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FACILITATION AND RETARDATION OF INSTRUMENTAL APPETITIVE LEARNING

BY PRIOR PAVLOVIAN AVERSIVE CONDITIONING

By

Edward A. Domber, Jr.

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M.S., University of Pittsburgh, 1969

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This dissertation was presented

by

Edward A. Domber, Jr.

It was defended on

October 15, 1971

and approved by

Dr. G. H. Shames

Dr. M. Moskowitz

Dr. A. W. Siegel

Dr. G. J. Wischner

Dr. H. Fowler

Chairman

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FOREWORD

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Edward Domber

October 1, 1971

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I. INTRODUCTION

A. Early Findings

Prior to 1934, the evidence regarding the effect of punishment on discrimination learning was in accord with the general view that punishment suppresses behavior; i.e., when selectively applied to the incorrect response, punishment in the form of electric shock produced more rapid elimination of errors than positive reinforcement for the correct response alone (Yerkes and Dodson, 1908; Dodson, 1917; Hoge and Stocking, 1912; Warden and Aylesworth, 1927; and Bunch, 1928). Contrary to this view, Muenzinger (1934) found that shock applied to the rewarded response (shock-right training), rather than suppressing the response to the correct alternative, actually facilitated discrimination performance. The paradoxical facilitating effect of shock-right (SR) training provided the basis for an extended series of studies in which Muenzinger and others attempted to isolate the mechanism by which punishment produced the unexpected outcome.

Many of these studies produced conflicting evidence, however, and were complicated by certain methodological difficulties. (For a full description of the early hypotheses and findings, see Fowler and Wischner, 1969.) For example, whereas Muenzinger (1934) and Drew (1938) found that the magnitude of SR facilitation was equivalent to facilitation produced by shock for the incorrect response (shock-wrong training), Fairlie (1937), Muenzinger, Bernstone and Richards (1938), and Muenzinger and Powloski (1951) found that shock-wrong (SW) training produced superior performance. Several studies (Muenzinger and Wood,

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1935; Muenzinger and Newcomb, 1936; and Freeburne and Taylor, 1952) also indicated that punishment for <u>both</u> correct and incorrect responses (shock-both training) produced facilitation; on the other hand, Prince (1956) found no difference between shock-both (SB) training and no-shock (NS) training.

Some of these inconsistent findings were directly attributable to procedural and/or methodological biases. For example, although Muenzinger and Wood (1935), Muenzinger and Newcomb (1936) and Fairlie (1937) claimed to find evidence for SR and SB facilitation, they did not employ a no-shock (NS) control in their studies; rather they assessed their results against the NS control of Muenzinger's original (1934) study! Furthermore, all of the early studies (excluding Prince, 1956 and Freeburne and Taylor, 1952) employed a retrace correction procedure in combination with shock grids that remained charged throughout the trial. Consequently, these procedures failed to equate the frequency and duration of punishment for SR, SB, or SW Ss on any single trial. Wischner (1947) further pointed out that, as a means for assessing punishment effects, the correction procedure is inferior to a non-correction procedure for two reasons: in correction training errors lead to a combination of incentives and, additionally, the time between a response and its consequent is badly controlled. Indeed, when Wischner (1947) employed a non-correction procedure, he found no overall difference between SR and NS groups, although early in training, the performance of his SR groups was <u>retarded</u> relative to the NS control. This latter finding suggested that SR training did in fact produce avoidance of the cues associated with shock, thus retarding rather than facilitating performance.

In a more recent series of parametric investigations designed to avoid the difficulties of the earlier studies, Wischner and Fowler confirmed Wischner's (1947) earlier observation of an avoidance-producing effect of SR training. Utilizing a non-correction procedure, Wischner, Fowler and Kushnick (1963) trained SR, SW and NS groups on an easy (bright-dark) discrimination which parametrically varied punishment intensity from 0 to 75 volts. Increasing shock intensity progressively reduced both errors and trials to criterion for the SW group and progressively increased errors and trials for the SR group. Presumably, shock selectively associated with either the positive or negative discriminative stimulus produced avoidance of the cue with which it was associated proportionate to the intensity of the aversive experience; thus performance was progressively facilitated for SW groups and progressively retarded for SR groups. In a subsequent study which also utilized an easy (bright-dim) discrimination, Wischner and Fowler (1964) varied shock duration (0.1, 0.2, and 0.4 sec) for both SR and SW groups. Comparable to the effect of punishment intensity in the previous study, increases in shock duration were associated with decreases in errors and trials to criterion for the SW group. However, contrary to the expectation based on the effect of shock intensity, the performance of all of the SR groups was comparable to that of the NS control.

B. The Development of the Distinctive-Cue Hypothesis

If avoidance of specific cues is a direct function of the duration of shock paired with those cues, then the absence of a retardation effect for the SR groups of the duration study indicates

that an additional factor was operating to offset the avoidance effect. Fowler and Wischner (1965) proposed that this additional factor could be related to the action of a "distinctive" cue. This explanation emphasizes the role of the acquired properties of the T-maze stimuli. That is, all of the stimuli in the correct arm of a T maze should acquire secondary reinforcing properties because of their association with food reinforcement. (Comparably, all stimuli in the incorrect arm of the T maze should acquire secondary non-rewarding, i.e., frustrative, properties. Although the original explanation proposed by Fowler and Wischner did not consider the possibility of generalized non-reinforcement effects, their most recent formulation does, and thus it is noted here.) Therefore, to the extent that the total stimulus complex representing the correct arm is similar to that representing the incorrect arm, a basis exists for the generalization of secondary reinforcement from correct to incorrect-arm cues and, comparably, for the generalization of secondary non-reinforcement from incorrect to correct-arm cues. It follows, then, that any incorrect choice is subject not simply to non-reinforcement (both primary and secondary), but also to _generalized_ secondary reinforcement; likewise, any correct response is subject not only to reinforcement (both primary and secondary), but also to _generalized_ secondary non-reinforcement.

Given the above interpretation of discrimination learning, the introduction of a highly discernible stimulus or "distinctive" cue (e.g. shock) into either the correct or incorrect arm of the maze should alter the complex of stimuli therein, thereby _reducing_ the similarity of correct and incorrect-arm cues and thus reducing between-arm

generalization effects. From the standpoint of this consideration, mild or moderate shock selectively associated with either the positive or negative discriminative stimulus, should serve as a "distinctive" cue to improve the performance of both SR and SW groups. Furthermore, when this distinctive-cue effect of the shock is considered in combination with shock's avoidance-producing effect, the performance of SW Ss should be considerably facilitated, since both effects (cue and avoidance) will act conjointly to reduce errors. However, the performance of the SR Ss can be either facilitated or retarded depending upon the relative magnitude of the two effects of shock; that is to say, the avoidance-producing effect should promote increased errors, whereas the cue effect should lead to a reduction in errors.

It should be noted that the distinctive-cue hypothesis does not suggest that shock serves as a discriminative stimulus since it is delivered subsequent to choice, and thus cannot control that choice directly; nor does it suggest that shock itself becomes a secondary reinforcer, acting backward on the choice response. This is not to say that shock cannot have these functions, but that the present explanation does not employ them in accounting for the SR facilitation effect. Quite apart from any of the other diverse functions of shock (cf. Fowler, 1971 and Fowler and Wischner, 1969), the distinctive-cue interpretation emphasizes shock's pure stimulus property, particularly its potential to change the total stimulus complex, thus controlling the between-arm generalization of conditioned reward and conditioned non-reward.

C. Assessments of the Distinctive-Cue Hypothesis

1. Discriminative Stimulus Manipulations

Fowler and Wischner (1965) assessed their proposed distinctive-cue effect of shock by manipulating the difficulty of the discrimination. If the cue function does operate, then its effect should be augmented by increasing the similarity of the discriminative stimuli since these stimuli constitute major components of the stimulus compounds representing the correct and incorrect arms. In this situation (e.g., a bright-dim discrimination), the stimulus compounds for the arms would be more similar, thus potentiating greater between-arm generalization effects and thus augmenting the potential cue effect of shock in reducing the generalization of secondary reinforcement and non-reinforcement. Using a set of bright-dim discrimination problems (rather than the typical light-dark problem) along with moderate shock, Fowler and Wischner found that, relative to NS training, both SR and SW training reduced errors and trials to criterion, and as expected, SW training was superior to SR training.

A subsequent study reported by Fowler and Wischner (1969) manipulated similarity between the arms of the T maze by varying the extent to which the discriminative stimuli (wall inserts) protruded into the arms of the maze. For this study black (S-) and white (S+) inserts were attached to the walls of the maze arms starting at the choice point and extending one third, two thirds, the entire length of the maze arm, or the entire arm including the far wall of the goal compartment. (Sections of the maze walls not covered by the discriminative stimuli were a mid-gray.) Comparable to the effect of decreasing the difference in brightness of the discriminative stimuli, as in the

previous study, decreasing the amount of discriminative-stimulus extension into the arms (i.e., from the entire arm and goal compartment to only one third of each arm) had the effect of increasing total errors and trials to criterion, and similarly of increasing the magnitude of the SR facilitation effect. Despite the utilization of discriminative stimuli which were highly dissimilar (black-white), between-arm generalization and consequently SR facilitation was promoted by controlling the extent of the similarity between the arms of the maze, i.e., through the proportion of the maze arms that were covered by gray.

2. Reinforcement Manipulations

The above findings indicate that operations which affect the similarity of the two arms of the T maze and which thus control the generalization of conditioned reinforcement and conditioned non-reinforcement between the maze arms, will also control the magnitude of the SR facilitation effect. When such generalization is high, shock selectively applied to either the correct or incorrect response can facilitate performance--more so than when it is low. Furthermore, because these generalization effects are potentially controlled by all of the stimuli in each arm, manipulating stimuli other than the discriminative stimuli should also control SR facilitation.

Following the above rationale, Fowler and Wischner instituted a series of studies that manipulated a component of the total stimulus complex of the T-maze arms which, like shock, also serves as a highly discernible stimulus (distinctive cue) and which is typically made

contingent upon a single response--namely, the food object itself.
Apart from its reinforcing or incentive property, the food object
should operate as a distinctive cue, because, like any other stimulus,
it can increase the discriminability of the two arms and thus reduce
between-arm generalization effects. The general approach of these
studies was to begin with an easy discrimination problem (light-dark)
and to assess the magnitude of SR facilitation when difficulty was
promoted, not by changing the relative brightnesses of the discrim-
inative stimuli, but by increasing the similarity of the goal
situations following correct and incorrect responses, in particular,
by manipulating the delay, magnitude and percentage of reinforcement.

   In one of these studies, Fowler, Fago, and Wischner (1971)
increased the similarity of the goal situations by instituting a
delay of reinforcement for the correct response. In effect, the
"infinite" delay of reinforcement for the incorrect response (i.e.,
no reinforcement) was matched by imposing a fixed delay of reinforce-
ment for the correct response, thereby increasing the similarity of
the stimulus compounds constituting the two arms and thus increasing
between-arm generalization effects. Consistent with the distinctive-
cue hypothesis, increasing delays of reinforcement were associated
with increasing errors and trials to criterion and, most importantly,
with increasing magnitudes of SR facilitation when shock was
administered in place of immediate food at the goal.

   In another study, Hochhauser (1970) promoted similarity between
the alternatives in the context of an easy (light-dark) discrimination
by manipulating the differential in amount of reinforcement for the two
alternatives. Specifically, different groups were trained under

selective or non-selective reinforcement entailing differential magnitudes of 1 and 0, 2 and 0, 3 and 1, or 5 and 1 pellets for the correct and incorrect responses, respectively. When the differential in reinforcement was low and thus the stimuli in the correct and incorrect goals more similar, errors and trials to criterion increased. That is, the 1-0 group was retarded relative to the 2-0 group, and the 3-1 group was retarded relative to the 5-1 group. Furthermore, whereas the difference between NS and SR subgroups of the 5-1 and 2-0 reinforcement conditions was clearly not significant, the SR subgroups of the combined 3-1 and 1-0 conditions were facilitated relative to their respective controls. When assessed separately, this SR facilitation effect was found to be reliable only for the 3-1 condition. Failure to find reliable SR facilitation for the 1-0 group may relate to the aversive function of the shock which, in combination with the reduced positive incentive for this group (only one pellet), may have overriden the cue effect of the shock.

Finally, in a study investigating reinforcement variations, Ascher (1968) manipulated the percentage of reinforcement for the correct alternative. If both food and shock do not occur for every correct response, but only on 50% of these trials, shock should have its maximal facilitating effect when it is applied to correct responses that are not food-reinforced, because it is these trials that provide a stimulus complex most similar to the complex following incorrect responses. Ascher investigated this possibility by training both NS and SR groups on an easy (light-dark) discrimination task which set the probability of food reinforcement and of shock at 50% and manipulated the correlation (-1, 0, +1) of food and shock for the

correct response. Although the performance of the SR groups was not facilitated relative to the NS control (i.e., 50% food, no shock), the SR groups ordered themselves as expected; that is, as the correlation increased from -1 (shock and food unpaired) to +1 (shock and food paired), errors and trials to criterion reliably increased. Furthermore, the negatively correlated SR group was not different from the NS control. Again, failure to find SR facilitation relative to the NS control probably relates to shock's aversive function, in combination with relatively low positive incentive (2 pellets, but only on half of the trials), overriding the cue effect of the shock.

3. Shock Manipulations

The interaction of the cue and aversive components of SR training was specifically investigated in a study which varied shock intensity in the context of a difficult (bright-dim) discrimination (Fowler, Goldman and Wischner, 1968). In this study, increases in shock intensity from 0 to 60 volts were associated with a reduction in errors and trials to criterion for SR groups, i.e., SR facilitation was produced. However, as shock intensity was further increased to 120 volts, the facilitation gave way to retardation. In contrast, the earlier Wischner et al. (1963) study which manipulated shock intensity in the context of an easy (light-dark) discrimination--one in which the potential cue function of shock is precluded by highly discriminable alternatives--indicated that the avoidance-producing function of shock was linearly related to shock intensity. Taken together, these findings argue that the cue effect of shock is some S-shaped function of shock intensity. This relationship describing

the cue effect of shock (i.e., its discriminability) as a function of shock intensity is in accord with the general relationship between discriminability and stimulus intensity as expressed by the Weber function. In the present study, the proposed combination of specific avoidance and cue functions would produce facilitation at low shock intensities followed by retardation as the avoidance function gained predominance at higher shock intensities.

In addition to being dependent on shock intensity, the cue effect of shock should also be a function of shock's point of application in the T maze. In particular, the distinctive-cue hypothesis suggests that to be most effective, shock should be applied at that point between choice and reinforcement which is most similar to the equivalent point in the incorrect response chain, because it is here that between-arm generalization effects will be greatest. In line with this consideration, Fowler and Wischner (unpublished study) trained SR and NS groups on a difficult bright-dim discrimination where the locus of shock was varied for subgroups of the SR condition, specifically by imposing shock directly after choice (locus 1), midway in the arm (locus 2) or in the goal (locus 3). The results of this study showed that SR facilitation was maximal at locus 2 and minimal (if existent at all) at locus 1 and 3. (It should be noted that in this study, reinforcement was presented immediately at the goal.) Interpreted in terms of the distinctive-cue hypothesis, this finding suggests that the correct and incorrect arms are more discriminable both at the choice point (because the discriminative stimuli and proprioceptive feedback from the choice response itself can differentiate one choice response from the other) and at the goal (because the relatively high magnitude

reward object--two pellets--delivered immediately can differentiate the correct and incorrect goals). At locus 2, however, the alternatives are not well differentiated (because, at this location in both arms, the animal is typically involved in running with its head down, therefore not receiving the discriminative stimuli), and consequently shock applied here would be most effect in reducing between-arm generalization effects. It is noteworthy that these findings determined the locus of shock for the delay of reinforcement and differential reinforcement studies cited above; although typically employed at locus 2, shock was applied at locus 3 in these reinforcement studies because, it was the goal situations themselves which were most similar.

Although the above findings are consistent with the interpretation of shock as a distinctive cue, such an interpretation also predicts that performance will not be facilitated when shock is nonselectively applied, i.e., presented for both correct and incorrect responses. This prediction appears not to be supported by some of the earlier studies, since both Muenzinger and Wood (1935) and Muenzinger and Newcomb (1936) found evidence for shock-both (SB) facilitation. However, these studies used a correction procedure that did not control the frequency of punishment for SR and SB groups; that is, an SB S received three times as much punishment for an error as did an SR S. This difference alone could account for the facilitated performance of SB Ss. Furthermore, Freeburne and Taylor (1952) found only marginal SB facilitation using non-correction training, and Prince obtained no difference between NS and SB groups

with the same procedure. Assessment of the SB factor within the Fowler and Wischner lab has also failed to provide evidence for facilitation by non-selective shock. Fowler and Wischner (1969) report an unpublished study using NS, SR and SB acquisition conditions along with a shock-paired (SP) condition. In this latter condition, the $\underline{S}$ received shock for both correct and incorrect responses, but only when a paired running mate of the SR condition made a correct response and thus received shock. These investigators found no evidence for facilitation by non-selective shock in either easy or difficult discrimination problems.

In total, then, the foregoing studies indicate that shock will facilitate performance via its cue properties if (a) the shock is selectively applied to the correct or incorrect response, (b) between-arm generalization effects are high, (c) shock is applied to the point of high similarity between the correct and incorrect response-chains, and (d) the intensity of shock is not so great as to produce avoidance effects which offset the benefit from the shock's cue effect.

D. Isolation of the Components of Distinctive Cues

The failure to observe SR facilitation when shock intensity (or duration) is relatively high clearly indicates that the presentation of shock represents a rather complex event. That is to say, shock can have both aversive and cue properties, and consequently, any effect of SR training on discrimination is determined by the interaction of at least these two properties. Furthermore, the distinctive-cue property of shock may derive from two separate components of the shock event, the

shock stimulus itself and the stimulus feedback from those responses elicited by shock (e.g., feedback from fear or emotional responses). Although the fear-eliciting property of shock presumably underlies its avoidance function, both the feedback of fear and the pure stimulus (i.e., pain) component of shock may contribute to its function as a distinctive stimulus. With these considerations at hand, the aim of recent research has been to assess the distinctive-cue function of shock apart from its aversive function, and to isolate the components of the total stimulus event (shock and fear-produced stimuli) which may contribute to the cue function.

In an initial study, Fowler, Goldman and Wischner (1968) attempted to separate the avoidance-producing function from the distinctive-cue function of shock-punishment by training rats under the influence of sodium Amytal, a drug which apparently acts to reduce fear and avoidance (cf. Miller, 1961). In the difficult, bright-dim discrimination employed, the performance of both placebo and of non-injection controls was initially facilitated but then retarded across increasing intensities (0-120 volts) of shock for the correct response. As previously noted, this retardation effect presumably relates to the dominance of the avoidance producing properties of shock at higher intensities. The SR $\underline{Ss}$ that received the drug showed facilitation which did not give way to retardation at higher intensities. Presumably, sodium Amytal had the effect of reducing the avoidance-producing properties of shock, allowing the distinctive-cue effect to predominate at these higher shock intensities. In this respect, it is noteworthy that facilitation for the drug $\underline{Ss}$ was an S-shaped function of shock intensity, consistent with the discriminable

properties (e.g., the intensity) of a stimulus as described by the Weber function.

Because it can not be certain that sodium Amytal acted in the prior study to reduce the fear or avoidance-producing component of the shock experience, rather than serving as an analgesic to reduce the painful intensities of shock for the drug $\underline{S}$s, subsequent research has attempted to demonstrate the distinctive-cue properties of an event by employing a "neutral" stimulus dimension, viz., white noise. Utilizing different intensities of white noise which ranged from subthreshold to suprathreshold values with respect to aversiveness, Fago and Fowler (1971) have recently assessed the effect of noise-right, noise-wrong, noise-paired, and no-noise training on a difficult, bright-dim discrimination task. In accord with the prior punishment data, noise for the correct or incorrect response generally facilitated performance whereas noise-paired training did not. More importantly, the amount of facilitation produced by noise-right and noise-wrong training was a statistically reliable S-shaped function of noise intensity. Furthermore, no evidence of an interaction of noise intensity and contingency was found; that is to say, without a large aversive component, the avoidance function did not operate to retard noise-right groups or to additionally facilitate noise-wrong groups. This study, like the prior-noted reinforcement studies, indicates that a response-contingent stimulus need not be aversive to function as a distinctive cue.

II. STATEMENT OF THE PROBLEM

On the basis of the foregoing findings, the most recent efforts in the Fowler and Wischner lab have been to isolate and assess the fear component of the punishment experience. An assessment of the distinctive-cue function of fear alone, i.e., an assessment of fear-right or fear-wrong training, is made possible by controlling fear with a stimulus which has little or no distinctiveness per se. The low intensity, subthreshold value of white noise employed by Fago and Fowler (1971) meets this requirement, since the performance of noise-right and noise-wrong groups trained with this relatively weak intensity (70 db) was not different from that of the no-noise control group. Consequently, by utilizing Pavlovian procedures, fear can be conditioned to this weak noise stimulus and in turn this stimulus can be selectively applied to the correct or incorrect response during the learning of the discrimination task. Compared with a group receiving Pavlovian fear conditioning designed to establish the noise signals as neutral with respect to fear, i.e., a Pavlovian control, differences in performance on the discrimination task would reflect differences due entirely to those responses (together with their stimulus feedback) that are conditioned during the course of Pavlovian training.

Data for a study utilizing these fear conditioning techniques has recently been collected (Fowler, Fago, Domber and Wischner, in preparation). The design employed various Pavlovian procedures to establish white noise or tones as signals controlling fear (CS+), signals controlling the inhibition of fear (CS-), or signals which were neutral with respect to fear (CSo). Following Pavlovian training, the Ss received

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noncorrection training on a difficult (bright-dim) discrimination in which the CSs were made contingent on the correct response (signal-right training), with different groups of Ss receiving CS+, CS- or CSo as the signal depending on their prior Pavlovian training. In addition, there were control Ss which received all three types of Pavlovian training but no signal during discrimination training (no-signal training). Finally, the signal-right and no-signal Ss of each group were subdivided with half being run under one of two conditions of discrimination training: a standard condition entailing food for the right response and no shock (NS), and a "fear" condition entailing both food for the right and shock for the wrong response (SW). This latter condition was included so as to potentiate the effect of the CS- (fear inhibition) signal for the correct response.

Selection of a particular procedure to establish the different CSs (+, -, and o) depends, to some extent, on the nature of classical conditioning itself. According to Rescorla (1967), the critical feature of the classical conditioning paradigm is the contingency between CS and US events. That is, whenever a CS predicts the occurrence of the US, that CS becomes a conditioned excitor; conversely, whenever the CS predicts the non-occurrence of the US, it becomes a conditioned inhibitor. Thus Rescorla argues that procedures which have typically been used as control procedures (e.g., backward conditioning, or explicitly unpaired groups) do not produce neutral CSs but rather conditioned inhibitors. The most appropriate control procedure according to this formulation is one which establishes no contingency (or correlation) between the CS and US events, i.e., one in which the CS and US occur randomly with respect to each other.

Following this rationale, there is no problem in establishing a CS+, as through a forward conditioning arrangement, but a variety of ways in which a CS- can be established. Accordingly, the present study employed forward conditioning in conjunction with backward-conditioning, differential-conditioning, and conditioned-inhibition procedures to establish the different CSs. Thus, the first procedure used a forward conditioning arrangement (2 sec ISI) to condition white noise as a signal controlling fear, and a backward-conditioning procedure (same ISI but reversed events) to establish the noise stimulus as a fear inhibitor. The control $\underline{S}$s received both forward- and backward-conditioning trials with the ISI varying within limits imposed by a one-minute discrete Pavlovian trial. The differential-conditioning procedure also used forward conditioning to establish white noise as a CS+, but in addition half of the trials for these $\underline{S}$s included neither US nor CS. For the CS- $\underline{S}$s, half of the trials included the US alone, and half contained only the CS. The control group for this procedure consisted of $\underline{S}$s given all four types of differential-conditioning trials. Finally, the conditioned-inhibition procedure employed two tones of different frequencies for each $\underline{S}$. The onset of the first tone (CS+) was followed 2 sec later by the US or 1.5 sec later by the second tone (CS-) but without shock. The control procedure in this case consisted of $\underline{S}$s given four types of tone (Ti) trials: T1-T2, T1-US, T1-T2-US, and T1 alone. For all procedures, the designated stimulus occurred at randomly varying times within a 30 sec (in the case of conditioned-inhibition or differential-condtioning procedures) or 1 min (in the case of the backward-conditioning procedure) Pavlovian trial.

It was expected that when these CSs were employed during discrimination training, they would facilitate performance to the extent that they function as cues which had acquired distinctiveness. Accordingly, for the NS trained $\underline{Ss}$, the no-CS and CSo groups should exhibit comparable performance because the intensity of the signal (CS) was only 70 db, a value which had previously been shown to have little or no distinctive cue effect per se (Fago and Fowler, 1971); furthermore, CSo training in the Pavlovian context should not have produced any acquired distinctiveness. On the other hand, the no-shock CS+ group should, like the typical shock-right group, show facilitated performance relative to that for its respective control (CSo) but now due to the distinctiveness provided by the fear-produced stimulation, i.e., as a consequence of fear conditioning. Finally, little if any difference was expected between the CS- and CSo groups because the absence of shock in the maze for the NS trained $\underline{Ss}$ precluded the presence of fear, thus nullifying any potential distinctiveness associated with fear inhibition. For the SW trained $\underline{Ss}$, the same relationships were anticipated except in the case of the CS+ and CS- groups. In this fearful (SW) context, the facilitating effect of the CS+ condition should be degraded if not offset completely because CS+ for the correct response now promotes added equivalence through the $\underline{Ss}$ experiencing fear in the correct arm (fear-right) as well as in the incorrect arm (shock-wrong). Conversely, the CS- condition should now lead to facilitated performance because fear is potentiated by the presence of shock in the incorrect arm, and consequently, fear reduction in the correct arm (i.e., through presentation of the CS-) provides an added source of reinforcement.

Furthermore, if the reduction of fear via CS- presentation can reduce the similarity between correct and incorrect arms of the maze, i.e., through the presence of shock and fear-produced stimulation in the incorrect arm and none in the correct arm, then such training should, according to the distinctive-cue hypothesis, additionally facilitate performance relative to that for the CSo controls. Finally, apart from these specific group differences, the performance of the SW $\underline{Ss}$ should be facilitated relative to that for the NS $\underline{Ss}$ due to the aversive and distinctive cue functions of shock for the incorrect response.

The data (including all three Pavlovian procedures) provide only limited support for these predictions. As expected, the SW condition facilitated performance relative to the NS condition and, within both of these conditions, the CSo group was comparable to the no-CS control group. Furthermore, although the CS+ (fear-right) group showed facilitated performance relative to the CSo group in the NS condition, it also showed facilitated performance in the SW condition! Conversely, the CS- (fear inhibition) group showed retarded performance relative to CSo group both in the NS condition, where there presumably was no fear to be reduced, and in the SW (fearful) condition where fear reduction through CS- presentation in the correct arm was at least expected to provide an additional source of reinforcement. Given these outcomes, the results for both the NS and SW conditions can be described very simply as constituting linear and symmetrical effects for CS+ through CSo to CS- training, i.e., from facilitation to retardation with CSo being comparable to no-signal

training. Quite obviously, these results are not readily amenable to the distinctive-cue hypothesis, at least as based on the foregoing analysis of conditioned fear and fear inhibition effects, and thus they suggest a reinterpretation of the nature of the interaction between Pavlovian fear conditioning and appetitive discrimination learning.

The distinctive-cue hypothesis identifies the transfer of particular responses (fear or the inhibition of fear) between Pavlovian and instrumental appetitive conditioning as the critical events affecting discrimination performance. An alternative explanation of the data, however, might emphasize the transfer of another property of Pavlovian CSs, namely, their signaling property. That is to say, Pavlovian fear conditioning can be viewed as establishing CSs which act as signals for the occurrence or non-occurrence of the reinforcer (i.e., US presence or US absence), in addition to controlling those specific responses (e.g., fear or the inhibition of fear) which have been elicited by the presence of absence of the US. It is suggested here that this signaling property of the CS constitutes, in part, a general property which can transfer from one reinforcer (US) to another. That is to say, the CS may readily come to signal the presence or absence of *any reinforcer* (e.g., food) and not just the particular US (e.g., shock) by which its general signaling properties were established. Consequently, when the aversively established CS is employed in an appetitive situation (e.g., appetitive discrimination training) where the *original* US is not present or is unimportant relative to the new US (viz., food), the CS may be trans-muted to a signal which indicates the presence or absence of food reinforcement! Correspondingly, it would seem that in the context of

food reinforcement, the specific responses (e.g. fear) originally controlled by the aversively established CS would be quickly degraded thus reducing their capacity to control performance. In contrast, the general signaling property of the CS would be maintained by the presence of a reinforcer (viz., food) in the situation.

Applied to the findings reported above, the foregoing interpretation suggests that the CS+ should have quickly been transformed to a signal which indicated the presence of food. Furthermore, since the general signaling function of the CS+ (i.e., reinforcement is coming) occurred in the correct arm, it signaled the occurrence of food reinforcement when, in fact, food was present. Such a positive correlation (+1) between the presence of food and the signaling value of the CS (i.e., the reinforcer is coming) could well have facilitated acquisition of the discrimination by aiding in the conditioning of anticipatory consummatory reactions (e.g., rg-sg) to the correct-arm cues. However, when the CS- was employed for the correct response, it presumably signaled the non-occurrence of a reinforcer, when, in fact, the reinforcer (food) was available. Thus, this negative correlation (-1) between the presence of food and the general signaling value of the CS- (i.e., the reinforcer is not coming) could well have interfered with the acquisition of appropriate anticipatory reactions and thus retarded overall discrimination performance. Although this explanation based on the presumed signaling properties of Pavlovian CSs can account for the effects observed in the above study, the explanation is admittedly post facto. A more complete assessment of the signaling hypothesis would suggest an extension of the above design

to include data collected under a wider variety of conditions. The present study proposes such an approach.

To establish a direct comparison between the previous and the proposed studies, the present design would employ no-shock discrimination training with a CS+, a CS- or a CSo selectively applied to the correct response. Replication of the previous findings for these groups would provide a baseline against which the performance of groups given two additional types of no-shock discrimination training could be evaluated. The first of these added conditions would assess the general signaling hypothesis by selectively applying the three types of CSs (CS+, CS-, or CSo) to the incorrect response. If the signaling hypothesis holds, a CS+ made contingent on the incorrect response should interfere with acquisition of the discrimination because it generates a negative correlation (-1) between the signaled event and the food event, i.e., it signals the occurrence of reinforcement when, in fact, none is present. Conversely, a CS- applied to the incorrect response should now facilitate discrimination performance because in this case, the signal value correlates positively (+1) with the absence of reinforcement (i.e., the absence of food is signaled when, in fact, it is not present). Furthermore, by using a Pavlovian procedure which would establish different CSs (both a CS+ and a CS-) for every S, an extension of the design would be permitted enabling an S to receive both CSs during discrimination training, one for the correct and one for the incorrect response. A group in which S received a positive correlation (+1) of signaled events and reinforcement events, i.e., CS+ for the correct response and CS- for

the incorrect response, should be maximally facilitated according to the general signaling hypothesis. On the other hand, a group in which $\underline{S}$ received the reverse combination (i.e., a negative correlation of signaled events and reinforcement events) should be maximally retarded in relation to those $\underline{Ss}$ of a group which received a non-functional, 0 correlation, i.e., two different CSo's, one for the correct and one for the incorrect response.

In total, then, the proposed study constitutes a complete 3 X 3 factorial design of three signal (CS) contingencies, signal-right, signal-wrong and signal-both, and three correlations (+1, -1, and 0) of the general signaling value of the CSs and the occasion or non-occasion of reinforcement. A tenth group will be added as a control for the presence of the CSs themselves, i.e. apart from their acquired signaling properties. This tenth group will receive no CS during discrimination training but will be comprised of an equal number of $\underline{Ss}$ given all types of Pavlovian training, that is, both functional (establishing a CS+ and CS-) and non-functional training (establishing CSo's).

III. METHOD

A. Subjects

Subjects were 120 male albino rats of the Sprague-Dawley strain, about 90 days old at the start of the experiment. The $\underline{S}$s were individually caged in the laboratory under controlled temperature and a reversed day-night cycle. One week prior to the start of the experiment they were started and maintained on a diet of 11 grams of Wayne Lab Blocks, with water available ad libitum.

B. Apparatus

1. Fear-Conditioning Apparatus

The fear-conditioning apparatus consisted of a black wooden chamber 10 1/2 in. long, 6 in. deep and 7 1/2 in. wide. A Jensen (model P4V3) 4 in., 3.2 ohm speaker was centered on the top of the chamber's transparent Plexiglas lid. This speaker was connected through a selector switch and Hunter-Timer circuitry to the output of both a Grason-Stadler (model 901B) white noise generator and a Hewlett-Packard (model 200CD) wide range oscillator. These signal generators provided the CSs: a 70 db, 0.2 sec duration burst of white noise and a 2000 Hz tone of equal intensity and duration. The floor of the chamber was comprised of a stainless steel grid with 3/32 in. diameter rods spaced 5/8 in. apart. The output of a transformer was connected through Hunter-Timer circuitry and a series resistance of .24 megohms to the shock grid. For the present study,

the US was a 60 c.p.s. unscrambled a.c. shock of 0.2 sec duration; its intensity was 120 volts, as metered across the output of the transformer.

2. Discrimination-Training Apparatus

The discrimination-training apparatus was an enclosed T maze consisting of a wooden shell painted flat black and a transparent Plexiglas top. The width and height of the maze was uniformly 3 3/4 in. and 4 1/2 in., respectively, with the length of the stem being 26 in. and each arm 36 in. The internal structure of each maze section was formed of two L-shaped strips of galvanized sheet metal, each strip forming a wall and half the floor. Together, the two L-shaped strips of sheet metal formed two 1 1/2 in. floor surfaces that were separated by a 3/4 in. gap. There was a guillotine door at the entrance to each arm, 3 in. from the center of the choice point. Equivalent doors were positioned 8 in. from the near end of the stem to form a start compartment and 12 in. from the end of each arm to form goal compartments. Each goal compartment had a transparent Plexiglas food well (3/4 in. diameter by 1/2 in. deep) and an end plate of frosted Plexiglas. Two 15 watt bulbs behind the end plates served as the discriminative stimuli; for the problem employed in the present study, the bulbs were set at 120 and 62.5 volts.

A Jensen (model P4V3) 4 in., 3.2 ohm speak was mounted on the transparent Plexiglas top of the maze in each arm, 4 in. from the goal-box doors. Each speaker was independently connected through switching and timing circuitry to the output of either the Grason-Stadler white noise generator or the Hewlett-Packard tone oscillator. Thus, the

selected signal was delivered to $\underline{S}$ when it interrupted, in the appropriate arm, an infrared photoelectric beam crossing the arm at a point 4 in. from the goal-box door. A manual priming feature of the signal circuitry prevented $\underline{S}$ from receiving more than one signal on any one trial. When a signal was delivered, it consisted of a 70 db, 0.2 sec duration burst of white noise or a 2000 Hz tone of equal intensity and duration.

C. Procedure

1. Pretraining

Pretraining was administered in the T maze to habituate $\underline{S}$ to the apparatus and reduce possible position and brightness preferences. Each $\underline{S}$ received a total of 16 forced, food-reinforced trials, administered 4 per day and randomly distributed with the restriction that half of the trials were to the bright and half to the dim goal. Forcing was accomplished by lowering the appropriate guillotine door at the entrance to the arm. Reinforcement on each trial consisted of P. J. Noyes Formula A rat pellets (45 milligrams per pellet). During pretraining, reinforcement was delivered according to the following procedure: on the first day pellets were liberally spread throughout the goal compartment; on subsequent days, the number and locus of pellets were systematically reduced until, on the last day, two pellets were given in the goal-box cup.

2. Fear Conditioning

Fear conditioning began on the day following termination of pretraining. All $\underline{S}$s received 16 conditioning trials per day for 6

consecutive days yielding a total of 96 trials in the fear-conditioning chamber. For this training, a discrete trial procedure was employed: Ss were placed into the chamber for 30 secs and then removed to a holding cage for an intertrial interval of approximately 5 minutes.

The Ss were randomly assigned to one of two fear-conditioning groups, a differential-conditioning (functional) group or a non-differential-conditioning (non-functional) group. On a random half of their daily trials, the functional Ss received one of the CSs (noise or tone) followed two seconds later by shock. On the other half of their trials, these Ss received the other CS alone. Thus this discriminative-training procedure employed forward trace conditioning with a 2 sec CS-US interval to establish one signal as a CS+, and extinction (CS alone) training to establish the other signal as a CS-. The non-functional control Ss received forward conditioning and extinction training with each of the two signals. That is, these Ss received an equal number of tone-shock, noise-shock, tone-alone, and noise-alone trials. For this type of training, there is no regular contingency between either CS event and the US, thus establishing both signals as CSo's.

3. Discrimination Training

On the day following the termination of fear conditioning, Ss began the instrumental discrimination-training phase. For this training, Ss received all free-choice trials, administered 4 per day for the first 6 days and 8 per day thereafter. During these trials, food reinforcement (two pellets) was obtained at the brighter goal, the left-right positioning of which was randomly varied over trials

with the restriction that the brighter goal was on the left for half
of the trials within any block of four trials. This procedure was
employed throughout training and continued until $\underline{S}$ reached a criterion
of 15 correct choices on 16 consecutive trials, with the restriction
that the last 8 were correct.

4. Design

Prior to the start of fear conditioning, the 120 $\underline{Ss}$ were
randomly assigned to 10 equally numbered groups. Nine of these groups
comprised a complete 3 X 3 factorial design of three signal (CS)
contingencies, CS right, CS wrong, or CS both, and three correlations
(+1, -1, or 0) between the general signaling value of the CSs and the
presence or absence of reinforcement (signal-reward correlation). The
tenth group controlled for the presence of the CSs per se, i.e., apart
from their acquired signaling properties. Accordingly, this group
did not receive any CS (no CS) during discrimination training.
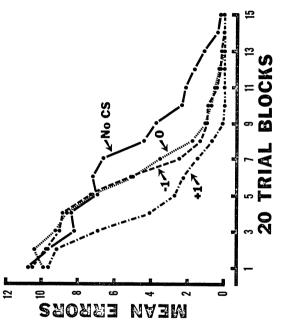
The CS-right and CS-wrong groups were balanced with respect to
the particular signal employed during discrimination training (noise
or tone), and comparably, the CS-both groups were balanced with
respect to which of the two signals (noise or tone) was employed in
the correct arm with the other being used in the incorrect arm.
Finally, the no-CS control group was comprised of an equal number of $\underline{Ss}$
given functional and non-functional Pavlovian conditioning.
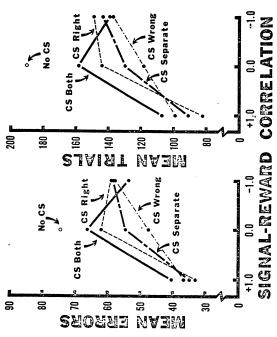
IV. RESULTS

Figure 1 presents mean errors in blocks of 20 trials for the no-CS control group and for each of the three signal-reward correlation groups (+1, 0, -1). These latter groups were collapsed across signal contingency (CS right, CS wrong and CS both) to depict the overall relationship between performance (errors and trials) and signal-reward correlation. Consequently, each data point comprising the curves for the signal-reward correlation groups represents a mean of 36 $\underline{S}$s, while the data points for the no-CS control group represent means based on only 12 $\underline{S}$s. Figure 1 indicates that, relative to the no-CS condition, the 0 and -1 signal-reward correlation conditions produced faster rates of error reduction (and similarly fewer trials to criterion), and that relative to these two groups, +1 correlation training produced even faster error reduction (and still fewer trials to criterion).

Because of the orderly progression of performance curves, the data were treated statistically on the basis of total mean errors and trials to criterion. Figure 2 presents these data for the no-CS control group and for the CS-contingency subgroups as a function of signal-reward correlation, the left panel showing errors and the right panel trials to criterion. The data are presented separately for the CS-both condition (comprised of $\underline{S}$s given one signal, tone or noise, for the correct response <u>and</u> the other signal for the incorrect response) and the CS-separate condition (comprised of $\underline{S}$s given one signal, tone or noise, for <u>either</u> the correct or the incorrect response). The CS-separate condition is further reduced in Figure 2 to its component CS-right and CS-wrong subconditions.

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Fig. 1. Mean errors in blocks of 20 trials for the no-CS control and for the +1, 0, and -1 signal-reward correlation groups, the latter being collapsed across signal contingencies.

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Fig. 2. Mean errors and trials to criterion for the no-CS, CS-both and CS-separate conditions as a function of signal-reward correlation. The CS-separate condition is further reduced to its CS-right and CS-wrong subconditions.

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Figure 2 suggests a linear relationship between performance (errors or trials to criterion) and signal-reward correlation for the CS-separate condition; in particular, +1 correlation training facilitated and -1 correlation training retarded performance relative to the 0 correlation controls. Consistent with this description, the individual functions for the components of the CS-separate condition, i.e., for the CS-right and CS-wrong conditions, also depict a linear relationship between errors or trials to criterion and signal-reward correlation. (The possible exception to this description derives from the errors data for the CS-right condition for which 0 correlation training resulted in performance slightly inferior to -1 correlation training. However, the distribution of both errors and trials to criterion for this particular group was positively skewed--there were no low extreme scores--thus artificially elevating the means, particularly in the case of the errors data.) For the CS-both condition, Figure 2 shows an inverted U-shaped relationship between performance (errors or trials) and signal-reward correlation. This suggests that -1 and +1 correlation training produced somewhat comparable effects within the CS-both condition (with the difference, if any, favoring superior performance on the part of the +1 correlation condition), and that relative to these two training conditions, 0 correlation training retarded performance. (These CS-both and CS-separate effects, when respectively combined into single functions for the +1, 0, and -1 signal-reward correlations, produce the overall equivalence of 0 and -1 training depicted in Figure 1.) Finally, Figure 2 indicates that the no-CS controls were retarded relative to all or most of the CS groups; in effect, a signal

(CS+, CSo, or CS-) for either the correct or incorrect response (or different signals for both correct and incorrect responses) facilitated acquisition of the discrimination.

Statistical analysis of the errors and trials data generally supports the above description. The results of an overall 3 X 3 analysis of variance of signal contingency (CS right, CS wrong, and CS both) and signal-reward correlation (+1, 0, -1) are presented in Tables 1 and 2 for errors and trials, respectively. These tables show that the overall effect of signal-reward correlation was significant for both the errors and trials measure. Moreover, in line with the above description of the data as a combination of the linear function of CS-separate training and quadratic function of CS-both training, both the linear and quadratic trend components of the effect of signal-reward correlation were reliable. However, there was no statistically significant effect of signal contingency, nor were any of the orthogonal sub-comparisons reliable (i.e., CS right vs. CS wrong, and CS separate vs. CS both). In addition, all interactions and their underlying trend components were non-significant. Thus, the difference indicated in Figure 2 between the CS-separate and CS-both functions was obscured in this overall analysis, presumably as a result of the sampling bias evidenced with the 0 correlation group of the CS-right condition.

To assess further the relationship between signal-reward correlation and CS contingency (separate or both), as well as to isolate the effects of each type of CS contingency, the overall 3 X 3 analysis was reduced to two subanalyses. The results of the first, an analysis of variance of CS-separate effects alone, are presented in Tables 3 and 4 for errors and trials, respectively. This 2 X 3 X 2

TABLE 1

Analysis of Variance of Errors to Criterion for CS-Right, CS-Wrong, and

  CS-Both Groups of the +1, 0, -1 Signal-Reward Correlation Conditions

Source	df	Mean Square	F	$\underline{p}$
A. Signal Contingency (Right, Wrong, Both)	2	272.128	0.658	----
1. Right vs. Wrong	1	224.013	0.542	----
2. Right and Wrong vs. Both	1	320.226	0.775	----
B. Signal-Reward Correlation (+1, 0, -1)	2	5229.350	12.656	.005
Linear	1	7360.888	17.814	.005
Quadratic	1	3097.796	7.497	.01
A X B	4	487.665	1.180	----
A1 X Linear B	1	90.750	0.219	----
A2 X Linear B	1	367.361	0.889	----
A1 X Quadratic B	1	1002.777	2.426	----
A2 X Quadratic B	1	489.814	1.185	----
Error	99	413.188		

TABLE 2

Analysis of Variance of Trials to Criterion for CS-Right, CS-Wrong, and
CS-Both Groups of the +1, 0, and -1 Signal-Reward Correlation Conditions

Source	df	Mean Square	F	$\underline{p}$
A. Signal Contingency (Right, Wrong, Both)	2	2479.306	1.407	----
1. Right vs. Wrong	1	806.680	0.457	----
2. Right and Wrong vs. Both	1	4151.893	2.356	----
B. Signal-Reward Correlation (+1, 0, -1)	2	24730.000	14.037	.005
Linear	1	37858.347	21.489	.005
Quadratic	1	11601.337	6.585	.025
A X B	4	2633.473	1.494	----
A1 X Linear B	1	2465.333	1.399	----
A2 X Linear B	1	1965.444	1.115	----
A1 X Quadratic B	1	3560.111	2.020	----
A2 X Quadratic B	1	2542.370	1.443	----
Error	99	1761.682		

TABLE 3

Analysis of Variance of Errors to Criterion for Signal Contingency

(CS Right and CS Wrong), Signal (Tone and Noise), and

Signal-Reward Correlation (+1, 0, and -1) Within the

CS-Separate Condition

Source	df	Mean Square	F	p
A. Signal Contingency (Right, Wrong)	1	224.000	0.588	----
B. Signal-Reward Correlation (+1,0,-1)	2	3823.600	10.049	.005
Linear B	1	6580.083	17.294	.005
Quadratic B	1	1067.111	2.804	----
C. Signal (Tone or Noise)	1	7.400	0.019	----
A X B	2	546.750	1.437	----
A X Linear B	1	90.750	0.238	----
A X Quadratic B	1	1002.777	2.635	----
A X C	1	42.000	0.110	----
B X C	2	479.550	1.260	----
Linear B X C	1	18.750	0.049	----
Quadratic B X C	1	940.444	2.471	----
A X B X C	2	700.700	1.841	----
A X Linear B X C	1	290.083	0.762	----
A X Quadratic B X C	1	1111.111	2.920	----
Error	60	380.473		

TABLE 4

Analysis of Variance of Trials to Criterion for Signal Contingency
(CS Right and CS Wrong), Signal (Tone and Noise), and
Signal-Reward Correlation (+1, 0, and -1) Within the
CS-Separate Condition

Source	df	Mean Square	F	p
A. Signal Contingency (Right, Wrong)	1	806.000	0.447	----
B. Signal-Reward (Correlation (+1,0,-1)	2	18744.000	10.407	.005
Linear B	1	34026.750	18.893	.005
Quadratic B	1	3461.361	1.921	----
C. Signal (Tone or Noise)	1	25.00	0.013	----
A X B	2	3013.000	1.672	----
A X Linear B	1	2465.333	1.368	----
A X Quadratic B	1	3560.111	1.976	----
A X C	1	160.000	0.088	----
B X C	2	1635.500	0.908	----
Linear B X C	1	208.333	0.115	----
Quadratic B X C	1	3061.777	1.700	----
A X B X C	2	3986.000	2.213	----
A X Linear B X C	1	200.083	0.111	----
A X Quadratic B X C	1	7773.361	4.361	.05
Error	60	1800.983		

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analysis of signal contingency (CS right and CS wrong), signal-reward correlation (+1, 0, -1), and type of signal (noise or tone) again shows a significant effect of signal-reward correlation for both errors and trials, but without the contribution of CS-both training, the linear component of the effect is highly reliable whereas the quadratic component is non-significant. Furthermore, as with the prior 3 X 3 analysis, the present analysis for both errors and trials shows no reliable difference between CS-right and CS-wrong groups. This finding, taken together with the absence of any interaction in the present analysis between signal contingency and signal-reward correlation indicates that the effect of a given signal-reward correlation (+1, 0, or -1) was the same regardless of the particular signal contingency (CS right or CS wrong) and the particular CS value (CS+, CSo, or CS-) which comprised it. In addition, the present analysis indicates no differential effect of the particular type of signal employed (noise or tone). There was, however, a marginally reliable effect relating to the interaction of type or signal and signal contingency with the quadratic component of signal-reward correlation (in this second order interaction, the F was significant for trials, $p < .05$, but not for errors). Apart from this seemingly spurious effect, the total combination of results for the CS-separate condition indicates that +1 correlation training facilitated and -1 correlation training retarded acquisition of the discrimination relative to the 0 correlation controls and, in view of the highly significant linear but non-significant quadratic trend, the best description of these effects is that they were essentially symmetrical about their reference condition (0 correlation).

The results of the companion analysis of variance of CS-both effects are presented in Tables 5 and 6 for errors and trials, respectively. In accord with the previous analyses, this 2 X 3 analysis of signal combination (tone-right, noise-wrong or noise-right, tone-wrong) and signal-reward correlation (+1, 0, -1) also shows a reliable effect of signal-reward correlation, but in this case (with the CS-separate effects omitted) the _quadratic_ component of the effect is reliable, whereas the linear component is unreliable. Furthermore, comparable to the effect of type of signal in the prior CS-separate analyses, the particular combination of signals employed in the CS-both condition produced no differential effect, nor did this variable interact with signal-reward correlation. Thus, in contrast to the linear effect of signal-reward correlation in the CS-separate condition, the present analysis indicates that 0 correlation training within the CS-both condition retarded performance relative to _both_ -1 and +1 correlation training, and that the relatively small difference between the -1 and +1 correlation groups, as depicted in Figure 2, did not reach statistical reliability. (It should be noted that the non-significant linear component reflects a direct comparison of the -1 and +1 correlation groups.)

The relationship of the no-CS control group to the several experimental groups was assessed by performing orthogonal comparisons between the no-CS control in combination with the CS-separate groups, and then again in combination with the CS-both groups. Because the no-CS control group itself was comprised of _S_s given both functional (CS+ and CS-) and non-functional (CSó) Pavlovian training, an analysis

TABLE 5

Analysis of Variance of Errors to Criterion for Signal-Reward

Correlation (+1, 0, and −1) and Signal Combination

(Tone-Right, Noise-Wrong and Noise-Right, Tone-Wrong)

Within the CS-Both Condition

	Source	df	Mean Square	F	$\underline{p}$
A.	Signal-Reward Correlation (+1, 0, −1)	2	1834.334	3.823	.05
	Linear A	1	1148.166	2.393	----
	Quadratic A	1	2520.500	5.254	.05
B.	Signal Combination (Tone-Right, Noise-Wrong or Noise-Right, Tone-Wrong)	1	5.444	0.011	----
A X B		2	635.444	1.324	----
	Linear A X B	1	37.500	0.078	----
	Quadratic A X B	1	1233.388	2.571	----
Error		30	479.000		

TABLE 6

Analysis of Variance of Trials to Criterion for Signal-Reward

Correlation (+1, 0, and -1) and Signal Combination

(Tone-Right, Noise-Wrong and Noise-Right, Tone-Wrong)

Within the CS-Both Condition

Source	df	Mean Square	F	$\underline{p}$
A. Signal-Reward Correlation (+1, 0, -1)	2	8239.675	4.785	.05
Linear A	1	5797.041	3.367	----
Quadratic A	1	10682.347	6.204	.025
B. Signal Combination (Tone-Right, Noise-Wrong or Noise-Right, Tone-Wrong)	1	536.600	0.311	----
A X B	2	1366.909	0.793	----
Linear A X B	1	57.042	0.033	----
Quadratic A X B	1	2676.680	1.554	----
Error	30	1721.661		

of variance was first performed on this variable. The results of this analysis are presented in Tables 7a and 7 b for errors and trials, respectively. Both the errors and trials analyses show no difference (F < 1) between the no-CS subgroups, and thus these groups were combined into a single control group for subsequent analyses. The first of these comprised a 1 X 7 analysis of variance of the no-CS control and the six groups of the CS-separate condition: CS+ right and CS- wrong (+1 signal-reward correlations), CSo right and CSo wrong (0 signal-reward correlations), and CS- right and CS+ wrong (-1 signal-reward correlations). The results of this analysis, which permits orthogonal comparisons of the component groups of each signal-reward correlation, are presented in Tables 8 and 9 for errors and trials, respectively. These comparisons show that there was no reliable difference between the two components of any signal-reward correlation, i.e., between CS+ right and CS- wrong, between CSo right and CSo wrong, and between CS- right and CS+ wrong. Like the prior analyses, however, the present analysis show a significant effect of signal-reward correlation (CS+ right and CS- wrong vs. CS- right and CS+ wrong), with the +1 correlation (former combination) being superior to the -1 correlation (latter combination). Taken together, these results again indicate that the effect of a given signal-reward correlation (+1, 0, or -1) was the same regardless of the particular combination of signal contingency (CS right or CS wrong) and CS value (CS+, CSo, or CS-) which comprised it. Importantly, the present results also show that the combined CSo groups had fewer errors and trials to criterion than did the no-CS control, and further, that these

TABLE 7

Analysis of Variance of Errors and Trials to Criterion for Functional
and Non-Functional Subgroups of the No-CS Control

a. Analysis of variance of errors

Source	df	Mean Square	F	p
Functional vs. Non-Functional	1	954.090	.0878	----
Error	10	1086.416		

b. Analysis of variance of trials

Source	df	Mean Square	F	p
Functional vs. Non-Functional	1	1220.200	0.222	----
Error	10	5474.280		

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TABLE 8

Analysis of Variance of Errors to Criterion for the

CS-Separate Groups and the No-CS Control

Source	df	Mean Square	F	p
Treatment	6	2501.083	5.197	.05
CS+ Right vs. CS- Wrong	1	121.500	0.252	----
CS- Right vs. CS+ Wrong	1	6.00	0.012	----
CS+ Right, CS- Wrong vs. CS- Right, CS+ Wrong	1	6580.083	13.672	.005
CSo Right vs. CSo Wrong	1	1190.041	2.472	----
CSo Right, CSo Wrong vs. No CS	1	2825.013	5.870	.025
CSo Right, CSo Wrong, No CS vs. All Others	1	4283.813	8.901	.005
Error	77	481.253		

TABLE 9

Analysis of Variance of Trials to Criterion for the

CS-Separate Groups and the No-CS Control

Source	df	Mean Square	F	p
Treatment	6	15414.262	6.765	.025
CS+ Right vs. CS- Wrong	1	1855.0416	0.814	----
CS- Right vs. CS+ Wrong	1	737.042	0.323	----
CS+ Right, CS- Wrong vs. CS- Right, CS+ Wrong	1	34026.7500	14.933	.005
CSo Right vs. CSo Wrong	1	4240.042	1.861	----
CSo Right, CSo Wrong vs. No CS	1	27495.1250	12.067	.005
CSo Right, CSo Wrong, No CS vs. All Others	1	24131.571	10.590	.005
Error	77	2278.571		

three groups combined were reliably inferior to the combination of all other groups.

The relationship between the no-CS control and the individual groups of the CS-both condition was assessed by performing orthogonal comparisons within a 1 X 4 analysis of variance which included the no-CS control group and each of the three signal-reward correlation groups (+1, 0, -1). These data are presented in Tables 10 and 11 for errors and trials, respectively. In contrast to the reliable difference between the effects of no-CS and CSo training within the CS-separate condition, the present analysis shows no reliable difference between the no-CS group and the 0 correlation group of the CS-both condition. Furthermore, there was no reliable difference between the +1 and -1 correlation groups. In fact, the only reliable comparison was that between the +1 and -1 correlation groups combined and the no-CS and 0 correlation groups combined. These findings are also in accord with the previous descriptions of the CS-both effects as depicting an inverted U-shaped relationship between performance and signal-reward correlation, and importantly, they indicate that for CS-both training, 0 correlation training did not produce facilitated performance relative to the no-CS control.

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TABLE 10

Analysis of Variance of Errors to Criterion for the

CS-Both Groups and the No-CS Control

Source	df	Mean Square	F	p
Treatment	3	2493.672	3.992	----
No CS vs. 0	1	459.375	0.735	----
+1 vs. −1	1	1148.167	1.838	----
+1, −1 vs. 0, No CS	1	5874.138	9.404	.005
Error	44	624.672		

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TABLE 11

Analysis of Variance of Trials to Criterion for the

CS-Both Groups and the No-CS Control

Source	df	Mean Square	F	p
Treatment	3	14660.028	5.817	.025
No CS vs. 0	1	5735.042	2.276	----
+1 vs. -1	1	5797.042	2.300	----
+1, -1 vs. 0, No CS	1	32448.000	12.876	.005
Error	44	2520.072		

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A. General Signaling Effects

The observed relationships between the CS-separate, CS-both and no-CS conditions may be interpreted as reflecting the operation of general signaling and/or distinctive-cue properties of the response-contingent CSs. In particular, the effect of signal-reward correlation for the CS-separate condition, i.e., the linear and symmetrical effects for +1 through 0 to -1 correlation training, may be attributed to the general signaling property of the CSs. The data show that prior pairing of a stimulus with shock (CS+) facilitated acquisition of the discrimination when that stimulus was made contingent on the correct response and retarded it when the same stimulus was made contingent on the incorrect response. Presumably, this CS+ acquired the capacity to signal the presence of shock during Pavlovian aversive conditioning; then, when it was made contingent on either the correct or incorrect response during acquisition of the appetitive discrimination, the CS+ was rapidly transmuted to a signal for the presence of food. In the case of the CS-right group, the CS+ signaled the presence of food when, in fact, food was there, thus facilitating acquisition of the discrimination; however, in the case of the CS-wrong group, the CS+ signaled the presence of food when, in fact, food was not present, and thus it interferred with acquisition of the discrimination.

In like manner, a stimulus paired with the absence of shock during Pavlovian training (CS-) also acquired the potential to signal the absence of any event, not merely the particular event, shock, by

which its signaling property was established. Thus, with the CS-separate condition, the response-contingent application of a CS- for either the correct or incorrect response facilitated or retarded discrimination performance depending upon the particular signal contingency for which the CS- was employed. That is to say, when the CS- was applied to the correct response it retarded performance because it signaled the absence of reinforcement when, in fact, reinforcement was present; but when applied to the incorrect response, the CS- facilitated performance because it signaled the absence of reinforcement when, in fact, reinforcement was not present.

These results are in agreement with the findings of the original Pavlovian-instrumental transfer study of the present type (Fowler, Fago, Domber and Wischner, in preparation). In particular, the CS-separate condition of the present study matches the no-shock condition of the Fowler et al. study in that both designs entailed the contingent application of an aversively established CS+, CSo, or CS- upon a particular response (correct or incorrect) during appetitive discrimination training. Although the Fowler et al. study was restricted to a CS-right contingency, both studies agree in finding only linear effects for signal-reward correlation; i.e., in both studies, +1 correlation training facilitated and -1 correlation training retarded performance relative to the 0 correlation control. Despite this congruence, note should be made of the slight and statistically unreliable deviation from linearity observed in the present study. Such a finding would seem attributable to one or both of the following: First, there was a sampling bias in the distribution of scores for the CS-right group given 0 correlation training (the

distribution was positively skewed), which may have artificially elevated the mean for this group. Second, the magnitude of the retarding effect of −1 correlation training may have been weaker than the magnitude of the facilitating effect of +1 correlation training, with the result that the overall mean for the −1 correlation groups was relatively close to that for the 0 correlation controls. This latter explanation becomes especially tenable if one considers the possible effect of appetitive discrimination training on the strength of the CS's signaling value.

The retarding effect of −1 correlation training depends upon the maintenance of a signaling function which is counter to the actual presence or absence of reinforcement in the appetitive discrimination, i.e., the effect depends on maintaining a signal which predicts the absence of food when, in fact, food is present, or on maintaining a signal which predicts the presence of food when, in fact, food is not present. During the course of discrimination training, however, the signaling value of these CSs should be counter-conditioned by the actual presence or absence of the food reinforcer. That is to say, the CS− can initially signal the absence of an event, but if made contingent on the correct response and thus associated with food reinforcement, it should eventually come to signal the presence of food reinforcement; comparably, a CS+ can initially signal the presence of an event but when made contingent on the incorrect response and thus associated with no reinforcement, it should eventually come to signal the absence of food reinforcement. So viewed, the aversively established signaling value of the CSs of the −1 correlation training condition is only temporary, and the magnitude of the retarding effect

of such training should thus depend on the initial strength of the CS's signaling value. Such a counter-conditioning effect, however, is not necessarily expected for +1 correlation training. With this condition, the actual presence or absence of reinforcement in the T maze is consistent with the CS's initial signaling value, i.e., reinforcement is present when the signal predicts it and is absent when the signal predicts its absence. Accordingly, the initially established signaling value of a CS within the +1 correlation training condition should be maintained and perhaps even increased by the actual presence or absence of food reinforcement during discrimination training.

Because signaling value should be maintained for +1 correlation groups and counter-conditioned for −1 correlation groups, the weaker effect of −1 correlation training suggested above would be expected particularly if the initial strength of the CS's signaling value was not sufficiently large to begin with, i.e., subsequent to Pavlovian training. In this vein, the difference in outcome between the Fowler et al. study and the present one, i.e., the linear and symmetrical effects of signal-reward correlation reported by Fowler et al., as compared with the relatively weaker effects of −1 correlation training in the present study, may be related to differences in the initial strength of signaling obtained in the two studies. Although the Pavlovian procedures of both studies employed comparable amounts of training (number of trials), the within-$\underline{S}$ procedure used in the present study may represent a more difficult discrimination as compared with the between-$\underline{S}$ procedure generally employed by Fowler et al. For a

given functional (CS+ or CS-) $\underline{S}$ in the present study, shock was paired with one signal (tone or noise) and the absence of shock was paired with the other. Contrastingly, for a given functional $\underline{S}$ in the previous study only one signal (noise) was employed: for each CS+ $\underline{S}$, noise was paired with shock on half the trials, but neither shock nor noise occurred on the other half; for each CS- $\underline{S}$, noise occurred on half the trials and shock on the other half. Thus, $\underline{Ss}$ of this between procedure were trained to differentiate noise and no noise with respect to their particular consequence (shock or no shock), whereas $\underline{Ss}$ of the present within procedure were trained to differentiate tone from noise. It is not unreasonable to view this latter procedure as representing a more difficult classical discrimination. Hence, given equal amounts of training, the signal value of the CS should be less well established for $\underline{Ss}$ of the present within procedure. In this respect, then, the weaker signal value of the present study could be expected to produce less of a retarding effect on discrimination performance for −1 correlation training but such a weaker signal value would not appreciably influence the facilitating effect of +1 correlation training because, as noted above, signaling value within this condition is actually supported by the presence or absence of food reinforcement in the appetitive discrimination.

In spite of the non-linearity suggested in Figure 2, it should be emphasized that the statistical analysis of the CS-separate effects showed no significant deviation from linearity, nor any difference between the trends for the CS-right and CS-wrong components. That is, the F-test results showed that neither the quadratic trend of signal-reward correlation nor the interaction of this trend with signal

contingency was statistically significant. (The second order
interaction of signal and signal contingency with the quadratic trend
of signal-reward correlation is considered spurious since it was a
marginal effect and only reliable for the trials measure.) Further-
more, orthogonal comparisons of the CS-right and CS-wrong subgroups
of the +1, 0, or -1 correlation training conditions did not produce
any reliable F ratios. Taken together, the data from the CS-separate
condition of the present study and the comparable no-shock condition
of the Fowler et al. study support the general signaling hypothesis
in finding facilitation and retardation for +1 and -1 correlation
training respectively, relative to 0 correlation controls.

In line with the above interpretation, it should be stressed
that the most striking evidence supporting the general signaling
hypothesis derives from the assessment in the present study of signal-
reward correlation effects for signals contingent on the <u>incorrect</u>
response, a design feature not common to the Fowler et al. study.
Consistent with the signaling hypothesis, a CS+ for the incorrect
response produced the same retarding effect on discrimination perform-
ance as a CS- for the correct response; likewise, a CS- for the
incorrect response produced the same facilitating effect as a CS+
for the correct response. (And, in line with these effects, a CSo for
the incorrect response and a CSo for the correct response produced
equivalent performance effects intermediate to those for the +1 and
-1 correlation conditions.) This dependence of CS+ and CS- effects
on signal contingency convincingly indicates control of performance
by signal-reward correlation and eliminates a possible explanation
of the Fowler et al. data based on the particular effects of CS+ and
CS- training, for example, one that would suggest that CS+ training

<u>generally</u> facilitates and CS- training <u>generally</u> retards discrimination performance regardless of the signal-reward correlation.

B. Distinctive-Cue Effects

In addition to the general signaling effects described above, the relationship between the CS-separate condition and the no-CS control implicates the supplementary action of the distinctive-cue properties of the response-contingent CSs. In particular, the ortho-gonal comparisons between the no-CS group and the combination of the two CSo groups (right and wrong) indicated that the groups receiving signals performed better than the group which received no signal at all. Because, in Pavlovian conditioning, there was no contingency between shock, tone and noise for the CSo groups, these CSs should not have developed any general signaling potential. Thus, superior performance for the CSo groups indicates that the stimuli themselves (tone or noise)--or the stimulus feedback associated with any "non-functional" responses that may have been conditioned during Pavlovian training--constituted distinctive cues (cf. Fowler, 1971a) which served to reduce the similarity between correct and incorrect-arm cues when selectively applied for either the correct or incorrect response. Such reduced similarity between correct and incorrect-arm cues would facilitate performance by reducing the generalization of conditioned reward from correct to incorrect-arm cues, as well as the generalization of conditioned non-reward from incorrect to correct-arm cues. These distinctive-cue effects should prevail for all CS-separate groups, not just the CSo groups, and thus all CS-separate groups should benefit

comparably relative to the no-CS control. In summary, then, the total
pattern of results for the CS-separate condition indicates that both
general signaling and distinctive-cue functions of the response-
contingent CSs combined to produce the observed outcomes.

For the CS-both condition, in contrast, the inverted U-shaped
function relating performance to signal-reward correlation may be
attributed entirely to the operation of the distinctive-cue properties
of both the response-contingent CSs and their response-produced feed-
back. Like the effects of CS-separate training, presentation of the
tone CS (and its response-produced feedback) in one arm of the maze
and the noise CS (and its response-produced feedback) in the other
arm of the maze should provide a basis for increasing the discrimin-
ability of the stimulus alternatives. Hence, this increased
discriminability should facilitate performance, relative to the no-CS
controls, for all groups of the CS-both condition, i.e., by decreasing
the between-arm generalization effects of conditioned reward and
conditioned non-reward. Orthogonal comparisons within the CS-both
condition showed, however, that only +1 and -1 correlation training
facilitated performance relative to the no-CS controls; the performance
of the 0 correlation group was not statistically different from that
of the no-CS group. This absence of a difference between the CSo and
no-CS Ss may be resolved by considering the effect of the feedback
produced by the specific responses controlled by the CSs. That is
to say, despite the fact that in the CSo condition tone was presented
for one response and noise for the other, both noise and tone
controlled the same response-produced stimuli, i.e., both controlled
whatever non-functional responses were conditioned during CSo

Pavlovian training. Hence, the increase discriminability potentiated by presenting tone in one arm and noise in the other could have been offset by the decreased discriminability resulting from the presentation of the same stimuli, viz., the response-produced stimuli associated with CSo training, in both arms. From this standpoint, theobserved outcome of no difference between both CSo groups and the no-CS control is consistent with the distinctive-cue interpretation of CS-both effects. (In the case of 0 correlation training for the CS-separate condition, the CSo and its response-produced feedback were present in either the correct or incorrect arm of the maze, not both. Thus, these stimuli, tone or noise, and response-produced feedback, in one arm of the maze would increase the discriminability of the arms when contrasted with the stimulus effects of no signal in the other arm.)

There remains the problem of accounting for the lack of a signaling effect for the CS-both condition, i.e., the failure to find a statistically reliable linear effect of signal-reward correlation. It should be noted that the difference between +1 and -1 correlation training, albeit not significant, was in the appropriate direction: +1 correlation training produced better performance than -1 correlation training. This suggests that the effect of signaling was present but obscured by other factors. Failure to find a statistically reliable signaling effect for CS-both training may relate to one of the same factors suggested above as contributing to the small difference in magnitude between the effects of +1 and -1 correlation training within the CS-separate condition. That is to say, as with

CS-separate training, the signal value of the CSs of the -1
correlation groups of the CS-both condition would be counter-
conditioned by the actual presence or absence of the reinforcer
during appetitive discrimination training. For the reasons noted
previously, this counter-conditioning would result in a relatively
weaker retarding effect for -1 correlation training, thus lowering
the mean for this group and decreasing the overall signaling effect.

C. General Signaling: Interpretive Paradigms

Interpretation of the foregoing results has thus far employed
the general signaling hypothesis to account for the common aspects of
this and the Fowler et al. study (in preparation). An additional
concern of this discussion is that of relating the signaling hypothesis
to the larger body of research bearing on Pavlovian-instrumental
transfer effects and of selecting a general interpretive paradigm which
is consistent with the present results.

One possible approach to the interpretation of the present type
of transfer data would emphasize the conditioned punishing and/or
conditioned rewarding properties of the response-contingent CSs. The
present study paired stimuli with shock or the absence of shock, thus
potentiating the former type of CS as a conditioned punisher and the
latter type as a conditioned reinforcer. It should be noted that
findings bearing on the establishment of a neutral stimulus as a
positive conditioned reinforcer, specifically by pairing it with the
offset of shock or by contrasting it with shock, indicate that such
procedures are not typically effective (cf. Beck, 1961)! However, the
data are not entirely definitive in this regard (cf. Lolordo, 1965)

and thus the possibility that such effects were operating in the present study should be entertained. Accordingly, an aversively established CS+ or CS-, when made contingent on either the correct or incorrect response during appetitive discrimination training, may be expected to influence performance via their respective punishing and rewarding properties.

The outcome of the present study clearly contradicts an interpretation based on such CS properties. Indeed, a conditioned punisher (CS+) presented for the incorrect response should facilitate acquisition of the discrimination, but when presented for the correct response, it should retard performance. (This interpretation emphasizes the suppressing effect of punishment apart from its possible distinctive-cue effect.) However, just the opposite result prevailed: when presented for the correct response, a CS+ facilitated performance, and when presented for the incorrect response such a CS retarded performance. Furthermore, if a CS- had conditioned rein-forcing properties, then training with it should have facilitated performance when such a CS was presented for the correct response and retarded performance when presented for the incorrect response. But again, the reverse outcome was observed.

While Pavlovian training apparently did not establish the CSs as conditioned punishers or reinforcers, such training could have served to condition general "alerting" or attending responses to the CSs. That is to say, pairing a neutral stimulus with shock might have established the neutral stimulus as a CS controlling an alerting or attending response, so that following its presentation S would be more likely to attend to its stimulus surround. In parallel fashion, the

pairing of a neutral stimulus with the absence of shock might well have conditioned non-attending or non-alerting responses to the CS, so that following its presentation, $\underline{S}$ would $\underline{not}$ attend to its stimulus surround. When such a CS+ is made contingent on the correct or incorrect response during appetitive discrimination training, it should serve then to increase the likelihood of $\underline{S}$ observing the particular discriminative stimulus (positive or negative) which is present, as well as the presence or absence of food reinforcement. Conversely, when a CS- is made contingent on the correct or incorrect response during discrimination training, it should serve to decrease the likelihood of observing the particular discriminative stimulus (positive or negative), and again the presence or absence of food. According to this hypothesis, training with a CS+ should facilitate discrimination performance and training with a CS- should retard performance, irrespective of the particular signal contingency (right or wrong). However, the data do not support this interpretation either. Although training with a CS+ for the correct response facilitated performance, training with a CS+ for the incorrect response retarded performance; conversely, training with a CS- for the correct response retarded performance, but training with a CS- for the incorrect response actually facilitated performance.

A third type of interpretation which has been employed to account for Pavlovian-instrumental transfer is one which identifies specific responses (operant or classical), acquired during Pavlovian conditioning, as behaviors which can affect performance in the instrumental task (cf. Rescorla and Solomon, 1967; Trapold and Overmier, 1969). Trapold and Overmier (1969) have considered the

problem of the transfer of <u>operants</u> in particular. These responses, presumably acquired during classical conditioning, may compete with or be compatible with the responses to be learned during instrumental conditioning, thus retarding or facilitating instrumental performance. Such effects are especially likely when the CSs employed during Pavlovian conditioning are utilized as the discriminative stimuli during instrumental discrimination training, as was <u>not</u> the case in the present study (the CSs in the present study were response-contingent events). Trapold and Overmier (1969) have presented convincing evidence which argues that transfer effects are evidenced even when interfering or facilitating operants are well controlled, thus implicating at least some other factor as controlling the transfer effect.

Indeed, the results of the present study would also appear to rule out specific operants as a source of transfer effects, for it is difficult to identify a specific operant which is controlled by a given CS (CS+ or CS-) which would facilitate performance when made contingent on one response (correct or incorrect) and retard performance when made contingent on the other. For example, if during Pavlovian training S learned to cringe in the presence of the CS+ (e.g., to reduce the aversiveness of the shock), then during discrimination training the CS+ should produce cringing when made contingent on either the correct or incorrect response. It is difficult to account for the facilitating effects of cringing in the correct arm of the maze and, at the same time, account for the retarding effect of cringing in the incorrect arm. A similar argument would hold for CS- presentations and associated non-cringing or

"releasing" behaviors. Furthermore, the prior considerations regarding the transfer of specific classical responses (fear or the inhibition of fear) between Pavlovian and discrimination training, which were entertained in relation to the Fowler, Fago, Domber and Wischner (in preparation) study, may also apply to the present study. That is, neither the distinctive-cue nor the possible punishing or reinforcing properties of the stimulus feedback from these responses can account for the particular outcome observed. For the same reasons, the motivational properties of fear and the inhibition of fear (cf. Rescorla and Solomon, 1967) also fail to account for the present results. That is to say, the reversibility of the effect (retardation or facilitation) of a CS+ or CS-, depending upon the particular response for which the CS is presented (correct or incorrect), eliminates any apparent interpretation based on such properties.

The present data require an interpretive paradigm employing a construct which accounts for the particular interaction of CS value (CS+, CSo, or CS-) with the presence or absence of reinforcement, i.e., with signal contingency. While the general signaling hypothesis is appropriately descriptive of such a relationship, its use has been limited to the results of the present study and those of Fowler, Fago, Domber and Wischner (in preparation). Two theoretical constructs of wider applicability, which have the potential to account for the present results, are those of arousal and incentive. The former construct generally has reference to a central motivational process which presumably underlies both appetitive and aversive conditioning and thus may serve a mediating role between them. The operation of a

common process for both appetitive and aversive conditioning is consistent with the general signaling description of the present data, which in themselves suggests an underlying similarity between both types of conditioning, specifically that the general signaling property of a CS is mediated by a process which is independent of the specific reinforcer (e.g., food or shock) with which the general signaling property is established. Furthermore, the mediation of Pavlovian-instrumental transfer by a central process is plausible; indeed, such an interpretation has been suggested by a number of investigators (e.g., Rescorla and Solomon, 1967; Trapold and Overmier, 1969). In this context, it is noteworthy that Rescorla and Solomon have documented the fact that research has failed to find a strong and consistent relationship between classical and instrumental responses (e.g., salivating and bar pressing) when both are measured concurrently during acquisition of the instrumental response. Consequently, these investigators have suggested that both classical and instrumental components are mediated by a common central process.

Like arousal, the incentive construct may also refer to internal states resulting from either appetitive or aversive conditioning (i.e., positive and negative incentive). Unlike arousal, however, incentive has traditionally been viewed as a motivational state which is mediated by a peripheral response, the anticipatory goal reaction. Recently, however, both Logan (1968) and Bindra (1968) have proposed that incentive, too, is best viewed as a central process. Like Rescorla and Solomon, both investigators note that research has failed to objectively identify a peripheral response mechanism (e.g., r_g-s_g) which corresponds closely to the motivational effects of incentive

on instrumental responding. Indeed, Bindra has specifically proposed a model of incentive as a central motive state, and recently Fowler (1971b) has extended this interpretation by arguing that arousal may be treate⋯ ⋯ ⋯ ⋯ al (e.g., neurophysiological) counterpart to incentive.

It would seem, then, that both the incentive and arousal constructs may be utilized to account for the general signaling effects of the present study. In particular, pairing a signal with shock can be assumed to condition heightened incentive-arousal to the CS+ and comparably, pairing a CS with the absence of shock can be assumed to condition a state of lowered incentive-arousal to the CS-. In similar fashion, the acquisition of an appetitive discrimination also involves the association of heightened incentive-arousal with the positive discriminative stimulus and lowered incentive-arousal with the negative discriminative stimulus. If both appetitive and aversive incentive-arousal implicate a common central process, then a stimulus which acquired control of incentive-arousal in an aversive situation ought also to control incentive-arousal in an appetitive situation. Hence, when a CS+ is made contingent on the correct response during appetitive discrimination training, conditioned incentive-arousal results, providing a situation which is appropriate to the association of such incentive-arousal with the positive discriminative stimulus. In this manner, acquisition of the discrimination should be facilitated. Furthermore, presentation of a CS-contingent on the correct response during discrimination training should result in lowered incentive-arousal, a state which should interfere with the process of conditioning heightened incentive-arousal

to the positive discriminative stimulus. In this case, discrimination performance should be retarded. In a similar manner, presentation of a CS+ or CS- contingent on the incorrect response during discrimination training should facilitate or interfere with the process of conditioning lowered incentive-arousal to the negative discriminative stimulus. Thus, discrimination performance should be facilitated by training with a CS- and retarded by training with a CS+ for the incorrect response. The observed outcome is consistent with this interpretation.

In summary, neither the "conditioned reinforcement/punishment" paradigm, nor the "general alerting or attention" paradigm, nor the "transfer of specific responses" interpretation can account for the data of the present study. This is not to say that the mechanisms and features described by such models do not affect Pavlovian-instrumental transfer, but only that they cannot account for the present results. Indeed, the CER procedure which employs Pavlovian aversive conditioning followed by the presentation of the aversive CS+ during the performance of an ongoing appetitive task is similar to the procedure employed in the present study. In the CER case, however, the most commonly observed outcome is suppression of performance by a CS+, not facilitation as was observed in the present study. Thus, it remains for additional research to isolate the conditions under which different properties of the CSs will be detected. The present study provides clear evidence for the existence of certain general properties of the CS. In particular, such an interpretation emphasizes the general signaling function of

these stimuli (a function which is but one of many) and suggests
that such a signaling function may be related to a central state
of incentive-arousal.

In a prior study investigating Pavlovian-instrumental transfer effects, different groups of $\underline{S}$s first received aversive Pavlovian conditioning designed to establish a CS as either a fear elicitor (CS+), a fear inhibitor (CS-), or neutral with respect to fear (CSo). This was followed by appetitive instrumental discrimination training during which these CSs were made contingent on the correct response. Relative to the CSo training, CS+ training facilitated and CS- training retarded discrimination performance. It was suggested herein, that aversively established Pavlovian CSs, as well as signaling the presence of electric shock (CS+) or signaling its absence (CS-), may also acquire a _general signaling property_, whereby they may, if employed in appetitive discrimination training, quickly come to signal the presence (in the case of CS+ training) or absence (in the case of CS- training) of the reinforcer which is available (i.e., food). Presented in the correct arm of a T maze, the CS+ may come to signal the presence of food and the CS- may come to signal its absence when, in fact, food is actually present in that arm. These signaling properties may aid in (in the case of CS+ training) or interfere with (in the case of CS- training) conditioning of appropriate anticipatory responses to the positive discriminative stimulus, thus facilitating discrimination performance in the former case and retarding it in the latter.

The present design tested the general signaling hypothesis by extending the design of the prior study to include training with

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all three types of CS events (CS+, CSo, or CS-) for the <u>incorrect</u> as
well as for the correct response. In addition, a Pavlovian procedure
was employed which allowed the establishment of two different CSs
(tone or noise) for each <u>S</u> (one CS+ and one CS- in the case of the
experimental groups and both CSo's in the case of the controls), thus
permitting the inclusion of groups given discrimination training with
one signal for the correct <u>and</u> the other for the incorrect response
(CS-both training). Finally, a group receiving Pavlovian training
but no CS presentations during discrimination training was included
to allow assessment of the effect of the presence of a signal <u>per se</u>.

Like the prior study, CS+ training facilitated and CS- training
retarded discrimination performance when these CSs were presented for
the <u>correct</u> response. Furthermore, relative to their CSo controls,
CS- training facilitated and CS+ training retarded discrimination
performance when these CSs were presented for the <u>incorrect</u> response,
presumably since the CS- predicted the absence of food and the CS+
predicted its presence when, in fact, it was <u>not</u> present. Finally,
the performance of these CSo control groups (CSo contingent on the
correct or incorrect response) was superior to that of the no-CS
group, indicating that the presentation of a signal <u>per se</u> facilitated
discrimination performance. For CS-both training, the signaling
effect was also present but degraded (i.e., <u>Ss</u> trained with a CS+
for the correct <u>and</u> a CS- for the incorrect response performed better,
but not reliably so, than <u>Ss</u> trained with the reverse combination),
but in addition, both of these groups were facilitated relative to
their CSo control. It was argued that the relatively retarded

performance of this CSo group related to the additional finding of no difference between this group and the no-CS group.

It was concluded that the data provide evidence to suggest that both Pavlovian and instrumental conditioning are mediated, at least in part, by a common central state. Arousal and incentive were discussed in this regard, and both were identified as possible mechanisms relating to the observed general signaling effects.

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APPENDIX

Raw Data

TABLE 1

Raw Data for Subjects of the No-CS (Functional) Condition*

S	Errors in blocks of 20 trials															Total Errors	Total Trials
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
1	12	8	9	9	11	10	9	9	12	10	10	7	6	4	2	128	300
2	12	13	9	12	10	10	10	4	2	-	-	-	-	-	-	82	178
3	10	14	14	9	11	10	5	3	6	4	4	3	-	-	-	93	238
4	10	8	8	7	6	5	6	4	1	-	-	-	-	-	-	55	176
5	12	15	6	12	4	5	4	1	-	-	-	-	-	-	-	59	152
6	12	16	9	12	9	11	10	3	-	-	-	-	-	-	-	82	160

* Subjects with the same serial number represent individual replications.

75

TABLE 2

Raw Data for Subjects of the No-CS (Non-Functional) Condition*

S	Errors in blocks of 20 trials															Total Errors	Total Trials
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
1	6	8	10	9	3	4	9	2	3	0	-	-	-	-	-	54	181
2	15	4	5	7	7	8	5	0	-	-	-	-	-	-	-	51	149
3	15	8	10	9	7	8	6	9	8	3	4	3	6	1	-	97	273
4	4	1	-	-	-	-	-	-	-	-	-	-	-	-	-	5	30
5	7	10	10	10	10	10	10	10	10	10	8	7	2	-	-	114	258
6	14	12	9	6	6	6	6	8	3	1	-	-	-	-	-	71	192

* Subjects with the same serial number represent individual replications.

76

TABLE 3

Raw Data for Subjects of the Tone-Right (CS+) Condition*

s	Errors in blocks of 20 trials															Total Errors	Total Trials
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
1	14	16	16	17	10	4	0	-	-	-	-	-	-	-	-	77	126
2	12	11	5	4	-	-	-	-	-	-	-	-	-	-	-	32	80
3	10	11	6	0	-	-	-	-	-	-	-	-	-	-	-	27	74
4	9	9	3	0	-	-	-	-	-	-	-	-	-	-	-	21	63
5	13	10	8	2	-	-	-	-	-	-	-	-	-	-	-	33	78
6	8	9	0	-	-	-	-	-	-	-	-	-	-	-	-	17	48

* Subjects with the same serial number represent individual replications.

77

TABLE 4

Raw Data for Subjects of the Noise-Right (CS+) Condition*

S	Errors in blocks of 20 trials															Total Errors	Total Trials
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
1	10	10	9	5	4	3	1	-	-	-	-	-	-	-	-	42	133
2	11	9	11	3	-	-	-	-	-	-	-	-	-	-	-	34	79
3	15	9	8	0	-	-	-	-	-	-	-	-	-	-	-	32	69
4	11	10	5	0	-	-	-	-	-	-	-	-	-	-	-	26	66
5	13	12	8	0	-	-	-	-	-	-	-	-	-	-	-	33	68
6	7	6	6	5	2	-	-	-	-	-	-	-	-	-	-	26	98

* Subjects with the same serial number represent individual replications.

78

TABLE 5

Raw Data for Subjects of the Tone-Wrong (CS-) Condition*

S	Errors in blocks of 20 trials															Total Errors	Total Trials
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
1	12	7	6	1	-	-	-	-	-	-	-	-	-	-	-	26	76
2	13	13	11	6	10	10	8	2	0	-	-	-	-	-	-	73	161
3	13	11	2	-	-	-	-	-	-	-	-	-	-	-	-	26	58
4	8	9	5	5	3	10	10	10	3	0	-	-	-	-	-	63	182
5	10	10	10	5	0	-	-	-	-	-	-	-	-	-	-	35	83
6	5	3	6	9	1	-	-	-	-	-	-	-	-	-	-	24	96

* Subjects with the same serial number represent individual replications.

79

TABLE 6

Raw Data for Subjects of the Noise-Wrong (CS-) Condition*

| S | Errors in blocks of 20 trials | | | | | | | | | | | | | | | Total Errors | Total Trials |
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
1	9	0	-	-	-	-	-	-	-	-	-	-	-	-	-	9	28
2	6	7	5	5	0	-	-	-	-	-	-	-	-	-	-	23	87
3	11	9	5	1	-	-	-	-	-	-	-	-	-	-	-	26	72
4	8	7	5	0	-	-	-	-	-	-	-	-	-	-	-	20	66
5	9	12	10	13	10	9	5	7	0	-	-	-	-	-	-	75	171
6	8	15	12	12	6	1	-	-	-	-	-	-	-	-	-	54	113

* Subjects with the same serial number represent individual replications.

80

TABLE 7

Raw Data for Subjects of the Tone-Right, Noise-Wrong

(+1 Signal-Reward Correlation) Condition*

S	Errors in blocks of 20 trials															Total Errors	Total Trials
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
1	7	12	10	10	10	10	6	3	0	-	-	-	-	-	-	68	163
2	8	14	11	12	9	9	6	0	-	-	-	-	-	-	-	67	144
3	10	9	8	0	-	-	-	-	-	-	-	-	-	-	-	27	69
4	8	5	0	-	-	-	-	-	-	-	-	-	-	-	-	13	45
5	10	10	6	4	7	8	11	3	0	-	-	-	-	-	-	59	162
6	7	6	5	4	4	0	-	-	-	-	-	-	-	-	-	26	113

* Subjects with the same serial number represent individual replications.

81

TABLE 8

Raw Data for Subjects of the Noise-Right, Tone-Wrong

(+1 Signal-Reward Correlation) Condition*

S	Errors in blocks of 20 trials															Total Errors	Total Trials
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
1	11	10	9	8	8	9	0	-	-	-	-	-	-	-	-	55	131
2	9	10	10	10	10	10	7	0	-	-	-	-	-	-	-	66	148
3	5	5	2	0	-	-	-	-	-	-	-	-	-	-	-	12	62
4	10	10	7	0	-	-	-	-	-	-	-	-	-	-	-	27	67
5	10	13	10	1	-	-	-	-	-	-	-	-	-	-	-	34	76
6	10	3	11	7	5	0	-	-	-	-	-	-	-	-	-	36	111

* Subjects with the same serial number represent individual replications.

82

TABLE 9

Raw Data for Subjects of the Tone-Right (CSo) Condition*

S	Errors in blocks of 20 trials															Total Errors	Total Trials
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
1	11	10	10	10	7	1	-	-	-	-	-	-	-	-	-	49	114
2	14	11	9	10	10	1	-	-	-	-	-	-	-	-	-	55	116
3	6	10	9	10	10	10	9	4	2	0	-	-	-	-	-	70	182
4	10	9	11	10	7	7	1	-	-	-	-	-	-	-	-	55	133
5	11	17	11	9	3	3	0	-	-	-	-	-	-	-	-	54	121
6	14	10	10	9	11	9	9	6	6	4	3	1	-	-	-	92	233

* Subjects with the same serial number represent individual replications.

83

TABLE 10

Raw Data for Subjects of the Noise-Right (CSo) Condition*

S	Errors in blocks of 20 trials															Total Errors	Total Trials
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
1	12	10	10	9	5	0	-	-	-	-	-	-	-	-	-	46	103
2	11	13	11	11	10	5	8	3	3	-	-	-	-	-	-	75	179
3	8	12	10	10	8	4	0	-	-	-	-	-	-	-	-	52	121
4	10	11	10	10	4	4	4	-	-	-	-	-	-	-	-	53	139
5	15	13	13	13	11	7	11	2	0	-	-	-	-	-	-	85	163
6	13	12	11	10	10	5	3	-	-	-	-	-	-	-	-	64	139

* Subjects with the same serial number represent individual replications.

84

TABLE 11

Raw Data for Subjects of the Tone-Wrong (CSo) Condition*

S	Errors in blocks of 20 trials															Total Errors	Total Trials
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
1	5	11	0	-	-	-	-	-	-	-	-	-	-	-	-	16	55
2	8	10	10	9	7	3	0	-	-	-	-	-	-	-	-	47	132
3	12	10	11	9	0	-	-	-	-	-	-	-	-	-	-	42	92
4	12	11	10	10	6	0	-	-	-	-	-	-	-	-	-	49	108
5	9	14	10	11	10	3	0	-	-	-	-	-	-	-	-	57	122
6	9	5	7	1	-	-	-	-	-	-	-	-	-	-	-	22	72

* Subjects with the same serial number represent individual replications.

85

TABLE 12

Raw Data for Subjects of the Noise-Wrong (CSo) Condition*

S	Errors in blocks of 20 trials															Total Errors	Total Trials
---	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
1	7	8	4	0	-	-	-	-	-	-	-	-	-	-	-	19	61
2	7	10	9	10	4	0	-	-	-	-	-	-	-	-	-	40	101
3	8	8	8	8	8	10	10	1	-	-	-	-	-	-	-	61	156
4	12	10	10	10	10	10	10	3	0	-	-	-	-	-	-	75	162
5	6	9	10	10	10	10	8	0	-	-	-	-	-	-	-	63	149
6	13	10	10	10	10	10	8	9	5	4	1	-	-	-	-	90	214

* Subjects with the same serial number represent individual replications.

86

TABLE 13

Raw Data for Subjects of the Tone-Right, Noise-Wrong

(0 Signal-Reward Correlation) Condition*

S	Errors in blocks of 20 trials															Total Errors	Total Trials
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
1	11	9	10	7	6	2	0	-	-	-	-	-	-	-	-	45	121
2	9	10	6	12	12	8	7	10	8	9	9	9	0	-	-	109	252
3	10	11	10	10	10	6	3	-	-	-	-	-	-	-	-	60	140
4	10	10	10	8	7	10	1	-	-	-	-	-	-	-	-	56	136
5	8	8	6	5	5	0	-	1	-	-	-	-	-	-	-	32	109
6	7	7	5	4	6	5	4	-	-	-	-	-	-	-	-	39	150

* Subjects with the same serial number represent individual replications.

87

TABLE 14

Raw Data for Subjects of the Noise-Right, Tone-Wrong

(O Signal-Reward Correlation) Condition*

S	Errors in blocks of 20 trials															Total Errors	Total Trials
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
1	8	10	10	10	10	10	10	7	2	0	-	-	-	-	-	77	183
2	11	10	10	10	11	12	10	11	12	10	8	0	-	-	-	115	229
3	10	10	10	10	9	4	0	-	-	-	-	-	-	-	-	53	123
4	9	7	10	5	8	9	5	0	-	-	-	-	-	-	-	53	151
5	10	16	8	9	10	6	6	2	-	-	-	-	-	-	-	67	157
6	11	14	17	12	10	9	2	5	0	-	-	-	-	-	-	80	165

* Subjects with the same serial number represent individual replications.

88

TABLE 15

Raw Data for Subjects of the Tone-Right (CS-) Condition*

S	Errors in blocks of 20 trials															Total Errors	Total Trials
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
1	11	3	7	5	5	5	6	9	9	7	3	-	-	-	-	70	220
2	9	10	9	10	7	5	5	0	-	-	-	-	-	-	-	55	151
3	12	9	11	10	9	5	2	-	-	-	-	-	-	-	-	58	140
4	13	9	11	10	8	7	1	-	-	-	-	-	-	-	-	59	136
5	10	12	12	5	1	-	-	-	-	-	-	-	-	-	-	40	91
6	14	12	10	9	8	5	2	-	-	-	-	-	-	-	-	60	137

* Subjects with the same serial number represent individual replications.

89

TABLE 16

Raw Data for Subjects of the Noise-Right (CS-) Condition*

| S | Errors in blocks of 20 trials | | | | | | | | | | | | | | | Total Errors | Total Trials |
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
1	8	9	5	4	5	1	-	-	-	-	-	-	-	-	-	32	117
2	9	10	10	12	10	10	8	6	4	3	2	-	-	-	-	84	217
3	13	9	10	10	10	8	3	1	-	-	-	-	-	-	-	64	151
4	9	10	10	7	9	12	5	1	-	-	-	-	-	-	-	63	153
5	10	10	10	10	10	6	3	0	-	-	-	-	-	-	-	59	144
6	11	17	12	13	10	6	1	-	-	-	-	-	-	-	-	70	136

* Subjects with the same serial number represent individual replications.

90

TABLE 17

Raw Data for Subjects of the Tone-Wrong (CS+) Condition*

S	Errors in blocks of 20 trials															Total Errors	Total Trials
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
1	14	10	11	11	10	10	8	4	0	-	-	-	-	-	-	78	164
2	12	12	7	11	10	8	9	11	8	9	10	9	6	3	3	128	300
3	12	13	12	7	12	7	4	0	-	-	-	-	-	-	-	67	142
4	10	9	10	9	8	0	-	-	-	-	-	-	-	-	-	46	113
5	9	10	10	10	9	1	-	-	-	-	-	-	-	-	-	49	114
6	12	11	9	5	3	0	-	-	-	-	-	-	-	-	-	40	106

* Subjects with the same serial number represent individual replications.

91

TABLE 18

Raw Data for Subjects of the Noise-Wrong (CS+) Condition*

S	Errors in blocks of 20 trials															Total Errors	Total Trials
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
1	11	11	2	6	1	-	-	-	-	-	-	-	-	-	-	31	90
2	11	11	10	10	9	3	-	-	-	-	-	-	-	-	-	54	120
3	14	10	8	8	3	3	0	-	-	-	-	-	-	-	-	46	121
4	10	10	10	10	11	10	2	-	-	-	-	-	-	-	-	63	137
5	10	9	8	6	6	2	-	-	-	-	-	-	-	-	-	41	117
6	12	11	9	11	5	10	1	-	-	-	-	-	-	-	-	59	136

* Subjects with the same serial number represent individual replications.

TABLE 19

Raw Data for Subjects of the Tone-Right, Noise-Wrong

(-1 Signal-Reward Correlation) Condition*

S	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total Errors	Total Trials
	Errors in blocks of 20 trials																
1	10	10	10	10	4	1	-	-	-	-	-	-	-	-	-	45	115
2	7	7	7	8	7	7	0	-	-	-	-	-	-	-	-	43	123
3	11	10	9	10	10	10	10	10	10	9	2	-	-	-	-	101	217
4	8	9	11	11	9	2	0	-	-	-	-	-	-	-	-	50	122
5	8	6	8	9	8	9	10	6	4	3	0	-	-	-	-	71	203
6	9	10	9	10	7	3	0	-	-	-	-	-	-	-	-	48	121

* Subjects with the same serial number represent individual replications.

93

TABLE 20

Raw Data for Subjects of the Noise-Right, Tone-Wrong

(-1 Signal-Reward Correlation) Condition*

S	Errors in blocks of 20 trials															Total Errors	Total Trials
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
1	12	8	9	10	10	10	2	-	-	-	-	-	-	-	-	61	140
2	14	10	9	5	0	-	-	-	-	-	-	-	-	-	-	38	90
3	6	9	11	14	10	4	6	0	-	-	-	-	-	-	-	60	154
4	7	8	6	8	5	2	0	-	-	-	-	-	-	-	-	36	121
5	12	9	7	7	7	7	0	-	-	-	-	-	-	-	-	49	128
6	10	9	8	10	10	6	1	-	-	-	-	-	-	-	-	54	130

* Subjects with the same serial number represent individual replications.

94