given free access to Purina rabbit chow throughout the duration of the experiment. In contrast to Experiment 1, water access was controlled as indicated in the procedure section.

3.1.2 Surgical Preparation

Ten to fifteen days prior to the start of the experiment, animals were surgically prepared with a head cap, mounting screw, and cheek cannula. Each rabbit was anesthetized by intravenous injection of Nembutal. A check canula was chronically implanted, following the procedure of Gormezano (1972). The rabbit's skull was bared and the skull cap constructed. In addition, two tungsten electrodes were implanted approximately one cm apart on the lower eyelid of all subjects and chronic wound clips were attached to both the middle of the lower jaw and the upper left eyelid. The sex, weight and surgical preparation of subjects described here was the same for all appetitive transfer studies.

3.1.3 Apparatus

Conditioning took place in one of three sound resistant chambers (Scientific Prototype Model SPO 300) with the rabbit confined in 18 x 14 x 41 cm plexiglas restraining boxes (see Method, Experiment 1). Jaw movement was recorded by a modification of Gormezano's (1972) technique. Briefly, a microtorque potentiometer rested on the side of the animal's head, level with the animal's lower jaw. The potentiometer was attached to a specially designed headmount fixed to a 10-32 x 1" flathead stainless steel screw chronically imbedded in a dental cement skull cap, which was affixed to the rabbit's skull by stainless steel screws. A piano wire extension of the arm of the potentiometer was attached in opposing tension with a woundclip on the rabbit's lower jaw. Jaw movements resulted in a deflection of the arm of the potentiometer causing a dc voltage change, which was amplified and monitered by a Grass Model 7a Polygraph. Outer eyelid responses were recorded via a

string and pulley arrangement, by a separate microtorque potentiometer located on the anterior portion of the headmount and monitored by an independent channel of the polygraph (see Method, Experiment 1).

The appetitive US, a 350 msec, 1 c.c. pulse of tap water, was delivered into the oral cavity via a polyethylene tube canula through the left cheek. A blunted size 14 luer-lok hypodermic needle, inserted directly into the canula, was supplied through Silastic tubing by one of three 2 liter water reserviors located approximately 1 meter above the subject. A solenoid valve controlled the duration, and consequently the volume, of the US. Aversive electric shock USs (100 msec, 2.0 mAmp, 200-V ac) were delivered to each animal through a pair of chronically implanted tantalum wire electrodes and were the same USs as in Experiment 1. The CS was a 1000 msec, 2000 Hz tone, raising the sound level in the chambers from a 56 db ambient white noise level to 72 db. The tone CS emanated from a speaker in the rear of the chamber as in Experiment 1.

3.1.4 Procedure

After the animals had recovered from surgery (10-15 days), they were habituated to the experimental chamber, restraining box, recording apparatus, and both water and shock delivery attachments during the three days prior to the aversive preconditioning phase as indicated in Experiment 1. During aversive preconditioning, the animals were assigned to one of four groups, each of which received a different training condition. Forward animals (FWD, N=5) were given 20 forward paired trials a day for ten days. The CS was a 1000 msec 2000 Hz tone presented with a 100 msec shock and a 1000 msec CS-US interval. Backward animals (BKD, N=5) received the same number of trials and

sessions and the same CS-US parameters except that the CS onset began immediately following US termination. Random animals (RDM, N=5) received the same CS presentations as group FWD and BKD, but the 20 US presentations were programmed independently throughout the session according to a random numbers table. Naive control animals (NPx, N=5) were simply restrained during the ten training sessions. On day 6 of aversive preconditioning, ad lib water availability was discontinued and all animals were placed on a moderate 90cc per day regimen of water deprivation for the remainder of the experiment. Except for the presence of water deprivation on sessions 6-10 and total number of trials per session (20 vs 40), BKD, RDM and NPx animals were treated identically to the training phase of Experiment 1.

On day 11, jaw movement conditioning began with 20 trials a day for 10 days. All animals were given forward jaw movement training with the 1000 msec tone CS paired with the 350 msec 1cc squirt of water directly into the oral cavity. A 1000 msec CS-US interval was used so that the US onset coincided with CS termination.

During all phases of the experiment both eyelid closures and jaw movements were monitored during the 1000 msec pre-CS period, the 1000 msec CS, and the respective US periods. Eyelid closures were recorded if a 2 mm movement of the pen on the polygraph record corresponding to a 2 mm eyelid movement occurred in the direction of closure. Jaw movements were recorded if a 1 mm movement of the pen on the polygraph record corresponding to a 2 mm jaw movement occurred in either direction. Responses during the CS prior to the US onset were scored as responses only if the 1000 msec pre-CS period were free from recorded movements of the respective responses. Although this criterion affected

some animals more than others, the number of discarded trials did not systematically vary between groups.

3.2 Results

3.2.1 Phase 1: Eyelid Conditioning

Both eyelid and jaw movement responses were recorded during eyelid conditioning.

3.2.1a Eyelid Response. Preconditioning eyelid responding showed clear acquisition of the aversive CR in Group FWD. Each group FWD animal maintained at least a 90% eyelid response level in sessions 9 and 10, whereas none of the animals in any other group showed more than a 10% eyelid response (Group BKD responding was not determined because the US preceeding the CS always disturbed the pre-CS and CS recording period).

3.2.1b Jaw Movement. Sessions 9 and 10 of eyelid pretraining also indicate asymptotic preconditioning performance levels of jaw movement responses in groups NPx, RDM, and FWD. Surprisingly, although the eyelid measure clearly differentiates the RDM and FWD treatments as expected, both groups show substantial (e.g., 30-40%) jaw movement responding to the CS during these sessions. In fact, although not significant, there is some suggestion that FWD animals produce more jaw movement than RDM animals. This observation raises the possibility that jaw movement was weakly conditioned during forward eyelid training in contrast to the claim of no conditioning in a similar situation (Scavio, 1974). Conditional jaw movement in response to shock pairings gains further credence in the observation that the level of shock used

reliably elicits both eyelid closure and jaw movement as an unconditional response.

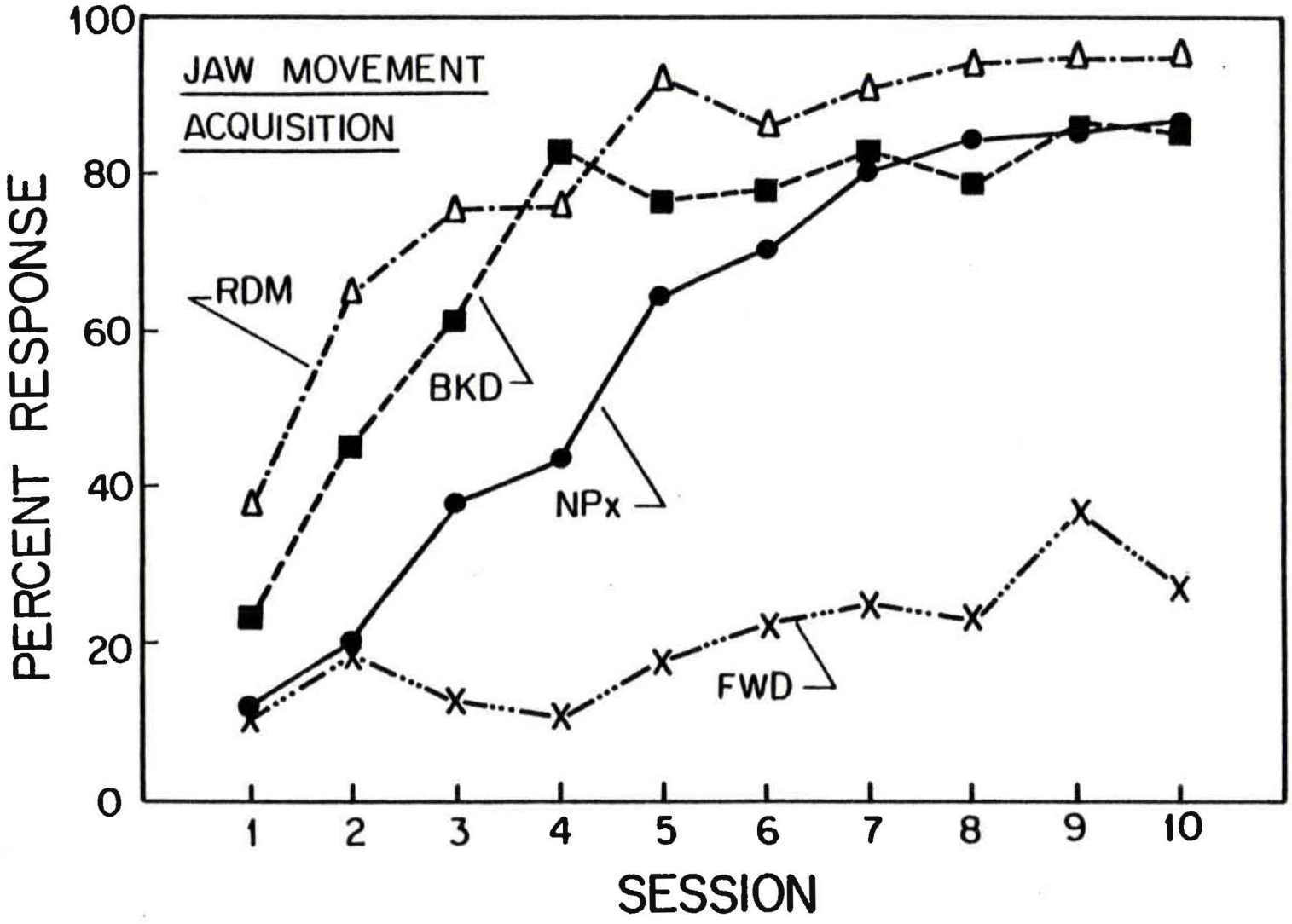
3.2.2 Phase 2: Jaw Movement Acquisition

3.2.2a Jaw movement. Figure 4 shows the mean percent jaw movement CR for each group over the ten sessions of jaw movement acquisition. Both groups RDM and BKD initially acquire higher levels of the conditioned response than the NPx control group. Group FWD, on the other hand, acquires the CR only very slowly and does not catch up to the other groups over the full ten days.

A two way mixed design ANOVA was consistent with these general observations. There were significant Conditions ($F_{3,16} = 16.7$, $p < .001$) Trials ($F_{9,144} = 23.1$, $p < .001$) and Trials x Conditions interaction ($F_{27,144} = 2.39$, $p < .005$) effects. Newman-Keul's comparisons of mean conditional responding over all ten sessions revealed that Group FWD responded less than any of the other three groups. Although these three conditions did not reliably differ from one another overall, the Trial x Condition interaction suggests that different performance levels were present.

In order to further analyze the nature of the data, separate Newman-Keuls tests were conducted on the mean performance during the first half of the conditioning phase and second half of the conditioning phase. As expected, FWD performance was significantly lower than the performance of the other three groups in both tests. Both the BDK and RDM groups evidenced significantly greater response levels than the NPx group in the first half of jaw movement conditioning ($p's < .05$), but not during the second half of conditioning. This comparison indicates

Figure 4: Aversive transfer to the acquisition of an appetitive jaw movement CR.


JAW MOVEMENT
ACQUISITION
PERCENT RESPONSE
100
80
60
40
20
0
RDM
BKD
NPx
FWD
1
2
3
4
5
6
7
8
9
10
SESSION

that BKD and RDM groups both acquired the jaw movement CR more rapidly than the NPX group.

3.2.2b Eyelid Response. Eyelid responding extinguished rapidly in the FWD group over the first two or three sessions. FWD eyelid responding did not exceed 10% in any session after session 2. In contrast to the eyelid conditioning phase, where jaw movement responses intruded during CS presentations, the non-conditioned response for this phase, eyelid closure, did not show any appreciable activity in any group (except the first two or three sessions of Group FWD).

3.2.2c Response Independence Analysis. Whenever the two measured responses occurred together in the same session for an individual animal, response independence was assessed using a χ^2 test (Scavio, 1974; Bromage & Scavio, 1978). None of these tests showed any dependent relationship between the two response measures (all $\chi^2 < 2.0$).

3.3 Discussion

The results of Experiment 2 are consistent with but do not provide conclusive evidence for the reciprocal inhibition theory of appetitive-aversive interactions. As the theory predicts, pretraining an excitatory aversive CS (Group FWD) interferes with the establishment of an appetitive CR to that stimulus compared to a random (Group RDM) or naive (Group NPX) control condition. Moreover, pretraining an inhibitory aversive CS (Groups BKD) facilitates appetitive CR acquisition to that stimulus compared to the naive control condition (Group NPx) as expected by the theory. On the other hand, the results indicate an enhancement of acquisition to the CS pretrained with random

control presentations (Group RDM) compared to the naive control (Group NPx). This effect was not anticipated. Facilitated acquisition in a critical control condition raises serious questions about the source of aversive inhibitory facilitation. Finally, analysis of conjoint occurrences of the two designated CRs during the two phases of conditioning raises some questions about the use of a test for response independence (Scavio, 1974) as the sole means for deciding whether peripheral interactions may account for the above transfer effects.

3.3.1 Aversive Excitatory Transfers

The results of the present experiment confirm the previous reports of Scavio (1974; Bromage & Scavio, 1978) and Konorski and Szwejkowska (1956) that an excitatory aversive CS is slow to acquire an excitatory CR when conditioned with an appetitive US. It should be noted that the comparison of the excitatory aversive group to the random control group is problematic because of the facilitation seen in the random control condition compared to the naive control condition. Nevertheless, a clear differentiation of appetitive acquisition in the transfer phase to the aversive excitatory condition and the random control serves to indicate that aversive excitatory transfer effects are not simply due to non-contingent exposure to the CSs and USs of the pretraining phase.

Logically, the first leg of deciding whether a transfer condition is inhibitory requires only that the putative treatment should be retarded in acquisition against the naive control treatment. This requirement is clearly met by the aversive excitatory treatment in Experiment 2. This finding should be added to other reports as support

for inhibitory transfer for an aversive excitatory CS on an appetitive retardation of acquisition test.

3.3.2 Aversive Inhibitory and Random Transfer

The effect of aversive inhibitory pretreatment on appetitive acquisition is consistent with the expectation of reciprocal inhibition, but, unlike the excitatory instance, clear conclusions are difficult due to the comparison with random pretreatment. In agreement with the suggestion of Bromage and Scavio (1978), pretraining an inhibitory aversive CS (Group BKD) does facilitate appetitive jaw movement conditioning with respect to a naive control condition. The source of this facilitation can not be attributed directly to the presence of aversive inhibition, however, since training an aversive random control (Group RDM) also facilitates jaw movement conditioning with respect to the naive control condition.

The enhanced appetitive acquisition seen in Group RDM compared to the naive control condition not only poses problems for interpreting aversive inhibitory transfer, but also is somewhat surprising against the background of Experiment 1, where random transfer to aversive acquisition is so dramatically retarded, presumably due to salience decrement. Although Mackintosh (1975) suggested that random CS/US inducement of a salience decrement may be US specific, he presents no evidence to suggest enhanced salience to conditioning with a different US. More rapid appetitive acquisition to the aversive random control condition is an interesting and novel result. Several alternative interpretations of the random preconditioning effects found here are possible and will be discussed later (see Random Control Effects, General Discussion).

The failure to differentiate the random control condition from the inhibitory backward condition in this transfer task does not by itself strike a convincing blow to the aversive inhibitory transfer side of reciprocal inhibition. Indeed, the random condition may facilitate jaw movement acquisition by a completely different mechanism than the backward condition, rather than by some common property of the two procedures. If this were the case, then the inhibitory condition would be demonstrably different from the random control on some other transfer tasks.

3.3.3 Independence of Conditional Responses

In addition to addressing the directional predictions of reciprocal inhibition, the results of Experiment 2 are in accordance with the response independence analysis suggested by Scavio (1974). In order to argue that the inhibitory effect of transfer of an excitatory CS from an aversive conditioning procedure to an appetitive conditioning procedure is in fact based on central interactions, it is necessary to rule out the possibility of peripheral response interactions. One method of persuasion is to demonstrate statistically that the two CRs occur independently during the transfer test (Scavio, 1974). The results of this experiment display such independence between the eyelid closure and jaw movement CRs. A second argument against peripheral response interaction interpretation of the present results is the persistence of interference with jaw movement acquisition after the eyelid response had completely extinguished (Session 3-10). Presumably, a response must be present for a peripheral interaction to take place. Thus, according to two separate approaches, the inhibitory effect of an excitatory aversive CS on acquisition of an appetitive conditional

response observed here does not represent a peripheral response interaction between the two CRs.

It should be noted, however, that contrary findings of response dependence on the χ^2 test would not prove conclusively that peripheral response interactions did exist. In fact, if the conditional aversive response reflects activation of a motivational state antagonistic to the appetitively controlled response, we might expect non-independence of the two responses with joint occurances of the two responses being highly unlikely events. This possibility is empirically ruled out here by the significant degree of conjoint jaw movement and eyelid responses occurring during the eyelid conditioning phase and the initial jaw movement conditioning phase of the experiment whenever the two responses occurred in the same session.

One problem raised by this experiment concerns the nature of conjoint eyelid and jaw movement CRs. Sessions 9 and 10 of pretraining reveal a significant level of jaw movement with only aversive training. Tait (1981) also reports a similar aversively based jaw movement response. Conjoint occurrences of the two responses might reflect the joint occurrence of two aversively based CRs rather than dual activation of two motivational states.* Regardless of the motivational basis of

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*Scavio (1974) did not record jaw movement during nictitating membrane conditioning stating that jaw movement did not condition during preliminary investigations of shock training. The contrary presence of possible conditioned jaw movement during eyelid conditioning in the present study may be based on several parameters: 1) the number of days of shock training, 2) the presence of water deprivations during the last five days of shock training, or 3) differences in CS and US intensity or duration. In any case, because these responses were not recorded, the analysis presented here can not be applied directly to Scavio's findings.

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the two responses, the lack of response dependence between eyelid closure and jaw movement still argues against peripheral response interactions as the basis of transfer effects. Response dependence does not, however, necessarily support a peripheral interaction and thus, use of this statistical tool may lead to unwarranted conclusions. In these cases, where response independence is not present, the question of peripheral interaction must be left indeterminant.

The problems raised by this theoretical analysis do not detract from the conclusions derived from this study, however, since two separate analyses support the peripheral response independence of the two designated CRs, eyelid closure and jaw movement, used in the studies reported here. Consequently, the retardation of acquisition to an excitatory aversive CS and the facilitation of acquisition to an aversive inhibitory or random CS can not be attributed to peripheral response interactions. Instead, the effects of aversive transfer to appetitive acquisition, which are essentially congruous with the predictions of reciprocal inhibition, are centrally mediated.

CHAPTER 4: Experiment 3: Aversive Transfer to Appetitive Discrimination Learning

In Experiment 2, the predictions of reciprocal inhibition were tested on direct transfer to acquisition of an appetitive-based CR to the pretrained stimulus. The results were largely consistent with the reciprocal inhibition theory. On the one hand, an excitatory aversive CS disrupted acquisition of the appetitive CR compared to control conditions. On the other hand, an inhibitory, aversive CS enhanced acquisition compared to the naive control condition, but not compared to the random control condition which itself acquired more rapidly than the naive control condition. Experiment 3 was designed to further analyze the basis of these transfer effects on a compound stimulus test.

Experiment 3 used the transfer to discrimination design of Experiment 1 to test the effect of aversive pretraining on the performance of appetitive conditional inhibition to the pretrained CS. The purpose of this transfer study was twofold. First, the discrimination design permits a summation test assessment of the assumed inhibitory nature of excitatory aversive transfer seen in the direct effects on appetitive acquisition. Second, the design permits a summation test assessment of the assumed facilitatory effects of inhibitory aversive transfer.

4.1 Excitatory Aversive Transfer

Retardation of appetitive CR acquisition to an excitatory aversive CS supports the conclusion that the aversive CS is inhibitory in the appetitive system. However, other reasonable accounts of such

interference can be based on stimulus habituation or decrements in stimulus salience to the CS, which would also retard CR acquisition. Such salience decrement accounts must be ruled out to make the more powerful inhibitory conclusion. In recognition of this ambiguity, two tests have been widely adopted as the defining criteria for determining whether or not a putative inhibitory pretraining procedure does, in fact, produce an inhibitory CS. Positive outcomes on both the retardation of acquisition test and the summation test minimally are necessary to eliminate salience or attentional accounts of inhibitory phenomena (Rescorla, 1971a; Hearst, 1972; see Section 1.4). The retardation of acquisition test achieved the desired result in Experiment 2. Also, this test has received supporting confirmation in many operant conditioning procedures which can not control so carefully for peripheral interactions (see Dickenson & Pearce, 1977 for a review).

A demonstration of the summation test of an excitatory aversive CS compounded with an excitatory appetitive CS, however, has not been reported in a procedure unconfounded by peripheral response interactions. A positive result on this test would be shown by a reduction in the magnitude of conditioned responding to the appetitive CS when it is presented together with the aversive CS as a compound stimulus. The argument is as follows: if the aversive CS retards jaw movement CR acquisition because of salience decrement of the CS with respect to the water US, then the aversive CS should have little effect on responding to another stimulus when the two are presented in compound. If, on the other hand, retardation occurs because of a response tendency opposite in direction to the appetitive CR (definition

of inhibition, Rescorla, 1971), then combining the two CSs in a summation test would reduce noticably the magnitude of the appetitive CR which would be seen normally when the appetitive CS had been presented alone.

In operant-Pavlovian transfer studies considerable evidence is available to support the summation effect. In fact, every conditioned emotional response experiment is a summation test where an aversive CS is imposed on appetitive operant behaviour (Estes and Skinner, 1941). Indeed, many of the theorists advocating the reciprocal inhibition position (e.g. Rescorla & Solomon, 1967) were mainly interpreting the suppression of appetitive behaviour by a signal for an aversive outcome in deriving their formulation. Literally, such response suppression must represent an opposite response tendency, but, alternative peripheral response interaction interpretations of the suppression seen in conditioned emotional response studies are easily constructed (Trapold & Overmier, 1972) and are not consistent with the central conotation usually attributed to inhibitory phenomena. It is these potential peripheral response interactions that confound interpretations of reciprocal inhibition by mutually antagonistic motivational systems. The aversive suppression of appetitive conditional responding necessary for a positive result on the summation test has not been reported in a conditioning preparation where the conditional responses can be shown to be peripherally independent. Thus, the central Pavlovian basis for interpreting conditional suppression results can be contested.

The design of the present experiment looked at the effect of aversive pretreatment conditions on the acquisition of a Pavlovian appetitive discrimination with the aversively pretrained CS used as the

inhibitory component of an A+,AB- procedure (see Excitatory and Inhibition Transfer to Discrimination Learning, p. 36). To recapitulate briefly, this transfer test involves following various preconditioning treatment with discrimination training. A novel CS, A+, is reinforced on half the trials and not reinforced on the other half of the trials when the pretrained stimulus is present, AB-. Early in the development of conditioned responding to the A+ stimulus, a comparison to response rates on the AB- trials provides a summation test of any inhibitory properties of the B stimulus. At the outset of measurable conditioning the inhibitory stimulus should reduce the magnitude of appetitive CRs on compound trials. Moreover, this initial inhibitory tendency should, of course, facilitate discrimination performance relative to control conditions.

The excitatory preconditioning group would therefore be expected to show lower response rates on compound AB- nonreinforced trials than on A+ reinforced trials not only during the acquisition of the discrimination but also as soon as conditional responding appears on the reinforced trials. Such a result would confirm the summation test prediction of the inhibitory transfer of aversive excitatory conditioning to appetitive based Pavlovian conditioning. Furthermore, such a result in conjunction with the retardation of acquisition found in Experiment 2 is not easily accounted for by any non-inhibitory interpretation of transfer phenomena.

4.2 Inhibitory Aversive Transfer

The A+, AB- discrimination procedure also should clearly indicate prior excitatory appetitive conditioning to the negative or B

element. Facilitation of appetitive responding to the B element by preconditioning would be revealed by higher levels of AB- trial response compared to control conditions. Reciprocal inhibition theories would expect the inhibitory aversive condition to produce higher levels of AB- responding than either the random or naive control conditions. Of course, discrimination acquisition would also be expected to be slower than in control conditions.

This experiment represents a second attempt to differentiate the backward (inhibitory) and random control conditions in their transfer effects on appetitive tasks. In Experiment 2, both groups facilitated direct acquisition of the appetitive CR. Facilitation of CR acquisition may result from several sources: one source might be an associative activation of the appetitive motivational center, but, as we have argued for the inhibitory-side of crossmotivational transfer, salience effects can also facilitate or retard CR acquisition. In the case of facilitation of acquisition, no less than in the case of retardation of acquisition, a summation test is necessary to decide whether a salience account of transfer effects is viable or an associative transfer effect must be assumed. Since in an A+, AB- discrimination no opportunity to acquire appetitive conditioning is available to the B element, any aversive inhibitory enhancement of conditional responding seen on AB- trials compared to control conditions would support the assumption of aversive inhibitory activation of the appetitive motivational center as expected by reciprocal inhibition. This finding would rule out a simple enhanced salience account of the enhanced acquisition seen in the inhibitory aversive trasnsfer to appetitive acquisition.

4.3 Method

4.3.1 Subjects and Apparatus

The 22 rabbits used in Experiment 3 were housed and maintained as described in Experiment 2. Surgical preparations and the eyelid and jaw movement conditioning procedures were also identical to those in Experiment 2 with the exception of the procedural modifications described here.

4.3.2 Procedure

After surgery, recovery and three days habituation in the chambers, the animals were randomly assigned to one of four groups which differed only with respect to their experience with the tone and shock during the ten session aversive preconditioning phase. One group of subjects (N=5) received forty trials per session of the tone paired with the shock as in Experiment 2 Group (FWD). A second group (N=5) received forty trials per session where the tone immediately followed shock termination, that is, backward conditioning (Group BKD). A third group (N=6) received forty tone presentations per session at approximately the same time as the first two groups but the forty shock presentations were occurred randomly throughout the session (Group RDM). Finally a fourth group (N=6) was simply restrained during these sessions with neither the tone nor the shock presented (Group NPx). All tone CSs were prsented at 1.0, 1.5, 2.0 min intertrial intervals according to a semi-random schedule. This aversive preconditioning phase, with the exception of adding the FWD group, was identical to that employed in Experiment 1.

During the five appetitive discrimination training sessions, which followed the aversive preconditioning phase, a light CS was introduced as the appetitive conditional excitor. The light CS (see

Procedure of Experiment 1) consisted of a one sec termination of the overhead light which illuminated the interior of the conditioning chamber. On the twenty positive conditioning trials in a given session the light CS was always followed immediately by the 350 msec, one cc pulse of water into the rabbit's oral cavity. On the twenty negative, inhibitory conditioning trials the light CS was presented simultaneously with the one sec tone which had been used during the aversive preconditioning phase. On these tone-light negative trials no water US was delivered. The order of positive and negative trials was randomly determined with the constraint that no more than three presentations of one trial-type occurred consecutively. Constraining the random sequence was done to minimize the possibility of response sets developing. Only eyelid closures were monitored in the preconditioning phase. Both eyelid closures and jaw movements were monitered throughout the discrimination phases.

4.4 Results

4.4.1 Eyelid Conditioning

All animals in Group FWD evidenced a 90% or better eyelid closure CR on days 9 and 10 of pretraining. This compared with a less than 10% level of responding in all control animals.

4.4.2 Discrimination Acquisition

The two measures of discrimination acquisition used in Experiment 1 were calculated for the transfer phase in Experiment 3 and are shown in Figure 5a and 5b. Difference scores were obtained by subtracting percent response on negative trials from percent response on

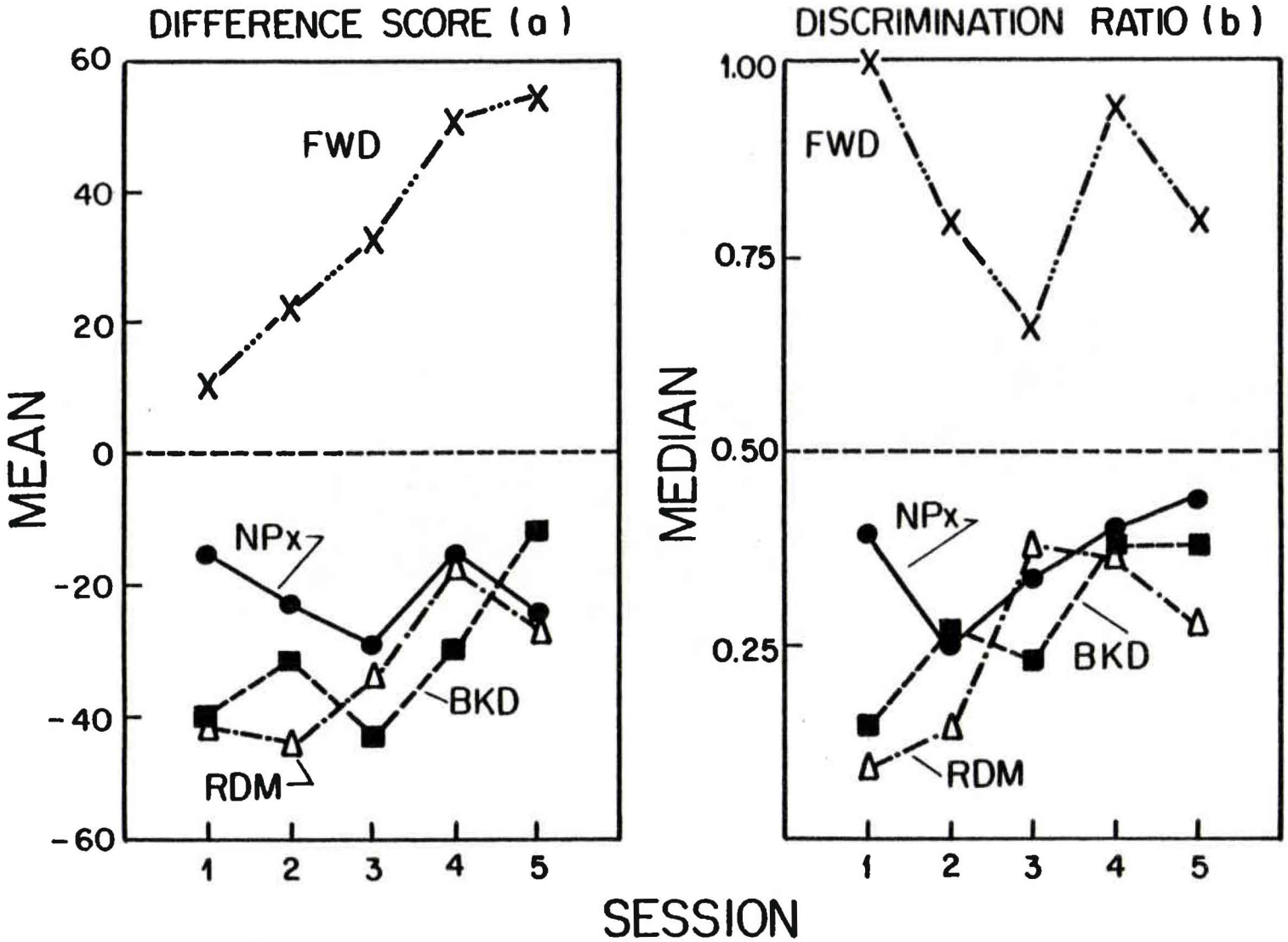
positive trials. Discrimination ratios were calculated by dividing percent positive trial response by percent total response (see p. 40).

Difference score measures (Figure 5a) show an orderly acquisition of the discrimination in the initial five sessions for only Group FWD. None of the other three groups show any apparent acquisition of the discrimination during these sessions. In fact, all three of the other groups reveal higher response levels on the negative light and tone compound trials than on the positive light alone trials. There is a slight indication that the initial difference scores show more comparative responding in the RDM and BKD groups than the NPx group.

Median discrimination ratios (Figure 5b) show an almost identical pattern of results. However, in contrast to the difference score measures, Group FWD levels of performance did not improve over the five sessions of discrimination acquisition. If any trend was present, the performance of Group FWD seems to deteriorate over training (non-significant). As indicated earlier (p. 40), this difference between the two measures probably reflects the sensitivity of the difference score to the absolute level of positive trial responding, whereas the discrimination ratio is sensitive to the relative response levels (see also, Positive Trial Acquisition, below).

The difference score was statistically analyzed by a two-way ANOVA with repeated measures on one factor (Sessions). Highly significant group ($F_{3,18} = 17.01$; $p < .001$) and sessions ($F_{4,72} = 6.42$; $p < .001$) effects were found. No reliable interaction effect was found ($p > .1$). Newman Keul's comparisons on five session total responses revealed Group FWD differed from all other groups over all

Figure 5: Difference score and discrimination ratio measures of aversive transfer to appetitive discrimination training.


DIFFERENCE SCORE (a)
DISCRIMINATION RATIO (b)
MEAN
MEDIAN
60
40
20
0
-20
-40
-60
1.00
0.75
0.50
0.25
FWD
NPx
BKD
RDM
1
2
3
4
5
SESSION

sessions (all ps < .025). Groups BKD, RDM and Group NPx, however, did not differ.

Because of the potential problems inherent in calculating ANOVAs with ratio measures of random variables, the predictions for the discrimination ratio were analyzed with comparisons using the Mann-Whitney U test. Although this method for assaying differences may be sensitive to a greater than .05 Type II error, these tests mainly confirmed the pattern of results obtained with the difference score measure. On examining average discrimination ratios over all five sessions, Group FWD showed better discrimination ratio performance than any of the other three groups [all U (5,6) or U (5,5) = 0; $p < .01$]. The BKD, RDM and NPx groups did not differ in five session average discrimination ratios.

In order to confirm the initial superiority of the FWD group and in view of the apparent initial differences between the NPx and BKD or RDM groups (Sessions 1 and 2, Figure 5b), the difference ratios for individual sessions were analyzed using Mann-Whitney U tests. On session one, the Mann-Whitney U tests reveal significant differences between group NPx and all other groups (FWD, U (5,6) = 3, $p < .025$; RDM, U (6,6) = 30, $p < .05$; and BKD, U (5,6) = 25, $p < .05$). On session two, group RDM differred from group NPx (U (6,6), = 30, $p < .05$), but group BKD did not. Group FWD differed from all other groups on each session (all U (5,6) or U (5,5) < 4, ps < .025). No other pairwise differences were significant. These individual session tests confirm the superior discrimination performance of Group FWD. Some support is also found for an initial tendency to higher relative response rates on the <u>negative</u> compound trials in both the BKD and RDM groups compared to

the NPx group. This latter observation, however, is not based on a conservative test nor is it confirmed statistically in the difference score measures. Thus, it should be viewed as tentative.

4.4.3 Positive Trial Acquisition

In order to further analyze the data, individual two-way ANOVAs (Group X Sessions) with repeated measures on the Sessions factor were calculated for performance on positive trials and on negative trials.

Figure 6 depicts the orderly acquisition of jaw movement to the positive light CS over the five training sessions. Each of the four groups acquires some conditional jaw movement during discrimination training. This result is supported by a significant Sessions effect ($F_{4,72} = 25.0$, $p < .001$). Moreover, each individual animal performed at a higher level on Sessions 4 and 5 than on Sessions 1 and 2. Group FWD appears to perform the conditional response at a higher level than the other three groups. Unfortunately the ANOVA revealed no significant Group X Sessions interaction ($F_{12,72} = 1.2$, NS) nor Group effect ($F_{3,18} = 1.7$, NS).

4.4.4 Negative Trial Performances

Figure 7 shows the negative trial response over the five discrimination sessions. The figure clearly illustrates the compound trial response suppression of Group FWD compared to the other three Groups. The suppression of jaw movement by the aversive tone in Group FWD is even more evident when compared to the slightly enhanced Group FWD performance shown on the positive trials (cf Figure 6). In contrast, Groups NPx, RDM and BKD presented more responding on the negative compound trial than on the positive trials (cf Figure 6 and negative scores in Figure 5a and 5b).

Figure 6: Acquisition of jaw movement CRs on positive trials during aversive transfer to appetitive discrimination training.

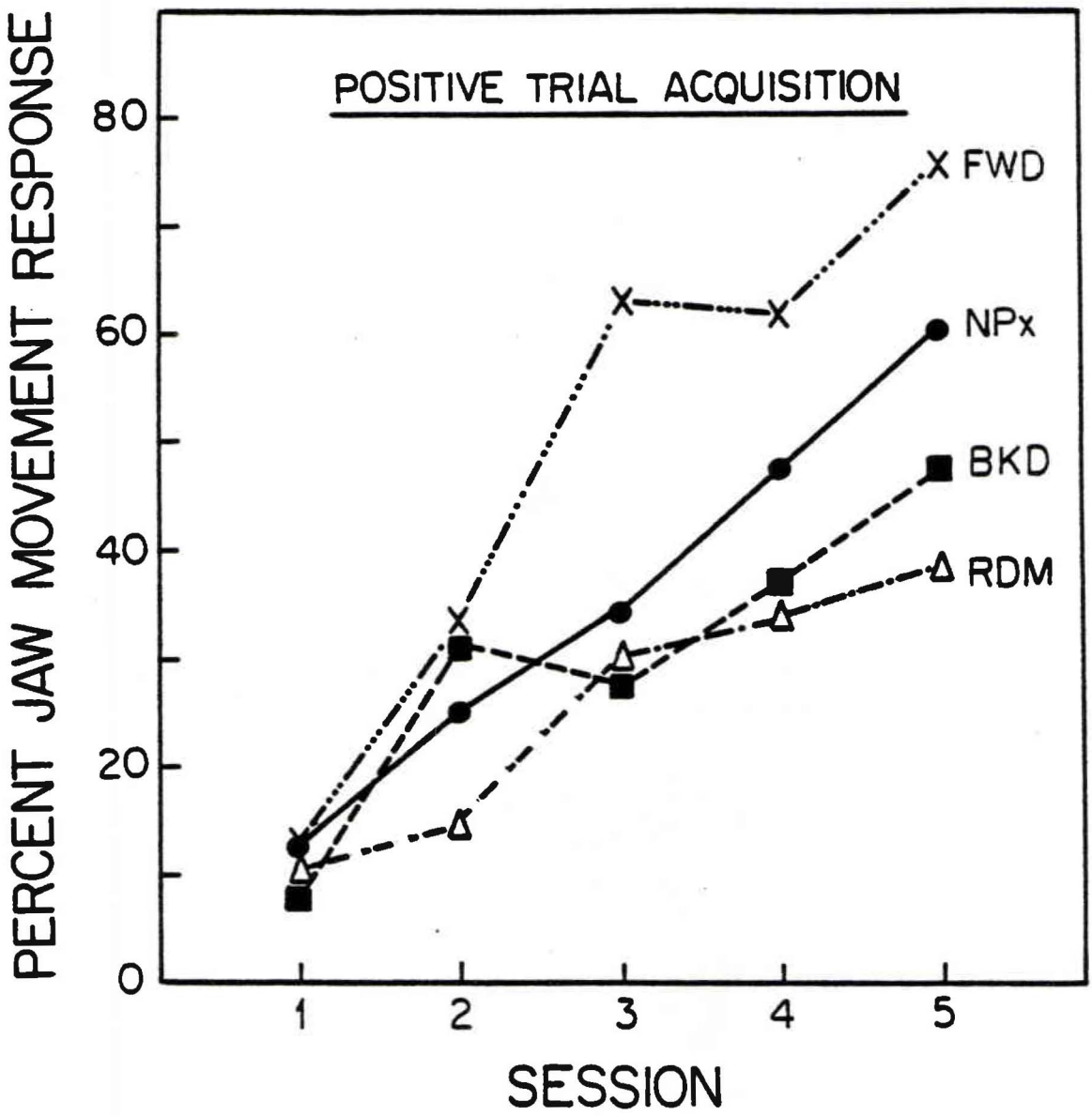
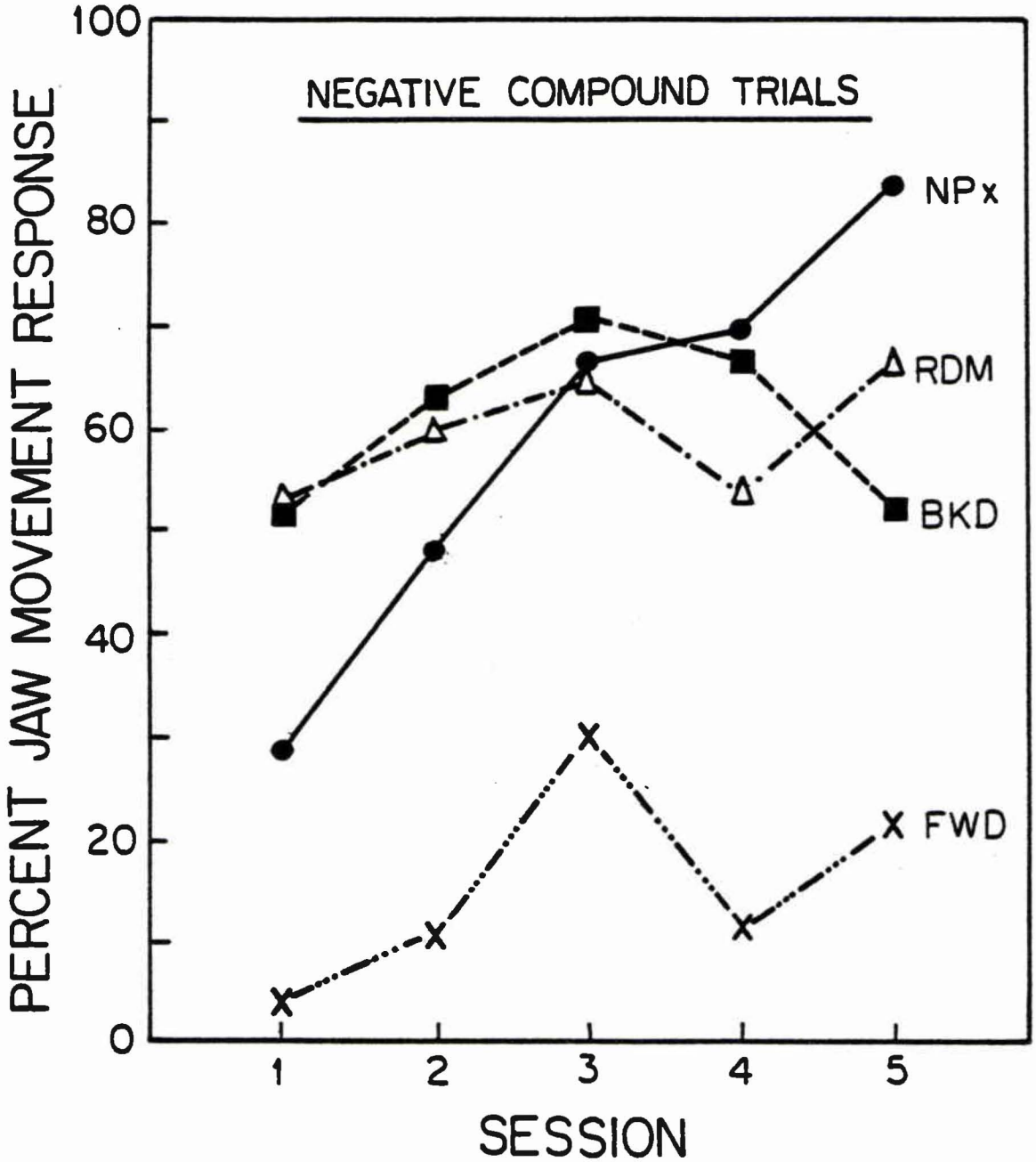

POSITIVE TRIAL ACQUISITION
PERCENT JAW MOVEMENT RESPONSE
0
20
40
60
80
1
2
3
4
5
SESSION
FWD
NPx
BKD
RDM

Figure 7: Jaw movement response on negative compound trials during aversive transfer to appetitive discrimination training.


NEGATIVE COMPOUND TRIALS
PERCENT JAW MOVEMENT RESPONSE
100
80
60
40
20
0
1
2
3
4
5
SESSION
NPx
RDM
BKD
FWD

Newman Keul's comparisons, based on a one way ANOVA of mean performances over all five sessions, differentiated Group FWD ($p < .01$) from all other Groups which did not differ from one another. This lack of a difference between Groups NPx, RDM and BKD was present even on a non-conservative Session by Session analysis, despite the observation that initial discrimination ratios (Figure 5b) did differ.

4.4.5 Eyelid Data

The eyelid response rate in each Group FWD animal decreased rapidly during Sessions 1 and 2 and did not show any appreciable activity (i.e. more than 10%) on Session 3, 4 and 5. The χ^2 analysis of jaw movement and eyelid responding showed no dependent relationship between the two on either Session 1 or 2. These analyses were performed only on the negative trials because no eyelid closure responses were observed on positive trials.

4.5 Discussion

4.5.1 Excitatory Aversive Transfer

The observed effects of excitatory aversive transfer to the B element in an appetitive A+; AB- discrimination are clearly consistent with the expectations of reciprocal inhibition. The presence of a pretrained aversive stimulus on negative trials suppresses the performance of the appetitive jaw movement response from the outset of training and throughout the acquisition of positive trial responding (Group FWD). Indeed, the presence of an antagonistic suppression of responding to the negative compound trials in the first and all subsequent sessions of discrimination training provides positive confirmation of the summation test for inhibition of Pavlovian

appetitive conditioned responses. Taken together with the retardation of acquisition results reported by Scavio (1974) and in Experiment 2, these findings argue for the existence of a centrally mediated inhibition of appetitive conditional responding by Pavlovian aversive CSs, as suggested by current theories of motivational interactions.

The central mediation of this summation test result is confirmed by an analysis of joint occurrences of the jaw movement and eyelid responses. No dependent relationship was observed. Moreover, the observed suppression of responding did not disappear as the conditional eyelid responding extinguished over appetitive discrimination training sessions. An explanation of response suppression by peripheral interactions would predict a decreased effect as the aversive consumatory CR extinguished. A central preparatory CR (i.e. fear), however, would be expected to persist after the consumatory CR had been extinguished (Konorski, 1967). Consequently, both the persistence of the suppressive effect after eyelid responding had ceased and the lack of any dependent relationship between the two CRs support a central interpretation of aversive inhibitory transfer onto the appetitive discrimination.

The aversive CS suppression of conditional responding is substantial in view of the tendency of naive animals (Group NPx) to respond more to the negative compound trials than to the positive trials over all five discrimination sessions. This higher response tendency on negative trials is also seen in the inhibitory (Group BKD) and random control (Group RDM) conditions. Although these observations are troublesome for interpreting discrimination performance in these three groups, their comparison with the excitatory aversive condition

indicates that the response suppression observed here is based on the presence of an excitatory aversive CS rather than some nonspecific effect of CS or US exposure during the preconditioning phase.

4.5.1a Protection from extinction: As noted in Experiment 1 the inhibitory view of the excitatory aversive tone for appetitive conditioning predicts a higher rate of response on the positive reinforced trials during discrimination acquisition in group FWD. Because the aversive tone in this group was inhibitory for appetitive conditioning, its presence on negative trials should protect the light stimulus from loosing associative strength due to nonreinforcement on the negative compound trials by reducing the discrepancy between the expected and actual trial outcome. Such protection from extinction by a conditional inhibitor is predicted by the Rescorla-Wagner model and was suggested as one explanation of differential acquisition in Experiment 1 (see p. 47). In fact, several East European investigators have reported the existence of a similar phenomenon in both appetitive (Soltysik, 1960 and Chorazyna, 1962) and aversive (Soltysik, 1963; 1979) procedures. According to our adaptation of the Rescorla-Wagner model for appetitive aversive interactions, the presence of the aversive CS on negative compound trials should serve to lessen the discrepency of the trial outcome and reduce the amount of extinction which would occur. This would be expected to maintain a higher level of performance on positive trials. Facilitation of positive trial performance in the excitatory aversive condition is not shown by conventional analysis of performance in Group FWD compared to all other conditions; however, there is a trend in the predicted direction, which while not support for the current

analysis would be consistent with the application of the Rescorla-Wagner model to reciprocal inhibition.

4.5.2 Inhibitory and Random Control Effects

Interpretations of the effects of inhibitory aversive and random control preconditioning are complicated by the performance of the naive control condition (Group NPx). There is no direct evidence that the naive control animals acquire any inhibition to the tone during the five training sessions. As a result, no appropriate baseline is available to compare the predictions of inhibitory aversive transfer against.

One confounding variable found in the present study is the apparent presence of pseudoconditioning on the negative trials. Pseudoconditioning is the increased tendency to emit the designated CR in the presence of a CS which has not been paired contiguously with the US. Pseudoconditioning has often been observed to the tone stimulus in jaw movement conditioning (Sheafov & Gormezano, 1972; Sheafor, 1975). The higher response level seen on negative compared to positive trials in Groups BKD, RDM and NPx (indicated by discrimination measures, cf Figures 5a and 5b) would be representative of pseudoconditioning to the tone CS. There is some indication that the initial discrimination ratios of Groups BKD and RDM are more negative than those of Group NPx. However, the fact that the effect rapidly diminishes as conditioned responding develops to the light suggests that the effect is primarily localized to an enhancement on the initial pseudoconditioned responding to the tone in the BKD and RDM groups.

Although the enhancement of appetitive pseudoconditioning by inhibitory aversive training is consistent with an interactive interpretation, it can not be determined from this experiment whether or

not such enhancement would translate into the anticipated retardation of discrimination learning since it seems that the presence of pseudo-CRs masks any acquisition of the discrimination over the five training sessions.* More importantly, however, the potential role of aversive conditional inhibition is questioned by the lack of any difference between the BKD and RDM group at any stage of discrimination training. Thus, as in Experiment 2, the facilitation predictions of reciprocal inhibition for the transfer of aversive inhibition to appetitive conditioning are only inconclusively supported.

The enhancement of appetitive pseudoconditioning in both the RDM and BKD conditions may provide a partial explanation of the facilitation of jaw movement acquisition found in Experiment 2. However, whereas facilitation of acquisition is pronounced over the first five sessions of training in Experiment 2, in Experiment 3 pseudoconditioning enhancement dissipates after the initial session. This suggests an additional associative factor may be operating to produce the results of Experiment 2.

4.5.3 Discrimination Training as a Test of Inhibition

Both Experiment 1 and Experiment 3 showed that transfer onto the acquisition of an A+; AB- discrimination is an effective method of detecting inhibition. The logic behind employing this design is that inhibitory transfer should be revealed by greater suppression of responding on AB- trials when compared to control conditions. Control

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*In the first replication, groups NPx and BKD received fifteen sessions of training on the discrimination. Each group revealed only marginal acquisition. Since the only major effects occurred early in training, I decided not to extend training in the other groups or in the second replication.

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comparisons were necessary because the discrimination training itself would be expected to make the B element an inhibitory CS. In both experiments, the suspected inhibitory condition produced an enhanced suppression on negative trials compared to both a random and naive control condition.

Of the two discrimination measures used to analyse inhibition, the discrimination ratio is preferred in both studies. The ratio measure is a better indicator of response suppression early in training when the small number of CRs limits the size of the difference score measure. As shown in a comparison of Group FWD performance in Figure 5a and 5b, a strong supression is revealed in the ratio measure, while only a slight positive difference is observed on the difference score. Discrimination acquisition as seen in the difference score measure accurately mirrors positive trial acquisition in Group FWD. This measure may provide a good indication of the level of discrimination performance, but it obscures the high level of inhibition in initial acquisition which may be seen through the ratio measure.

Both experiments also suggest a potential effect of inhibitory pretraining on positive trial acquisition. In Experiment 1, aversive CR performance to the positive trial stimulus is greater following backward inhibitory pretraining than following random control pretraining. In Experiment 3, there is a trend suggesting appetitive positive trial performance is greater in the excitatory aversive group than in either the random or the naive control groups. Both these findings are consistent with an interpretation based on the inhibitory stimulus effecting positive trial acquisition through greater protection from extinction on negative compound trials. Although these effects in

each case are not very powerful, their presence may be a secondary source of confirmation of the A+, AB- test for inhibition to the B element.

As a test for inhibition, the A+, AB- discrimination performs essentially the same function as the traditional summation test. It rules out the reduced salience account of the retardation of acquisition test. The discrimination test, however, combines the two phase summation test into a single test phase. Although this may not imply that the discrimination test is superior to the summation test as an inhibitory assay, the fact that it is simpler to conduct and provides reasonably interpretable and robust results (particularly with the discrimination ratio measure) certainly recommends its consideration as an alternative.

CHAPTER 5: Experiment 4: Aversive transfer to compound stimulus acquisition

Experiments 2 and 3 established that an aversive excitatory CS controls a response tendency opposite in direction to an excitatory appetitive stimulus, that is, suppression of appetitive CRs on a summation test and retardation of acquisition of appetitively based conditional responding. These effects were present both in comparison with a naive and a random control condition. These experimental tests were necessary to eliminate alternative attentional explanations of excitatory aversive transfer effects and, thus, were critical to the conclusion that the aversive CS is inhibitory for appetitive responding. Moreover, the nature of jaw movement and eyelid closure conditioning preparations eliminates the peripheral response interaction account as a reasonable alternative to central mediation of the antagonistic interaction (Scavio, 1974; see Discussion, Experiment 2).

Suppression of conditional responding and retardation of acquisition, although a defining characteristic of conditional inhibition, are not the only properties of a conditional inhibitor suggested by the Rescorla-Wagner model. Indeed, the model makes several counterintuitive predictions for inhibitory transfer in certain circumstances (Wagner and Rescorla, 1972). One of these is protection from extinction which may have contributed to the results observed in Experiments 1 and 3. Other formulations would not have predicted a reduced impact of nonreinforcement caused by the presence of an inhibitory CS.

One intention of the present experiment was to investigate another counterintuitive prediction of reciprocal inhibition based on an application of the postulates of conditional inhibition derived from the Rescorla-Wagner theory.

5.1 Excitatory Aversive Transfer:

The present experiment tests the effects of an aversive excitatory CS as a component of a compound stimulus used in appetitive acquisition. Essentially, this approach is designed to extrapolate previous findings with explicitly established conditional inhibitors to aversive-appetitive transfer studies and test for a functional similarity between the two. Testing whether excitatory aversive transmotivational inhibition is similar to inhibition expected by a negative relationship with the appetitive US serves several purposes. First, it provides a fruitful approach to extending our knowledge of appetitive-aversive transfer effects. Second, it would determine the extent to which our adaptation of the Rescorla-Wagner formulation accurately predicts new phenomena. Finally, demonstrating a functional similarity between transmotivational inhibition and conditional inhibition in other transfer tasks would add supportive evidence for the hypothesis that the mechanism of inhibitory transfer effects is the same for both sources.

One unique area that the Rescorla-Wagner model makes predictions distinctive from most other theories is in the effectiveness of reinforcement and non-reinforcement to an associatively neutral stimulus presented in compound with a conditioned inhibitor. According to the theory, a novel stimulus reinforced in compound with an established inhibitory stimulus will condition more rapidly than if the novel stimulus were reinforced by itself. Rescorla (1971b) termed this

inhibitory effect 'superconditioning'. Superconditioning has been demonstrated successfully with an inhibitory exteroceptive CS in CER conditioning (Rescorla, 1971b) and with an inhibitory odour in taste aversion learning (Tauklis & Revusky, 1975). Thus, inhibition produced by an excitatory aversive CS may do more than control conditioned suppression of appetitively based responding: an aversive CS also might enhance conditioning to concurrently occurring stimuli which are reinforced by an appetitive US.

In a recent appetitive-aversive transfer study Dickenson (1977) reports the enhancement of CER performance to a test stimulus by presenting a conditional excitor for food concurrent with the test stimulus during training. This finding, he argues, is evidence for an inhibitory interaction between an excitatory appetitive CS and Pavlovian aversive responding. Although Dickenson's study is not directly relevant to the present aversive to appetitive transfer experiment, our formulation of the reciprocal inhibition theory would expect this result.

The theory also predicts that an aversive conditional excitor would enhance acquisition to an appetitive excitor if the two CSs were appetitively reinforced in compound. The logic in both cases is the same. The presence of an excitatory CS from one motivational state would be inhibitory during acquisition in the opposite motivational state. In compound conditioning, the presence of inhibition on the compound reinforced trial would increase the discrepancy between expected and actual trial outcome. According to the Rescorla-Wagner model, a larger discrepancy will result in more acquisition in associative strength on the compound trial. This more rapid acquisition

should be apparant in the comparison between a group with a novel CS reinforced alone and a group with a novel CS reinforced in conjunction with an inhibitory CS. In the present context, this inhibition for appetitive system would be expected by the presence of an excitatory aversive CS.

Fowler and his colleagues (see Fowler, 1978) report some data that directly support a transmotivational enhancement of appetitive acquisition. In Fowler's preparations an appetitive operant discrimination task is learned in the presence of stimuli, which had, in the past, been presented to the animal either positively correlated (excitatory), negatively correlated (inhibitory*), or uncorrelated (random*) with an aversive shock US. Under some circumstances, the positively correlated with shock group learned the discrimination more rapidly than either the negatively correlated or uncorrelated with shock groups. Fowler argues convincingly that this transmotivational enhancement ocurs as a result of compound conditioning where the presence of the aversive CS actually improves the rate of appetitive conditioning to the positive stimulus element of the A+;B- discrimination.

Without going into detail, this argument is based on the fact that, contrary to simple expectation, the presence of a positively correlated aversive CS enhances acquisition when placed in compound with the positive element of the appetitive discrimination. This would occur if the presence of the aversive excitatory CS were inhibitory for the

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*It is unclear what the final outcome of these two treatment procedures were, since they were not independently assessed.

appetitive system. As Dickenson (1977) suggests for motivational transfer in the opposite direction (appetitive to aversive), Fowler (1978) suggests such inhibition would enhance appetitive conditioning to the positive element of the discrimination. This Pavlovian enhancement would, then, be the basis of more accurate discrimination performance.*

Although Fowler's analysis of his discrimination data is consistent and compelling, no direct evidence demonstrates that the postulated transmotivational enhancement of Pavlovian appetitive conditioning does, in fact, occur. The design of the present study permits a straightforward assessment of the aversive Pavlovian to appetitive Pavlovian enhancement predicted by reciprocal inhibition. Transmotivational enhancement of appetitive Pavlovian conditioning to a novel CS reinforced in compound with an aversive CS would strengthen Fowler's interpretation of aversive transfer to appetitive discrimination training. More importantly, such transmotivational enhancement would be similar to the "superconditioning" reported in compound conditioning with an inhibitor established in the same motivational system. The similarity between these two phenomena would argue strongly in favour of the application of the Rescorla-Wagner discrepancy model to reciprocal inhibition.

5.2 Inhibitory Aversive Transfer

The transfer to compound acquisition provides another test of the facilitatory role proposed for aversive inhibitory CSs in appetitive

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*Although this rendition does not do justice to the elegant experimentation and theoretical analysis of Fowler's group, it is sufficient for the current application to Pavlovian transfer.

conditioning. In contrast to the enhanced appetitive acquisition expected to a novel CS reinforced in compound with an excitatory aversive CS, an inhibitory aversive CS would be expected to block (Kamin, 1969) appetitive acquisition to a novel CS reinforced in compound with it. According to our reciprocal inhibition formulation, the presence of an inhibitory aversive CS would reduce the discrepancy between the actual and anticipated outcome on a compound reinforced trial. Thus, the change in associative strength to the novel CS would be less than if the novel CS were reinforced alone or if it were reinforced with a random control CS.

Fowler (1978) and his colleagues also have presented evidence that the presence a negatively correlated (inhibitory) aversive CS does, in fact, reduce the rate of acquisition in an operant discrimination task compared to naive and random control conditions. According to an argument similar to the one outlined above, Fowler (1978) has interpreted this result as support for transmotivational blocking. This evidence is the best available at present in support of the facilitatory role of aversive inhibition in the appetitive system.

The present study will replicate the blocking design of Fowler and his associates, but in a strictly Pavlovian preparation. Moreover, in contrast to previous investigations, the aversive inhibitory condition and random control condition used here have been tested for their associative properties (Experiment 1). Blocking would be clearly supported by a lower level of acquisition to the novel CS when reinforced in compound with the aversive inhibitory CS than when reinforced in compound with the random control CS or a non-preexposed CS. The naive control group is an essential comparison, since the mere

presence of an additional stimulus on compound trials is sufficient to reduce conditioning to the other CS (overshadowing; Pavlov, 1927; Kamin, 1969). Transmotivational blocking would only be supported if the inhibitory aversive CS suppressed acquisition to the other CS more than overshadowing by a similar CS. Such aversively based disruption of appetitive compound conditioning would support Fowler's interpretation of negatively correlated aversive transfer to operant appetitive discrimination learning. Transmotivational blocking in the Pavlovian to Pavlovian preparation used here would also provide the first unequivocal evidence that aversive inhibition is facilitatory for the appetitive motivational system. Finally, a clear demonstration of transmotivational blocking would provide independent support for the Rescorla-Wagner model application to reciprocal inhibition.

5.3 Pilot Study

In an initial attempt to demonstrate the effects of prior aversive preconditioning on compound acquisition to a novel CS, a pilot study explored acquisition to a light CS which was reinforced 80% of time in compound with the tone CS used in aversive preconditioning and 20% of time alone. It was anticipated that the impact of compound reinforcement could be measured by the strength of responding on light alone trials. This procedure, in fact, turned out to be very efficient in establishing a CR to the light in all preexposure conditions; but did not demonstrate any significant differences in the strength of responding to the light between training conditions.

Although the pilot study was unsuccessful in producing the outcome expected by reciprocal inhibition, this failure could be

reasonably interpreted as a ceiling effect since all groups acquired to the novel light CS very rapidly. There was some suggestion, however, of the expected enhancement effect by the excitatory aversive condition very early in training. The presence of light alone reinforced trials may have added to the strength of the light CR in all groups and obscured any transfer effects. As a consequence, the following experiment investigated the effect of aversive transfer on two compound conditioning sessions without any light alone trials. Appetitive CR acquisition to a novel non-preexposed CS was tested in extinction following compound acquisition.

5.4 Method

5.4.1 Subjects and Apparatus

Forty rabbits surgically prepared as in Experiments 2 and 3 served as subjects. The chambers, recording procedures, light and tone CSs, and the shock and water USs were the same as in Experiment 3.

5.4.2 Procedure

Following surgery, recovery and habituation the rabbits were assigned to one of five groups. These groups differed in the pretraining conditions which lasted for ten sessions. These assignments were identical to those in Experiments 2 and 3, with the exception that for control purposes in this experiment there were 2 naive control conditions. Group FWD (N=8) received forward tone-shock pairings; group BKD (N=8) received backward shock-tone pairings; and group RDM (N=8) received similar tone presentations with the shocks occurring randomly throughout each session. Two naive control groups, Groups NPx-L (N=8) and NPx-LT (N=8) received neither the tone nor the shock during the

pretraining phase, that is, these rabbits were simply restrained in the conditioning chambers for the duration of each of the 10 sessions. During this and all subsequent phases the CS-CS presentation interval varied between 1.5, 3.0 and 4.5 min. On day 6 of the preexposure phase, all animals were placed on a 90 cc per day water deprivation regime for the rest of the experiment.

The compound jaw movement conditioning phase followed this aversive preconditioning phase for all groups except Group NPx-L. In compound conditioning, a trial consisted of the one sec light CS and the one sec tone CS occurring simultaneously and terminating with the onset of the 350 msec 1cc pulse of water delivered into the rabbit's mouth. In contrast to all other groups, during this phase, Group NPx-L received trials consisting of only the light CS followed immediately by the water US: the tone did not occur in the conditioning phase for this group. Group NPx-L was included to assess single element acquisition to the light under control conditions. The inhibitory induced enhancement of acquisition should be revealed in this comparison as well as the control comparisons with compound acquisition. This conditioning phase lasted two sessions each of which contained twenty trials.

On the third day, all groups received a one session extinction test where ten separate presentations each of the light CS and the tone CS occurred and no US presentations occurred during the session.

5.5 Results

5.5.1 Eyelid conditioning

Eyelid conditioning showed the same results as in the earlier experiments: all Group FWD animals gave eyelid responses on at least

90% of the trials in the last two sessions of eyelid conditioning; whereas none of the other animals responded on more than 10% of the trials.

5.5.2 Compound Acquisition

Figure 8 illustrates jaw movement acquisition during the two training sessions of Experiment 4. Groups BKD and RDM jaw movement performance exceeded that of the other three groups. Group NPx-LT also performed a higher level of the jaw movement response than Group FWD or Group NPx-L which do not appear to differ. These different levels of responding are confirmed by a significant between groups effect ($F_{4,35}$= 3.19, $p < .025$) in a two-way mixed design ANOVA and by subsequent between group Newman Keul's comparisons (all p's < .05). Acquisition of the response is shown by a significant sessions effect ($F_{1,35} = 64.36$) and the higher level of responding in Session 2 than Session 1 in all individual animals. The interaction does not approach significance ($F < 1$, n.s.).

Eyelid responding in Group FWD decreases rapidly over the two compound acquisition sessions. Again no χ^2 analysis between eyelid and jaw movement responding revealed any response dependence.

5.5.3 Single element testing

The results of component testing of the light CS during extinction are shown in Figure 9. Group FWD performed at greater than twice the response level of any of the other four groups. Group NPx-LT, on the other hand, showed an almost negligible response to the light CS.

A one-way ANOVA revealed a significant group effect ($F_{4,35} = 6.56$; $p < .001$). Newman Keul's comparisons based on this analysis

Figure 8: Acquisition of jaw movement CRs in averisve transfer to appetitive compound conditioning.

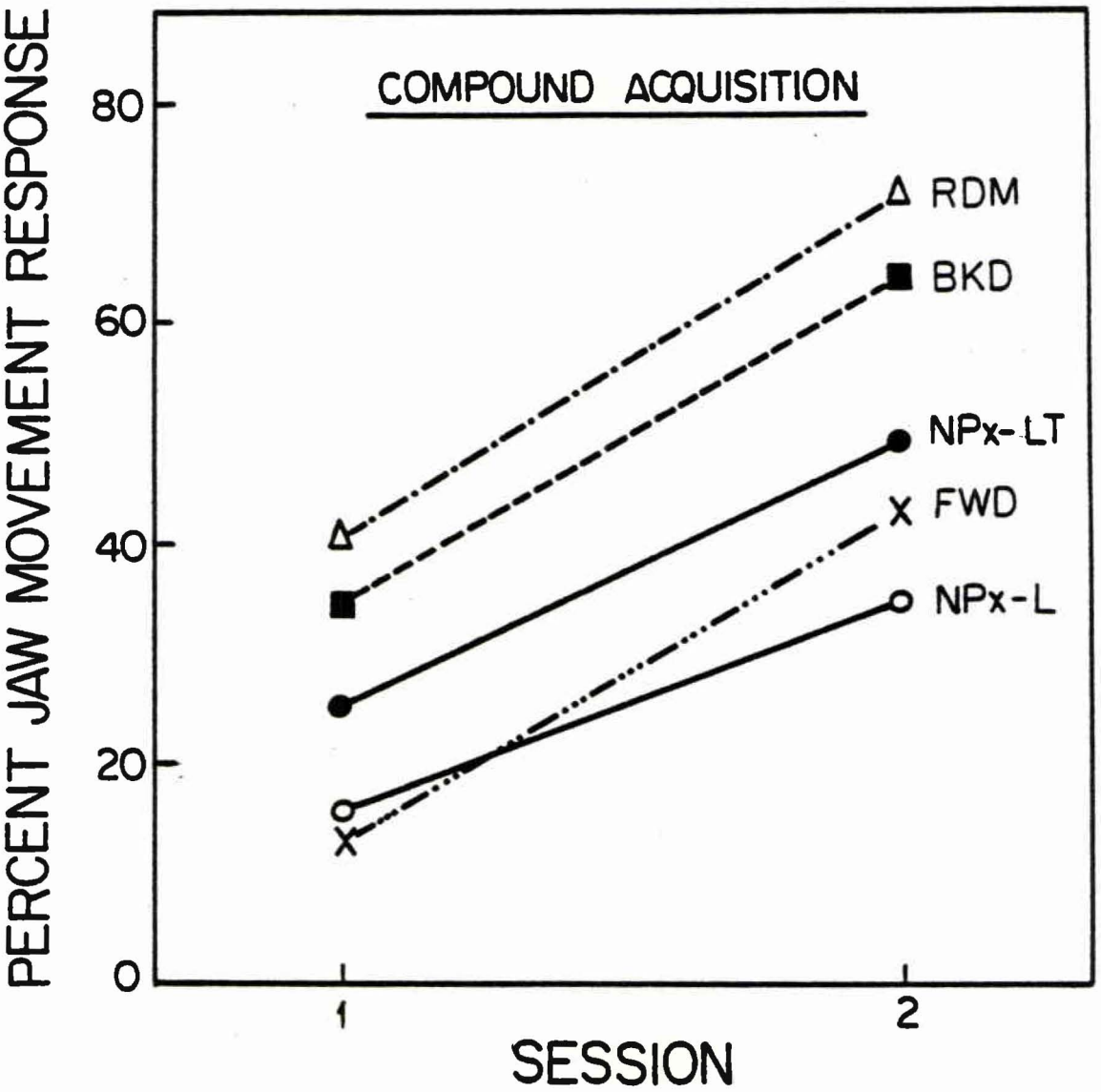
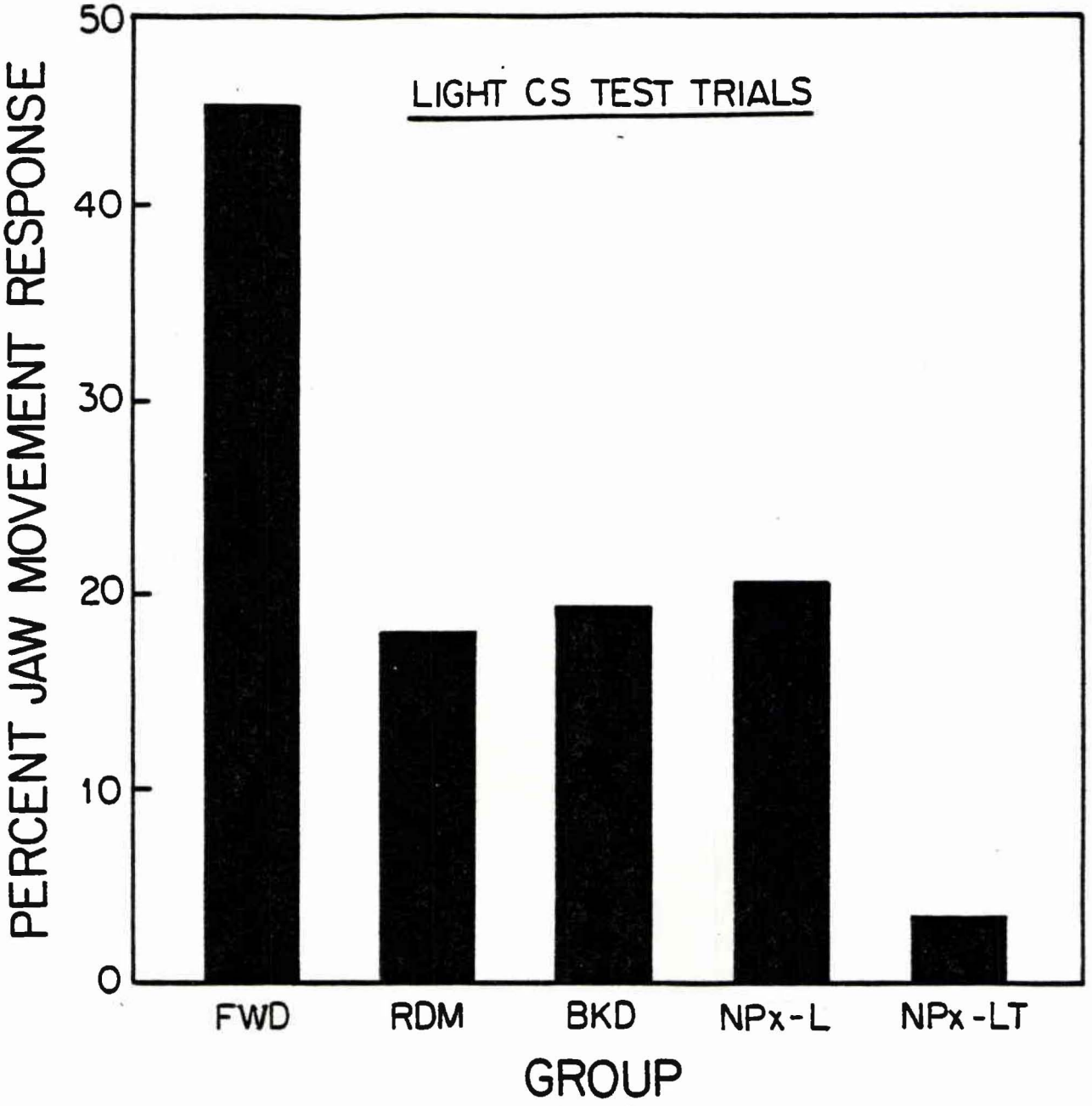

COMPOUND ACQUISITION
PERCENT JAW MOVEMENT RESPONSE
80
60
40
20
0
1
2
SESSION
RDM
BKD
NPx-LT
FWD
NPx-L

Figure 9: Jaw movement performance on light CS test trials during extinction in aversive transfer to appetitive compound conditioning.


LIGHT CS TEST TRIALS
PERCENT JAW MOVEMENT RESPONSE
50
40
30
20
10
0
FWD
RDM
BKD
NPx-L
NPx-LT
GROUP

confirmed the superior performance in Group FWD compared to all other conditions (all p's < .05). Groups BKD, RDM and NPx-L did not differ, but Group NPx-LT showed significantly less jaw movement than any of the four other groups (all p's < .05).

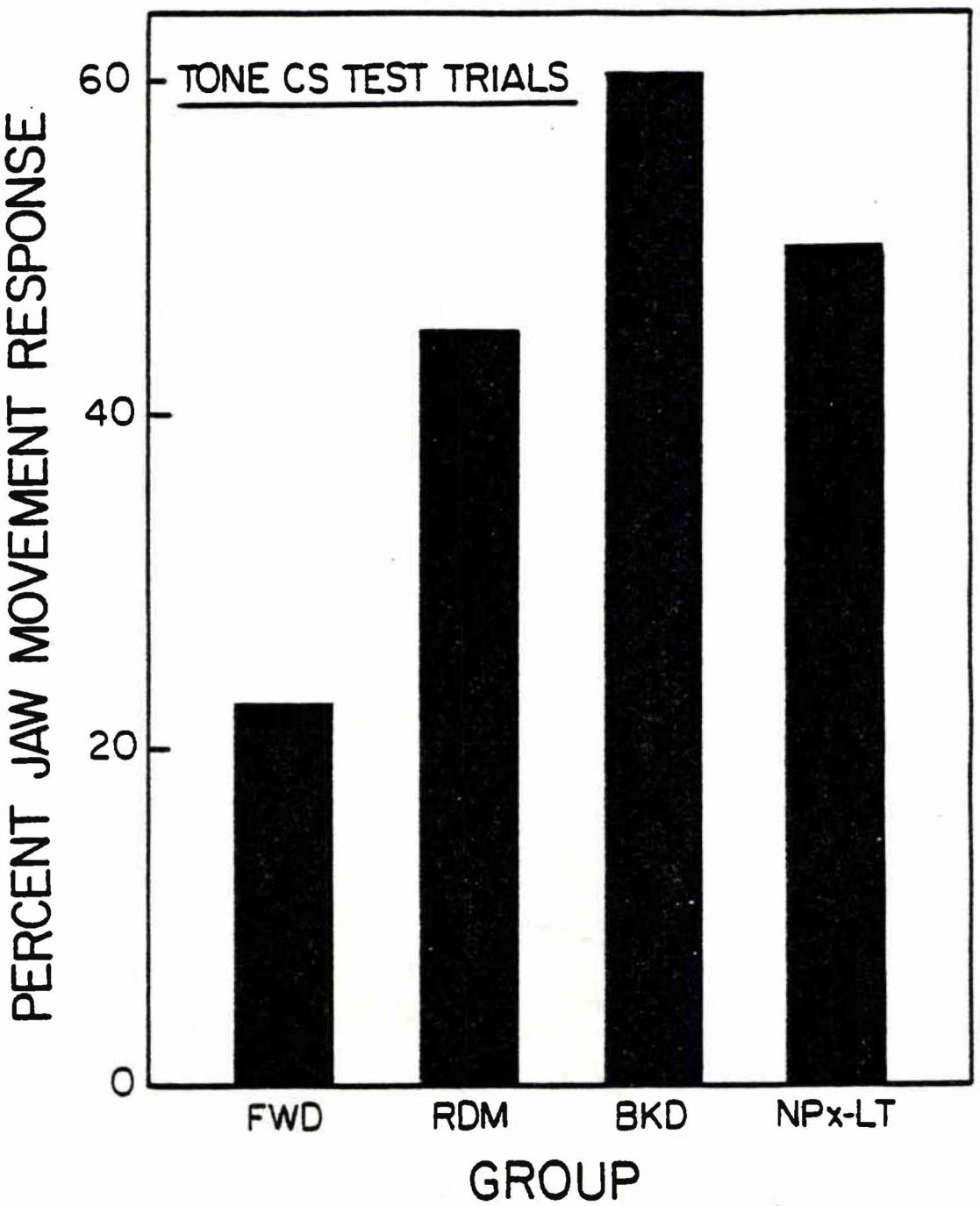
Conditional response levels to the tone CS component are shown in Figure 10 for the four groups which received compound conditioning in the jaw movement training phase. A one way ANOVA of tone CS responding revealed a significant group effect ($F_{3,28} = 2.69$, $p < .05$), but although Group FWD showed a lower level of responding to the tone compared to the other three groups, Group FWD differed significantly only from Group BKD (Newman Keul's, $p < .05$). Response rates to the tone CS were characterized by an unusually high variance.

5.6 Discussion

5.6.1 Aversive Excitatory Transfer

The main finding of interest in this study is the enhancement of jaw movement acquisition to the light CS reinforced in compound with the excitatory aversive tone CS. This transmotivational enhancement of appetitive conditional response acquisition is revealed by the higher percentage of CRs to the light CS during extinction testing in Group FWD compared to the percentage of CRs to the light CS during extinction testing in Group L Alone. Moreover, the superior performance levels in Group FWD are not due simply to a nonspecific enhancement of acquisition caused by the mere exposure to the tone CS and aversive US in the preconditioning phase of the experiment. On light CS trials, Group FWD jaw movement responding is higher than the jaw movement responding of either the random control condition or the inhibitory backward

Figure 10: Jaw movement performance on tone CS test trials during extinction in aversive transfer to appetitive compound conditioning.


TONE CS TEST TRIALS
PERCENT JAW MOVEMENT RESPONSE
60
40
20
0
FWD
RDM
BKD
NPx-LT
GROUP

condition. These confirm the expectation of transmotivational enhancement predicted by a reciprocal inhibition analysis of exitatory aversive transfer to appetitive compound conditioning.

Transmotivational enhancement resembles "superconditioning" and is a strong prediction of inhibitory influences on compound acquisition. The presence of such enhancement in an aversive to appetitive transfer test clearly indicates the Rescorla-Wagner discrepancy formulation of the effectiveness of reinforcement in Pavlovian acquisition applies to Pavlovian transmotivational interactions. As Dickenson (1977) points out, this enhancement of acquisition to another stimulus is not easily explained by alternative, non-central interpretations of transfer effects. Thus, this observation compliments the central interaction interpretation of reciprocal inhibition provided by the peripheral response independence analysis.

The presence of the aversive excitatory tone on compound acquisition trials suppresses the level of compound conditional response below that of all other compound Groups (though not below the single element acquisition group, Group NPx-L). This suppression is noteworthy in view of the higher level of responding to the light CS shown in the test phase. Indeed, despite the fact that testing took place in extinction Group FWD had about the same level of response to the single light CS element as it did to the compound stimulus on the second acquisition day (cf. Figures 8 & 9). All other groups had lower response rates on both tone and light CSs during single element testing than they had to the compound CS on the second acquisition day. These observations indicate that the excitatory aversive tone masked the

higher level of the jaw movement response CR acquired by the light during the initial training phase.

Although the response level to the tone in Group FWD only differs significantly from Group BKD in single element testing, the failure to obtain significant differences with the other two groups probably reflects a lack of precision, due to high variance, rather than a lack of difference. On the whole, responding to the compound CS and the tone CS is consistent with the suppressive effects of the aversive excitatory CS observed in Experiments 2 and 3.

These consistent suppressive effects compliment the reciprocal inhibition analysis of excitatory aversive transfer to compound appetitive acquisition. Transmotivational enhancement to the novel CS and suppression of responding by the preexposed CS both fit the reciprocal inhibition model proposed here.

5.6.2 Aversive Inhibitory Transfer

Although aversive excitatory transfer effects on compound acquisition support reciprocal inhibition and its application to Pavlovian appetitive-aversive interactions through the Rescorla-Wagner discrepancy formulation, aversive inhibitory transfer effects do not. Appetitive acquisition to the light CS was comparable whether reinforced in compound with an inhibitory aversive tone, reinforced in compound with a random control tone, or reinforced singly, that is, with no tone present. Both aversive inhibitory and aversive random preexposure conditions do seem to reduce the overshadowing found when a novel tone is appetitively reinforced with the light CS (i.e. Group NPx-LT). This reduction of overshadowing might be anticipated for the random condition as a result of a loss of stimulus salience to the tone CS as was

suggested by Experiment 1; but, according to our current formulation of reciprocal inhibition the opposite effect, that is, transmotivational blocking, should have occurred for the aversive inhibitory condition. The present difference in the wrong direction is particularly damaging for the reciprocal inhibition formulation of the effects of aversive inhibition transferred to appetitive tasks.

Unlike the failure of reciprocal inhibition predictions in Experiments 2 and 3, the lack of transmotivational blocking can not be attributed to an unexpected effect in the random control condition. In Experiments 2 and 3, the aversive inhibitory stimulus produced outcomes compared to the naive control condition that were consistent with reciprocal inhibition. The problem in interpreting these results was that the random control condition also produced similar outcomes. Although the absence of a difference between the inhibitory aversive and random control conditions is not consistent with the predictions of reciprocal inhibition, in Experiments 2 and 3, it was necessary to consider the possibility that both reciprocal inhibition and random control effects were present and were producing similar outcomes by separate processes. In Experiment 4, again there is no significant difference between the performance levels of the inhibitory aversive and random control conditions, but the compound conditioning effect of both conditions compared to a naive control condition (overshadowing) is an enhanced level of responding to the novel CS. This enhancement of responding is a powerful disconfirmation of the facilitatory role postulated for aversive inhibition by recent reciprocal inhibition theories.

Fowler and his associates (see Fowler, 1978) have reported that operant appetitive discrimination learning was retarded when a negatively correlated aversive CS was compounded with the correct, reinforced choice. This result was interpreted as supporting a reciprocal inhibition based blocking by an inhibitory aversive CS. However, no report of transmotivational blocking has been made in procedures which do not have this operant discrimination component. Nevertheless, blocking of appetitive acquisition in operant discrimination tasks has been the primary basis for postulating inhibitory facilitation in transmotivational transfer tasks. The present findings indicate that another interpretation of Fowler's results may be necessary, since blocking is not found in a Pavlovian to Pavlovian transfer test. Were another explanation of this operant-Pavlovian interaction developed successfully, the bulk of evidence in favor of an inhibitory aversive facilitation of appetitive responding could be discounted.

5.6.2a Attention and Blocking. One possible explanation for the failure of aversive conditional inhibition to block appetitive acquisition to another CS deserves consideration. Recent evidence suggests that, in part, blocking may be the result of attentional factors (Mackintosh, 1975), rather than the discrepancy formulation of the Rescorla-Wagner model. It is plausible that an aversive inhibitor does not disrupt attention to the novel CS since it is not a better predictor of the appetitive US than the new stimulus. Consequently, acquisition to the novel CS reinforced in compound with the aversive inhibitor would be similar to acquisition to the novel CS reinforced singly. A similar argument could be made for the random condition. In

fact, random preexposure may very well reduce salience for aversive conditioning (see Chapter 2) and, thus, may also reduce salience for appetitive conditioning (though Mackintosh, 1974 and the results of Experiment 2 suggest not). In any case, the finding that both the inhibitory and random conditions affect compound acquisition similarly suggests the possibility that a common, perhaps nonassociative factor, may be responsible for the disruption of overshadowing. According to the attentional approach, it must be assumed that aversive pretraining generally renders the preconditioned CS less likely to interfere with attentional processing of a novel CS.

It should be noted, however, that the attentional interpretation of reduced overshadowing here is somewhat suspect, since there is no difference in tone CS responding between the overshadowed (NPx-LT) group and the two aversive preexposure (BKD and RDM) groups. It would be reasonable to expect attentional differences to show up in these tone response rates. Indeed, reduced salience would predict lower levels of conditional responding to the tone CS in both the inhibitory and random groups compared to the non-preexposed CS: there is no suggestion in the data that such reduced salience occurs.

Even if the attentional explanation of blocking were to provide a reasonable avenue for explaining the failure of an aversive inhibitory or an aversive random CS to overshadow appetitive acquisition to a novel CS, such an approach does not salvage the predictions of reciprocal inhibition. It is clear that the results of compound acquisition with an aversive inhibitory stimulus do not resemble the expected results of compound acquisition with an appetitive excitatory stimulus (blocking) as predicted by theories of reciprocal inhibition. Interpretation of

the present findings clearly requires a revision of our current formulation of inhibitory aversive transfer effects in reciprocal inhibition.

5.2.6b Aversive inhibition and facilitation. Reciprocal inhibition theories would expect conditional responding to the inhibitory aversive CS would be enhanced. The lack of such an inhibitory-based facilitation is suggested by a comparison of response rates to the tone CS during extinction testing. Although there is a nonsignificant trend suggesting that the random CS controls less conditional responding than the inhibitory CS, this is a weak comparison because such a discrepancy would be anticipated from stimulus salience arguments developed here in Chapter 2. The more meaningful comparison is against the novel tone CS in Group NPx-LT. Again, although there is a slight trend in this direction, the inhibitory CS fails to show any superiority over the non-pretrained CS in conditional responding. Again, the inhibitory facilitation side of reciprocal inhibition is not supported.

Interestingly, although no facilitation in tone conditional response rates are evident during single element testing, both the random and inhibitory conditions facilitate acquisition to the compound stimulus compared to the naive control groups. The rapid CR formation in the random and inhibitory conditions replicates the results of single stimulus acquisition in Experiment 2.

Once again as in Experiment 2, there is a slight tendency (non-significant) toward superior performance in the random condition over the inhibitory condition. Initial pilot work on compound acquisition following random and inhibitory preconditioning treatments indicated the

same small trend toward more rapid acquisition in the random group compared to the inhibitory group. Thus, this tendency, though small, seems to be replicable. In any case, these data reveal a lack of facilitation in the inhibitory condition compared to the random control condition which is clearly inconsistent with reciprocal inhibition predictions.

It should be noted again that this enhancement is also inconsistent with an attentional account of the disruption of overshadowing and failure of transmotivational blocking observed here. More importantly, although such enhancement would be expected in both the inhibitory and random control conditions on the basis of Experiment 2, the fact that these groups do not differ from the nonpreexposed control group in responding to the tone during extinction testing indicates that this phenomenon is not necessarily specific to the preexposed CS.

The presence of a generalized enhancement of appetitive acquisition in both the aversive inhibitory and random control conditions suggests the possibility that some common element of the two preconditioning experiences is responsible for the enhancement of appetitive acquisition. The obvious initial candidate is the presence of unsignalled shock in both conditions. The studies conducted here do not provide a definitive demonstration that unsignalled shock has effects on appetitive conditioning similar to the inhibitory and random control conditions. Nevertheless, this analysis is plausible and will be presented in the context of all three transfer studies in the General Discussion.

Chapter 6: General Discussion, Implications, and Conclusions

The results of the three appetitive-aversive transfer studies may be divided into three categories: 1) aversive excitatory transfer effects; 2) aversive inhibitory transfer effects; and 3) random control effects. The data from all three studies strongly support a reciprocal inhibition interpretation of aversive excitatory transfer to appetitive conditioning. The data from aversive inhibitory transfer do not support a facilitative role for aversive inhibition in appetitive conditioning when compared to the random control condition, and, in fact, contradict the facilitative role in compound conditioning. Finally, the random control condition produces effects similar to the aversive inhibitory condition when compared to a naive control condition. These random control effects require a discussion of attentional, psuedoconditioned, and contextual phenomena and imply that greater consideration be afforded these alternative accounts, when attempts are made to demonstrate the inhibitory side of aversive transfer to appetitive conditioning.

6.1 Excitatory Aversive Transfer Effects

There are four major findings in these experiments which support the reciprocal inhibition theory of transfer effects of an aversive exciter onto Pavlovian conditioned appetitive responding. In summary, prior aversive excitatory training produces the following outcomes: 1) retardation of appetitive CR acquisition to the preconditioned CS (Experiment 2 and Experiment 4); 2) suppression of conditioned appetitive responding by the preconditioned CS (Experiment 3 and

Experiment 4); 3) enhanced acquisition of a Pavlovian discrimination when the preconditioned CS is used as the inhibitory component of an A+;AB- design (Experiment 3); and 4) faster acquisition to a novel CS which was reinforced in compound with the preconditioned CS than if the novel CS were reinforced alone, transmotivational enhancement (Experiment 4). Comparing these findings with the reciprocal inhibition predictions made in Table 1 shows that all of the predicted effects were obtained. Each of these effects would be expected on the basis of our reciprocal inhibition formulation which incorporates the inhibitory predictions from the Rescorla-Wagner theory (Wagner and Rescorla, 1972).

Taken together, these excitatory aversive transfer effects strongly indicate a one-way functional isomorphism between aversive excitation and appetitive inhibition in the appetitive motivational system. In all of the tests devised here on the basis of known inhibitory phenomena, aversive excitation behaves as if it were an appetitive inhibitor. Attentional interpretations are eliminated by the inability of salience changes to account for both active response suppression and retardation of acquisition. Competing response notions of appetitive-aversive transfer are ruled out by the eyelid and jaw movement conditioning paradigm, in which the two CRs are shown to be peripherally independent, and by the effects of compound stimulus presentations (i.e. transmotivational enhancement), which could not be derived from a competing response formulation. These demonstrations consequently provide the most clear cut and unambiguous evidence supporting the reciprocal inhibition claim that activation of the aversive motivational state inhibits activation of the appetitive

motivational state. In each case, the excitatory aversive CS influences appetitive conditioning in the same manner that a conditional inhibitor would be expected to influence conditioning (see Implications for Inhibition below). Thus, these results complement and extend the reciprocal inhibition interpretation of aversive excitatory transfer effects on many forms of appetitive conditioning (see Dickenson, 1977 for a review).

6.2 Inhibitory Aversive Transfer Effects

With respect to aversive conditional inhibition transfer effects, this complementary picture does not present itself. In Experiment 2, the aversive conditional inhibition group does acquire rapidly to the tone; unfortunately, a random control group acquires the appetitive CR just as fast and perhaps even more rapidly (Figure 4, see sessions 1 and 2). This marginal superiority of acquisition in the random group over the inhibitory group was not significant, but was replicated in the compound acquisition phase of Experiment 4 (see Figure 8) and in the compound acquisition phase of pilot studies for Experiment 4 (data not shown here). Although these observations do not substantiate faster acquisition in the random group over the inhibitory group, clearly the alternative ordering, suggested by reciprocal inhibition, is not true. In Experiment 3, the conditional inhibition group shows an initial effect on the measures for discrimination performance in the anticipated direction, but again, this condition is indistinguishable from the random control condition. In Experiment 4, the most damaging evidence is revealed. Aversive conditional inhibition does not enhance overshadowing or produce blocking in appetitive

compound conditioning: instead, aversive conditional inhibition eliminates the overshadowing effect found in the naive control condition. Moreover, in this compound stimulus acquisition procedure, single element tests of the inhibitory CS reveal no stimulus specific enhancement of conditional responding. Again random control performance is statistically indistinguishable from that of the inhibitory group. Taken together, these observations suggest that the facilitative role given to aversive inhibition in recent formulations of reciprocal inhibition is incorrect.

Normally, difficulties would arise in the interpretation of the negative results found with inhibitory transfer in these studies. The present series of studies as a package, however, advances a consistent pattern of theoretical disconfirmation. In only a single instance (Experiment 4) is a trend toward a difference between the random and inhibitory conditions present which would support the theory's predictions. In experiment 4, more conditional response activity may have occurred to the inhibitory CS then the random CS in single element testing. But, this trend could easily be attributed to the reduction of salience to the random CS that was demonstrated in Experiment 1. Even in this instance, performance in the inhibitory condition fails to surpass performance of the naive control condition (see Figure 10). The inhibitory aversive transfer condition fails to produce any of the predicted effects of reciprocal inhibition (see Table 1) when compared to the random control condition in three separate appetitive transfer tasks. These tasks were explicitly designed to test these transfer predictions, and clear evidence is found for the predicted excitatory

aversive transfer effects. Insensitivity of the appetitive response measures is not a viable interpretation of the results.

Preliminary analysis of the transfer conditions in Experiment 1 eliminates several other difficulties for interpretating the appetitive-aversive transfer studies. The results of Experiment 1 indicated that, with the particular parameters used in this preparation, the major effects of random presentations of the tone and shock were 1) reduced salience to the tone and 2) US habituation. These effects were clearly different than those of backward shock-tone presentations, which indicated inhibition in the aversive conditional inhibition transfer situation. Thus, the repeated failure to differentiate the random condition from the inhibitory condition does not reflect either (a) inadvertently produced inhibition in the random condition or (b) inadequate inhibitory training in the backward condition. Instead, the consistent similarity of appetitive-aversive transfer effects in these two conditions is much more likely due to similarities between some aspect of the two preconditioning procedures, rather than a convergence of different associative and/or salience phenomena. In other words, inhibitory transfer effects in the present studies may be interpreted as arising from common features with the random control condition rather than the effects of reciprocal inhibition.

6.3 Random Control Effects

Aversive preconditioning with either random or inhibitory procedures produces several interesting and unanticipated findings which would seem to require an unified account. First, both random and inhibitory aversive preconditioning facilitate appetitive CR performance

(Experiment 2 and Experiment 4). Such aversively induced enhancement is not necessarily specific to the pretrained CS (Experiment 4). Second, both aversive conditions temporarily enhance responding to the negative element of an appetitive conditional inhibition discrimination (Experiment 3). Finally, both aversive conditions disrupt overshadowing of a novel CS reinforced in compound with the pretrained CS (Experiment 4).

Because the appetitive-aversive transfer studies reported here were designed explicitly to test the inhibitory and excitatory transfer predictions of reciprocal inhibition, these experiments do not address the source of effects not based on specific associative transfer (i.e. the effects seen in both the random and inhibitory conditions). Consequently, several interpretations of these findings can be entertained at present. One interpretation, which has already been discussed with respect to the disruption of overshadowing (Experiment 4), is an attentional effect. A second explanation could be developed from notions of pseudoconditioning. Finally, based on the results reported with excitatory aversive transfer, particularly transmotivational enhancement, some of the unanticipated results could be interpreted as contextual conditioning phenomena.

6.3.1 Attention and Salience

The attentional interpretation would say that both random and inhibitory aversive pretraining reduce stimulus salience for appetitive USs and thereby reduce competition for associative strength during appetitive compound acquisition. Although consistent with recent accounts of blocking, the simple attentional model fails to account for the enhanced responding to the pretrained CS in Experiments 2 and 3.

Clearly, an attentional decrement that permits enhanced responding to that CS is not a likely alternative. It should be noted that recent theoretical accounts of random preexposure effects are somewhat at odds with these data. As indicated earlier, Mackintosh (1973; 1975) has suggested that uncorrelated presentations of a CS and a US result in a loss of salience to the CS (learned irrelevance). Baker and Mackintosh (1977) have presented data indicating that learned irrelevance interferes not only with excitatory conditioning but also with inhibitory conditioning. Experiment 1 confirms this second observation for random transfer to a conditional inhibition discrimination. These observations are each consistent with an interpretation of random control effects based on a reduction of attentional processing. Unfortunately, Experiments 2 and 4 are not all congruent with the reduction of attentional processing to the random CS. The response level to the tone in Experiment 4 gives no indication that conditioning to the random CS is slower than either the nonpreexposed or backward CS. Even more damaging to the reduced attentional account is the finding of enhanced appetitive acquisition to the random aversive CS in Experiment 2 when compared to the nonpreexposed CS. In the face of this result, either learned irrelevance is incorrect or notions of salience must include specific reference to the US involved in initial training. Thus, although a role for attentional or salience effects in the findings of Experiment 4 cannot be eliminated, other factors must also contribute.

6.3.2 Pseudoconditioning

The second two possible explanations of random and inhibitory transfer effects are based on the observation that these two conditions seem to produce a single outcome in each transfer study: the enhancement

of appetitive responding. Notice that in each case, where differences between the RDM-BKD groups and the NPx group obtained, more responding occurred to the CSs when pretraining with random or inhibitory presentations had taken place than if no pretraining had taken place. Even in Experiment 4, the apparent disruption of overshadowing may be viewed as an enhancement of overall jaw movement responding.

A pseudoconditioning interpretation of such enhancement would say that some common property of both inhibitory and random aversive pretraining produces a greater propensity to emit the appetitive response in the presence of a stimulus. This increased tendency to produce the response to a CS need not be based on an association of the CS with the appetitive US (see Gormezano, 1972; Sheafor, 1974). Instead, general processes such as sensitization could increase the CS's probability of releasing the response independent of the CS's associative strength. The administration of shock during the pretraining phase could well produce such sensitization. Indeed, inclusion of a random control condition in transfer studies is done partly to control for non-associative effects such as sensitization (Rescorla, 1969a). The enhancement of an inherent tendency to respond more to the tone as the negative element observed in the appetitive conditional inhibition experiment supports a non-associative interpretation based on more pseudoconditional responding in the two aversively preexposed groups. The pseudoconditioning account of enhanced appetitive responding, however, does not account for the lack of differential response rates to the tone CS found in single element testing in Experiment 4. The random control and aversive inhibitory

groups do not respond more to the tone than the naive control group following compound conditioning (Figure 10).

It should be noted that psuedoconditioning as a theoretical interpretation is strictly non-associative only in so far as reference is made to the enhancement of CS specific non-associative responding. Sheafor (1974) has reported data indicating that excitatory appetitive conditioning to the background, contextual, or situational cues present during conditioning is responsible for the increased tendency for a CS to produce jaw movement under circumstances where no association between the explicit CS and US is established. Psuedo-CRs occurred only when situational cues associated with reinforcement were present.

Both the random and inhibitory aversive conditions set the occasion for developing an association between the contextual or background cues and the aversive US. The presence of such associations in the eyelid conditioning preparation and their influence in US habituation affects on aversive conditioning has been amply documented (Dweck & Wagner, 1977 and Hinson, 1982). Non-specific sensitization-like effects could be elicited by contextual cues associated with shock during the preconditioning phase of these experiments. The problem with this conjecture is the clear inhibitory transfer effects of aversive excitation. It is unclear why a specific stimulus such as a tone would suppress jaw movement responding and a contextual stimulus would enhance it. It would be reasonable to expect an account of shock induced enhancement to be consistent with other transfer effects.

6.3.3 Contextual Conditioning

Clearly, the design of the present experiments do not permit a clear demonstration that background conditioning is the source of the

random and inhibitory aversive transfer effects. Such speculation is derived only from the observation that the appropriate conditions are present for aversive contextual conditioning to occur. Nevertheless, this issue is important: the potential for contextual conditioning has been ignored in most interpretations of appetitive-aversive transfer studies (see Implications for Transfer Studies, below).

The potential for aversive contextual conditioning in these transfer studies gives rise to a third interpretation of the observed random and inhibitory enhancement of jaw movement conditioning based on an associative mechanism. Notice that the presence of an excitatory aversive background would activate the aversive motivational state, and thus, should be inhibitory for appetitive conditioning. The data obtained here with excitatory aversive transfer support this inhibitory influence in each instance tested with an explicit CS. Recall specifically that an aversive excitatory CS as an appetitive inhibitor enhances acquisition to a novel CS reinforced in compound with it (transmotivational enhancement, Experiment 4). Thus, an excitatory aversive background would set the stage for greater acquisition to a CS appetitively reinforced in the aversive context than to a CS appetitively reinforced in a neutral context. Consequently, contextual preconditioning with the shock US would be expected to enhance appetitive acquisition.

Although the logic of a contextually-induced enhancement account is compelling, this associative interpretation can not explain the increased jaw movement to the negative element of appetitive conditional inhibition discrimination nor the lack of random and inhibitory facilitation of jaw movement to the positive element in the same

discrimination. Nevertheless, aversive context-induced enhancement, if present, would undoubtedly contribute to inhibitory and random control transfer effects.

On the whole, both the psuedoconditioning and the contextual approach seem to have some merit in explaining the results of random and inhibitory aversive transfer to appetitive jaw movement conditioning. To what extent attentional or associative factors also would influence these transfer effects is a question that would require studies designed specifically to partition these effects (e.g., Hinson, 1982). Also, further investigation is needed to substantiate the possible role of contextual conditioning and pseudoconditioning in these transfer effects. It seems likely that some combination of these three interpretations will be necessary to explain all the effects of the random control condition in aversive transfer to appetitive conditioning.

Irrespective of the outcome of investigations designed to explain random transfer, one major conclusion can still be drawn: aversive inhibitory transfer effects can be explained by the same mechanism. There is no need to invoke reciprocal inhibition to explain aversive inhibitory facilitation of jaw movement conditioning (e.g. Bromage & Scavio, 1978 and Scavio & Gormezano, 1980) when several promising alternative accounts are available. Moreover, as we have already argued, the stimulus specific facilitation predicted by reciprocal inhibition is ruled out in the sensitive compound acquisition test because enhancement is found where blocking is predicted. The positive observation that both random and inhibitory aversive pretreatments produce results resembling the predictions of reciprocal

inhibition in Experiments 2 and 3 is far short of building a foundation for the inhibitory aversive side of the theory. Instead, the failure to differentiate these two conditions, despite carefully demonstrating that inhibition was actually produced (Experiment 1), strongly implies that alternative (e.g. attentional, contextual or pseudoconditioning) accounts must be given prominent consideration in appetitive-aversive transfer studies before concluding that aversive inhibition facilitates appetitive conditioning (e.g. Fowler, 1978 and Bromage and Scavio, 1978). Consideration of these control factors in the present studies, leads to the conclusion that aversive inhibition has no direct effect on transfer to Pavlovian appetitive conditioning.

6.4 Implications for Previous Transfer Studies

6.4.1 Jaw Movement Transfer Studies

The results of Experiment 2, 3, and 4 are consistent with the results of other reported aversive transfer to jaw movement conditioning studies in those cases where similar conditions were assessed (Scavio, 1974, Bromage and Scavio, 1978). However, although the data of the present studies do not clash with the data of previous jaw movement studies, one of the conclusions drawn in previous studies does clash significantly with those suggested here. Since Bromage and Scavio (1978) did not include a random control condition for comparison against their putative inhibitory condition (unpaired CSs and USs), these authors concluded that the facilitation of jaw movement acquisition resulting from the unpaired (CS; Shock) pretraining procedures provided some support for the aversive inhibition facilitation side of reciprocal inhibition formulations. In contrast, the results of the three transfer

studies reported here do not suggest aversive inhibitory facilitation compared to a random control condition and provide an alternative framework for interpreting aversive inhibitory transfer effects based on common properties of aversive inhibitory and random pretreatments (see General Discussion: 6.2 & 6.3).

6.4.2 Transfer to appetitive operant conditioning

A number of studies supporting reciprocal inhibition have used operant transfer tasks to assess aversive transfer effects. In contrast to jaw movement studies, most of the more recent aversive to appetitive operant transfer studies contain random control conditions for comparison with the putative inhibitory conditions (see Fowler, 1978 for a review). With a few notable exceptions where peripheral response interactions were likely to directly intervene (e.g., Overmier and Schwarzkopf, 1974) much of the aversive transfer to appetitive operant acquisition and operant discrimination is consistent with a reciprocal inhibition formulation of motivational interactions which incorporates the compound stimulus predictions of the Rescorla-Wagner model (Dickenson and Pearce, 1977; Fowler, 1978).

Unfortunately, in the direct test of these predictions in Experiment 4, only the aversive excitatory part of the compound stimulus predictions (i.e. transmotivational enhancement) was confirmed. Blocking by an aversive conditional inhibitor plays a prominent role in Fowler's (1978) discussions of transfer to appetitive operant discrimination acquisition, but blocking is not observed in the Pavlovian transfer task. The present studies suggest that other interpretations of operant discrimination transfer should be explored.

In Experiment 1, the importance of independently assessing the effectiveness of aversive transfer conditions was emphasized. The differentiation of random and inhibitory aversive transfer conditions was particularly important for our purposes because of the failure to find differences between these conditions on the appetitive transfer tasks. Theoretically, however, demonstrating that the pretraining conditions effectively produce the associative or control effects postulated is no less important when differences are observed.

Take, for example, the following illustration. Under certain conditions, the random control procedure actually produces excitation in the presumed neutral CS (Kremer and Kamin, 1971 & Benedict and Ayres, 1971). Of course, that randomly-induced excitation would be less than that obtained with the same number of explicit CS-US pairings. Moreover, no excitation would be likely to occur in a putative inhibitory condition. Consequently, in transfer to an appetitive situation, there would be a natural progression of the magnitude of aversive excitatory transfer with the greatest amount of transfer in the explicitly excitatory condition, followed by some excitatory transfer in the random control condition, and, lastly, no excitatory transfer in the inhibitory condition. Accordingly, the data of Fowler and his associates (1978) could be ordered by differences in excitatory associative strength, rather than the presence of inhibitory effects. Without a direct and sensitive test of the properties of aversive transfer conditions, this explanation of findings, which appear to support the aversive inhibitory side of reciprocal inhibition, can not be ruled out. In fact, Fowler (1978), in one instance, presents evidence that indicates excitatory effects in his random control group.

This observation suggests that the differential excitation argument developed here is a strong candidate to resolve the differences between Experiment 4 and Fowler's work.

Another possible resolution of the difference between Pavlovian transfer effects and apparent operant transfer effects may lie in the nature of operant-Pavlovian interactions. For example, these interactions may be greatly influenced by general approach-avoidance tendencies (Wasserman, Franklin & Hearst, 1974), whereas Pavlovian interactions between discrete and independent skeletal responses may not be so influenced. An aversive inhibitory CS may occassion an approach response tendency particularly against an aversive background. Such an approach tendency could produce aversive inhibitory facilitation of appetitive operant conditioning, but not in the appetitive Pavlovian conditioning procedures used here.

Finally, the results of the present studies suggest that aversive background conditioning should be considered in assessing aversive to appetitive transfer effects. Aversive inhibition would be expected to decrease aversive background excitation and may be differentiated from the random condition by counteracting the transfer effects of the background excitation. Some suggestion of such an effect is found in the apparant superiority of appetitive response acquisition enhancement of the random condition over the inhibitory condition seen in Experiments 2 and 4 and pilot studies (see pg. 95 for a discussion). The application of experimental techniques designed to assess the role of contextual conditioning (e.g. Hinson, 1982) would be an important avenue to test the source of differences between operant and Pavlovian transfer.

6.5 The Role of Inhibition in Motivational Interaction

6.5.1 Reciprocal Inhibition

The results of the transfer studies reported here confirm several theoretical assumptions and, at the same time, suggest modifications of the reciprocal inhibition model for appetitive-aversive interactions proposed by Konorski (1967) and elaborated on in Section 1.5. Specifically, the data confirm the inhibitory effects of aversive excitation on the appetitive motivational system and indicates that the application of the Rescorla-Wagner discrepancy formulation provides a good description of these motivational transfer effects. On the other hand, aversive inhibition does not show the motivational transfer effects predicted. The failure of inhibitory facilitation in transmotivational transfer suggests a clear modification of current models of reciprocal inhibition -- a modification which is consistent with recent approaches to conditional inhibition (e.g. Wagner, 1977).

With the exception of the lack of aversive inhibitory transfer to appetitive conditioning, the results of these transfer studies, including aversive-aversive transfer in Experiment 1, have supported the Rescorla-Wagner model and its application to reciprocal inhibition. In each of these instances, a stimulus with established associative strength is transferred to a procedure designed to assess the influence of the preconditioning episode. The model assumes that the discrepancy between expected and actual trial outcome ($\lambda - V_T$) provides a directional indication of comparative levels of conditional responding on these tasks. Accurate predictions for the obtained results are calculated by combining the discrepancy notion with the additional assumption that total appetitive associative strength is represented by

a subtraction relationship with the aversive system. Specifically, total appetitive associative strength is given by:

$$V_{T,AP} = V_{Z,AP} - V_{X,AV},$$

where $V_{Z,AP}$ is the associative strength of the appetitive stimuli and $V_{X,\ AV}$ is the associative strength of the aversive stimuli present on a trial. When $V_{X,AV}$ is positive, that is, excitatory, the aversive stimuli would act as an inhibitor for the appetitive system just as an appetitive conditional inhibitor would be expected to act. In fact, in a number of defining tests an aversive excitatory CS behaves as an inhibitory appetitive CS would be expected to behave.

Consistent support for the discrepancy approach may not be too surprising. After all, the tests of inhibition were not novel, but rather, were based on known transfer conditions. Nonetheless, the conclusion that conditional inhibition and reciprocal inhibition behave similarly is not trivial: both, it seems, can be described by a conditioning model that involves a simple comparator function ($\lambda - V_T$) and subtractive effect of inhibitory stimulation.

It is interesting to note that, whereas the two forms of inhibition seem to involve the same mechanism, major differences in the properties of the two are evident. Most notable and obvious is that an excitatory aversive CS controls aversive CRs (e.g. eyelid closure and fear). An appetitive conditional inhibitor does not necessarily control any overt responding. One of the problems in studying conditional inhibition is the general lack of any indicant response. Conditional inhibition is usually only inferred by the effects an inhibitory stimulus has on an excitatory CS. The two forms of inhibition also differ procedurally: reciprocal inhibition is established by the pairing of

two events, CS-US_{AV}; whereas conditional inhibition is established by the pairing of a CS with the absence of an expected US_{AP}. Nevertheless, the effects of both sources of inhibition are best modelled as a reduction in activation (excitation) of the central, appetitive, motivational state. I would argue that such convergence of mechanisms from vastly different procedures favors viewing inhibition as a process based on a comparator function ($\lambda-V_T$) with negative values of V_T rather than simply a procedural or behavioral outcome.

6.5.2 Revision of the Model

A simple revision of the reciprocal inhibition model follows from the suggestion that inhibition as a process represents only an ability to reduce excitatory strength. Recent models of conditional inhibition postulate that an inhibitory stimulus operates only on the level of activation of a US memory (Wagner, 1977), which is equivalent, in the earlier theories, to values of associative strength. Thus, inhibitory effects would only be observed in the presence of an excitatory CS and, unless the original source of the inhibition had observable effects, the inhibitory impact would be null in the absence of excitation.

A modified model of reciprocal inhibition would postulate a single inhibitory connection between the aversive motivational state and the appetitive motivational state. The activity of this connection would be determined by the level of activation of the aversive motivational state. However, because inhibition of the aversive state will have no further effect on responding once activation is completely eliminated, an inhibitory stimulus will have no further effect on the motivational interaction. Consequently, this model would account for

the failure of an aversive inhibitory stimulus to exert any facilitatory transfer effects on appetitive Pavlovian conditioning.

In order to calculate aversive inhibitory effects, the following procedure would be used. First, calculate the level of aversive excitatory strength. $V_{E,AV}$, then subtract the level of aversive inhibitory strength $V_{I,AV}$. This would give total aversive associative strength,

$$V_{X,AV} = V_{E,AV} - V_{I,AV}. \qquad (a)$$

Finally, the inhibitory effect of aversive activation on the appetitive system would be determined by:

$$V_{T,Ap} = V_{Z,AP} - V_{X,AV}; \quad \text{if } V_{X,AV} > 0 \qquad (b)$$

and

$$V_{T,AP} = V_{Z,AP} \quad ; \quad \text{otherwise.} \qquad (c)$$

These equations would formalize the one-way, asymetric, aversive to appetitive, transfer effects obtained in these studies. As is indicated by the subtractive nature of Equation (b) and the lack of any influence in Equation (c), only inhibitory motivational interactions are postulated in this model.

Our discussion of formal models has centered around the discrepancy notion ($\lambda - V_T$) and ignored many other details postulated by Recorla and Wagner (1972). We have been concerned with the way in which motivational factors might modify the V_T component of the formula. This was done purposely. Subsequent models of conditioning (Mackintosh, 1975 and Pearce and Hall, 1980) have used a different approach to the conditioning process than Rescorla and Wagner proposed. Because of the compelling findings, which are based the role of discrepancy in conditioning, the later models, however, still rely on the discrepancy

value as a kernal feature of the original model. Thus, the predictions derived here for reciprocal inhibition through the Rescorla-Wagner model will also hold, under most conditions, for the more recent models.

6.5.3 Conclusion

By the way of summary, the findings obtained here are consistent with a model of reciprocal inhibition which suggests that excitation of the aversive motivational state activates a process of inhibition for the appetitive motivational state. Further, the model assumes that the level of excitation and inhibition for the appetitive state determines significantly the level of appetitive conditioning performance according to the descrepancy rules originally developed by Rescorla and Wagner (1972). Conditional inhibition in this model acts only on the level of excitation of the motivational state of the US used to establish it. This feature is in direct opposition to part of Konorski's (1967) theory, but is necessary to interpret the current data. In contrast to other approaches to motivational interactions (Konorski, 1967; Dickenson & Pearce, 1977; Fowler, 1978), the results of these studies indicate the presence of only inhibitory motivational interactions in averisve transfer to appetitive conditioning.

Several direct lines of research are suggested by the results of these studies. First, the current data address only aversive appetitive transfer and say nothing about the contralateral side of reciprocal inhibition appetitive to aversive transfer. The conditioning procedures used here would provide an excellent avenue to study appetitive effects on aversive conditioning. Secondly, the results of control conditions in these studies indicate that contextual conditioning may be important in transfer effects. Finally, a

comparison of the present data with operant transmotivational transfer data indicate a possible need to reevaluate previous interpretations. Contextual conditioning may offer one fruitful approach, but combined with that, the application of Pavlovian conditioning to approach-avoidance responding in general may lead to a solution to the difficulties posed by these findings.

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