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THE EFFECT OF INTERPOLATED EXTINCTION TRAINING ON THE REVERSAL OF A SIMULTANEOUS BRIGHTNESS DISCRIMINATION

by

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ABSTRACT

THE EFFECT OF INTERPOLATED EXTINCTION TRAINING ON THE REVERSAL OF A SIMULTANEOUS BRIGHTNESS DISCRIMINATION

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Reversal learning, which involves the extinction of the original discrimination and the acquisition of the reversed discrimination, logically should be facilitated by extinction training interpolated between discrimination and reversal learning. However, in the several experiments that have employed interpolated extinction training, it has not served to facilitate (or protract) reversal learning. The focus of this investigation is on the process that underlies this phenomenon and on the relevant theoretical approaches.

In automated shuttleboxes, 108 albino rats received 20 noncorrection trials per day until they learned a simultaneous brightness discrimination. They were then matched and assigned to nine groups. In a 3x3 factorial design, each group received interpolated training with one of the possible combinations of stimulus and reinforcement experience: Each stimulus could be present for ten reinforced daily trials, present for ten nonreinforced daily trials, or absent during the five days of interpo-

lated training. All groups then learned the discrimination reversal.

As in previous studies, the interpolated extinction training did not alter the number of days required to meet the reversal criterion. In contrast to the analysis of overall reversal performance, other analyses indicated that significant changes within the course of reversal learning did occur. Interpolated extinction training significantly facilitated the first part of reversal learning and, to a corresponding degree, protracted the later parts.

It was concluded that interpolated extinction training produces multiple effects on reversal learning; these effects operate in opposing directions at different points in the course of reversal learning. The observation of sequentially contravening effects is incompatible with theoretical approaches such as attention theory that postulate the dissociation of a secondary, mediating process of learning during interpolated extinction training and the consequent protection of the original discrimination associations from the extinction effects. A single process, associative model was proposed that can accommodate the observed changes within specified parts of reversal learning as well as the overall reversal performance following interpolated extinction training. This model can also account for the overtraining reversal effect.

The significant interaction between the effects of interpolated experience with each stimulus indicates that reversal learning is more appropriately viewed as a relationship between two sets of stimulus-reinforcement contingencies than as an algebraic difference between independent response gradients along the given stimulus dimension. In light of the observed interaction, it becomes appropriate to assess independent stimulus effects only when found significant beyond any interaction effect that may be present. There was an independent effect of interpolated experience with the stimulus nonreinforced in reversal learning. Moreover, any interpolated experience that did not include this stimulus and couple it with nonreinforcement served to protract reversal learning.

A general implication of the sequential contravention conclusion is that manipulations conceived as a single operation, such as extinction training, need not have simple and unidirectional effects. A related implication is that the reversal learning process is not adequately represented by single measures of overall performance, such as trials or days to meet a performance criterion. Analyses of individual learning phases are necessary.

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I appreciate the guidance and encouragement received from my supervisory committee: Dr. Harry M. Jagoda, Dr. May D'Amato, and Dr. Solomon Weinstock.

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The reversal of a discrimination is generally considered to involve at least two essential steps. Reversal learning is described by Sutherland and Mackintosh (1971, p. 258) "as consisting of two parts: first, the extinction of the original discrimination, and second, the acquisition of the reversal discrimination." Sperling (1970) includes the same basic components in her three-phase concept of reversal learning.

It follows that extinction training, interpolated between the acquisition of a discrimination and its reversal, should hasten the extinction of the original discrimination response habits and thereby facilitate reversal learning. However, this expected facilitation has not been observed. Interpolated extinction training has been found to produce no facilitation (or protraction) of reversal learning, as compared with reversal learning not preceded by interpolated training. This paradoxical extinction effect (PERE) is the focus of the present investigation. The PERE problem has remained unresolved since its original report by D'Amato and Jagoda in 1960.

<u>PERE Background</u>

D'Amato and Jagoda (1960) tested the hypothesis that interpolated extinction trials would reduce the number trials required to learn the reversal of a brightness discrimination. In an automated Y-maze, rats were either given 60 extinction trials or reversed immediately upon meeting the discrimination criterion. Considering the extinction trials not as part of the reversal training but as a seperate stage of training interpolated between discrimination and reversal learning, the two groups did not differ in their reversal learning facility.

Reviewing the effect of interpolated extinction training on reversal learning, Sperling (1965) concluded: "Interspersed extinction, then has no apparent effect on reversal learning per se." Given the peculiarity of such a conclusion and its implications for established learning principles, Sperling speculated that D'Amato and Jagoda's 60 interpolated extinction trials may not have provided sufficient extinction of the original discrimination response habits for the predicted reversal facilitation to occur.

Because the PERE seems so discrepant with the usual effects of extinction training and with the view of reversal learning as fundamentally the same process as discrimination learning, a study (unpublished, 1970) was conducted in Jagoda's lab to test the earlier PERE report and to take into account Sperling's speculation that 60 extinction trials may not have been sufficient. Upon learning a simultaneous brightness discrimination in an automated shuttlebox, 30 rats were matched for discrimination performance and assigned to three groups. Group C began reversal training on the day following the meeting of the discrimination criterion. Group E-20 received 20 nonreinforced trials (10 with each stimulus) per day for 10 days prior to reversal training. Group E-50 received 50 nonreinforced trials (25 with each stimulus) per day for 4 days. Groups E-20 and E-50 both received a total of 200 interpolated extinction trials. Group E-50 was included to test the possible effect of denser massing of the extinction training; Stanley (1952) found that greater massing of extinction trials produced greater extinction effects on discrimination learning where learning was measured by stimulus choice.

Groups C, E-20, and E-50 did not differ significantly in the number of days required to meet the reversal criterion ($F < 1$, $df = 2,16$). Figure 1 shows the daily reversal performance for each of the three groups. The curves are virtually identical. Thus, the PERE was replicated; 200 interpolated extinction trials did not facilitate reversal learning.

Scope and Purpose

The PERE has been studied and consistently observed in simultaneous brightness discriminations. The scope of the present inquiry is limited to those situations.

The purpose of this investigation is to test the reliability of the PERE and to determine the process that underlies it. The implications of the PERE and its underlying process for current theories that bear on rever-

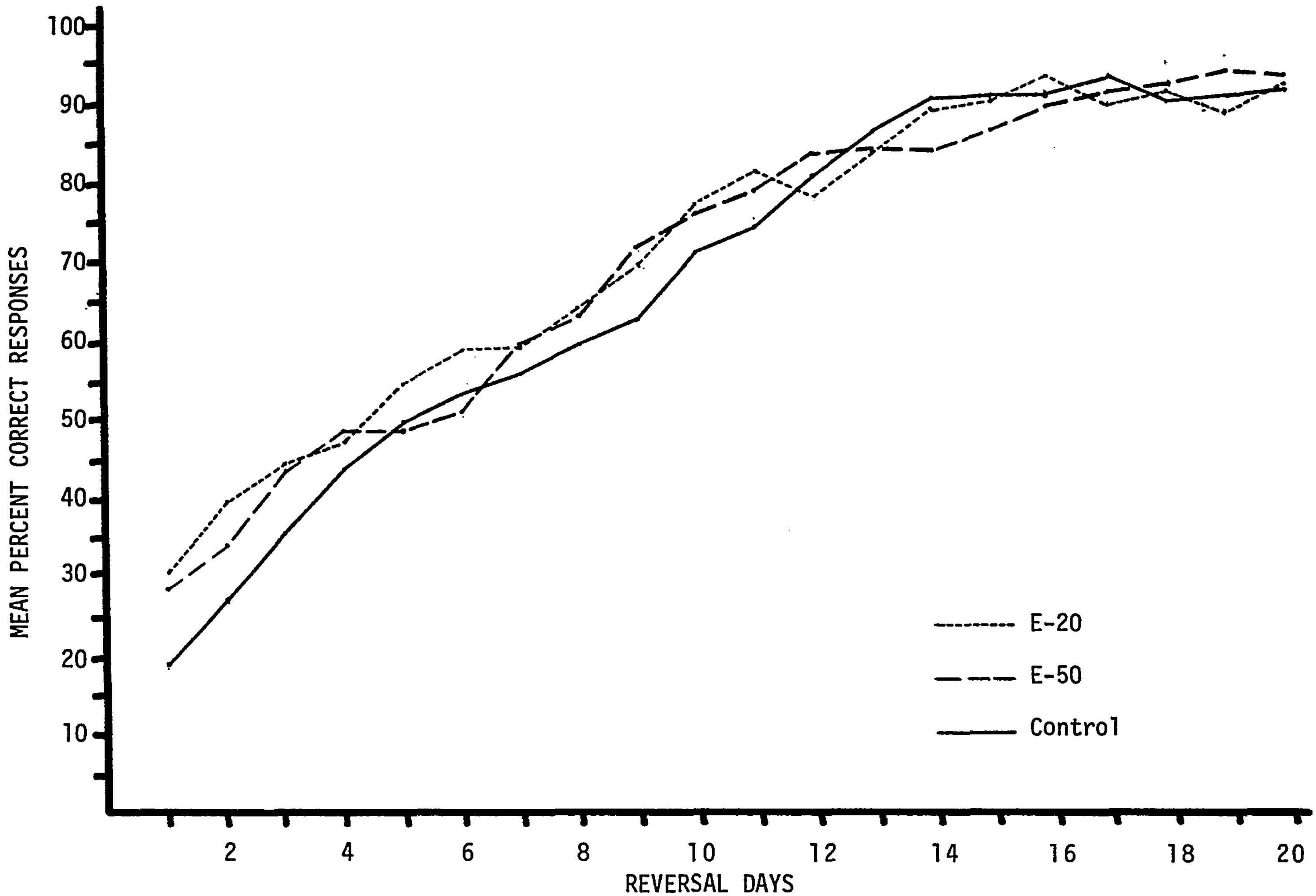

Fig. 1. Daily Mean Percent Correct Responses in Reversal Learning for Groups Receiving Interpolated Extinction Massed at 20 or 50 Trials per day and for a Control Group Receiving No Interpolated Training.

sal learning will be explored.

Theoretical Approaches

Current theoretical approaches to reversal phenomena are usually dichotomized as single and dual process approaches. Single process approaches explain reversal behavior in terms of an associative process. Dual process approaches include this associative process and postulate a second, mediating process, such as attending to the appropriate stimulus dimension, that governs the extent to which the associative process may operate. This dichotomy, though traditional, is of limited value here, for it does not closely correspond to the differential predictions of the several theoretical approaches that relate to reversal phenomena.

A different classification of theoretical approaches seems more appropriate for the investigation of the PERE. One group of approaches posits the operation of some factor to suspend modifications of associations and thereby to protect the response habits from change during interpolated training. The locus of this factor may be internal, such as the central or peripheral mediators of attention theory, or it may be external and reside in the nature of the learning situation. Thus, protection approaches may include both single and dual process theories.

A second group of approaches postulates effects of interpolated training that can counteract each other.

Contravention approaches do not postulate the suspension of the associative process during interpolated training. They may be viewed as single process, in that only an associative process is involved. They may also be viewed as dual process, in that the operation of two effects is proposed to result from interpolated training and to independently influence reversal performance.

Protection Approaches

Attention theory. Of the approaches that predict that interpolated extinction will not substantially reduce the response strength of the original discrimination habits, attention theory enjoys the greatest current popularity. Models of reversal learning based on selective attention to the relevant stimulus dimension were proposed by Lovejoy (1966), Mackintosh (1965), Sutherland (1959), and Trabasso and Bower (1968). The most comprehensive exposition of attention theory, and its most developed model, is provided by Sutherland and Mackintosh (1971).

Attention theory can readily accommodate the PERE. If interpolated extinction training serves to rapidly extinguish attention to the appropriate stimulus dimension before the specific response associations can be substantially diminished, then the original discrimination will survive the interpolated extinction training intact.

Sutherland and Mackintosh (1971, p. 268) explain:

> During extinction trials, the relevant analyzer is extinguished to the point where it no longer controls behavior and subjects respond at chance with respect to the relevant cue. The responses attached to the outputs of the analyzer, however, have not been equalized, although this is not apparent from the subject's choice behavior since his behavior is now predominantly controlled by some other analyzer.

Interpolated extinction training is thought to cause attention to shift away from the brightness dimension and so protect the original discrimination associations from substantial diminution.

If the original discrimination response habits are found to survive interpolated extinction training substantially undiminished, attention theory will remain a viable approach to the PERE. If, however, the original discrimination response habits are substantially reduced, attention theory will be incompatible with the observed behavior.

Attention theory provides a second prediction that, although not directly related to the PERE, is testable in the present study. Overtraining the discrimination prior to reversal should strengthen the brightness analyzer; this should result in fewer responses to stimulus dimensions other than brightness during reversal learning. Less position-based responding is predicted in reversal following overtraining. In Sutherland and Mackintosh's

(1971, p. 468) formal model, Rule E-39 states: "overtraining decreases the number of responses to irrelevant cues made in the course of reversal learning, and results in a shorter plateau (at 50% correct) in the course of reversal." This prediction would be confirmed by a reduction in position-based responding during reversal following interpolated overtraining; it would remain unconfirmed if the position-based responding following interpolated overtraining is increased or unchanged.

Attention theory provides a third prediction that is testable in this study. Forced reversal training, experienced during what ordinarily would be the period of position-based responding in which the brightness analyzer is claimed to be switched out, should retard reversal learning. Sutherland and Mackintosh's (1971, p. 465) Rule E-8 states; "Giving reversal pretraining while animal's responses are controlled by a position habit retards subsequent learning." Slower reversal learning by subjects learning the middle phase under forced reversal conditions is predicted.

In summary, the prediction by attention theory that bears directly on the PERE is the postulated switching out of the brightness analyzer that serves to protect the discrimination from the effects of interpolated extinction. This mechanism, note Hilgard and Bower (1966), enables attention theory to explain why a discrimination habit "can be preserved more or less intact" throughout interpolated training.

Yet, the prediction of protection of the discrimination during interpolated extinction training can also stem from approaches that require no second, mediating learning process.

Cue function approach. D'Amato and Jagoda (1960) hypothesized that the presence of reward in the learning situation may serve to maintain the original response tendencies during reversal learning: "if reward were removed from the situation, at least for a time, reversal learning might be facilitated." They concluded that the presence of reward does serve as a "cue factor" which maintains the original response habits.

Two predictions issue from the cue function approach. The first is the protection prediction, identical in result to the major prediction of attention theory, but based on an external mediator. If the response associations of the original discrimination are not salient during interpolated extinction training due to the absence of reward but are resurrected upon the re-introduction of reward when reversal training begins, then the original response habits will be protected from the effects of interpolated extinction training.

The second prediction concerns an interpolated condition in which both stimuli are experienced and both are reinforced. The presence of reinforcement should maintain the salience of the original response habits and render them more vulnerable to equalization during such interpolated training. Consequently, interpolated training in which both stimuli are present and reinforced should result in less resistance to extinction of the original discrimination response habits during reversal learning and faster meeting of the reversal learning criterion.

The differential reinforcement approach. The differential reinforcement approach also predicts the protection of the original discrimination without postulating a second learning process within the subjects. Discrimination learning is fundamentally acquiring differential responses to distinguishable stimuli as a result of their contrasting reinforcement contingencies. Perhaps differential reinforcement is essential for the learning or reversal of a discrimination. This view is supported by the results of Andelman and Sutherland (1970) and Fox et al. (1970). As opposed to concepts of discrimination based on algebraic differences between independent gradients along a given stimulus dimension, the differential reinforcement approach emphasizes the nature of the relationship among stimulus-reinforcement combinations.

The differential reinforcement approach predicts that, in the absence of at least two differentially reinforced stimuli, discrimination learning is simply not subject to much acquisition or extinction. This approach accounts for the PERE via the suspension of the discrimination learning situation due to the absence of differential reinforcement during interpolated extinction training. In addition to the protection prediction, this approach predicts that subjects given any interpolated training that includes differential reinforcement will undergo considerable modification of the original discrimination response habits, while other subjects will not.

The protection approaches, in common, predict the survival with little diminution of the original discrimination through interpolated extinction training, and thus account for the PERE. These approaches also generate other testable and unique predictions that permit empirical evaluation.

Contravention Approaches

Contravention accounts of the PERE propose that interpolated extinction training produces more than one effect on reversal performance and that these effects counteract each other.

Contravention approaches are based on a peculiar aspect of extinction training. In providing nonreinforcement for responses to each of the stimuli, extinction training incorporates reversal training of the originally reinforced stimulus and overtraining of the originally nonreinforced stimulus. Contravention approaches propose that these two components serve respectively to facilitate and to protract reversal learning, thus producing a net cancellation of extinction training effects on reversal learning.

Simultaneous contravention. If interpolated extinction training produces counteracting effects, it is possible that these effects operate at the same point within the course of reversal learning. The simultaneous contravention hypothesis would be supported by the observation of the PERE plus the equivalence of reversal performance at every phase of reversal learning by the group receiving interpolated extinction training and by the group reversed with no training interpolated between discrimination and reversal learning. Differences between these groups at any reversal phase would disconfirm the simultaneous contravention hypothesis.

Sequential contravention. It is also possible that interpolated extinction training produces counteracting effects that operate at different points within the course of reversal learning.

This approach depends, for the measurement of relevant behavior, on the assumption that reversal learning consists of distinguishable phases. As mentioned earlier, Sutherland and Mackintosh (1971) think that reversal learning consists of an extinction phase and a reversal learning phase. Sperling (1970) delineates an extinction phase, a position-based responding phase, and a reversal learning phase. The notion of distinct reversal learning phases need not be accepted at this point, however. If the phases differentiated do not correspond to reversal behavior, differences among the groups at different phases simply will not emerge. On the other hand, the emergence of such differences would support the appropriateness of the phase representation of reversal learning.

The specific predictions of the sequential contravention approach are also based on a view of extinction training as involving reversed and overtrained stimulus components. Interpolated extinction training is predicted to produce the response-strength decrement in accord with general learning principles. Therefore, such training should reduce the perseveration of the original discrimination response habits during reversal learning. In addition, interpolated extinction training is predicted to produce other effects that operate at later phases of reversal learning to counteract the facilitation of reversal learning by reduced perseverative responding. If these contravening effects are about equal, the interpolated extinction group will not differ in overall reversal speed from the group receiving no interpolated training prior to reversal learning.

Several theoretical approaches that might account for the PERE have been proposed. Some posit protection of the discrimination during interpolated extinction training. Other approaches suggest multiple effects of extinction training that can contravene. Whatever process underlies the PERE, the observed reversal behavior must be based on the effects of experience with specific stimuli.

The Role of Experience with Each Stimulus

The role of each stimulus in reversal learning has been considered by D'Amato and Jagoda (1960, 1961). In their view at that time, the most crucial part of reversal learning is to extinguish the tendency to avoid the previously negative stimulus. In recent years however, Jagoda has come to view the acquisition of the tendency to avoid the previously positive stimulus as the most important part of reversal learning. D'Amato (1969) has expressed the same revised view. Stevens and Fechter (1967) provided interpolated nonreinforced experience with the previously reinforced stimulus for one group and found faster reversal learning than exhibited by another group given reinforced experience with the previously nonreinforced stimulus.

If reversal learning obeys the same laws as discrimination learning in general, evidence concerning the role of each stimulus in discrimination learning becomes relevant. A larger body of literature becomes available; it supports the attribution of greater importance to experience with the nonreinforced stimulus.

Denny and Dunham (1951) held the number of reinforced trials constant and varied the number of nonreinforced trials. They found that greater amounts of nonreinforcement resulted in faster discrimination learning. Fitzwater (1952) investigated the relative influence of different proportions of reinforced and nonreinforced trials while holding the total number of trials constant. He concluded that "an appreciable discrimination does not seem to occur if an approach habit is established alone." Birch (1955) observed that differential ratios of nonreinforcement resulted in differential discrimination proficiency. Lachman (1961) used three ratios of reinforced and nonreinforced trials. He determined that "Discrimination learning was decreased by a relatively large proportion of forced choices to the rewarded cue and enhanced by a greater proportion of forced choices to the nonrewarded cue." Mandler (1970) used a substitution technique in which one of the discriminative stimuli was varied for each of the groups; the nonreinforced stimulus experience was again found to be the most crucial. Olton (1972) also found that experience with the nonreinforced stimulus has a greater influence on discrimination learning than experience with the reinforced stimulus.

The present study is intended, as a secondary purpose, to assess the contribution of each stimulus to reversal learning.

The Interaction of Experience with Each Stimulus

If discrimination learning is fundamentally the acquisition of a relationship between response tendencies associated with each stimulus, it may not be appropriate to simply consider the independent contribution of experience with each stimulus.

Discrimination learning was defined by Kimble (1961, pp. 362-364) as maintaining response strength to one stimulus through reinforcement while reducing response strength to another stimulus through extinction. "Looked at in operational terms, one fact about discrimination learning is inescapable: The procedure is a combination of two simpler procedures." Spence (1937) viewed discrimination learning as the development of positive and negative generalization gradients; the form of each gradient was thought to be determined independently by experience with the relevant stimulus.

But recent research indicates that discrimination learning is more complex. Honig, Thomas, and Guttman (1959) found that the "combination of generalization gradients for reinforcement and for extinction fails to account for discrimination gradients." Hanson (1959) reached a similar conclusion. Reynolds (1961) found that nonreinforcement of the negative stimulus increased response strength to the positive stimulus. Lachman (1961) observed that discrimination learning was facilitated by the visibility of the second stimulus as well as the first at the choice point. Fox et al. (1970) reported that the performance to one cue may depend upon the contingencies and presence of the other cue.

Discrimination, then, may well consist of more than the simple effects of experience with the individual stimuli. To the extent that discrimination is basically a relationship between the effects of stimulus experience, those effects will prove interactive. The present study will manipulate the experience with each stimulus factorially during interpolated training. The interaction between the effects of interpolated experience with each stimulus can thus be assessed.

If there is no significant interaction between the effects of interpolated training with each stimulus, consideration of independent stimulus effects will be appropriate. However, if a significant interaction effect emerges, consideration of independent stimulus contributions will be inappropriate. In the presence of a significant interaction effect, individual stimulus contributions should be reported only where they are found significant over and above the interaction effect.

Summary

Current theoretical approaches relevant to the PERE have been examined. Protection approaches predict that the discrimination is not subject to much modification during interpolated extinction training. Contravention approaches predict that the extinction training produces multiple and counteracting effects on reversal learning. The several protection and contravention approaches also generate predictions unique to each, permitting assessment of the approaches subsumed by each. The contribution of experience with each stimulus, and the possible interaction of experience with each stimulus, will be evaluated.

METHOD

Subjects

Twenty-two days prior to the first day of discrimination training, 119 female albino rats of strain CFE, weighing 170-180 gm. were supplied by Carworth, Inc. (Rockland County, New York). In the course of the experiment, four Ss were dropped due to programming errors; five Ss, matched with the above four Ss, were dropped to equalize the cells; and two Ss were run through discrimination acquisition as spares. Data from the dropped and spare Ss are excluded from all analyses.

Environmental conditions. The Ss were housed in pairs in 7x7x14-inch cages made of stainless steel mesh. Food (Purina Lab Chow) was always available in the home cages. The animal colony temperature was automatically maintained at 72°F. 4°. Relative humidity was automatically maintained at 55% ±10%. The air was filtered and passed through ultra-violet radiation from germicidal lamps. The daily illumination cycle was 12 hours each of light and darkness.

Apparatus

The apparatus included six identical shuttleboxes constructed by Lehigh Valley Electronics, Inc. The internal dimensions of each shuttlebox were: 18" long, 8¼" wide, and 7½" high. The long walls and hinged lid were made of transparent plexiglass. The floor consisted of steel rods, $\frac{1}{8}$" in diameter. It toggled on a central pivot, producing a maximum vertical excursion of $\frac{1}{4}$" at each end. S's location was registered at any given moment by the position of the toggle floor. Beneath the floor was an excreta pan. The shuttlebox is pictured in Figure 2.

At each end of the shuttlebox was an aluminum intelligence panel, $8\frac{1}{4}$" wide and $7\frac{1}{2}$" high, with a low-reflectance black coating. The intelligence panel, as visible to S at the beginning of each trial, is shown in Figure 3. In each panel were two openings, $1\frac{1}{2}$" square, spaced $4\frac{1}{2}$" between centers. Within each of the openings was a "stimulus-response-reinforcement chamber" (SRRC). Each SRRC was $2\frac{1}{2}$" deep. The SRRC design provides spatial fusion of the presentation of stimuli, the registration of responses, and the delivery of reinforcement. The SRRC's appear in Figure 3 and are illustrated in cross-section in Figure 4.

Stimuli were produced by a General Electric #304 24-volt Aircraft-Type lamp, housed behind a diffusion panel. This panel was made of transluscent plexiglass, $1\frac{1}{2}$" square, located at the end of each SRRC. The bright stimulus (S1) was produced by supplying 24 volts D.C. to the stimulus lamp. The dim stimulus (S2) was produced by supplying 8.5 volts D.C. to the stimulus lamp. As viewed from the aperture in the barrier, the stimuli were sepa-

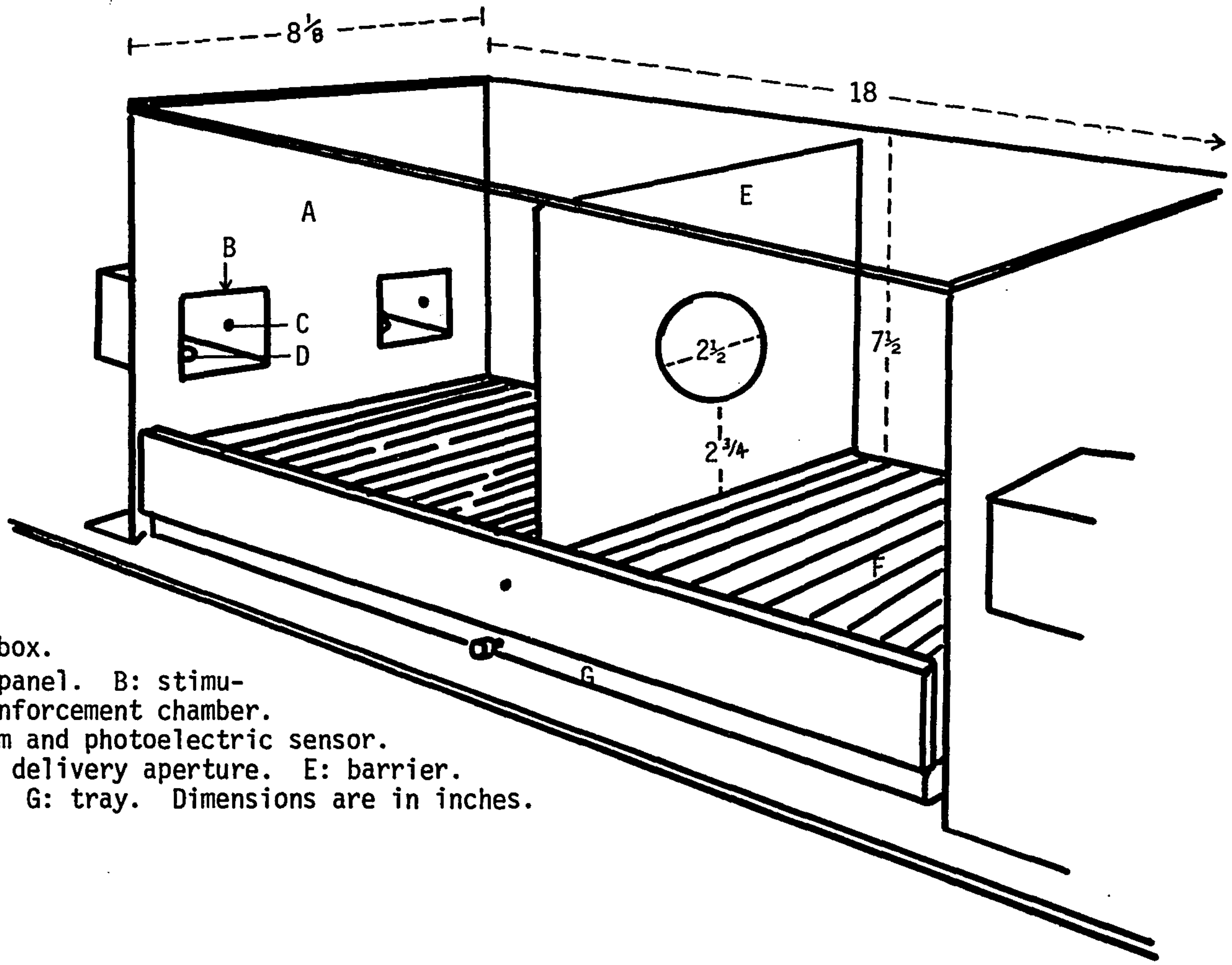

Fig. 2. Shuttlebox.
A: intelligence panel. B: stimulus-response-reinforcement chamber.
C: red light beam and photoelectric sensor.
D: reinforcement delivery aperture. E: barrier.
F: toggle floor. G: tray. Dimensions are in inches.

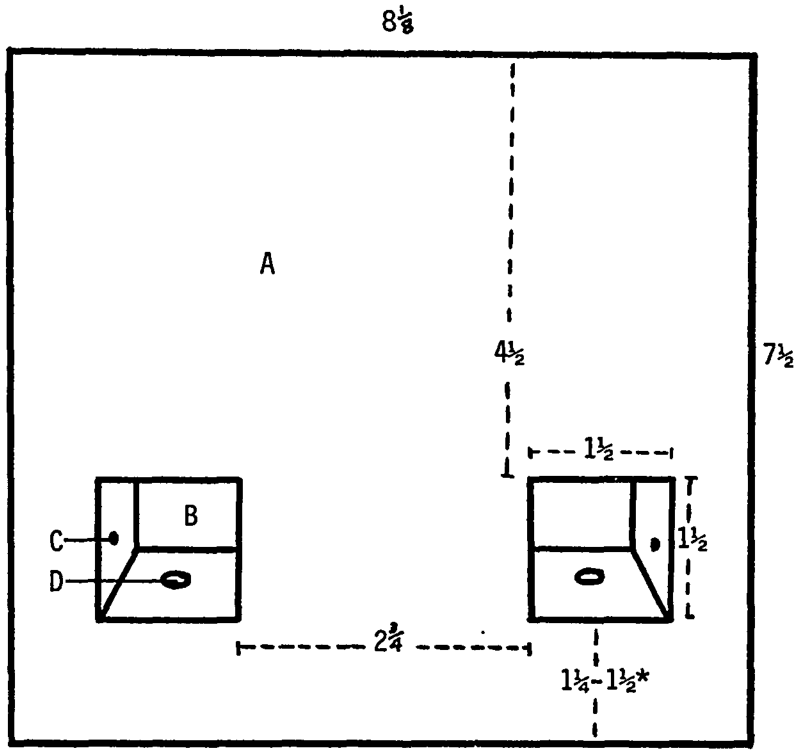

Fig. 3. Intelligence panel and stimulus-response-reinforcement chambers. A: intelligence panel. B: stimulus diffusion panel. C: red light beam and photoelectric sensor. D: Reinforcement delivery aperture. *This dimension varies with the position of the toggle floor. Dimensions are in inches.

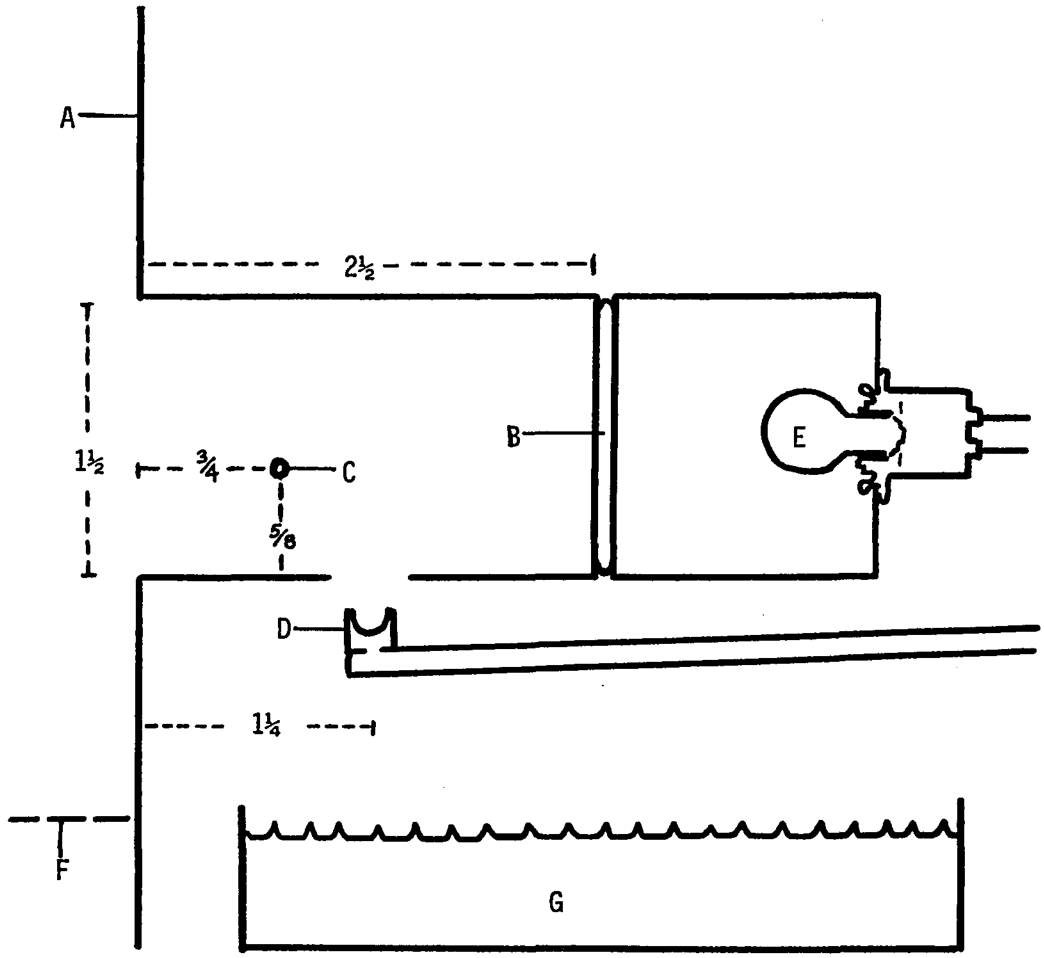

Fig. 4. Cross section of stimulus-response-reinforcement chamber. A: intelligence panel. B: diffusion panel. C: red light beam and photoelectric sensor. D: dipper. E: lamp. F: floor. G: water magazine. Dimensions are in inches.

rated by an angle of 28 degrees.

A response was defined as the completion of approach to a stimulus, as measured by the entry of S's head into the SRRC. A beam of deep-red light, approximately $\frac{1}{32}$" in diameter, passed across the SRRC, $\frac{3}{4}$" from the front opening and $\frac{5}{8}$" from the bottom of the SRRC. The interruption of this beam of light was registered as a response.

Reinforcement (+) was provided by a dipper, containing .25 cc. water, which rose to an aperture in the bottom of the SRRC, $1\frac{1}{4}$" from the front opening.

Either of two types of barriers could be inserted into the shuttleboxes. Barrier 1, shown inserted in the shuttlebox in Figure 2, was an aluminum panel, $8\frac{1}{4}$" wide and $7\frac{1}{4}$" high, with a $2\frac{1}{2}$" diameter opening located $2\frac{3}{4}$" above the floor. The centrally-located aperture in Barrier 1 permitted S to pass easily from one section of the shuttlebox to the other, while assuring that the stimuli were observed from a central choice point. Barrier 2 divided the shuttlebox into two straight alleys, with a single SRRC at each end. A solid aluminum panel, 18" long, was mounted perpendicular to a panel similar to Barrier 1 except that it had two $2\frac{1}{2}$" apertures, one at each side of the solid panel. Barrier 2 was used during interpolated training to provide S with a single stimulus on each trial.

Each shuttlebox was housed in a shock-mounted enclusure, with lightproof and sound-absorbant foam-filled walls. Continuous ventilation and masking noise were provided by a blower system that drew air through the enclosure, filtering the air through one-inch-thick foam filters at both intake and exhaust ducts. One-way mirror observation windows were covered by opaque doors when not in use.

An independent control circuit for each shuttlebox was located in an adjacent room. Eight-channel, paper tape programming permitted any predetermined combination of stimuli and reinforcement contincengies. To compensate for rapid heating, hence earlier onset, of the stimulus lamp when the higher S1 voltage was supplied, as opposed to the delayed onset when the lower S2 voltage was supplied, a 100 ms. delay circuit was included for S1 presentations, thus providing simultaneity of stimulus onset. The duration of most timed functions, including the duration of reinforcement, delay of stimulus termination, and intertrial interval, were adjustable. Trial-by-trial data were recorded on 12-channel printout counters.

Procedure

All training occurred over 61 consecutive days.

Pretraining. The Ss were handled daily for the 19 days preceding the first day of discrimination training.

Ten days prior to discrimination training, the Ss were placed on a 23-hour daily water deprivation schedule. Each S received free access to water for one hour in the home cage, approximately one hour after each training session. Deprivation time for each S was 22 hours 20 minutes.

Three days before discrimination training, the Ss were habituated to the apparatus in pairs (cagemates) for ten minutes with barrier 1 in place. On the following day, the Ss received five dipper training -shaping trials with no barrier present; S1+ was provided in both SRRC's, and the reinforcement duration was set at 15 seconds. On the following day, another five pretraining trials were provided, but barrier 1 was inserted and the reinforcement duration was set at 10 seconds. The intertrial interval for all trials, including pretraining trials, was set at 10 seconds.

Discrimination acquisition. A discrimination trial was defined by the following sequence: (1) the simultaneous onset of the programmed stimuli in the section of the shuttlebox opposite to S's location at the moment of onset; (2) the movement of S through the choice point aperture; (3) the response to one stimulus by entry into an SRRC; (4) the delivery of reinforcement for 7 seconds if the stimulus programmed for reinforcement was chosen, or no delivery of reinforcement if the other stimulus was chosen; (5) the termination of the stimuli 0.5 second after either the end of the reinforcement interval or the choice of the nonreinforced stimulus; and (6) the 10 second intertrial interval. All training employed a noncorrection procedure; trials were terminated after any response, whether or not the reinforced stimulus was chosen.

Discrimination acquisition training consisted of 20 trials per day to S1+S2- with barrier 1 in place. The sequence in which each stimulus appeared in the left or in the right SRRC was determined by Gellerman's (1933) sequences 14, 17, 24, 28, and 29. The sequences were rotated daily, so that no S could encounter the same pattern less than five days apart. All Ss received discrimination training until the .80 criterion (16 correct choices out of the daily 20 trials) was met.

True counterbalancing of the reinforcement contingencies of each stimulus is not possible in brightness discrimination reversal studies using rats. Had half the Ss received discrimination training to S1-S2+, they would have run in accordance with their strong, reliable, negative phototropism. They would have approached or met the discrimination criterion from the outset, having learned little if anything about the discrimination task. For those Ss, reversal learning would then have been, in effect, acquisition of the initial discrimination rather than reversal learning. Such behavior could hardly be interpreted in terms of reversal learning. Consequently, this study follows the usual practice of running all Ss against their pre-existing stimulus preferences.

Assignment to groups. Upon meeting the criterion for discrimination acquisition, each S was assigned to one of nine groups. Since a +0.80 correlation between acquisition and reversal facility was found in previous studies using the same apparatus, Ss were matched primarily for the number of days required to meet the discrimination acquisition criterion. Within this constraint, Ss were also matched for the total number of correct choices, which is equivalent to the number of reinforcements, in discrimination acquisition. Cagemates were never assigned to the same group.

Interpolated training. Each S began training under one of the nine experimental conditions the day after meeting the discrimination acquisition criterion. Interpolated training lasted for five days. On each of those days, the same training was provided for each S within each of the nine groups, although the specific presentation sequence was varied each day. Each stimulus was either present for ten trials or absent; if present, the stimulus was either reinforced or nonreinforced for all ten trials. If both stimuli were presented, the ten trials of each were interspersed with those of the other stimulus.

For example, the S1+S1- group received ten reinforced trials to the bright stimulus interspersed with ten nonreinforced trials to the dim stimulus daily. Group S1- received ten nonreinforced trials to the bright stimulus daily. Group NT was scheduled for no training between discrimination acquisition and reversal, and these Ss began reversal learning the day after meeting the discrimination acquisition criterion. The experimental design is summarized in Table 1. Barrier 2 was used during interpolated training so that a single SRRC was located directly in front of the barrier aperture on each trial. Thus, interpolated training would not contribute to any stimulus position preferences that might become evident during reversal learning.

Reversal training. Upon completion of the five days of interpolated training, each S began reversal training to S1-S2+. All other conditions were the same as in discrimination training.

The reversal learning criterion, as in discrimination acquisition, was .80 correct choices, but the Ss were run until they met a complex termination criterion. The termination criterion included all of the following requirements: (1) S met the reversal learning criterion. (2) S completed at least 20 days of reversal training (to provide reversal curve data). And (3) S completed at least 10 days of training after meeting the reversal criterion.

Table 1

Experimental Design

Dim Stimulus	Bright Stimulus: Reinforced	Bright Stimulus: Absent	Bright Stimulus: Nonreinforced
Reinforced	S1+S2+	S2+	S1-S2+
Absent	S1+	NT	S1-
Nonreinforced	S1+S2-	S2-	S1-S2-

The nine possible combinations of stimulus experience and reinforcement contingency are represented. Each stimulus present may be reinforced (+) or nonreinforced (-) for ten trials per day for each of the five days of training interpolated between discrimination acquisition and reversal. Since both interpolated stimuli were absent for group NT, reversal learning was begun the day after meeting the discrimination acquisition criterion.

Analyses

Since some Ss began interpolated training before all Ss had completed discrimination training, the equivalence of the nine groups could not be assured in advance. Because of this, and because of the known correlation between discrimination and reversal facility, it is particularly important to assess the initial discrimination performance of the groups for possible differences among them.

Multiple comparisons. The Tukey B procedure was selected for multiple comparison analyses, since, according to Petrinovich and Hardyck (1969), it has an experimentwise error rate similar to the Scheffé procedure and is slightly less insensitive to real differences. Petrinovich and Hardyck concur with Scheffé's (1953,1959) recommendation to employ Tukey's method when making paired comparisons among groups of equal size.

Reversal phases. The delineation of sequential segments of the reversal learning process is mandated by the prediction of differences within the course of reversal learning that might not be reflected in overall reversal performance differences. The first three phases are operations developed to correspond to Sperling's (1970) three-phase view of reversal learning. The pre-position-responding phase is defined as the number of days in reversal learning prior to making .80 responses to either the left or the right stimulus position. The position-responding phase is defined as the number of reversal days spent by each S making .80 responses to either the left or the right stimulus position. The post-position responding phase is defined as the number of reversal days from the last position responding day to the day on which the S meets the reversal learning criterion. A perseveration phase is defined as the number of reversal days in which the S continues to respond at criterion level to the discrimination acquisition task; that is, the number of reversal days spent making .80 responses to S1-. A post-reversal criterion phase is defined as the ten days after S meets the reversal criterion.

RESULTS

Pre-treatment Equivalence of the Groups

The mean number of days for each group to meet the discrimination acquisition criterion and the corresponding standard deviation appear in Table 2. An analysis of variance, summarized in Table 3, indicated no significant differences among the nine groups in discrimination acquisition facility, $F\ (2,99) < 1$, $p > .05$).

To determine whether there were differences among the groups in their preferences for each stimulus at the beginning of discrimination learning, the initial two responses by each S on the first day of discrimination training were examined. The groups were not found to differ significantly in their initial preferences for the stimuli, $\chi^2(16) = 5.16$, $p > .05$.

The first two trials on the first day of discrimination training were also examined for possible differences among the groups in their preferences for left or right stimulus position. Table 4 shows the mean initial position preferences for each group. The groups were not found to differ significantly in their initial position preferences, $\chi^2(16) = 6.72$, $p > .05$.

TABLE 2

Mean Days to Meet
the Discrimination Learning Criterion
and the Corresponding Standard Deviations

Group	Mean Days	Standard Deviation
S1+S2+	2.58	1.04
S2+	2.50	0.96
S1-S2+	2.58	1.12
S1+	2.50	0.96
NT	2.67	1.03
S1-	2.50	1.12
S1+S2-	2.62	0.95
S2-	2.75	1.23
S1-S2-	2.50	0.96
$\overline{X}$	2.57	1.04

Each S received 20 trials per day.

TABLE 3

Analysis of Variance for the Mean Number of Days for Each Group to Meet the Discrimination Criterion

Source of Variation	Sums of Squares	df	Mean Square	F
S1	0.240	2	0.120	<1
S2	0.074	2	0.037	<1
S1×S2	0.426	4	0.107	<1
Within	119.667	99	1.209	
Total	120.407	107		

TABLE 4

Initial Position Preferences

Group	Mean Preference
S1+S2+	1.33
S2+	0.58
S1-S2+	0.75
S1+	1.00
NT	0.83
S1-	0.75
S1+S2-	0.83
S2-	0.67
S1-S2-	1.00
$\overline{X}$	0.86

Initial position preference was determined for each S based on the first two responses in discrimination training. Scaling: both choices to left = 2, one choice to each stimulus position = 1, both choices to left = 0.

Overall Reversal Performance

The mean number of days for each group to meet the criterion for reversal learning and the corresponding standard deviation appear in Table 5. An analysis of variance for the mean number of days for each group to meet the reversal learning criterion is summarized in Table 6. A significant interaction between the effects of interpolated training with each stimulus was found, $F\ (4,99) = 13.96$, $p < .05$. Since the analysis of variance was based on the fixed-effects model, significant interaction effects, strictly speaking, preclude statements about the main effects. A common practice, however, is to compute F for main effects using the interaction mean square as the error term. This comparison yielded a significant main effect for S1 manipulation, $F\ (2,4) = 6.29$, $p < .05$. But the main effect for S2 manipulation did not remain significant, $F\ (2,4) = 2.19$, $p > .05$.

The effects of experience with each interpolated stimulus were additionally assessed by single-classification analyses of variance. In each of these analyses, the level (reinforced, nonreinforced, or absent) of one stimulus was systematically varied while the level of the other stimulus was held constant. The analysis of variance for the mean number of days to meet the reversal criterion when interpolated experience with S2+ is held constant and the level of S1 varies is summarized in

TABLE 5

Mean Days to Meet the Reversal Criterion
and the Standard Deviation for Each Condition

Dim Stimulus	Bright Stimulus: Reinforced	Bright Stimulus: Absent	Bright Stimulus: Nonreinforced
Reinforced	S1+S2+ 11.25 (1.53)	S2+ 11.33 (2.29)	S1-S2+ 4.08 (1.38)
Absent	S1+ 11.25 (1.72)	NT 8.67 (2.09)	S1- 8.50 (1.55)
Nonreinforced	S1+S2- 15.50 (2.25)	S2- 11.75 (1.42)	S1-S2- 8.75 (1.30)

For each interpolated condition, the condition is specified, the group mean number of days to meet the reversal criterion is given, and, in parentheses, the group standard deviation is presented.

TABLE 6

Analysis of Variance for the Mean Days to Discrimination Reversal Criterion

Source of Variation	Sums of Squares	df	Mean Square	F
S1	567.130	2	283.565	87.927 *
S2	196.908	2	98.454	30.528 *
S1 x S2	180.148	4	45.037	13.965 *
Within	319.250	99	3.225	
Total	1263.436	107		

* $p < .05$

Table 7. There were significant differences among the three groups, $F(2,33) = 54.51$, $p < .05$. The means for these three groups and the results of multiple comparisons among the means, using the Tukey B procedure recommended by Petrinovich and Hardyck (1969) are presented in Table 8.

An analysis of variance for the mean number of days to meet the reversal criterion when interpolated experience with S2 is absent and the level of interpolated experience with S1 varies is summarized in Table 9. The means differed significantly, $F(2,33) = 10.71$, $p < .05$. The three means and multiple comparisons among the means appear in Table 10.

An analysis of variance for the mean number of days to meet the reversal criterion when interpolated experience with S2- is held constant and the level of interpolated experience with S1 varies is summarized in Table 11. The means differed significantly, $F(2,33) = 42.93$, $p < .05$. The three means are presented in Table 12, along with multiple comparisons among them.

An analysis of variance for the mean number of days to meet the reversal criterion when interpolated experience with S1+ is held constant and the level of interpolated S2 experience varies is summarized in Table 13. Significant differences among the means were indicated, $F(2,33) = 24.97$, $p < .05$. The three means

TABLE 7

Analysis of Variance for the Mean Number of Days to Meet the Reversal Criterion when Interpolated Experience with S2+ is Held Constant and the level of S1 varies

Source of Variation	Sums of Squares	df	Mean Square	F
S1 level	415.72	2	207.86	54.51 *
Within	125.84	33	3.81	
Total	541.56	35		

* $p < .05$

TABLE 8

Comparisons among the Means for Each Group
for the Number of Days to Meet the Reversal
Criterion when Interpolated Experience with
S2+ is Held Constant and the level of S1 varies

Group	S1-S2+	S1+S2+	S2+
Mean	4.08	11.25	11.33

Means not commonly underlined differ significantly ($p < .05$), based on the Tukey B procedure (WSD=1.97, df=33).

TABLE 9

Analysis of Variance for the Mean Number of Days to Meet the Reversal Criterion when Interpolated Experience with S2 is Absent and the Level of S1 Varies

Source of Variation	Sums of Squares	df	Mean Square	F
S1 level	57.06	2	28.53	10.71 *
Within	87.92	33	2.66	
Total	144.97	35		

* $p < .05$

TABLE 10

Comparisons among the Means of Each Group for the Number of Days to Meet the Reversal Criterion when Interpolated Experience with S2 is Absent and the Level of S1 Varies.

Group	S1-	NT	S1+
Mean	8.50	8.67	11.25

Means not commonly underlined differ significantly ($p < .05$), based on the Tukey B procedure (WSD=1.64, df=33).

TABLE 11

Analysis of Variance for the Mean Number of Days to Meet the Reversal Criterion when Interpolated Experience with S2- is Held Constant and the Level of S1 varies

Source of Variation	Sums of Squares	df	Mean Square	F
S1 level	274.50	2	137.25	42.93 *
Within	105.50	33	3.20	
Total	380.00	35		

* $p < .05$

TABLE 12

Comparisons among the Means for Each Group for the Number of Days to Meet the Reversal Criterion when Interpolated Experience with S2- is Held Constant and the Level of S1 varies

Group	S1-S2-	S2-	S1+S2-
Mean	8.75	11.75	15.50

All means differed significantly ($p < .05$), based on the Tukey B procedure (WSD=1.80, df=33).

TABLE 13

Analysis of Variance for the Mean Number of Days to Meet the Reversal Criterion when Interpolated Experience with S1+ is Held Constant and the Level of S2 varies

Source of Variation	Sums of Squares	df	Mean Square	F
S2 level	144.50	2	72.25	24.97 *
Within	95.50	33	2.89	
Total	240.00	35		

* $p < .05$

and multiple comparisons among them are shown in Table 14.

An analysis of variance for the mean number of days to meet the reversal learning criterion when interpolated experience with S1 is absent and the level of interpolated experience with S2 varies is summarized in Table 15. The means differed significantly, $F\ (2,33) = 7.94$, $p < .05$. The three means and multiple comparisons among them are presented in Table 16.

An analysis of variance for the mean number of days to meet the reversal criterion when interpolated experience with S1- is held constant and the level of interpolated experience with S2 varies is summarized in Table 17. The means differed significantly, $F\ (2,33) = 32.42$, $p < .05$. The three means and multiple comparisons among them appear in Table 18.

Reviewing the single-classification analyses, significant differences among the groups were observed in all analyses. In five of the six multiple comparisons among means, one of the three means differed significantly from the other two, which did not differ significantly from each other. In the sixth multiple comparison, interpolated experience with S2- was held constant and the level of interpolated experience with S1 varied. All three means differed significantly from each other. Reversal learning was most rapid where S1 was nonreinforced and least rapid where S1 was reinforced.

TABLE 14

Comparisons among the Means for Each Group for the Number of Days to Meet the Reversal Criterion when Interpolated Experience with S1+ is Held Constant and the Level of S2 varies

Group	S1+S2+	S1+	S1+S2-
Mean	11.25	11.25	15.50

Means not commonly underlined differ significantly ($p < .05$), based on the Tukey B procedure (WSD=1.71, df=33).

TABLE 15

Analysis of Variance for the Mean Number of Days to Meet the Reversal Criterion when Interpolated Experience with S1 is Absent and the Level of S2 varies

Source of Variation	Sums of Squares	df	Mean Square	F
S2 level	67.17	2	33.58	7.94 *
Within	139.58	33	4.23	
Total	206.75	35		

* $p < .05$

TABLE 16

Comparisons among the Means of Each Group for the Number of Days to Meet the Reversal Criterion when Interpolated Experience with S1 is Absent and the Level of S2 varies

Group	NT	S2+	S2-
Mean	8.67	11.33	11.75

Means not commonly underlined differ significantly ($p < .05$), based on the Tukey B procedure (WSD=2.07, df=33).

TABLE 17

Analysis of Variance for the Mean Number of Days to Meet the Reversal Criterion when Interpolated Experience with S1- is Held Constant and the Level of S2 varies

Source of Variation	Sums of Squares	df	Mean Squares	F
S2 level	165.39	2	82.69	32.42 *
Within	84.17	33	2.55	
Total	249.56	35		

* $p < .05$

TABLE 18

Comparisons among the Means for Each Group for the Number of Days to Meet the Reversal Criterion when Interpolated Experience with S1- is Held Constant and the Level of S2 varies

Group	S1-S2+	S1-	S1-S2-
Mean	4.08	8.50	8.75

Means not commonly underlined differ significantly ($p < .05$), based on the Tukey B procedure (WSD=1.61, df=33).

Clustering of Overall Reversal Effects

Multiple comparisons among the mean number of days to meet the reversal criterion for each of the nine groups using the Tukey B procedure are presented in Table 19. Four distinct clusters were found. Within each cluster, no group differed significantly from any other group in overall reversal performance. All comparisons between groups in different clusters indicated significantly different mean numbers of days to meet the reversal criterion.

The clustering of the S1-, NT, and S1-S2- groups received further support from the virtually overlapping reversal curves shown in Figure 5. Similarly, the clustering of the S1+S2+, S2+, S1+, and S2- groups received further support from the close correspondence of the reversal curves shown in Figure 6. The four clusters formed on the basis of overall reversal performance are presented in Table 20. Reversal curves for the four distinct reversal performance patterns are shown in Figure 7. The average reversal curve for each cluster is plotted in Figure 7 because of the statistical difference pattern and the difficulty of seperating virtually identical curves.

Effects of the Forcing Procedure

Since, during interpolated training, Ss had no

TABLE 19

Comparisons Among the Means for Each Group of the Number of Days to Meet the Reversal Criterion

S1-S2+	S1-	NT	S1-S2-	S1+S2+	S1+	S2+	S2-	S1+S2-
4.08	8.50	8.67	8.75	11.25	11.25	11.33	11.75	15.50

Means not commonly underlined differ significantly ($p < .05$) based on the Tukey B procedure.

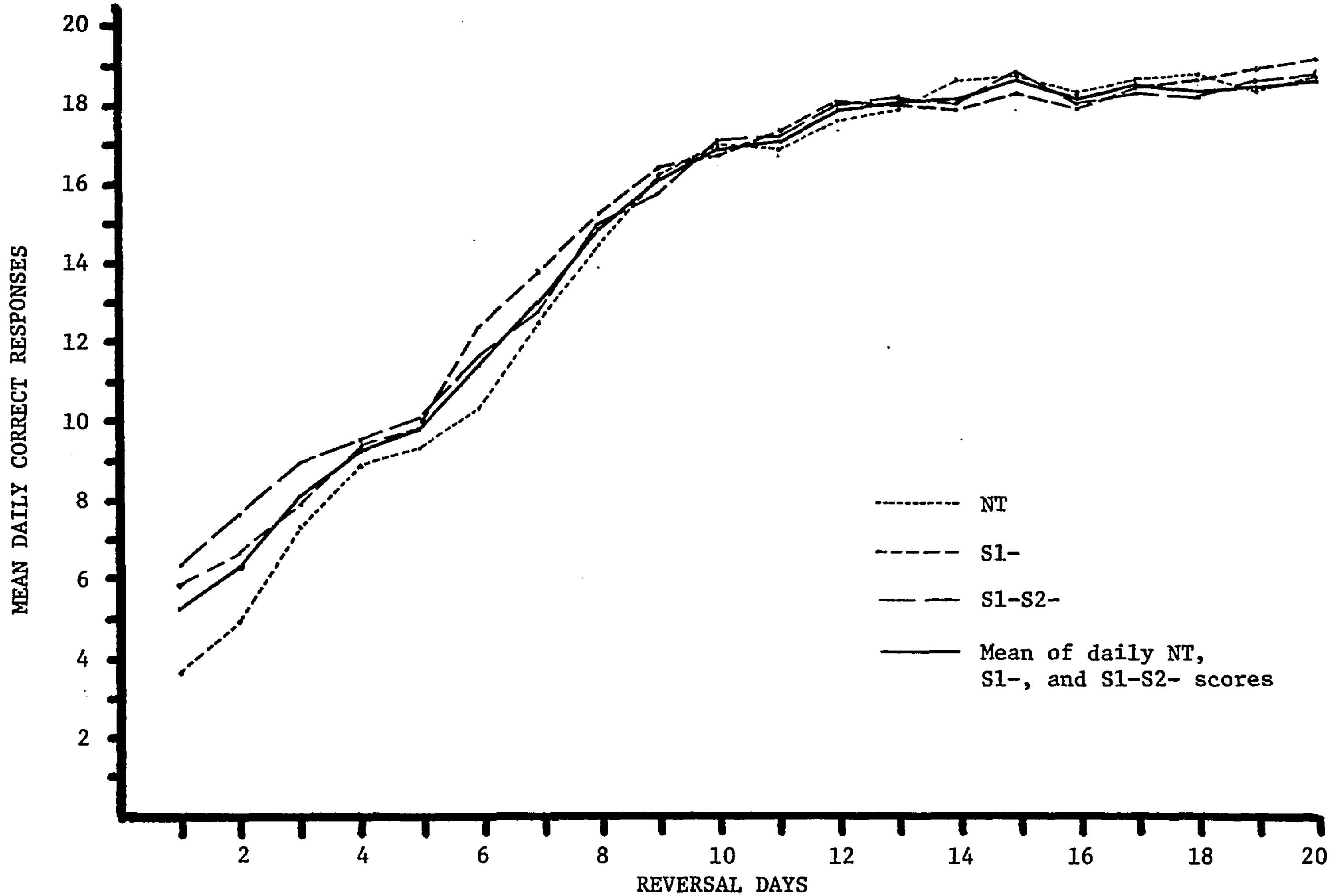

Fig. 5. Daily reversal performance for interpolated conditions NT, S1-, and S1-S2- and the daily mean of the three interpolated conditions.

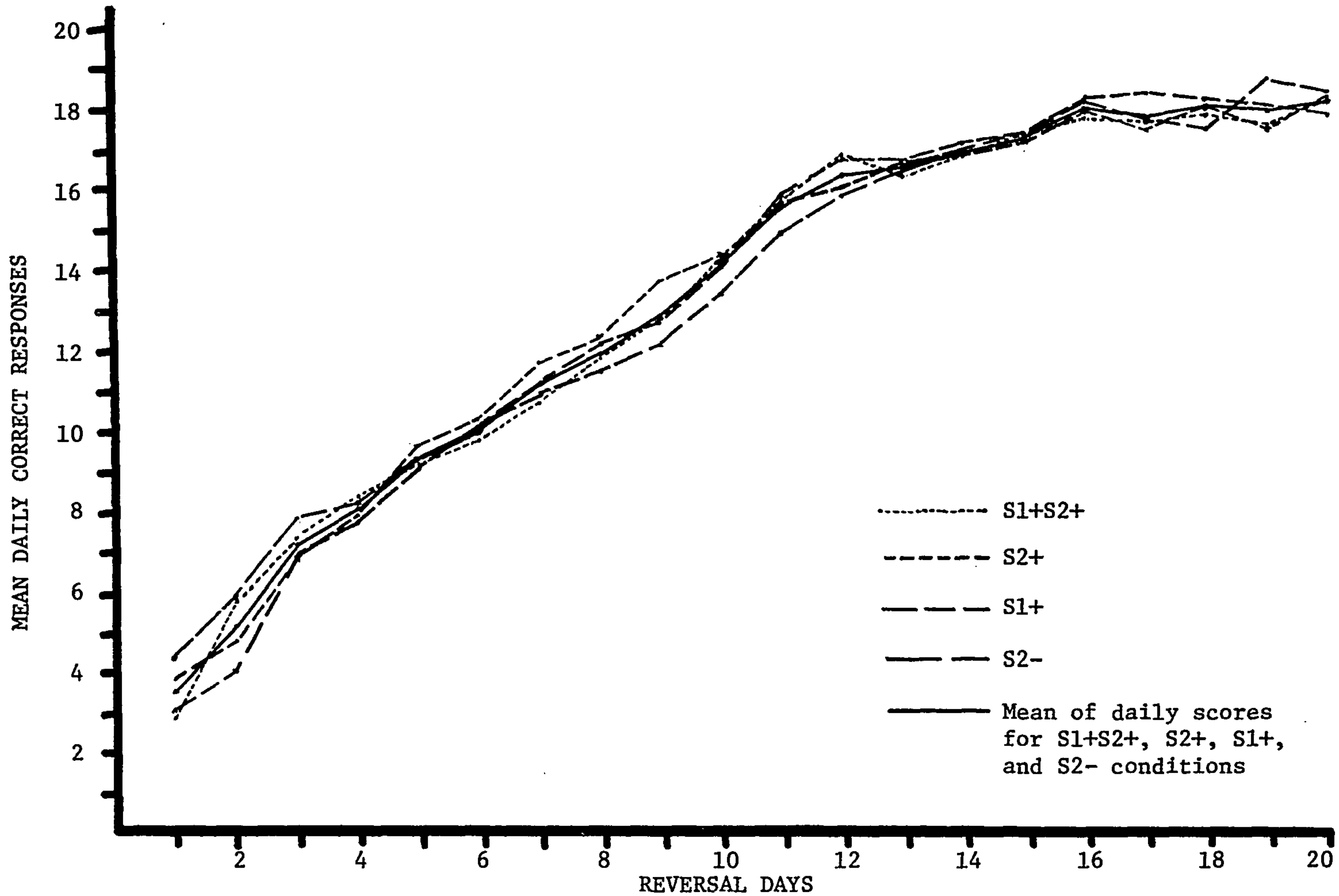

Fig. 6. Daily reversal performance for interpolated conditions S1+S2+, S2+, S1+, and S2- and the daily mean of the four interpolated conditions.

TABLE 20

Clustering of Groups Based on the Mean

Number of Days to Meet the Reversal Criterion

Reversal Facilitated	Reversal Not Different Than NT	Reversal Protracted	Reversal Protracted beyond All Other Gps.
S1-S2+	NT S1-S2- S1-	S1+S2+ S1+ S2+ S2-	S1+S2-

Groups in separate columns differed significantly ($p < .05$)
Groups within each column did not differ significantly.

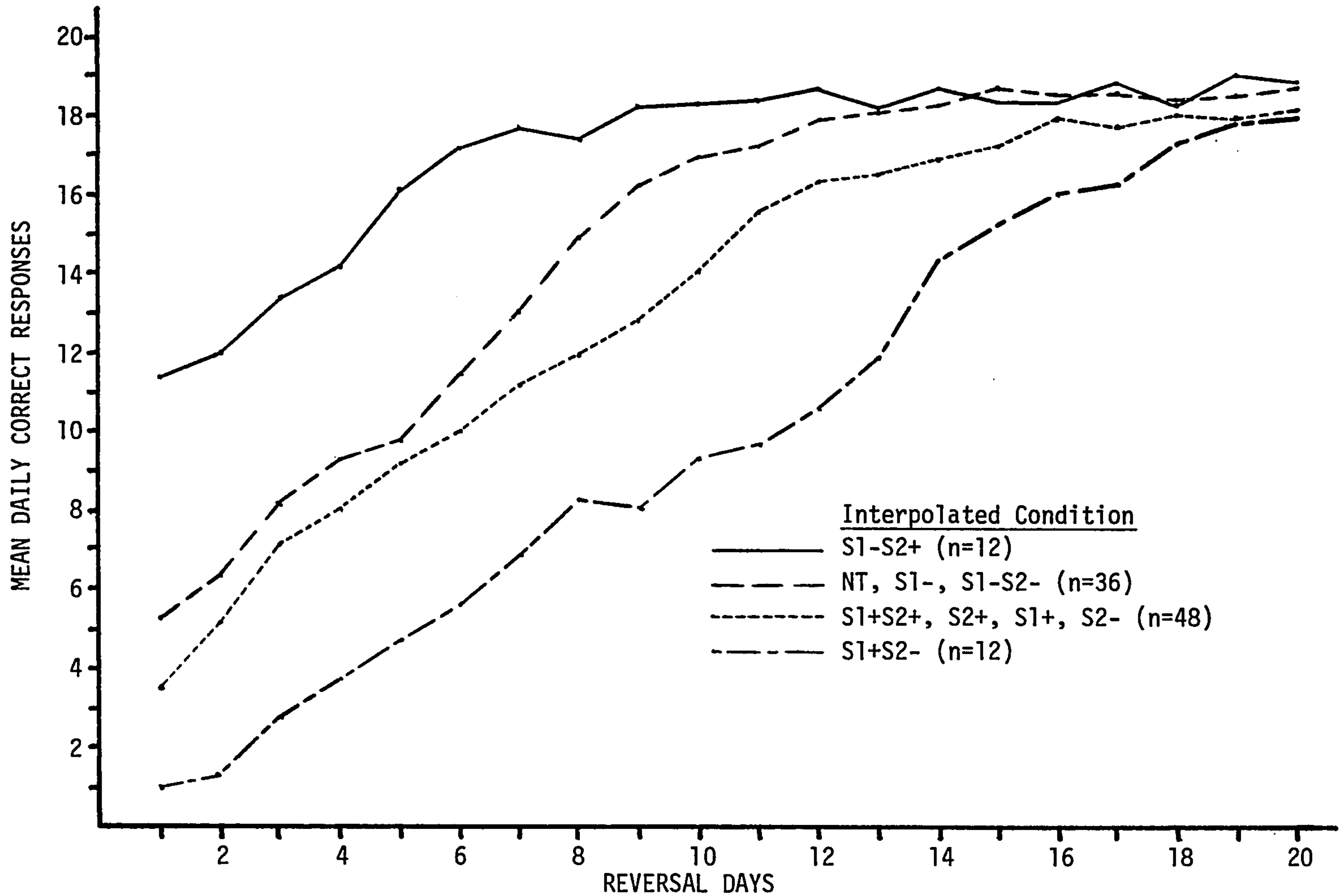

Fig. 7. Reversal performance. Group curves have been combined where they did not differ statistically.

choice of stimuli, the question of forcing effects arises. Possible forcing effects may be assessed by comparing the groups reciving forced reversal training and free reversal training. For this comparison, the interpolated forced reversal training of the S1-S2+ group must be regarded, not as prereversal training, but as part of reversal learning. The S1-S2+ group met the reversal criterion in a mean of 9.08 days. The NT group did so in a mean of 8.67 days. The difference is not significant; the difference between the means of 0.41 days does not approach the Tukey WSD of 2.33 days.

Effects of Interpolated Training with One or Both Stimuli

To evaluate the possible effect of the presence of one as opposed to two stimuli during interpolated training, the reversal performance of groups receiving interpolated training with a single stimulus was compared to that of groups receiving interpolated training with both stimuli. Group NT, which received no interpolated training, was excluded from this comparison. The mean number of days to meet the reversal criterion for the S1+, S1-, S2+, and S2- groups combined was 10.71. The combined mean for the S1+S2+, S1+S2-, S1-S2+, and S1-S2- groups was 9.90. The difference between the combined means was not found significant, $t\ (6) = 0.325$, $p > .05$.

Analyses of Reversal Phases

To determine the locus of observed effects within the course of reversal learning, each phase was separately examined.

Pre-position responding phase. The mean number of days in reversal learning required to meet the position responding criterion is presented for each group in Table 21. An analysis of variance for these means is summarized in Table 22. A significant interaction effect was found, $F\ (4,99) = 15.73,\ p < .05$. As in the analysis of overall reversal performance, the main effects were assessed by using the interaction mean square as the error term. Using this procedure, the effects of interpolated S1 experience were not found significant, $F\ (2,4) = 2.28,\ p > .05$; neither were the effects of interpolated S2 experience, $F\ (2,4)\ \ 1,\ p > .05$.

The effects of each interpolated stimulus were further evaluated by single-classification analyses. In each of these analyses, the level of interpolated experience with one stimulus is held constant while the other is systematically varied.

An analysis of variance for the mean number of days to meet the position responding criterion when interpolated experience with S2+ is held constant and the level of interpolated experience S1 is varied is summarized in Table 23. The differences were found significant,

TABLE 21

Mean Pre-Position-Responding

Days in Reversal Learning

Dim Stimulus	Bright Stimulus: Reinforced	Bright Stimulus: Absent	Bright Stimulus: Nonreinforced
Reinforced	S1+S2+ 2.08	S2+ 2.17	S1-S2+ 0.92
Absent	S1+ 2.75	NT 2.67	S1- 1.25
Non-Reinforced	S1+S2- 7.42	S2- 1.92	S1-S2+ 1.00

TABLE 22

Analysis of Variance of the Mean

Pre-Position-Responding Days in Reversal Learning

Source of Variation	Sums of Squares	df	Mean Square	F
S1	167.463	2	83.732	35.049*
S2	56.519	2	28.260	11.829*
S1xS2	150.370	4	37.593	15.735*
Within	236.500	99	2.389	
Total	610.853	107		

* $p < .05$

TABLE 23

Analysis of Variance for the Mean Number of Days to Meet the Position-responding Criterion when Interpolated Experience with S2+ is Held Constant and the Level of S1 varies

Source of Variation	Sums of Squares	df	Mean Square	F
S1 level	11.72	2	5.86	4.90 *
Within	39.50	33	1.20	
Total	51.22	35		

* $p < .05$

$F\ (2,33) = 4.90$, $p < .05$. The means are presented in Table 24 along with multiple comparisons among them.

An analysis of variance for the mean number of days to meet the position responding criterion when interpolated experience with S2 is absent and the level of interpolated experience with S1 varies is summarized in Table 25. The differences were found significant, $F\ (2,33) = 7.57$, $p < .05$. The three means and multiple comparisons among them are presented in Table 26.

An analysis of variance for the mean number of days to meet the position responding criterion when interpolated experience with S2- is held constant and the level of interpolated experience with S1 varies is summarized in Table 27. The differences were found significant, $F\ (2,33) = 29.84$, $p < .05$. The three means and multiple comparisons among them are shown in Table 28.

An analysis of variance for the mean number of days to meet the position responding criterion when interpolated experience with S1+ is held constant and the level of interpolated experience with S2 varies is summarized in Table 29. The differences were found significant, $F\ (2,33) = 21.99$, $p < .05$. The three means and multiple comparisons among them are given in Table 30.

An analysis of variance for the mean number of days to meet the position responding criterion when interpolated experience with S1 is absent and the level of inter-

TABLE 24

Comparisons among the Means for Each Group for the Number of Days to Meet the Position-responding Criterion when Interpolated Experience with S2+ is Held Constant and the Level of S1 varies

Group	S2+	S1+S2+	S1-S2+
Mean	2.17	2.08	0.92

Means not commonly underlined differ significantly ($p < .05$), based on the Tukey B procedure (WSD=1.10 df=33).

TABLE 25

Analysis of Variance for the Mean Number of Days to Meet the Position-responding Criterion when Interpolated Experience with S2 is Absent and the Level of S1 varies

Source of Variation	Sums of Squares	df	Mean Square	F
S1 level	17.06	2	8.53	7.57 *
Within	37.17	33	1.13	
Total	54.22	35		

* $p < .05$

TABLE 26

Comparisons among the Means for Each Group for the Number of Days to Meet the Position-responding Criterion when Interpolated Experience with S2 is Absent and the Level of S1 varies

Group	S1+	NT	S1-
Mean	2.75	2.67	1.25

Means not commonly underlined differ significantly ($p < .05$), based on the Tukey B procedure (WSD=1.07 df=33).

TABLE 27

Analysis of Variance for the Mean Number of Days to Meet the Position-responding Criterion when Interpolated Experience with S2- is Held Constant and the Level of S1 varies

Source of Variation	Sums of Squares	df	Mean Square	F
S1 level	289.06	2	144.53	29.84 *
Within	159.83	33	4.84	
Total	448.89	35		

* $p < .05$

TABLE 28

Comparisons among the Means for Each Group for the Number of Days to Meet the Position-responding Criterion when Interpolated Experience with S2- is Held Constant and the Level of S1 varies

Group	S1+S2-	S2-	S1-S2-
Mean	7.42	1.92	1.00

Means not commonly underlined differ significantly ($p < .05$), based on the Tukey B procedure (WSD=2.21 df=33).

TABLE 29

Analysis of Variance for the Mean Number of Days to Meet the Position-responding Criterion when Interpolated Experience with S1+ is Held Constant and the Level of S2 varies

Source of Variation	Sums of Squares	df	Mean Square	F
S2 level	202.67	2	101.33	21.99 *
Within	152.08	33	4.61	
Total	354.75	35		

* $p < .05$

TABLE 30

Comparisons among the Means of Each Group for the Number of Days to Meet the Position-responding Criterion when Interpolated Experience with S1+ is Held Constant and the Level of S2 varies

Group	S1+S2-	S1+	S1+S2+
Mean	7.42	2.75	2.08

Means not commonly underlined differ significantly ($p < .05$), based on the Tukey B procedure (WSD=2.16 df=33).

polated experience with S2 varies is summarized in Table 31. The differences were not found significant, $F\ (2,33) = 0.97,\ p > .05$. The means for the three groups and multiple comparisons among them are shown in Table 32.

An analysis of variance for the mean number of days to meet the position responding criterion when interpolated experience with S1- is held constant and the level of interpolated experience with S2 varies is summarized in Table 33. The differences were not found significant, $F\ (2,33) < 1,\ p > .05$. The three means are presented in Table 34.

Multiple comparisons among the nine means for pre-position responding days, using the Tukey B procedure, appear in Table 35. The significant pre-position responding effects reported in Table 22 are attributed to the greater number of days spent in this phase by the S1+S2- group than was spent by the other eight groups, which did not differ significantly from each other.

<u>Position responding phase</u>. The mean number of days spent by each group responding at the position responding criterion of .80 choices to the preferred stimulus position is presented in Table 36. The combined mean for the nine groups was 5.39 days. An analysis of variance of these means is summarized in Table 37. A significant interaction effect was detected, $F\ (4,99) = 3.68,\ p < .05$. Assessing the main effects by using the interaction mean

TABLE 31

Analysis of Variance for the Mean Number of Days to Meet the Position-responding Criterion when Interpolated Experience with S1 is Absent and the Level of S2 varies

Source of Variation	Sums of Squares	df	Mean Square	F
S2 level	3.50	2	1.75	0.97
Within	59.25	33	1.80	
Total	62.75	35		

TABLE 32

The Means of Each Group for the Number of Days to Meet the Position-responding Criterion when Interpolated Experience with S1 is Absent and the Level of S2 varies

Group	NT	S2+	S2-
Mean	2.67	2.17	1.92

No means differed significantly (p > 05), based on the Tukey B procedure.

TABLE 33

Analysis of Variance for the Mean Number of Days to Meet the Position-responding Criterion when Interpolated Experience with S1- is Held Constant and the Level of S2 varies

Source of Variation	Sums of Squares	df	Mean Square	F
S2 level	0.72	2	0.36	0.47
Within	25.17	33	0.76	
Total	25.89	35		

TABLE 34

The Means of Each Group for the Number of Days to Meet the Position-responding Criterion when Interpolated Experience with S1- is Held Constant and the Level of S2 varies

Group	S1-	S1-S2-	S1-S2+
Mean	1.25	1.00	0.92

No means differed significantly ($p > .05$), based on the Tukey B procedure.

TABLE 35

Mean Number of Days to Meet the Position Responding Criterion and Multiple Comparisons among the Means

S1-S2+	S1-S2-	S1-	S2-	S1+S2+	S2+	NT	S1+	S1+S2-
0.92	1.00	1.25	1.92	2.08	2.17	2.67	2.75	7.42

Means commonly underlined do not differ significantly, while means not commonly underlined differ significantly ($p < .05$), based on the Tukey B procedure.

TABLE 36

Mean Position-Responding Days

Dim Stimulus	Bright Stimulus: Reinforced	Bright Stimulus: Absent	Bright Stimulus: Nonreinforced
Rein-forced	S1+S2- 6.92	S2+ 6.50	S1-S2+ 1.75
Absent	S1+ 6.25	NT 4.42	S1- 4.50
Non-Reinforced	S1+S2- 6.00	S2- 6.75	S1-S2- 5.75

TABLE 37

Analysis of Variance of the Mean

Position-Responding Days in Reversal Learning

Source of Variation	Sums of Squares	df	Mean Square	F
S1	126.000	2	63.000	8.574 *
S2	24.000	2	12.000	1.633 *
S1xS2	108.167	4	27.042	3.680 *
Within	727.500	99	7.348	
Total	985.667	107		

* $p < .05$

square as the error term, the S1 effect was not found significant, $F\ (2,4) = 2.33$, $p > .05$; neither was the S2 effect, $F\ (2,4) < 1$, $p > .05$.

The contribution of interpolated experience with each stimulus to effects in the position responding phase of reversal learning was evaluated by single-classification analyses of variance.

An analysis of variance for the mean number of days spent by each group during reversal learning at the position responding criterion when interpolated experience with S2+ is held constant and the level of interpolated experience with S2 varies is summarized in Table 38. The differences were found significant, $F\ (2,33) = 13.25$, $p < .05$. The three means and multiple comparisons among them are shown in Table 39.

An analysis of variance for the mean number of position responding days when interpolated experience with S2 is absent and the level of interpolated experience with S1 varies is summarized in Table 40. The differences were not found significant, $F\ (2,33) = 2.75$, $p > .05$. The means are presented in Table 41.

An analysis of variance for the mean number of position responding days when interpolated experience with S2- is held constant and the level of interpolated experience with S1 varies is summarized in Table 42. The differences were not found significant, $F\ (2,33) < 1$, $p > .05$.

TABLE 38

Analysis of Variance for the Mean Number of Position-responding Days when Interpolated Experience with S2+ is Held Constant and the Level of S1 varies

Source of Variation	Sums of Squares	df	Mean Square	F
S1 level	197.72	2	98.86	13.25 *
Within	246.17	33	7.46	
Total	443.89	35		

* $p < .05$

TABLE 39

Comparisons among the Means for Each Group for the Number of Days to Meet the Position-responding Criterion when Interpolated Experience with S2+ is Held Constant and the Level of S1 varies

Group	S1+S2+	S2+	S1-S2+
Mean	6.92	6.50	1.75

Means not commonly underlined differ significantly ($p < .05$), based on the Tukey B procedure (WSD=2.75 df=33).

TABLE 40

Analysis of Variance for the Mean Number of Position-responding Days when Interpolated Experience with S2 is Absent and the Level of S1 varies

Source of Variation	Sums of Squares	df	Mean Square	F
S1 level	25.72	2	12.86	2.75
Within	154.17	33	4.67	
Total	179.89	35		

TABLE 41

Comparisons among the Means for Each Group for the Number of Position-responding Days when Interpolated Experience with S2 is Absent and the Level of S1 varies

Group	S1+	S1-	NT
Mean	6.25	4.50	4.42

No means differed significantly ($p > .05$, based on the Tukey B procedure (WSD=2.17, df=33).

TABLE 42

Analysis of Variance for the Mean Number of Position-responding Days when Interpolated Experience with S2- is Held Constant and the Level of S1 varies

Source of Variation	Sums of Squares	df	Mean Square	F
S1 level	10.72	2	5.36	0.54
Within	327.17	33	9.91	
Total	337.89	35		

The three means appear in Table 43.

An analysis of variance for the mean number of position responding days when interpolated experience with S1+ is held constant and the level of interpolated experience with S2 varies is summarized in Table 44. The differences were not found significant, $F\ (2,33) < 1$, $p > .05$. The means appear in Table 45.

An analysis of variance for the mean number of position responding days when interpolated experience with S1 is absent and the level of interpolated experience with S2 varies is summarized in Table 46. The differences were not found significant, $F\ (2,33) < 1$, $p > .05$. The three means appear in Table 47.

An analysis of variance for the mean number of position responding days when interpolated experience with S1- is held constant and the level of interpolated experience with S2 varies is summarized in Table 48. The differences were found significant, $F\ (2,33) = 11.61$, $p < .05$. The three means and multiple comparisons among them are provided in Table 49.

Multiple comparisons among the mean position responding days for each of the nine groups are presented in Table 50, based on the Tukey B procedure. The significant position responding effects reported in Table 37 are attributed to the fewer position responding days required by the S1-S2+ group than by the remaining eight

TABLE 43

Comparisons among the Means for Each Group for the Number of Position-responding Days when Interpolated Experience with S2- is Held Constant and the Level of S1 varies

Group	S2-	S1+S2-	S1-S2-
Mean	6.75	6.00	5.75

No means differed significantly ($p > .05$), based on the Tukey B procedure.

TABLE 44

Analysis of Variance for the Mean Number of Position-responding Days when Interpolated Experience with S1+ is Held Constant and the Level of S2 varies

Source of Variation	Sums of Squares	df	Mean Square	F
S2 level	5.39	2	2.69	0.22
Within	405.17	33	12.28	
Total	410.56	35		

TABLE 45

Comparisons among the Means for Each Group for the Number of Position-responding Days when Interpolated Experience with S1+ is Held Constant and the Level of S2 varies

Group	S1+S2+	S1+	S1+S2-
Mean	6.92	6.25	6.00

No means differed significantly ($p > .05$), based on the Tukey B procedure.

TABLE 46

Analysis of Variance for the Mean Number of Position-responding Days when Interpolated Experience with S1 is Absent and the Level of S2 varies

Source of Variation	Sums of Squares	df	Mean Square	F
S2 level	39.39	2	19.69	3.28
Within	198.17	33	6.01	
Total	237.56	35		

TABLE 47

Comparisons among the Means for Each Group for the Number of Position-responding Days when Interpolated Experience with S1 is Absent and the Level of S2 varies

Group	S2-	S2+	NT
Mean	6.75	6.50	4.42

No means differed significantly ($p > .05$), based on the Tukey B procedure (WSD=2.47, df=33).

TABLE 48

Analysis of Variance for the Mean Number of Position-responding Days when Interpolated Experience with S1- is Held Constant and the Level of S2 varies

Source of Variation	Sums of Squares	df	Mean Square	F
S2 level	87.39	2	43.69	11.61 *
Within	124.17	33	3.76	
Total	211.56	35		

* $p < .05$

TABLE 49

Comparisons among the Means for Each Group for the Number of Position-responding Days when Interpolated Experience with S1- is Held Constant and the Level of S2 varies

Group	S1-S2-	S1-	S1-S2+
Mean	5.75	4.50	1.75

Means not commonly underlined differ significantly ($p < .05$), based on the Tukey B procedure (WSD=1.95 df=33).

TABLE 50

Mean Number of Days of Responding at the Position Responding Criterion and Multiple Comparisons among the Means

S1-S2+	NT	S1-	S1-S2-	S1+S2-	S1+	S2+	S2-	S1+S2+
1.75	4.42	4.50	5.75	6.00	6.25	6.50	6.75	6.92

Means commonly underlined do not differ significantly, while mean not commonly underlined differ significantly ($p < .05$), based on the Tukey B procedure.

groups, which did not differ from each other in the amount of position responding.

Post-position responding phase. The mean number of days required by each group to progress from responding at the position responding criterion to meeting the reversal learning criterion is shown in Table 51. The mean post-position responding days for the nine groups combined was 2.24. The analysis of variance summarized in Table 52 indicated no significant differences among the groups, all F's < 1, $p > .05$.

Post-reversal criterion phase. To evaluate the possibility of differences among the groups in post-criterion stability of reversal performance or in asymptotic level of reversal performance, the number of incorrect choices per day was averaged over the ten days of post-criterial reversal training for each S. The mean for each group is given in Table 53. The mean for the nine groups combined was 2.04 errors per day, corresponding to a reversal performance level of approximately 90 percent correct choices. The mean for all groups on the tenth day of post-criterial training was 1.47 errors per day, corresponding to a 92.7 percent correct performance level. Once meeting the reversal criterion, every group performed at least at that level on all subsequent days of reversal training. An analysis of variance of the mean post-criterial errors, summarized in Table 54, indicated no sig-

TABLE 51

Mean Post-Position-Responding

Days in Reversal Learning

Dim Stimulus	Bright Stimulus: Reinforced	Bright Stimulus: Absent	Bright Stimulus: Nonreinforced
Reinforced	S1+S2+ 2.42	S2+ 2.50	S1-S2+ 1.33
Absent	S1+ 2.67	NT 1.75	S1- 2.50
Non-Reinforced	S1+S2- 1.83	S2- 2.92	S1-S2- 2.25

TABLE 52

Analysis of Variance of the Mean

Post-Position-Response Days in Reversal Learning

Source of Variation	Sums of Squares	df	Mean Square	F	p
S1	2.574	2	1.287	1	NS
S2	1.352	2	0.676	1	NS
S1xS2	20.482	4	5.121	2,067	NS
Within	245.333	99	2.478		
Total	269.741	107			

TABLE 53

Stability of Post-Criterion

Reversal Learning

Group	Mean Errors
S1+S2+	2.47
S2+	1.92
S1-S2+	2.05
S1+	2.17
NT	1.86
S1-	2.14
S1+S2-	1.91
S2-	2.08
S1-S2-	1.86
$\overline{X}$	2.04

The daily group means of the Ss' daily mean errors are shown.

TABLE 54

Analysis of Variance of the

Stability of Post-Criterion Reversal Learning

Source of Variation	Sums of Squares	df	Mean Square	F
Groups	6.773	8	0.8466	1.88
Within	36.444	81	0.4499	
Total	43.217	89		

The means of the mean errors for each group for each of ten days of postcriterion reversal training are compared.

nificant differences among the groups in post-criterial reversal performance stability, $F(8,81) = 1.88$, $p > .05$.

Perseveration phase. The perseveration phase is the number of days in which an S makes .80 responses to S1- during reversal learning. The means for this phase are presented in Table 55. The combined group mean perseveration days was 1.58. An analysis of variance of the perseveration means is summarized in Table 56. A significant interaction effect was detected, $F(4,99) = 7.48$, $p < .05$. When the main effects were tested using the interaction mean square as the error term, the effect of interpolated experience with S1 remained significant, $F(2,4) = 5.87$, $p < .05$. The effects of interpolated experience with S2, however, did not remain significant, $F(2,4) = 1.14$, $p > .05$.

The contribution of interpolated experience with each stimulus to the perseveration phase effects was assessed by single-classification analyses.

An analysis of variance for the mean number of perseveration days during reversal learning when interpolated experience with S2+ is held constant and the level of interpolated experience with S1 varies is summarized in Table 57. The means differed significantly, $F(2,33) = 12.59$, $p < .05$. The three means appear in Table 58, as do multiple comparisons among them.

TABLE 55

Mean Perseveration Days

in Reversal Learning

Bright Stimulus

Dim Stimulus	Reinforced	Absent	Nonreinforced
Rein-forced	S1+S2+ 1.83	S2+ 1.67	S1-S2+ 0
Absent	S1+ 1.83	NT 1.83	S1- 0.25
Non-Reinforced	S1+S2- 4.83	S2- 1.92	S1-S2- 0.08

TABLE 56

Analysis of Variance of the

Mean Perseveration Days in Reversal Learning

Source of Variation	Sums of Squares	df	Mean Square	F
S1	136.056	2	68.028	43.889 *
S2	26.389	2	13.195	8.513 *
S1xS2	46.388	4	11.597	7.482 *
Within	153.417	99	1.550	
Total	362.250	107		

* $p < .05$

TABLE 57

Analysis of Variance for the Mean Number of Perseveration Days when Interpolated Experience with S2+ is Held Constant and the Level of S1 varies

Source of Variation	Sums of Squares	df	Mean Square	F
S1 level	24.67	2	12.33	12.59 *
Within	32.33	33	0.98	
Total	57.00	35		

* $p < .05$

TABLE 58

Comparisons among the Means of Each Group for the Number of Perseveration Days when Interpolated Experience with S2+ is Held Constant and the Level of S1 varies

Group	S1+S2+	S2+	S1-S2+
Mean	1.83	1.67	0.00

Means not commonly underlined differ significantly ($p < .05$), based on the Tukey B procedure (WSD=1.00 df=33).

An analysis of variance for the mean number of perseveration days during reversal learning when interpolated experience with S2 is absent and the level of interpolated experience with S1 varies is summarized in Table 59. The means were found to differ significantly, $F(2,33) = 14.03$, $p < .05$. The three means and multiple comparisons among them appear in Table 60.

An analysis of variance for the mean number of perseveration days when interpolated experience with S2- is held constant and the level of interpolated S1 experience varies is summarized in Table 61. The means were found to differ significantly, $F(2,33) = 23.31$, $p < .05$. The three means and multiple comparisons among them are presented in Table 62.

An analysis of variance for the mean number of perseveration days when interpolated experience with S1+ is held constant and the level of interpolated experience with S2 varies is summarized in Table 63. The means were significantly different, $F(2,33) = 12.77$, $p < .05$. The three means and multiple comparisons among them appear in Table 64.

An analysis of variance for the mean number of perseveration days when interpolated experience with S1 is absent and the level of interpolated experience with S2 varies is summarized in Table 65. The means did not differ significantly, $F(2,33) < 1$, $p > .05$. The three means

TABLE 59

Analysis of Variance for the Mean Number of Perseveration Days when Interpolated Experience with S2 is Absent and the Level of S1 varies

Source of Variation	Sums of Squares	df	Mean Square	F
S1 level	20.06	2	10.03	14.03 *
Within	23.58	33	0.71	
Total	43.64	35		

* $p < .05$

TABLE 60

Comparisons among the Means of Each Group for the Number of Perseveration Days when Interpolated Experience with S2 is Absent and the Level of S1 varies

Group	S1+	NT	S1-
Mean	1.83	1.83	0.25

Means not commonly underlined differ significantly $p < .05$), based on the Tukey B procedure (WSD=0.85 df=33).

TABLE 61

Analysis of Variance for the Mean Number of Perseveration Days when Interpolated Experience with S2- is Held Constant and the Level of S1 varies

Source of Variation	Sums of Squares	df	Mean Square	F
S1 level	137.72	2	68.86	23.31 *
Within	97.50	33	2.95	
Total	235.22	35		

* $p < .05$

TABLE 62

Comparisons among the Means of Each Group for the Number of Perseveration Days when Interpolated Experience with S2- is Held Constant and the Level of S1 varies

Group	S1+S2-	S2-	S1-S2-
Mean	4.83	1.92	0.08

Means not commonly underlined differ significantly ($p < .05$), based on the Tukey B procedure (WSD=1.73 df=33).

TABLE 63

Analysis of Variance for the Mean Number of Perseveration Days when Interpolated Experience with S1+ is Held Constant and the Level of S2 varies

Source of Variation	Sums of Squares	df	Mean Square	F
S2 level	72.00	2	36.00	12.77 *
Within	93.00	33	2.82	
Total	165.00	35		

* $p < .05$

TABLE 64

Comparisons among the Means of Each Group for the Number of Perseveration Days when Interpolated Experience with S1+ is Held Constant and the Level of S2 varies

Group	S1+S2-	S1+	S1+S2+
Mean	4.83	1.83	1.83

Means not commonly underlined differ significantly ($p < .05$), based on the Tukey B procedure (WSD=1.69 df=33).

TABLE 65

Analysis of Variance for the Mean Number of Perseveration Days when Interpolated Experience with S1 is Absent and the Level of S2 varies

Source of Variation	Sums of Squares	df	Mean Square	F
S2 level	0.39	2	0.19	0.11
Within	57.25	33	1.73	
Total	57.64	35		

and multiple comparisons among them are shown in Table 66.

An analysis of variance for the mean number of perseveration days when interpolated experience with S1- is held constant and the level of interpolated experience with S2 varies is summarized Table 67. The means did not differ significantly, $F\ (2,33) = 2.03$, $p > .05$. The three means appear in Table 68.

Multiple comparisons among the mean number of perseveration days for each of the nine groups are shown in Table 69.

<u>Phase clustering</u>. The relations among the pre-position, position, post-position, and perseverative responding phases of reversal learning within each of the nine groups are presented in Figure 8.

The clustering of the effects of each type of interpolated training, based on the Tukey B procedure, is shown for all phases and for overall reversal learning in Table 70.

<u>Further consideration of the S1-S2- group's performance</u>

The observation that the S1-S2- group perseverated significantly less than did the NT group but did not meet the reversal criterion sooner requires further examination. The overall reversal performance of the S1-S2- group (8.75 days) and that of the NT group (8.67 days) differed by less than one percent (0.08 days). Yet, the S1-S2- group exhibited a shortening of the perseveration

TABLE 66

Comparisons among the Means of Each Group for the Number of Perseveration Days when Interpolated Experience with S1 is Absent and the Level of S2 varies

Group	S2-	NT	S2+
Mean	1.92	1.83	1.67

All means differed significantly ($p < .05$), based on Tukey B procedure (WSD=1.33, df=33).

TABLE 67

Analysis of Variance for the Mean Number of Perseveration Days when Interpolated Experience with S1- is Held Constant and the Level of S2 varies

Source of Variation	Sums of Squares	df	Mean Square	F
S2 Level	0.39	2	0.19	2.03
Within	3.17	33	0.10	
Total	3.56	35		

TABLE 68

Comparisons among the Means of Each Group for the Number of Perseveration Days when Interpolated Experience with S1- is Held Constant and the Level of S2 varies

Group	S1-	S1-S2-	S1-S2+
Mean	0.25	0.08	0.00

No means differed significantly ($p > .05$), based on the Tukey B procedure (WSD=0.31, df=33).

TABLE 69

Mean Perseveration Days and Multiple Comparisons among the Means

S1-S2+	S1-S2-	S1-	S2+	NT	S1+	S1+S2+	S2-	S1+S2-
0.00	0.08	0.25	1.67	1.83	1.83	1.83	1.92	4.83

Means commonly underlined do not differ significantly ($p > .05$), while means not commonly underlined differ significantly ($p < .05$), based on the Tukey B procedure.

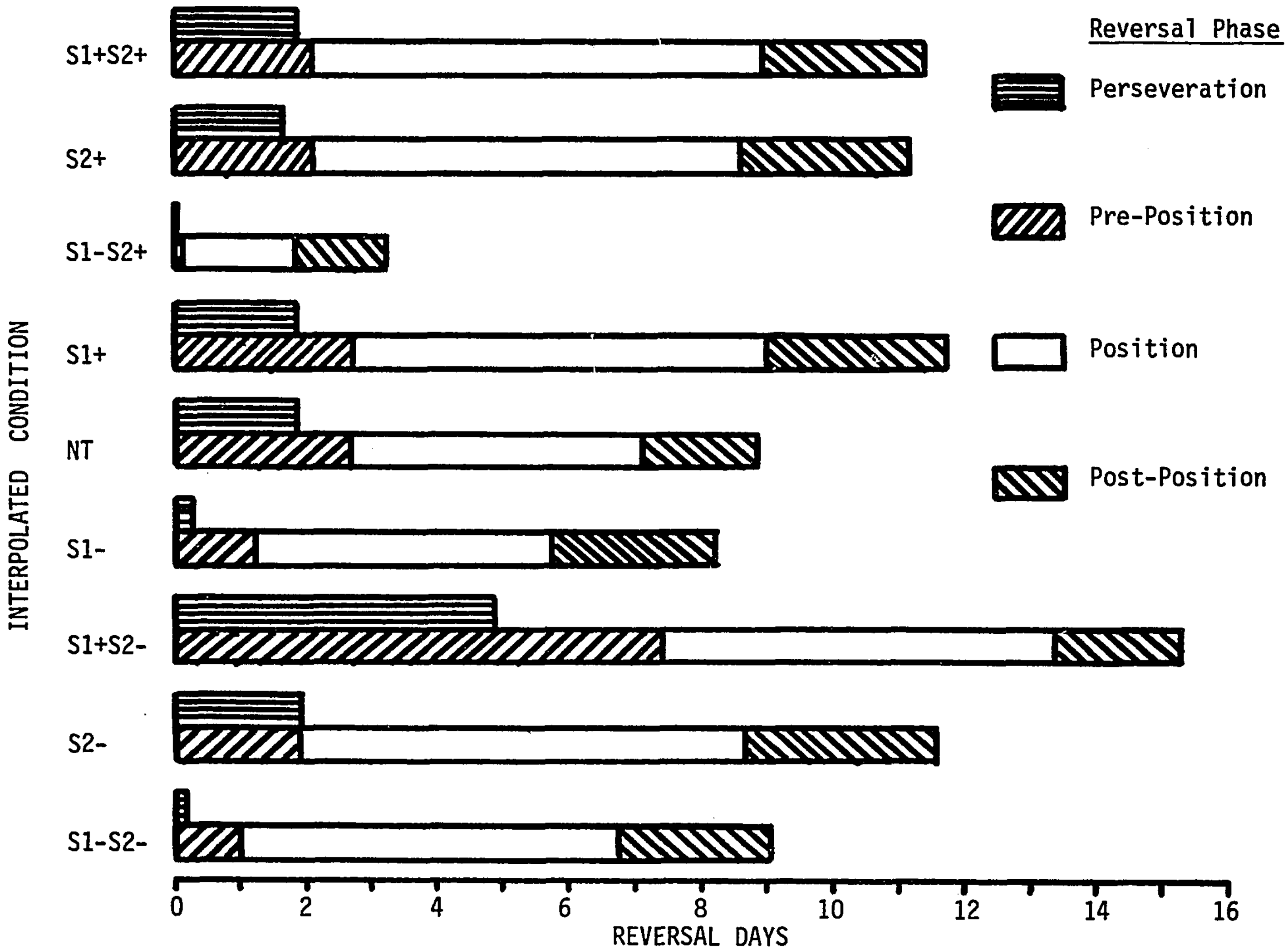

Fig. 8. Reversal phase duration for each interpolated condition

TABLE 70

Clustering of Effects within Reversal Phases

Effect on Reversal	Reversal Performance				
		Reversal Phase			
	Overall	Perseveration	Pre-position	Position	Post-position
Facilitated	S1-S2+	S1-S2+ S1-S2- S1-		S1-S2+	
No Effect	NT S1-S2- S1-	S2+ S1+ S1+S2+ NT S2-	S1-S2+ S1-S2- S1- S2- S1+S2+ S2+ NT S1+	NT S1- S1-S2- S1+S2- S1+ S2+ S2- S1+S2+	S1-S2+ NT S1+S2- S1-S2- S1+S2+ S1- S2+ S1+ S2-
Protracted	S1-S2+ S1+ S2+ S2-	S1+S2-	S1+S2-		
Greatly Protracted	S1+S2-				

Within each column, groups listed as exhibiting the same effect did not differ significantly; groups listed as exhibiting different effects differed significantly ($p < .05$) based on the Tukey B procedure for multiple comparisons.

phase of about 22 percent (1.75 days). If the S1-S2- group perseverated significantly less but reversed in virtually the same number of days as did the NT group, a protraction of other phases for the S1-S2- group is indicated.

Indeed, examination of the nonsignificant differences between the S1-S2- and NT groups in the later phases of reversal learning revealed a total protraction of reversal learning for the S1-S2- group just about equivalent to the significant facilitation of the perseveration phase. In the position responding phase, the S1-S2- group required 5.75 days as opposed to the NT group which required 4.42 days——an S1-S2- group protraction of 15 percent. In the post-position phase, the S1-S2- group required 2.25 days as compared with the NT group which required 1.75 days——an S1-S2- group protraction of 6 percent. The total S1-S2- group protraction of reversal learning in the later phases was 21 percent. The significant facilitation of perseveration phase responding for the S1-S2- group was 22 percent. Thus, the nonsignificant differences summed to equal and counteract the significant perseveration facilitation for the S1-S2- group, minus the observed one percent difference.

DISCUSSION

The major results will be discussed with respect to the resolution of the PERE problem and to the implications for current theories relevant to the PERE.

The Process Underlying the PERE

The PERE was replicated in this study. Interpolated extinction training significantly reduced perseveration of the original discrimination response habits during reversal learning. Yet, interpolated extinction training did not hasten the meeting of the reversal criterion. Therefore, in addition to facilitating the first part of reversal learning, the extinction training must have also protracted the later parts of reversal learning.

Indeed, as compared with the NT group, the S1-S2-group exhibited 22 percent less perseveration; this facilitation was counteracted by a 15 percent protraction of the position responding phase and a 6 percent protraction of the post-position responding phase. While these two protraction effects were not individually significant, their sum is precisely equivalent to the significant reduction of perseverative responding, particularly if the observed one percent difference in overall reversal performance is included.

Thus, the PERE is attributed to multiple and counteracting effects of the interpolated extinction training.

Implications for Theories Relevant to the PERE

The sequential contravention approach was confirmed. Protection approaches, which attribute the PERE to the protection of the original discrimination from the effects of interpolated extinction training, were disconfirmed.

Attention theory. Attention theory predicts that interpolated extinction training rapidly extinguishes attention to the brightness dimension, before the response associations with the stimuli can be substantially diminished. This prediction is contradicted by the observed reversal behavior. Interpolated extinction training did significantly reduce perseveration of the original discrimination response habits during reversal learning. The original discrimination was not protected by the switching-out of the brightness analyzer.

The formal model of attention theory of Sutherland and Mackintosh (1971) provided two further predictions. The S1+S2- group was predicted to exhibit reduced position responding. Yet no such reduction occurred. It was also predicted that reversal learning would be protracted by the provision of forced reversal training at a time when position responding would be observed in a free reversal situation. The S1-S2+ group received forced reversal training until all Ss had passed the position responding point in their development of the reversal. The

S1-S2+ group should then have reversed slower than the NT group. Just the opposite was observed. The S1-S2+ group learned the reversal significantly faster than any other group.

<u>The cue function approach</u>. According to D'Amato and Jagoda (1960), the presence of reward in the experimental situation serves a cue function which maintains the salience of the discrimination. This approach attributes the PERE to the absence of reward during interpolated extinction training. Performance appropriate to the original discrimination is "resurrected" by the reintroduction of reward when reversal learning begins. Like the attention model, this protection approach is disconfirmed by the significant reduction of perseverative responding in reversal learning.

The cue function approach generates another testable prediction. The S1+S2+ group, having received interpolated experience with both stimuli reinforced, should have exhibited rapid reversal learning. The presence of reward should have maintained the salience of the original discrimination response associations and rendered them more vulnerable to the equalizing effect of identical reinforcement. The S1+S2+ group should, then, have exhibited less perseveration of the original response habits during reversal learning than did the NT group. No such perseveration decrease occurred. The S1+S2+ training actually served to significantly increase perseverative responding and to significantly protract reversal learning.

<u>The differential reinforcement approach</u>. If discrimination learning is fundamentally a relationship between response habits based on the relationship of their reinforcement contingencies, then little discrimination learning could occur in the absence of differential reinforcement. True, the greatest differences among the groups occurred where the interpolated training included differential reinforcement, which lends some credence to this approach. However, the observation of significant changes at certain points in the course of reversal learning and in overall reversal performance in groups not receiving differentially reinforced training argues against this explanation of the PERE. The absence of differential reinforcement did not protect the original discrimination response habits from the effects of interpolated extinction training. The differential reinforcement approach is weakened still further by the observation of significant effects of interpolated training with a single stimulus.

<u>The simultaneous contravention approach</u>. The simultaneous contravention approach predicts that the two components of interpolated extinction training——specifically, reversing S1 and overtraining S2——cancel, producing the PERE. The results indicate that the effects of

interpolated extinction training do not simply cancel. Significant differences emerged during different phases of reversal learning.

The sequential contravention approach. The sequential contravention approach predicts that the two components of interpolated extinction training operate at different points within the course of reversal learning to counteract each other and produce the PERE. This approach was confirmed by the significant facilitation of the perseveration phase and the equivalent, though not individually significant, protractions of the later phases of reversal learning. The sequential contravention approach fits the observed behavior, both in terms of the overall reversal behavior and in terms of the performance within the phases of reversal learning.

A Theoretical Interpretation of the PERE

The factors that lie beneath the process that lies beneath the PERE remain speculative. The principle of parsimony holds that the least complex theoretical structure that can accommodate the observed behavior be sought. Consequently, a single process, associative theory of the PERE will be offered. It is based on the relative points in the course of reversal learning that the appropriate response tendencies are developed.

Interpolated extinction training has been shown to significantly reduce perseverative responding in reversal learning. Therefore, such training results in earlier sampling of S2+, as compared with no interpolated training prior to reversal training, assuming a constant number of daily reversal trials. Thus, the tendency to approach S2 develops relatively early for S1-S2- Ss, before the usual amount of experience with S1- can be gained. Due to delayed and less concentrated experience with S1-, the tendency to avoid S1 is delayed.

Evidence for the greater importance of experience with the nonreinforced stimulus in reversal learning has been reviewed earlier (cf. p. 15), and is in agreement with the present results. If interpolated Ss go through the early part of reversal learning gaining less experience with the nonreinforced stimulus, they are placed at a disadvantage in the later parts of reversal learning. In this manner, interpolated extinction training serves to protract the later phases of reversal learning.

This model of the PERE fits the observed effects of interpolated extinction training. It is further supported by the present finding that any interpolated training that does not include S1- experience serves to protract reversal learning. The proposed model accounts for the observed differences within the course of reversal learning as well as for the overall PERE without invoking a second, mediating learning process.

<u>The Role of Experience with Each Stimulus</u>

The present design affords an opportunity to assess the interactive and independent effects on reversal learning of interpolated experience with the stimuli.

<u>Interactive stimulus effects</u>. The significant interaction between the effects of interpolated experience with each of the stimuli suggests that reversal learning is crucially influenced by the specific relationship between the interpolated stimuli. Assuming that reversal learning obeys the same laws as discrimination learning in general, the interactive conclusion is not in accord with the views of Spence (1937) and Kimble (1961), who regard discrimination as the difference between independent gradients along the given stimulus dimension. The interactive conclusion, however, is in agreement with the findings of Andelman and Sutherland (1970), Fox et al. (1970), Hanson (1959), Honig, Thomas, and Guttman (1959), Lachman (1961), and Reynolds (1961), whose views of discrimination emphasize the relationship between the stimuli based on the relationship between their reinforcement contingencies. The present finding that the most powerful effects of interpolated training occur where the stimuli have contrasting reinforcement contingencies strengthens the view of the learning process as fundamentally interactive.

The few studies employing interpolated training to evaluate the role of the stimuli have not used factorial designs, hence they could not detect the interaction effect observed in this study. For example, Stevens and Fechter (1967) compared one group receiving interpolated S1- training with another group receiving interpolated S2+ training, in order to determine the contribution of each stimulus to reversal learning. In light of the powerful interaction effect found in the present study, it becomes appropriate to assess independent effects of interpolated stimulus experience only where they extend beyond any interaction effects that may be present.

Independent stimulus effects. Some of the effects of interpolated stimulus experience remained significant when tested using the interaction mean square as the error term; others did not. The effect of S1 experience was found significant over and above the significant interaction. This was not the case for the effect of S2 experience. This assertion is supported by the 3x3 factorial analysis and by the single-classification analyses. In the latter analyses, the level of interpolated experience with one stimulus was held constant while the other stimulus level was systematically varied. Significant effects of variations in S1 level were found; no significant effects of S2 variation were found.

Examination of the general pattern of the results provides further, albeit less formal, support for the conclusion that interpolated S1 experience has independent reversal effects, while interpolated S2 experience does not. In all groups where S1 was nonreinforced during interpolated training, the reversal was learned as fast as or faster than in the NT group. In all groups where S1 was absent or reinforced, reversal learning was significantly slower than in the NT group. On the other hand, there was no systematic relation between the level of interpolated S2 experience and reversal performance. In fact, where S2 was presented alone during interpolated training, the same protraction of reversal learning occurred whether S2 was reinforced or nonreinforced.

The emphasis on the contribution of S1 experience in determining reversal performance is consonant with the conclusions of Biederman (1967) and Mandler (1968). It is also in agreement with the more recent view of D'Amato (1969) and the personally expressed view of Jagoda. The opposite view had been expressed by D'Amato and Jagoda in 1960; yet, the results that supported their 1960 hypothesis that extinguishing the avoidance of S2 is of primary importance depends on data that can also be interpreted to attribute primary importance to the development of avoidance of S1.

The present conclusion that interpolated experience with S1 is of the greatest importance in reversal learning is in agreement with the larger body of discrimination learning literature emphasizing the greater importance of experience with the nonreinforced cue (amsel, 1962; Birch, 1955; D'Amato, 1969; Denny and Dunham, 1951; Fitzwater, 1952; Khavari and Heise, 1967; Lachman, 1961; Mandler, 1970; and Olton, 1972). Mackintosh (1969), on the contrary, thinks that experience with the reinforced stimulus plays the more crucial role, because reinforced experience contributes to the strength of the relevant stimulus analyzer as well as to the strength of the specific response associations. But Mackintosh's model is not compatible with the present data, nor is it in accord with the many experiments that have provided support for the greater importance of nonreinforced experience.

The present conclusion about the effects of S1 and S2 training generates the next line of inquiry. How does this function operate? Which S1 levels of interpolated training produce which specific reversal effects? The most intuitively apparent answer is that interpolated S1-training, since it includes one of the reversal components, serves to facilitate reversal learning. The answer, however, does not seem to be quite that simple.

Stevens and Fechter (1967) reported that reversal learning was swifter following interpolated experience with S1- than with S2+. Each of these conditions includes one component of the reversal task. While their finding of relative differences stands, it is not at all clear from Stevens and Fechter's experiment which condition exerted the greater influence on reversal learning. Did interpolated S1- training facilitate reversal learning, or did S2+ training protract it? Comparisons among several pairs of groups in the present study provide pertinent information.

Interpolated S1-S2- training resulted in faster reversal learning than did S1+S2+ training. It must be that either the S1- component facilitates reversal more than does the S2+ component, or the S1+ component protracts reversal more than does the S2- component. Since the S1-S2- training had no overall effect compared with the NT condition, it follows that S1+ training protracts reversal learning more than does S2- training, and not that S1- training facilitates reversal learning more than does S2+ training.

Other comparisons lead to the same conclusion, including comparisons among groups receiving interpolated training with only one stimulus. Interpolated S1- training produced faster reversal learning than did S2+ training. But the S1- training did not produce significantly faster reversal learning than did the NT condition. Therefore, interpolated S1- training does not facilitate reversal learning, while S2+ training does protract it.

This, then, is the follow-up to the question raised by Stevens and Fechter's results: It is concluded that any interpolated training that does not include S1-

experience serves to protract reversal learning. Stevens and Fechter's observed differences can be attributed to the protracting effect of interpolated S2+ training and not to a facilitating effect of S1- training.

Implications for the ORE

The overtraining reversal effect (ORE) is the faster reversal of overtrained Ss than criterion trained Ss. The ORE has been extensively reviewed by Lovejoy (1966), Mackintosh (1965), Paul (1965), Sperling (1965), Sutherland and Mackintosh (1971), and Warren and McGonigle (1969). The results of the present study appear to have relevance for the ORE and the search for appropriate ORE models.

It is possible that the same process underlies the PERE and ORE. Interpolated extinction training was found to reduce the perseveration phase and to correspondingly protract the later phases of reversal learning. Overtraining prior to reversal training is known to increase perseverative responding at the beginning of reversal learning (Eimas, 1967; Hooper, 1967; Mandler 1966, 1968; Mandler and Hooper, 1967; Lukaszewska, 1968; and Siegel, 1967). Yet, when the ORE is observed, overtrained Ss learn the reversal faster despite their extended perseveration at the beginning of reversal learning. Extending the PERE process to the ORE case, it may well be that the ORE is attributable to the facilitative effects of overtraining on reversal learning. Overtraining may facilitate the later parts of reversal learning as well as protract the first part.

The single process model proposed to account for the PERE can accommodate the ORE with no additional assumptions or modifications. Since overtraining increases perseveration responding in the beginning of reversal learning, the overtrained Ss must receive high concentrations of S1- experience, as compared with criterion-trained Ss. In other words, overtrained Ss go through the first part of reversal learning having experienced more S1- and, given a constant number of daily trials, less S2+ than criterion-trained Ss. The primary importance of experience with the nonreinforced stimulus was reviewed earlier (cf. p. 15). Due to the increased responding of overtrained Ss to the nonreinforced stimulus during the first part of reversal learning, they can progress through the later parts at an accelerated rate. In this manner, overtraining produces sequentially contravening effects that protract the first part and facilitate the later parts of reversal learning.

Conclusions

The PERE was replicated and attributed to sequentially contravening effects of interpolated extinction training on reversal learning. Such training reduces perseverative responding, facilitating the early part of reversal learning, but it also protracts the later parts of reversal learning. Theories that postulate some internal or external mechanism that suspends associative modifications during interpolated extinction training were disconfirmed by the observation of significant modifications in the course of reversal learning following such training.

It was also concluded that the data fit a single process associative model, which can accommodate the ORE as well as the PERE. It does not seem necessary to invoke a second mediational learning process.

The interaction between the effects of interpolated experience with each stimulus suggests that reversal learning is fundamentally the learning of a relationship between the reinforcement contingencies of each stimulus rather than the learning of independent response habits associated with each stimulus. It becomes appropriate to assess individual stimulus effects only where they are found significant over and above any interaction effects.

Individual stimulus effects were found to extend significantly beyond the interaction effects for interpolated S1 but not S2 training. It is further concluded that any interpolated training that does not include S1-experience serves to protract reversal learning.

A general implication of the sequential contravention finding is that manipulations conceived as a single operation, such as extinction training, need not have simple and unidirectional effects. A related implication is that the reversal learning process is not adequately represented by single measures of overall performance, such as the number of trials or days to meet a performance criterion. Analyses of individual learning phases are necessary.

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