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WARNING AND SAFE SIGNALS IN THE MAINTENANCE OF RESPONDING UNDER NONCONTINGENT SHOCK

by

JULIE SAGE-DAY

A dissertation submitted to the Graduate
Faculty in Psychology in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy, The City University
of New York.

1976

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May 14, 1976
date

Robert L Thompson
Chairman of Examining Committee

May 17, 1976
date

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Professor Sheila Chase

Professor Donald Mintz
Supervisory Committee

The City University of New York

Abstract

WARNING AND SAFE SIGNALS IN THE MAINTENANCE OF RESPONDING UNDER NONCONTINGENT SHOCK

Julie Sage-Day

Advisor: Professor Robert L. Thompson

Rats trained on a discrete-trial shock avoidance procedure were transferred to a schedule of noncontingent (response-independent), intermittent, inescapable shock. The earlier avoidance response now produced one of two auditory signals differentially predictive of shock (warning signal) and the absence of shock (safe signal) on a given trial, but did not affect overall shock probability. Failure to respond resulted in nondifferentially signaled shock and shock-free trials. Responses maintained by the production of reliable warning and safe signals are analogous to observing responses described in the appetitive literature (e.g., Wyckoff, 1952). In past work a clear functional separation of warning and safe signals was not possible because the signals were perfectly, though inversely correlated: the safe signal was merely the withdrawal or absence of the warning signal and vice versa. Since the present procedure permitted independent manipulation of the predictive value of warning and safe signals, it established the basis for a functional distinction between the two types of signals.

Experiment 1 studied the effects of maximally informative (i.e., fully predictive) and maximally noninformative (fully nonpredictive) warning and safe signals on observing response performance with a fixed shock probability of .5. Responding was maintained under the maximally informative signal condition and was significantly weakened under the noninformative condition. These results were consistent with studies comparing performance under correlated and uncorrelated signal-shock conditions (e.g., Badia & Culbertson, 1972; Lockard, 1963; Rescorla, 1968).

Two subsequent experiments studied the effect on observing response maintenance of independently degrading the warning and safe signals while overall shock probability remained constant at .5. Observing response probability was generally intermediate between maximally informative and wholly noninformative signal conditions. The procedure and results were considered within the contingency analysis of Gibbon, Berryman, and Thompson (1974). When the degree of degradation of signal information was equivalent in statistical association value expressed as root mean square contingency (ϕ), both studies demonstrated a significantly higher probability of the observing response under degraded warning signals (reliable safe signals) than under degraded safe signals (reliable warning signals).

A fourth study explored observing response probability under maximally informative and degraded signal conditions at shock probabilities of .3, .5, and .7. The data were consistent with the previous studies in establishing asymmetrical effects under degraded warning and degraded safe conditions. Apparently, subjects weight predicted shock omission more heavily than predicted shock delivery in indexing different associative strengths of signal-shock relations with their observing behavior. The asymmetrical effects of degraded predictiveness of warning and safe signals forces reevaluation of the symmetrical statistical association measures.

The maintenance of the observing response appeared to depend principally on the production of reliable safe signals in these studies. Although there were individual differences among rats, shock-elicited responding, shock density per se, and adventitious avoidance conditioning appeared to contribute little to response probability.

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INTRODUCTION

Until recently the importance of contingency (dependence between events) in classical conditioning procedures has largely been overlooked in the literature. Traditionally the emphasis in Pavlovian experiments has been placed on stimulus parameters such as the number of pairings of the conditional (CS) and unconditional (US) stimulus or their temporal associations rather than on their contingent relationship. The term contingency here refers to the relationship between the presence or absence of the US and the presence or absence of the CS. A contingency analysis, by definition, would require examining behavior under a variety of associations between the US and the presence or absence of the CS. By contrast, few early classical conditioning experiments departed from a maximal contingency between stimuli, that is, the US was consistently paired with the CS or one of the two stimuli was presented entirely in the absence of the other. The few exceptions were those procedures in which the frequency of CS presentations was increased relative to US occurrence (i.e., the CS was occasionally presented alone.) Indeed, such a partial reinforcement procedure was studied by Pavlov (1927) who showed that salivary conditioning failed to occur when the CS was followed by the US only on every fourth trial (p. 384). Another early partial reinforcement study and among the first to explore the problem on a baseline of maintained performance, was undertaken by Brogden (1939). It was demonstrated that the frequency of conditioned forelimb flexion, when once established in a maximally contingent situation with either food, avoidable, or unavoidable shock as the outcome, was relatively insensitive to subsequent schedules of partial reinforcement. That is, the conditioned flexion response was maintained on at least 80 percent of the trials under conditions of only 20 percent reinforcement. A recent review of partial reinforcement in classical conditioning procedures can be found in Terrace (1973).

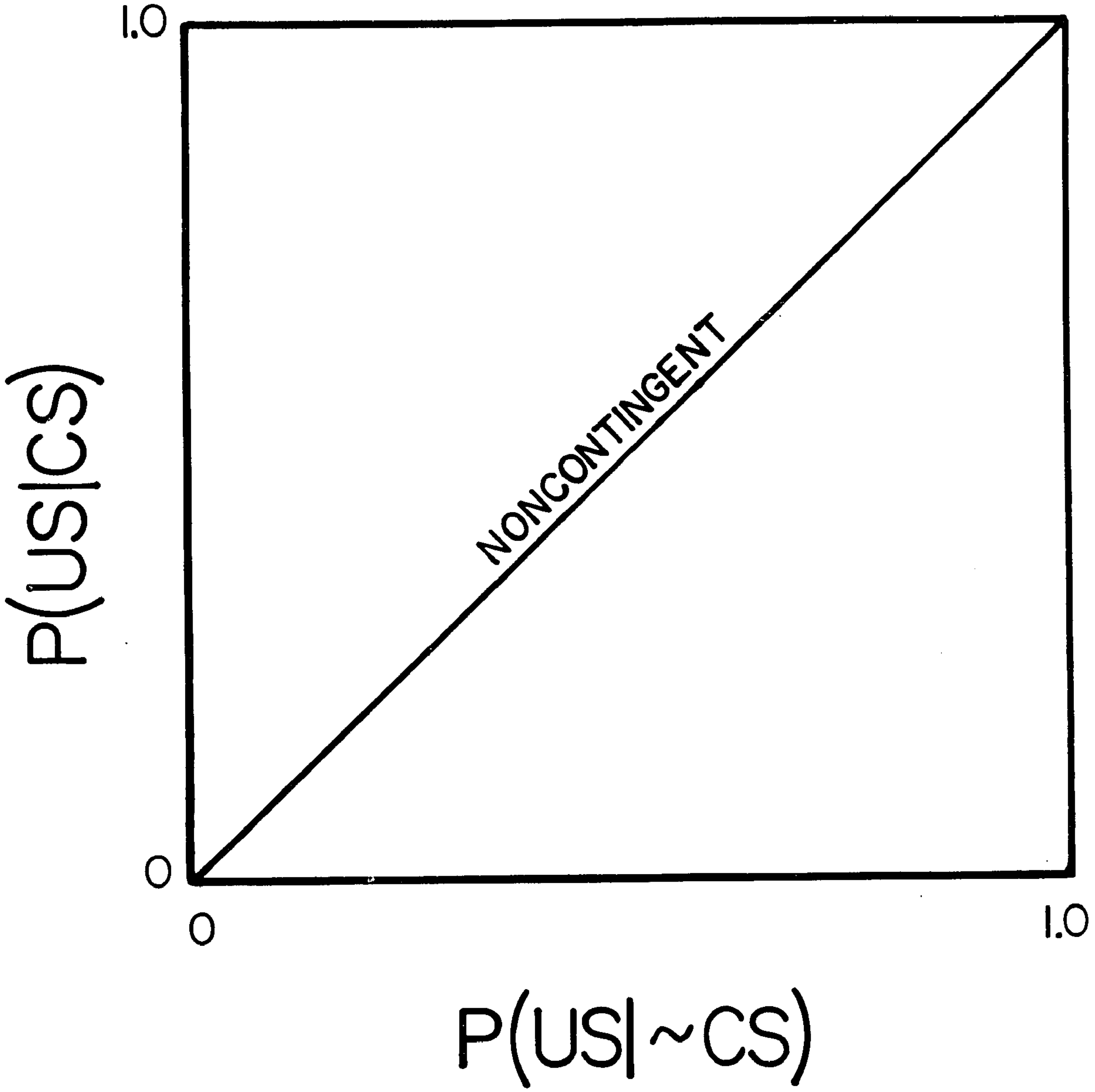
For approximately 25 years following Brogden's experiments no attention was given to the systematic study of CS-US contingencies in classical conditioning other than in the context of partial reinforcement effects. However, in 1967 Rescorla published a critical review of the procedures typically used in classical conditioning experiments to control for nonassociative factors such as pseudoconditioning or sensitization. Rescorla pointed out that procedures in which either the CS or the US is presented alone or both stimuli are scheduled, but explicitly unpaired, merely establish a new contingency in which the US becomes contingent on the absence of the CS. Therefore, Rescorla proposed the <u>truly random control</u> procedure as a more appropriate control procedure in that no contingency was arranged between CS and US--the CS occurred equally often in the presence and absence of the US. Because a truly random procedure involves some pairing of CS and US, additional studies were undertaken to determine whether conditioning took place under such conditions (Benedict & Ayres, 1972; Bull & Overmeier, 1968; Kremer & Kamin, 1971). These studies did not produce consistent results. Nevertheless, the emphasis on contingency suggested a more systematic examination of procedures in which the US occurs in the absence of the CS as well as in the presence of the CS with a probability of less than 1.0.

A quantitative description of CS-US contingencies has appeared in several papers (Catania, 1971; Church, 1969; Gibbon, Berryman, &

Thompson, 1970; 1974; Seligman, Maier, & Solomon, 1971) as a contingency square or contingency space in which the probability of US given the occurrence of CS, $P(US|CS)$, is plotted against the probability of US presented in the absence of CS, $P(US|\sim CS)$. This representation is shown in Figure 1. Points on the contingency square may be referred to by their x, y coordinates. To simplify notation these will be given in parentheses as (x, y). For example, the upper left corner, where $x = 0$, $y = 1$, is expressed as $(0, 1)$ and represents the case where CS reliably precedes US and the US never occurs in the absence of the CS. Points along the left edge ($x = 0$, $0 < y < 1$) describe the partial procedures referred to above in which CS occasionally occurs in the absence of the US, but the US never occurs in the absence of the CS ($\sim$CS). The upper edge ($0 < x < 1$, $y = 1$) also describes a region of partial procedures, but here the CS reliably precedes the US, while the US occasionally occurs in the absence of the CS. The condition under which CS and US are uncorrelated (i.e., the truly random control) is shown along the ascending diagonal.

The quantitative implications of contingency analysis have recently been developed by Gibbon, Berryman, and Thompson (1974). In their paper two experiments by Rescorla were considered in the context of contingency analysis. The earlier study (Rescorla, 1968) in which Pavlovian fear conditioning was examined was represented in part by coordinates located along the left edge of the contingency square. This region is representative of partial reinforcement procedures in which the CS is presented with some specified probability in the absence of the US. Rescorla also studied procedures along the diagonal, the region of noncontingent CS-US presentations. The degree of

Figure 1. Contingency square representing the possible associations of the unconditional stimulus (US) given the presence or absence of the conditional stimulus (CS). The diagonal represents the region in which CS and US are uncorrelated.


1.0
0
0
1.0
NONCONTINGENT
P(US|CS)
P(US|~CS)

suppression at each contingency sampled was shown by Gibbon et al. (1974) to increase in proportion to the association value expressed as root mean square contingency or phi (ø) coefficient of the coordinates. The noncontingent points all yielded approximately the same suppression ratio value of .5 (i.e., no suppression).

The second study (Rescorla, 1969) dealt with conditioned inhibition of fear. The procedures used in this experiment were shown by Gibbon et al. (1974) as points along the horizontal edge of the contingency square or on the diagonal. The points along the horizontal edge correspond to contingencies in which US occurs with some probability in the absence of the CS. The data indicated that as $P(US|\sim CS)$ approached 1.0 the CS increasingly inhibited fear. Thus, Rescorla's experiments demonstrate that the degree of conditioning, whether excitatory (i.e., Pavlovian fear conditioning in the presence of the CS) or inhibitory (i.e., conditioned inhibition of fear in the presence of the CS) increases in proportion to the distance from (0, 0) along the left and lower edges of the contingency square.

Although these results clearly emphasize the importance of contingency in controlling behavior in a conditioned emotional response (CER) situation, other Pavlovian procedures lend themselves equally well to contingency analysis. For example, Gamzu and Williams (1971; 1973) were among the first to systematically examine the contingency between CS and US in an autoshaping experiment. Their work represents an extension of Rescorla's findings to the appetitive situation in that responding under a procedure in which signal and food were noncontingent was compared with responding under a partial reinforcement procedure. Gamzu and Williams demonstrated that pigeons acquired and maintained responding under the partial reinforcement condition, but did not do so under the noncontingent procedure. These authors point out that responding decreased under the noncontingent procedure even though reinforcement was added to the total stimulus situation. That is, food was added to ~CS intervals. These results are clearly consistent with Rescorla's (1967) argument that the contingency between CS and US is the important parameter in establishing conditioning and not merely the association of CS with US.

Both Rescorla and Gamzu and Williams demonstrated that $P(US|CS)$ per se was not sufficient to account for their results. For example, as Mackintosh (1974) has pointed out, in the CER paradigm explored by Rescorla (1968) subjects showed less response suppression under one condition (.2, .4) containing four times as many CS-US pairings as another condition (0, .1). In a recent paper by Gibbon, Locurto, and Terrace (1975) the relationship between frequency of positive trials (signal paired with food) and contingency between signals and food was explored in an autoshaping situation. These authors showed that manipulating either variable altered the effectiveness of the other. That is, increasing the frequency of positive trials within a fixed time period [previously shown by Terrace, Gibbon, Farrell, & Baldock (1975) to delay acquisition] inhibited responding even though signals and food were contingent. Moreover, responding was also inhibited by removing the contingency between food and signals even when infrequent trials were scheduled. Gibbon et al. (1975) argued that the frequency of positive trials interacted with contingency by affecting the amount of reduction in the error rate associated with "anticipating" or "predicting" reinforcement. Attending to a reliable predictor of food, for example, results in a proportionally greater reduction in anticipatory errors when the food occurs infrequently in contrast to frequent food presentations. According to Gibbon et al. (1975), "Intuitively, correct predictions are rare when reinforcements are rare, and so attending to the signals may produce a more substantial improvement" (p. 324).

A contingency analysis is particularly applicable to another type of procedure which has not yet been systematically examined from this point of view, namely, the observing response experiment. In a Pavlovian context, an observing response (R_O) produces a stimulus which is predictive of a designated outcome (e.g., food or no food); the outcome generally being independent of the R_O. Expressed another way, the R_O produces a change in stimulus conditions which reduces uncertainty with respect to US occurrence. The observing response procedure is similar to classical conditioning studies in that a schedule of CS-US contingencies is arranged by the experimenter. But, since the CS is response-dependent, the associative arrangements of CS and US are only specified in the event of a response. In the absence of a response, the "noninformative" stimulus condition may be one of several types. For example, the US may be delivered with a probability of .5 in the presence of a neutral stimulus, e.g., white key rather than red or green key (Wyckoff, 1952) or the CS may follow rather than precede US occurrence (e.g., Knapp, Kause, & Perkins, 1959).

The first experimental treatment of observing responses was undertaken by Wyckoff (1952) in an operant context; a more detailed description of the method appears in Hendry (1969). Wyckoff's procedure involved training pigeons on a fixed interval 30 sec extinction schedule

(FI 30 sec EXT). At the start of a trial an observing response (pedal press) produced a change in key color from white to either red or green. A green key, for example, indicated that a peck on the key after 30 sec would produce food, i.e., the FI 30 sec component was in effect, whereas a red color signaled no food after 30 sec, i.e., the extinction component was in effect. Failure to respond resulted in no change in key color. Both key pecks per minute and time spent on the pedal increased when the two stimuli were reliably correlated with schedule components and decreased when they were not differentially associated with the schedule components. Observing responses have also been shown to be maintained by stimuli predicting unavoidable shock (Badia & Culbertson, 1972; Lockard, 1963; Perkins, Levis, & Seymann, 1963; Perkins, Seymann, Levis, & Spencer, 1966).

Several hypotheses have been advanced to account for the maintenance of observing responses. A reliable CS, for example, may enable the animal to make "preparatory" responses (preparatory response hypothesis) that reduce the pain of shock or increase the reinforcing value of food. Alternatively, as Wyckoff proposed, the R_O may be maintained by the conditioned reinforcing effect of the response-produced stimuli paired with food. When the outcome is shock $\sim$CS trials designating the absence of shock serve as conditioned inhibitors of fear (safety signal hypothesis). A third alternative suggests that signaled events are more reinforcing than unsignaled events insofar as uncertainty about the onset of shock is reduced (uncertainty reduction hypothesis). Such an hypothesis, according to information theory (Attneave, 1962), predicts that CS and $\sim$CS contribute equally to uncertainty reduction and as such are equally reinforcing. A review of these theories follows.

A preparatory response hypothesis (Perkins, 1955) was applied by Prokasy (1956) to data obtained in an appetitive observing response procedure. The study is described below in some detail since it served as a model for many subsequent R_O procedures. Prokasy's apparatus consisted of an E maze in which delay chambers and goal boxes on two arms of the maze were painted either black or white. On the "consistent" (informative" side, differentiated by floor surface (hardware cloth or smooth substrate), one of the two colors was always correlated with food. On the "inconsistent" (uninformative" side, food and color were not correlated. Food was delivered with a .5 probability on both sides. To ensure equal exposure to both sides of the maze, rats were forced to the opposite side once half the trials had taken place on a given side. The results of this procedure showed that the number of forced trials to the inconsistent side significantly increased over sessions indicating that rats ran more often to the informative section of the maze. Prokasy argued that a signal reliably preceding food enabled the animal to produce optimal amounts of salivation in preparation for food. Such a conditioned response was assumed to be more reinforcing than too much or too little salivation elicited on the noninformative side of the maze.

A preparatory response hypothesis has since been applied more generally to aversive conditioning procedures. For example, Lockard (1963) trained rats in a shuttlebox in which a 2-sec shock was delivered at variable intervals. On one side of the shuttlebox a blinking light preceded shock onset by 5 sec whereas on the other side the light was presented between shocks (i.e., "explicitly unpaired"). Responding during this training as well as in a subsequent extinction procedure when the light was presented alone indicated a "preference" for the signaled shock. Lockard suggested several explanations for this behavior including the possibility (noted by Campbell & Teghtsoonian, 1958) that current density per square unit of tissue could be reduced through postural adjustments. However, use of a constant-current shock generator reduced the likelihood that rats could affect shock intensity. Moreover, no consistent postural differences were detected between experimental and control animals.

Other similar studies have confirmed Lockard's results. Perkins et al. (1963, 1966) exposed rats to a light preceding shock at intervals ranging from .5 to 18.0 sec on one side of a shuttlebox. On the other side shock was followed by the light stimulus. Shock was delivered either through a floor grid or through ear clips. Under these conditions rats spent a significantly greater amount of time on the signal-shock side than on the shock-signal side of the shuttlebox. Perkins et al. (1966) concluded that the aversiveness of shock was reduced by the opportunity (provided by the signal preceding shock) to make covert preparatory responses.

Whether shock intensity was physically attenuated in these studies was questioned by Biederman and Furedy (1970, 1973). These investigators failed to demonstrate a preference for signaled shock when shock intensity was unmodifiable (e.g., shock delivered through implanted electrodes). On the other hand, recent studies in which implanted electrodes were used (Griffin, Honaker, Jones, & Pynes, 1974; Miller, Daniel, & Berk, 1974) affirm the results reported by Perkins et al. (1963; 1966). Moreover, Cantor and Lolordo (1970) demonstrated preference for signaled electrical stimulation of the brain (ESB), a US that does not seem to be modifiable by overt postural responses.

The preparatory response hypothesis proposes that the aversiveness of a stimulus may be attenuated by reliably establishing when the aversive event is due to occur. For example, Badia, Suter, and Lewis (1966) reported reduced frequency of vocalization in rats to a shock preceded by a CS in comparison with vocalizations to unsignaled shock. In another experiment using rats as subjects Lykken (1962) showed that the GSR was reduced when shock was preceded by a tone. Gaebelin, Taylor, and Borden (1974) described a study in which human subjects were given either an accurate (clock) or vague (verbal estimate) means of determining the onset of shock. Significant changes in heart rate and skin conductance were noted prior to shock for the clock group whereas the verbal estimate group showed increased levels of these responses during shock and one minute following shock. Gaebelin et al. proposed that subjects in the clock group were "prepared" for shock in contrast to the verbal estimate group. In another experiment using human subjects Lovibond (1968) made shock predictable or unpredictable by presenting it at fixed or random intervals. Under these conditions GSRs to predictable shock declined over sessions whereas no decline was apparent for subjects given unpredictable shock. In addition, subjects in the predictable shock condition rated shock aversiveness as either constant or reduced significantly more often than subjects in the unpredictable shock condition. Other studies in which the duration of the CS-US interval was manipulated (Kimmel, 1967; Suboski, Brace, Jarold, Teller, & Dieter, 1972) lend further support to a preparatory response hypothesis by establishing a CS-US interval that was judged to be optimal for the reduction of shock aversiveness.

In a recent paper, Furedy (1975) criticized the conclusions drawn from such studies on the basis that shock-elicited autonomic indices are confounded by a response-interference factor. When this confounding factor is eliminated by establishing secondary signals which themselves indicate whether or not a consequent series of shocks will be signaled (Furedy & Klajner, 1972), neither autonomic indices nor verbal ratings indicated that shock aversiveness is attenuated by signals preceding shock. However, Furedy (1975) acknowledged that these procedures sometimes failed to establish a correlation between an autonomic index (e.g., GSR) and differences in shock intensity. The absence of such a correlation would make the effects of signaled shock difficult to evaluate.

Although many of the studies described above show differential responding in the presence of predictable and unpredictable shock, it is not clear whether the responses per se reduce shock aversiveness or whether they are indicative of a more central "fear reduction" mechanism.

Alternatively, periods free from shock which are identified by ~ CS may reduce the overall aversiveness of the shock situation. Such a "safety signal" hypothesis as stated by Seligman (1968) emerged from studies on conditioned inhibition of fear (e.g., Rescorla & Lolordo, 1965). The theory assumes that once a discrimination is formed between signals predicting shock and signals predicting no shock, responding will occur because the overall aversiveness of the situation is reduced. This theory has received considerable support from subsequent studies on the fear-inhibiting properties of stimuli identifying shock-free periods (Bull & Overmeier, 1968; Maier, Seligman, & Solomon, 1969; Weisman & Litner, 1971). In addition, results showing greater response suppression and gastrointestinal ulceration in rats during unpredictable shock (Seligman, 1968; Seligman & Meyer, 1970) have been offered in support of a safety signal hypothesis. This theory has been further elaborated by Weiss (1971a, 1971b, 1971c) who proposed that the amount of "relevant feedback" (i.e., stimuli not associated with shock) from a response as well as the number of responses emitted determine the probability of stomach ulceration.

A response-independent shock procedure that has yielded results consonant with a safety signal hypothesis was first explored by Badia and Culbertson (1972). These authors trained rats on a procedure in which a lever response produced a light stimulus correlated with signaled shock. During the 3-min interval associated with the light stimulus, shocks were preceded by 5-sec tones. Responses had no effect on shock delivery. Under these conditions rats responded sufficiently often to produce the correlated light stimulus 80 to 90 percent of the time. Responding was only slightly less frequent when the light stimulus without the 5-sec tones preceding shock was made response contingent. Response levels were substantially reduced, however, when a response produced only the 5-sec tone preceding shock and not the correlated stimulus. Badia and Culbertson concluded from these results that the correlated stimulus identified a period of safety because shock only occurred in the presence of the light and tone together and never in the presence of the light alone. The positive reinforcing value of a safe signal, according to Badia and Culbertson, maintained responding.

A study described by Arabian and Desiderato (1975) combines some features of the Badia and Culbertson choice procedure with a shuttlebox situation in an effort to compare the safety signal and preparatory response hypotheses. Three situations were compared. In the first (cf. reliable danger, reliable safety as used later in the present paper) a correlated stimulus (light) was scheduled for 10 minutes during which time a 5-sec signal (tone) preceded shock and, therefore, functioned as a warning signal. No signals or shocks occurred in the 10-min absence of the correlated stimulus (safe period). The second condition (cf. unreliable danger, reliable safe) resembled the first with the exception that signals during the correlated stimulus occurred independently of shock. In the third condition (cf. unreliable danger, unreliable safe) signals and shock occurred independently of one another and independently of the correlated stimulus. When given a choice between totally unreliable signals on the one side of the shuttlebox and either totally reliable or partially reliable signals on the other side, rats spent significantly more time on the latter side. However, a choice between totally reliable signals and unreliable danger, reliable safety resulted in less time spent under the former condition. That is, rats "preferred" partially reliable signals to totally reliable signals. Such a result appears to be inconsistent with both the preparatory response hypothesis and the safety signal hypothesis. Not only is the opportunity for preparatory responses eliminated during the correlated stimulus, but the overall identifiable safe time is reduced in comparison with the reliably signaled first condition. Arabian and Desiderato, however, suggested that the signal preceding shock served as a Pavlovian fear elicitor and, as such, was sufficiently intense to override any fear inhibiting properties of the correlated stimulus. Such a posteriori reasoning illustrates the problem of assessing the effects of warning and safe signals independently of one another particularly under compound stimulus conditions.

The third explanation of the observing response phenomenon suggests that reduction in outcome uncertainty alone is sufficiently reinforcing to maintain observing responses. Lanzetta and Driscoll (1966), for example, adapted the observing response procedure to human subjects and concluded that uncertainty reduction was responsible for preference for signaled outcomes. In their procedure subjects were given an R_O and a non-R_O choice. The R_O produced a change in stimulus color associated with one of a pair of possible outcomes, e.g., reward versus no reward, shock versus no shock, or reward versus shock. Each outcome within a pair was scheduled with a probability of .5. Choice of the non-R_O option resulted in no change in stimulus color. The main finding of this study was that subjects made significantly more "information-search" responses than noninformation responses regardless of the choice of outcomes. In addition, changes in GSR as a function of information were not sufficiently pronounced, according to Lanzetta and Driscoll, to provide strong support of a preparatory response hypothesis. Moreover, since the probability of a "search" response was greatest after "empty" trials, i.e., unsignaled trials on which an event did not occur, Lanzetta and Driscoll argued that search behavior was motivated by the uncertainty generated by such trials.

Efforts to test an uncertainty reduction hypothesis have generally focused on eliminating or changing the informative value of the signal. One method, for example, has been to add a "free" predictive signal, thereby making the consequences of an observing response redundant. A related approach, also intended to increase redundancy, has involved removing one of two schedules of reinforcement or removing one of two signals differentially associated with each schedule. A third group of studies has centered on manipulating the probability of reinforcement. A brief discussion of each of these approaches follows.

The first method, i.e., adding a cue to the stimulus complex, was examined in one of four experiments by Bower, McLean, and Meacham (1966). Contrary to their expectations, observing responses were maintained when a signal (cross) was added to the CS just prior to reinforcement. Bower et al. argued that the addition of such a cue was no different than many such cues associated with the occurrence of reinforcement (e.g., the sound of the feeder) and should not override the informative value of the signal. In another experiment Seligman (1966) adapted the well-known work of Egger and Miller (1962, 1963) to an aversive conditioning situation in order to determine if a redundant predictor of shock would acquire secondary punishing value. The outcome demonstrated that a redundant secondary punisher significantly suppressed responding maintained on an appetitive baseline and thus failed to confirm Egger and Miller's results. Seligman suggested that informational aspects of stimuli might exert proportionally less control than stimulus contiguity in aversive procedures compared to appetitive procedures. The implications of these two studies are that redundant stimuli may function as conditioned reinforcers in observing response procedures as well as in aversive conditioning.

An observing response may produce one or the other of two discriminative stimuli correlated with different schedules of response-produced reinforcement, or the stimuli correlated with different noncontingent (response-independent) consequences. In either case, an uncertainty reduction hypothesis predicts extinction of the observing response if one of the schedules or events is eliminated because the signal associated with that schedule or event then becomes redundant (i.e., non-informative). By the same argument, however, the conditioned reinforcing properties of the signal are also removed since it has been shown in an appetitive situation that redundant stimuli fail to acquire conditioned reinforcing value (Egger & Miller, 1962, 1963). It is, therefore, unclear whether failure to respond is due to removal of outcome uncertainty or removal of the conditioned reinforcing properties of the signal. The weight of the evidence points toward the maintenance of observing responses by the hedonic value of the signal rather than the opportunity for uncertainty reduction per se. For example, the Bower et al. (1966) results described above demonstrated that observing responses were maintained despite the addition of a redundant stimulus. Moreover, there is evidence that observing responses are maintained by stimuli predictive of the positive schedule, but not by stimuli associated with a negative schedule (Dinsmoor, Flint, Smith, & Viemeister, 1969; Jenkins & Boakes, 1973; Kendall & Gibson, 1965; Kendall, 1973a). It sould be added, however, that there are two studies (Schaub, 1969; Schaub & Honig, 1967) in which stimuli predicting a negative schedule were claimed to have sustained observing responses. The possibility that the absence of the negative predictive stimulus in these studies served as a conditioned reinforcer, however, cannot be excluded. In general, then studies of this type do not exclude a conditioned reinforcement explanation of observing response production.

Finally, an uncertainty hypothesis predicts that a stimulus signaling one of two outcomes should be maximally reinforcing when the probability of the outcome is .5. If the frequency of trials having the particular outcome is increased relative to trials with no outcome or an alternative outcome, the predictive stimulus becomes proportionally less informative and, according to an uncertainty reduction theory, less reinforcing. This argument follows directly from information theory in which maximum information resides in equally likely alternatives and decreases as one alternative becomes more or less likely (Attneave, 1959). Such an argument was proposed in a study by Wilton and Clements (1971a) in which food was delivered on every trial regardless of which stimulus (red or green light) followed an observing response, i.e., the probability of food was 1. Response rates under this condition were approximately equal to those produced by an uncorrelated (i.e., NO INFO) stimulus condition in which the probability of food was equal to .5. A further prediction derived from information theory is that reducing or increasing the probability of food by an equal amount should produce an equal reduction in observing responses. That is, responding should be the same for a probability of food of .8 as that of .2. But experiments by McMichael, Lanzetta, and Driscoll (1967) and Wilton and Clements (1971b) showed greater responding when 20 percent of the trials were followed by food than when reinforcement was scheduled on 80 percent of the trials. Kendall (1973b) reported similar results in that observing responses were most frequent when the probability of food was .25 rather than .50 or .75. These results are clearly consistent with the autoshaping studies (e.g., Terrace, Gibbon, Farrell, & Baldock, 1974) in which keypecking was inhibited by frequent reinforcement at short intertrial intervals and Gibbon et al. (1975) in which pecking occurred to intermediate or infrequent positive trials, but far less often to frequent positive trials. These results also argue against an uncertainty reduction hypothesis as solely responsible for the maintenance of observing responses.

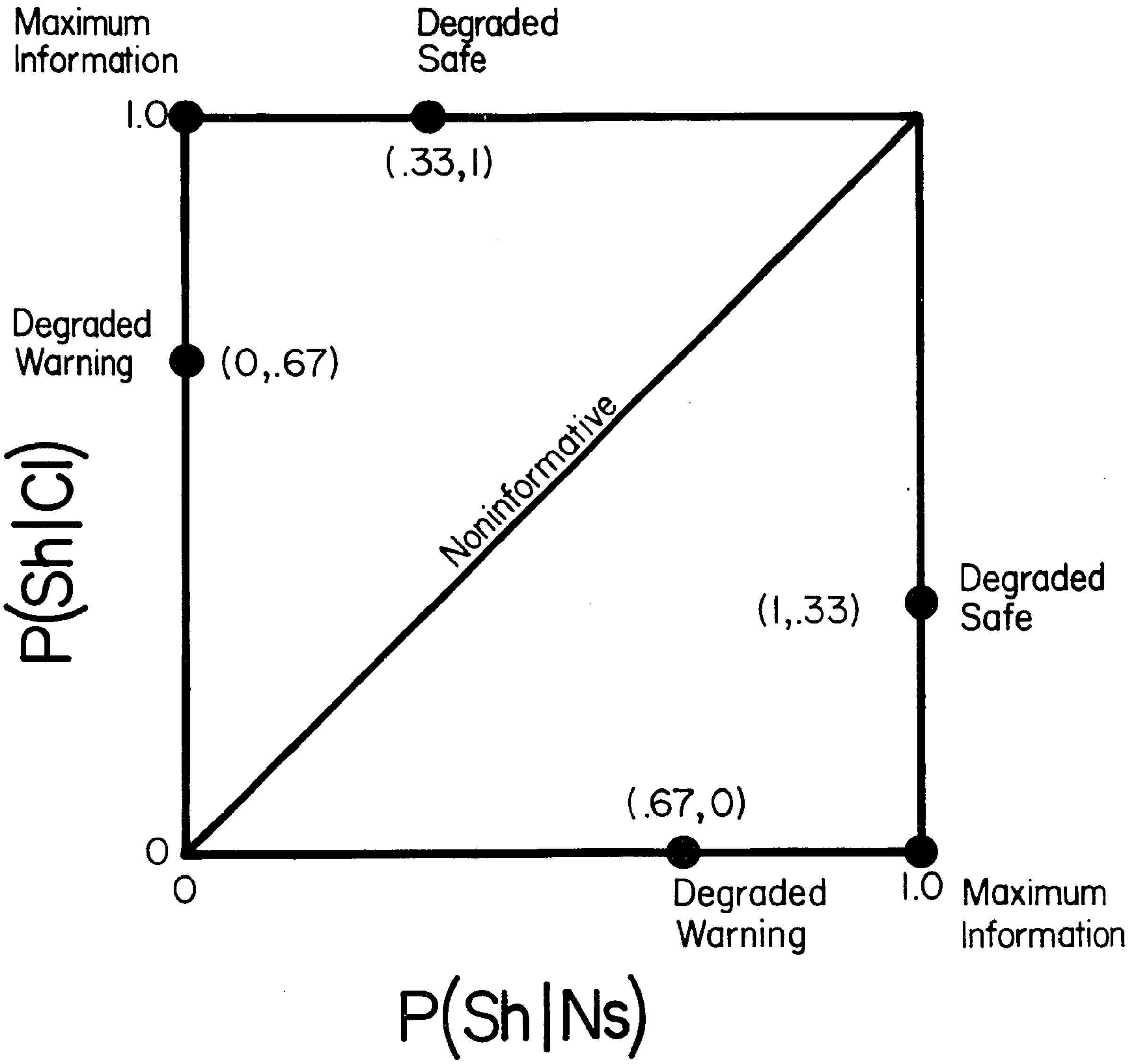
The above remarks were intended to provide a critical review of theories concerning the reinforcing value of informative stimuli in various conditioning procedures. Although contingency analysis per se is not a theoretical system, nevertheless, it offers a useful means of examining the associative effects of the CS and US in such procedures. A contingency analysis as Gibbon et al. (1974) have suggested, may reveal different "cost" values associated with different kinds of anticipatory error. That is, a situation in which shocks are "unexpected" may be more aversive to a subject than one in which an anticipated shock doesn't occur. Although some studies have explored such possibilities (e.g., Badia & Culbertson, 1972; Arabian & Desiderato, 1974), a systematic analysis of contingency applied to an observing response situation in which warning and safe signals precede shock and no shock, respectively, has not been accomplished. The following studies were, therefore, undertaken for the purpose of assessing the contribution of contingency to the reinforcing value of warning and safe signals in an observing response procedure.

Consider a situation in which there are two separate and distinct signals, a clicking sound (Cl) and white noise (Ns), one of which is paired with shock (Sh) and the other of which is associated with the absence of shock ($\sim$Sh). The conditional probability of shock given each of the signals may be plotted in such a way as to form a contingency square. For example, Figure 2 shows the conditional probability of shock given the clicking sound, $P(Sh|Cl)$, plotted against the conditional probability of shock given white noise, $P(Sh|Ns)$. At the upper left corner labelled Maximum Information with (x, y) coordinates (0, 1), the click is a reliable warning signal since it is always followed by shock: $P(Sh|Cl) = 1$. At the same time, noise is a reliable safe stimulus since it is never followed by shock: $P(Sh|Ns) = 0$.

Points along the left edge of the contingency square ($x = 0$, $0 < y < 1$) describe the warning signal degraded in informative value since not all click signals are followed by shock. For example, the coordinates (0, .67) represent the condition under which only two-thirds of the click stimuli are followed by shock: $P(Sh|Cl) = .67$. However, the noise signal remains a reliable safe signal since it is never followed by shock: $P(Sh|Ns) = 0$. Points along the upper edge ($0 < x < 1$, $y = 1$) represent the safe signal degraded in informative value since it is followed by shock some percentage of the time. The coordinates (.33, 1), for example, indicate that one-third of the noise signals are followed by shock, $P(Sh|Ns) = .33$, whereas all of the click signals are followed by shock: $P(Sh|Cl) = 1$. The lower right corner and adjacent edges represent corresponding conditions in which the roles of the click and noise stimuli as warning and safe signals have merely been reversed. The condition under which signals and shock are uncorrelated (noninformative) is shown along the ascending diagonal.

Given a discrete-trial situation there are limits to the range over which warning and safe signals may be independently manipulated for a given probability of shock. For example, considering the diagonal, if $P(Sh) = .5$, only the midpoint on the diagonal may be sampled.

Figure 2. Contingency square representing the possible associations of shock (Sh) given the occurrence of a clicking sound (Cl) or white noise (Ns). Contingency square coordinates are shown in parentheses.


Maximum Information
Degraded Safe
1.0
(.33,1)
Degraded Warning
(0,.67)
Noninformative
P(Sh|Cl)
(1,.33)
Degraded Safe
(.67,0)
0
0
Degraded Warning
1.0
Maximum Information
P(Sh|Ns)

Selecting other points along the diagonal requires an increase or decrease in shock probability. These limitations also apply to edge values. For a shock probability of .5, the edges adjoining the coordinates of Maximum Information may only be sampled to .5.

The associative arrangements described above may be examined within an observing response paradigm. That is, if a response-independent shock is scheduled with a probability less than 1 at the end of a trial, then a response-produced signal preceding the shock may serve as a warning signal. A signal associated with no shock may, in turn, serve as a safe signal. Moreover, if only one response is permitted per trial, the consequences of that response (e.g., click preceding shock or noise preceding no shock) are clearly defined. Failure to respond would result in an unsignaled trial without, however, affecting the probability of shock. This procedure allows the informative value of the warning signal to be manipulated independently of the safe signal. That is, the warning signal may occasionally precede no shock (i.e., degraded warning signal) without affecting the reliability of the safe signal. Thus, different signal-shock contingencies may be sampled under constant shock density (within the limitations described above). In addition, the effects of different shock probabilities may be assessed while holding constant the signal-shock contingency.

Although responses have no scheduled effect on shock in the procedure described above, nevertheless, this situation shares some aspects in common with partial avoidance and partial punishment procedures (Neffinger & Gibbon, 1975). For example, if animals are given preliminary avoidance training, subsequent exposure to maximally informative signals resembles in some part (to the animal) a partial avoidance condition. That is, responses are followed some percentage of the time by the absence of shock, a condition which is indiscriminable from a successful avoidance trial and which may, therefore, support avoidance responding. Since a pretraining avoidance procedure was used in the studies described below, "superstitious" or incidental avoidance responding may have contributed to performance maintained under the discrete-trial observing response procedure. This possibility is not suggested here as a limitation on the use of the observing response procedure, but rather as an interpretive issue which is treated in more detail in the discussion section.

The present experiments were designed to investigate the effects on an observing response of manipulating the reliability of warning and safe signals predicting shock or no shock, respectively. In each experiment the absolute probability of shock was fixed and was independent of responding. A first study compared responding under conditions of maximally informative and maximally noninformative signals. Two subsequent studies inquired into the effects of independently manipulating warning and safe signal reliability under response-independent shock probability. A final study explored the effects of signal reliability at other values of the fixed shock probability.

General Method

Subjects. In the experiments to be described two strains of male rat (Long-Evans hooded and Sprague-Dawley albino) were used in an effort to select the strain of rats most likely to acquire and maintain an observing response under conditions of signaled, response-independent shock. Although male and female Sprague-Dawley albino rats have typically served as subjects in observing response procedures with shock as the outcome (Arabian & Desiderato, 1975; Badia & Culbertson, 1972; Lockard, 1963; Miller, Daniel, & Berk, 1975; Perkins et al., 1963, 1966), hooded rats have also acquired responding under response-independent shock (Gibbon & O'Connel, 1974; Macko, 1973). All rats (described in detail under each experiment) were obtained from Rockland Farms, Inc., Gilbertsville, Pennsylvania and Blue Spruce Farms, Altamont, New York. The animals were approximately 70 days old at the time of delivery.

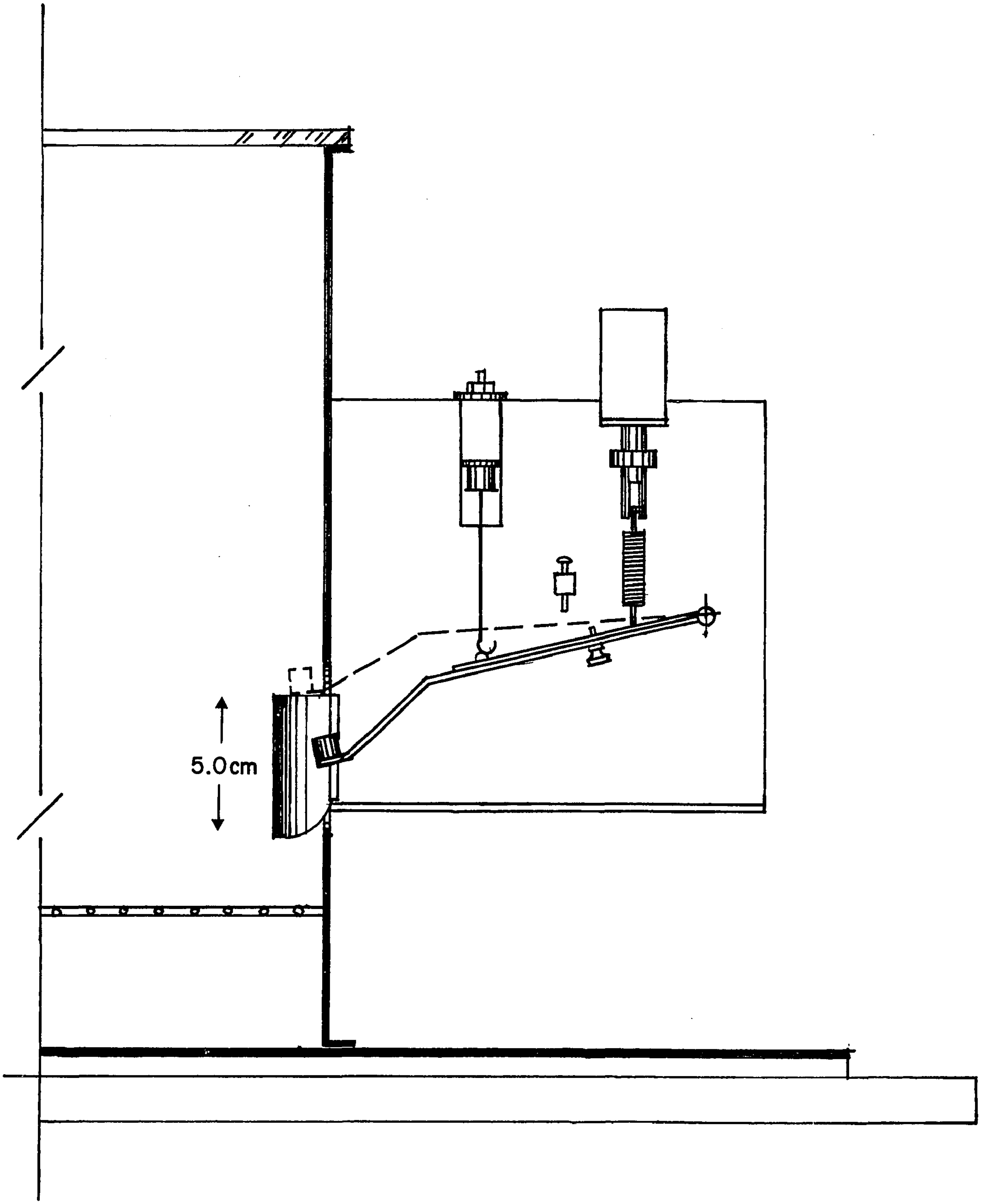
The rats were individually housed in cages of approximately 19.0 cm wide by 27.0 cm deep by 19.0 cm high. The cages were located in a small room of approximately 1.8 by 1.8 meters. The room was illuminated by a frosted 75 watt light bulb that was turned on at 8 AM and turned off at 8 PM. Temperature in the room was maintained between 21.0 and 27.0 degrees Centigrade throughout the study.

Animals were maintained on an ad libitum schedule of Purina Laboratory Chow pellets with tap water continuously available. Animals were weighed daily prior to being placed in the experimental chambers.

Apparatus. The four experiments to be described were conducted in commercially manufactured operant conditioning chambers (Model 1111-L, Grason-Stadler Co., Concord, Massachusetts). One chamber was used in Experiment 1, two chambers in Experiment 2, three chambers in Experiment 3, and four chambers in Experiment 4. Each chamber was enclosed in a sound-attenuating box (Model 1101, Grason-Stadler Co.). The section of the chamber in which the subject was placed measured approximately 30.0 cm wide by 30.5 cm deep by 26.5 cm high. This area was illuminated by a General Electric No. 1815 lamp operated at 14 volts, .12 amperes located in the upper left corner of the front panel approximately 25.0 cm above the grid floor and 14.0 cm to the left of the manipulandum. The two levers normally supplied with this model rat chamber were removed and aluminum plates bolted over the slots.

A retractable manipulandum was fashioned from a liquid dipper (Model GS-RA, 24 VDC, Ralph Gerbrands Co., Arlington, Massachusetts) which could be made to project upward into the chamber just above a curved aluminum shield (Figure 3). The shield, which extended about 1.5 cm outward from the lower center of the subject panel, was installed to prevent the subject from making contact with the dipper when it was withdrawn. The shield was attached to the aluminum subject panel and both were electrically isolated from the dipper. A contact-sensitive relay (Drinkometer, Model E4690A, Grason-Stadler Co.) placed across the dipper and shield produced a switch closure whenever the rat completed the circuit by making contact across the dipper and shield or dipper and subject panel. A response in these experiments was defined as any behavior producing such a switch closure. It was estimated that the duration of dipper withdrawal from the fully extended to resting position was at most 500 msec. The time from maximum projection to a point at which the dipper was no longer accessible to the rat was estimated at approximately 300 msec. This fast and reliable response mechanism provided a satisfactory alternative to commercially-

Figure 3. The retractable manipulandum fashioned from a Gerbrands liquid dipper (Model GS-RA, 24 VDC). The solid lines show the dipper retracted behind the curved aluminum shield. The dashed lines show the position of the dipper at the initiation of a trial.


5.0cm

available retractable manipulanda.

The arm of the dipper rested on a microswitch which was closed when the dipper was raised. Operation of the microswitch controlled the lighting of a pilot light (No. 1815, General Electric, operated at 14 VDC) positioned behind the subject panel just above the dipper opening.

The floor grid in the chamber consisted of 23 stainless steel bars each approximately 3 mm in diameter and spaced 9 mm apart. Shock of .8 ma rms intensity, 60 Hz, and of .2 sec duration was delivered by a calibrated, constant current shock source (Model 700, Grason-Stadler Co.) through the floor grid. Prior to each experimental session the floor bars of each chamber were cleaned with steel wool to allow maximally effective foot shock.

Each chamber contained a 7.0 cm speaker with an impedance of 45 ohms through which sound stimuli, either a train of clicks or white noise, could be presented. The train of clicks was generated by an oscillator described by Malis and Curran (1960). The circuit was modified to provide an output of approximately 12 clicks per second. A noise generator (Model 901B, Grason-Stadler Co.) delivered the white noise. Additional sound was produced by a ventilator fan which was operated continuously during the session. The sound pressure level in the presence of the fan alone, measured at a point approximately 3.0 cm in front of the dipper, was 75 decibels re: .00002 N/m^2 on the C scale of a sound level meter (General Radio Co., Concord, Massachusetts, Model 1551 B). When either the click stimulus or white noise was on, sound pressure level measured at the same point in front of the dipper was approximately 80 decibels.

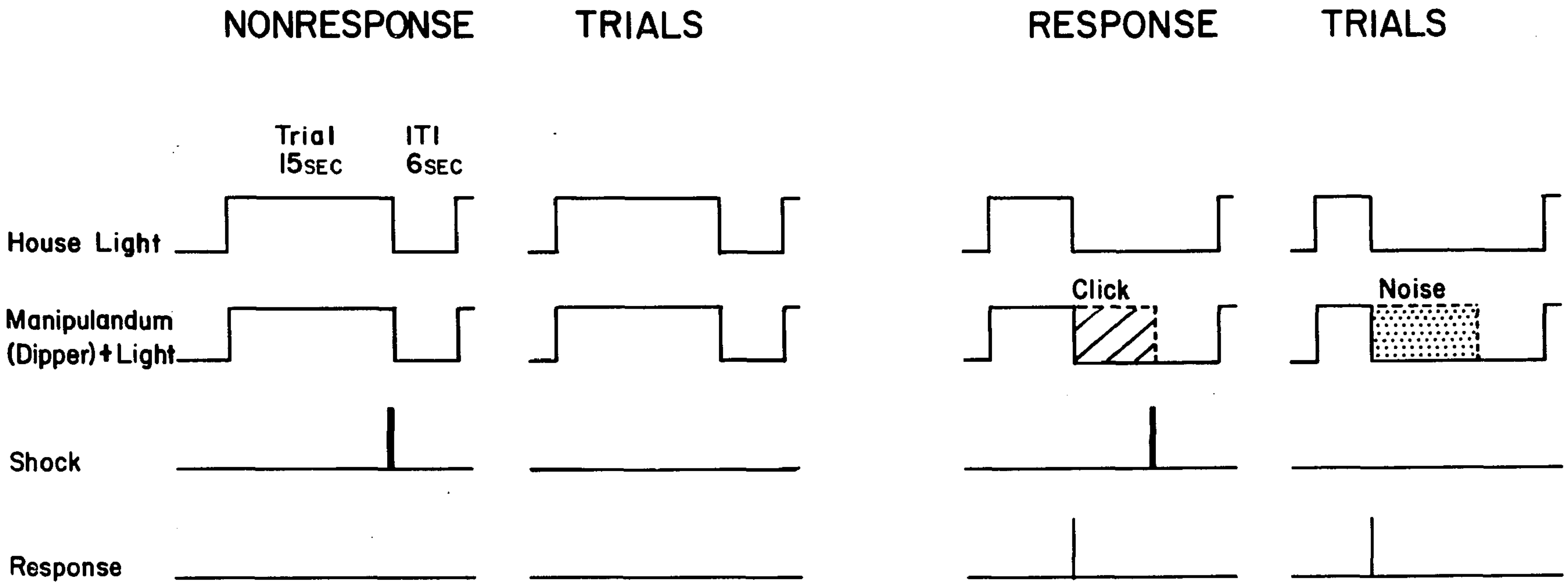
The research chests were placed next to each other on tables in a small experimental cubicle. Programming and control apparatus was housed in a cubicle adjacent to the experimental cubicle. Connecting cables were passed through a hole in the cubicle wall filled with pieces of absorbent material to aid in acoustic isolation.

The programming and control apparatus consisted of conventional electromechanical relays, timers, counters, and other standard electronic devices. Three-channel variable interval timers (Model PT-3A, Ralph Gerbrands, Co.) were used to program shock and stimulus events for each trial. The stimulus events for each of the 200 trials were punched onto 35 mm film loops. The film loop advanced with each trial. Responses, shock occurrence, and trial duration were recorded on cumulative recorders (Model C-3, Ralph Gerbrands Co.). Responses were also cumulated on counters and response latencies in class intervals of 3 sec were recorded on five counters.

Experimental paradigm. Figure 4 shows the discrete trial, response-independent shock procedure used in the four experiments. A trial was initiated by presentation of the dipper and onset of the house light and dipper light. If no response occurred, the trial was terminated after 15 sec by withdrawal of the dipper behind the shield and extinction of the house light and dipper light. Shock onset occurred .2 sec prior to the end of the trial and its termination coincided with removal of the dipper and extinction of the stimulus lights. Shock was presented with a probability less than 1.0 for all experiments. A 6-sec intertrial interval separated each trial. During the intertrial interval the dipper was inaccessible to the subject.

A response (contact by the rat across the dipper and shield or

Figure 4. Schematic diagram of the discrete trial procedure for the Maximum Information (MAX INFO) condition. The onset of the house and dipper lights and presentation of the manipulandum marked the beginning of a trial. Shock was presented, if scheduled, .2 sec before the end of the 15 sec trial. If no response occurred during a trial, the dipper was removed and dipper and house light were turned off. Shock terminated simultaneously with these events. Following a response, either of the two auditory signals could serve as a warning or safe signal. Here, a train of clicks (striped area) is shown as a warning signal immediately following a response on a shock trial. White noise (stippled area) is shown following a response when no shock was scheduled. The dipper was removed and dipper light extinguished after a response. Each trial was followed by a 6-sec intertrial interval. The probability of shock for a given post-response auditory signal was varied for conditions other than MAX INFO. The frequency of shock relative to no-shock trials (with or without a response) was changed in Experiment 4.



NONRESPONSE TRIALS

RESPONSE TRIALS

dipper and chamber wall) occurring at any time during the trial with the exception of the final .2 sec was followed by the immediate removal of the dipper, extinction of the dipper light, and production of either the click or white noise stimulus which remained on until the end of the trial. A response occurring during the final .2 sec was recorded, but had no other experimental consequences. Only one response could be made during the trial.

Responses were grouped in counters according to events on the previous trial so that sequential response patterns could be analyzed. In order to provide an identifiable stimulus combination at the start of the session, the first trial was always a shock-free trial.[1] There were 200 trials per session and each session lasted approximately 70 min.

EXPERIMENT 1

Experiment 1 was undertaken to determine whether responding established in an avoidance procedure could be maintained in the discrete-trial procedure described above where inescapable shock was presented randomly on 50 percent of the trials and a response produced a reliable warning or reliable safe signal. This condition is described by the coordinates of maximum information (MAX INFO) at the upper left and lower right corners of the contingency square (see Figure 2). The study was designed to compare MAX INFO with totally noninformative signals (NO INFO), that is, the condition under which there was an equal probability of shock following each of the two response-produced signals. Such a condition is represented by the midpoint of the diagonal on the version of the contingency square shown in Figure 2.

Method

Subjects. A group of 16 rats (6 Sprague-Dawley albino and 10 Long-Evans hooded rats) served as the initial subject pool from which subjects were selected for Experiments 1 and 3. The rats were all obtained from Blue Spruce Farms, Altamont, New York. Of these 16 animals, three (2 albinos and 1 hooded rat) were selected for study in Experiment 1 and six rats (all hooded) were selected for Experiment 3. Since the pretraining procedures were the same for subjects in Experiments 1 and 3, the pretraining methods for all 16 rats are described below.

Initially, all 16 animals were run under operant level conditions consisting of exposure to all aspects of the discrete-trial procedure described in the General Method section with the exception that the shock source was disconnected. Next, a sample of seven rats selected at random (including rats 432 and 424 retained in the present study) were given four sessions of training on a discrete-trial procedure designed to shape responding (see Appendix I). Since this procedure was unsuccessful in facilitating responding, a second preconditioning procedure was initiated. This involved training all 16 rats on a discrete-trial avoidance procedure in which a response during a trial always produced a safe signal followed by no shock. The avoidance procedure was intended to establish a level of responding sufficient for the rat to sample signal-shock associations when introduced to the Maximum Information (MAX INFO) condition, the first experimental phase. Four of the 16 animals were eliminated for failing to avoid at least 25 percent of the shocks scheduled during the first two sessions of training. The remaining 12 rats were given a minimum of five sessions of avoidance training. If a criterion of 90 percent of the shocks avoided was not reached at that time, additional sessions were scheduled. Under these conditions all rats avoided at least 75 percent of the shocks by the end of training. Further details of the pre-experimental procedures and the results of this training for the three rats retained in Experiment 1 are given in Appendix I.

After avoidance training each of the remaining 12 rats was exposed to the signaled, response-independent shock procedure described in the General Method section. In this first experimental phase (MAX INFO) warning and safe signals were both reliable predictors of shock and no shock, respectively. Only the rats that maintained an average response probability of at least .25 over the last eight sessions of this condition were retained for further study.

The mean age of the subjects at the start of training on the MAX INFO condition was 237 days (ranging from 232 to 246 days).

Procedure. The discrete-trial procedure described in the General Method section was used in all studies. Table 1 shows the number of trials scheduled and the conditional probabilities of shock given either the noise or click signal for the two experimental conditions investigated in this study. These were the maximally informative signal condition (MAX INFO) and the maximally noninformative signal condition (NO INFO). The conditional probabilities shown for these two conditions correspond to contingency square coordinates. In both conditions equal numbers of shock and shock-free trials were scheduled: P(Sh) = .5. Under the MAX INFO condition two stimulus arrangements are shown. The upper 2 x 2 table describes the situation in which white noise served as the warning signal and the click was the safe signal for rats 432 and 427. The lower table shows the counterbalanced case in which noise was a warning signal and click was safe for rat 424. The signals were counterbalanced to control for differential responding to the click or noise signals due either to the acoustic effects of the signals per se, or to possible interactions between acoustic stimuli and aversive stimuli. Subjects might, for example, show a higher response probability under certain conditions in which shock is paired with click than shock paired with white noise. Subjects were given the same safe signal under MAX INFO as under the pretraining conditions.

The schedule of shocks during each session was a two-choice event series (Fellows, 1967) which was expanded to include four, rather than three "runs" of the same event in sequence (i.e., shock or shock-free trial). This was done to provide greater flexibility in constructing sequences of events over the 200 trials. See Appendix I for a description of the shock schedule.

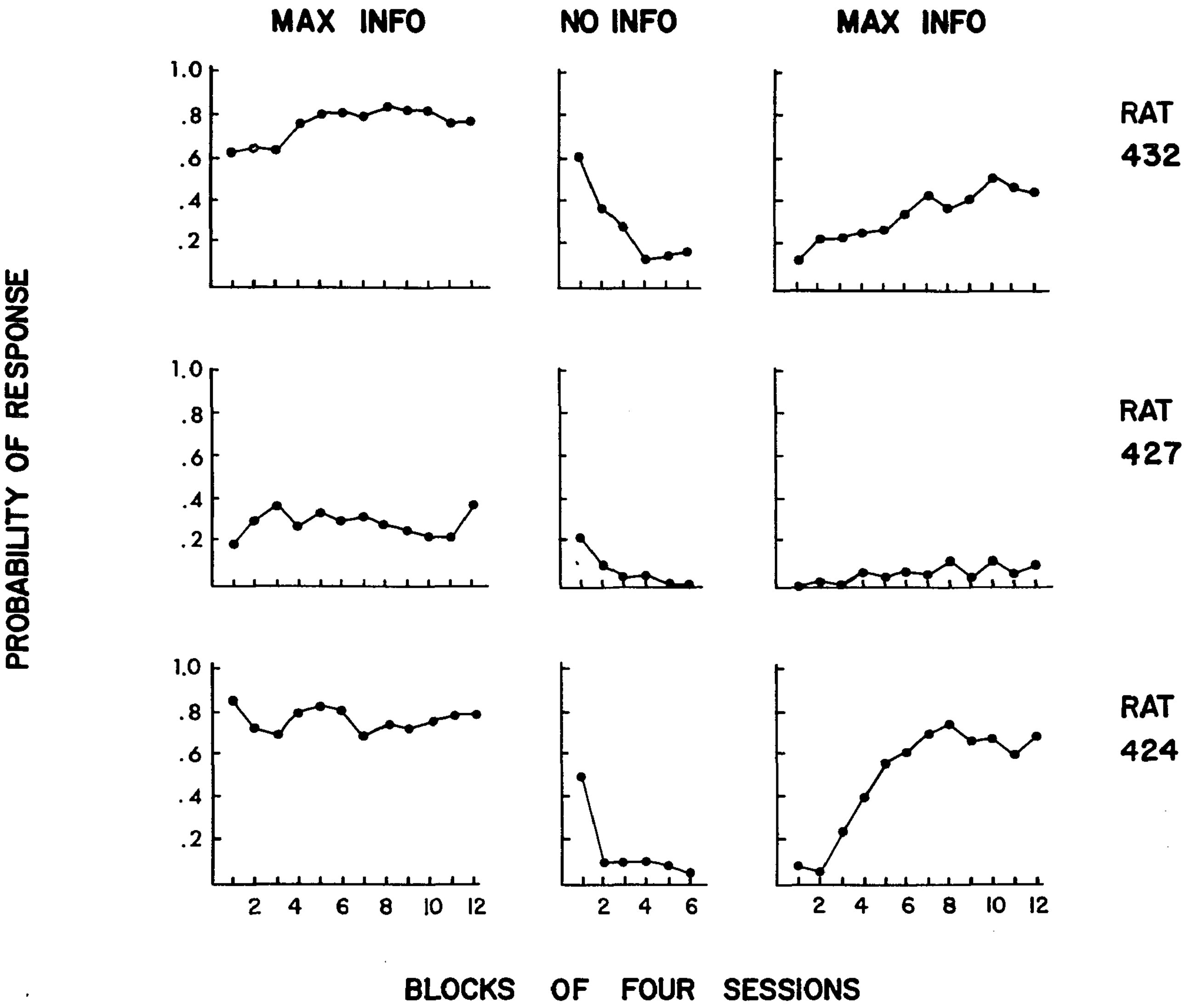
The three rats were given 48 sessions of training under MAX INFO followed by 24 sessions of exposure to NO INFO. Rats were then returned to MAX INFO for an additional 48 sessions.

Results.

Overall response probability. Figure 5 shows response probability, P(R), in blocks of four sessions for the three rats given training on the maximally informative signal condition before and after exposure to the noninformative signal condition. During the initial MAX INFO condition rats 432 and 424 responded at consistently high levels [e.g., P(R) in 4-session blocks exceeded .60 for both rats over all sessions], whereas 427 responded at a lower level [e.g., P(R) in blocks of four sessions was maintained between .20 and .38 over all sessions].

When the rats were subsequently exposed to the noninformative condition, the mean response probability over the last eight sessions declined to .17 for rat 432, .08 for rat 424, and .02 for rat 427. Reinstating MAX INFO resulted in different levels of recovery for each rat. During the last eight sessions of the recovery phase rat 424 attained a response probability of approximately 83 percent of the initial MAX INFO phase. Rat 432, on the other hand, attained an intermediate level of recovery (i.e., 60 percent of the initial MAX INFO condition). Rat 427 showed only slight evidence of recovery (i.e., the mean response probability over the last eight sessions of the recovery phase was .09 or 30 percent of initial MAX INFO levels). Since this animal also responded at a relatively low level in the first MAX INFO condition and very infrequently at the end of the NO INFO phase, responding during the recovery phase may not have been sufficient for the rat to adequately sample the reinstated signal-shock contingency.

Figure 5. Probability of a response presented in blocks of four sessions over successive experimental conditions for each rat in Experiment 1.


MAX INFO
NO INFO
MAX INFO
RAT 432
RAT 427
RAT 424
PROBABILITY OF RESPONSE
1.0
.8
.6
.4
.2
2
4
6
8
10
12
BLOCKS OF FOUR SESSIONS

The effects, if any, of the acoustic properties of the click and noise signals are difficult to evaluate given the few subjects and the pronounced differences in response levels between subjects. However, inspection of response probability under the initial MAX INFO and NO INFO conditions for rats 432 (click as warning signal) and 424 (noise as warning signal) show no obvious differences in response patterns which could be attributed to differential effects of signal quality. Moreover, the operant level data showed no differences with regard to signal quality.

Sequential effects. On the assumption that events on an immediately preceding trial influence response probability on the subsequent trial, an analysis of sequential responding was undertaken. The purpose of the analysis was to specify in more detail the stimulus events that sustained responding under the MAX INFO condition in contrast to the NO INFO condition. If rats were differentially sensitive to the type of signal-outcome pairing, sequential analysis might show a different response probability after safe-no shock trials than after warning-shock trials. If responding were also controlled by the informative value of the signal, then such differential sensitivity to warning and safe signals might be obliterated under the NO INFO condition. Additional factors such as the occurrence or nonoccurrence of a response or shock pooled over signal types might also affect response probability on the succeeding trial.

Table 2 shows response probability on trial n + 1 conditional on events occurring on the n^{th} trial for each experimental condition. The values were obtained by dividing the number of occasions on which a response followed a particular type of trial (e.g., response-produced

Table 2

Probability of a Response on Trial n + 1 Conditional on Events Occurring on Trial n in Experiment 1

	Response Trials (Signaled Trials)		Nonresponse Trials (Unsignaled Trials)	
	MAXIMUM INFORMATION (First Phase)			
Rat	Warning	Safe	Shock	No Shock
432	.77	.90	.64	.53
427	.35	.64	.24	.21
424	.93	.96	.29	.19
	NO INFORMATION			
432	.16	.22	.19	.14
427	.0	.14	.03	.02
424	.08	.11	.07	.08
	MAXIMUM INFORMATION (Recovery Phase)			
432	.49	.60	.48	.33
427	.17	.12	.09	.07
424	.87	.92	.21	.26

warning signal paired with shock) by the total number of such trials presented. Thus, regardless of the total number of responses made during a session, an animal that always responded after warning-shock trials, for example, would have a conditional probability of 1.0 given that type of trial. The conditional response probability shown for each rat represents an average of the last eight sessions of each experimental condition.

The values shown at the left of the table (response trials) were consistently higher than those shown at the right of the table (nonresponse trials) under the maximally informative condition. That is, response probability was higher after a previous response (signaled) trial than a previous nonresponse (unsignaled) trial. Such a difference was not, however, apparent under the maximally noninformative condition. Also, response probability following a safe trial was higher than following a warning trial under the informative condition, but again, no such difference appeared under the noninformative condition. These data suggest that reliable signals, particularly reliable safe signals, produce a higher response probability than either no signals or unreliable signals. In addition, on unsignaled trials a higher response probability after shock than after nonshock trials was evident under the initial MAX INFO condition.

To statistically assess these differences a three-way analysis of variance was carried out on the mean response probability over the last eight sessions of each condition for each subject following a warning signal, safe signal, or no signal on the previous trial. Planned comparisons were then conducted on the differences between trial events (i.e., warning, safe, or no signal). Only the first MAX INFO condition was included in the analysis in view of the large differences between subjects in recovery levels following exposure to NO INFO.

The outcome of this analysis is shown in Table 3. The total variance for each main effect and interaction is shown preceded by letters in parentheses. Since each comparison represents a portion of the total variance for a given factor, the comparisons are listed below that factor and the sums of squares and degrees of freedom for each comparison are placed in parentheses. The results show a significant difference between the MAX INFO and NO INFO conditions which is consistent with overall differences in response probability previously described. The difference between trial events was also significant. Planned comparisons showed further that response trials (warning and safe combined) were followed by a significantly greater probability of response than nonresponse (unsignaled) trials. Warning and safe trials per se were not, however, found to differ significantly from each other. It should be noted that the same error term was used for both these comparisons [i.e., (B) x (S)] which renders these comparions nonindependent. A more conservative approach (e.g., Keppel, 1973, p. 430) is to use separate error terms[2] for each comparison. When this was done, however, neither comparison reached significance [i.e., response vs. nonresponse trials, $\underline{F}(1, 2) = 9.44$, $p > .05$ and warning vs. safe trials, $\underline{F}(1, 2) = 4.80$, $p > .05$].

In similar manner when a combined error term was used [(A) x (B) x (S)] a significant interaction was found between conditions and response vs. nonresponse trials. That is, response probability was significantly greater after a response (signaled) trial than a nonresponse (unsignaled) trial under reliable signal conditions. This difference was

Table 3

Summary of Analysis of Variance and Planned Comparisons

Conducted on Sequential Response Data in Experiment 1

Source	SS	df	MS	F
(A) Between Conditions MAX INFO, NO INFO	11,919.68	1	11,919.68	39.41*
(B) Among Events Warning, Safe, No Signal	2,294.70	2	1,147.35	8.12*
Comparison: 1. Signal vs. No Signal	(1,908.23)	(1)	1,908.23	13.50*
2. Warning vs. Safe	(386.47)	(1)	386.47	2.73
(C) Among Subjects	1,765.44	2	882.72	7.44*
(A) x (B)				
Comparison: 1. Conditions x Signal vs No Signal	(1,470.73)	(1)	1,470.73	12.39*
2. Conditions x Warning vs Safe	(42.18)	(1)	42.18	< 1
(B) x (S)	565.36	4	141.34	1.19
(A) x (S)	604.83	2	302.42	2.55
(A) x (B) x (S)	474.72	4	118.68	
Total	19,137.64	17		

$*p < .05$

significantly less when signals were noninformative. Again, however, use of the more conservative error term resulted in a nonsignificant interaction [$\underline{F}(1, 2) = 6.58, p > .05$].

In addition to differences between conditions and between trial events, subjects were found to differ significantly from one another. This outcome was also clearly apparent in the description of overall response probability.

In procedures such as the one at hand, noncontingent shock may be sufficient to maintain responding at least in certain rats (Neffinger & Gibbon, 1975). Therefore, to test the contribution of shock, both alone, and in combination with signals, response (signaled) and nonresponse (unsignaled) trials were subdivided into shock and nonshock trials. A four-way analysis of variance with one random factor--subjects--and three fixed factors: (a) conditions, (b) response (warning and safe trials combined) vs. nonresponse trials, and (c) shock vs. nonshock trials was performed on the mean conditional response probability over the last eight sessions of each condition. The outcome of this analysis revealed a nonsignificant difference between shock and nonshock trials [$\underline{F}(1, 2) = .17, p > .05$]. However, the interaction between shock and response (signaled) trials was significant [$\underline{F}(1, 2) = 19.24, p < .05$]. That is, a shock in the absence of a signal produced a higher probability of response on the next trial than no shock. When a signal occurred, however, the reverse was true, i.e., response probability was higher after no shock than after shock. Such a result may be characterized as a win-stay, lose-shift type of strategy. The remaining interactions associated with shock were all nonsignificant.

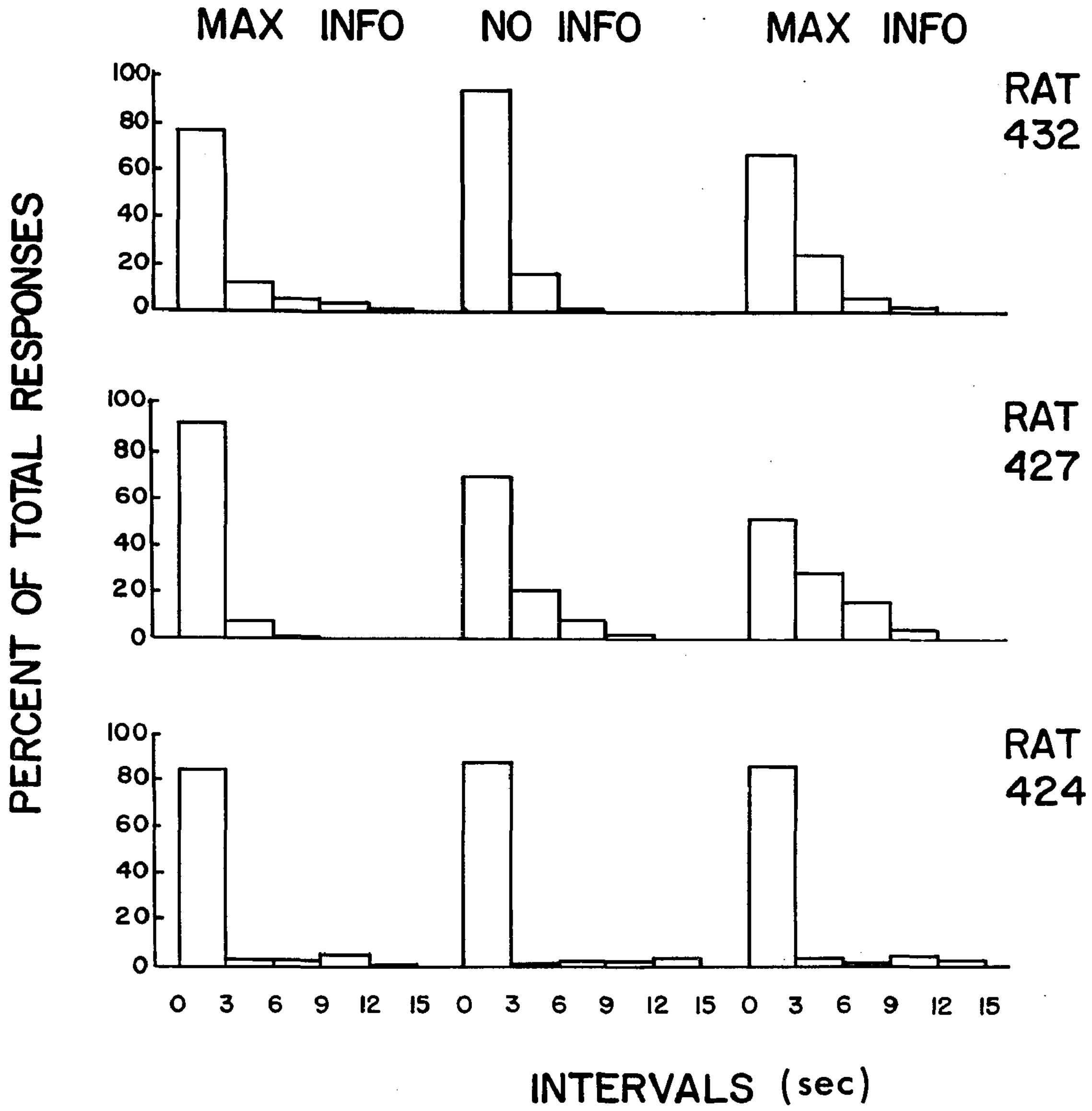
Response latency. The latency of a response during a trial was also examined as a function of experimental condition. This was done in order to determine whether time spent in the presence of the signal (i.e., time remaining in the trial following a response) was correlated with changes in the informative value of the signal. Figure 6 shows a frequency distribution of response latencies over the last eight sessions of each experimental condition divided into five, 3-sec periods. Responses during the final .2 sec of the trial (period during which shock could occur) are not included. These responses were observed to occur when the animal was positioned just over the dipper at the time shock was delivered. The probability of such shock-induced responses in any session for any rat in this study was less than .04.

The results show that rats responded predominantly in the first three seconds of the trial over all conditions. Latency of responding as measured here does not appear to be influenced by the informative value of the signal, however, the possibility that latencies under 3 sec are affected is not excluded.

Discussion

These initial findings were generally in agreement with published results (e.g., Lockard, 1963) in demonstrating that responding was maintained under reliably signaled, unavoidable shock, but was not maintained under unreliably signaled, unavoidable shock. Further, the sequential response analysis suggested that signaled trials, in general, were more effective than unsignaled trials in sustaining response probability reliable signal conditions. This difference was, however, eliminated by unreliable signals. The conditional response probability data suggested also that safe signals were more effective than warning signals under informative conditions although this effect did not

Figure 6. Response latencies for each 3-sec interval during the 15-sec trial expressed as a percentage of total responses and averaged over the last eight sessions of each experimental condition.


MAX INFO
NO INFO
MAX INFO
RAT 432
RAT 427
RAT 424
100
80
60
40
20
0
PERCENT OF TOTAL RESPONSES
0 3 6 9 12 15
INTERVALS (sec)

reach statistical significance. Finally, analysis of response probability conditional on shock and nonshock trials revealed that shock alone (unsignaled trial) was associated with a higher probability of a response on the subsequent trial than a signaled shock. The implications of these results are that the occurrence of a signal decreases the animal's tendency to respond primarily after shock and since reliable safe signals support more responding than warning signals, it may be argued that identifiable safe periods function effectively as conditioned positive reinforcers for responding (producing the signal).

An alternative explanation of these results is that responding under the MAX INFO condition was supported by pretraining on the avoidance schedule. That is, rats became "superstitious" avoiders when the schedule was changed from the maximal avoidance condition to one that resembled partial avoidance (i.e., 50 percent shock). Only when exposed to the NO INFO condition did animals learn that responding had no effect on the shock schedule. This argument, however, does not account for the recovery performance for two of the three rats under a second phase of MAX INFO in which only the signal value and not the shock schedule, was changed.

The idiosyncratic recovery of responding under MAX INFO in this study is, however, puzzling. It does not appear to be related to pretraining procedures since the three rats responded similarly under operant level and avoidance conditions (see Appendix I). Nor were response levels under the initial MAX INFO condition necessarily predictive of the extent of recovery. Rats 432 and 424, for example, responded at approximately equal levels under the initial MAX INFO condition, but recovery of responding following exposure to NO INFO was considerably less complete for rat 432. Wide differences in performance between human subjects encountering an observing response procedure have also been noted by Lanzetta and Driscoll (1966) and were attributed to individual differences in the "desire for certainty" (Brim & Hoff, 1957).

On the basis of these results it was decided that independent manipulation of warning and safe signal reliability might provide stronger evidence of their differential effects. A second study was, therefore, undertaken with the purpose of replicating and extending the results of Experiment 1.

EXPERIMENT 2

Experiment 2 was a preliminary investigation of the effects of manipulating the informative value of warning and safe signals independently of one another. To this end, the discrete-trial procedure described in Experiment 1 was adapted in such a way that either the warning or safe signal was a reliable predictor of shock or no shock, respectively, while the other signal was made an unreliable predictor. This condition may be represented along the edges of the contingency square (see Figure 2). Two contingency square points were selected for investigation, each located at equal distances from the coordinates of Maximum Information. One set of coordinates represented the warning signal degraded in informative value while the other represented the safe signal equally degraded in informative value. The study was designed to explore response probability under these two degraded signal conditions in comparison with responding under maximally informative and maximally noninformative signal conditions.

Method

Subjects. Of the six male hooded rats (Long-Evans) serving as subjects in Experiment 2, five were given preliminary exposure to a variety of signaled and unsignaled response-independent shock procedures. These procedures (see Appendix II for details) were similar to the basic experimental paradigm described in the general method section. The sixth rat (369) was trained on a free-operant discriminated avoidance schedule prior to exposure to MAX INFO, the first phase of Experiment 2 (see Appendix II). The six rats retained in Experiment 2 were selected on the basis of a response on greater than 25 percent of the trials under the initial MAX INFO condition.

Five of the six rats were obtained from Rockland Farms, Inc., Gilbertsville, Pennsylvania and were 260 days old at the start of the experiment. The remaining animal (380) was obtained from Blue Spruce Farms, Altamont, New York and was 186 days old at the start of experimental training.

Trial events. Table 4 shows the number of trials scheduled and the contingency square coordinates, i.e., conditional probabilities of shock given either the noise or click signal, for each of the four experimental conditions studied in Experiment 2. In all conditions 200 trials per session occurred with equal numbers of shock and shock-free trials. Two conditions, maximally informative signals (MAX INFO) and maximally noninformative signals (NO INFO), were identical to those presented in Experiment 1. In the MAX INFO condition the click served as a reliable warning signal and white noise served as a reliable safe signal for all rats. In the NO INFO condition, where both signals were unreliable, there was an equal probability of shock following either the noise or click stimulus. Equal numbers of noise and click trials were scheduled for these two conditions. There was no counterbalancing of the signal roles attempted in this experiment.

Under the degraded warning signal (DW) and degraded safe signal (DS) conditions, one of the two signals was made unreliable. For example, under the degraded warning condition only 67 percent of the warning signals (Cl) were followed by shock, but the safe signal was always followed by no shock $\left[P(Sh|Cl) = .67;\ P(Sh|Ns) = 0\right]$. When the safe signal (Ns) was degraded, 33 percent of the safe signals were followed by shock whereas the warning signal was always followed by shock $\left[P(Sh|Ns) = .33;\ P(Sh|Cl) = 1\right]$. In both degraded conditions

Table 4

Number of Trials and Conditional Probabilities of Shock Given Signals for Each Experimental Condition Occurring in Experiment 2

MAXIMUM INFORMATION (MAX INFO)

	Number of Trials			Conditional Probabilities	Signal Type
	No Shock	Shock	Σ		
Noise	100	0	100	P(Sh|Ns = 0	Reliable Safe
Click	0	100	100	P(Sh|Cl) = 1	Reliable Warning
Σ	100	100	200		

NO INFORMATION (NO INFO)

	No Shock	Shock	Σ		
Noise	50	50	100	P(Sh|Ns) = .5	Unreliable Safe
Click	50	50	100	P(Sh|Cl) = .5	Unreliable Warning
Σ	100	100	200		

DEGRADED WARNING (DW)

	No Shock	Shock	Σ		
Noise	50	0	50	P(Sh|Ns) = 0	Reliable Safe
Click	50	100	150	P(Sh|Cl) = .67	Degraded Warning
Σ	100	100	200		

DEGRADED SAFE (DS)

	No Shock	Shock	Σ		
Noise	100	50	150	P(Sh|Ns) = .33	Degraded Safe
Click	0	50	50	P(Sh|Cl) = 1	Reliable Warning
Σ	100	100	200		

unequal numbers of click and noise trials were scheduled in order to maintain an equal number of shock and shock-free trials. Thus, three times as many warning signals (click) as safe signals (noise) were scheduled under the degraded warning condition. The reverse was true for the degraded safe condition.

Since the production of a signal was contingent on a response, the number of signaled trials shown in Table 4 represents the schedule of events available to the animal only if a response was made on every trial. The actual number of trials on which a signal occurred depended on response probability during the session[3]: signal and shock parameters were otherwise the same as in Experiment 1.

Experimental phases. The order in which these experimental phases was presented and number of sessions scheduled for each rat appears in Table 5. Although 10 rats were given training on the first phase of MAX INFO, only the six rats that responded on at least 25 percent of the trials over the last eight sessions of this condition were retained for further study. The response criterion was selected as in Experiment 1 to ensure a level of responding sufficient for the animals to sample the post-response signal during subsequent phases of the experiment.

Following training on the MAX INFO condition, the six rats were exposed to 23 sessions of NO INFO. Rats were then divided into three pairs. The first pair received 20 sessions of training on the degraded warning (DW) condition and a second pair received 20 sessions of the degraded safe (DS) condition. The third pair, the two rats with the lowest response probability on NO INFO for the last three sessions of training, was returned to MAX INFO for 15 sessions to recover a higher level of responding. These rats were then separated and each assigned

Table 5

The Order of Experimental Conditions and Number of Sessions Presented for Each Animal in Experiment 1

Conditions	MAX INFO	NO INFO	MAX INFO	DW	MAX INFO
Coordinates*	(0, 1)	(.5, .5)	(0, 1)	(0, .67)	(0, 1)
Rat					
375	23	23	---	20	23
369	23	23	---	20	23
380	23	23	15	23	27

Conditions	MAX INFO	NO INFO	MAX INFO	DS	MAX INFO
Coordinates*	(0, 1)	(.5, .5)	(0, 1)	(.33, 1)	(0, 1)
Rat					
368	23	23	---	20	23
371	23	23	---	20	23
366	23	23	15	23	27

---

*$P(Sh|Ns)$; $P(Sh|Cl)$. See Figure 2.

to one of the two degraded conditions for 23 sessions. All six rats were reconditioned on MAX INFO for a minimum of 23 sessions.

Shock schedules. Two shock schedules were used in order to find a type of schedule appropriate for experiments involving these contingencies. The first was a randomized series with only the restriction that an equal number of shock and nonshock trials was presented. However, in order to minimize long "runs" of either the click or noise stimulus under the degraded signal conditions in which unequal frequencies of the click and noise stimuli were used, the random shock schedule used during MAX INFO and NO INFO was replaced by a second shock schedule based on a Gellerman (1933) series. In both schedules the probability of shock was .5. Behavioral effects which may have been introduced by the change in schedules were assessed by giving four rats additional training on the MAX INFO condition after they completed the training described in Table 5. Comparison of performance on the two schedules showed that behavior was not affected by minor differences in construction of the two schedules. The shock schedules, as well as a fuller description of the comparison of these schedules, appears in Appendix II.

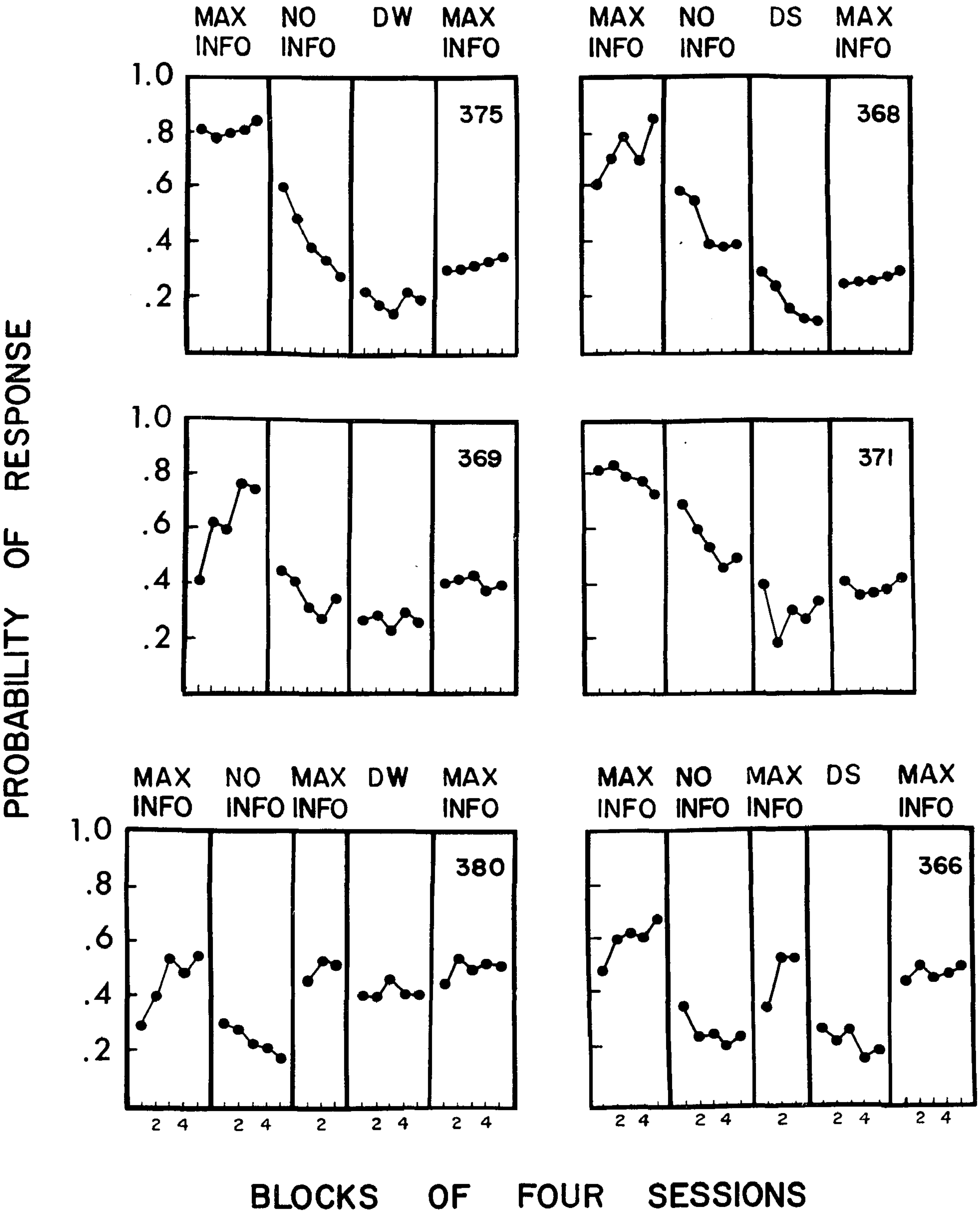
Schedule of sessions. Experimental sessions were scheduled daily. During the five-month experimental period, there were three major interruptions in the schedule to allow for programming apparatus or equipment repair. The first interruption was a 7-day period between sessions 15 and 16 of the MAX INFO condition. The second was a 16-day break between sessions 20 and 21 of NO INFO, and the third was a 10-day interval between the degraded conditions and recovery on MAX INFO.

Results

Overall effects. The probability of a response for each of the six rats over successive conditions is presented in blocks of four sessions in Figure 7. The last five such blocks are shown in each condition with the exception of the second MAX INFO phase for rats 366 and 380. The last three blocks are plotted for this condition since only 15 sessions were given. In addition, one session was eliminated for each of three rats as a result of equipment breakdown or scheduling error. The sessions eliminated were: (a) Session 22 of NO INFO for rat 368 due to a disproportionate number of shocks delivered and (b) Session 9 of each of the two degraded conditions for rats 375 and 380 due to a reversal of DW and DS. Where these errors occurred the mean probability of response was based on a block of three sessions.

Response probability under the initial MAX INFO condition was comparable to response levels for rats in Experiment 1. That is, mean response probability over the last eight sessions was .78 (S.D. = .07) for the rats shown in the upper four panels and .59 (S.D. = .10) for the rats shown in the lower two panels. When rats were subsequently exposed to the NO INFO condition, response probability declined for all animals. Training on the degraded signal conditions resulted in a further decline for the rats shown in the upper four panels. The two remaining rats were returned to MAX INFO to recover a higher response level following training on NO INFO. Subsequent exposure to the degraded warning condition for rat 380 produced only a slight reduction in response probability compared with response levels on the previous MAX INFO condition. Rat 366, by contrast, responded at a considerably lower level under DS than under the previous MAX INFO condition.

Figure 7. The probability of a response for each rat in blocks of four sessions over the last 20 sessions of each condition. (See text for exceptions.)


MAX INFO
NO INFO
DW
MAX INFO
375
MAX INFO
NO INFO
DS
MAX INFO
368
369
371
MAX INFO
NO INFO
MAX INFO
DW
MAX INFO
380
MAX INFO
NO INFO
MAX INFO
DS
MAX INFO
366
1.0
.8
.6
.4
.2
2
4
PROBABILITY OF RESPONSE
BLOCKS OF FOUR SESSIONS

Response probability for this animal was less than earlier response levels under NO INFO. All rats showed some increase in response probability when the reliability of both signals was restored in the final MAX INFO phase. Only the two rats (366 and 380) given training on MAX INFO immediately following exposure to NO INFO showed recovery of responding comparable to the initial phase of training. It should be noted, however, that response levels under the initial MAX INFO condition were lower for these two rats than initial levels for the remaining four animals.

Response latency. The time elapsed between the start of the trial and a response was also examined as a function of experimental condition. In accordance with the results described in Experiment 1, the highest proportion of responses occurred during the first three seconds of the trial. Moreover, the distribution of response latencies was similar for all rats over all conditions. A more detailed description of the latency distributions is given in Appendix II.

Discussion

The results of the first two phases of Experiment 2 were consistent with those of Experiment 1. That is, response probability was maintained under response-independent shock by maximally reliable signals, but declined under maximally unreliable signals. Experiment 2 demonstrated, in addition, that response probability was reduced when one of the two signals was made unreliable (degraded signal condition) in comparison with responding under reliable signals (MAX INFO).

The results shown for two rats (380, 366) suggest that response probability may be more adversely affected by a degraded safe signal than by a degraded warning signal. That is, rat 380 showed response probability under degraded warning at levels intermediate between responding under maximally informative and maximally noninformative conditions. Response probability for rat 366 under degraded safe signals was, by contrast, lower than responding under maximally noninformative signals. Differences between degraded warning and degraded safe conditions for the remaining four rats may have been obscured by training on maximally noninformative signals just prior to exposure to degraded conditions. That is, reinstating the reliability of only one signal may not have produced a change in schedule sufficient to overcome the low level of responding induced by the noninformative signal condition. It should be noted, for example, that response levels for the four rats trained on NO INFO just prior to the degraded conditions averaged .38 (S.D. = .10) over the last block of sessions. By comparison, rats 380 and 366, given training on MAX INFO just before the degraded conditions, showed response probabilities of .52 (S.D. = .06) and .54 (S.D. = .11), respectively. Nevertheless, the data of rats 375, 369, 368, and 371 point to a greater loss of responding under degraded safe conditions relative to degraded warning conditions. Because of variability in the pretraining of subjects for Experiment 2 and because of differing treatments within the experiment, further statistical analysis of the data was not undertaken. Experiment 3 is a replication and expansion of Experiment 2, and statistical analysis is carried out there.

EXPERIMENT 3

Since the results of Experiment 2 suggested that degrading warning and safe signals independently of one another produced differential behavioral effects, a more systematic investigation was carried out in Experiment 3. This was done by alternating exposure to degraded signal conditions with recovery under fully and equally reliable signals (MAX INFO). The purpose of this procedure, based on evidence presented in Experiment 2, was to re-establish a high probability of responding between exposures to degraded signal conditions so that on initial exposure to a degraded signal condition, rats might adequately sample the signal-shock associations.

Method

Subjects. The six male Long-Evans hooded rats serving as subjects in Experiment 3 were selected from the sample of 16 rats described in Experiment 1. Operant level measurements were recorded initially for all rats. One animal (430) was first given training on the discrete-trial procedure designed to shape responding (see Appendix I). All rats were trained on the discrete-trial avoidance procedure described in Experiment 1 in which a response was always followed by a safe signal and no shock. The safe signal was the same as that used in the experiment proper. Finally, the six rats subsequently retained as subjects in Experiment 3, were selected according to a criterion of a response on greater than 25 percent of the trials over the last eight sessions of exposure to MAX INFO, the first experimental phase. See Appendix III for the results of these pretraining procedures.

The mean age of the subjects at the start of training on MAX INFO was 242 days (ranging from 164 to 320 days).

Trial events. The conditional probabilities of shock given signals and frequency of signaled trials for both the maximally informative (MAX INFO) and degraded signal conditions (DW and DS) remained the same as described in Experiment 2. In addition, the click and noise signals were counterbalanced as described in Experiment 1. That is, four subjects (430, 434, 442, 403) were given white noise as the warning signal and two subjects (433, 431) were given the click as the warning signal.

Order of conditions. Table 6 shows the sequence of experimental conditions and number of sessions scheduled for each rat in Experiment 3. Training under maximally informative signals was alternated with exposure to degraded conditions. Subjects in Group A were trained on degraded warning and then, following recovery of responding under MAX INFO, were exposed to degraded safe signals. Subjects in Group B were given the reverse order of degraded conditions. That is, following initial training on MAX INFO, Group B subjects were exposed to degraded safe signals and then degraded warning signals after recovery under MAX INFO. The third exposure to degraded signals constituted a replication of the first degraded condition for each group. That is, subjects in Group A were given a second exposure to degraded warning signals and subjects in Group B were given a second exposure to degraded safe signals.

Rats were given 24 sessions of training for the first three experimental phases, 28 sessions in the fourth phase, and 24 sessions in the fifth phase. Twelve sessions were scheduled for each of the last two phases. Daily sessions were given for six consecutive days each week.

Shock schedule. The shock schedule used was the same as in Experiment 1: a modification of a two-choice event sequence proposed

Table 6

Experimental Conditions Expressed as Contingency Square Coordinates

	Condition	MAX INFO	DW	MAX INFO	DS	MAX INFO	DW	MAX INFO
	No. Sessions	24	24	24	28	24	12	12
	Rat							
Group A	430	(1,0)	(.67,0)	(1,0)	(1,.33)	(1,0)	(.67,0)	(1,0)
	434	"	"	"	"	"	"	"
	433	(0,1)	(0,.67)	(0,1)	(.33,1)	(0,1)	(0,.67)	(0,1)

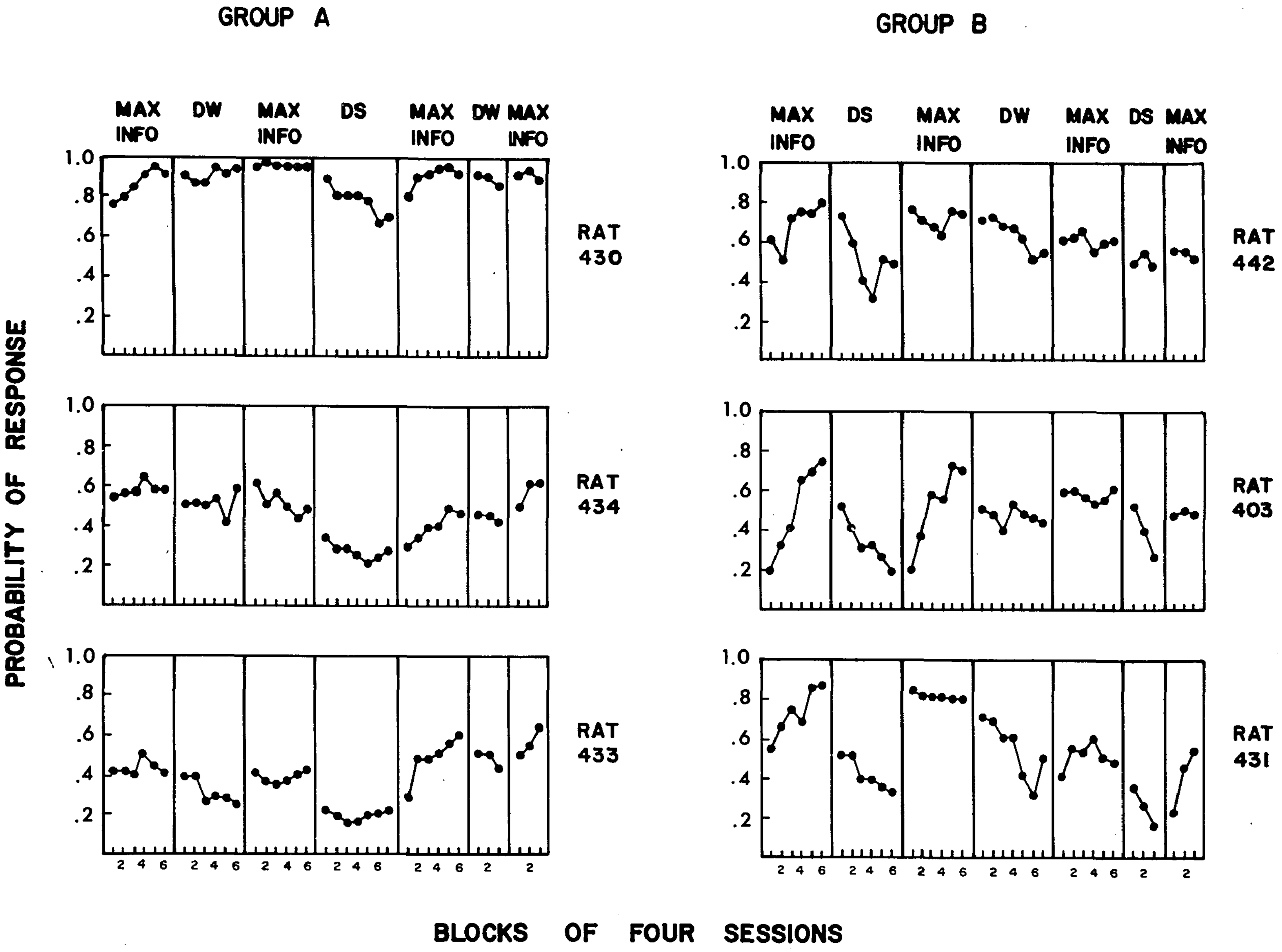
	Condition	MAX INFO	DS	MAX INFO	DW	MAX INFO	DS	MAX INFO
	No. Sessions	24	24	24	28	24	12	12
	Rat							
Group B	442	(1,0)	(.33,1)	(1,0)	(.67,0)	(1,0)	(.33,1)	(1,0)
	403	"	"	"	"	"	"	"
	431	(0,1)	(1,.33)	(0,1)	(0,.67)	(0,1)	(1,.33)	(0,1)

by Fellows (1967). Equal numbers of shock and shock-free trials were scheduled for each session. The modified Fellows schedule was similar to the Gellerman series used in Experiment 2, but provided more adequate control of sequential dependencies based on the order in which shock and shock-free trials were arranged. The order of click and noise trials in conjunction with shock delivery for the degraded warning and degraded safe conditions is given in Appendix III.

Results

Overall effects. In Figure 8 response probability presented in blocks of four sessions is shown for each rat over each experimental condition. The results for two of the Group A rats (430, 434) show response levels under DW to be slightly, if at all, less than responding under the initial phase of MAX INFO. The third rat in Group A (433) responded at a lower level (i.e., 63 percent of the previous MAX INFO condition averaged over the last eight sessions of each condition). On this basis, rat 430 is unchanged and rat 434 shows a response level of about 80 percent of the initial MAX INFO performance. Response levels were substantially reinstated under a second exposure to MAX INFO. All three rats in Group A showed a decrease in response probability under degraded safety to levels below those of the earlier DW condition. Under a third recovery phase, responding increased substantially for all three rats. Subsequently, a second determination of DW produced virtually no change in response levels for rats 430 and 434 and a small decline for rat 433 (i.e., 19 percent below that of the previous MAX INFO phase). Finally, reinstating MAX INFO resulted in maintained performance for rat 430 and an increase in responding for rats 434 and 433 over the previous condition.

Figure 8. Probability of a response presented in blocks of four sessions over successive experimental conditions for each rat in Experiment 3.


GROUP A
GROUP B
MAX INFO
DW
MAX INFO
DS
MAX INFO
DW
MAX INFO
MAX INFO
DS
MAX INFO
DW
MAX INFO
DS
MAX INFO
1.0
.8
.6
.4
.2
RAT 430
RAT 434
RAT 433
RAT 442
RAT 403
RAT 431
PROBABILITY OF RESPONSE
2 4 6
2
BLOCKS OF FOUR SESSIONS

Group B rats also showed substantially reduced response levels when exposed to degraded safe signals. Subsequent recovery under MAX INFO yielded response levels similar to the initial phase of MAX INFO. Response probability for Group B rats under the DW condition fell over the 28 sessions of this phase, but remained, nevertheless, above levels shown for the previous DS condition. Recovery following the DW condition was to a lower probability of responding than under the earlier recovery condition. A redetermination of the degraded safe condition resulted in a pronounced response decrement for two rats (403, 431). Although the third rat (442) showed little if any response decrement, it is suggested that additional sessions of exposure to DS might have resulted in a further response decline. Finally, the three rats in Group B all showed increased response levels on the last recovery phase. It should be noted that Session 17 of the DW condition for rat 403 was eliminated as a result of a scheduling error. The mean response probability for this block of sessions is, therefore, based on three, rather than four, sessions.

These results are consistent with Experiment 2 data in that degrading safety produced a generally lower level of observing response probability than degrading danger signals for both groups of rats. The data also show that observing response levels that have been decreased by exposure to degraded signals may be restored by reinstating maximally informative signals.

Recovery of MAX INFO baseline. To determine whether response levels differed significantly over successive determinations of MAX INFO, a three-way analysis of variance with two fixed factors (replications and sessions) and one random factor (subjects) was performed on the mean response probability of the last eight sessions of the first three replications of MAX INFO. Since the final two experimental phases (degraded and MAX INFO conditions) were continued only long enough (12 sessions) to demonstrate response trends, neither phase was included in the analysis. A summary of the analysis of MAX INFO performance is presented in Table 7.

The differences in response probability among replications of the MAX INFO condition were not significant which indicates that response probability was substantially recovered on repeated exposure to MAX INFO following the degraded conditions. Moreover, the absence of a significant effect for sessions demonstrated that over the last eight sessions of each condition stable response levels had been achieved. There was, however, a large difference between subjects, an effect previously noted in the first two experiments. In addition, the interaction between subjects and replications was significant. That is, response probability for individual subjects differed at different replications of MAX INFO. Referring to Figure 8, for example, Group B rats showed some evidence of an overall decline in response probability under MAX INFO whereas levels for Group A remained approximately the same or increased (note rat 433). The interaction between subjects and sessions was also significant. That is, different subjects demonstrated different response trends over the last eight sessions of each replication.

Analysis of conditions. Planned comparisons were conducted on response probability under the first five experimental conditions. The last two experimental conditions were excluded from the analysis as mentioned earlier. Since the previous analysis of MAX INFO performance

Table 7

Summary of Analysis of Variance of Overall Response Probability Over the Last Eight Sessions of Three Replications of MAX INFO

Source	SS	df	MS	F
(A) Replications	128.00	2	64.00	1.07
(B) Sessions	2,330.00	7	332.90	1.52
(S) Subjects	34,525.00	5	6,905.00	248.92***
(A) x (B)	268.00	14	19.10	1
(A) x (S)	599.00	10	59.90	2.16*
(B) x (S)	7,650.00	35	218.60	7.88***
(A) x (B) x (S)	1,942.00	70	27.74	
Total	47,442.00	143		

---

*$p < .05$

***$p < .001$

yielded no significant differences between replications of MAX INFO, the three replications of MAX INFO were combined and compared with responding under the degraded warning and degraded safe conditions. In addition, differences between sessions (the last eight sessions in each condition) and between subjects were analyzed in an overall F test. A summary of this analysis is shown in Table 8. As in Experiment 1 the total variance for each factor is designated by a letter in parentheses. The sums of squares and degrees of freedom for each comparison are listed below the corresponding main factor and are enclosed in parentheses to show that these values represent subtotals.

The results of this analysis show significant differences between MAX INFO and the combined degraded conditions as well as between each degraded condition. That is, the pooled mean response probability under MAX INFO (.68) was significantly higher than under the combined degraded conditions (.45). In addition, the pooled mean response probability under DW (.52) was significantly greater than under DS (.38). A comparison of MAX INFO and DW[4], although nonorthogonal, was considered of sufficient interest to include in the analysis. This comparison showed that response probability under DW (.52) was significantly less than under MAX INFO (.68). Examination of Figure 8 reveals that this outcome was contributed primarily by Group B rats. Analysis of other main effects revealed a significant difference between subjects, also reported in Experiment 1, and a nonsignificant difference between sessions. This latter outcome demonstrates that response levels were stable over the last eight sessions of each condition.

The interaction between conditions and subjects also reached significance which suggests that the order of exposure to degraded con-

Table 8

Summary of Analysis of Variance and Planned Comparisons Conducted on Overall Response Probability Under MAX INFO, DW, and DS Conditions

Source	SS	df	MS	F
(A) Among Conditions	21,384.04	2	10,692.02	24.09***
Comparisons:				
1. MAX INFO vs. Pooled Deg.	(16,460.54)	(1)	16,460.54	35.05**
2. DW vs. DS	(4,923.50)	(1)	4,923.50	11.77*
3. MAX INFO vs. DW	(5,779.96)	(1)	5,779.96	9.99*
(B) Among Sessions	298.00	7	42.57	1.11
(S) Among Subjects	40,898.00	5	8,179.60	165.06***
(A) x (B)	712.00	14	50.86	1.03
(A) x (S)	4,438.56	10	443.86	8.99***
Comparisons:				
1. Subjects x MAX INFO vs. Pooled Degraded	(2,347.89)	(5)	469.58	17.19***
2. Subjects x DW vs. DS	(2,090.67)	(5)	418.13	5.55***
(B) x (S)	1,348.00	35	38.51	< 1
(A) x (B) x (S)	3,468.86	70	49.56	
Comparisons:				
1. MAX INFO vs Pooled Deg. x (B) x (S)	(826.88)	(35)	27.31	
2. DW vs DS x (B) x (S)	(2,641.98)	(35)	75.48	
Total	72,547.46	143		

*p < .05
**p < .01
***p < .001

ditions may influence responding under subsequent conditions. For example, referring to Figure 8, Group A rats (given DW prior to DS) showed a higher response probability under the DW condition relative to responding under MAX INFO than Group B rats (given DS prior to DW).

These results confirm observations that responding was significantly reduced under degraded warning conditions in comparison to maximally informative conditions. Moreover, degraded safe signals produced a further reduction in response levels significantly below responding under the degraded warning condition.

Signal properties. To determine whether the acoustic properties of the signal (i.e., click or noise as the warning signal) influenced response probability, a two-way analysis of variance was performed. Response probability for subjects receiving the click as the warning signal was compared with response probability for subjects receiving white noise as the warning signal over the first three replications of MAX INFO. The analysis of signal properties was restricted to MAX INFO since any differences in responding due to the acoustic properties of the signals ought to be most apparent when response probability was highest as under the MAX INFO condition. Of course, a ceiling effect might occlude such differences, but examination of response performance in Figure 8 revealed no such effect for at least five of the six rats. The results of the analysis yielded no significant difference between signals, $F(1, 12) = .84$, $p > .05$. These results indicate that animals were not differentially affected by the click signal paired with shock compared to white noise paired with shock.

Sequential effects. A description of sequential responding similar to the one presented in Experiment 1 is shown in Table 9. The values

Table 9

Mean Probability of a Response for Six Rats on Trial n + 1

Conditional on Events Occurring on Trial n

	MAX INFO				DEG WARN					DEG SAFE				
	Response		Nonresponse		Response			Nonresponse		Response			Nonresponse	
	Warn	Safe	No Signal		"Warn"		Safe	No Signal		Warn	"Safe"		No Signal	
	Sh	~ Sh	Sh	~ Sh	Sh	~ Sh	~ Sh	Sh	~ Sh	Sh	Sh	~ Sh	Sh	~ Sh
430	.98	.94	.85	.55	.99	.96	.87	.87	.54	.94	.89	.58	.84	.35
434	.58	.55	.53	.36	.61	.39	.67	.43	.45	.32	.41	.21	.30	.20
433	.58	.73	.43	.21	.44	.30	.62	.30	.12	.20	.41	.26	.27	.11
442	.87	.84	.44	.27	.71	.71	.84	.39	.20	.84	.79	.61	.40	.17
403	.68	.72	.78	.44	.45	.29	.62	.61	.34	.32	.39	.21	.28	.15
431	.76	.90	.54	.29	.59	.35	.72	.44	.24	.66	.34	.14	.51	.22
Mean	.74	.78	.60	.35	.63	.50	.72	.51	.32	.55	.54	.34	.43	.20

represent response probability on trial n + 1 conditional on events presented on the n^{th} trial. Each value was obtained by averaging the conditional response probabilities over the last eight sessions of each experimental condition for each rat. The analysis includes the data for the first three replications of MAX INFO combined. As noted above, the last two experimental phases were excluded from the analysis.

The sequential response data are similar in at least two respects to data presented in Experiment 1. First, under MAX INFO the pooled response (signaled) trials supported a higher response probability than the pooled nonresponse (unsignaled) trials. This result was also evident under the DW and DS conditions. Secondly, in all three conditions a nonresponse-shock trial yielded a higher probability of response on the succeeding trial than a nonresponse-nonshock trial. This finding corresponds to a win-stay, lose-shift type of strategy previously noted in Experiment 1. Compared to Experiment 1 results (i.e., pooled mean response probability after warning trials was .68 and after safe trials was .83 in the initial MAX INFO condition) an informative warning trial supported only a slightly lower pooled mean response probability (.74) than an informative safe trial (pooled mean of .78). Such a difference was more pronounced under the DW condition when "correct" warning and safe signals were compared (pooled mean response probability of .63 compared to .72). It is of interest that the "incorrect" warning signal (i.e., a warning signal accompanied by no shock) in this condition was followed by a lower response probability (pooled mean of .50) than the two "correct" signals. Finally, under the DS condition the probability of a response relative to "correct" safe and warning signals was reversed in comparison with the DW condition.

That is, the pooled mean after a "correct" warning trial was greater (.55) than after a "correct" safe trial (.34). Interestingly, "incorrect" safety (i.e., a safe signal followed by shock) resulted in a response probability on the next trial (.54) approximately equal to a "correct" warning signal in that condition (.55).

It may be argued from these results that the unreliable signal (i.e., "warning" in the DW condition and "safe" in the DS condition, see Table 9) was treated as a nonresponse trial by the rat. That is, a warning-shock trial produced a higher response probability than a warning-nonshock trial under DW. Likewise, a safe-shock trial resulted in a higher response probability than a safe-nonshock trial under DS. Given this interpretation it may be argued that in the absence of a reliable signal, response probability on trial n + 1 was controlled by the occurrence or nonoccurrence of shock on trial n.

To statistically assess differences between conditions and trial events in the sequential response analysis, the unreliable trials (i.e., trials listed under "warning" and "safe" headings in Table 9) were combined for both degraded conditions. In addition, nonresponse (i.e., unsignaled-shock and unsignaled-nonshock) trials were combined. Thus, trials on which a warning or safe signal occurred (response trials) were compared with trials on which no signal occurred (nonresponse trials) over the three experimental conditions. A summary of the three-way analysis of variance with repeated measures (Keppel, 1973, p. 430) including the planned comparisons carried out on these data is given in Table 10.

The significant differences obtained among conditions (A) and among subjects (S) have already been described in terms of overall

Table 10

Summary of Analysis of Variance and Planned Comparisons

Conducted on Sequential Response Data in Experiment 3

Source	SS	df	MS	F
(A) Among Conditions	5,766.67	2	2,883.34	21.46***
Comparisons:				
1. MAX INFO vs Pooled Deg	(3,581.10)	(1)	3,581.10	22.82**
2. DW vs DS	(2,185.56)	(1)	2,185.56	19.53**
(B) Among Events	5,900.19	2	2,950.10	11.25**
Comparisons:				
1. Signaled vs Unsignaled	(5,900.10	(1)	5,900.10	13.88*
2. Warning vs Safe	(.09)	(1)	.09	< 1
(S) Among Subjects	11,195.40	5	2,239.08	38.19***
(A) x (B)	1,795.06	4	448.76	7.66***
Comparisons:				
1. Conditions x Signaled vs Unisgnaled Trials	(254.50)	(2)	127.25	2.40
2. Conditions x Warning vs Safe Trials	(1,540.56)	(2)	770.28	12.00**
(A) x (S)	1,343.95	10	134.39	2.29
Comparisons:				
1. Subjects x MAX INFO vs Pooled Degraded	(784.50)	(5)	156.90	3.23
2. Subjects x DW vs DS	(559.45)	(5)	111.89	1.63
(B) x (S)	2,623.66	10	262.37	4.48**
Comparisons:				
1. Subjects x Signaled vs Unsignaled Trials	(2,125.74)	(5)	425.15	8.03**
2. Subjects x Warn vs Safe	(497.92)	(5)	99.58	1.55
(A) x (B) x (S)	1,171.45	20	58.57	
Total	29,796.38	53		

$*p < .05$

$**p < .01$

$***p < .001$

response probability (see Table 8). The main effects of trial events (B), i.e., the effect on response probability of a warning, safe, or no signal occurring on trial n was also significant. Combining warning and safe trials (i.e., signaled trials) and comparing them with unsignaled trials also yielded significance as shown by Comparison 1 under (B). Thus, a response occurred more often after response trials than after nonresponse trials in all conditions. Although a further comparison of warning and safe trials shown by Comparison 2 under (B) was not significant, there was a significant interaction between warning and safe trials and conditions.[5] That is, response probability after safe trials was not changed (relative to MAX INFO) by a degraded warning signal, but was decreased significantly by a degraded safe signal. Additional significant interactions were found between subjects and response-nonresponse trials. These interactions may be accounted for by differences in the order of exposure to degraded conditions as previously argued.

Sequential effects of shock. As described in Experiment 1, a further analysis of the effect of shock on response probability was undertaken in a four-way analysis of variance. The four factors were: (a) conditions, (b) response (signaled) and nonresponse (unsignaled) trials, (c) shock and nonshock trials, and (d) subjects.

The results of this analysis demonstrate that shock was followed significantly more often by a response on the next trial than no shock, $F(1, 5) = 25.24$, $p < .01$. This effect was primarily associated with nonresponse (unsignaled) trials. Indeed, as reported in Experiment 1 there was a significant interaction between response trials and shock, $F(1, 5) = 21.52$, $p < .01$. That is, a higher response probability occurred after a signaled shock-free trial than a signaled shock trial, whereas the reverse was true after unsignaled trials. A shock-by-condition interaction was also significant, F(1, 5) = 6.60, $p < .025$, indicating that the increased probability of a response after shock trials was less under MAX INFO and DW than under the DS condition. It was also found that shock and nonshock trials interacted significantly with response, nonresponse trials, and conditions, F(2, 10) = 9.59, $p < .01$. That is, rats show a greater response probability after a response (signaled) trial than a nonresponse (unsignaled) trial. More specifically, after nonresponse trials the probability of a response was greater if a shock occurred than if no shock occurred. However, given a response trial, response probability was greater after no shock, but only when the signal associated with no shock was informative (i.e., under MAX INFO and DW). When the safe signal was unreliable (DS), rats responded with a higher probability after warning-shock trials. Finally, a significant interaction was found between subjects and shock, nonshock trials, F(5, 10) = 5.84, $p < .01$. In view of the differences between subjects reported in previous analyses, this effect was not surprising.

Response latency. The mean probability of a response in each of the 3-sec segments of a trial was determined for each rat over the last eight sessions of each condition. The results (see Appendix III) showed that the probability of a response in the first 3-sec trial interval was .75 or greater over all conditions. No systematic differences in the distribution of response latencies were found either between or within subjects. It is apparent, therefore, that this response measure was insensitive to changes in the informative value of the signal.

Body weight. Changes in body weight during repeated exposure to a particular experimental condition is frequently used as a measure of the degree of stress induced by signaled shock (Arabian & Desiderato, 1975; Weiss, 1970, 1971). Reduced weight is taken as evidence of stress. Accordingly, each rat was weighed prior to each experimental session. To determine whether changes in gross body weight occurred during exposure to a particular experimental condition, the average weight over the first four days of training was compared with the average weight over the last four days of training under a given condition. The animals showed a gradual weight gain over the entire course of training with no apparent changes in weight related to the informative value of the signal (see Appendix III).

Discussion

The results of interest concerning the analysis of overall response probability in Experiment 3 were that: (a) reasonably consistent observing response levels were maintained by repeated exposure to maximally informative signal conditions alternating with exposure to degraded conditions, and (b) degrading "safety" was significantly more detrimental to observing response maintenance than degrading "danger". These results were consonant with results obtained in the two previous experiments.

The sequential analysis yielded several additional results of interest. First, the probability of a response on the trial after a nonresponse (unsignaled) shock trial was greater than after a nonresponse (unsignaled) shock-free trial for all conditions. Such a finding is also consistent with results from Experiment 1 and suggests that in the absence of informative signals, shock alone has a facilitating effect on behavior. Secondly, when a signal occurred, the response probability on the succeeding trial was greater after a reliable than an unreliable signal. That is, under the degraded warning condition, the likelihood of a response was greater after a reliable safe signal than after an unreliable warning signal, whereas the reverse was true under the degraded safe condition. Thirdly, when an unreliable signal was presented, the probability of a response on the succeeding trial was enhanced by the occurrence of shock. In this respect, trials on which unreliable signals occurred were functionally similar to nonresponse (unsignaled) trials.

In summary, the results of the overall response probability analysis suggest that observing responses are maintained substantially by reliable safe signals. The sequential analysis shows, in addition, that rats are sensitive to differences in the reliability of signals within a paired signal condition (i.e., a degraded signal paired with a reliable signal). However, it should be noted again that in order to degrade the informative value of signals, either the relative frequency of click and noise trials or the probability of shock must be changed. In the first three experiments, the former alternative was followed; in a final experiment the second alternative was investigated. Thus it was asked whether similar results would be obtained under degraded signal conditions when shock probability was changed.

EXPERIMENT 4

In Experiment 4 differences between warning and safe signals were investigated at different overall shock probabilities. This was done in an effort to extend the generalization that observing responses are primarily maintained by the production of reliable safe signals. By manipulating shock probability, Experiment 4 also provided a control for the unequal frequencies of click and noise trials scheduled (or available to the rat after a response) in the previous two experiments when warning and safe signals were degraded at a constant shock probability of .5.

Method

Subjects. Twenty-four male, Long-Evans hooded rats were acquired from Blue Spruce Farms (Altamont, New York) to serve as subjects in Experiment 4. Following operant level determinations rats were given training on the discrete-trial avoidance procedure described in Experiment 1. Five animals failed to avoid shock on 75 percent of the trials and were eliminated from the study. Subsequent training on MAX INFO resulted in the elimination of an additional five rats for failing to maintain an average response probability of at least .25 over the last eight sessions of this condition. The remaining 14 rats were retained for additional training. Details of the preexperimental procedures are given in Appendix IV.

Trial events. Table 11 shows the number of trials and contingency square coordinates (conditional probability of shock given a signal) for the conditions in which shock probability was greater or less than .5. To minimize confusion the table shows values only for the situation in which white noise served as the warning signal and the click served

Table 11

Number of Trials and Conditional Probabilities of Shock Given Signals for Experimental Conditions Presented in Experiment 4

	Number of Trials			Conditional Probabilities	Signal Type
DEGRADED WARNING P(Sh) = .33					
	No Shock	Shock	Σ		
Noise	33	67	100	$P(Sh \mid Ns) = .67$	Degraded Warning
Click	100	0	100	$P(Sh \mid Cl) = 0$	Reliable Safe
Σ	133	67	200		
MAXIMUM INFORMATION P(Sh) = .33					
	No Shock	Shock	Σ		
Noise	0	67	67	$P(Sh \mid Ns) = 1$	Reliable Warning
Click	133	0	133	$P(Sh \mid Cl) = 0$	Reliable Safe
Σ	133	67	200		
DEGRADED SAFE P(Sh) = .67					
	No Shock	Shock	Σ		
Noise	0	100	100	$P(Sh \mid Ns) = 1$	Reliable Warning
Click	67	33	100	$P(Sh \mid Cl) = .33$	Degraded Safe
Σ	67	133	200		
MAXIMUM INFORMATION P(Sh) = .67					
	No Shock	Shock	Σ		
Noise	0	133	133	$P(Sh \mid Ns) = 1$	Reliable Warning
Click	67	0	67	$P(Sh \mid Cl) = 0$	Reliable Safe
Σ	67	133	200		

as the safe signal. In practice the signals were counterbalanced. Eight rats were given white noise as the warning signal and the remaining six rats received the click as the warning signal. As described in Experiment 3, however, the acoustic properties of the signals produced no differential effects on responding (see Appendix IV).

In both degraded conditions equal frequencies of warning signals and safe signals were scheduled. This was accomplished by scheduling unequal numbers of shock and shock-free trials. Thus, twice as many shock-free trials (133) as shock trials (67) were scheduled in the degraded warning condition. In the degraded safe condition the ratio of shock to nonshock trials was reversed. The number of shock trials was twice that of shock-free trials. Note that the conditional probabilities of shock given the click and noise signals for each degraded condition are the same as those scheduled in Experiments 2 and 3. Included in the table as well are maximally informative signal conditions which were equal in shock probability to a given degraded condition, but contained unequal numbers of warning and safe trials.

Sequence of conditions. Table 12 shows the sequence of experimental conditions for each rat in Experiment 4. All rats were first given training on the maximally informative signal condition at a shock probability of .5 in order to establish baseline response levels. Half the rats were then exposed to degraded warning signals (Group DW) at a shock probability of .33 while the other half were given degraded safe signals (Group DS) at a shock probability of .67. This was done to determine whether response levels similar to those under degraded conditions in Experiments 2 and 3 could be reproduced at different shock probabilities. Signal reliability was then restored for the

Table 12

Experimental Treatments Expressed as Contingency Square

Coordinates in Experiment 4

Condition		MAX INFO	DW	MAX INFO	MAX INFO
P(Shock)		.5	.33	.33	.5
	Rat				
	458	(1, 0)	(.67, 0)	(1, 0)	(1, 0)
	467	"	"	"	"
	452	"	"	"	"
Group DW	453	"	"	"	"
	461	(0, 1)	(0, .67)	(0, 1)	(0, 1)
	457	"	"	"	"
	444	"	"	"	"

Condition		MAX INFO	DS	MAX INFO	MAX INFO
P(Shock)		.5	.67	.67	.5
	Rat				
	466	(1, 0)	(1, .33)	(1, 0)	(1, 0)
	470	"	"	"	"
	469	"	"	"	"
Group DS	465	"	"	"	"
	462	(0, 1)	(.33, 1)	(0, 1)	(0, 1)
	449	"	"	"	"
	468	"	"	"	"

two groups of rats, but at shock densities equal to those experienced under the previous degraded condition. The purpose of this procedure was to permit a measure of the effects of shock density apart from signal reliability. Finally, all rats were retrained on the 50 percent shock condition with maximally reliable signals.

There were 24 sessions of exposure to each condition. As in previous experiments daily sessions were scheduled for six days a week.

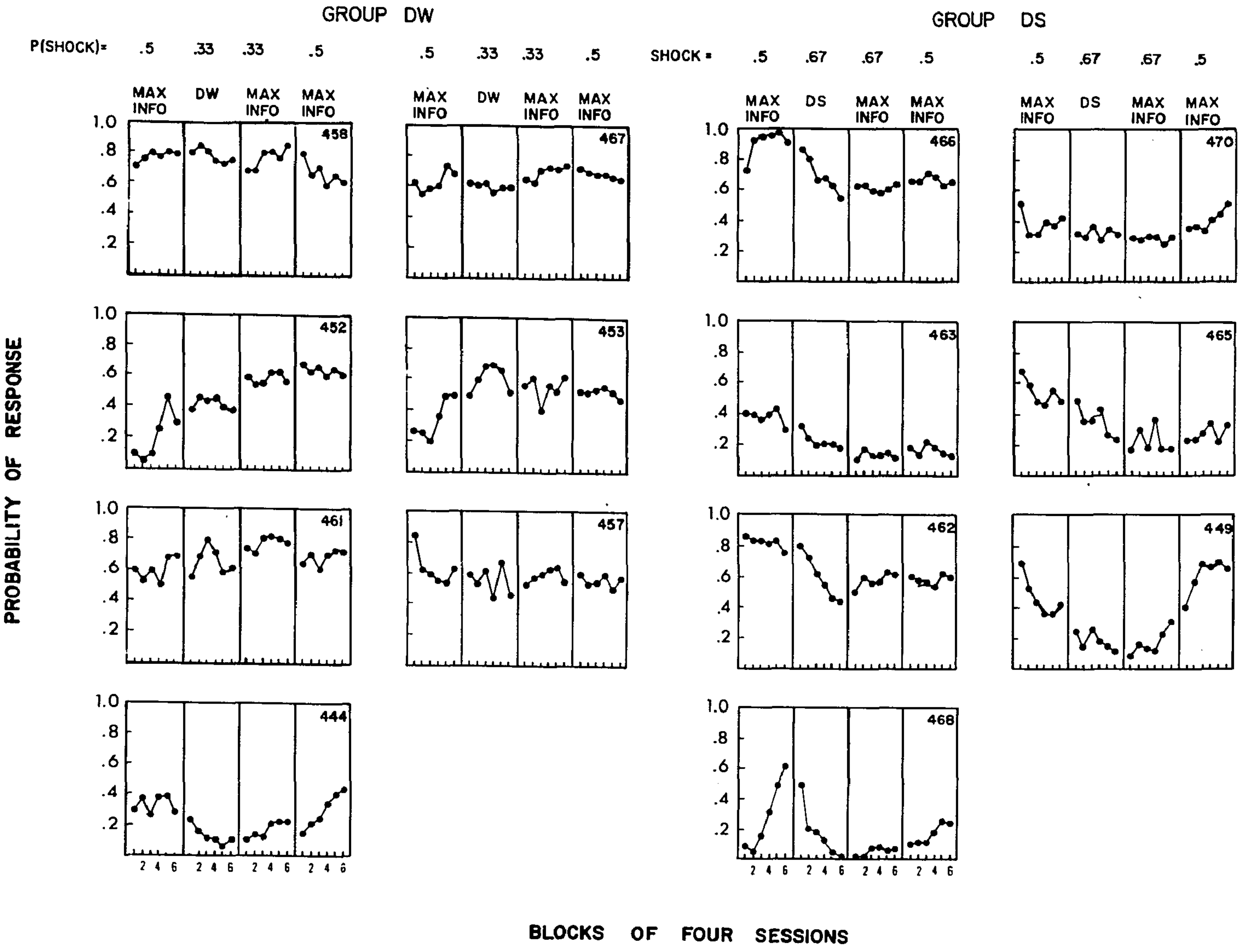
Shock schedule. The schedule of shock and shock-free trials for the first and fourth phases of Experiment 4 was identical to the expanded Fellows (1967) series described in Experiment 1. Since two phases of Experiment 4 involved unequal numbers of shock and shock-free trials, a modified version of the Fellows schedule was presented (see Appendix IV) for these conditions.

Results

Overall effects. Figure 9 presents the probability of a response in blocks of four sessions for each of the rats given training on degraded warning and degraded safe conditions. The two upper rows for both groups represent conditions under which white noise served as the warning signal and the click served as the safe signal. This situation was reversed for the animals whose data are presented in the lower two rows.

Consider response probability shown at the upper left corner for rat 458 given training on degraded warning signals. Response levels over the first three conditions were approximately similar for this rat. Thus response levels acquired under maximally informative signals at a shock probability of .5 were unchanged when the warning signal was degraded and fewer shocks were presented, or merely fewer shocks

Figure 9. Probability of a response presented in blocks of four sessions over successive experimental conditions for each rat in Experiment 4.


GROUP DW
P(SHOCK)= .5 .33 .33 .5 .5 .33 .33 .5
MAX INFO DW MAX INFO MAX INFO
GROUP DS
SHOCK = .5 .67 .67 .5 .5 .67 .67 .5
MAX INFO DS MAX INFO MAX INFO
458
467
466
470
452
453
463
465
461
457
462
449
444
468
1.0
.8
.6
.4
.2
2 4 6 2 4 6 2 4 6 2 4 6
PROBABILITY OF RESPONSE
BLOCKS OF FOUR SESSIONS

were given in combination with reliable signals. Responding declined slightly when shock probability was restored to .5 in the final condition although this result was not typical of all rats in this condition.

Responding for the remaining rats exposed to degraded warning signals showed no clear differences between conditions that would typify the group as a whole. There were, however, considerable differences between individuals as noted in all three previous experiments.

Responding under degraded safe signals, by comparison, was clearly affected. Note response probability for rat 466 shown at the top of the left column under Group DS. The data for this rat reveal a substantial decline in responding when safe signals were degraded. For example, response probability declined from an average of .94 (S.D. = .05) over the last eight sessions of initial training on MAX INFO to .59 (S.D. = .07) over the last eight sessions of DS. Restoring signal reliability without changing shock probability produced no further decline. In fact, response levels were approximately similar to the average response probability over the last eight sessions of DS. Restoring shock probability to .5 in the final recovery phase produced no apparent change in the direction of responding.

The remaining rats in Group DS all showed a decline in response levels under the degraded safe condition compared to previous responding under MAX INFO. Restoring reliable signals followed by restoring shock probability to .5 produced a nearly continuous recovery function for three of the remaining rats (470, 449, and 468) and a flat function for the other four rats (466, 463, 462, and 465). On the basis of the recovery functions described in Experiment 1, it may be that training on maximally reliable signal conditions was simply not continued long enough in Experiment 4 to reinstate initial response levels.

To further analyze differences between conditions a two-way analysis of variance was performed on the mean response probability over the last eight sessions of each of the four experimental conditions encountered by Group DW rats. Subjects were included as replications. The outcome revealed a nonsignificant difference between conditions, $\underline{F}(3, 18) = 2.14$, $p > .05$. Differences between subjects were, however, greatly significant, $\underline{F}(6, 18) = 68.53$, $p < .001$. These results confirm observations described above that neither degrading the warning signal nor reducing the number of shocks produced a change in response levels acquired under reliable signal conditions at a shock probability of .5.

Response probability over the last eight sessions of each condition encountered by Group DS rats was also analyzed. In order to investigate differences between specific conditions, planned comparisons were conducted with subjects included as replications. A comparison of the two replications of MAX INFO at a shock probability of .5 revealed a nonsignificant difference, $\underline{F}(1, 6) = 1.93$, $p > .05$. This result is somewhat misleading since two subjects (470, 449) showed response levels greatly increased under the final MAX INFO condition compared to initial training whereas the remaining five subjects all showed incomplete recovery of responding on the final MAX INFO phase.

Response probabilities under each of the two MAX INFO conditions at shock probabilities of .5 each were combined for each subject and compared with responding under MAX INFO at a shock probability of .67. This comparison revealed a significant difference, $\underline{F}(1, 6) = 39.05$, $p < .001$. Since the informative value of the signal was held constant in these conditions it would seem that increasing the total number of shocks per session resulted in a substantial response decrement although it may be that recovery of responding following exposure to DS was not complete for all rats. Indeed, a final comparison undertaken between the MAX INFO and DS conditions (shock probability of .67 in each condition) resulted in a nonsignificant difference, $\underline{F}(1, 6) = .75$, $p > .05$ which suggests that response levels had not been recovered for all rats after 24 sessions of restored signal reliability paired with 67 percent shock.

Discussion

The results presented above are consistent with the general finding described in the previous two experiments that degrading safe signals produced more of an effect on response probability than degrading warning signals. More specifically, Experiment 4 demonstrated that the differential effects of warning and safe signals could be replicated at different shock probabilities. This study also controlled for changes in signal frequency by scheduling equal numbers of warning and safe trials in the two degraded conditions. Since the results of this study concur with previous findings it may be argued that the asymmetrical effects of DW and DS conditions do not rest solely on differences in the frequency of warning and safe signals.

General Discussion

It has been shown here that a response class established and maintained in a discrete trial shock-avoidance procedure may be maintained or may be weakened when all subsequent shocks are made response-independent and delivered according to an intermittent (partial) schedule. The maintenance or reduction of response probability depends directly upon the reliability of response-produced signals predicting shock or the absence of shock on a given trial. There was no convincing evidence of a substantial contribution to the maintenance of response probability from either shock-elicited responding or shock density per se.

Since the response-independent shock procedure employed here is not generally familiar, it will be worthwhile to review it in terms of the contingencies it carries. In the absence of responding the possible outcomes of shock and no shock occurring at the end of a trial correspond to a schedule of partial reinforcement in classical aversive conditioning. When a response occurs during a trial the absence of any contingency between the response and the trial outcome (shock or no shock) places this procedure along the diagonal of an instrumental "contingency square" (Gibbon et al., 1974, Figure 5; Neffinger & Gibbon, 1975, Figure 1). When the consequences of a response are, however, predictive of the predesignated trial outcome (i.e., response-produced warning and safe signals) an observing response procedure is identified. The relationship of the response-produced signals to shock and shock omission is conceptualized in Figure 2 of the introduction.

The points of interest emerging from the four experiments center on two main findings. First, wholly unreliable or noninformative signals as in the NO INFO condition did not support behavior otherwise maintained under reliably signaled outcomes (MAX INFO). Secondly, degrading warning and safe signals independently of one another (DW and DS) produced different levels of responding. That is, degraded warning signals sustained a significantly higher response probability than degraded safe signals.

In demonstrating that a condition of nondifferentially signaled shock failed to maintain observing responses, the results of Experiments 1 and 2 are consistent with studies based on both positive (e.g., Bower et al., 1966) and aversive (e.g., Lockard, 1963) outcomes. Such results are also consistent with Rescorla's (1966, 1968) finding that animals show no evidence of conditioning in a CER paradigm under the "truly random control" procedure. In addition, an analysis of sequential responding in Experiment 1 revealed that unreliable warning and safe signals in the NO INFO condition were functionally indistinguishable from nonresponse or unsignaled trials in this condition. This result suggests that factors other than the predictive value of the signals, e.g., intermittent shock or perhaps the prior experience with maximally informative signals maintained some low probability of response under the NO INFO condition.

The second outcome of interest, i.e., the asymmetrical effects of degraded warning and degraded safe signals, is also consistent with published reports (e.g., Badia & Culbertson, 1972). Such results cannot adequately be accounted for by a strictly informational or correlational (i.e., contingency) approach, either of which would predict equal response degradation for equal signal degradation. For example, the root mean square contingency or ∅ coefficient is an expression of the degree of association between the response-produced signals and the occurrence or nonoccurrence of shock. The two degraded signal conditions which are equidistant from the point of maximum information are represented by the same value of ∅. Because different levels of responding were obtained under the two degraded conditions, it follows that ∅ is not an adequate measure of observing response probability under these conditions. Since, however, measures of response suppression (cf. Rescorla, 1968, 1969) correlate well with ∅ values, it is suggested that observing responses at least in the present procedure are not strictly equivalent to the type of conditioned response characterized by a suppression ratio. Rather, to account for the asymmetrical effects on observing response probability of the degraded warning and degraded safe conditions, one would have to assign different weights to the conditioned effects of warning and safe signals. For example, consider a response that is followed by a safe signal as being positively reinforced and one that is followed by a warning signal as being "punished". Since observing responses are maintained under the MAX INFO condition, the aversive effects of the warning signal must perforce be outweighed by the positive value of the safe signal. Making the warning signal less "punishing" (DW condition) then results in less response degradation than making the safe signal less positively reinforcing (DS condition).

A quantitative hypothesis along these lines has been proposed by Wilton (1972) to account for observing responses maintained by signaled positive reinforcement. Assuming that the amount of punishment contributed by the negative (nonreward) stimulus was small relative to the amount of reinforcement delivered by the positive stimulus, Wilton proposed that the amount of punishment in the negative stimulus was a constant fraction of the information contributed by that signal. Thus, the average reinforcing value of the positive stimulus was taken to be p log 1/p where p was the probability of the positive signal. The average reinforcing value of the negative stimulus was (1-p)(log 1/1-p).

One of the predictions of this model is that observing responses will be maintained at maximum levels under infrequent reinforcement (e.g., at 25 percent food-reinforced trials). As mentioned previously in the introduction (p. 19) such a result has been well established (Kendall, 1973b; McMichael, Lanzetta, & Driscoll, 1967; Wilton & Clements, 1971b). Assuming further that safe signals reinforce observing responses in an aversive procedure, Wilton proposed that response levels would be maximal when safe trials were relatively infrequent. The results of Experiment 4, however, do not support this view. That is, when safe trials under the MAX INFO condition were less frequent (i.e., a shock probability of .67 relative to .5) response levels were substantially reduced. Moreover, an increase in safe trials (i.e., a shock probability of .33 relative to .5) produced inconsistent results, i.e., no change in behavior for four rats, an increase in response probability for three rats, and a decrease for one rat.

A statistical correlational framework also fails to provide a satisfactory account of these shock probability effects. In the Gibbon et al. (1974) paper it is argued that in the tetrahedral space very high or very low shock probabilities are located near the noncontingent region whereas intermediate values are further away. In an avoidance procedure, for example, if animals are responding maximally the frequency of shock is so low that a discrimination between contingent and noncontingent conditions may not be possible. Since there is a direct relationship between correlational and informational measures, a contingency view would also predict different effects for high or low shock probabilities compared to intermediate values. That is, response probability under MAX INFO at very high or very low shock probabilities should resemble response probability under the NO INFO condition. Such an outcome was noted in these studies for an increase in shock probability (i.e., to 67 percent), but not consistently among subjects for a corresponding decrease in shock probability (i.e., to 33 percent).

The absence of any systematic change in latency of responding over conditions suggests that response probability and "timing" are independent. Neffinger and Gibbon (1975) report a similar result in that rats showed little change in response latency as a function of partial-contingency treatments under schedules of punishment or omission. Once timing behavior was established under avoidance training in the Neffinger and Gibbon experiments, it remained "invariant with changes in the level of response, independently of how such changes were produced" (p. 448). According to Gibbon (1972) such a result represents one of two separate processes which govern behavior. The one is a scalar timing process which accounts for <u>when</u> in a particular preshock interval a response will occur. The second process is related to <u>whether</u> a response will occur and depends on a "worthwhile" improvement in the overall shock density. A similar point has been made by Shimp and

Hawkins (1974) who described two time-allocation functions in accounting for concurrent reinforcement interaction. The one function was determined by the percentage of reinforcements for a particular component; the second was determined by the overall reinforcement rate in both components. Analogously, in the present experiments the "decision" to respond was presumably determined by the overall amounts of "punishment" and conditioned reinforcement conveyed by the warning and safe signals, respectively, in each condition.

Factors underlying the location of a response within a given trial in the present studies are somewhat more difficult to specify. The short latency pattern observed in all experiments under all conditions suggests shock-elicited effects, i.e., the often-observed post-shock "bursting" in avoidance schedules (e.g., Church & Getty, 1972). Such effects are plausible in the present studies given the relatively short intertrial interval (6 sec). However, one might then expect an increased probability of response under increased shock density while, in fact, the reverse was obtained. It is, therefore, unlikely that shock-elicited effects contributed greatly to responding here.

The short latency response pattern is characteristic of the Class II animals described by Neffinger and Gibbon (1975). These animals were identified by their tendency to continue responding under noncontingent shock following initial avoidance training. Since Class II rats also showed responding proportional to shock density under the noncontingent condition, they were apparently sensitive to both contingency and shock density. It follows that the rats in the present studies, which were first given avoidance training and then placed on a noncontingent shock schedule, resembled the Class II animals to the extent that responding was maintained under both conditions. Certainly, the sequential effects are similar for both groups with respect to the increased response probability after unsignaled shock in contrast to unsignaled shock-free trials. Nevertheless, none of the rats in Experiment 4 continued to respond at high levels under increased shock probability which suggests that other factors, namely the informational value of the signals, contributed to the behavior of these animals.

The results of the partial punishment procedure described in the Neffinger and Gibbon study raises a further question concerning the possibility that observing responses in the present studies were maintained by "superstitious" or adventitious events. For example, if one considers that all animals in Experiments 1, 3, and 4 were given preliminary avoidance training and all achieved a criterion of at least 75 percent shock avoidance, then the shift to noncontingent shock might seem to the rat to be indistinguishable from a partial punishment procedure. Thus, while 50 percent of the trials would appear to be unavoidable, the remaining 50 percent might seem to be potentially avoidable through adventitious association of a response with the absence of shock. Loosely speaking, under the MAX INFO condition the rat might "think" that the safe-nonshock trial was produced by him. Under the degraded warning condition the response-produced safe trial which is fear-inhibiting is preserved (although it occurs less frequently in Experiments 2 and 3 as a result of the constant shock probability) and so responding is maintained. Under the degraded safe condition as well as under the NO INFO condition, the information about shock omission following a "safe" signal is delayed until the end of the trial (i.e., the occurrence or nonoccurrence of shock) and so responding declines.

The argument for a "superstitious" account of the results rests on an assumption that the rat "thinks" he has produced the omission of shock.

It is difficult to counter such an argument. However, there is some evidence that a "superstitious avoidance" position does not adequately account for the data. That is, assuming that the rat is "superstitiously avoiding" then all that is necessary is that a response occur sufficiently often to "produce" the 50 percent nonshock trials. Such an argument requires only that rats attend to whether or not a response has occurred and not to a particular signal. Under such conditions, if shock probability is constant, there should be no differences in response probability while signal-shock associations are manipulated. It is clear, however, that such changes do occur in the present studies.

Finally, if observing response behavior in these studies is maintained by adventitious association of responses and shock-free trials, then increases or decreases in shock density should produce concomitant changes in response probability (cf., the degraded effects obtained by Neffinger & Gibbon along the diagonal). That is, there should be fewer adventitious associations of response-produced safe signals with shock-free trials when shock density is increased and therefore from the rat's point of view responses should be less effective. On the other hand the rat might regard responses as more effective if shock density is reduced. The results of Experiment 4 support this prediction only insofar as increased shock probability was associated with a decreased response probability. The reverse was not found, however. That is, response levels did not change with respect to the 50 percent shock condition when shock was reduced to 33 percent.

FOOTNOTES

1. At the time these experiments were undertaken, it was not understood by the experimenter that in procedures of this sort a shock is typically scheduled at the start of a session to serve a kind of "priming" function. However, inspection of the first few trials of each session suggested that animals responded quite readily without evidence of a "warm-up" effect. It is, therefore, doubtful that the absence of shock on the first trial delayed or inhibited responding at the start of the session.

2. The error terms for these planned comparisons were:

Source	SS	df	MS
(B) x (S)			
Comparison 1	404.38	2	202.19
Comparison 2	160.98	2	80.49

3. It is possible despite the carefully imposed restrictions of the stimulus schedule that a disproportionate sampling of trials of one type or another might have accounted for some of the variance in these studies. Due to the large amount of data collection it was beyond the capabilities of the available experimental equipment to systematically analyze and correct for, if necessary, such sampling discrepancies.

4. The error term for this comparison was:

Source	SS	df	MS
(A) x (S)			
Comparison 3	2,892.95	5	578.59

5. The error terms for the (A) x (B) comparisons listed in Table 10 were:

Source	SS	df	MS
(A) x (B) x (S)			
Comparison 1	529.72	10	52.97
Comparison 2	641.73	10	64.17

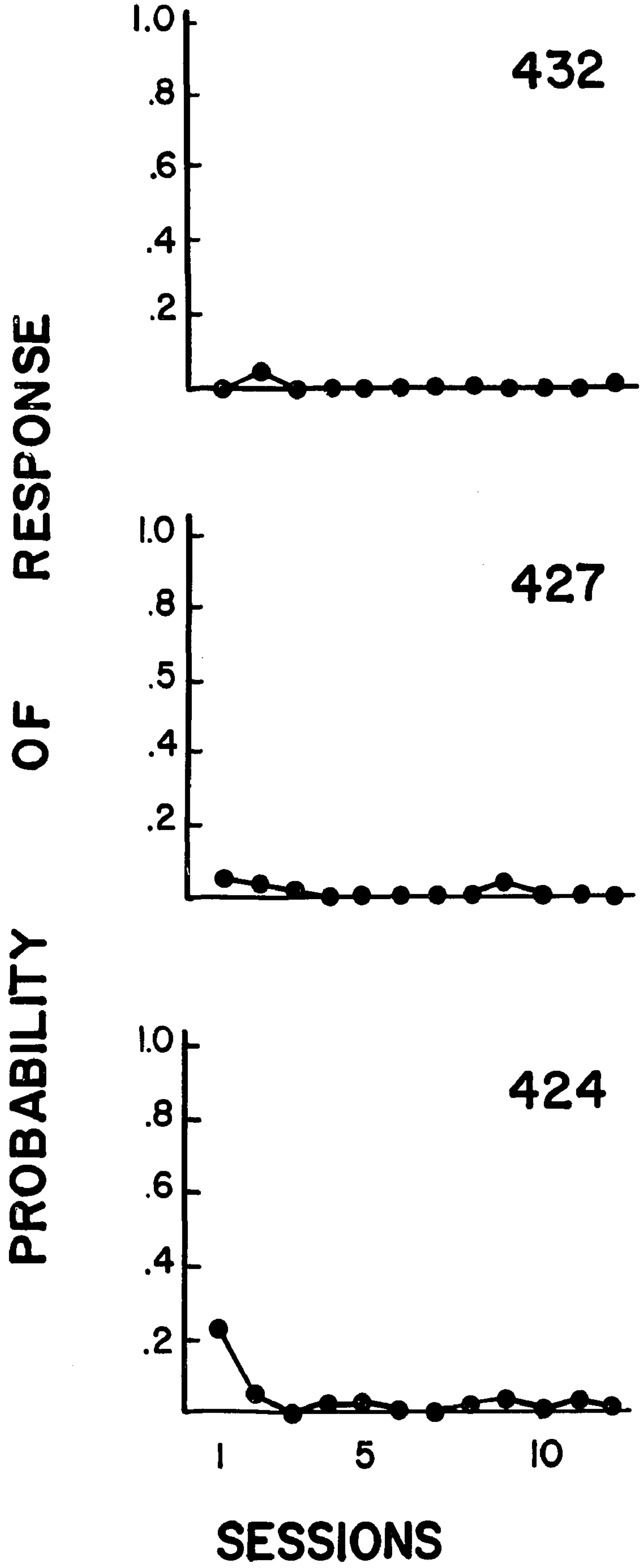
The error terms for the (A) x (S) comparisons were:

Source	SS	df	MS
(A) x (B) x (S)			
Comparison 1	485.68	10	48.57
Comparison 2	686.70	10	68.67

The error term for the (B) x (S) comparisons was the pooled (A) x (B) x (S) error term listed in Table 10.

APPENDIX I

Figure A. Response probability over twelve consecutive sessions of the operant level condition. A response was followed by withdrawal of the dipper, extinction of the dipper light and production of either the clicking sound or white noise for the furation of the trial. The stimulus arrangements were the same as those described in the General Method section with the exception that the shock source was disconnected.


PROBABILITY OF RESPONSE
1.0
.8
.6
.4
.2
432
1.0
.8
.5
.4
.2
427
1.0
.8
.6
.4
.2
424
1
5
10
SESSIONS

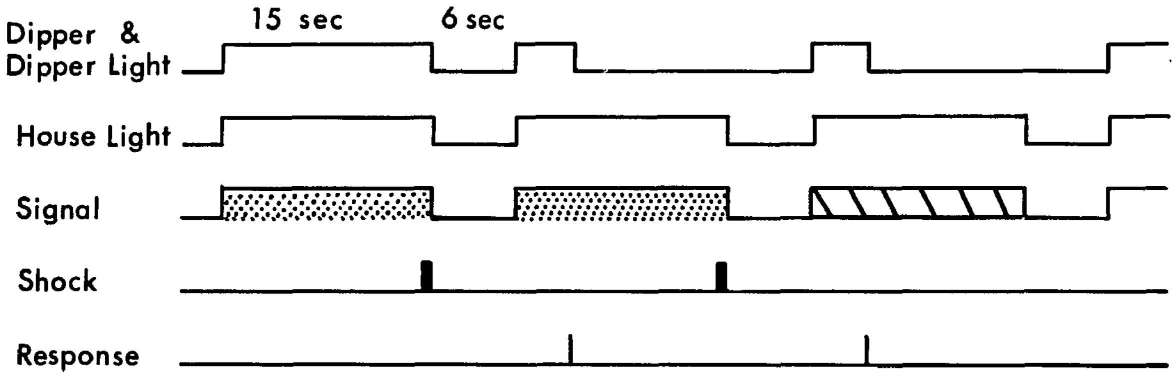
PREEXPERIMENTAL PROCEDURES

The preliminary training procedures scheduled in all four experiments were devised for the purpose of increasing the likelihood of responding when the rat was initially exposed to the MAX INFO condition at the start of experimental training. Since signal production was response-contingent, unless the rat responded with some frequency greater than zero, the animal would not encounter the signal-shock contingency. Therefore, one preconditioning procedure entailed pairing the click and noise signals with shock and no shock, respectively, for the duration of the trial in an effort to facilitate associative learning when the signals were subsequently made response-contingent. This procedure is shown in schematic form at the top of Figure B. Responses during the trial had no consequences other than to produce removal of the dipper and extinction of the dipper light. There were 100 trials in each of two consecutive sessions and shock was presented with a probability of .5 at the end of each trial. Three rats were trained on this procedure: 432 and 424 were subsequently exposed to Experiment 1 procedures and 430 was later included in Experiment 3.

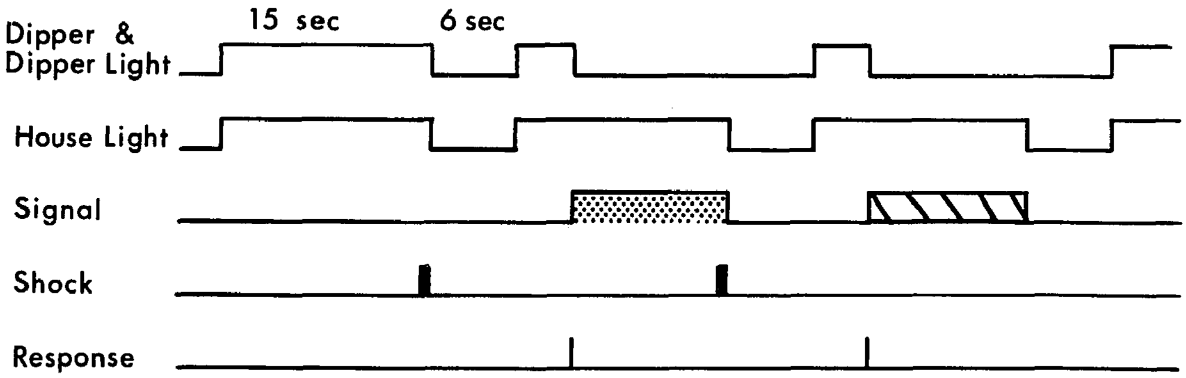
Following this training rats were given two additional sessions of 100 trials each in which the warning and safe signals were made response-contingent and a shaping technique was used (lower diagram in Figure B). Thus, response approximations as well as responses were followed by removal of the dipper and presentation of a reliable warning or safe signal. The stimulus arrangements were, in fact, identical to those described in the General Method section. Rats 430 and 432 received white noise as the warning signal and the click as the safe signal. Rat 424 was given the click as the warning signal and white

Figure B. Event diagrams of preexperimental procedures for rats 432, 424, and 430. The stippled area represents white noise and the striped area, the clicking sound. See text for further details.

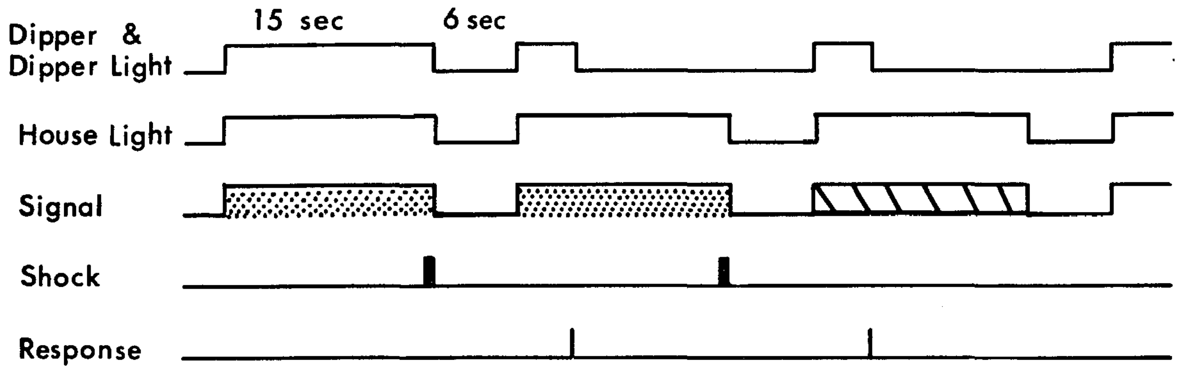
PHASE 1, CONTINUOUS SIGNALS



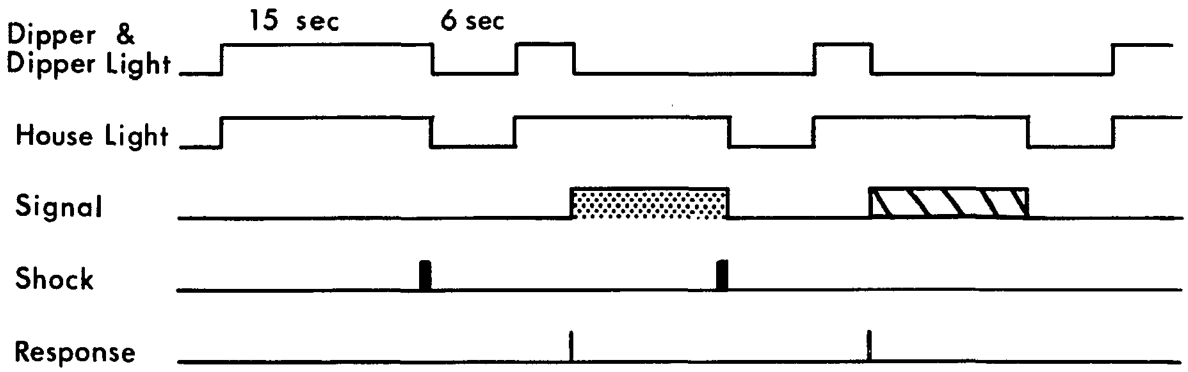
PHASE 2, RESPONSE-CONTINGENT SIGNALS



PHASE 1, CONTINUOUS SIGNALS



PHASE 2, RESPONSE-CONTINGENT SIGNALS



noise as the safe signal.

Since these procedures were not successful in facilitating response levels as shown in Table A, rats were next given training on a discrete-trial avoidance schedule in which a response made during the trial was always followed by a safe signal and no shock. For the animals serving in Experiment 1, two rats (432, 427) received the click as the safe signal and the third (424) received the white noise as the safe signal. A shaping procedure was used in which response approximations were followed by removal of the dipper and production of the safe signal. The shaping procedure was discontinued after the fourth session. Sessions each consisted of 400 trials. Rats were given training on the avoidance schedule for at least five sessions. If subjects had not responded sufficiently often to avoid 90 percent of the shocks by the fifth session, training was continued for an additional five sessions or until the criterion of 90 percent of the shocks avoided was met. The results of the avoidance training are shown for individual rats in Figure C.

Table A

Probability of Response During Each Session of the Two Preexperimental Procedures for Each Rat

	Phase 1 - Continuous Signals		
Rat No.	432	424	430
Session			
1.	.00	.14	.03
2.	.00	.03	.01
	Phase 2 - Response-Contingent Signals		
1.	.05	.00	.01
2.	.02	.01	.02

Figure C. Percent shock trials avoided for each rat in Experiment 1 over successive sessions. (Shaping trials are excluded.) A response produced a "safe" signal and postponed shock until the end of the next trial. Training was discontinued after five sessions if rats avoided 90 percent of the scheduled shocks. If the response criterion was not met on the fifth session, training was continued for an additional five sessions or until 90 percent of the shocks had been avoided. There were 400 trials per session.

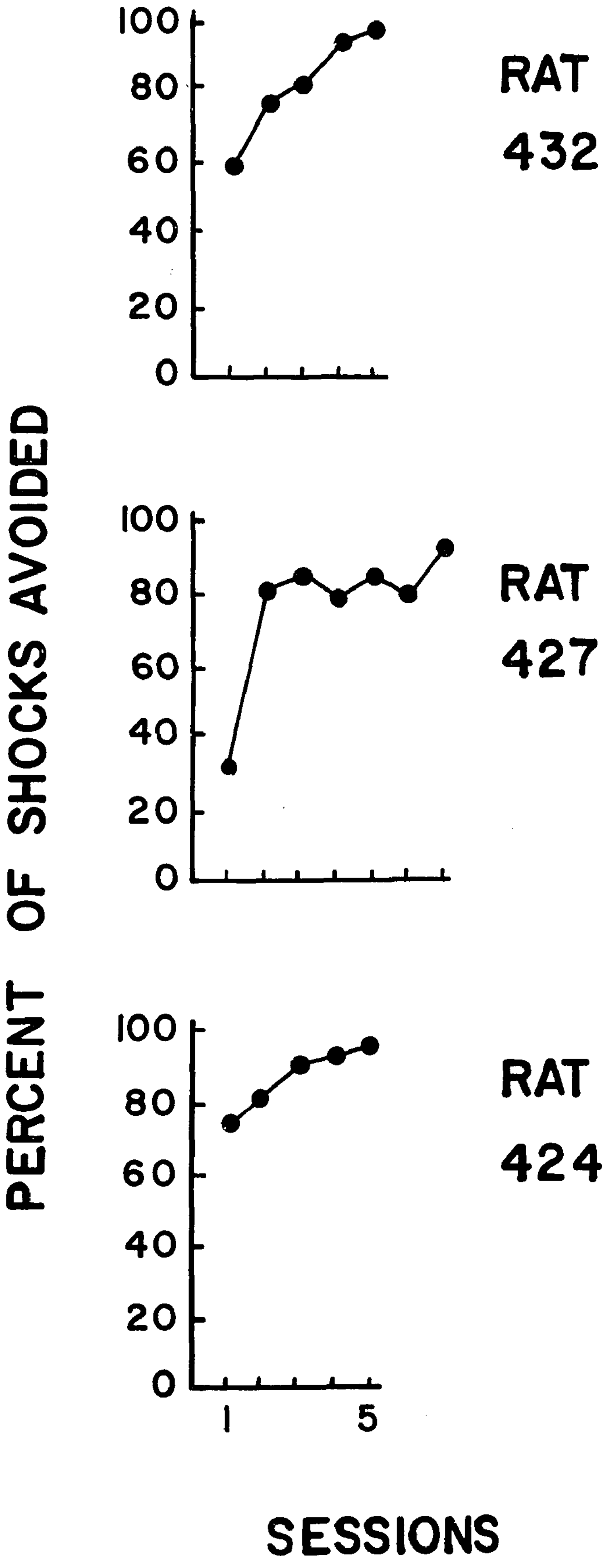

PERCENT OF SHOCKS AVOIDED
100
80
60
40
20
0
RAT 432
100
80
60
40
20
0
RAT 427
100
80
60
40
20
0
1
5
RAT 424
SESSIONS

Table B

Sequences Used to Schedule Shocks for Both Conditions Studied in Experiment 1. Signals are Given for the NO INFO Condition[a]

Trials					
1.	NNNCNNNCCN 0111011000	8.	CCCNNNCNNC 1111000110	15.	NCNCNCCCNN 0111100110
2.	NNNCNNCNCC 1001111000	9.	CCCNNNNCCN 1000011100	16.	NCNNCNCCCN 1100010000
3.	CNNNCCNCCC 1101110000	10.	NCCCCNCNNN 1100010000	17.	NCCNNNCNCC 1111001110
4.	NCCCNNCNCN 1100001110	11.	CNCCCCNNNN 1110111100	18.	CCNCNCNNCC 1110000101
5.	NCNNNCCNCC 0111100010	12.	CNCNCNCNNC 1110110001	19.	NNCNNCCNNC 1001111000
6.	NCCCCNCNNC 1111011100	13.	CNCCCCNNCC 0011110000	20.	CNNCCCNCCC 1001111000
7.	NNNCNCCCNN 1000110000	14.	NNNNCCCNCC 1000011100		

---

[a] The letters *C* and *N* represent click and noise trials and the digits *1* and *0* represent shock and nonshock trials. The shock series was taken from Fellows (1967) and expanded to include "runs" of four events. The series of signals were selected from a random numbers table (Arkin & Colton, 1950, p. 159) with the restrictions imposed by the NO INFO condition, i.e., that P(Sh|Ns) = P(Sh|Cl) = .5. The start of the sequence for each session was varied, but the first trial was always a nonshock trial so as to provide a common starting point for the sequential response analysis.

APPENDIX II

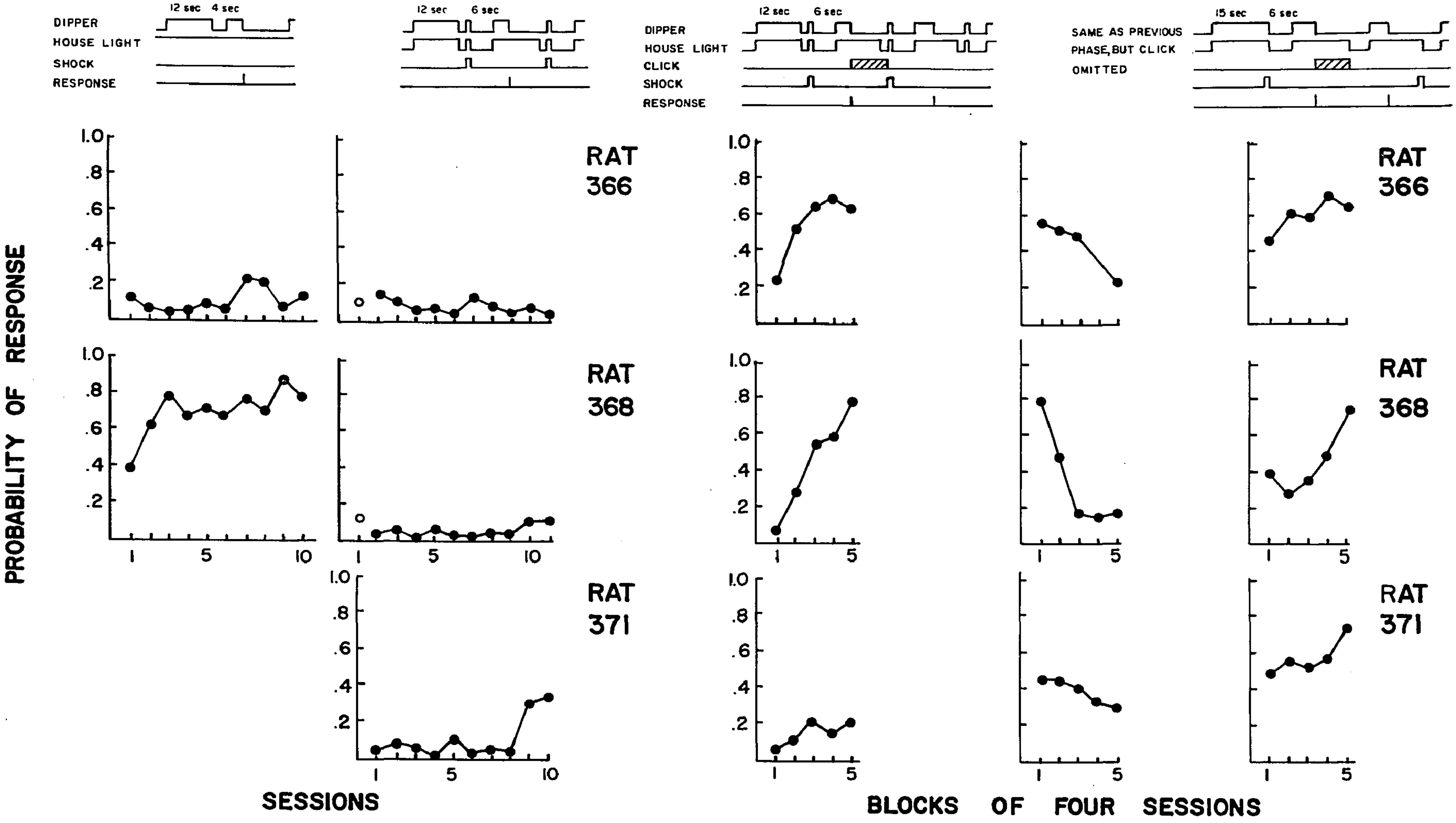
PREEXPERIMENTAL PROCEDURES

The training given rats prior to Experiment 2 was intended to explore several possible stimulus arrangements for the purpose of ultimately facilitating acquisition of the observing response under the MAX INFO condition. These procedures, with one exception (Phase 2 for rat 369) all involved response-independent outcomes. Basically, three variables were manipulated: (a) duration of the trial and inter-trial interval, (b) dipper presentation, and (c) presence or absence of a signal. The results of the preexperimental training are described first for rats 366, 368, and 371.

Initially, responding was assessed under conditions in which the dipper alone was presented without signals or shock. For example, the first phase of training shown at the left of Figure D for rats 366 and 368 shows response probability when the only consequence of a response was removal of the dipper. The schematic diagrams shown at the top of the figure represent the stimulus arrangements for the data which are plotted below. Under the first condition, for example, rat 368 showed responding apparently maintained by dipper withdrawal alone. In this phase the house light was presented continuously. The dipper light was always correlated with dipper operation and therefore is not shown separately in the diagram. Sessions were approximately 100 trials long.

In the second phase of training several changes in the schedule were made. One such change involved scheduling a rapid (0.3 sec) presentation and withdrawal of the dipper at the end of the trial. A 2-sec interval was interpolated between dipper removal (after 12 sec) and the rapid up-down motion of the dipper at the end of the trial.

Figure D. Event diagrams representing successive preexperimental procedures and response probability in each of these procedures for rats 366, 368, and 371.



12 sec
4 sec
DIPPER
HOUSE LIGHT
SHOCK
RESPONSE
12 sec
6 sec
12 sec
6 sec
DIPPER
HOUSE LIGHT
CLICK
SHOCK
RESPONSE
15 sec
6 sec
SAME AS PREVIOUS
PHASE, BUT CLICK
OMITTED
PROBABILITY OF RESPONSE
1.0
.8
.6
.4
.2
RAT 366
RAT 368
RAT 371
1
5
10
SESSIONS
BLOCKS OF FOUR SESSIONS

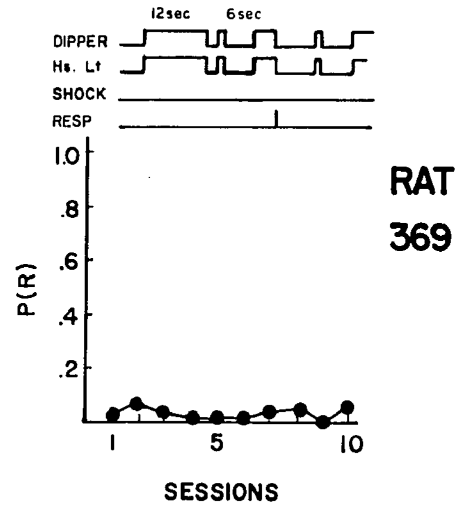
This procedure was adapted from a similar method used by Gibbon and O'Connell (1974) in which the acquisition of a bar press appeared to be influenced by the rapid insertion and removal of a retractable manipulandum just prior to shock. In addition, it was found necessary to increase the intertrial interval to 6 sec to avoid overheating the dipper mechanism. A response during the trial resulted in removal of the dipper for the remainder of the 12-sec period, but did not affect the .3-sec presentation of the dipper just prior to the start of the intertrial interval. The house light remained on during the 12-sec segment of the trial whether or not a response occurred, and was turned on during the .3-sec presentation of the dipper as well. Noncontingent shock was presented at the end of every trial for one session only (closed data points). For the remainder of the phase shock was scheduled with a probability of .5 at the end of the trial. The duration of the shock coincided with the brief presentation of the dipper. There were 100 trials per session.

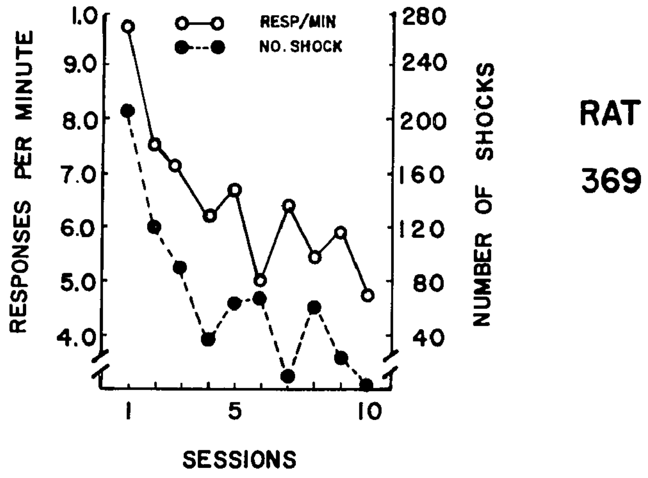
The results of training on this schedule revealed minimal response levels for rats 366 and 368. Rat 371 was also exposed to these stimulus arrangements, but without shock delivery. The data for rat 371, therefore represent a type of operant level determination for this schedule from which it appeared that responding, at least in the last two sessions, was sensitive to dipper presentation alone.

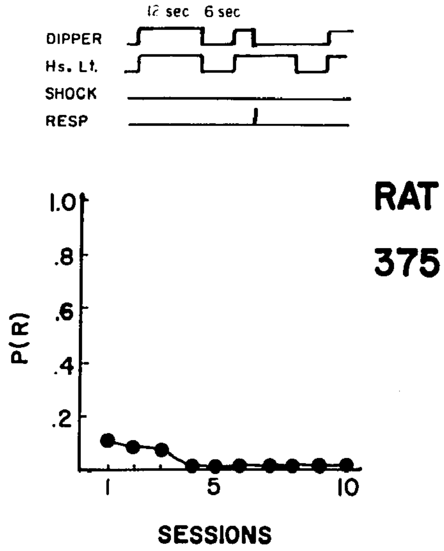
The three subsequent phases of training for rats 366, 368, and 371 represented attampts to manipulate responding under conditions of constant probability [P(Sh) = .5] signaled shock and shock-free trials. This was done by adding a clicking stimulus contingent on a response in the event of a shock scheduled at the end of the trial. In addition, the interval between dipper removal and dipper presentation at the end of the trial was reduced from 2 sec to .2 sec. The clicking stimulus functioned as a warning signal and its absence as a safe signal. Failure to respond resulted in no signal being presented. Sessions consisted of 200 trials. Substantial response levels were acquired under this condition for two rats (366, 368), while the third (371) showed a small increase in responding over sessions. In the next phase removal of the clicking stimulus produced a decline in responding for all three animals. Finally, reinstating the click as a safe signal (last column) resulted in increased responding for the three rats. This final preexperimental procedure incorporated most of the stimulus arrangements (the exception being the second auditory signal) used in the general experimental paradigm. Specifically, the duration of the trial was extended to 15 sec and the rapid dipper presentation-removal sequence was eliminated. There were 200 trials per session in each of these latter two phases.

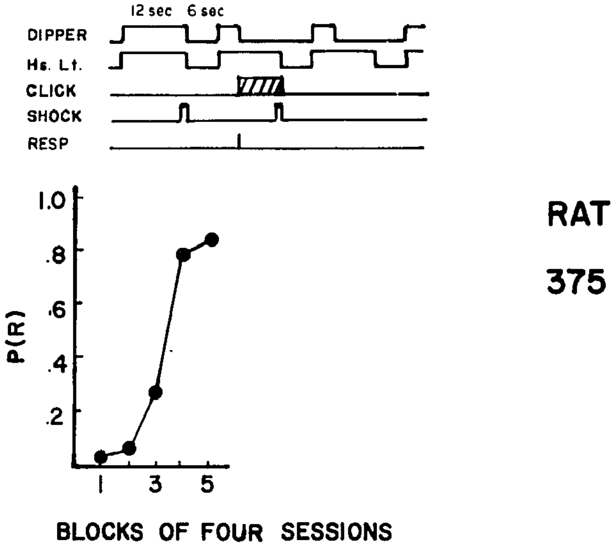
The procedures and results of preexperimental training for the three remaining rats in Experiment 2 are shown in Figure E. Rats 369 and 375 were first given 10 sessions of training on discrete-trial procedures similar to those described for rats 366, 368, and 371, but without shock in order to establish operant level baselines (i.e., responding to the dipper alone). Procedures for both rats consisted of a 12-sec presentation of the dipper during which time the house light was illuminated. A 6-sec intertrial interval was also scheduled. Rat 369 was given, in addition, a brief (.3 sec) exposure to the dipper following a .2-sec delay at the end of the trial. A response occurring

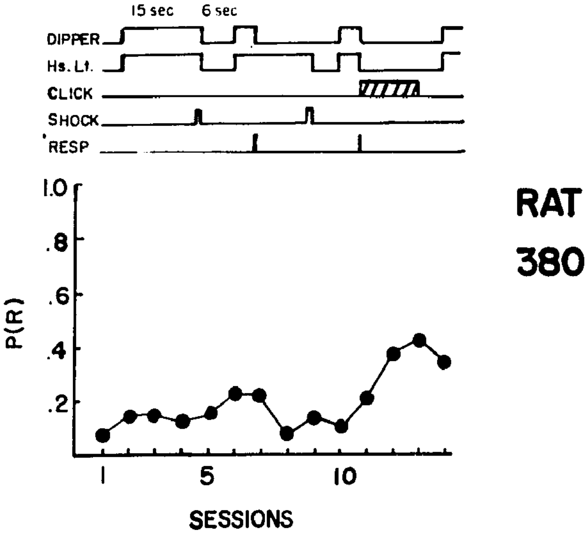
Figure E. Event diagrams illustrating preexperimental procedures and the results of each of these procedures for rats 369, 375, and 380.


12sec
6sec
DIPPER
Hs. Lt
SHOCK
RESP
1.0
.8
.6
.4
.2
P(R)
1
5
10
SESSIONS
RAT
369


RESP/MIN
NO. SHOCK
RESPONSES PER MINUTE
1.0
9.0
8.0
7.0
6.0
5.0
4.0
NUMBER OF SHOCKS
280
240
200
160
120
80
40
1
5
10
SESSIONS
RAT
369


12 sec
6 sec
DIPPER
Hs. Lt.
SHOCK
RESP
1.0
.8
.6
.4
.2
P(R)
1
5
10
SESSIONS
RAT
375


12 sec
6 sec
DIPPER
Hs. Lt.
CLICK
SHOCK
RESP
1.0
.8
.6
.4
.2
P(R)
1
3
5
BLOCKS OF FOUR SESSIONS
RAT
375


15 sec
6 sec
DIPPER
Hs. Lt.
CLICK
SHOCK
RESP
1.0
.8
.6
.4
.2
P(R)
1
5
10
SESSIONS
RAT
380

during the 12-sec trial segment for this rat resulted in removal of the dipper and extinction of the house light. The first phase for rat 375 did not include the brief dipper presentation just prior to the intertrial interval. In addition, a response made during the trial produced removal of the dipper, but did not turn off the house light. Responding for these two rats was clearly not acquired under these conditions.

In a second phase of training rat 369 was given 10 sessions of exposure to a free operant discriminated avoidance schedule. This was done in a further attempt to increase the likelihood of a response being emitted when the rat was subsequently placed in the signaled response-independent shock situation. A secondary purpose of this training was to provide normative data on the dipper mechanism so as to determine whether responding might have been influenced by some artifactual aspect of the dipper mechanism itself. For this purpose the dipper was held in the "up" position to allow for free-operant responding. The schedule parameters consisted of a 2-sec shock-shock interval and a 20-sec response-shock interval. Shock was a single .1-sec pulse at 1.0 mA intensity. White noise served as the warning stimulus and was presented for 4 sec prior to shock unless terminated by an avoidance response. The increasingly efficient avoidance behavior shown by this animal over sessions (upper right corner of Figure E) was in accordance with behavior described by Sidman (1955) for rats trained on discriminated avoidance schedules with conventional response manipulanda.

Rat 375 was exposed to 20 sessions of signaled noncontingent shock in the second phase of preexperimental training. During the 12-sec trial the dipper was presented and the house light illuminated. A 6-sec intertrial interval followed during which neither the dipper nor the house light was presented. A response made during the trial resulted in removal of the dipper and onset of a click stimulus if shock was scheduled at the end of the trial. No signal was presented following a response in the case of a shock-free trial. The probability of shock at the end of the trial was .5. Each session consisted of 200 trials. Each data point represents the mean response probability of four sessions. A gradual increase in response probability occurred over sessions for this rat.

Rat 380 was given 14 sessions of training on a schedule similar to that of rat 375 only the response-produced click stimulus functioned as a safe signal. No signal was given following a response on shock trials. This procedure was, in fact, identical to the last phase of training for rats 366, 368, and 371 and the results are similar in that responding was clearly acquired under conditions of signaled "safety".

Table C

Sequences Used to Schedule Shocks for the MAX INFO and NO INFO Conditions in Experiment 2. Signals are Given for the NO INFO Condition[a]

Trials

1. NNCNCCCNCN
   0010001000
2. CCNNCNCCCN
   1110111000
3. NNCNNCCCCN
   0010011010
4. CNCCCNNNCC
   1001111100
5. CNNNCNNCNC
   1110111101
6. NNCNNNNCNN
   1001111101
7. CCCCCNNCCN
   0000000001
8. CNCCNNCNCN
   1110111011
9. NCCNCNCNCN
   0110000100
10. CNNNCNCCCC
    0100101001
11. CNNNCCCNCC
    1100001110
12. CNCCNNCNCC
    1110111100
13. NCNNCCNCNN
    0000101000
14. CNNNCNCCCN
    0101111100
15. NNNCNNNCNC
    1110011011
16. NCCNCCCCCC
    0111000010
17. NCCCNNCCCN
    1001101011
18. NNNCNNNCCC
    1101011010
19. NNCNNNCCNC
    0011001011
20. CNNCNNNCNN
    0010100100

---

[a] The letter C represents the click stimulus. The letter N represents the noise stimulus. Shock trials are indicated by 1 and nonshock trials by 0. Shock was randomized according to a random numbers table (Arkin & Colton, 1950, p. 158) with the restriction that an equal number of shock and nonshock trials were scheduled during a session. The click and noise stimuli were also randomized in such a way that each stimulus was presented equally often and that each stimulus preceded shock and nonshock trials equally often. The start of the sequence for each session was varied, but the first trial was always a shock-free trial so as to provide a common starting point for the sequential response analysis.

Table D

Sequences Used to Schedule Signal and Shock Trials for the Degraded Warning (Top Row in Each Series) and Degraded Safe (Second Row in Each Series) Conditions in Experiment 2[a]

			Trials		
1.	NCNCCNCCCC NNNNCNNNCN 0001101011	8.	CCCCNCNCCC NNNCNNNNNC 0011010011	15.	CCCCCNNNCC NNNCCNNNCN 0101100011
2.	CNNCCCCCCC NNNCNNCCNN 0001101101	9.	CCCCNCCCNC NNNNNCCNNN 0011011001	16.	CCCNCNCCCC NNCNNNNNNC 0110001011
3.	NCCNCCCCCC NNNNCNNCNC 0010100111	10.	NNCCCNCCCC NNCNCNNNNC 0011100101	17.	NCCNCCCCNC NCNNNNCNNC 0110001101
4.	NCCNCCNCCC NNNNCNNNNC 0010110011	11.	CNCCCCCNCC NNNCCNCNNC 0011101001	18.	CCCNCCCNCC NNCNNNNNCN 0110010011
5.	NNCCCCCCNC NNCNNCNNNN 0010111001	12.	CCCNCNNCCC NNNNNNNCNN 0100100111	19.	NCCCCCCNCC NNCNNNCNNC 0110010011
6.	CNCCCNCCCC NNCNNNNNCC 0011001011	13.	NCCNCCCCCC NNNNNCNNCN 0100110011	20.	NCCCCNCNCC NNCNNNNNNC 0110100011
7.	NCCCCNCCNC NNNCNNCCNN 0011001101	14.	NCNCCCCNCC NCNNCNNNNC 0100111001		

---

[a] Each C represents the click stimulus and each N the noise stimulus. A shock trial is indicated by 1 and a nonshock trial by 0. The digits in the third row of each 10-trial block correspond to the first 20 series of trial orders published by Gellerman (1933). The click and noise signals were selected from a random numbers table (Arkin & Colton, 1950, p. 158) with the restrictions imposed by each of the conditions concerning the relative frequency of click to noise trials and the conditional probabilities of shock given a particular signal. The start of the sequence was varied for each session, but the first trial was always a nonshock trial so as to provide a common starting point for the sequential response analysis.

Table E

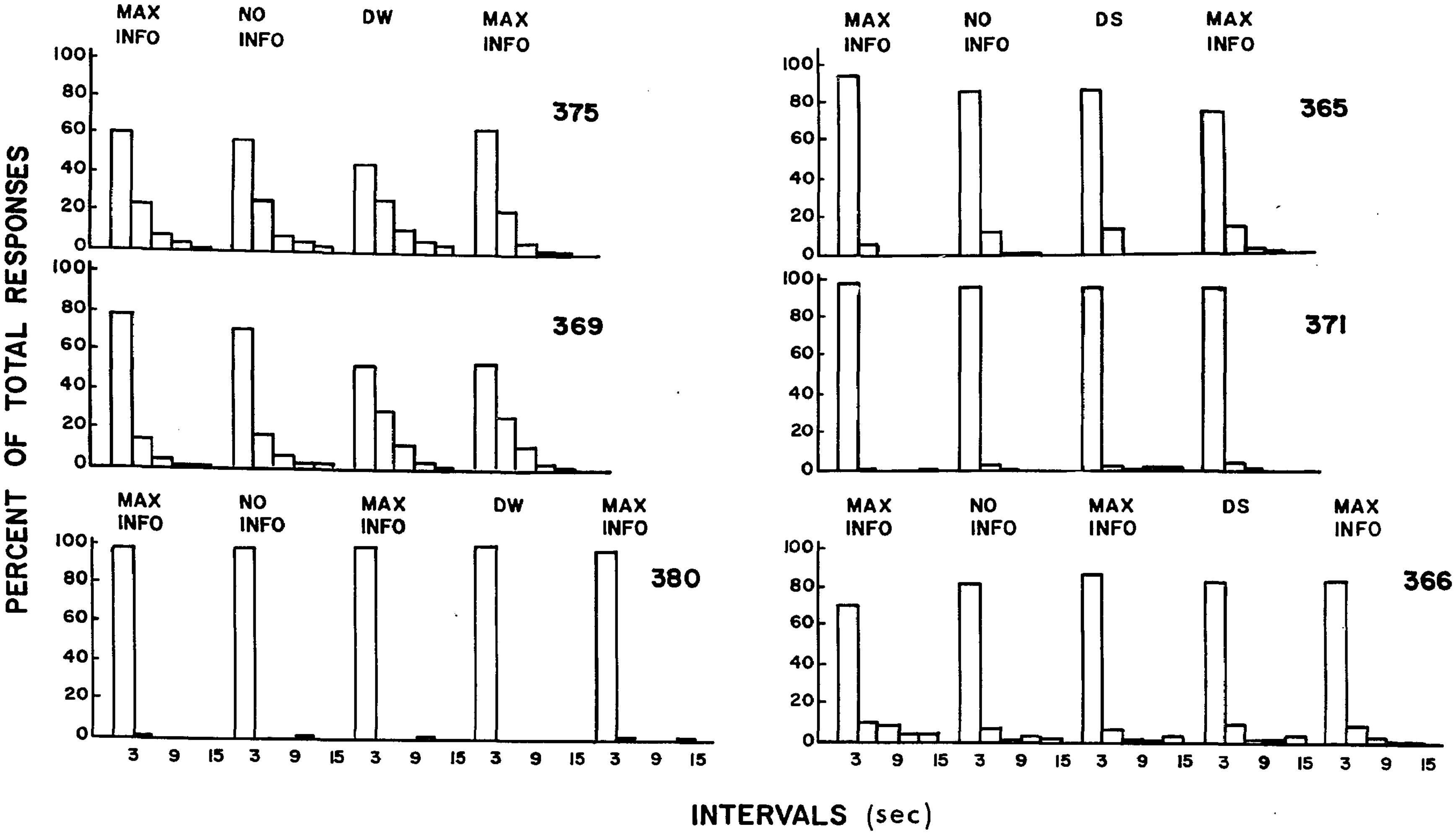
Comparison of P(R)[a] for Four Rats Given the Two Different Shock Schedules in Effect During Additional Sessions of MAX INFO

	Shock Schedule			
	Random		Gellerman	
Rat No.	368	371	369	375
Sessions				
25-27	.41	.35	.39	.36
38-30	.42	.33	.38	.47
31-33	.38	.38	.40	.40
34-36	.36	.46	.32	.49
37-39	.28	.36	.32	.42
40-42	.31	.30	.28	.41
Mean	.36	.36	.35	.41

---

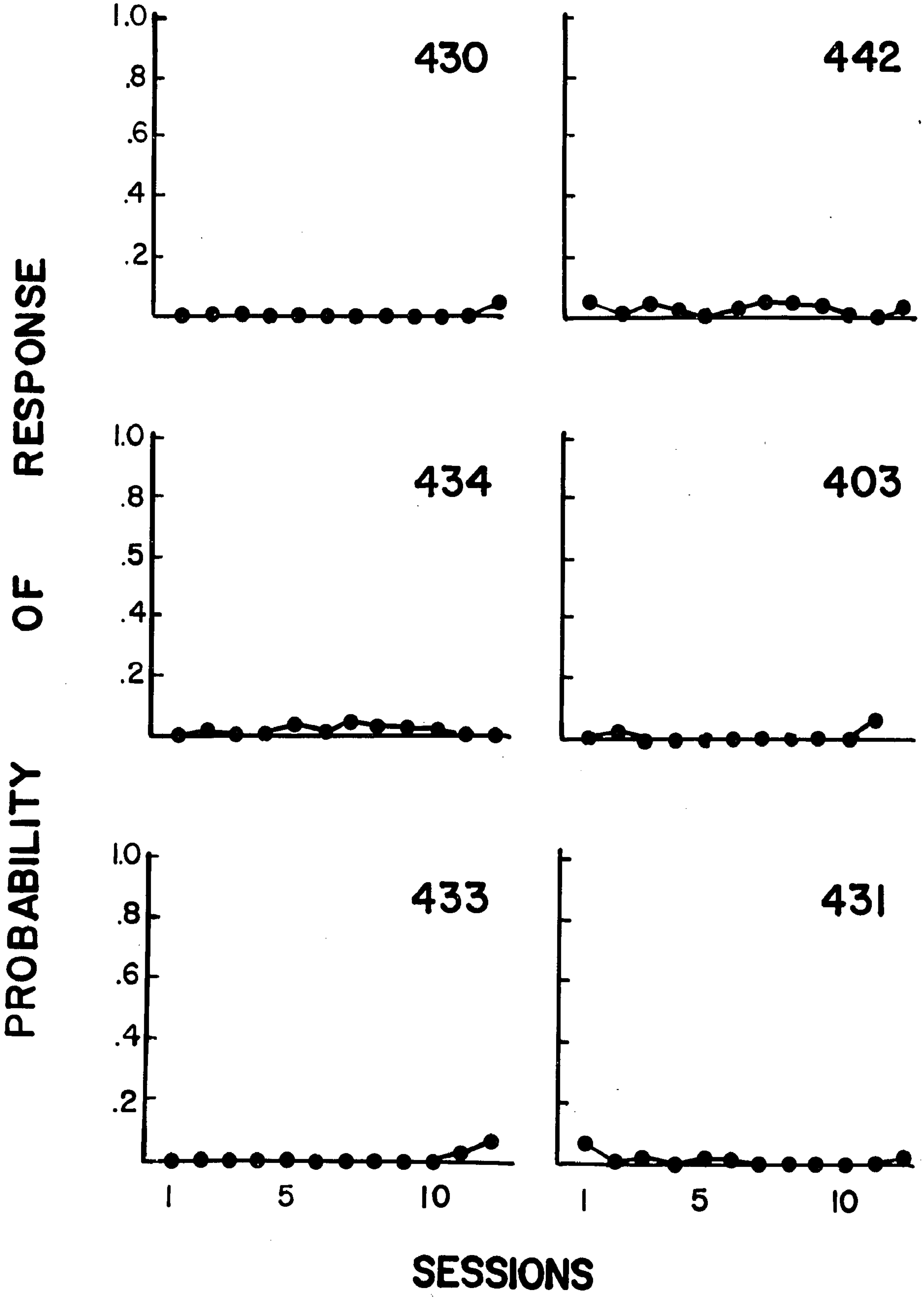
[a] Values represent the mean probability of a response over three consecutive sessions. A t test for independent groups between the combined scores for rats 368 and 371 versus rats 369 and 375 revealed a nonsignificant difference, i.e., $t(5) = 1.23$, $p > .05$.

Figure F. Latency of response represented as the percent of total responses falling within each of five consecutive 3-sec intervals for each rat under each experimental condition. A mean of the last eight sessions in each condition is shown.


MAX INFO
NO INFO
DW
MAX INFO
375
369
MAX INFO
NO INFO
DS
MAX INFO
365
371
MAX INFO
NO INFO
MAX INFO
DW
MAX INFO
380
MAX INFO
NO INFO
MAX INFO
DS
MAX INFO
366
100
80
60
40
20
0
3
9
15
PERCENT OF TOTAL RESPONSES
INTERVALS (sec)

APPENDIX III

Figure G. Probability of response for six rats in Experiment 3 over consecutive sessions during operant level training. The schedule was identical to the procedure described for the MAX INFO condition (see General Method section) with the exception that the shock source was disconnected. There were 200 trials per session.


430
442
434
403
433
431
1.0
.8
.6
.4
.2
1.0
.8
.5
.4
.2
1.0
.8
.6
.4
.2
1
5
10
1
5
10
PROBABILITY OF RESPONSE
SESSIONS

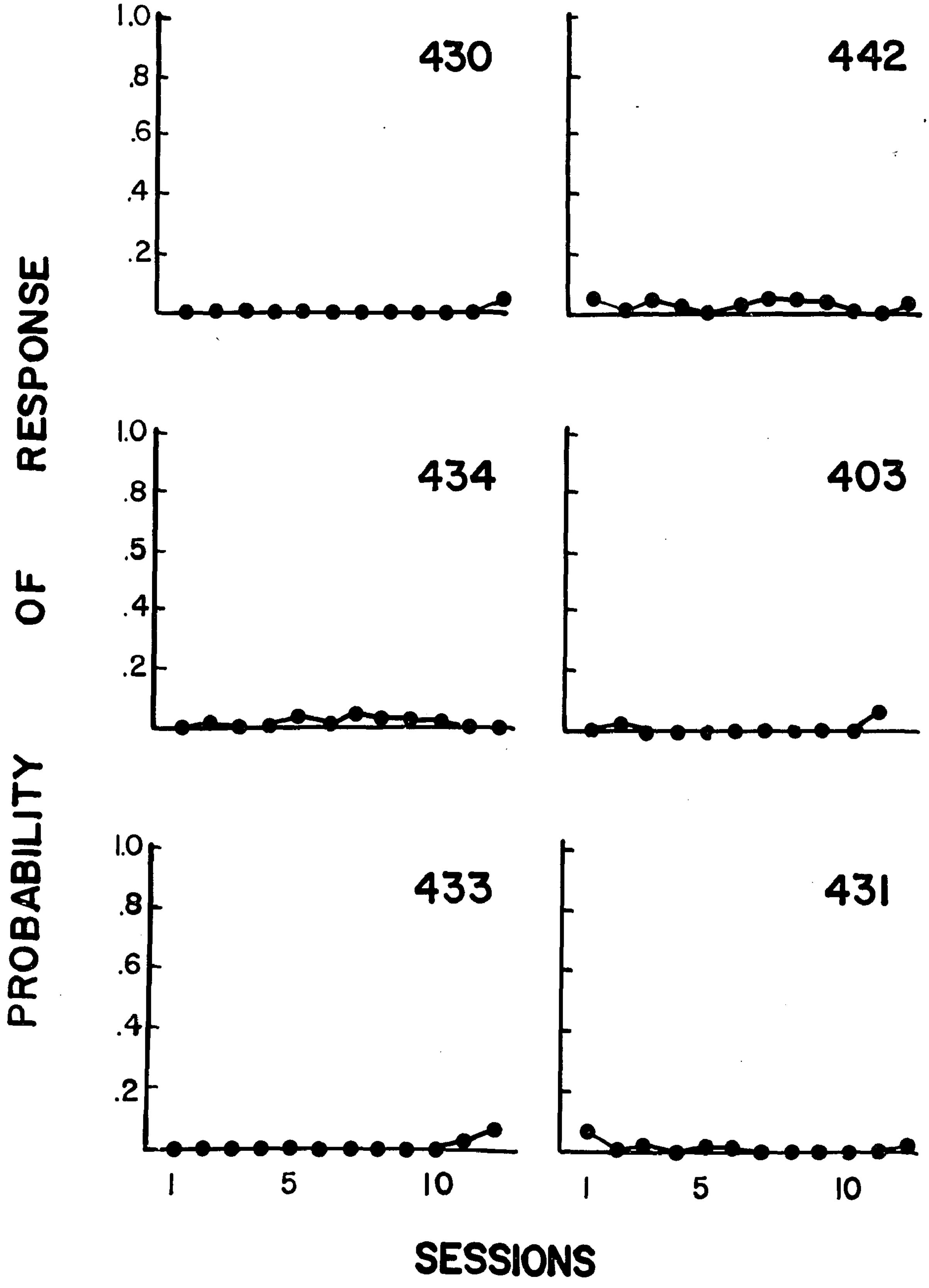

PROBABILITY OF RESPONSE
1.0
.8
.6
.4
.2
430
442
1.0
.8
.5
.4
.2
434
403
1.0
.8
.6
.4
.2
433
431
1
5
10
1
5
10
SESSIONS

Figure H. Percent of shock trials avoided over sessions for each rat in Experiment 3. There were 400 trials per session.

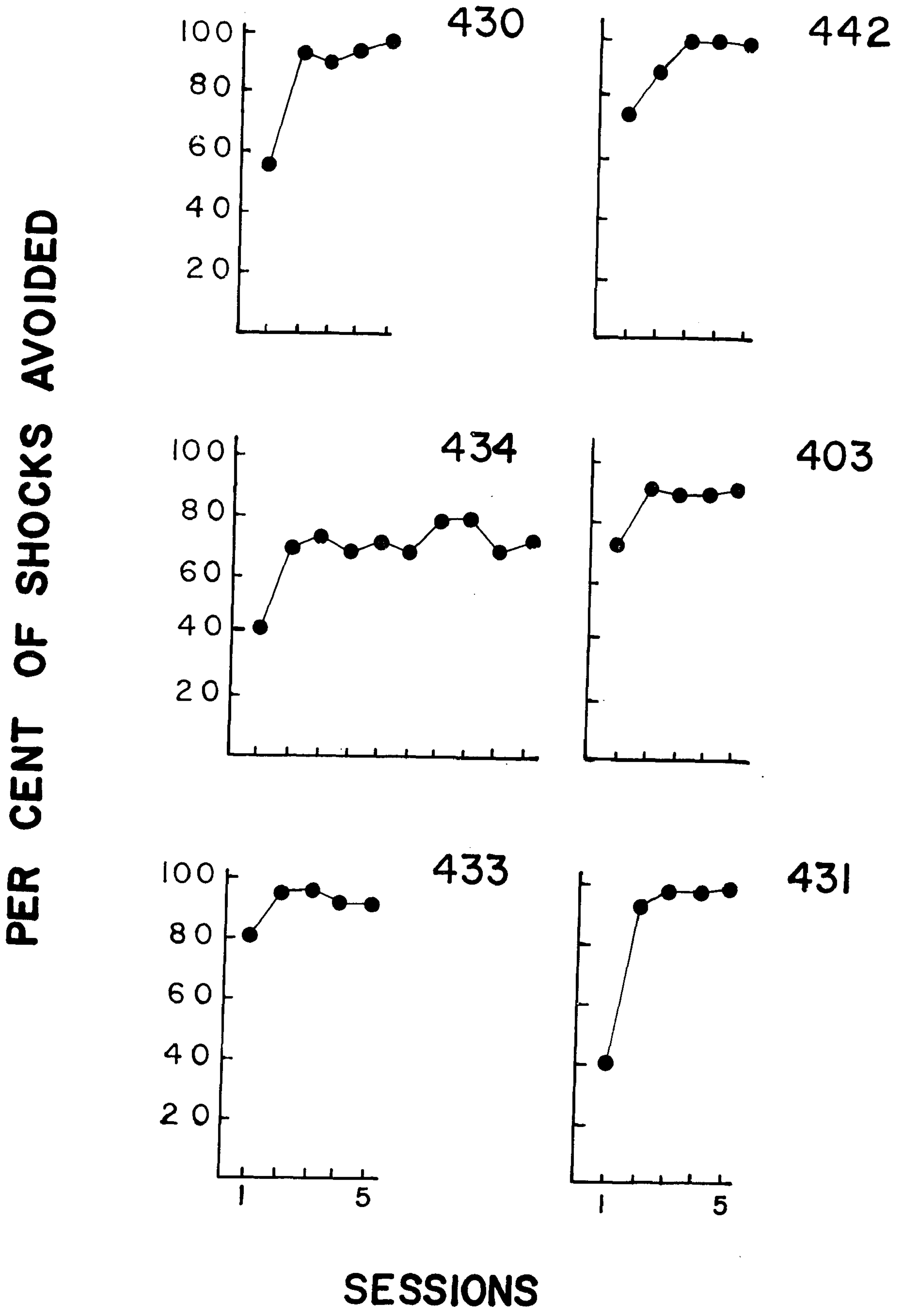

PER CENT OF SHOCKS AVOIDED
430
442
434
403
433
431
100
80
60
40
20
1
5
SESSIONS

Table F

Sequences Used to Schedule Signal and Shock Trials for the Degraded Warning (Top Row in Each Series) and Degraded Safe (Second Row in Each Series) Conditions in Experiment 3[a]

	Trials
1.	NCCCNCCCCC NNCCNCCNNN 0111011000
2.	CNCCCCCCNC CNNNNCCNNN 1001111000
3.	CCCCCCNCNN CNNNNCNNNN 1101110000
4.	CCNNCCCCCC CNNNNNNCCN 1100001110
5.	NCCCCCCNCN NNNCCNNNNN 0111100010
6.	CCCCCCCCNC CCCNNCNNNN 1111011100
7.	CCNNCCNCNC NNNNCNNNNN 1000110000
8.	CCCCCCCCCC CNNNNNNNCN 1111000110
9.	CNNNNCCCCN CNNNNCNCNN 1000011100
10.	CCCNCCCNCN CCNNNNNNNN 1100010000
11.	CCCNCCCCCN CNNNNCCNNN 1110111100
12.	CCCCCCNNCC NCNNCNNNNC 1110110001
13.	CNCCCCNNCC NNNCCNNNNN 0011110000
14.	CCNNNCCCCN CNNNNNCNNN 1000011100
15.	NCCCCCCCCC NCCNNNNNCN 0111100110
16.	CCCNCCNNCN NCNNNNNNNN 1100010000
17.	CCCCCCCCCN NCCNNNNCCN 1100010000
18.	CNNCCCCCCC CCNNNNNCNC 1110000101
19.	CNNCCCCCCC NNNCNNNNNN 1001111000
20.	CCCCCCCNNN NNNNNCNNNN 1001111000

---

[a] The letters C and N represent click and noise trials, respectively, and the digits 1 and 0 represent shock and shock-free trials, respectively. The shock series was taken from Fellows (1967) and expanded to include "runs" of four events. The series of signals were selected from a random number table (Arkin & Colton, 1950, p. 159), but were restricted by the relative frequency and conditional probability of shock given a particular signal for each condition as described in the text. The role of the signals was counterbalanced by simply substituting the click for the noise signal in each condition. The start of the sequence for each session was varied, but the first trial was always a shock-free trial so as to provide a common starting point for the sequential response analysis.

Figure I. Latency of response represented as the percent of total responses falling within each of five consecutive 3-sec intervals for each rat under each experimental condition. Combined latencies are shown where conditions were replicated. A mean of the last eight sessions in each condition is shown.

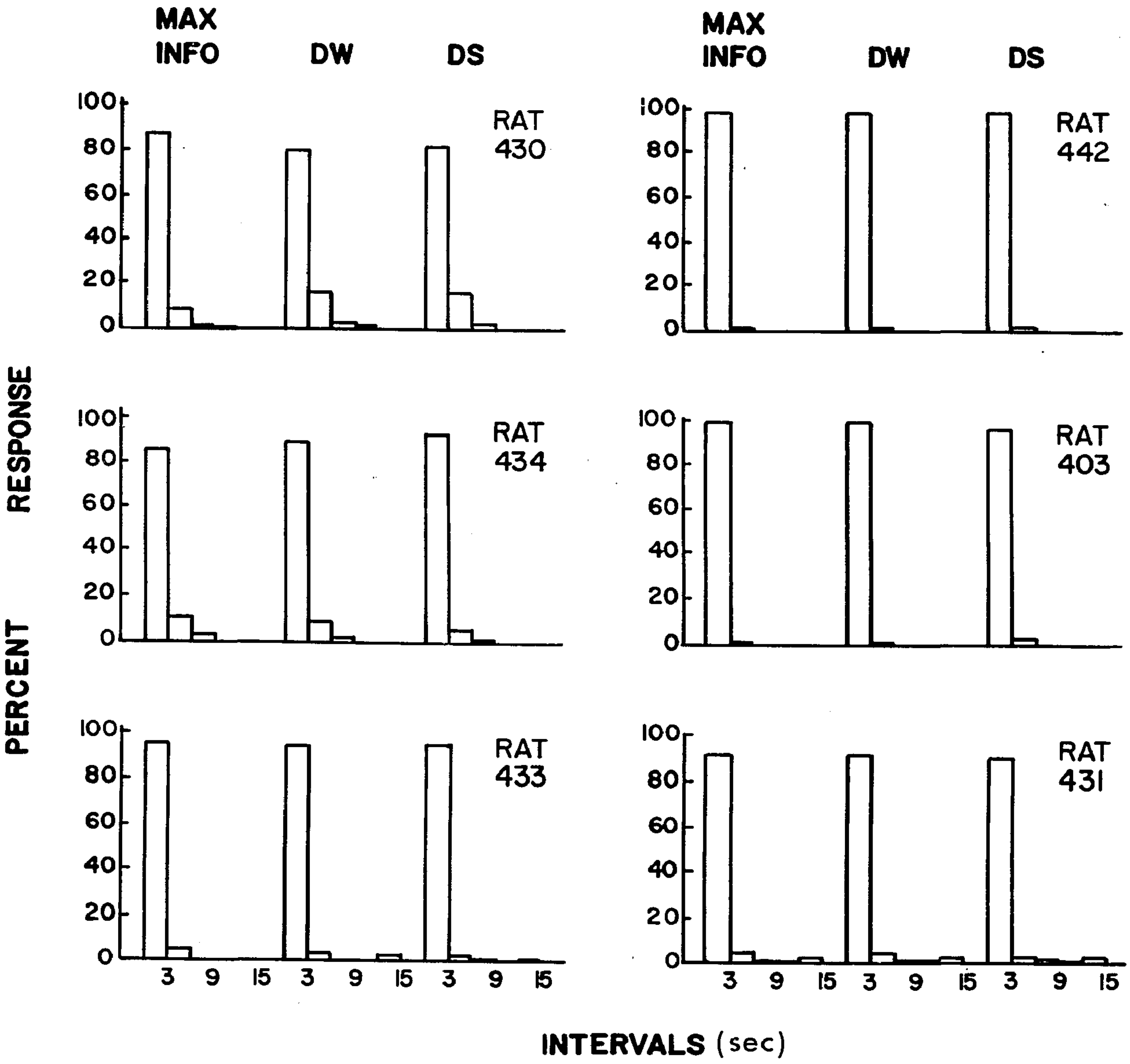

MAX INFO
DW
DS
MAX INFO
DW
DS
RAT 430
RAT 442
RAT 434
RAT 403
RAT 433
RAT 431
100
80
60
40
20
0
PERCENT RESPONSE
3
9
15
INTERVALS (sec)

Table G

Difference in Weights (grams) of Rats Between the First Four and Last Four Sessions of Training Under Each Experimental Condition[a]

Rat No.	Condition				
	MAX INFO	DW	MAX INFO	DW	MAX INFO
430	-4.0	6.0	-8.8	-0.5	-5.0
434	6.5	20.5	-11.0	24.8	8.2
433	-6.8	28.0	38.2	15.8	5.0
	MAX INFO	DS	MAX INFO	DW	MAX INFO
442	-9.8	16.0	28.0	-2.5	2.0
403	-12.8	4.5	-7.0	8.0	-4.8
431[b]	---	---	---	3.2	14.2

---

[a] Rats were weighed at the beginning of each session. The mean weight for sessions 1-4 for each experimental condition was subtracted from the mean weight for sessions 21-24 of that condition for each rat.

[b] Data for this rat were not available for the first three conditions.

APPENDIX IV

Figure J. Probability of a response for each rat in Experiment 4 over successive sessions of operant level exposure. The schedule was identical to the procedure described for the MAX INFO condition (see General Method section) with the exception that the shock source was disconnected and only 100 trials per session were scheduled.

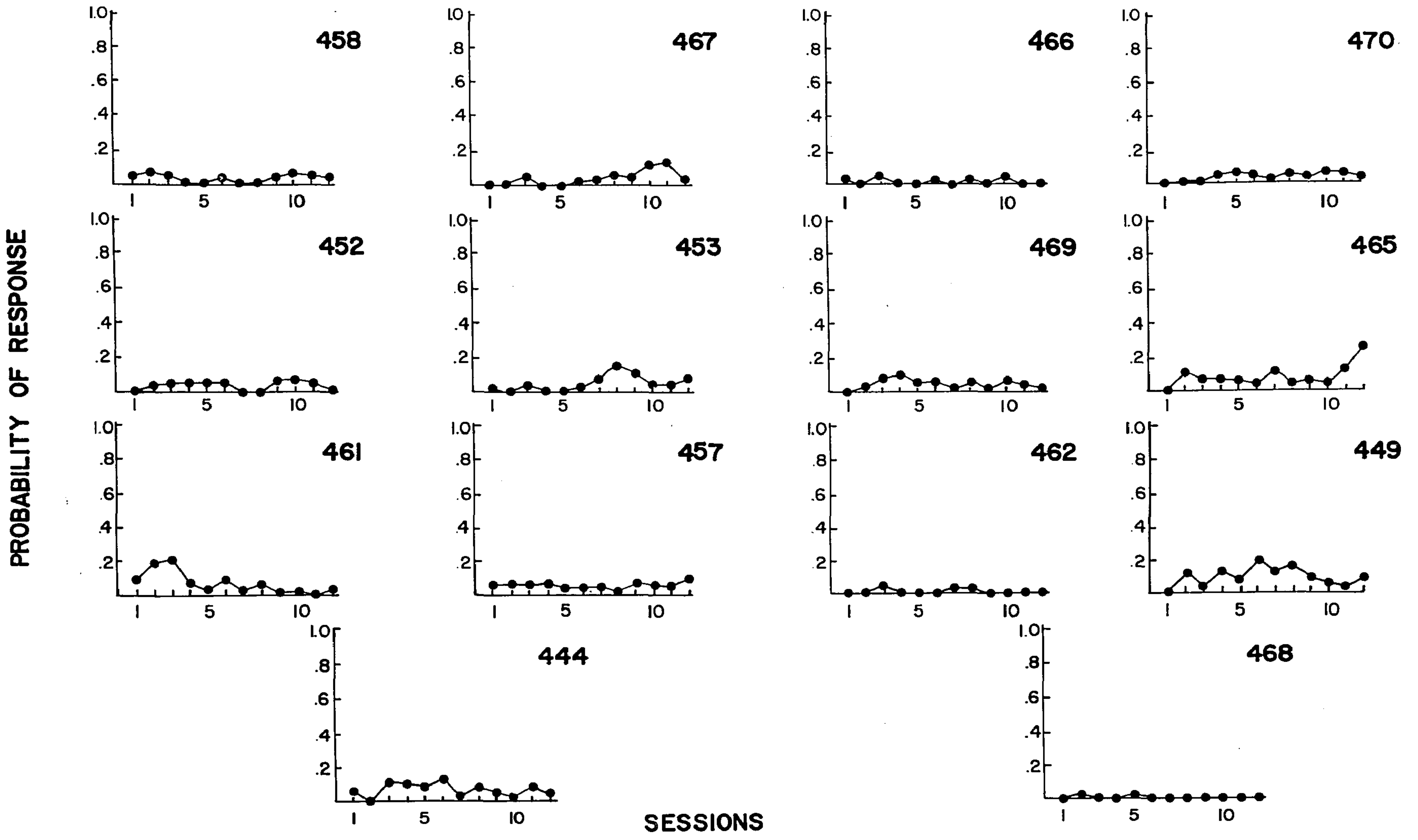

PROBABILITY OF RESPONSE
SESSIONS
458
467
466
470
452
453
469
465
461
457
462
449
444
468
1.0
.8
.6
.4
.2
1
5
10

Figure K. Percent of shock trials avoided over sessions for rats in Experiment 4. Shaping trials are excluded. There were 400 trials per session.

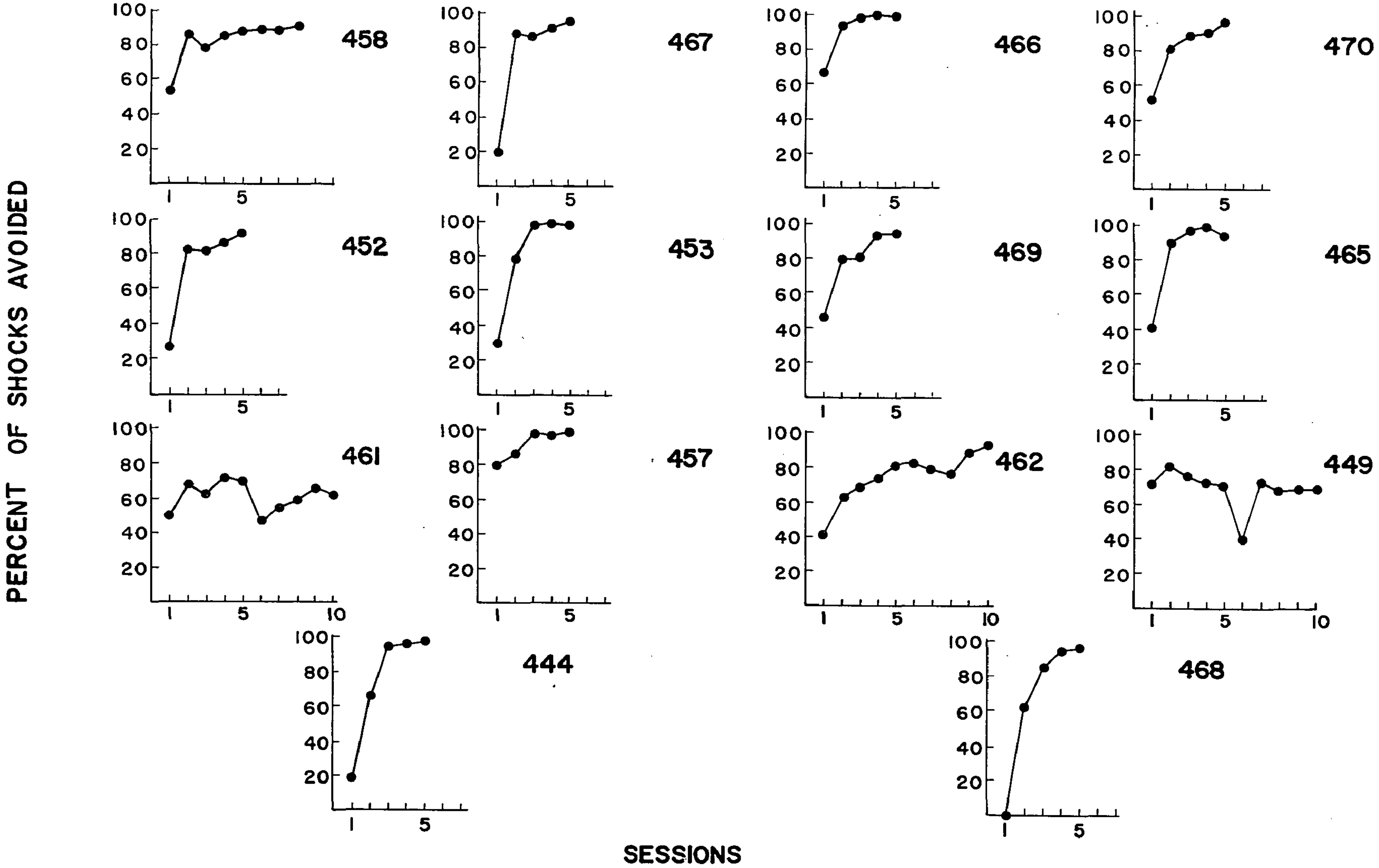

PERCENT OF SHOCKS AVOIDED
SESSIONS
458
467
466
470
452
453
469
465
461
457
462
449
444
468
100
80
60
40
20
1
5
10

Table H

Summary of Analysis of Variance of Mean Response Probability Over Initial and Final MAX INFO Conditions for Subjects Given Click as the Warning Signal vs. Subjects Given Noise as the Warning Signal

Source	SS	df	MS	F
(A) Click vs. Noise	79.23	1	79.23	< 1
(S/A)	8,453.25	12	704.44	
(B) Initial vs. Final MAX INFO	47.58	1	47.58	< 1
(A) x (B)	.30	1	.30	< 1
(B) x (S/A)	2,477.35	12	206.44	
Total	11,057.71	27		

Table I

Sequences Used to Schedule Signal and Shock Trials for the Degraded Warning Condition in Experiment 4[a]

			Trials		
1.	NNCNNNCCCC 0010000111	8.	CCNCNNNNCC 0001000011	15.	NNCNCNNCCC 0000100011
2.	CNCNCNNNCC 1000100010	9.	NCCCCCCNNN 0000111000	16.	CCCNNCNNNC 1000010001
3.	NCCNCNCCCN 0110000110	10.	NCCNCNNCNC 0110100001	17.	NNNCCNCNCC 0001100011
4.	NCCNNNCCCN 0010001110	11.	NCCCCCCNCC 0011101011	18.	CNNCCCNNNC 0000110001
5.	NNNCNCNCNC 0001010001	12.	NCNCNNNNCC 0001000010	19.	NCNNCCNNCN 0000100010
6.	CNNNCCNCNC 1000010001	13.	NNNCNNCCNN 0001001000	20.	NNCNNNCCNN 0010000100
7.	NNCNCNNCCC 0000100011	14.	CCNCNNCCCC 1100001111		

---

[a] The letters C and N represent click and noise trials and the digits 1 and 0 represent shock and nonshock trials. The shock series used in Experiments 1 and 3 was modified to provide 133 nonshock trials and 67 shock trials. In addition, the click and noise trials were scheduled in accordance with the conditional probabilities of shock given a particular signal as described in the text. The role of the signals was counterbalanced by reversing the click and noise signals.

Table J

Sequences Used to Schedule Signal and Shock Trials for the Degraded Safe Condition in Experiment 4[a]

	Trials	
1. NCNCNCCCNN 0111011101	8. CNNNNNNCCC 1111000111	15. NNNCCNCCCN 0111101110
2. CNNCNCNNNC 1001111001	9. CNNCNCCNCN 1001011110	16. CCCNNCNCNN 1110011100
3. CNNCCCNNNC 1101110001	10. CNNNNNNCNN 1100010100	17. NCCNNNCCCN 1111001110
4. CCCNCNCNCN 1110101110	11. CNCNCCCCNN 1110111101	18. CNCCNNCCNC 1111011101
5. NCCCNNCNCN 0111101110	12. CCCNCCNNCC 1110110111	19. CCNCCCNNCC 1101111011
6. CCNCNCCNNN 1111011100	13. NNCNCCNNNN 0011110000	20. CCNCCCNNNN 1101111000
7. NNCNCCCCNN 1110111100	14. CCNCNCCNNN 1111011100	

---

[a] The same procedure was used to generate signal and shock sequences as described in Appendix IV, Table H with the exception that 67 non-shock trials and 133 shock trials were scheduled here.

Figure L. Latency of response represented as the percent of total responses in each of five consecutive 3-sec periods during the 15-sec trial for each rat in Group DW. A mean of the last eight sessions in each condition is shown.

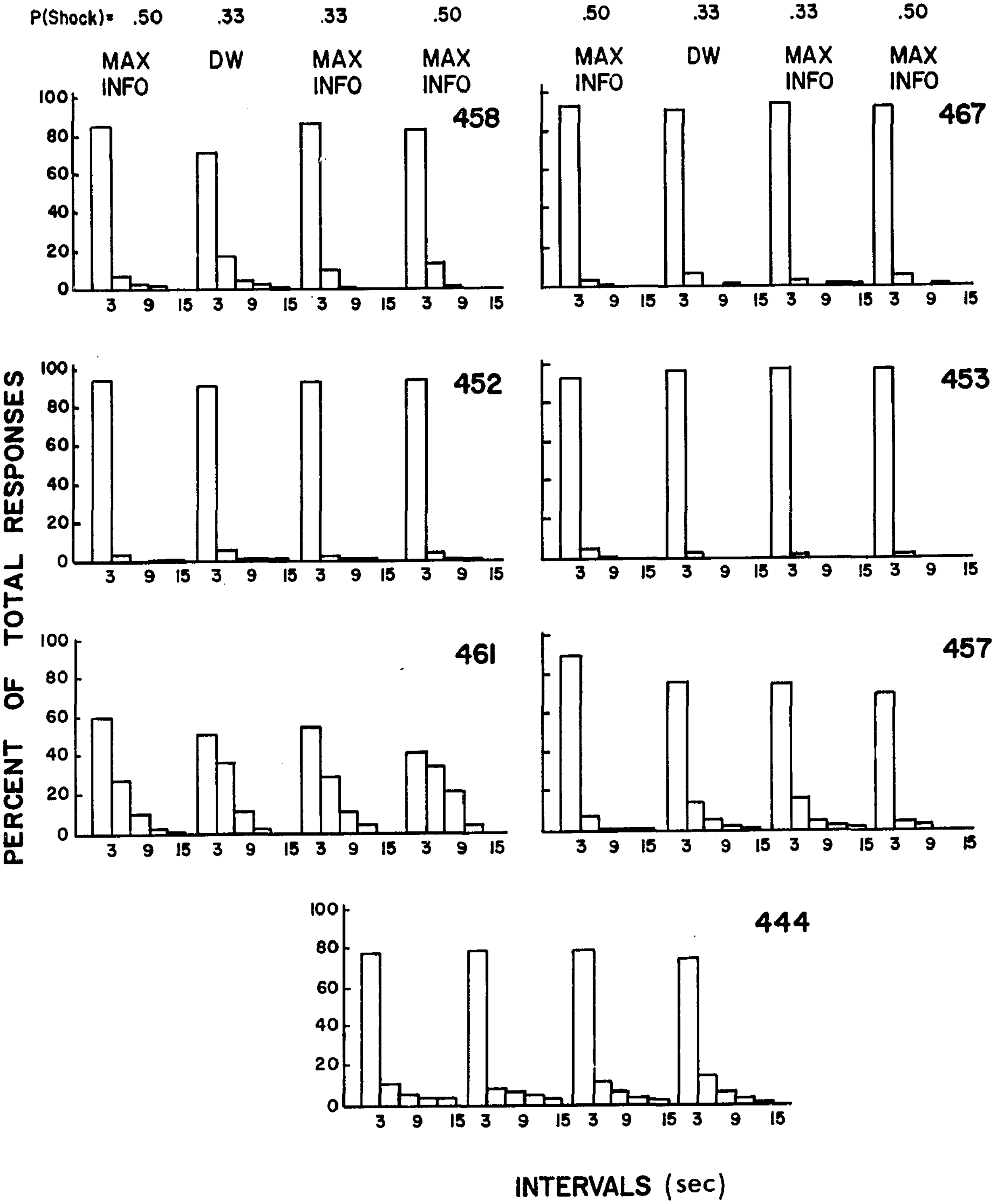

P(Shock)= .50
.33
.33
.50
.50
.33
.33
.50
MAX INFO
DW
MAX INFO
MAX INFO
MAX INFO
DW
MAX INFO
MAX INFO
458
467
452
453
461
457
444
100
80
60
40
20
0
3
9
15
PERCENT OF TOTAL RESPONSES
INTERVALS (sec)

Figure M. Latency of response represented as the percent of total responses in each of five consecutive 3-sec periods during the 15-sec trial for each rat in Group DS. A mean of the last eight sessions in each condition is shown.

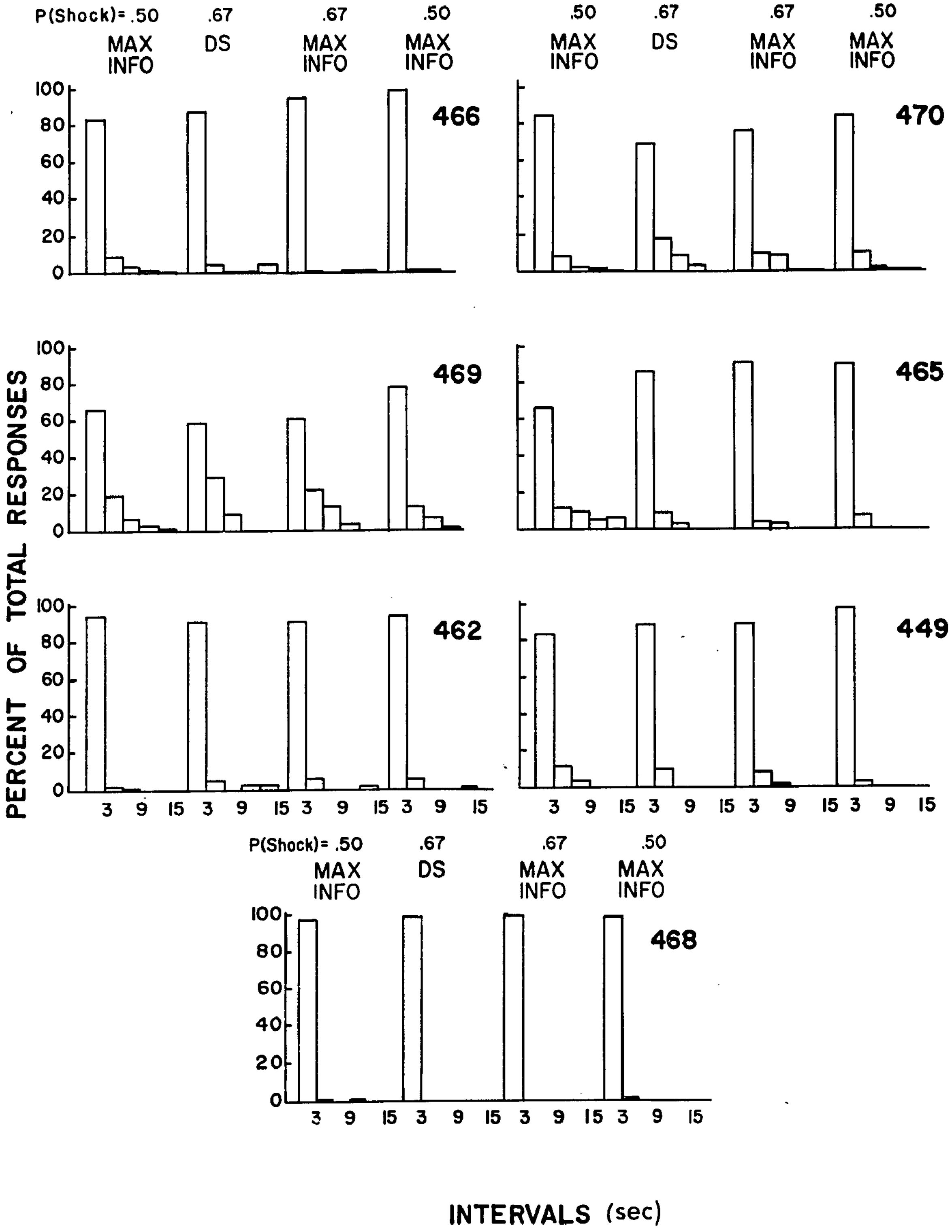

P(Shock)= .50
.67
.67
.50
MAX INFO
DS
MAX INFO
MAX INFO
.50
.67
.67
.50
MAX INFO
DS
MAX INFO
MAX INFO
466
470
469
465
462
449
468
100
80
60
40
20
0
PERCENT OF TOTAL RESPONSES
3
9
15
P(Shock)= .50
.67
.67
.50
MAX INFO
DS
MAX INFO
MAX INFO
INTERVALS (sec)

Table K

Difference in Weight (grams) of Rats Early and Late in Training Under Each of the Four Experimental Conditions[a]

Rat No.	Condition			
	MAX INFO P(Sh) = .5	DW P(Sh) = .33	MAX INFO P(Sh) = .33	MAX INFO P(Sh) = .5
458	9.4	13.2	6.4	-6.5
467	26.0	19.4	6.3	14.3
452	25.0	33.0	24.4	20.7
453	24.5	21.5	15.4	18.5
461	19.4	13.0	18.3	29.0
457	24.8	15.8	16.5	11.0
444	11.0	1.0	7.5	14.4
Mean	20.0	16.7	13.5	14.5
	MAX INFO P(Sh) = .5	DS P(Sh) = .67	MAX INFO P(Sh) = .67	MAX INFO P(Sh) = .5
466	5,8	20.6	27,8	21.2
470	27.0	31.3	14.0	17.5
469	25.0	2.4	-2.2	37.8
465	14.0	9.6	6.2	6.3
462	13.7	10.3	13.2	8.0
449	33.0	17.3	25.8	27.0
468	10.0	9.3	18.7	11.0
Mean	18.4	14.4	14.8	14.8

---

[a] The mean weight during sessions 1-4 was subtracted from the mean weight for sessions 21-24 for each rat.

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