EFFECTS OF ALLEY BRIGHTNESS CUE MANIPULATION PRECEDING SHOCK ON SELF-PUNITIVE RESPONDING IN THE RAT

by

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Chapter 1

Introduction

In 1947, Mowrer first reported an observation by J. S. Brown regarding the maintenance of running behavior in the rat with the application of a punishing stimulus (shock) during the extinction of aversively motivated responding. This facilitative effect of punishment on extinction responding was given the label "vicious circle behavior," and was compared to the compulsive and "viciously circular" processes of neurotic humans (Horney, 1937).

The first systematic study of the facilitative effects of punishment on an aversively motivated locomotor response was reported by Gwinn (1949), who actually utilized a circular runway in his experiments. Since that time, "self punitive" responding has been extensively investigated in perhaps more than 75 published reports, and has proven to be a robust phenomenon. In addition, this area of research has been the topic of three recent reviews, each serving to detail many of the conditions under which vicious-circle (VC) behavior has been obtained (Brown, 1969; Eaton, 1974; Melvin, 1971).

In the standard paradigm, an animal is given escape training on an electrified runway for some number of trials, followed by one of two types of extinction procedures. In regular extinction (RE) procedure, all shock is removed from the runway at the end of training. This condition is contrasted with punished extinction (PE), where shock is removed from the startbox and most of the alley, but continues to be administered in some intermediate segment. Under these conditions, animals given PE trials tend to respond reliably longer and faster than animals receiving RE trials. This is referred to as "self-punitive" responding because animals in this situation leave a "safe" start area and traverse an electrified alley segment before reaching the goalbox. Such behavior continues despite the fact that if the animal remained in the start area, it would receive no shock (Brown, 1969).

Three criteria have been proposed in defining self-punitive responding during punished extinction procedures (Brown, 1969; Melvin, 1971). The first of these involves speed of responding during extinction trials. If the effects of punishment are to be considered facilitative, one would expect punished animals to run faster during extinction than RE animals. Second, one would expect that PE animals would show less decrease in speeds over trials than RE animals. This, of course, is not as important as the first criterion, and many researchers claim to have obtained VC responding as long as there is a difference in speeds between RE and PE groups. However, animals in PE conditions often show speed increases during extinction trials, as opposed to RE animals which show speed decreases over trials (Eaton, 1974). Such an increase in speed, or at least the absence of a speed decrease, would seem to strengthen the case for facilitative effects of punishment. The final criterion for VC responding involves the number of trials to extinction. One would expect that self-punitive animals would take reliably more trials to meet an extinction criterion (for example, failing to enter the goalbox within sixty seconds) than RE animals. Although many researchers have found it sufficient to meet only one of these criteria in researching VC behavior, it would seem necessary to obtain all three in order to establish most clearly the facilitative effects of punishment during extinction.

The most commonly accepted explanation of the VC phenomenon is the "conditioned-fear" hypothesis of Mowrer (1947) as modified by Brown (1969). This hypothesis proposes that fear becomes conditioned to the cues of the startbox and runway during the training trials of an aversively motivated locomotor response. Shock is not present in the goalbox, however, and presumably fear is not conditioned to the cues present in this area. During extinction, animals leaving the pre-punishment areas of the alley encounter shock, which provides additional fear-conditioning trials, through the pairing of shock with the cues present in the alleyway. Thus PE subjects are reinforced for continued locomotor responding by reduction of both pain and fear upon entry into the safe goal area. It is further assumed that the fear conditioned to the alley cues generalizes back to the pre-punishment and start areas, and that animals in the PE condition leave the startbox to escape fear that has in part generalized from similar alley cues. This generalized fear is strengthened when the animal again encounters shock in the alley. As a result, a "vicious circle" is created: running from fear results in shock, which produces more fear, which results in continued running.

The RE subjects encounter no shock in the alley during extinction. As a result, the RE and PE extinction conditions differ in two important ways. First no further fear-conditioning trials take place for the RE animals, since shock is no longer paired with runway cues. Thus the level of fear decreases during the course of extinction trials for RE subjects and the resulting motivation for escape is reduced in comparison to the PE subjects. Second, goalbox entry is no longer reinforced by pain reduction for RE animals. Therefore, the locomotor responding for animals in RE groups should extinguish fairly rapidly in comparison to animals in the PE groups (Brown, 1969).

Alternative explanations of self-punitive responding often involve some variation of a discrimination hypothesis (e.g., Church, 1963; Dreyer & Renner, 1971; Mowrer, 1960; Smith, Misanin & Campbell, 1966a, b). The simplest of these approaches assumes that PE subjects continue to respond because they fail to distinguish between conditions of training and those of extinction (Church, 1963). This explanation is often referred to as the "stimulus-similarity" discrimination hypothesis, and its major proposal is that a subject's resistance to extinction is a direct function of the similarity between the conditions of extinction and those of acquisition (Eaton, 1974).

A second variation of the discrimination hypothesis, proposed by Mowrer (1960), and Dreyer and Renner (1971), has been called the "cognitive discrimination" hypothesis. These authors propose that self-punitive animals fail to discriminate the start area from the shocked segment of the runway. Subjects cannot distinguish that shock is not present in the start area during extinction, and this failure to discriminate causes forward movement that leads to punishment. Both this version of the discrimination hypothesis and the version proposed by Church, however, suffer from a degree of circularity in that animals can only be said to have discriminated if they cease running. Therefore, discrimination must be defined by the very response it is intended to predict (Brown, 1969).

Most vicious-circle research has been interpreted in terms of either a conditioned-fear or a discrimination hypothesis, and both appear to account fairly well for most of the research findings. However, there is at least one area of investigation where problems of interpretation have arisen for both of these hypotheses, i.e., studies in which the shock zone of the alley was made distinctive through the manipulation of alley cues (both brightness and tactile). Both the Mowrer-Brown hypothesis and the discrimination hypotheses would seem to predict that if one were to change the cues associated with shock during extinction, thus making those cues less similar to those in the start area and the rest of the alley, self-punitive responding should decrease. Thus if the shocked segment of a runway was made distinctive from the rest of the alley during punished-extinction procedures, the stimulus-similarity discrimination hypothesis (Church, 1963) would predict less self-punitive responding, since a clear distinction would exist between training and extinction conditions. Dreyer and Renner's (1971) cognitive discrimination hypothesis would also predict reduced VC responding under conditions in which the subject could distinguish the shocked segment from the start area. Since it is a failure to discriminate that is responsible for continued running according to this hypothesis, making the shock zone distinctive should provide the animals a way for making the discrimination between the start area and the shocked area.

The Mowrer-Brown hypothesis would make predictions similar to those of the discrimination hypothesis when the cues associated with shock during punished extinction are altered. This interpretation would suggest that making the shocked segment distinctive from the rest of the alley would result in less generalization of fear from the shocked area to the antecedent cues. Thus fear would be conditioned during punished extinction to cues that were dissimilar to the pre-punishment area. Consequently, fear that had been conditioned to the startbox and pre-punishment segments during training should extinguish in the absence of further conditioning, and self-punitive responding should cease. Under these conditions, RE and PE animals should respond approximately the same in regard to speed of responding and number of trials required to meet the extinction criteria.

Surprisingly, attempts to eliminate self-punitive responding by making the shocked area clearly distinctive from the rest of the alley have been largely unsuccessful. In two separate experiments, Brown (1970) obtained results quite the opposite of what one might expect on the basis of the conditioned-fear and discrimination hypotheses. These counter-intuitive findings were later substantiated by Brown, Beier, and Lewis (1971).

Brown's first experiment involved the manipulation of brightness cues in the shocked segment during punished extinction. Shock-escape training was administered in a six-foot gray alley, with a black goalbox. In extinction, PE subjects encountered shock in the second alley segment. For half of the punished and half of the nonpunished animals, however, the second segment (shock zone) was made distinctive by insertion of black-and-white striped overlays on the segment walls. For the rest of the animals the alley walls remained gray in extinction (Brown, 1970). Contrary to what might be expected, these conditions failed to produce decrements in VC responding. In fact, animals punished during extinction and provided with shock location "cues" actually ran faster in the shocked segment than PE subjects not provided such cues, though the difference was not reliable.

In a second experiment, using black masonite flooring to provide the distinctive cues, Brown obtained results much the same as in the first experiment. In this particular study, masonite panels were placed on the startbox floor and in the first and third alley segments, while the grid floor of the second segment was left uncovered. The sidewall cues in this experiment remained the same for both training and extinction. The exposed flooring comprised the shock zone for the animals punished during extinction. Again, the PE animals ran faster than controls, despite the distinctive floor cues. Brown concluded from these two experiments that animals provided with cues as to the location of shock did not run slower than those not given such cues, and suggested that " . . . increasing the distinctiveness of a punishment region may either weaken self-punitive behavior, leave it unaltered, or paradoxically, strengthen it" (Brown, 1970).

Brown, Beier, and Lewis (1971) attempted to demonstrate objectively that animals could "discriminate" the shock zone, independent of the predicted running response. This was accomplished by noting the presence or absence of attempts to leap over the shocked segment when that segment was made distinctive from the rest of the alley. As with Brown's (1970) study, distinctive cues in the shock zone (in the form of exposed shock grids in contrast to masonite flooring in the rest of the alley) failed to reduce self-punitive responding. In addition, it was found that animals provided with such cues made significantly more jumps than animals not provided with such cues. These investigators concluded that rats may indeed discriminate the changed shock segment cues, but this discrimination fails to produce a decrement in locomotor responding.

There is no question that these studies reported by Brown and his associates are difficult to reconcile with a discrimination hypothesis, unless one simply denies that any discrimination was made despite the distinctive cues that were provided. Such an interpretation would lead to the same circularity mentioned previously, since discrimination can then only be defined in terms of the predicted response, and thus must always be entirely post hoc.

The results of the distinctive shock zone studies are also quite inconsistent with any conditioned-fear hypothesis based on simultaneous conditioning of fear to the cues present in the shocked area of the runway. Of course, it may be possible to attempt such an explanation in terms of stimulus generalization, by arguing that despite cue changes in these studies, fear continued to generalize to the pre-punishment sections of the alley, maintaining the locomotor response. Such an explanation, however, commits one to the same kind of post hoc explanations that the discrimination hypotheses are thought to generate, as stimulus generalization can in this case only be defined in terms of the predicted response. But as Eaton (1974) suggests in his review, it may be possible to render a conditioned-fear interpretation consistent with the distinctive shock zone experiments by stressing forward rather than simultaneous fear conditioning.

It is well documented in classical-conditioning research (MacKintosh, 1974) that the pairing of a conditioned stimulus (CS) with an unconditioned stimulus (UCS) is most effective when there is some interval between the onset of the CS and that of the UCS. Further, it is generally found that as the CS-UCS interval increases, performance increases to a point of maximum responding, then decreases

(Kimble, 1961; McAllister & McAllister, 1971). It may also be plausible to consider the vicious-circle paradigm in a similar classical-conditioning framework, since it involves a UCS of shock presumably paired with alley cues that may act as a CS. The Mowrer-Brown hypothesis would suggest that the shock present in the alley elicits both pain and fear, and after a number of such pairings the cues in the alley then elicit a conditioned response of fear. Thus it would seem reasonable to expect that the same conditions that provide for the most effective CS-UCS pairing in standard classical-conditioning procedures would be applicable to the VC phenomenon, if in fact the conditioning of fear to the apparatus cues is presumed to play a major role in self-punitive responding.

Generally, research indicates that the relationship between the temporal interval between the CS and UCS onset and strength of classical conditioning is applicable to fear conditioning (McAllister & McAllister, 1971), though systematic studies using a fear response have been few with delay conditioning procedures. Libby (1951), using response suppression (lever pressing) as a measure of conditioned fear, found the CS-UCS pairing to be most effective at intervals of 7 to 20 sec., while it was suggested that less fear was conditioned at intervals greater or lesser than these. Murfin (1954), using hurdle jumping as the fear measure, found that conditioned fear was maximal with a CS-UCS interval of 5 sec., while fear was less at shorter or longer intervals. Other studies using response suppression (Lyon, 1963; Stein, Sidman, & Brady, 1958) also support the suggestion that for delay conditioning procedures a curvilinear relationship exists between the CS-UCS interval and the effectiveness of the CS in fear conditioning.

Although two experiments using trace conditioning procedures have failed to demonstrate the curvilinear function of CS-UCS interval and amount of fear conditioned (Leaf & Leaf, 1966; Strouther, 1965), other studies have obtained results consistent with those found with delay procedures. Ross (1961) conditioned fear in human subjects using CS-UCS intervals of .5 to 10 sec. As with delay conditioning, a curvilinear relationship was found, with the most effective CS-UCS pairing occurring with the 2 and the 5 sec. intervals. No evidence of conditioning was found at the shortest interval.

Kamin (1965) used suppression of bar pressing as a measure of fear in a trace-conditioning paradigm. The effectiveness of the CS-UCS pairing decreased with intervals ranging from 61.5 to 180 sec., but only when a trace interval of at least 60 sec. was used. This finding held for several durations of the CS. A shorter trace interval, however, (.5 - 5 sec.) increased the effectiveness of the CS-UCS pairing, as did the use of a stronger CS (80db vs. 60db). Thus there is evidence that trace conditioning also yields a similar curvilinear relationship between the CS-UCS interval and effectiveness of the CS in eliciting fear. However, with trace conditioning this effect can be altered with shorter trace intervals or a stronger CS (McAllister & McAllister, 1971).

Viewing the VC paradigm in terms of classical conditioning, and taking into consideration the results of most classical conditioning research, it may be apparent why the previous attempts to eliminate self-punitive behavior though alley cue manipulation have failed. When distinctive cues in punished extinction are provided only in the same segment or area in which shock occurs, what results is a simultaneous presentation of a CS (changed or distinct alley cues) and the UCS (shock). Although Heth and Rescorla (1973) have shown evidence of simultaneous conditioning, most studies that have employed this procedure have not reported significant conditioning effects (Asratyan, 1965; Bitterman, 1964; MacKintosh, 1974; Smith Campbell & Misanin, 1969).

It would appear that for a CS to be maximally effective in fear conditioning, there must be some interval between the CS (alley cues in this case) and the UCS (shock). If this is the case in the VC paradigm, then in punished extinction the most effective CS will not be the cues of the shocked segment itself, as Melvin has assumed (1971), but rather the alley segment cues encountered in the pre-punishment sections. Thus an alternative assumption would be that the most effective CS for fear conditioning in the VC paradigm would be one presented at some interval before shock. Contrary to Brown, then, it would seem most reasonable to expect that the crucial section for the elimination of self-punitive responding through cue changes is in one or more segments preceding shock.

In the first "distinctive cue" study by Brown (1970), the segments preceding shock were not altered in extinction, and still resembled the start area. According to the argument presented above, fear should be conditioned to cues in the pre-punishment segment and then generalized back to the startbox. In the distinctive cue studies, these remained similar, thus the results obtained by Brown in his first experiment were consistent with the present interpretation.

Brown's second experiment, along with those reported by Brown, Beier, and Lewis (1971), is much more difficult to discuss in the present framework. The major problem with these studies is that the pre-punishment cues remained similar to the startbox cues. It is possible that despite a cue change, encountering shock in extinction still constituted a fear-conditioning trial that generalized back to the startbox.

The present interpretation of the conditioned-fear hypothesis has several implications for VC behavior, especially regarding the issue of shock location in extinction. Given the assumptions delineated previously, it is clear that self-punitive locomotor responding should be greater (in speed and resistance to extinction) the closer the shock zone is to the start area. This follows because the likelihood of fear being directly conditioned to the start area would be increased if fear is in fact conditioned to cues preceding shock. Under such conditions fear would not simply be generalized to the start-area cues, but would be conditioned directly to them, thus any decrement in conditioning that may result from the generalization of fear would be eliminated. This would lead one to expect faster and more persistent VC responding with shock located in the first or second segment than in the third segment (shock in the startbox no longer constitutes self-punitive responding, but rather escape responding, and need not be considered here).

In general, the data suggest that VC responding is indeed more persistent when shock is placed closer to the start area. Though self-punitive responding has been obtained with shock located in various segments, first and second segment shock do appear to produce self-punitive behavior more effectively than third segment shock (Brown, Horsfall & Van Bruggen, 1969; Campbell, Smith, & Misanin, 1966; Martin & Melvin, 1964; Melvin, Athey, & Heasley, 1965; Melvin & Bender, 1967; Melvin & Stenmark, 1969). Brown (1969) and Melvin (1971) both surmised that shock located in the middle segment should be the most facilitative, but the conclusion was based on a comparison between several experiments by Brown, Horsfall & Van Bruggen (1969). Eaton (1974) reported an unpublished study (Eaton, 1972) that found shock in the first segment to yield greater resistance to extinction than middle segment shock.

The conditioned-fear explanation of vicious-circle behavior proposed here also has important implications for the issue of the elimination of VC behavior through alley cue manipulation. The most obvious of these is that alley cue changes should eliminate self-punitive responding when changes occur in the segments preceding shock; cue changes in one should have greater impact than changes in the other in eliminating VC behavior. This prediction follows from previous classical-conditioning research investigating fear responses with different CS-UCS intervals during conditioning. These studies indicated the existence of an optimal CS-UCS interval for CS effectiveness in fear conditioning which may be reflected by differences in cue change effectiveness in the pre-shock segments.

The present study was designed to test the following hypotheses: 1. that brightness cue changes can indeed eliminate self-punitive responding; 2. an important section in which cue changes during punished extinction will affect VC responding is the area preceding shock; 3. that the same curvilinear relationship found in earlier fear-conditioning research between the CS-UCS interval and the effectiveness of the CS in eliciting the fear response also applies to the VC paradigm. Thus given two segments preceding shock, there should be a greater decrement in self-punitive responding following cue changes in one segment in comparison to the other. Two experiments were designed to test these predictions, each using brightness cue changes in the runway as the form of alley cue manipulation.

The first experiment was designed to demonstrate that changing brightness cues is effective in eliminating self-punitive responding. To accomplish this, an experiment manipulating total alley brightness cues was performed. After training in either an all-white or all-black runway (with a distinct goalbox), two punished-extinction groups were compared. These two groups differed only in the presence or absence of a brightness cue change during extinction. One group received extinction trials with the alley cues remaining the same as those in training (NCPE), while the second group received extinction trials with alley brightness changed in all three alley segments (CPE). Only the startbox and goal area remained the same as during training for this group. An RE group for each of these extinction conditions was also included (NCRE, CRE).

In addition to the brightness cue manipulations, the present study differed from that performed by Brown (1970) in another important aspect. In this experiment, shock for the PE groups was administered in the third segment, instead of the second. Though this typically does not produce the highest level of VC responding, it is still reported to produce reliable self-punitive behavior. Further, such shock placement allows for cues to be manipulated in a greater number of segments preceding shock.

Except for the location of the shock zone, the RE and PE groups for which the alley cues remained constant during extinction comprise standard VC conditions. Thus group NCPE was expected to show typical self-punitive responding, with animals in this group running reliably faster and requiring more trials to reach an extinction criterion than NCRE controls.

For the two groups in which the alley cues were changed during extinction (CRE & CPE) there was a clear distinction between the start area and all alley cues preceding and simultaneous with shock. Consequently, it was expected that the extinction performance of group CPE would be much the same as that of group CRE, since in both groups fear should be eliminated as a motivation for responding due to the cue change. Further, any fear that may be conditioned during the punished-extinction trials to the new alley brightness cues would not be expected to generalize as effectively back to the start area, in comparison to the generalization presumed to take place for group NCPE. Thus there should be a greater decrease in self-punitive responding for group CPE in comparison to group NCPE.

In the second experiment, training in either an all-white or all-black runway was followed by three manipulations of alley brightness cues during extinction trials. Figure 1 illustrates the brightness cue manipulations in Experiments 1 and 2.

Group C1+2RE and C1+2PE resembled groups CRE and CPE from Experiment 1, with one exception; instead of having all three alley segments changed in extinction, Segment 3 remained the same as in training. Animals in group C1+2RE were expected to respond similarly to those in group C1+2PE during extinction, and similarly to groups CPE and CRE in Experiment 1. Despite the fact that shock occurred in a segment with cues similar to those in the start area, the preceding segments did differ in brightness, thus fear should not have generalized back to the start area to initiate the running response.

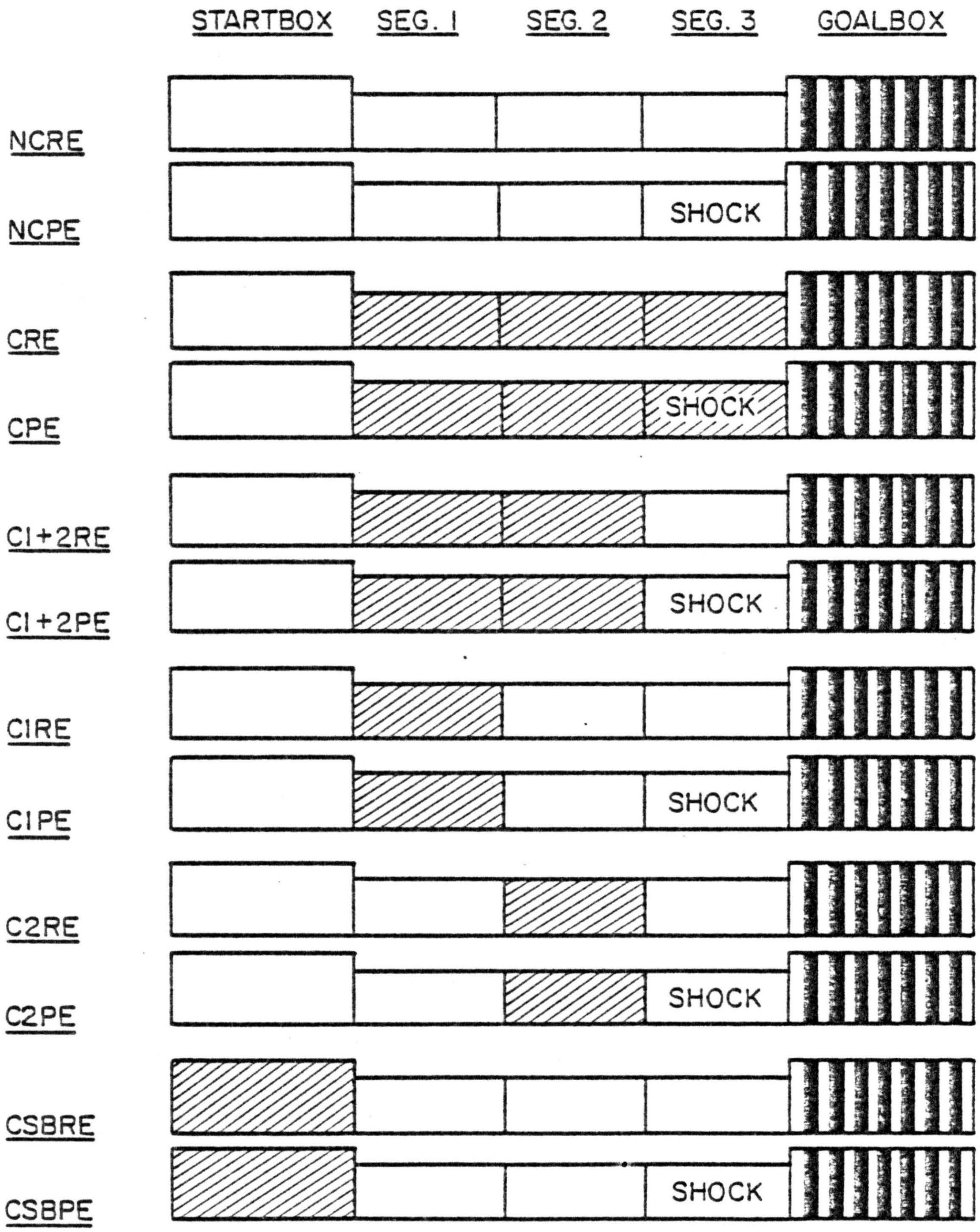

Figure 1. Alley Brightness Extinction Conditions for all Groups in Experiments 1 and 2; Darkened Segments denote a change in Brightness Cues from Training.

Groups C1PE and C2PE were especially important in Experiment 2. Animals in group C1PE received punished-extinction trials in an alley that had only the cues in Segment 1 changed from training. Animals in group C2PE received a similar treatment except that in extinction only the cues in Segment 2 were changed. Thus the only difference between these two groups was the placement of the distinctive alley cues in the pre-punishment sections. It was assumed that both conditions would provide an equally discriminable change between training and extinction conditions. Therefore, if a significant difference were found in self-punitive responding between these two groups, it would provide strong evidence against the discrimination hypothesis.

A difference between groups C1PE and C2PE in terms of self-punitive responding would also provide support for the expanded version of the conditioned-fear hypothesis proposed previously. Assuming the same curvilinear relationship between the CS-UCS interval and the effectiveness of the CS in fear conditioning demonstrated in previous research, it was likely that animals encountering cue changes in one segment preceding shock would cease responding more rapidly than those subjected to changes in the other segment. Though difficult to explain in terms of a discrimination hypothesis, such a result would be consistent with previous fear research and would provide support for the conditioned-fear explanation proposed in this study.

Groups C1RE and C2RE served as controls for the above two PE conditions. No difference was expected between these groups in either speed or number of trials required to meet extinction criterion, making a direct comparison between the corresponding PE groups possible. The cue changes for each group were the same as those of the corresponding PE groups, but no shock was present during extinction.

The final two groups in this experiment were also quite important in testing the conditioned-fear hypothesis proposed here. Animals in groups CSBPE and CSBRE encountered cue changes in the lower tier of the startbox during extinction trials. Shock was present in the third alley segment for group CSBPE, while no shock was present during extinction for group CSBRE. These last two groups were included because one of the crucial assumptions of the Mowrer-Brown hypothesis is that fear generalizes back to the startbox during punished extinction. This assumption is important since it is presumed that it is the startbox cues which initiate the locomotor response in self-punitive responding. It was thus expected that changing the cues in the startbox would serve to block generalization of fear to these cues. As a result, animals in this group were expected to show reduced self-punitive responding in comparison to their controls.

The crucial comparisons made in this experiment involved the extinction performance of groups C1PE, C2PE, and CSBPE. It was expected that a comparison of groups C1PE and C2PE would find little or no decrement in self-punitive responding under one of these cue change conditions, while animals in the other cue change group should show a much greater elimination of self-punitive behavior. However, since previous research in fear conditioning had demonstrated a curvilinear relationship between CS-UCS intervals and CS effectiveness, it was not possible to make a prediction as to which of the cue changes would show the most effective elimination of VC behavior. Thus only the prediction that there should be a difference in self-punitive responding between these two cue change conditions was made. Finally, the animals in group CSBPE were also expected to show reduced VC responding, due to the presumed importance of the start area in initiating the self-punitive locomotor response.

Chapter 2

Method

Experiment 1

Apparatus. The apparatus consisted of a two-tiered startbox, a 183 cm three-segment alley, and a goalbox, similar to the runway described by Brown, Martin, and Morrow (1964). Both the startbox and the alley segments were initially white, but could be altered by the insertion or removal of black cardboard inserts on the inside walls. These inserts were held in place by small white velcro patches attached to both the apparatus walls and the cardboard inserts. The goalbox was black with white stripes on the walls and floor.

The upper tier of the startbox (measuring 23.3 cm x 11.3 cm x 17.3 cm) employed a trap-door floor, which upon release dropped subjects onto the grid floor of the lower startbox compartment (40.3 cm x 11.6 cm x 20.3 cm). This lower compartment connected directly to the first of three grid-floored alley segments. Each segment was separately wired, and measured 61.0 cm x 11.6 cm x 20.3 cm. The goalbox measured 44.9 cm x 25.1 cm x 20.0 cm, and had a flat wooden floor. A manually operated guillotine door was employed to confine subjects in the goalbox.

Individual photocells were located in the lower compartment of the start box and 2.2 cm from the end of each segment, permitting measurement of both total runway time per trial, and time spent in each individual segment for each trial. Starting time, total time, and culmulative time per segment were recorded for each trial; however, total alley time (in the form of alley speeds) figured most prominantly in the data analysis.

Start time was defined as the time interval between the release of the trap door and the interruption of the photocell beam at the end of the lower startbox compartment. Each runway photocell was connected to one of four Lafayette Electric Timers, via two Hunter photocell relays. Times were recorded to the nearest one-hundredth of a second. All clocks were activated by the release of the start box trap door, and were stopped by the interruption of their corresponding photobeam.

A Grayson-Stadler Shocker-Scrambler was employed to deliver a constant ac shock in the lower tier of the startbox and each alley segment. Shock was delivered through grids which measured 3 cm in diameter and were spaced 1.2 cm apart measured from their center.

Subjects and design. Subjects were 40 male Long-Evans derived hooded rats bred in the animal colony at VPI & SU. Animals were 90-110 days old on Day 3 of training. Subjects were housed in pairs in hanging metal cages in the main departmental colony, and given ad libitum food and water access. Two weeks before training these animals were assigned to one of four extinction groups in a 2x2 design, with 10 animals per group. The presence or absence of shock in extinction and the presence or absence of brightness cue change were the independent variables.

A third variable was included in training that was analyzed separately from the extinction manipulations. In order to insure that brightness changes from light to dark were not somehow more effective cue changes than changes from dark to light, these changes were balanced across all groups. Thus half of the subjects were trained in a white alley, the other half in black. Appropriate cue changes were then effected by insertion or removal (respectively) of the black inserts. Thus the overall design was actually a 2x2x2.

Procedure. All training and extinction trials were conducted in a single session. Two subjects were run per day; one regular-extinction (RE) and one punished-extinction (PE) subject from one of the two alley brightness conditions in extinction (change vs. no change; or C vs. NC), and from one of the two alley brightness training conditions. Assignment to training conditions, extinction groups, running days, and order of running were all randomly determined.

On Day 1 for each animal, there was a 10 min. handling session, with the subject remaining on the experimenter's hand for most of this period. On Day 2, each animal was given another 5 min. of handling, followed by 5 min. of exploration in the runway. The latter procedure consisted of placing the subject in the upper level of the startbox and dropping it to the lower level. The animal then had free access to the entire alley with no shock present.

Training began on Day 3. Each subject received a total of 15 training trials. The first six of these were pre-training trials, used to shape the running response. On Trial 1 the startbox and the goalbox were connected in tandem, with a constant current ac shock of 0.8 ma (at 416v) administered in the lower compartment of the startbox. For Trials 2 and 3, the first electrified 60 cm alley segment was inserted between the startbox and the goalbox. For Trials 4 and 5, the second electrified alley segment was added. The third electrified segment was added for the last pre-training trial (Trial 6), completing the 183 cm alley. For the remaining training trials, 7-15, all three segments remained with their grids electified. Thus each animal received 10 trials with shock present in the entire alley.

Subjects were dropped from the upper level of the startbox onto the grid floor of the lower compartment to begin each trial. A guillotine door was lowered upon the animals entry into the goalbox, thus separating the subject from the rest of the runway. Goalbox confinement lasted for 30 sec., after which the subject was transferred to an unpainted neutral wooden holding cage (35.2 cm x 13.2 cm x 20.2 cm) for approximately 20 sec. Following this period, the animal was again placed into the startbox to begin another trial. Total ITI was approximately 1 min., timed from the subject's entry into the goal box to the release of the startbox trap door for the next trial.

Extinction trials began immediately following the last training trial. These trials continued until one of two criteria had been met: one trial in which the subject failed to enter the goalbox within 60 sec. after entry into the runway; or completion of 60 extinction trials. If the subject completed a 60 sec. trial in less than 60 extinction trials, all remaining trials were assigned a total alley time of 60 sec., with a starting time and individual segment times of 15 sec. each. For the first 60 sec. trial, the start and segment times were retained if they were less than 15 sec.; if not, they were also assigned the default value.

In this experiment, there were four extinction groups, differing in the presence or absence of shock in the third alley segment (RE or PE), and changed or unchanged total alley brightness cues (excluding the startbox) in relation to training cues. Thus animals in group NCRE received extinction trials with the alley segments remaining the same in terms of brightness cues as during training trials, but with no shock present. This group served as a control group for the second group, NCPE, which also experienced extinction trials with the alley brightness cues similar to those in training, but with shock remaining in the third segment. Groups CRE and CPE, however, were given extinction trials with the alley brightness cues changed in all three alley segments. Thus if a subject in one of these groups had been trained in a black runway, extinction trials took place with all three alley segments changed to white, while the startbox (both levels) and the goalbox remained the same as during training. Group CRE received no shock during extinction trials, similar to group NCRE, while CPE received punished-extinction trials much like NCPE (shock in the third segment).

Experiment 2

Apparatus. The basic apparatus was the same as in Experiment 1, using the two-tiered startbox, three-segment alley, and striped goalbox. Photocells were located as before, with latencies obtained in the same manner as described previously. As in Experiment 1, black cardboard inserts were removed or added during extinction in order to manipulate brightness cues.

Subjects and design. Subjects were 80 male Long-Evans derived hooded rats bred in the animal colony at VPI & SU. All animals were 90-110 days old on Day 3 of training, and were housed and maintained similarly to the animals used in Experiment 1. Animals were randomly assigned to one of eight extinction groups in a 2 x 4 design, with 10 animals per group. The independent variables were the presence or absence of shock (RE vs. PE) and alley brightness cue manipulations in one of four runway areas (C1+2, C1, C2, CSB). A training variable was also included in which half the subjects in each group were trained in a white alley and half in black. Cue changes were effected by insertion or removal of the black inserts. The formal design was then a 2 x 2 x 4, but only the two extinction manipulations were utilized in analysis.

Procedure. Four subjects were run each session, two in PE groups and two in RE groups, randomly assigned as in Experiment 1. Handling and exploration, pre-training, and training trials were also identical to the first experiment. Half the animals in each group were trained in an all-white alley, and the other half in an all-black alley, while the goalbox remained striped for all groups during all trials.

During extinction PE subjects encountered shock only in the third alley segment, while RE subjects received no shock in any segment. Two groups, C1+2RE and C1+2PE, received extinction trials in a runway that had the brightness cues in alley segments 1 and 2 changed from those in training. Thus if an animal in one of these groups had been trained in an all-white alley, Segments 1 and 2 would be changed to black during extinction trials. For groups C1RE and C1PE, cue changes in extinction took place only in Segment 1 of the runway, while the startbox and Segments 2 and 3 remained the same as in training. Groups C2RE and C2PE differed from the previous two in that the center segment (Segment 2) had the brightness cues altered, while the first and the third segments remained the same. Finally, groups CSBRE and CSBPE had only the lower level of the startbox changed from training, while the three alley segments remained constant. Extinction criteria for these groups were identical to those employed in Experiment 1.

Chapter 3

Results

Experiment 1

Median latencies of total times over blocks of three trials were converted into speed scores (cm/sec) for each subject. Pre-training trials (Trials 1-6) were not included in the analyses. Number of trials to reach the extinction criterion and total alley speeds served as dependent variables.

Training. Mean total alley speeds for each group for the three training blocks are plotted on the left side of the graph in Figure 2. The overall mean speeds for the three blocks were as follows: 102.24, 117.57, 114.57 cm/sec.

A repeated-measures analysis of variance was performed on total speeds. Extinction Condition (PE vs. RE) and Cue Condition (C vs. NC) were Between-Subjects factors, while Blocks of trials served as a Within-Subjects factor. A summary table of the analysis of variance for training trials is presented in Table 1.

The main effect of Blocks ($p < .0001$) and the Cue Condition x Blocks interaction ($p < .05$) were the only significant effects obtained in the analysis of training speeds. A summary of the simple effects analysis of variance for the Cue Condition x Blocks interaction is presented in Table 2. The results of these analyses indicate that

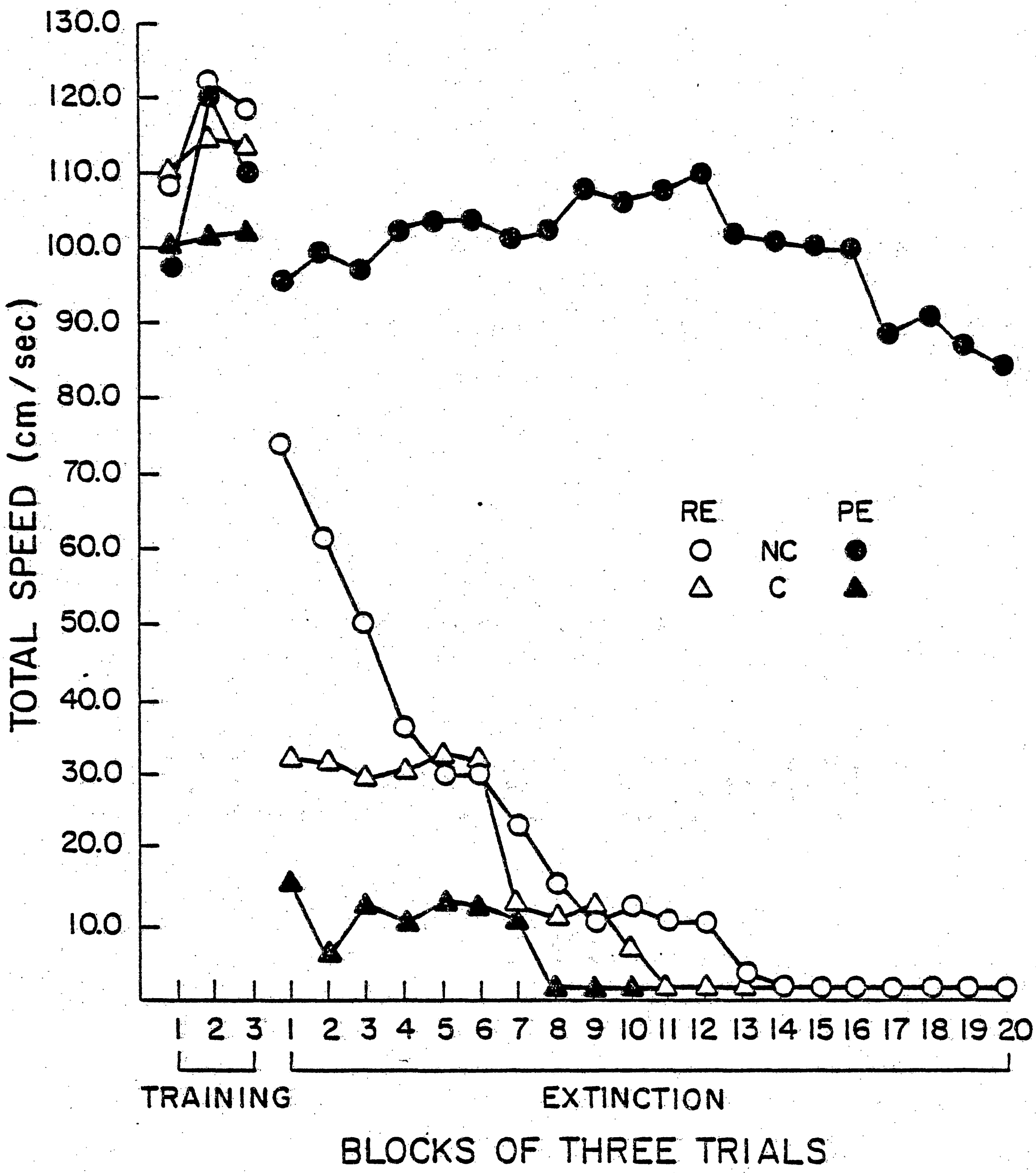

Figure 2: Mean Total Alley Speeds for Training and Extinction Trials from Experiment 1.

TABLE 1

Summary of Analysis of Variance of Total Alley Speeds for Training Trials from Experiment 1

Source	df	Ms	F	P
Between Subjects	39			
Extinction Condition (EC)	1	440.23	.87	>.10
Cue Condition (CC)	1	3.16	.01	>.10
CC x EC	1	32.67	.06	>.10
error b	36	506.83		
Within Subjects	80			
Blocks (B)	2	2638.78	24.63	<.0001
EC x B	2	24.56	.23	>.10
CC x B	2	361.84	3.38	<.05
CC x EC x B	2	73.11	.68	>.10
error w	72	107.14		
Total	119			

TABLE 2

Summary of Simple Effects Analysis of Variance of Total Speeds for the Cue Change By Blocks Interaction for Training Trials From Experiment 1

Cue Condition

Block #	Source	df	MS	F	P
1	Cue Condition	1	313.93	1.11	>.05
1	error w	38	282.23		
2	Cue Condition	1	412.68	3.60	>.05
2	error w	38	114.74		
3	Cue Condition	1	235.27	.77	>.05
3	error w	38	303.78		

Cue Condition	Source	df	MS	F	P
No Change	Blocks	2	2413.84	15.99	<.0001
No Change	error w	38	150.92		
Changed	Blocks	2	586.77	10.25	<.001
Changed	error w	38	57.23		

Cue Condition group C did not differ from group NC for any of the three training blocks. Speed scores did increase significantly over Blocks for both Cue Condition groups, and this difference was slightly more reliable for NC groups ($p<.0001$) than for C groups ($p<.001$). A Duncan's Multiple Range test indicated increases in speeds from Training Block 1 to Blocks 2 and 3. Blocks 2 and 3, however, did not differ in mean speeds. Further, these speed increases across blocks were greater for some groups (Cue Condition C) than for others (Cue Condition NC).

Extinction. A separate analysis of variance was performed on the Direction of Change variable (comparing changes from light to dark with those from dark to light) for both trials to extinction and total alley speeds. The effects of changing alley brightness cues from light to dark did not differ significantly from those of changing from dark to light, nor were there any significant interactions involving this variable. Summaries of these analyses for Experiment 1 are presented in the top sections of Tables 3 and 4.

The right side of the graph in Figure 2 presents the group means for total alley speeds over blocks of extinction trials. This figure indicates an important interaction between Cue Condition and Extinction Condition, in that group NCPE responded consistently faster than the remaining three groups. Repeated measures analyses of variance were conducted, using Cue Condition and Extinction Condition as Between-Subject effects, and Blocks as a Within-Subjects effect. Significant differences were obtained for all three main effects, as

TABLE 3

Summary of Analysis of Variance of Total Speeds for Direction of Change for Extinction Trials from Experiment 1 and Experiment 2

Experiment 1

Source	df	MS	F	P
Between-Subjects	3			
Direction of change (DC)	1	774.61	.04	>.10
CD x Cue Condition	2	10527.86	.52	>.10
Within Subjects	32			
error w	32	20077.08		
Total	35			

Experiment 2

Source	df	MS	F	P
Between-Subjects	4			
Direction of Change (DC)	1	15947.96	.69	>.10
DC x Cue Condition	3	43544.81	1.89	>.10
Within Subjects	64			
error w	64	23039.58		
Total	68			

TABLE 4

Summary of Analysis of Variance of Trials to Extinction for Direction of Change from Experiment 1 and Experiment 2

Experiment 1

Source	df	MS	F	P
Between Subjects	3			
Direction of Change (DC)	1	4973.17	.96	>.10
DC x Cue Condition	2	2411.16	.47	>.10
Within Subjects	32			
error w	32	5170.40		
Total	35			

Experiment 2

Source	df	MS	F	P
Between Subjects	4			
Direction of Change (DC)	1	8450.43	.29	>.10
DC x Cue Condition	3	17289.38	.59	>.10
Within Subjects	64			
error w	64	29139.40		
Total	68			

well as for the Extinction Condition x Blocks interaction and the Cue Condition x Extinction Condition interaction. Each effect was significant at the $p<.0001$ level, except Extinction Condition, which was significant at the $p<.001$ level. These results are presented in Table 5.

A simple effects analysis of variance of the Cue Condition x Extinction Condition interaction indicated that RE and PE groups differed reliably only for the NC Cue Condition, with group NCPE responding reliably faster ($p<.0001$) than the NCRE control group (see Table 6). The RE and PE groups for the Cue Condition C groups did not differ statistically, indicating that the presence of shock did not facilitate responding under this Cue Condition. Concommitantly, Cue Condition groups did differ for the PE groups, with group NCPE responding significantly faster than CPE ($p<.0001$), while no difference was found for the RE groups. These results indicate that changing the brightness cues in the entire alley from those present during training reduced the speeds of the PE groups, while it did not affect the RE groups.

The simple effects analysis of variance for the Extinction Condition x Blocks interaction (Table 7) revealed that the main effect of Blocks was significant only for the RE groups ($p<.0001$), reflecting a substantial decrease in total alley speed during extinction for these groups. This decrease was not present for the PE groups, as there was no significant change in speed over blocks. However, this finding is mitigated by the Cue Condition x Extinction Condition interaction. Indeed, upon examining Figure 2, it is clear

TABLE 5

Summary of Analysis of Variance of Total Alley Speed for Extinction Trials From Experiment 1

Source	df	MS	F	P
Between-Subjects	39			
Extinction Condition (EC)	1	264921.36	14.27	$<.001$
Cue Change (CC)	1	489501.25	26.37	$<.0001$
CC x EC	1	376343.69	20.28	$<.0001$
error b	36	18559.59		
Within-Subjects	760			
Blocks (B)	19	3829.95	9.07	$<.0001$
EC x B	19	2131.53	5.05	$<.0001$
CC x B	19	337.45	.80	$>.10$
CC x EC x B	19	608.37	1.44	$>.10$
error w	684	422.21		
Total	799			

TABLE 6

Summary of Simple Effects Analysis of Variance of Total Speeds for the Cue Condition by Extinction Condition Interaction for Total Speeds From Experiment 1

Cue Condition

Extinction Condition	Source	df	MS	F	P
PE	Cue Condition	1	862131.87	26.46	<.0001
PE	error b	18	32581.40		
RE	Cue Condition	1	3713.07	.81	>.10
RE	error b	18	4537.65		

Extinction Condition

Cue Condition	Source	df	MS	F	P
No Change	Extinction Condition	1	636387.94	18.67	<.0001
No Change	error b	18	34078.17		
Changed	Extinction Condition	1	4877.11	1.60	>.10
Changed	error b	18	3041.00		

TABLE 7

Summary of Simple Effects Analysis of Total Speeds for Blocks Holding Extinction Condition Constant for Extinction Trials from Experiment 1

Extinction Condition	Source	df	MS	F	P
RE	Blocks	19	5548.04	11.64	<.0001
	error w	361	476.68		
PE	Blocks	19	413.45	1.11	>.10
	error w	361	373.07		

that group CPE shows no decrease in responding during extinction trials due to a large initial decrement in response speed from Training Block 3 to Extinction Block 1, which made further significant decreases in speeds across extinction blocks unlikely. Group NCPE, however, did not suffer from this floor effect, and unlike CPE, shows substantially faster and more consistent speeds than its RE control.

In the above analyses, runspeeds were analyzed across all 23 extinction trial blocks. However, many of the animals in some groups met the extinction criterion well before the last trial block. In fact, 30 out of the 40 subjects had met the extinction criterion by Extinction Block 10 (within 30 trials). As a result, much of the overall analyses were based on default scores assigned to animals that were no longer running; for example, all 10 animals in group CPE had met the extinction criterion by Trial Block 8. For this reason the total alley speed data was re-analyzed including only those blocks in which some animals in each group were still responding; i.e., Blocks 1-7. Although many animals had also met extinction criterion by Block 7, enough did continue to respond during these trials so that 140 of the 280 times recorded were based on actual performance and not experimenter assigned default scores. This was in contrast to the overall analysis where only 251 of 800 observations were not default scores.

Table 8 presents the analysis of variance of total alley speeds for extinction trial Blocks 1-7. The results are quite similar to

TABLE 8

Summary of Analysis of Variance of Total
Alley Speeds for Extinction trial Blocks 1-7
From Experiment 1

Source	df	MS	F	P
Between Subjects	39			
Extinction Condition (EC)	1	28736.29	2.95	>.10
Cue Condition (CC)	1	188379.87	19.36	<.0001
CC x EC	1	95980.60	9.86	<.005
error b	36	9732.84		
Within Subjects	240			
Blocks (B)	6	1183.28	3.45	<.005
EC x B	6	1846.13	5.38	<.0001
CC x B	6	435.63	1.27	>.10
CC x EC x B	6	924.99	2.70	<.05
error w	216	343.11		
Total	279			

those obtained for the analysis of variance including all 20 extinction blocks, with one exception. In this last analysis the Cue Condition x Extinction Condition x Blocks interaction was significant ($p<.05$). However, a simple effects analysis holding each block constant (Table 9) revealed that the important Cue Condition x Extinction Condition interaction was reliable for each extinction block, except Block 1 ($.05<p<.09$). Thus these alley speed analyses do not conflict with the analyses including all 20 extinction blocks, even though the majority of the scores in the latter analyses were default scores.

The mean number of trials to extinction for each extinction group is presented in the upper portion of Table 10. Table 11 presents the results of the analysis of variance for the number of trials to extinction. Significant effects were found for Cue Condition, Extinction Condition, and the Cue Condition x Extinction Condition interaction, with significance levels of $p<.0001$ for each effect.

Table 12 presents the simple effects analysis of variance for trials to extinction for the Cue Change x Extinction Condition interaction. These results are consistent with the results obtained in the alley speed analysis. The RE and PE groups differed in trials to extinction only for the NC Cue Conditions ($p<.001$). Thus group NCPE took reliably more trials to meet the extinction criterion (mean=44.8) than its RE control group, NCRE (mean=14.0). Groups CRE and CPE did not differ on this measure (means=8.3 and 3.0, respectively), indicating the absence of VC responding for these

TABLE 9

Summary of Simple Effects Analysis of Variance of Total Alley Speeds for the Cue Condition by Extinction Condition by Blocks Interaction for Extinction Trial Blocks 1-7 From Experiment 1

Block Number	Source	df	MS	F	P
1	Cue Condition (CC) by Extinction Condition (EC)	1	4069.32	3.17	<.09
	error	36	1284.39		
2	CC x EC	1	9613.65	6.09	<.02
	error	36	1578.51		
3	CC x EC	1	10532.83	5.52	<.03
	error	36	1907.27		
4	CC x EC	1	19241.35	11.23	<.005
	error	36	1714.02		
5	CC x EC	1	21115.50	11.34	<.005
	error	36	1861.76		
6	CC x EC	1	20031.61	10.95	<.005
	error	36	1829.37		
7	CC x EC	1	15842.39	10.00	<.005
	error	36	1583.79		

TABLE 10

Summary of Mean Number of Trials to the Extinction Criterion From Experiment 1 and Experiment 2

Experiment 1

Group	Mean	SD	Group	Mean	SD
NCPE	44.8	23.97	CPE	3.0	6.72
NCRE	14.0	13.74	CRE	8.3	10.43

Experiment 2

Group	Mean	SD	Group	Mean	SD
C1+2PE	5.6	7.69	C2PE	33.5	28.7
C1+2RE	8.8	9.27	C2RE	5.0	4.39
C1PE	13.3	22.65	CSBPE	26.8	25.0
C1RE	7.8	9.72	CSBRE	11.1	9.89

TABLE 11

Summary of Analysis of Variance of the Number of Trials to Extinction Criterion from Experiment 1

Source	df	MS	F	P
Between Subjects	3			
Extinction Condition (EC)	1	48691.50	10.00	<.0001
Cue Condition (CC)	1	110814.58	22.76	<.0001
CC x EC	1	90625.18	18.61	<.0001
Within Subjects				
error w	36	4869.68		
Total	39			

TABLE 12

Summary of Simple Effects Analysis of Variance of the Cue Condition by Extinction Condition Interaction For Number of Trials to Extinction Criterion from Experiment 1

Extinction Condition	Source	df	MS	F	P
RE	Cue Condition	1	507.15	.19	>.10
	error	18	2612.42		
PE	Cue Condition	1	200932.60	28.19	<.0001
	error	18	7126.93		

Cue Condition	Source	df	MS	F	P
NC	Extinction Condition	1	136086.40	17.08	<.001
	error	18	7968.22		
C	Extinction Condition	1	3230.35	1.82	>.10
	error	18	1771.13		

groups. In addition, the effect of Cue Condition was significant ($p < .0001$) only for the PE groups, and not for the RE groups. Group NCPE responded significantly longer in extinction than group CPE (means 44.8, 3.0, respectively), giving further evidence that the cue changes employed reduced the facilitative effects of punishment on VC behavior.

Experiment 2

Training. An analysis of variance for total alley speeds for training trial blocks yielded a significant effect only for Blocks ($p < .0001$). Mean speeds for the three training blocks were as follows: 112.86, 120.36, and 123.73 cm/sec. This indicates a reliable increase in total alley speeds across the three blocks. The results of this analysis are presented in Table 13.

Extinction. As in Experiment 1, an analysis of variance was performed on the Direction of Change variable using trials to extinction and total alley speeds as dependent variables. As before, these comparisons yielded no significant differences in either measure, indicating that brightness cues had similar effects when changed from light to dark as when changed from dark to light. A summary of these results is presented in the lower portion of Tables 3 and 4.

Group means of total speeds across blocks for each extinction group are plotted in Figure 3. This graph indicates that groups C2PE and CSBPE responded faster in extinction than the remaining two PE groups, although the responding of group C2PE appeared more stable across trial blocks than CSBPE. The RE groups responded similarly to one another in regard to total speed during extinction trials. A repeated measures analysis of variance was performed for total alley speeds (Table 14) and yielded significant main effects for Blocks ($p < .0001$), Extinction Condition ($p < .01$), as well as for Cue condition x Extinction Condition ($p < .05$), Cue Condition x Blocks ($p < .0001$), and Extinction Condition x Blocks ($p < .0001$). The main

TABLE 13

Summary of Analysis of Variance of Total Alley Speed for Training Trials from Experiment 2

Source	df	Ms	F	P
Between Subjects	79			
Extinction Condition (EC)	1	1832.87	2.00	>.10
Cue Condition (CC)	3	345.91	.38	>.10
CC x EC	3	858.73	.93	>.10
error b	72	916.43		
Within Subjects				
Blocks (B)	2	2088.93	11.81	<.0001
EC x B	2	48.49	.27	>.10
CC x B	6	160.86	.91	>.10
CC x EC x B	6	102.62	.58	>.10
error w	144	176.83		
Total	239			

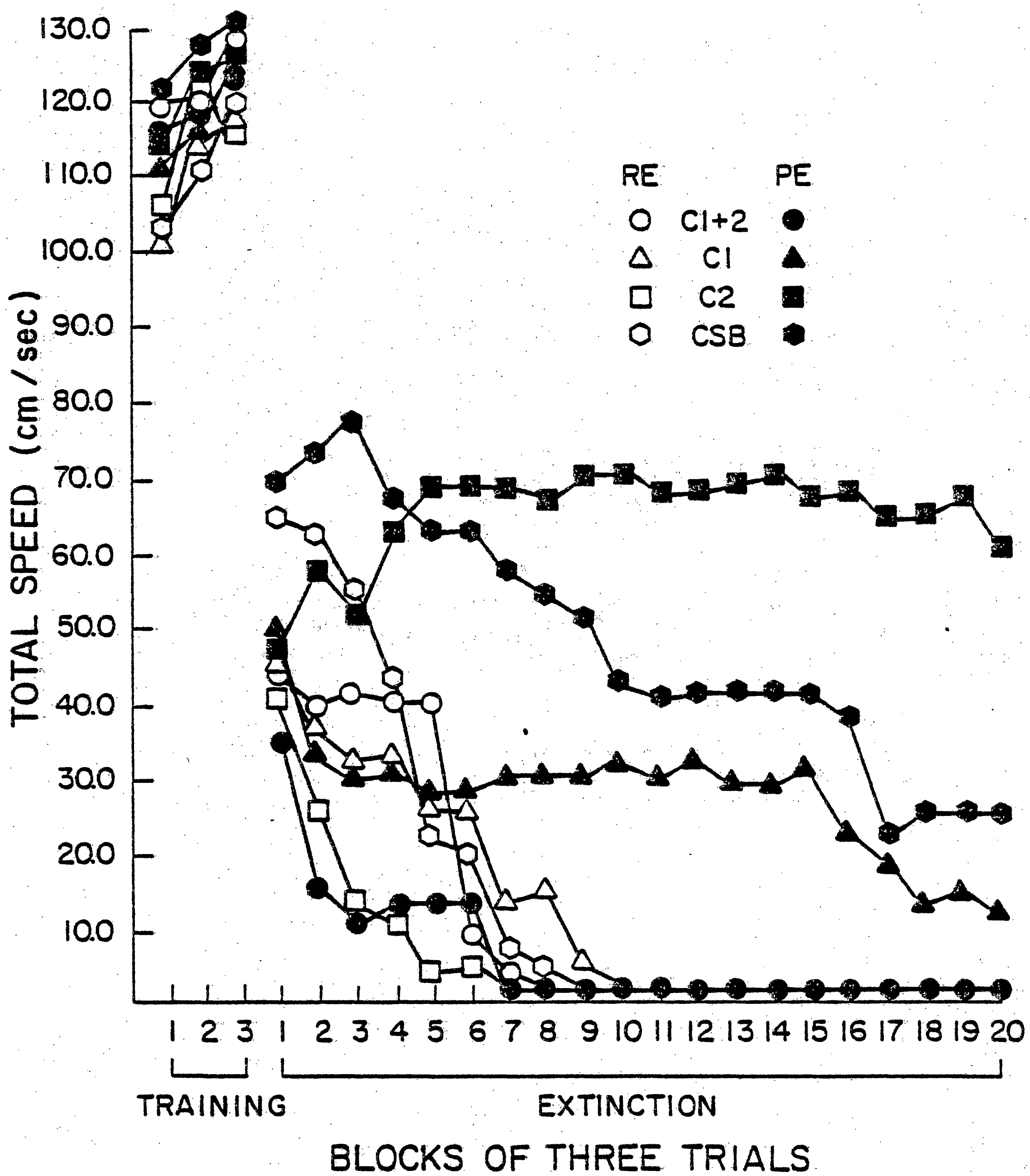

Figure 3. Mean Total Alley Speeds for Training and Extinction Trials from Experiment 2.

TABLE 14

Summary of Analysis of Variance of Total Alley Speed
for Extinction Trials from Experiment 2

Source	df	Ms	F	P
Between Subjects	79			
Extinction Condition (EC)	1	231490.29	10.45	$< .005$
Cue Condition (CC)	3	53170.0	2.40	$< .08$
CC x EC	3	74536.23	3.37	$< .05$
error b	72	22150.13		
Within Subjects	1520			
Blocks (B)	19	8577.47	19.47	$< .0001$
EC x B	19	2152.62	4.89	$< .0001$
CC x B	57	1130.84	2.57	$< .001$
CC x EC x B	57	365.26	.83	$> .10$
error w	1368	440.50		
Total	1599			

effect of Cue Condition was only marginally reliable ($p < .08$).

Simple effects analysis of variance for the Cue Condition x Extinction Condition interaction are presented in Table 15. These analyses revealed that Cue Condition had a significant effect for the PE groups only ($p < .05$), and had no reliable effect for the RE groups. A Duncan's Multiple Range test indicated that group C2PE responded reliably faster than groups C1PE and C1+2PE ($p < .05$), while group CSBPE differed reliably only from group C1+2PE. Groups C1PE and C1+2PE did not differ significantly. In addition, these results indicate that PE groups responded reliably faster than RE groups for the C2 and CSB Cue Conditions ($p < .01$ and $p < .05$, respectively). RE and PE groups did not differ in the C1 and C1+2 Cue Conditions.

Additional analyses were performed on total speeds for extinction trial Blocks 1-7 only. In this experiment, 69 out of 80 animals had met the extinction criterion by Trial 30. Limiting the analyses to the first seven blocks only partially solved the problem of analyzing default scores, as only 224 out of 560 observations were based on actual performance for these blocks. However, this was an improvement over the analysis for all 20 extinction trial blocks, where only 365 out of 1600 observations were non-default scores.

The results of the analysis of variance for total alley speeds for extinction Blocks 1-7 differed in some ways from the analyses performed on all 20 blocks. A summary of the results of this analysis is presented in Table 16. Of the main effects, only Blocks was significant ($p < .0001$), while the Extinction Condition x Blocks interaction and the Cue Condition x Extinction Condition x Blocks interaction were both

TABLE 15

Summary of Simple Effects Analysis of Variance of Total Alley Speeds for the Cue Condition by Extinction Condition Interaction from Experiment 2

Extinction Condition	Source	df	Ms	F	P
RE	Cue Condition	3	3728.51	1.12	>.10
	error	36	3325.89		
PE	Cue Condition	3	123977.72	3.03	<.05
	error	36	40974.39		

Cue Condition	Source	df	Ms	F	P
C1+2	Extinction Condition	1	4916.27	1.66	>.10
	error	18	2969.24		
C1	Extinction Condition	1	19820.74	.78	>.10
	error	18	35322.05		
C2	Extinction Condition	1	329514.14	8.27	<.01
	error	18	3927.84		
CSB	Extinction Condition	1	100847.84	4.91	<.05
	error	18	20481.76		

TABLE 16

Summary of Analysis of Variance of Total Alley Speeds for Extinction Trial Blocks 1-7 from Experiment 2

Source	df	Ms	F	P
Between Subjects	79			
Extinction Condition (EC)	1	24805.93	2.05	>.10
Cue Condition (CC)	3	23087.38	1.90	>.10
CC x EC	3	28308.09	2.33	<.08
error b	72	12139.70		
Within Subjects	480			
Blocks (B)	6	4285.73	10.36	<.0001
EC x B	6	1739.72	4.20	>.0005
CC x B	18	600.48	1.45	>.10
CC x EC x B	18	785.23	1.90	<.05
error w	432	413.74		
Total	559			

significant ($p < .0005$, and $p < .05$, respectively). More importantly, the Cue Condition x Extinction Condition interaction showed only marginal reliability ($p < .08$).

Table 17 presents the simple effects analysis of variance for Blocks, holding Cue Condition and Extinction Condition constant. All extinction groups showed reliable decreases in total alley speeds over Blocks 1-7 ($p < .05$), except group C2PE, which showed a reliable increase in speed (Block 1=48.4, while Block 7=69.1; $p < .05$). Thus seven of the extinction groups were showing decreases in total speed similar to that seen in typical RE trials, including three out of four of the PE groups. Only group C2PE showed evidence of facilitation effects of punishment in the form of alley speed maintenance over trials.

Because the predictions made earlier about VC behavior in this experiment rely heavily on RE and PE comparisons across Cue Conditions, and because a block-by-block analysis was not expected to be particularly informative in this regard, a simple effects analysis was performed on the Cue Condition x Extinction Condition interaction for extinction Blocks 1-7 together. Despite the fact that the reliability of this interaction was only marginal ($p < .08$), an analysis was performed to test for group differences that had been predicted previously; i.e., that self-punitive behavior would exist in some cue conditions, but not in others.

Table 18 presents the simple effects analysis of variance for the Cue Condition x Extinction Condition interaction for extinction Blocks 1-7. This analysis indicated that Cue Condition was marginally reliable for the PE groups ($p < .07$), but not for the RE groups. More

TABLE 17

Simple Effects Analysis of Variance of Total Alley Speeds for Blocks holding Cue Condition and Extinction Condition Constant from Experiment 2

Cue Condition	Extinction Condition	Source	df	Ms	F	P
C1+2	RE	Blocks	6	1241.62	5.16	<.01
		error	63	240.62		
	PE	Blocks	6	1236.75	6.41	<.01
		error	63	192.94		
C1	RE	Blocks	6	1149.11	4.01	<.01
		error	63	386.56		
	PE	Blocks	6	1004.72	3.80	<.05
		error	63	264.40		
C2	RE	Blocks	6	1104.82	6.21	<.01
		error	63	177.91		
	PE	Blocks	6	1081.02	3.71	<.05
		error	63	291.38		
CSB	RE	Blocks	6	1253.21	7.29	<.01
		error	63	171.91		
	PE	Blocks	6	881.463	2.54	<.05
		error	63	347.03		

TABLE 18

Summary of Simple Effects Analysis of Variance of Total Alley Speed for the Cue Condition by Extinction Condition Interaction for Blocks 1-7 from Experiment 2

Extinction Condition	Source	df	Ms	F	P
RE	Cue Condition	3	10331.69	1.18	>.10
	error	36	8774.48		
PE	Cue Condition	3	41063.78	2.65	<.07
	error	36			

Cue Condition	Source	df	Ms	F	P
C1+2	Extinction Condition	1	13942.93	1.65	>.10
	error	18	8457.70		
C1	Extinction Condition	1	201.41	.01	>.10
	error	18	16128.56		
C2	Extinction Condition	1	74041.14	6.40	<.05
	error	18	11569.82		
CSB	Extinction Condition	1	21544.71	1.74	>.10
	error	18	12402.71		

importantly, the results indicated that RE and PE groups differed reliably only for Cue Condition C2 ($p < .05$). Thus, only group C2PE showed reliable self-punitive behavior across the first seven extinction blocks, while the remaining RE and PE groups did not differ significantly.

The above analyses are in contrast with the overall analysis of variance that included all 20 extinction trial blocks in several ways, including the finding of a significant three-way interaction between Cue Condition, Extinction Condition, and Blocks. Most important, however, was the finding of a reliable difference only between the RE and PE groups for Cue Condition C2. Using all 20 extinction blocks, this difference was also obtained for the CSB Cue Condition. This discrepancy in the two analyses may be due to the greater percentage of default scores included in the first analysis.

Since the present experiment dealt with cue changes in individual segments, the effects observed for the total speed analysis could differ from analyses performed on the data from the pre-punishment sections of the runway. In addition, the use of data that included time spent in the shocked segment of the alley may have biased the results against the RE groups, which received no shock. For these reasons, analyses were performed on start speeds, Segment 1 speeds, and Segment 2 speeds. None of these sections contained shock during extinction, and each was involved in a cue change for one or more extinction groups. The analyses were limited to the first seven extinction blocks.

Group means of start speeds, Segment 1 speeds, and Segment 2 speeds for each extinction group are presented in Figures 4, 5, and 6. The pattern of responding for these groups is consistent with that presented in Figure 3, for total speed. That is, group C2PE responded most rapidly and most consistently over all blocks; while group CSBPE showed initially fast speeds followed by a gradual decrease over blocks. The only deviation from this pattern occurs in Segment 2 speeds, where the speed of CSBPE is elevated above other groups for the first few blocks, but then decreases across blocks, as shown in the other figures. RE groups do not appear to differ in any of these figures, and groups C1+2PE and C1PE also appear to respond much like the RE groups in each of the alley sections.

Tables 19, 20, and 21 present summaries of the analyses of variance for Startbox, Segment 1, and Segment 2 speeds for trial blocks 1-7. In the start speed analysis (Table 19) and the Segment 1 speed analysis (Table 20), Blocks was the only significant main effect ($p < .001$). However, the Cue Condition x Blocks interaction ($p < .05$), the Extinction Condition x Blocks interaction ($p < .05$), and the Cue Condition x Extinction Condition interaction ($p < .05$) were all reliable effects. The Cue Condition x Extinction x Blocks interaction was reliable for Segment 1 speeds ($p < .05$), but only marginally reliable for start speeds ($p < .07$).

Table 21 presents the analysis of variance for the Segment 2 speeds. The main effects of Blocks and Cue Condition were both

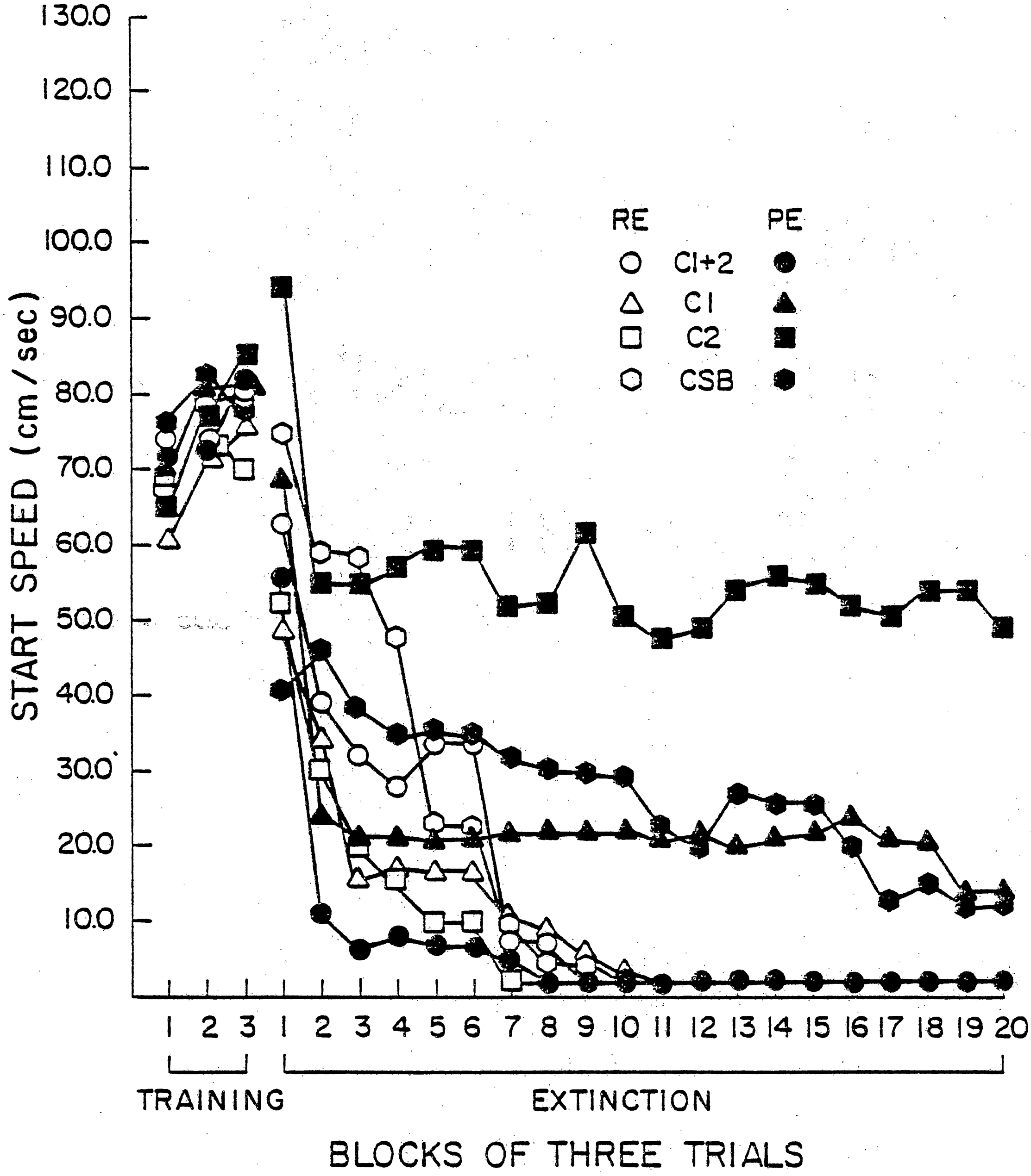

Figure 4. Mean Startbox Speeds for Training and Extinction Trials from Experiment 2.

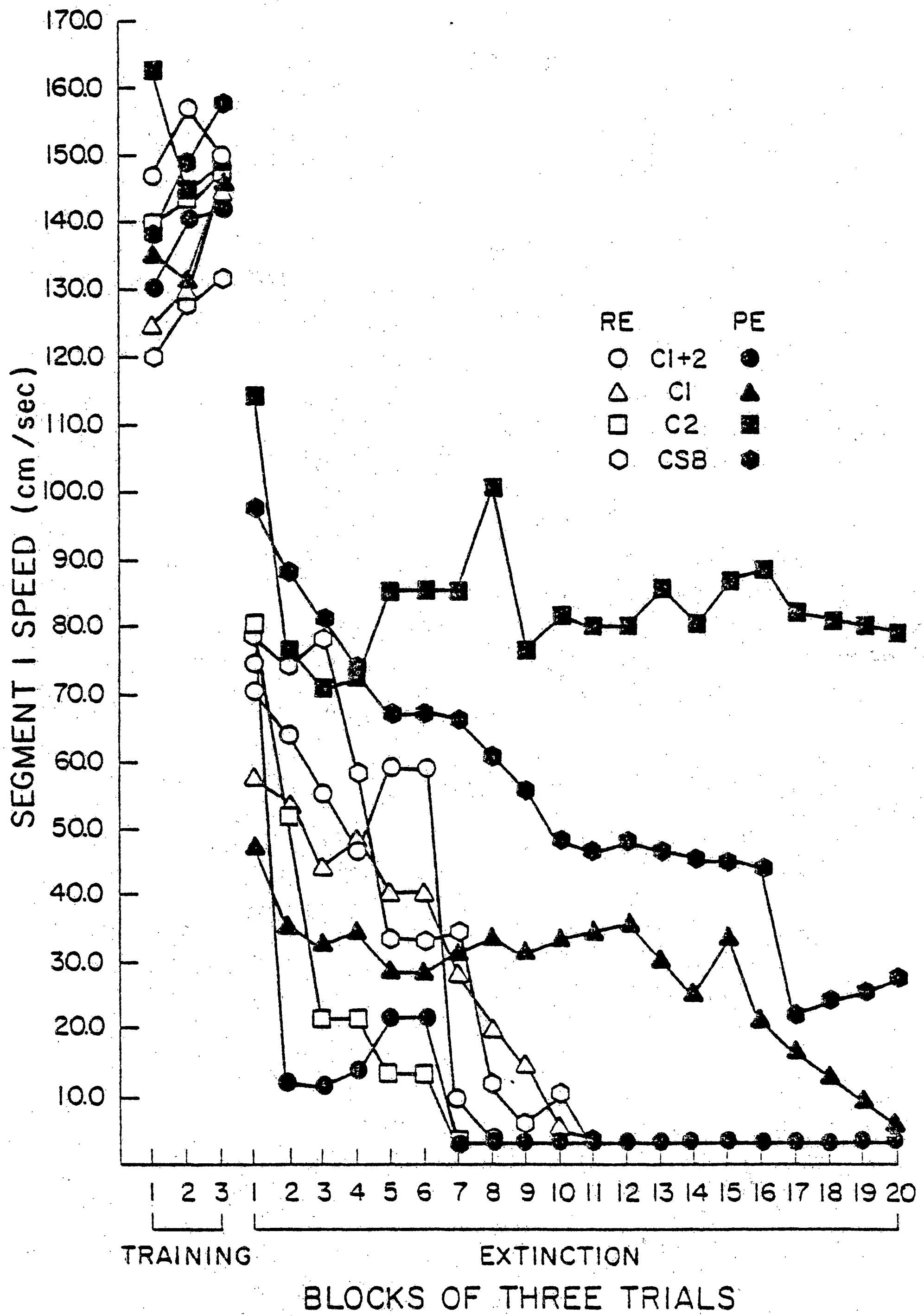

Figure 5. Mean Segment 1 Speeds for Training and Extinction Trials from Experiment 2.

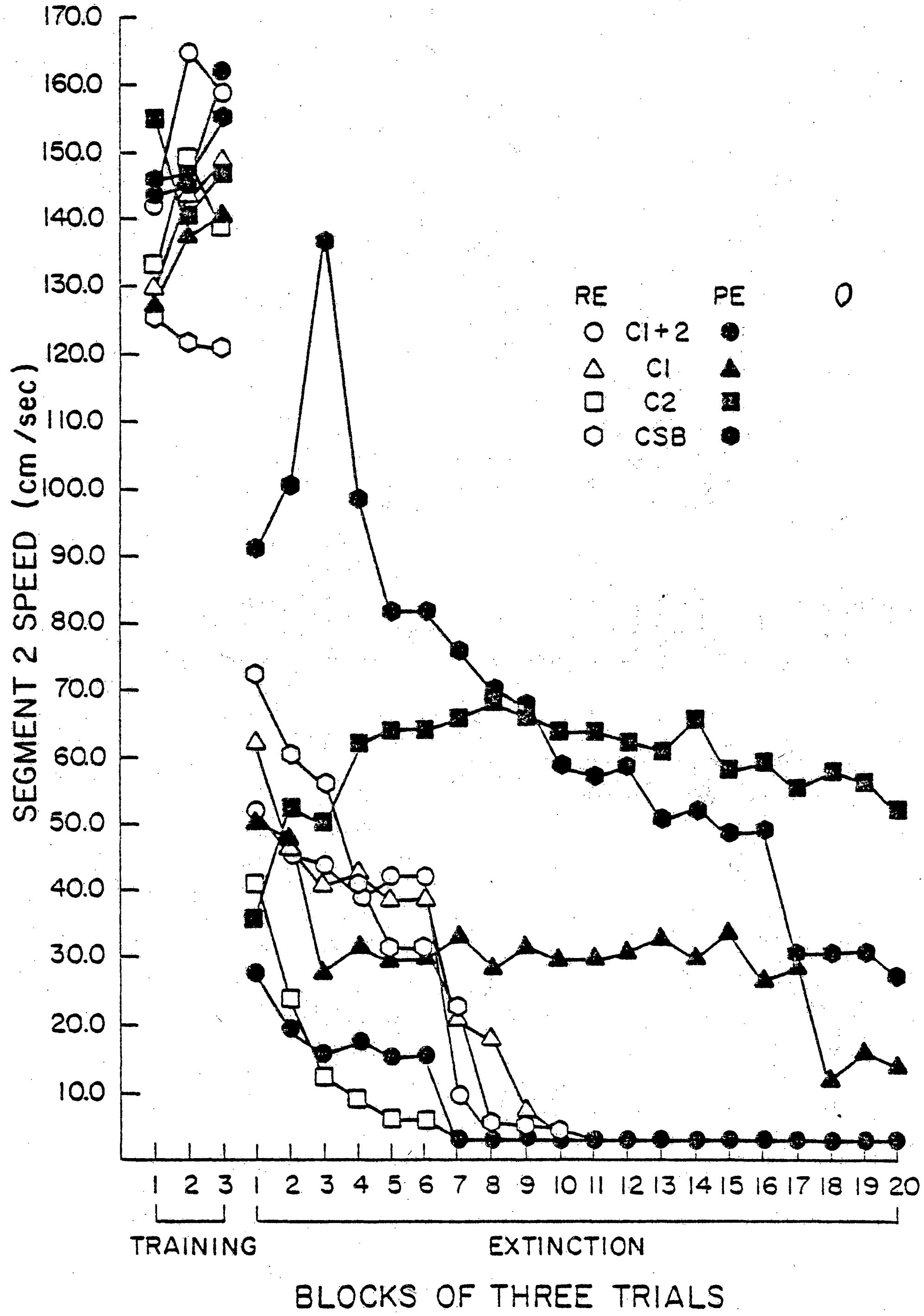

Figure 6. Mean Segment 2 Speeds for Training and Extinction Trials from Experiment 2.

TABLE 19

Summary of Analysis of Variance of Start Speeds for Extinction Trial Blocks 1-7 from Experiment 2

Source	df	Ms	F	P
Between Subjects	79			
Extinction Condition (EC)	1	4151.08	.67	>.10
Cue Condition (CC)	3	11579.59	1.88	>.10
CC x EC	3	24129.08	3.91	<.05
error b	72	6166.34		
Within Subjects	480			
Blocks (B)	6	15829.17	46.50	<.0001
EC x B	6	1287.93	3.78	<.005
CC x B	18	617.71	1.81	<.05
CC x EC x B	18	456.16	1.34	<.07
error w	432	340.42		
Total	559			

TABLE 20

Summary of Analysis of Variance of Segment 1 Speeds for Extinction Trial Blocks 1-7 from Experiment 2

Source	df	Ms	F	P
Between Subjects	79			
Extinction Condition (EC)	1	11677.61	.63	>.10
Cue Condition (CC)	3	28300.27	1.53	>.10
CC x EC	3	50820.94	2.74	<.05
error b	72	18547.79		
Within Subjects	480			
Blocks (B)	6	16049.60	18.71	<.001
EC x B	6	2635.83	3.07	<.01
CC x B	18	1818.01	2.12	<.01
CC x EC x B	18	883.16	1.03	>.10
error w	432	857.82		
Total	559			

TABLE 21

Summary of Analysis of Variance of Segment 2 Speeds for Extinction Trial Blocks 1-7 from Experiment 2

Source	df	Ms	F	P
Between Subjects	79			
Extinction Condition (EC)	1	52312.68	3.01	<.09
Cue Condition (CC)	3	53678.50	3.08	<.05
CC x EC	3	54937.64	3.16	<.05
error b	72	17404.10		
Within Subjects	480			
Blocks (B)	6	7854.34	2.78	<.05
EC x B	6	4576.46	1.62	>.10
CC x B	18	3343.29	1.18	>.10
CC x EC x B	18	3473.62	1.23	>.10
error w	432	2825.35		
Total	559			

reliable ($p < .05$), while the main effect of Extinction Condition was marginally reliable ($p < .09$). In contrast to the previous two analyses, only the Cue Condition x Extinction Condition interaction was reliable ($p < .05$).

The most important finding in the above analyses is that the Cue Condition x Extinction Condition interaction was reliable for speeds in each alley section. Since one of the major predictions for this experiment stated that RE-PE differences (VC behavior) would differ over Cue Conditions, this hypothesis was then examined for each of the pre-punishment sections. The analyses of the Cue Condition x Block interaction and Extinction Condition x Blocks interaction found with start speeds and Segment 1 speeds, however, would not add much information to the previous total speed analyses, since changes in speed over blocks in individual segments had little bearing on the predictions made earlier. Thus, only the Cue Condition x Extinction Condition interaction was statistically examined further for the three pre-punishment alley sections.

Table 22 presents a summary of the simple effects analysis of variance for starting speeds from Blocks 1-7. The effect of Cue Condition was reliable only for the PE groups ($p < .05$), but not for the RE groups. Thus, the PE groups did differ reliably from one another in start speeds over the first seven trial blocks, but the RE groups did not differ from one another. Also the results indicated that RE and PE groups differed significantly only for the C2 Cue Condition ($p < .05$), while no differences were obtained for the remaining Cue

TABLE 22

Summary of Simple Effects Analysis of Variance of Start Speeds for the Cue Condition by Extinction Condition Interaction for Blocks 1-7 from Experiment 2

Extinction Condition	Source	df	Ms	F	P
RE	Cue Condition	3	8011.29	1.71	>.10
	error	36	4674.82		
PE	Cue Condition	3	27715.53	3.62	<.05
	error	36	7657.85		

Cue Condition	Source	df	Ms	F	P
C1+2	Extinction Condition	1	13868.62	2.40	>.10
	error	18	5765.85		
C1	Extinction Condition	1	1166.86	.16	>.10
	error	18	7375.99		
C2	Extinction Condition	1	60394.65	8.09	<.01
	error	18	7465.99		
CSB	Extinction Condition	1	1108.20	.19	>.10
	error	18	5898.81		

Conditions. Thus, only group C2PE showed reliable self-punitive facilitation of speeds in the startbox.

Table 23 presents a summary of the simple effects analysis of variance for Segment 1 speeds. The results were similar to those obtained for the start time analysis. As before, only the PE groups showed reliable differences between Cue Conditions ($p < .05$), while the RE groups showed no reliable differences. In addition, only group C2PE differed from its RE control ($p < .05$), and thus was the only group showing reliable self-punitive behavior across the first seven blocks in this alley section.

A summary of the simple effects analysis of variance for Segment 2 speeds across Blocks 1-7 is presented in Table 24. The results are similar to the previous two analyses, in that Cue Condition was a reliable effect only for the PE groups ($p < .05$), and not the RE groups. However, for these analyses, both C2PE and CSBPE differed significantly from their RE controls ($p < .05$). Thus, group CSBPE, which had shown no reliable self-punitive facilitation of speed in either the startbox or Segment 1, does in fact show such behavior in Segment 2. Taken with the previous two analyses, this result indicates that group CSBPE animals do not run fast enough in the startbox and Segment 1 to differ from RE animals, but that when these animals reach Segment 2 the difference between their speeds and that of their controls does become reliable. Inspection of Figures 4, 5 and 6 shows that the RE-PE difference for the CSB condition is due more to an increase in Segment 2 speed for group CSBPE from the

TABLE 23

Summary of Simple Effects Analysis of Variance of Segment 1 Speeds for the Cue Condition by Extinction Condition Interaction for Blocks 1-7 from Experiment 2

Extinction Condition	Source	df	Ms	F	P
RE	Cue Condition	3	9462.47	.56	>.10
	error	36	16917.76		
PE	Cue Condition	3	65995.29	3.27	<.05
	error	36	20177.82		

Cue Condition	Source	df	Ms	F	P
C1+2	Extinction Condition	1	29869.47	2.02	>.10
	error	18	14765.53		
C1	Extinction Condition	1	3526.64	.14	>.10
	error	18	24590.98		
C2	Extinction Condition	1	103862.11	5.91	<.05
	error	18	17583.46		
CSB	Extinction Condition	1	15891.85	.92	>.10
	error	18	17251.19		

TABLE 24

Summary of Simple Effects Analysis of Variance of Segment 2 Speeds for the Cue Condition by Extinction Condition Interaction for Blocks 1-7 from Experiment 2

Extinction Condition	Source	df	Ms	F	P
RE	Cue Condition	3	31569.92	2.14	>.10
	error	36	14783.71		
PE	Cue Condition	3	77046.22	3.85	<.05
	error	36	20024.49		

Cue Condition	Source	df	Ms	F	P
C1+2	Extinction Condition	1	18535.91	1.65	>.10
	error	18	11265.68		
C1	Extinction Condition	1	1119.77	.05	>.10
	error	18	22734.69		
C2	Extinction Condition	1	111848.85	6.79	<.05
	error	18	16478.21		
CSB	Extinction Condition	1	85621.08	4.47	<.05
	error	18	19137.84		

Startbox and Segment 1 speeds, rather than a decrease in the speed of group CSBRE over these alley sections.

The above analyses are consistent with the total alley speed analyses for Blocks 1-7 in that group C2PE shows consistently reliable self-punitive responding. However, individual segment analyses indicate an unusual effect for group CSBPE, which shows a reliable difference from its RE control in Segment 2, but not in the Startbox or in Segment 1.

The mean number of trials required to meet the extinction criterion for each of the extinction groups is presented in the lower portion of Table 8. Table 25 presents a summary of the analysis of variance of these data. Results revealed a reliable effect for Cue Condition, Extinction Condition, and their interaction ($p < .05$). A simple effects analysis of variance was performed to evaluate the Cue Condition x Extinction Condition interaction (Table 26). Group C2PE took significantly more trials to meet the extinction criterion than its RE control (means = 33.5 and 5.0; $p < .05$), while the RE-PE difference was marginally reliable for the CSB Cue Condition (means = 26.8 and 11.1; $p < .06$). PE groups in the C1 and the C1+2 Cue Conditions (means = 13.3 and 5.6, respectively) did not differ from their RE controls (means = 7.8 and 8.8, respectively). The effect of Cue Condition on the number of trials to extinction was significant ($p < .05$) only for the PE groups. A Duncan's Multiple Range test revealed that group C2PE responded for significantly more trials ($p < .05$) than groups C1PE and C1+2PE. Groups C1PE and C1+2PE did not differ on the number

TABLE 25

Summary of Analysis of Variance of Number of Trials to Extinction from Experiment 2

Source	df	Ms	F	P
Between Subjects	7			
Extinction Condition (EC)	1	60307.15	9.41	<.05
Cue Condition (CC)	3	19372.90	3.02	<.05
CC x EC	3	23639.78	3.69	<.05
Within Subjects	72			
error w	72	6407.03		
Total	79			

TABLE 26

Summary of Simple Effects Analysis of Variance for the Cue Condition by Extinction Condition Interaction for Number of Trials to Extinction from Experiment 2

Extinction Condition	Source	df	Ms	F	P
RE	Cue Condition	3	1469.51	.93	>.10
	error	36	1571.73		
PE	Cue Condition	3	41543.18	3.70	<.05
	error	36	11242.34		

Cue Condition	Source	df	Ms	F	P
C1+2	Extinction Condition	1	2496.60	1.98	>.10
	error	18	1338.60		
C1	Extinction Condition	1	3478.75	.50	>.10
	error	18	6991.62		
C2	Extinction Condition	1	93408.75	9.62	<.01
	error	18	9714.31		
CSB	Extinction Condition	1	31689.40	4.18	<.06
	error	18	7583.61		

of trials required to meet the extinction criterion. Group CSBPE responded for significantly more trials than only group C1+2PE, and did not differ from either group C2PE or C1PE in number of trials to extinction.

Overall, the analyses of Experiment 2 indicated that only the C2PE group met all of the criteria for self-punitive responding: Group C2PE not only failed to show extinction effects in regard to alley speeds (i.e., speeds did not decrease over extinction trials) after the first extinction block, but this group also differed significantly from its RE control in both total speeds and trials to extinction. Group CSBPE also differed from its control group, CSBRE, in total alley speeds when all 20 extinction blocks were analyzed. However, when only Blocks 1-7 were analyzed, group CSBPE was significantly different from its control only with Segment 2 speeds. This group also showed a decrease in total speeds over extinction trials, but still yielded marginally reliable differences from its control in number of trials required to meet the extinction criterion.

It was hypothesized that the PE groups receiving cue changes in only one of the pre-shock alley segments (C1PE and C2PE) would differ from one another in extinction performance (total speeds, trials to extinction, and changes in total speeds over extinction trials). This prediction was in fact confirmed, both in comparisons between these two groups and in comparisons with the respective control groups. Group C2PE responded faster during extinction and took reliably more trials to extinguish responding than did its control group C2RE. Group

C1PE, however, did not differ from its control (C1RE) on either of these measures. Group CSBPE showed evidence of self-punitive responding, though it did not meet all three of the previously mentioned criteria. However, these results are consistent with the prediction of reduced VC responding with a brightness cue change in the startbox, although the reduction in responding was not of the magnitude found with Group C1PE.

Chapter 5

Discussion

Experiment 1 demonstrated that changing brightness cues in the runway during punished-extinction procedures eliminated VC responding. The PE group which encountered no cue change during extinction showed typical self-punitive responding relative to RE controls, as measured by alley speeds and number of trials to extinction. In contrast, the PE group which encountered a brightness change in all three alley segments showed no evidence of self-punitive responding. Extinction was almost immediate for this group.

The results of Experiment 1 did not differentially support either the Mowrer-Brown hypothesis or a discrimination hypothesis, because these hypotheses would predict a cessation of responding in extinction following a change of cues in all three alley segments. According to the Mowrer-Brown hypothesis the decreased resistance to extinction of animals in the cue change condition was due to the removal of feared cues. A discrimination hypothesis would account for the reduction of self-punitive locomotor responding by arguing that the cue changes increased the PE animals' ability to discriminate between training and extinction trials, thus making it possible for these subjects to distinguish that shock was not present in the entire alley (Church, 1963). Further, one could argue that the contrast between the startbox and the rest of the alley during extinction procedures in Experiment 1 made a cognitive discrimination possible between the startbox and the shock zone for PE subjects.

This cognitive discrimination is also presumed to be necessary by some researchers in order to eliminate self-punitive responding (Dreyer & Renner, 1971).

The purpose of Experiment 2 was twofold. One purpose was to test the hypothesis that changing alley brightness cues in differential parts of the area preceding shock would eliminate VC responding. The results of Experiment 2 confirmed this hypothesis. Animals that encountered a change in cues in both alley segments preceding shock rapidly extinguished locomotor responding, and showed no sign of self-punitive behavior. The mean total alley speeds for groups C1+2PE and C1+2RE from Experiment 2 were nearly identical to those of animals in groups CPE and CRE from Experiment 1. These results indicated that a change in brightness cues in a large area preceding shock can eliminate self-punitive responding.

The second purpose of Experiment 2 was to examine the relative effectiveness in reducing VC behavior of cue changes in the individual segments preceding shock. Previous research with fear conditioning has demonstrated that the strength of classically-conditioned fear varies in a curvilinear fashion with the length of the CS-UCS interval (McAllister & McAllister, 1971). Most of these studies have shown the existence of an optimal interstimulus interval (ISI) for fear conditioning (e.g., Libby, 1951; Lyon, 1963; and Murfin, 1954). If the strength of fear is related to the CS-UCS interval, and if fear plays a major role in maintaining VC responding, then it would be expected that fear would be differentially conditioned to alley cues (CS) depending upon their relationship in a spatio-temporal dimension to shock (USC). Thus, if the strength of fear is differentially established to an extended set of alley cues, then changes in one set of cues may be more effective in alleviating fear, and thus reduce VC behavior, than changes in another set of cues. In this study, cue changes were made in the startbox, Segment 1, and Segment 2, each of which was expected to yield different spatio-temporal ISI's between cue change and shock. A change was not made in Segment 3 alone (the shock segment) since previous research had demonstrated that cue changes occurring in the shock segment did not result in a reduction of VC behavior (Brown, 1970; Brown, Beier, & Lewis, 1971; Gwinn, 1949).

Results showed that there were differences in extinction performance following cue changes in different pre-punishment runway sections. Comparisons of RE and PE groups in Cue Conditions C1, C2, and CSB indicated that a change in brightness cues at different spatio-temporal intervals preceding shock did result in differences in self-punitive responding, as measured by alley speeds and in criterial indices of extinction. Thus, group C2PE showed reliable VC behavior while group C1PE showed no evidence of VC behavior. Group CSBPE showed some evidence of VC behavior, and did not differ from either C1PE or C2PE in alley speeds on trials to extinction.

Based on the Mowrer-Brown hypothesis it had also been predicted that changes in brightness cues in the lower startbox would reduce VC responding, because the start area is presumed to play an important role in initiating the self-punitive response. The Mowrer-Brown hypothesis states that fear is conditioned to the alley cues which are paired with shock, and fear subsequently generalizes back to cues in the startbox. Thus startbox cues elicit generalized fear which in turn motivates forward locomotion. Accordingly, if cues in the start area are changed, making this area distinct from the area where fear was originally conditioned, fear should not generalize to the start area, and VC responding should be reduced. The results of Experiment 2 partially supported this prediction.

Specifically, the analysis of the first seven extinction trial blocks showed no difference between the PE group receiving a cue change in the startbox (group CSBPE) and the RE control (group CSBRE). However, analysis of total speeds over all 20 extinction blocks indicated that group CSBPE did show VC responding when compared to group CSBRE. Finally, analyses of individual segment speeds showed that group CSBPE did not differ from its RE control in start and Segment 1 speeds. The absence of punishment-induced facilitation of start speeds is entirely consistent with the Mowrer-Brown hypothesis, which proposes generalization of fear from the alley to the startbox. However, in Segment 2 there was reliable evidence for VC behavior, as group CSBPE did differ significantly from its RE control in Segment 2 speeds. This latter finding is important since it does support the present hypothesis of an optimal ISI between cue change and shock in eliminating VC behavior. Thus only a cue change in Segment 1 resulted in the elimination of VC responding in all three pre-punishment sections of the alley, and presumably only that change resulted in the elimination of further fear conditioning to the remainder of the pre-shock alley cues.

The Mowrer-Brown hypothesis is further supported by the trials to extinction data for group CSBPE, which showed a marginally reliable difference from its control group. The absence of reliable VC responding on this measure for group CSBPE supports the hypothesis that fear generalizes back to the startbox as a factor maintaining self-punitive responding, since the cue change was presumed to prevent such generalization of fear. Yet the fact that group CSBPE did show a marginal difference from its control while group C1PE did not indicate that it was not the most effective area for reducing VC behavior by changing alley brightness cues, thus supporting the present proposal of an optimal ISI between cue change and shock in reducing self-punitive responding.

Perhaps the most important finding in this study involved the results of cue changes in Segment 1 (groups C1RE and C1PE) compared to the results of cue changes in Segment 2 (groups C2RE and C2PE). These two groups received the same amount of change in brightness cues, but encountered the change in different areas preceding shock. However, group C2PE differed reliably from its RE control in response speeds in each pre-punishment section, in total runway speeds, and in the number of trials to the extinction criterion. Group C1PE did not differ from its control on any measure. Thus a change in brightness cues in Segment 1 eliminated self-punitive responding, while a change in Segment 2 did not.

The above results are difficult to explain in terms of either of the discrimination hypotheses mentioned previously. The difference in VC performance between groups C1PE and C2PE, both when compared directly or with their RE controls (which did not differ) was not predictable from the cognitive discrimination hypothesis, nor from the stimulus-similarity hypothesis. Groups C1PE and C2PE received the same degree of change in brightness cues in terms of amount and intensity of brightness. The main apparent difference between these conditions was the location of the alley cues; one group encountered changes in Segment 1 alley cues, the other a change in Segment 2 cues. However, neither version of the discrimination hypothesis makes any statement about such cue location, since they do not directly involve the start and shocked segment. Thus there is no clear reason according to these hypotheses for such a difference in effectiveness in cue location for either making the start area more discriminable from the shocked area, or in making ttaining trials distinguishable from extinction trials.

Post-hoc discrimination arguments would also appear untenable in explaining the difference in VC responding obtained following a cue change in Segment 1 versus a similar change in Segment 2. One possibility is that because of the relative distance between the startbox and Segment 1 and Segment 2, animals in group C2PE may have had more time to detect the cue change than animals in C1PE. However, the results were actually the opposite of those which one would expect on the basis of this explanation. Animals in group C1PE failed to show VC responding, while those in C2PE continued to run despite the cue change.

Another discrimination interpretation could be that animals are more likely to discriminate a change in cues if the cues which are changed occur early in the response chain. Thus the closer the area of the cue change is to the area in which the response chain is initiated, the more disruptive that change might be. Though such an explanation would account for the difference in performance of groups C1PE and C2PE, it would not explain the performance of group CSBPE. Though a startbox cue change did eliminate the punishment-induced facilitation of start and Segment 1 speeds, it did not eliminate such facilitation of Segment 2 speeds, or total speeds across all 20 extinction blocks. The cue change in Segment 1, however, clearly eliminated VC response facilitation in each pre-punishment segment, as well as across all 20 extinction blocks. Yet the above hypothesis would predict maximal reduction of VC behavior with a cue change in the startbox. It is clear from the results of Experiment 2 that it was the cue change in Segment 1 that most effectively reduced VC behavior throughout the alley.

The above results are also unexplainable by a hypothesis which states that fear is most strongly conditioned to the cues of the shock area (Melvin, 1971). This hypothesis would make no predictions about the differences between group C1PE and C2PE in extinction performance. Further, the results of Brown's (1970) first experiment also contradict a simultaneous fear conditioning interpretation of VC responding. The addition of distinctive cues in the shocked segment would be expected to prevent the generalization of fear from the shocked segment to the rest of the alley, thereby reducing VC responding. This cue change, however, failed to reduce self-punitive behavior in Brown's experiment.

It is possible, however, for a conditioned-fear hypothesis to account for the results of Experiment 2 in terms of the relationship between the ISI and the strength of conditioned fear. In classical fear-conditioning research, there has been a general finding of a curvilinear relationship between the CS-UCS interval and the strength of fear conditioned to the CS (e.g., Libby, 1951; Lyon, 1963; Murfin, 1954). If the strength of conditioned fear varies with the CS-UCS interval in the VC situation as in other fear-conditioning paradigms, then fear may be differentially conditioned to alley cues (CS) depending upon their spatio-temporal proximity to shock (UCS). Alterations in VC responding as a function of changing cues in different alley segments may then depend upon the proximity of the segment to shock. Thus if cues were changed in an alley segment to which fear was strongly conditioned because of that segment's favorable location on the spatio-temporal dimension (in relation to the shock - UCS), then stimulus change in that segment might prevent the generalization of fear to other segments antecedent to shock, and VC behavior should be disrupted. If stimulus change occurs in a segment to which fear was not strongly conditioned, while the stimuli in the area of maximum fear conditioning remained unchanged, then fear should still generalize from this maximum conditioning area to other unchanged areas, and VC responding should not be disrupted.

In Segment 2, the total elimination of VC behavior with a change in Segment 1 cues, but not with Segment 2 and startbox cues, were results which were consistent with the preceding analysis. The elimination of VC responding in all three pre-shock alley segments with animals receiving a cue change in Segment 1 may indicate that fear was conditioned most strongly to the cues in this area. Changing the startbox cues clearly resulted in a decrease in VC responding in the startbox itself and Segment 1 for the first seven trial blocks, but did not eliminate reliable self-punitive locomotor responding when measured in Segment 2, or across all 20 extinction blocks. This would indicate that fear is less strongly conditioned directly to this area than to Segment 1.

The present analysis is also consistent with the results obtained in Brown's (1970) first experiment. If fear is more strongly evoked by cues in segments prior to the shock segment because of a more favorable CS-UCS interval, it is not surprising that a cue change in the shock segment would be ineffective in stopping VC behavior. The results of Brown's experiment follow because changing cues in the shock area would not substantially influence the effective CS for fear.

It is important to note that despite an initial decrease in the amount of conditioned fear evoked when cues are changed in a segment in which cues are paired favorably with shock, fear can be conditioned to the changed cues if the animal continues to run and encounters shock. When this occurs, fear should not generalize as much to the rest of the alley (to the unchanged cues) even though it may be strongly conditioned to the new, changed cues. Thus one would expect extinction of fear conditioned to the old, unchanged alley cues, and cessation of VC responding. It may be important to maintain an adequate physical difference between the brightness cues paired most effectively with shock and the remaining alley brightness cues in order to eliminate VC responding. Thus changing two segments (group C1+2PE) or three segments (group CPE) should reduce self-punitive responding due to the added presence of neutral cues; but it is also important to maintain an adequate physical difference in brightness between the area of maximal fear conditioning and some other pre-punishment alley section, to insure that fear is not re-conditioned to the entire alley after a few shock trials.

The importance of a physical distinction between the alley cues in at least two pre-shock alley sections is suggested by the results of the experiments of Brown (1970), and Brown, Beier, and Lewis (1971). In these studies, floor texture was changed by the insertion of masonite flooring. However, the texture cues between the pre-shock segments remained similar, since all areas preceding shock had the masonite flooring added. Thus, given a high level of shock and many training trials, the animals did not stop running immediately, and fear was then conditioned to some of the changed cues. Without some adequate physical difference in cues, it was possible for fear to generalize to the changed alley cues in the remainder of the runway. Thus for PE subjects, fear was conditioned and then generalized to the changed cues, resulting in VC behavior in these experiments.

In order to insure that the effects of brightness cue changes in eliminating VC behavior obtained in Experiment 2 are not peculiar to punished-extinction procedures utilizing third-segment shock, a follow-up experiment using second segment shock would be necessary. In the latter case, one would still be able to manipulate alley brightness cues in Segment 1, the lower tier of the startbox, and the upper tier of the startbox, thus achieving a situation analogous to Experiment 2 of the present study. Further, the analysis of VC responding presented here would make specific predictions about the extinction behavior of animals presented with such cue changes.

The three spatio-temporal intervals between changed cues and shock employed in Experiment 2 resulted in differing degrees of effectiveness of these changed cues in reducing VC responding. If it is the interval that is important, and not the particular segment itself, then the same relative interval which was most effective in reducing VC responding in Experiment 2 should be effective regardless of the shock location. That is, moving the shock zone forward or backward one segment in the alley for the punished-extinction procedure should move the most effective segment for cue change forward or backward correspondingly. With second-segment shock, the lower level of the startbox should become the area in which cue change is most effective in reducing VC behavior. Cue changes in Segment 1 should have little effect on VC behavior, while such a change in the upper level of the startbox may slow VC behavior slightly, but not completely eliminate it. A confound would exist for any group receiving a cue change in the upper startbox, since the animals are always forced to leave the upper tier of the startbox (via the trapdoor) and fall into a segment where cues have not been changed. However, the cue changes may reduce fear in the upper level sufficiently to slow the animals' starting performance.

The results of the present study are consistent with an expanded interpretation of the Mowrer-Brown conditioned-fear hypothesis. Experiment 1 indicated that VC responding can be eliminated with the use of a brightness cue change preceding shock. Such brightness cue changes were utilized in different pre-punishment sections of the alley in Experiment 2 to determine the relative effectiveness of such cue changes on VC responding. With third-segment shock, it was found that changing the cues in different pre-shock segments reliably affected self-punitive responding. The results were consistent with a curvilinear relationship between the strength of fear conditioned to alley cues, and location of these cues on a spatio-temporal dimension in relation to shock. Such an analysis is also consistent with much of the research on the relationship of ISI and strength of classically-conditioned fear elicited by a CS (McAllister & McAllister, 1971).

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EFFECTS OF ALLEY BRIGHTNESS CUE MANIPULATION PRECEDING SHOCK ON SELF PUNITIVE RESPONDING IN THE RAT

by

Stephen Thomas Perconte

(ABSTRACT)

Several studies have shown that the strength of classically-conditioned fear varies inversely with the length of the CS-UCS interval (McAllister & McAllister, 1971). If fear conditioning is important in the vicious-circle (VC) phenomenon (Brown, 1969; Melvin, 1971; Mowrer, 1947), then the interstimulus interval between brightness cues (CS) and shock (UCS) may similarly affect VC behavior.

Experiment 1 examined effects of brightness cue change on VC responding. Forty male hooded rats were assigned to four groups in a 2 x 2 design, using the presence or absence of shock in the third segment during extinction and the presence or absence of cue change as independent variables. Experiment 2 examined the effects of pre-shock brightness cue changes on VC behavior, and varied the interval between the cue change location and shock. Eighty male hooded rats were assigned to eight groups in a 2 x 4 design, using the presence or absence of shock in the third segment and cue change placement as independent variables.

The results indicated that brightness cue changes can reduce VC behavior. Experiment 2 also demonstrated that a cue change in the first alley segment reduced VC responding as effectively as a total

alley cue change. Changing the lower startbox cues was less effective and changing Segment 2 cues had little effect on VC behavior. The results were consistent with the ISI effects found in conditioned-fear research, since there was a relationship between the strength of VC responding and the spatio-temporal interval between changed cues and shock.