SOME EFFECTS OF PRIOR EXPERIENCE WITH SHOCK ON EMOTIONAL CONDITIONING

SOME EFFECTS OF PRIOR EXPERIENCE WITH ELECTRIC SHOCK

ON THE ACQUISITION OF

A CONDITIONED EMOTIONAL RESPONSE

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SCOPE AND CONTENTS:

This thesis is concerned with the effects of previous experience with electric shock on the acquisition of a conditioned emotional response (CER) to a signal preceding shock. Rats with prior shock experience were slow to acquire the normal CER, which is manifested by a decrease in the rate of food-motivated lever pressing. However, this slow acquisition did not seem to result from adaptation or habituation to shock, as had previously been proposed. Rather, prior experience with unsignalled shock tended in itself to inhibit the rate of lever pressing. When later presented with a warning signal preceding shock, rats with prior shock experience <u>increased</u> their rate of responding. This "dis-inhibition" persisted for several days, after which the usual decrease in rate occurred.

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CHAPTER ONE

INTRODUCTION AND HISTORY

The problem with which this thesis is concerned arose from two recent experiments, by Miller (32) and by Kamin (24). Although these experiments will later be described in detail, it will now be useful to sketch them briefly in order to set the stage for a review of the considerable literature relevant to the problem.

Miller found that rats exposed to a series of gradually increasing shock intensities were subsequently more persistent in running through intense shock to a food reward than were rats with no previous shock experience. Kamin, employing the conditioned emotional response as a technique, found that rats which had received a series of shocks of a constant intensity were less disrupted by shock, while subsequently performing a food-rewarded task, than were control rats without prior shock experience. The two experiments each suggest some such notion as "adaptation" or "habituation;" presumably, repeated experience with stressful stimulation has served to diminish the animal's emotional reactivity to such stimulation. The Miller study, however, seems to assume implicitly that the most effective adaptation is produced by exposing the animal to a pattern of increasing shock intensities; the Kamin study, on the other hand, reported a substantial adaptation effect with a constant intensity pattern. Thus it seemed worthwhile to investigate the effects of experience with different "intensity patterns" of shock on subsequent emotional reactivity to shock. The results of such experience, it may be noted, need not always be adaptation; there are many suggestions, both in the experimental and the clinical literature, that previous experience with stress may under some circumstances produce a "sensitization" effect - an increased emotional responsiveness to later stress. Perhaps intensity pattern is one of the variables controlling the outcome. In any event, this thesis is concerned with the effects of different intensity patterns on subsequent adaptation to shock. The basic procedure employed is the conditioned emotional response (CER) utilized by Kamin. Thus it will be necessary to review first the CER procedure and its history, and then studies on adaptation and the effects of previous experience with stress on later reaction to stress.

The CER

The CER technique, first reported by Estes and Skinner (14), employed rats as subjects. The unconditioned stimulus (UCS) was electric shock delivered through the grid floor of the experimental box, and the conditioned stimulus (CS) was a tone. Each of the twenty-four subjects was individually housed during the daily one-hour experimental session in a light-proof and nearly soundproof box containing a lever which could be easily depressed.[1] The ap-

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[1] This standard operant conditioning apparatus is commonly referred to as the "Skinner box" in acknowledgement of its originator, and against his expressed wishes.

paratus was so programmed that the first lever press made after every four minute interval delivered a single pellet of food. In technical terms, the rats were trained on a four minute fixed interval food reinforcement schedule (see 15, pp. 133-326). After this preliminary conditioning of the pressing response the subjects were divided into two groups. One group was kept at a relatively high and the other at a relatively low drive (food deprivation) level throughout the experiment. This resulted in correspondingly high or low rates of responding. Training on the periodic food reinforcement schedule continued for two weeks. Following this, two 3-minute tones, each of which terminated with a brief electric shock, were presented during the one hour bar-pressing session. The two daily tone-shock presentations continued for six days, at which time the tone was lengthened to five minutes, and given only once during each ensuing experimental hour. Tone-shock pairings were independently superimposed on the food reinforcement schedule, which remained in effect at all times. The results of this procedure were unequivocal. Initially there was virtually no effect of the tone on bar pressing, but after a number of tone-shock pairings presentation of the tone resulted in practically complete stoppage of lever pressing. The low drive group did not display differential response rates during tone present and tone absent periods, presumably because their baseline responding was nearly non-existent. When, however, these animals were later switched to a higher drive level, which in turn resulted in a higher baseline response rate, the reduction in bar pressing rate during the presence of the CS was quite apparent. Estes and Skinner further noted that with the development of depressed responding during the tone there followed a period of accelerated bar pressing immediately after tone termination. They attributed this to a compensatory phenomenon, for the "surplus" responses after the CS approximated the number of responses "missed" during the CS.

The Estes and Skinner phenomenon, which has become known as the Conditioned Emotional Response (CER) or conditioned suppression effect, seems to involve the following. An originally neutral stimulus (CS), through pairing with an aversive stimulus (UCS), acquires fear - or anxiety-eliciting properties. This is indicated by the fact that after a number of pairings, the presence of the CS will disrupt or suppress ongoing operant behavior. Although the original demonstration was performed under quite specific experimental conditions, the reviews by Annau (2) and by Sidman (43) make clear that subsequent investigations have replicated the suppression effect under such a wide variety of conditions that the generality of the phenomenon seems amply demonstrated.

Following the original report on the CER, there was approximately a 10 year period during which no further work on the phenomenon was done. The procedure was then revived by Hunt and Brady (22) who employed the conditioned suppression effect as a tool in an extensive series of studies on the apparent fear-reducing effects of electroconvulsive shock. Other investigators followed this tradition, concerning themselves with the CER only as a convenient and relatively precise technique with which to evaluate the effects on "fear" or "anxiety" of other variables, such as drugs (7, 20).

More recently parametric studies of the CER phenomenon itself have been reported. Libby (31) studied CS-UCS interval and number of CS-UCS pairings, and Stein, Sidman, and Brady (47) investigated the effects of the temporal relationship between CS present and absent periods. Kamin (23) studied the CER with different trace conditioning intervals and Annau and Kamin (3) investigated the effects of the intensity of the UCS. Stimulus generalization studies were conducted by Ray and Stein (39) and by Fleshler and Hoffman (16).

In general, the parametric studies seem to indicate that the CER is controlled by the same variables that control Pavlovian conditioning. This tends to confirm Schoenfeld's (42, p. 71) observation that the "experimental paradigm for anxiety" involves classical or Pavlovian conditioning so that an originally neutral stimulus through pairing with a noxious stimulus becomes "capable of eliciting....various autonomic respondents and ('involuntary') skeletal muscle movements." These classically conditioned respondents, it is commonly assumed, are incompatible with operant behavior such as lever pressing, and thus mediate the observed decrease in rate of lever pressing. Thus it has seemed reasonable to many investigators to quantify the degree of disruption of lever pressing produced by the CS, and to use this quantity as an index of the degree of "fear of" or "emotional reactivity to" the CS. The fact that intense shock results in a more drastic disruption of lever pressing than does weak shock (3), and the observation that various "tranquilizing" drugs attenuate the disruption (7), support the plausibility of this assumption. The CER is employed in the present experiment in just this fashion; we shall take variations in its magnitude as indices of the degree of emotional responsiveness to aversive stimulation.

Adaptation and Habituation

Some Definitional Problems: The earliest systematic account of adaptation was given in 1933 by Humphrey (21), who presented the following experiment as a paradigm for adaptation. Snails of the *Helix albolabris* species reflexively withdraw their antennae when exposed to mechanical shock. When Humphrey placed a snail on a wooden board which was jerked along a horizontal plane at two-second intervals, the antennae withdrawal response at first occurred quite consistently. With repetition of the movement, however, the response quickly diminished until it could no longer be observed. This illustrates the essence of the adaptation phenomenon, viz. "the decrement in a response which is a consequence of its repeated elicitation" (27, p. 477). As Humphrey pointed out, a similar process has been observed in animals over the entire phylogenetic scale, ranging from the amoeba to man. Thorpe (49, p. 54) goes so far as to suggest that "perhaps, indeed, in one or other of its forms it [adaptation] may be said to be one of the fundamental properties of living matter." Throughout the range of examples that might be given, however, there appears a distinction between two varieties of adaptation, which, if not qualitatively, are at least quantitatively, different. Humphrey, recognizing this distinction, suggested that the term "sensory adaptation" be applied to cases of the phenomenon "apparently due to processes occurring mainly in the receptor system" while "negative adaptation" be employed for examples which appear to have "a central origin." "Habituation" was used as a general term to incorporate both classes of adaptation. Thorpe, on the other hand, restricts the word "adaptation" to the transient sensory phenomenon, while defining "habituation" as (49, pp. 54-55) "the relatively permanent waning of a response as a result of repeated stimulation which is not followed by any kind of reinforcement." Following Thorpe's lead, then, we define habituation as: <u>the relatively permanent decrement in a response which is a consequence of its repeated elicitation and which is due, presumably, to changes in the central nervous system rather than in the sensory receptors</u>.

Operationally, the distinction between habituation and adaptation is in temporal terms. In the former case the decrement in the response persists for substantial time intervals, while in the latter, it is relatively transient. When the effect lasts for days, as in the case reported by the Peckhams (38) of spiders who no longer reacted to the sound of a tuning-fork, it is clear that habituation is the phenomenon under study. When, on the other hand, the changes in taste threshold due to repeated stimulation with sodium chloride have substantially disappeared after 30 seconds (17), it is equally clear that one is studying sensory adaptation. Unfortunately, in many of the experimental results which we shall encounter classification as to habituation or adaptation can only be made with difficulty, as the investigators were concerned with the change in responsiveness, per se, rather than with the persistance of the change. As a corollary of the temporal distinction, it is assumed that habituation involves the central nervous system while adaptation takes place in the sensory receptors. The ambiguity in this dichotomy is suggested by Dethier (10), who found that what appeared to be a simple case of short duration (1 to 13 seconds) sensory adaptation of the taste receptors in the leg of the blowfly must have also involved the central nervous system. This was shown when it was found that the effect could be demonstrated equally well by stimulating a previously unexposed leg. Consequently we are forced to conclude that while sensory adaptation may involve central processes as well as the more obvious receptor changes, habituation, by the very fact that the effect is of long duration, must involve the central nervous system.

Although, as mentioned earlier, examples of habituation are well documented at all levels of the animal kingdom (see reviews by Thorpe (49) and by Harris (18)); in the psychological literature on learning, the process is more or less taken for granted, ignored, or treated as synonymous with experimental extinction. The latter stand is the one taken by Woodworth and Schlosberg, who state that (52, p. 559): "adaptation shows such formal characteristics of extinction as spontaneous recovery and disinhibition....but [as] we know less about adaptation in general than we do about experimental extinction in particular ....we gain nothing by using the more general term." It is not surprising that Pavlov also took the view that habituation (referred to as "extinction of the orientation reflex") was (37, p. 256) "analogous in details to the extinction of conditioned reflexes." According to Razran (40) this statement by Pavlov, although qualified to some extent, is still held to be valid by contemporary Russian psychologists. Evidently Konorski (29), according to Thorpe, also thinks of the extinction of conditioned and orientation reflexes as synonymous, with both cases representing an internal inhibitory process. Although experimental extinction and habituation may in many ways be similar, there remains the obvious distinction in terms of the former being based on learned or conditioned responses, while the latter concerns innate or unconditioned reactions.

Thus it appears necessary to restrict the definition of habituation further so that it finally reads: "the relatively permanent decrement in an <u>unlearned or unconditioned response</u> which is a consequence of its repeated elicitation and which is due, presumably, to changes in the central nervous system rather than in the sensory receptors." With this definition as a guide we can now proceed to review the experimental literature on the problem.

Although experiments specifically designed to study habituation to noxious stimuli are rather infrequent in the psychological literature, there are a number of investigations with varying degrees of relevance to the problem. These can be classified as follows: studies which measure, either directly or indirectly, changes in reaction due to repeated exposure to noxious stimulation; studies of the effects of prior experience with electric shock on later avoidance or escape training; and finally, investigations of habituation of the unconditioned stimulus prior to acquisition of a classically conditioned response.[2] The plan for the remainder of the introductory section is to examine the investigations in the framework given above. We shall then return to the Miller and Kamin studies which prompted this experiment.

<u>Repeated Exposure to Noxious Stimulation</u>: As early as 1934 Seward and Seward (43) reported a detailed study of habituation to electric shock. The authors applied a series of five strong shocks to human subjects in each of 29 daily training sessions, and recorded changes in the GSR, breathing, and general body movement. As the experiment progressed, they found a tendency for reactions to diminish and for subjects to report that the shocks became less unpleasant.

McCulloch and Bruner (36) also studied the effect of repeated exposure to electric shock. A litter of hooded rats, 90 days old, was split into an experimental and control group of three animals each. The experimental subjects were subjected to a ten day period of shock, with daily sessions consisting of four 25-second shock applications. The intensity was individually adjusted to produce tetanization ap-

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[2] The experiments designed to study the effects of stimulation during infancy on emotional behavior at maturity might be regarded as relevant to the habituation problem. However, the relevance is marginal, and even a cursory examination of these studies indicates no general agreement whatever as to the empirical facts (see review by Ader (1)). For these reasons, the studies have not been included.

proximately half of the time. Beginning on the day following the last shock, both experimental and control animals were given six trials a day on a brightness discrimination task in a McDougall water tank. After the first two days, errors were punished by shock, again adjusted so as to be tetanizing approximately 50% of the time. Both for trials to meet a criterion of two successive days of errorless performance, and for total errors made, the experimental group was significantly inferior to the controls - actually there was no overlap between the two groups. The authors further observed that (36, p. 335) "the same amount of current was necessary for producing tetanic responses in both groups in the discrimination situation." Thus, although there does not appear to have been a conspicuous habituation of the reaction involving the gross musculature, there does seem to be evidence of a decrement in the emotional or motivating properties of electric shock.

Steckle and O'Kelly (46) reported a study which in many ways is a direct precursor to the investigation by Miller cited earlier. Rats were used as subjects. The experimental group of 17 animals was introduced to cages at twenty days of age where water was obtainable only by crossing, and then standing on, a continually electrified grid. This treatment persisted for 32 days. Five other subjects acted as a control for the effects of water deprivation, per se, without shock. At the end of the 32 days of pre-training both the shock and water-deprivation groups were given a two-week rest in conventional cages. When testing began, a control group of 19 normally reared animals was added. The test situation consisted of a runway electrified in the centre portion with (46, p. 3) "a current slightly stronger than that of the cage shock period." Water was the incentive in the goal box. All animals were given training in the runway, with the shock off, until they met a running time criterion of four seconds or less. The centre portion was then electrified and a maximum of ten minutes allowed for each ensuing trial. Although individual comparisons were often of only borderline statistical significance, overall results were consistently in the same direction. Experimental animals were superior to both control groups on such criteria as number of animals consistently crossing the grid, number of approaches and contacts with the grid, and number of shock crossings. When a subject met the criterion of 10 consecutive daily crossings of the activated grid, water reinforcement was discontinued. The experimental group again showed a greater persistence, making on the average 20 crossings in comparison with 7 for the controls. In agreement with Miller's results, the Steckle and O'Kelly study demonstrates that animals rewarded while exposed to electric shock are later less disturbed by shock. As Kamin's data indicate, however, it appears that such an effect does not require gradual increases in the intensity of the noxious stimulus.

Kellogg (25), employing dogs as subjects, secured strong evidence of habituation to electric shock. Animals were given twenty classical conditioning trials daily. The CS was a tone and the UCS an electric shock delivered to the right hind foot and automatically terminating when the foot was moved a height of two inches. Adopting the view that (25, p. 87) "a constant performance by the subject means a constant intensity of stimulation from the subject's point of view" the experimenter adjusted the intensity of the shock from trial to trial so as to maintain a flexion reflex in each subject of approximately four inches. Two hundred conditioning trials were given over a period of 10 days. Within each daily series of trials the typical finding was that high voltage was necessary to elicit the criterion response on the first two or three trials, followed by a rapid diminution in shock intensity until a fairly constant level was reached for the last half of the trials of each daily session. This daily pattern appeared to be independent of the stage of learning, suggesting to the author that it was due to (25, p. 90) "changing resistance within the organism" or what we would call sensory adaptation. To look at the trend over a longer period of time the voltages at the end of each daily session were compared, and in this case it was found that over the ten experimental days the average terminal voltage increased approximately 50%. On the other hand, over the same period of time micturitions and defecations decreased. Summating the two types of evacuation to give an emotional index, there was found to be a rank-order correlation between emotionality and voltage level of -.82.

Kellogg (25, p. 92) interpreted his findings as indicative of "habituation....to the whole experimental situation." That there was habituation of the flexion reflex to electric shock is clear from the voltage increase necessary to maintain a constant reaction from day to day.

MacDonald (35) studied adaptation in human subjects to reactions accompanying electric shock and corneal air puffs. For the shock segment of her experiment the psychogalvanic response of subjects to the verbal statement "Now you are going to get a series of electric shocks" was measured before and after the delivery of 50 shocks. Although the difference was found to be highly significant, it does not really offer evidence of habituation to shock, as the comparison made was between the reaction to expectation of shock before and after it was experienced. In regard to eye-blink MacDonald measured spontaneous blinking rate for the minute prior to any air puffs, for the minute following five puffs, and for the minute following fifty additional puffs. It was found that there was a reliable increase in the spontaneous blinking rate following five puffs which, after 50 further trials, had significantly decreased, so that the rate on conclusion was not different from the initial base line. The author (35, p. 5) concludes that the data "shows that frequent presentation of the unconditioned stimulus alone results in a marked adaptation of the affective or 'drive-producing' function, as measured by responses other than the direct reflex." Whether the experiment can be considered an example of habituation or not is a moot question. There was no demonstration of the "relative permanence" of the waning of the response but, on the other hand, the fact that a presumably affective reaction, rather than a direct response, was measured argues for a central mechanism being involved. It is interesting to note that in regard to the 50 "adaptation" shocks the author reports that there appeared to be a curvilinear relationship with trials (35, p. 9) "a cumulative or sensitization effect appearing before adaptation begins to take place." Most subjects when asked which shocks seemed most unpleasant replied those "toward the middle." Similarly the air puffs "toward the beginning" (underlining mine) were reported by the subjects as most annoying, which may also be indicative of sensitization.

Libby (31) studied the effect of the number of CS-UCS pairings on suppression of bar pressing during later presentation of the CS. Six groups of animals were given, over a period of ten days: 0, 5, 10, 20, 40, or 80 signal-shock presentations. It was found that in a CER-type test situation there was a maximum depressant effect for the 40 pairings group on the first test day, which shifted to the 20 pairings group on the second and third days. The author attributed the curvilinear functions to adaptation to shock, but as bar pressing was acquired in the three days following emotional conditioning the effect can be spoken of as habituation. Unfortunately, emotional conditioning took place over 10 days for all groups, so that massed versus distributed exposure was confounded with number of pairings.

Kimble (26) measured the prevalence of the jump reaction in rats to each of nine different shock intensities, repeating the entire series 16 times. The one-second duration shock presentations were delivered at fixed intervals of 30 seconds. Comparing the first and second series of 72 shocks, there was found to be a highly significant decrement (p .005), although the change in mean absolute threshold was only .15 ma. These results possibly reflect, in the main, sensory adaptation.

Taylor (50) has reported a decrement in the amplitude of the response to repeated corneal air puffs. There were three experimental groups of 20 subjects each, which received air puffs produced by a 15, 30, or 80 mm. fall of mercury. Fifty trials delivered at fixed irregular intervals averaging 20 seconds resulted in a highly significant decrement in the eye-lid response. Although the between groups comparison fell short of significance it was in the expected direction, with response amplitude increasing with the intensity of the stimulation. Furthermore, there was a significant trials by group interaction due to the fact that the milder puff strengths resulted in relatively greater response decrement. Taylor speaks of her results in terms of "adaptation" which, in view of the short training session employed, is perhaps a more appropriate classification than "habituation."

Summarizing the experiments on habituation to noxious stimuli, it seems clear that the phenomenon has been amply demonstrated. Direct striped muscle reaction in response to electric shock (25, 26, 43) as well as accompanying emotional or motivating reactions (31, 36, 43, 46) have been shown to decrease with repeated stimulation. These effects have been observed both in the rat and in man. Similarly there is some evidence to suggest that the direct eye-lid response to air puffs may be habituated (50), as well as the accompanying reactions indicative of tension or emotionality (35). There is, it should be noted, some evidence for a sensitization effect, even within studies which demonstrate habituation. This was indicated by an initial augmentation of the response, before the subsequent decrease. This was reported for both the case of electric shock (25) and for air puffs (35).

Avoidance and Escape: Studies of avoidance and escape learning after prior experience with shock present a confused picture. The plan, therefore, is to review the experiments rather quickly and then deal at greater length with their possible interpretations. While some of the experiments falling under this heading were designed primarily to investigate effects of infantile experience on adult behavior, the findings are nevertheless relevant to the habituation problem.

Stanley and Monkman (45) studied the effect of exposing infant mice to electric shock. There were three treatment conditions employed: (1) shock termination contingent on movement to the safe end of the apparatus; (2) exposure to shock matched for duration to group (1) but not response contingent, and (3) exposure to the shock apparatus for a duration equal to (1) and (2) but with the shock turned off. When the subjects were eight days of age they received five daily trials for four days. At approximately 90 days of age avoidance training was given and the group having received early experience with escapable shock was found to be marginally superior. For trials to a criterion of five successive avoidances, the medians for the three groups, which in infancy had received; response-contingent shock, arbitrary shock, or no shock, were respectively: 10.0, 10.5, and 10.5 - none of the differences being statistically significant. For the same three groups median response times for the first nine trials were: 1.6, 1.8, and 1.8 seconds, with the difference between the first and third group having a one-tailed p value of .02.[3] The results are interpreted by the authors as evidence of transfer of training, rather than as a change in emotional reactivity. That is, animals which had received specific training in running to terminate shock were assumed to transfer this to the later learning situation.

Chevalier and Levine (9) and Levine, Chevalier and Korchin (30) gave rats early experience with inescapable electric shock. There were three groups, which for the 20 days following birth, received daily shock, were placed on the grid but did not receive shock, or were ignored. At 60 days of age avoidance training was instituted, and it was found that the unmanipulated controls were inferior to the other two groups on all measures. The authors argued that (9, p. 432) "the absence of extrinsic stimulation in infancy....rendered the No-Handling subjects more susceptible to emotional disturbance when presented with new stimuli, which then contributed to their slowness in learning the avoidance problem." Why an assumed emotional disturbance should impede, rather than facilitate, the development of an aversively motivated habit is not entirely obvious.

Baron et al. (4) studied the effects of infantile and adult shock-trauma upon later avoidance and escape learning. The traumatizing shock consisted of 1.25 ma. administered in a grid box for three minutes on two successive days. Shock was presented to the experimental

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[3] It is obvious that the difference reported is quite borderline. The one-tailed test is certainly open to question.

groups when the subjects were 20, 26, or 80 days of age. Between 120 and 140 days of age subjects were tested in either an escape or avoidance situation, employing either a high (1.25 ma) or low (.25 ma) shock as the UCS. The authors summarizing their results (4, pp. 534-535) report that animals "subjected to traumatizing shock at any time prior to learning exceeded control subjects in escape learning under high and low shock and in avoidance learning under high shock. The difference in the low-shock avoidance condition was not significant although it was in the same direction."

Dinsmoor and Campbell (12, 13) and Dinsmoor (11) have studied escape-from-shock training following exposure to inescapable shock. They found that giving rats 15 minutes of prior shock exposure significantly delayed the first escape response (bar press) in training, and reduced the number of presses in a thirty-five minute session. A similar effect was obtained (13) with 50 minutes of pre-exposure shock, tested 24 hours later. Further, the disruption in escape learning was greater when .4 ma rather than .2 ma shock was employed in the pre-exposure session, regardless of the shock intensity used in escape training. The interpretation given the results was in terms of competing instrumental responses learned during the inescapable shock period. The significant effect of shock pulse duration (11) suggested that subjects learned (11, p. 534) "to retract their paws from the grid in response to the onset of each successive pulse and that this activity interfered with the subsequent learning of bar-pressing as a means of escaping shock." Thus, while Stanley and Monkman attributed a facilitating effect of prior shock to positive transfer, Dinsmoor attributed an interfering effect to negative transfer.

Part of the difficulty with the avoidance and escape studies is that the different experimenters are not always consistent in interpreting their results. Chevalier and Levine suggest that superior avoidance learning indicates lessened emotional reactivity (on the assumption that emotion "disorganizes" adaptive behavior), while Dinsmoor and Campbell point out that inferior escape performance is normally taken as indicative of "adaptation." To round out the disagreement, Baron et al. interpret both superior escape and avoidance learning as evidence of sensitization or traumatization (i.e. just the reverse of habituation).

The problem of interpretation of these studies is knotty. First, as Kimble has stated (26, p. 281) "some authors stress the point that shock increases activity; others have claimed that inactivity is dominant in the hierarchy of reactions to shock." Thus it is difficult to know whether failure to locomote in an escape or avoidance situation is indicative of heightened or lessened emotionality. Added to this is the level of arousal thesis, which states (5, p. 246) "There is an optimum range of level of arousal within which a given measure of performance will reach its highest (or lowest) value; the greater the deviation in either direction from the optimum arousal level, the greater will be the decrease (or increase) in the performance measure." In regard to electric shock the well known Yerkes-Dodson (53) finding seems to support such a hypothesis. Thus habituation might conceivably lead to an increment in performance if the pre-habituation arousal level were too high, or to a decrement if the pre-habituation arousal level were at, or less than, the optimum.

A further complexity comes from a recent study by Black, Adamson, and Bevan (6) that appears to demonstrate that the incentive value of electric shock is related to past shock experience in an "adaptation-level" manner (19). Ten escape trials were given with weak shock in one apparatus, and ten minutes later a further ten trials were given with medium shock in a different apparatus. The group of rats so treated had faster response times in the later runway situation than those given medium shocks in both situations, or than control animals run with medium shock in the test apparatus only. A group which received strong shock initially ran more slowly than either of the above experimental groups when tested under a medium level shock. It thus appears that some sort of contrast of present with past experience operates either to intensify or reduce the effective value of the shock.

Now it would doubtless be possible, by judicious use of the above ideas, to reinterpret the avoidance and escape studies so that they at least did not contradict the habituation hypothesis. This might prove to be an interesting intellectual exercise, but would hardly be convincing evidence to offer as support of an habituation effect. The more reasonable approach seems to be to conclude that, in general, the studies of previous shock experience on later avoidance and escape training give equivocal results in regard to habituation. The Dinsmoor (11) and Stanley and Monkman (43) studies in particular emphasize a problem which plagues habituation research in this area. When an instrumental response is employed as the criterion, there is always the possibility that the animal is transferring to the test situation motor responses acquired during the habituation phase of the study. These responses may either interfere with, or facilitate, learning following habituation. Thus the criterion response may be a misleading index of emotional habituation.

Habituation to the UCS: The studies of adaptation or habituation to the UCS employed in later classical conditioning can be reviewed rather quickly, not due to the lack of importance of the topic, but due, happily, to the unanimity of the results. Two of the three studies (35, 50) have already been mentioned in connection with diminution of response accompanying repeated elicitation. MacDonald (35) conditioned the eyelid reflex and finger retraction response in humans, with and without a series of 50 prior adaptation trials with the UCS (air-puff or electric shock). She found that the effect of the "adaptation" trials was to reduce the mean number of conditioned responses from 27.7 to 6.0 in the case of the eye-blink and from 27.1 to 10.0 in the case of finger withdrawal.

Taylor (50) found that for groups given 50 prior presentations of an air puff produced by a 15, 30, or 80 mm. fall of mercury, the mean number of conditioned responses made in fifty later conditioning trials was: 16.4, 12.2, and 9.1 respectively. A control group which did not receive any "adaptation" trials made 22.2 CR's.

Kimble and Dufort (28) similarly have reported a decrement in conditioned responses when 20 adaptation trials are given prior to eyelid conditioning. The effect which they observed was less than that reported by MacDonald and by Taylor, presumably due to the fewer number of adaptation trials employed.

There is one question which arises in regard to the conditioning experiments just outlined. This is whether a transient sensory adaptation or a more permanent habituation has occurred. In all three examples conditioning trials started immediately after pre-exposure to the UCS which, unfortunately, makes dismissal of the adaptation interpretation difficult. On the other hand, the authors unanimously suggest that it is the emotional or motivating factor accompanying noxious stimulation which changes. This suggests involvement of a central process which in turn implies habituation.

In either case, adaptation or habituation, it is clear that prior exposure to noxious stimulation (either air puffs or electric shocks) leads to poorer classical conditioning when the same stimulation is used as the UCS. Furthermore, at least within some range of values, the decrement increases with the intensity of the prior stimulation, and evidently also with the number of pre-exposure trials given.

Looking back over the long list of studies cited, one can conclude that, despite the difficulties in interpreting some studies due to the ambiguity of the measures employed, and other studies due to the adaptation-habituation confusion, the evidence for an habituation effect is overwhelming. However, the conditions which maximize this effect, and the conditions which might lead to a sensitization effect instead, are not well understood. The present experiment was designed to contribute toward an understanding of this problem, and can now best be introduced by a description of the studies by Kamin and by Miller.

Background to the Present Experiment

The Kamin study grew from an accidental observation that animals given "free" or unsignalled shock while engaged in bar pressing later show retardation in the development of suppression during CER training. Kamin (24) interpreted this as evidence of "adaptation of emotional reactivity to electric shock" and referred to the phenomenon as an "apparent adaptation effect." To study the phenomenon specifically the following procedure was adopted. Rats, reduced to 75% of their ad lib weight, were trained to bar press in a Skinner box, receiving a minimum of 10 hours experience under a 2½ minute variable interval food reinforcement schedule. For the ten days following this the experimental group was presented with four unsignalled or "free" one-half second shocks which occurred at fixed irregular intervals during each two-hour experimental session. Both experimental and control animals were then given standard CER training. The CS was low volume white noise; the UCS, electric shock of one-half second duration, and the CS-UCS interval, three minutes. Four CS-UCS pairings were given during each experimental session. Typically the result of such a procedure is that after four or five CS-UCS presentations the animal "freezes" (i.e. ceases to bar press) during the CS interval, although responding in a fairly regular manner both prior to, and following, the signal. In the case of the subjects which had received prior "free" shock, however, there was a retardation in the development of this typical pattern. The subjects acquired the CER very slowly. Kamin (24) summarized his findings as follows:

> Prior experience with shock produced decrements in the acquisition of suppression in two independent experiments. The degree of decrement was then shown to be a direct monotonic function of the intensity of the prior shocks, holding shock intensity during CER training constant.

In the light of our earlier discussion, Kamin would have been better advised, in view of the long time intervals between free shock and CER training, to refer to the effect as habituation rather than adaptation.

What appeared to be another case of habituation to shock, in a different setting, was reported by Neal Miller (32). Miller employed the standard approach-avoidance runway situation (33) where animals are first rewarded and then punished in a goal box. He found that if during the approach training phase a series of shocks of gradually increasing intensity was administered in the goal box, then, when later tested with relatively intense shock in the goal box, these animals ran faster (and more of them reached the goal box within a three minute time limit) than control animals which had not received previous shock experience.

While quite different in many respects, both the Kamin and Miller studies agree that prior shock experience reduces the later disruptive effects of shock on hunger-motivated operant behavior. There is, however, a difference in procedure between the two studies which seems to merit closer examination. Miller, who viewed the problem as training an animal to "resist stress," quite naturally began by introducing very mild stress, and then gradually increasing shock intensity on successive days. The Miller report seems to assume implicitly that this "increasing" pattern is the most effective in producing habituation. Kamin, however, obtained a marked habituation effect (as have many other investigators) while utilizing a "constant" pattern of shock intensity. The question is thus open as to what type of pattern will be most effective in producing habituation.[4] There is also, of course, the possibility that some patterns may "boomerang" - i.e., may produce a sensitization effect, the direct opposite of habituation. That such a reverse effect can occur under some conditions is suggested by the previous review of the literature.

The present experiment, then, was designed to investigate the effects of a number of different patterns of prior shock intensities on subsequent emotional reactivity to shock. The Kamin CER procedure was utilized, with the different patterns of prior shock and a control condition with no prior shock. The patterns investigated were: gradually increasing intensities, gradually decreasing intensities, and irregular

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[4] The problem of sequential _patterning_ of stimulation, as distinct from relative _frequencies_ of different classes of stimulation, has been conspicuously ignored by learning theory. The recent mathematical models (e.g. the linear operator model of Bush and Mosteller (8)) specifically incorporate an "independence of path" assumption, thereby by definition ruling out pattern as a variable determining behavior.

(unpredictable) intensities. The focus of interest of the study is the effect of these patterns of prior shock intensities on subsequent acquisition of the CER, with the CER taken as an index of the subject's emotional reactivity.

This study, then, should provide data on the effect of a variable which has never been investigated in the habituation context, and which has seldom been investigated in any experimental context. The theoretical and practical significance of increasing our understanding of the habituation phenomenon is obvious. Theoretically, habituation and/or sensitization phenomena must be involved in most studies which employ aversive stimulation repeatedly - studies of punishment, of avoidance, of escape, of emotional arousal, etc. The familiar clinical problem of "traumatic experience" is clearly closely related.

Practically, the educational or "training" significance of an understanding of habituation is difficult to exaggerate. How do we best go about training organisms to be relatively indifferent to such stresses as pain, fear, fatigue, frustration, noise, and extremes of temperature?

The experiment was designed with problems such as these in mind. The results, however, will indicate that the main contribution of the study - quite unexpectedly - lies in a very different area.

CHAPTER TWO

METHOD

The study to be reported involved, ultimately, three separate - but closely related - experiments. The apparatus and the basic procedures were in large part identical for the three experiments. The simplest form of presentation will be to describe first the basic apparatus and procedures for Experiment I, followed by the results. The changes in procedure introduced for the subsequent experiments will be described when the results of these studies are presented.

Subjects and Apparatus

The subjects in all experiments were naive male hooded rats from the McMaster colony, approximately six months of age. There were forty subjects in Experiment I, randomly assigned to four groups.

The apparatus consisted of eight standard Skinner boxes individually housed in sand-filled "ice-chest" type wooden boxes.[5] One wall of the Skinner box contained the food receptacle, the response lever, and a loudspeaker. The floor consisted of steel grid bars connected to a Grason Stadler E1064GS shock generator. The shock generator employed a high voltage, high resistance circuit in order to minimize

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[5] The Skinner boxes were employed in a counter-balanced design to insure that each box was used equally often for each experimental group.

the effect of changes in the rat's resistance on current flow. A shock scrambler reversed the polarity of the grids, walls, and lever approximately every 0.3 seconds so that the rat could not avoid shock by standing on any particular pair of grid bars or by maintaining contact with the walls or lever of the Skinner box. Shock intensity settings of 0.25, 0.5, 1.0, 2.0, and 4.0 ma. on the shock generator were used. Annau (2) has estimated that the amperage received by a representative male rat at each of the above settings is: .28, .49, .85, 1.55, and 2.91 ma. Whenever delivered, shock was of 0.5 seconds duration.

The CS was a 3 minute white noise produced by a Model 901A Grason Stadler noise generator which fed into the loudspeakers attached to the outside walls of the Skinner boxes. The mean baseline noise level for the eight Skinner boxes, with the exhaust fans operating, was 62.3 db. as measured by a General Radio Sound Survey Meter. Presentation of the CS raised the noise to a mean level of 69.4 db.

Grason Stadler operant conditioning units which automatically programmed the experimental procedure and recorded responses were contained in a room adjacent to the Skinner boxes.

Procedure:

Preliminary Training: This was identical for all experiments. The animals were first put on a 24 hour feeding rhythm which reduced them to about 75% of their ad lib body weight. The subjects were then maintained at this weight throughout the experiment, being fed once daily, approximately one hour after conclusion of the daily 2-hour experimental session. The preliminary training concluded with 10 hours' experience (five daily sessions) bar pressing under a

2.5 minute variable interval food reinforcement schedule. This produced a relatively stable rate of baseline bar pressing. The last day of preliminary training (Day P) included a pre-test, to determine whether the CS, before being paired with the UCS, affected rate of bar pressing. The CS, on Day P, was presented four times, at 19, 55, 95, and 115 minutes after the beginning of the session.

Habituation Training: Within Experiment I, the ten days following preliminary training (Days H-1 through H-10) were devoted to habituation training. There were four groups, each receiving a different treatment during this phase of the experiment. The control group, during Days H-1 through H-10, were simply given daily two-hour sessions of bar pressing. The experimental groups, while allowed to bar press on these days, were given four "habituation" or "free" shocks daily, programmed independently of the food reinforcement schedule. The free shocks, each of .5 seconds duration, were delivered 22, 58, 98, and 118 minutes after the beginning of the session. The three experimental groups differed solely in terms of the sequential patterning of the intensities of the shocks delivered during the free shock days. The "Ascending" group received its shocks in a series of gradually increasing intensity (two days at .25 ma, two days at .50 ma....until, finally, two days at 4.0 ma). The "Descending" group received the reverse sequence. The "Irregular" group received its shock intensities in a fixed irregular pattern; the consecutive daily intensity being: 1.0, .25, 2.0, 4.0, .50, 2.0, .25, .50, 4.0 and 1.0 ma. Thus, by the end of habituation training, each experimental group had had two days' experience with each of the five intensities employed.

CER Training: This was indentical for all groups in Experiment I, and for all experiments. CER training was begun on the day following Day H-10, and continued for ten days. Within each daily two-hour session, four CS-UCS sequences were programmed independently of the food reinforcement schedule. The 3-minute CS was presented 19, 55, 95, and 115 minutes after the beginning of the session, terminating with delivery of a .5 second shock. The shock during CER training was, for all groups and all experiments, 1.0 ma.

The magnitude of the CER was measured by the "suppression ratio" adopted by Kamin (3, 23, 24). The ratio is $\frac{B}{A + B}$, where 'B' represents the number of bar presses made during the CS and 'A' the number of responses made in an identical interval of time preceding the CS. The numbers of responses made during intervals A and B for each CS-UCS sequence were recorded on Grason Stadler print-out counters, but for most purposes daily ratios were calculated by cumulating the responses made during the four CS-UCS presentations.

CHAPTER THREE

RESULTS[6]

The analysis of the data is divided into two major categories: suppression ratios during CER training, and baseline bar pressing rates during both habituation and CER training. These classes of data will be examined separately, although, as will be seen, they are by no means independent of each other.

Experiment I

Suppression Ratios: A daily suppression ratio was calculated for each rat for each day by cumulating the responses recorded during the four pre-CS and four CS periods. The median ratios for all groups over the ten CER training days are presented in Figure 1. The three groups, it will be seen, show a marked retardation in acquisition of suppression, compared to the control animals. The data in this sense replicate Kamin's earlier report (24) of an "apparent adaptation effect". The most striking finding, however, is the prevalence of very high ratios - above .50 - during the early days of training. These "super-normal" ratios, the obverse of suppression, indicate that the animals are responding during the CS at a rate faster than that in effect be-

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[6] The raw data for all experiments are presented in the Appendix.

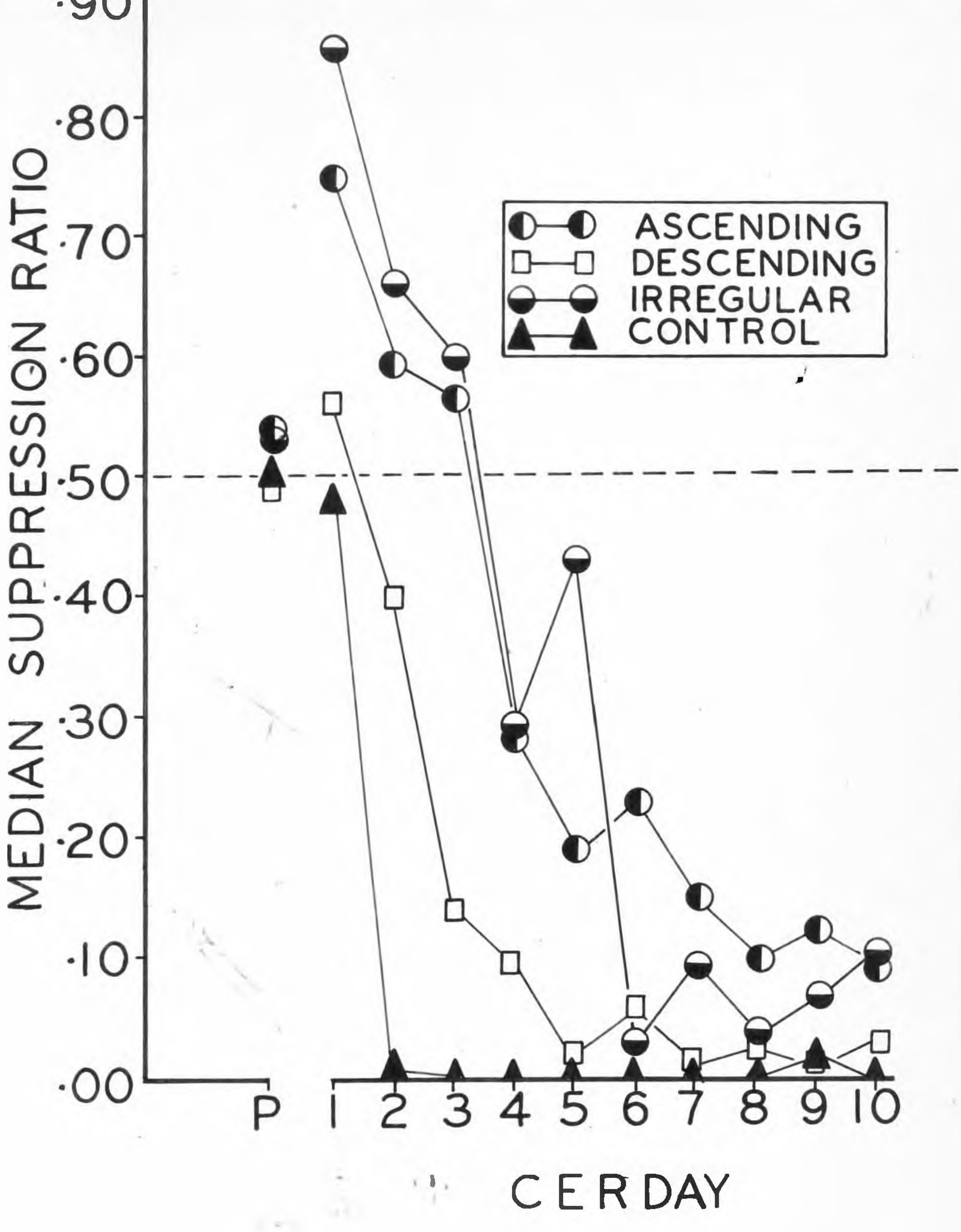

FIGURE 1

MEDIAN SUPPRESSION RATIOS AS A FUNCTION OF CER TRAINING DAY fore the CS. With continued training, however, all groups ultimately acquire quite low suppression ratios.

To test for differences among groups in suppression ratios over a number of days of training, each rat was given a suppression score for CER Days 1-5 and CER Days 6-10. This score was simply the arithmetic mean of the five daily ratios. These data are summarized in Table I.

TABLE I

Mean Suppression Ratios For Blocks of Five Days

CER DAYS 1 - 5

	Ascending	Descending	Irregular	Control
Mean	.63	.30	.65	.11
Median	.51	.27	.68	.10
Range	.27-1.00	.17-.45	.27-1.00	.01-.21

CER DAYS 6 - 10

	Ascending	Descending	Irregular	Control
Mean	.25	.05	.19	.01
Median	.17	.04	.04	.01
Range	.01-.68	.00-.14	.00-.68	.00-.03

The data were submitted to the Kruskal-Wallis ranked analysis of variance. While there are no significant differences among groups on Day P ($H = 4.1$, $.20 < p < .30$), there are great differences during CER Days 1-5. For these days, the value of H was 26.8, $p < .001$. To assess differences among pairs of groups, multiple U tests were made by means of Ryan's multiple comparison technique (41). Adopting a 5% "experimentwise" significance level, all pairs of groups, except the Irregular and Ascending, were found to differ significantly from each other. Thus, the groups fall into three clusters. The first cluster (Irregular and Ascending groups) has the highest ratios, followed by the Descending group, which in turn has higher ratios than the Control group. These differences, however, progressively diminish until, for CER Days 6-10, H is not significant ($H = 5.5$, $.10 < p < .20$).

The super-normal median ratios displayed early in CER training by the experimental groups were observed quite consistently in individual animals. When the ratio for CER Day 1 is contrasted to that of Day P, 26 of the 30 experimental animals show higher ratios on CER Day 1, while only 3 out of the 10 controls do so. For the experimental subjects, this is a highly significant deviation from a 50-50 split ($p < .0001$); and the proportion of experimental animals with higher ratios is greater than the corresponding proportion of Controls ($p < .002$, Fisher's exact test).

Baseline Rates: Throughout the experiment records were kept of bar presses made during the four 3-minute periods of the daily session which, on CER training days, immediately preceded CS presentation. Thus, for all days of the experiment, a baseline rate per minute could be computed from a 12-minute sample of the day's session. The median baseline rates for the four groups over the 10 habituation days are presented in Figure 2. The figure indicates that, despite considerable day to day variation, the Control group concluded this phase of the study with much the same baseline rate as that with which it began. The Ascending and

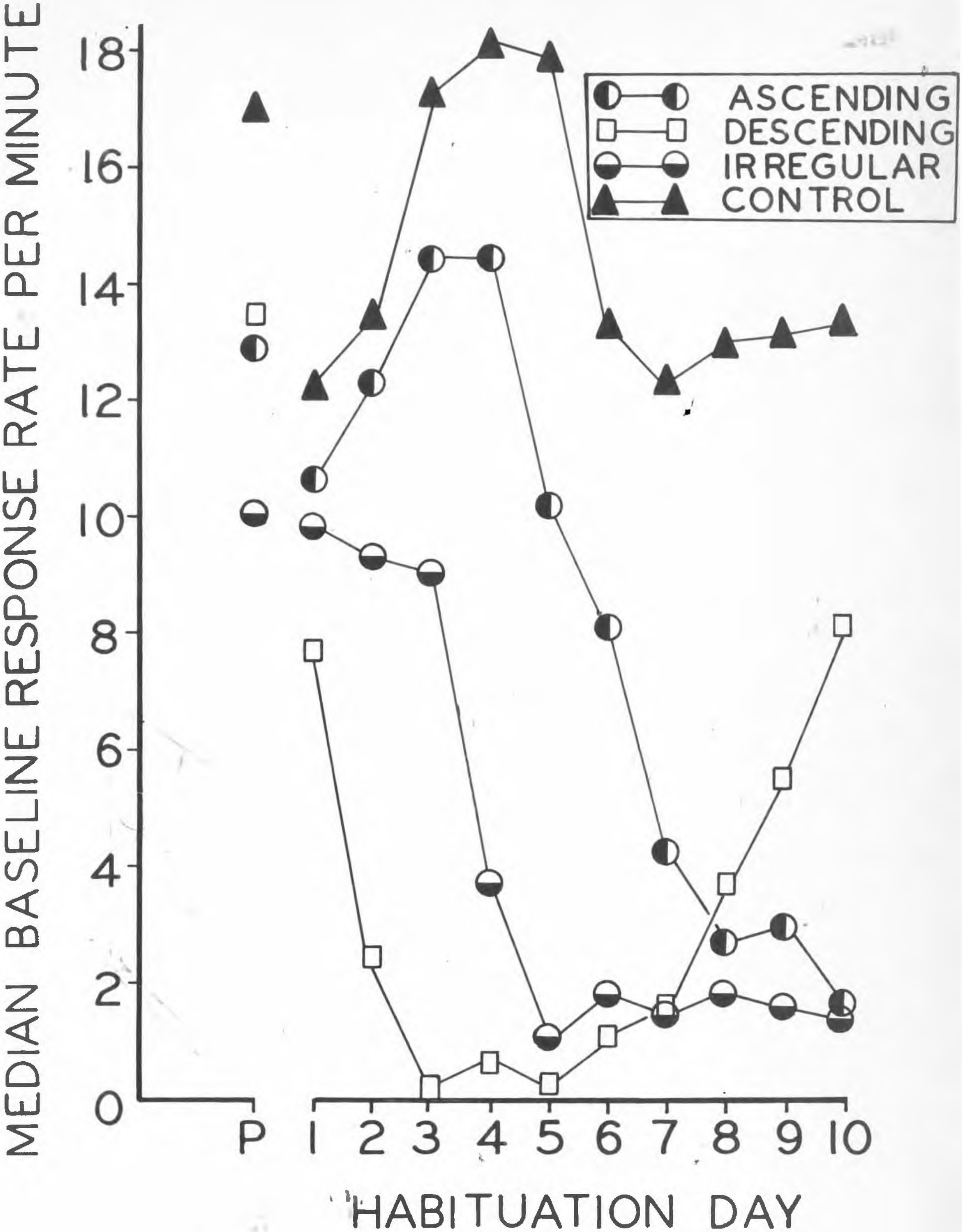

FIGURE 2

MEDIAN BASELINE RESPONSE RATES AS A FUNCTION OF HABITUATION DAY

Irregular groups, however, show a progressive decline throughout habituation training, to a very low terminal baseline level. The Descending group, after an initial drastic drop in baseline, eventually makes a considerable recovery.

Table II summarizes baseline data for Days P and H-10. For Day P the differences among groups in baseline rates do not approach signifi-

TABLE II

Baseline Response Rate Per Minute

DAY P

	Ascending	Descending	Irregular	Control
Mean	13.9	15.9	13.5	18.9
Median	13.0	13.5	10.2	17.1
Range	3.1-25.0	4.0-35.3	5.3-30.1	8.3-33.3

DAY H-10

	Ascending	Descending	Irregular	Control
Mean	2.7	8.9	2.2	15.1
Median	1.7	8.1	1.4	13.3
Range	.2-7.8	0-25.9	0-5.3	4.3-32.5

cance ($H = 2.3$, $.50 < p < .70$). By Day H-10, however, the groups do differ significantly ($H = 21.1$, $p < .001$). Within Day H-10 Ryan's test shows that the four groups form two non-overlapping clusters. The Control and Descending animals have higher rates than do the Ascending and Irregular groups. The three experimental groups each show, by

Wilcoxon's test for paired replicates, significant drops in baseline from Day P to Day H-10, but this is not true of the Control group.

Turning to baseline rates during CER training, the median rates for the four groups over the 10 CER days are portrayed in Figure 3. Summary data for CER Days 1 and 10 are presented in Table III. The value

TABLE III

Baseline Response Rate Per Minute

CER DAY 1

	Ascending	Descending	Irregular	Control
Mean	1.9	10.5	1.8	15.0
Median	.9	8.5	.1	10.0
Range	0-8.1	0-39.4	0-6.4	1.1-34.4

CER DAY 10

	Ascending	Descending	Irregular	Control
Mean	4.6	7.5	4.2	12.0
Median	3.1	5.8	4.8	7.0
Range	0-15.1	2.6-22.4	0-8.8	.5-40.4

of H for CER Day 1 is 19.6, $p < .001$, and Ryan's test again reveals two clusters; the Ascending and Irregular groups have lower rates than the Descending and Control groups. By CER Day 10, however, no differences exist among groups ($H = 6.6$, $.10 < p < .20$).

<u>Discussion</u>: The analysis to this point indicates some significant parallelisms. The severest retardation in acquisition of the CER,

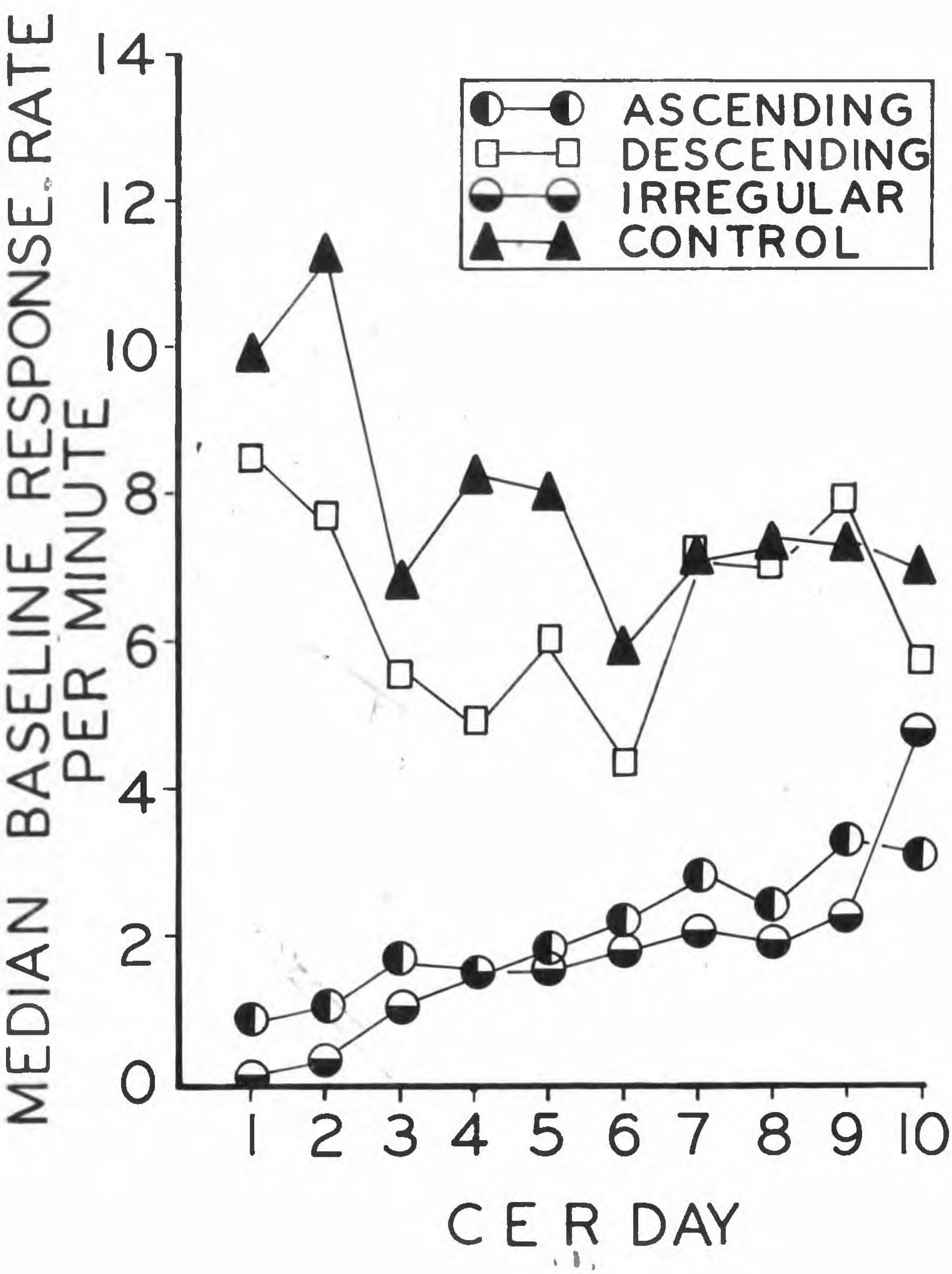

FIGURE 3

MEDIAN BASELINE RESPONSE RATES AS A FUNCTION OF CER TRAINING DAY and the most pronounced super-normal ratios, and the lowest baseline rates, are each displayed by the Ascending and Irregular groups. This clearly suggests the possibility that Kamin's "apparent adaptation effect," and the differences in ratios among our experimental groups, may be attributable to differential effects of the habituation procedures on the groups' baselines. To examine this more closely, the rank order correlation between the drop in baseline from Day P to CER Day 1, and the suppression ratio on CER Day 1, was computed.[7] The correlation coefficient, pooling all animals in Experiment I, was $-.83$, $p < .001$. That is, there is a highly significant tendency for a lowered baseline to be associated with high suppression ratios - and, in fact, with super-normal ratios.

There is, of course, the possibility that this correlation represents some kind of statistical artifact. The habituation procedure, it will be remembered, often drove the animal's baseline to a very low level - sometimes, in fact, to zero. When, in the limiting case, the baseline is literally zero, the rate during the CS, if it changes at all, can move only in an upward direction. Thus this tendency could conceivably account for the association between low baselines and high

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[7] For this analysis, the baseline rates for the 16 minutes preceding the first CS-UCS sequence were computed for each rat for Days P and CER-1. The rate on Day CER-1 was then expressed as a percentage of the rate on Day P to index the rat's drop in baseline over the free shock period.

ratios. There are, however, a number of observations which argue convincingly against such an interpretation.

First, we can look at the proportions of animals which display, on CER Day 1, ratios above and below .50. There are, in the experimental groups, only six animals with a zero baseline on CER Day 1 (three in the Irregular group, two in the Ascending, and one in the Descending group). There thus remain 24 experimental animals which, on CER Day 1, were free during the CS, either to increase or decrease their rates. If we now ask how many of these animals moved in which direction (disregarding the magnitude of the change), we find that 22 of the 24 rats increased their rates. This proportion deviates markedly from a chance level ($p < .001$); and the proportion of experimental animals with increased rates is greater than the proportion (3 out of 10) of similar control animals ($p < .0007$, Fisher's exact test). Parenthetically, we can note that the two experimental rats with decreased rates during the CS were in the Descending group; and each of the six animals with zero baselines did respond during the CS.

Second, we have available an empirical control against the possibility that the structure of the experimental situation is such that, whenever baseline rates are low, super-normal suppression ratios will necessarily occur. The response counts during the "pre-CS" and "CS" periods on the habituation days (when in fact no CS was presented) were available for computing "dummy" ratios. The Descending group had its lowest baseline rates (cf. Figure 2) on Days H-3 through H-5, the Ascending and Irregular groups had their lowest rates on Days H-8 through H-10. The median dummy ratios for these groups on these days were, respectively, .43, .66, .51; .53, .50, .48; .53, .55, .48. While a low baseline tends to increase the variability of suppression ratios, the central tendency clearly hovers about .50. The mean median dummy ratio for these days is .52, the median, .51. The baselines during these days were extremely low.

Finally, it should be noted that the tendency to increase rate during the CS on CER Day 1 was not a trivial effect, attributable to a few "accidental" responses superimposed on a low baseline. The numbers of responses during pre-CS and CS periods on Day 1 were, for some representative experimental animals, 9-50, 0-20, 4-22, 76-136, 59-118, 1-24, 0-41. For low responding animals typically 40 to 80% of the total responses made during a daily session occurred during the CS.

The conclusion is thus perfectly clear that, in the experimental groups, high - indeed, super-normal - ratios are associated with the low baselines produced by free shock, and that this association is not the result of a statistical artifact. Thus it seemed plausible that the effects of free shock on subsequent acquisition of the CER were mediated entirely by its effect on baseline bar pressing rate. This was an unexpected conclusion, and one which would drastically affect interpretation of the data. The next experiment was designed to check the feasibility of this conclusion. In Experiment II subjects are first given free shock to depress their baseline rates; half of the subjects are then allowed undisturbed practice at bar pressing in order to substantially recover their baseline rates. The acquisition of the CER is then compared for groups which have had similar free shock experience, but which differ in baseline rates.

Experiment II

Method: The subjects in Experiment II were 20 hooded rats, divided randomly into two experimental groups. The Control group of Experiment I was also utilized for some comparisons.

The apparatus was identical to that of Experiment I, but, when called for by the experimental design, a false wall was inserted into the Skinner box, shielding the subject from the lever and food cup. The experimental apparatus had, between Experiments I and II, been moved to a new laboratory building with improved soundproofing. The mean noise level in the Skinner boxes was now 55.9 db, increased to 61.9 db. by the CS.

Preliminary training for all subjects was identical to that described for Experiment I. The habituation training, identical for both groups in Experiment II, differed from that of Experiment I in the following details. There were only three habituation days, during which the free shock employed was always 3.0 ma. This habituation training was sufficient to depress baselines radically.

"Recovery training" differed for the two experimental groups. The "Recovery" group, immediately following Day H-3, was given five daily sessions of bar pressing, identical in procedure to that employed during preliminary training. The "No Recovery" group was placed in the Skinner box for five daily two-hour sessions, but with the lever and food cup shielded by the false wall. The No Recovery group controls for the passage of time between habituation training and CER training. While it was recognized that mere exposure to the Skinner box might result in some recovery of baseline rate by the No Recovery group, it was assumed that this would be substantially less than that obtained in the Recovery group. Following recovery training, eight days of CER training were given, identical in detail to that of Experiment I.

Results: The first questions to be answered concern the effects of habituation and recovery training on baseline rates. Figure 4 portrays median baselines for both groups during habituation and CER training. These data for selected days are summarized in Table IV. The two groups,

TABLE IV

Baseline Response Rate Per Minute

NO RECOVERY

	Day P	Day H-3	CER Day 1	CER Day 8
Mean	8.1	4.4	3.4	8.2
Median	7.6	2.4	2.3	6.8
Range	3.3-14.3	0-16.5	0-13.9	0-26.3

RECOVERY

	Day P	Day H-3	CER Day 1	CER Day 8
Mean	16.1	2.8	16.8	13.2
Median	15.2	2.1	12.8	8.2
Range	3.3-38.0	0-9.0	3.8-52.7	3.8-35.8

peculiarly, differed significantly in baseline rates on Day P ($U = 22$, $p < .05$). However, as Figure 4 makes clear, habituation training

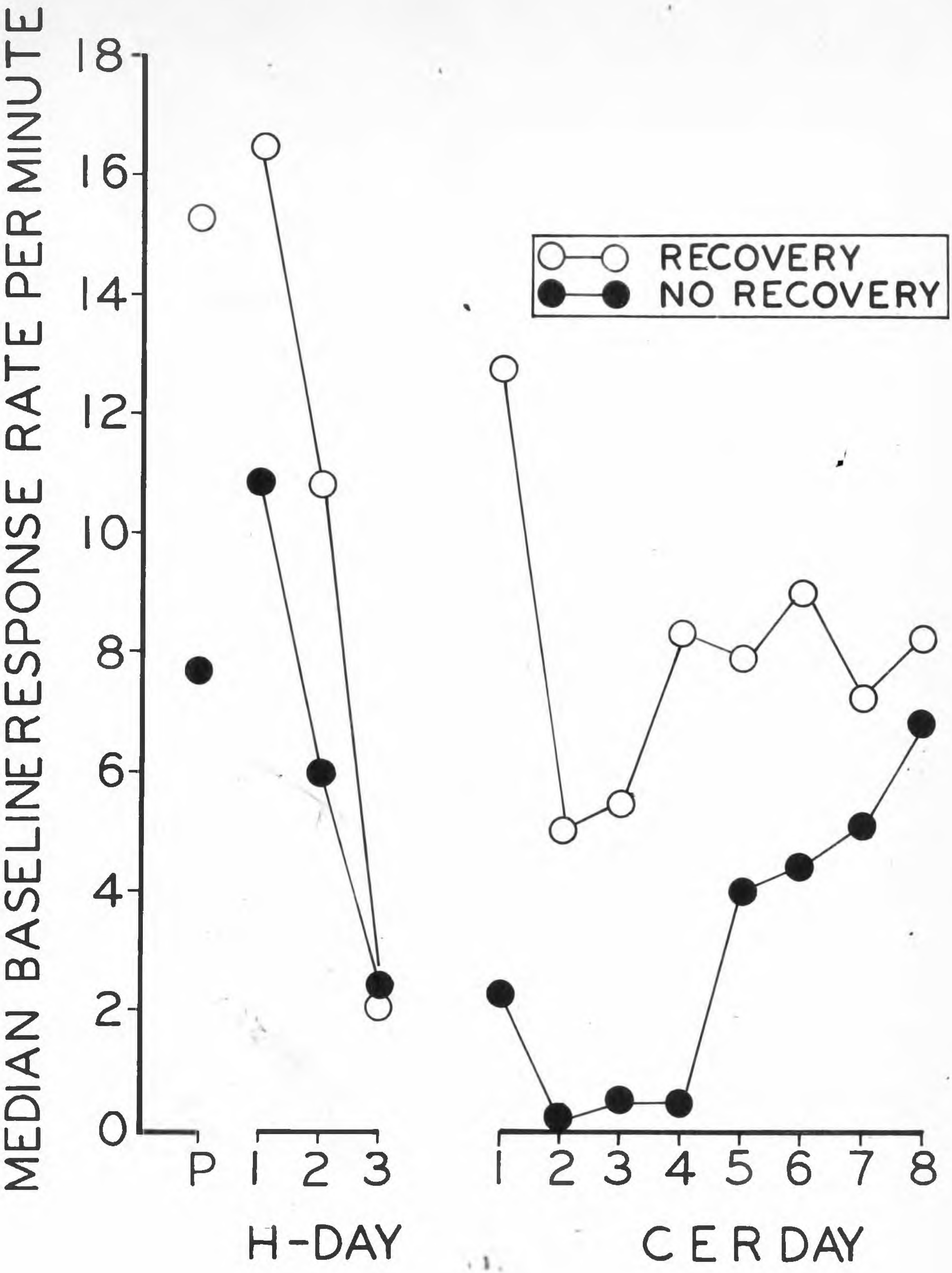

FIGURE 4

MEDIAN BASELINE RESPONSE RATES AS A FUNCTION OF HABITUATION AND CER TRAINING DAYS severely depressed the baselines of both groups, so that on Day H-3 the groups no longer differ ($U = 44.0$, $p > .60$). Figure 4 also indicates that, after the interpolated recovery training, the Recovery group has a relatively high baseline on CER Day 1, while the No Recovery group has much the same low baseline as that on Day H-3. The difference between groups on Day CER-1 was significant ($U = 7.0$, $p < .002$), but this may merely reflect the original difference between groups observed on Day P. We can ask, however, whether the two groups differed in the degree to which their baselines dropped from Day P to CER Day 1. To assess this, a difference score was computed for each animal. Wilcoxon's test showed a significant drop in baseline for the No Recovery group ($T = 6.0$, $p < .05$) but no significant effect for the Recovery group ($T = 22.5$, $p > .60$). We can thus conclude that the habituation training depressed the baseline rates of both groups, but that the Recovery group had substantially regained its baseline by the beginning of CER training. Finally, the difference between groups has disappeared by the end of CER training; on CER Day 8, $U = 31.0$, $p > .10$.

Turning to suppression ratios, Figure 5 presents the median daily ratios of the two experimental groups, and of the Control group from Experiment I. Table V summarizes the mean ratio data for CER Days 1-4 and 5-8. The No Recovery group, in contrast to the Recovery group, had super-normal ratios on Day 1 and a slower acquisition of the CER. The acquisition curve of the Recovery animals is almost superimposed on that of the Controls.

For CER Days 1-4, there are marked differences among the groups

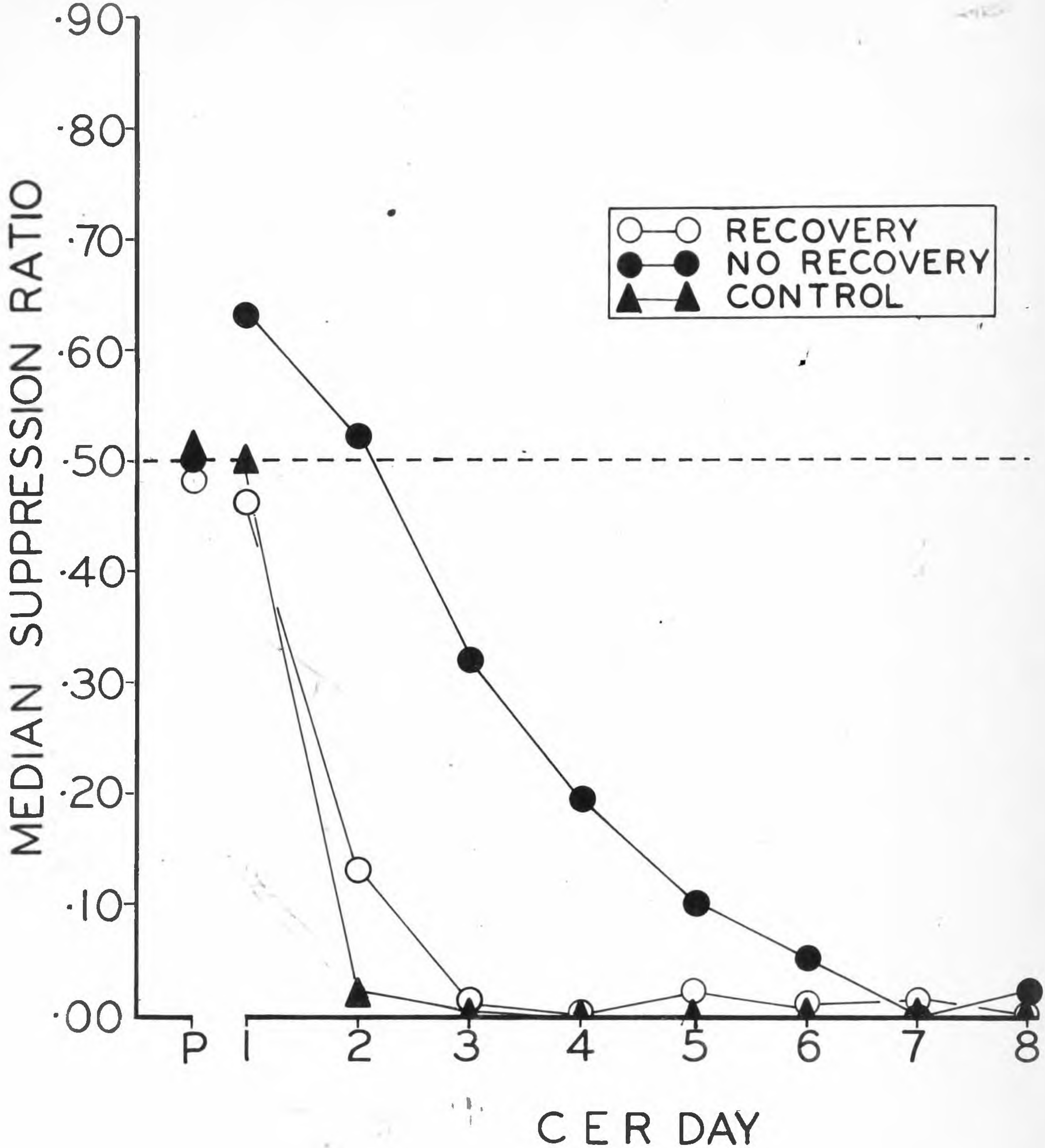

FIGURE 5

MEDIAN SUPPRESSION RATIOS AS A FUNCTION OF CER TRAINING DAY

TABLE V

Mean Suppression Ratios For Blocks of Four Days

CER DAYS 1 - 4

	No Recovery	Recovery	Control
Mean	.53	.21	.15
Median	.56	.18	.14
Range	.07-1.00	.11-.41	.09-2.6

CER DAYS 5 - 8

	No Recovery	Recovery	Control
Mean	.09	.04	.01
Median	.06	.02	.01
Range	.00-.33	.00-.14	.00-.02

($H = 11.5$, $p < .01$). Ryan's test indicates that the No Recovery animals differ significantly from the remaining two groups. The difference between groups is still significant on Days 5-8 ($H = 7.7$, $p < .05$), although inspection of Figure 5 suggests that had CER training been continued for ten days, as in Experiment I, there would probably have been no differences during the latter half of training.

Finally, the rank order correlation between baseline drop and suppression ratio on CER Day 1 was computed in a manner analogous to that for Experiment I. For the 20 experimental animals of the present study, the correlation was $-.55$, $p < .05$.[8] That is, once again animals with lowered baselines displayed the highest suppression ratios.

Discussion: The results of Experiment II seem to make clear that previous experience with shock, when it results in a lowered baseline rate, sets up a tendency for the animal to increase its response rate when presented with the CS. This tendency, obviously, conflicts with the classical CER tendency to decrease response rate. Thus the CER acquisition curves in Experiments I and II may be viewed as the composite of these two opposed tendencies. The Control group, which had no previous experience with shock, provides a clear picture of the development of the "decreasing" tendency over ten days. We have, however, no clear picture of the development of the "increasing" tendency, uncomplicated by the simultaneous development of the CER. The

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[8] This correlation ($-.55$) is substantially lower than that observed in the first experiment ($-.83$), due presumably to the fact that it is based on a more restricted range of values. There was in the present experiment only one depressed baseline group (10 subjects) in comparison with three groups (30 subjects) in the previous experiment. Further, the depressed baseline group in the present experiment did not, in general, have as low a response rate on CER Day 1 as two of the three comparable groups in Experiment I. As the correlation coefficient is accounted for by a reduction in baseline being associated with supernormal ratios, the above factors would lead one to expect a lower correlation in the present experiment than in the previous one.

following experiment was designed to provide this information.

Experiment III

<u>Method</u>: The subjects in Experiment III were 20 hooded rats, divided randomly into two experimental groups. The data for one animal in the "No Recovery" group, which died in the course of the study, was excluded from all the analyses.

The apparatus was identical to that of Experiment II. The preliminary training, habituation training, and recovery training procedures were also identical to those of Experiment II. The only difference between the two experiments was that, in Experiment III, CER training was replaced by "CS training." The CS training duplicated CER training in all but one crucial respect: during CS training, no shock was ever delivered. Thus, in the present experiment, CS suppression ratios could be computed for groups which had received habituation shock, with and without subsequent recovery training, uncomplicated by the development of a CER.

<u>Results</u>: The baseline data are portrayed in Figure 6, and summarized in Table VI. The groups do not differ in rates on Day P ($U = 30.0$, $p > .10$) and the habituation training radically lowers the baselines of both groups so that they also do not differ on Day H-3 ($U = 36.0$, $p > .40$). Surprisingly, however, the groups do not differ in baselines on CS Day 1, following differential recovery procedures ($U = 36.0$, $p > .40$). Both groups show substantial recovery of their baselines. The difference between the groups, however, is in the expected direction, which is the reverse of the direction displayed on Day P. Thus if, as in

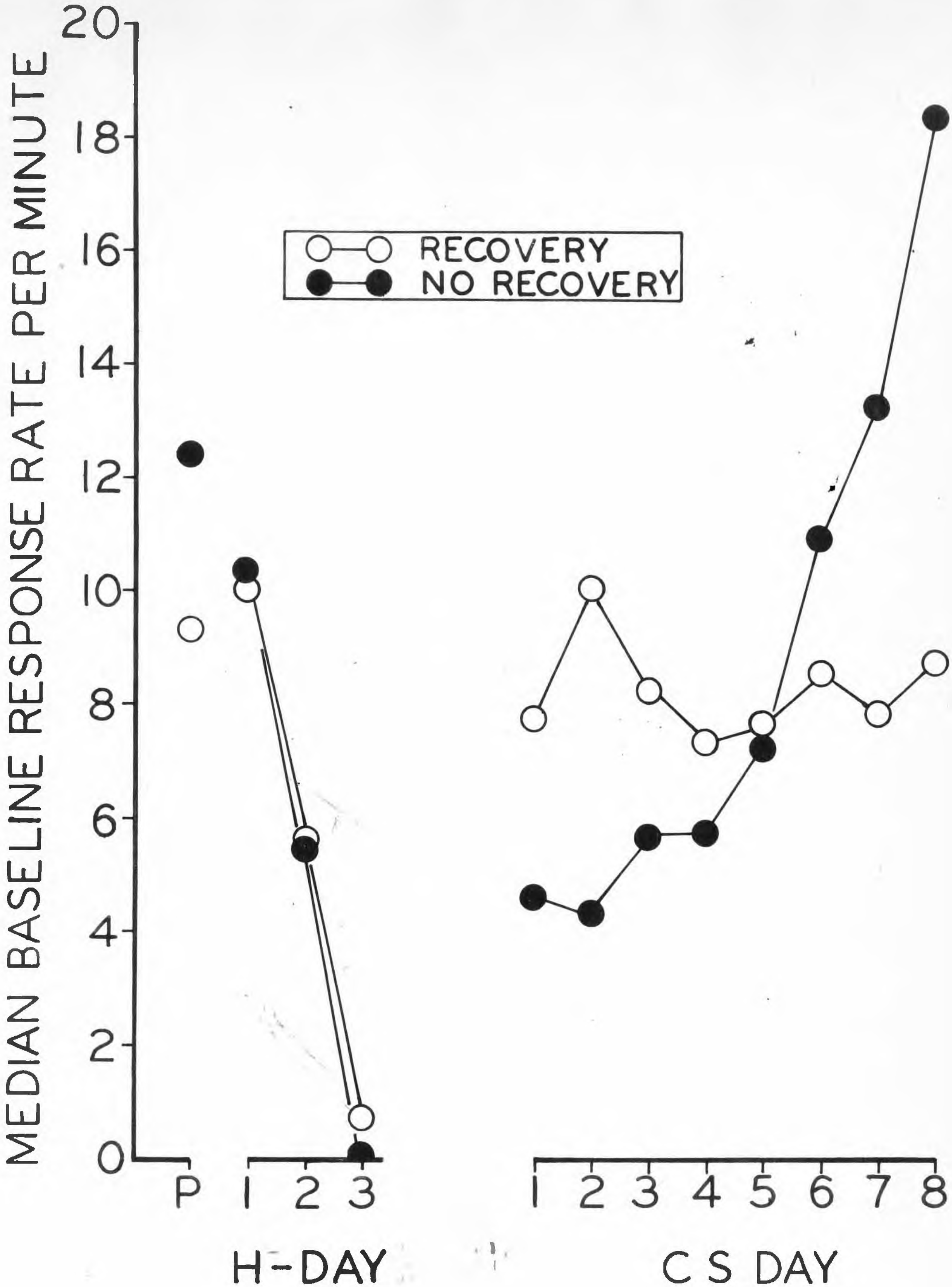

FIGURE 6

MEDIAN BASELINE RESPONSE RATES AS A FUNCTION OF HABITUATION AND CS TRAINING DAY

TABLE VI

Baseline Response Rate Per Minute

NO RECOVERY

	Day P	Day H-3	CS Day 1	CS Day 8
Mean	16.4	1.1	6.8	20.1
Median	12.4	0.0	2.8	18.3
Range	3.8-48.0	0.0-5.6	2.3-20.5	6.1-62.8

RECOVERY

	Day P	Day H-3	CS Day 1	CS Day 8
Mean	9.8	1.2	10.3	9.8
Median	9.3	0.7	7.7	8.7
Range	1.8-17.2	0.0-3.0	1.0-39.9	3.4-24.0

Experiment II, we compute a difference score for each animal (Day P rate minus Day CS-1 rate), Wilcoxon's test shows that the No Recovery animals have a significant drop in baseline ($T = 0.0$, $p < .01$), but the Recovery animals do not ($T = 14.0$, $p > .10$). We can thus conclude that the habituation training decreased the baselines of both groups, and that, while the No Recovery group entered CS training with a relatively high baseline, their recovery was not so substantial as that of the Recovery group. The No Recovery animals, as Figure 6 makes clear, were pressing at a very rapid rate by the end of CS training, suggesting that, experimental manipulations aside, they might have been higher responders than the rats assigned to the Recovery group.

Turning to suppression ratios, Figure 7 presents the median daily ratios for both groups, and Table VII summarizes the mean ratio data for CS Days 1-4 and 5-8. The figure indicates a tendency for both groups to have ratios above .50 during the early training days, although this is considerably more conspicuous in the No Recovery than in the Recovery group. On CS Day 1 all nine of the No Recovery rats ($p < .01$) while only eight of the ten Recovery subjects ($p = .11$) had ratios higher than on Day P. Thus only the No Recovery group can be said to display significantly super-normal ratios. For CS Days 1-4 the ratios of the

TABLE VII

Mean Suppression Ratios for Blocks of Four Days

	CS DAYS 1-4		CS DAYS 5-8	
	No Recovery	Recovery	No Recovery	Recovery
Mean	.64	.54	.54	.51
Median	.62	.55	.53	.52
Range	.52-.78	.40-.71	.49-.60	.41-.63

No Recovery group are higher than those of the Recovery group ($U = 19.5$, $p < .05$) although this difference has disappeared by CS Days 5-8 ($U = 44.5$, $p > .80$).

Finally, the rank order correlation between change in baseline from Day P to CS Day 1, and suppression ratio on CS Day 1, was computed. For the 19 experimental animals of this study, the correlation was -.63, $p < .01$; again, drops in baseline were associated with high ratios.

Discussion: The results of Experiment III indicate that the

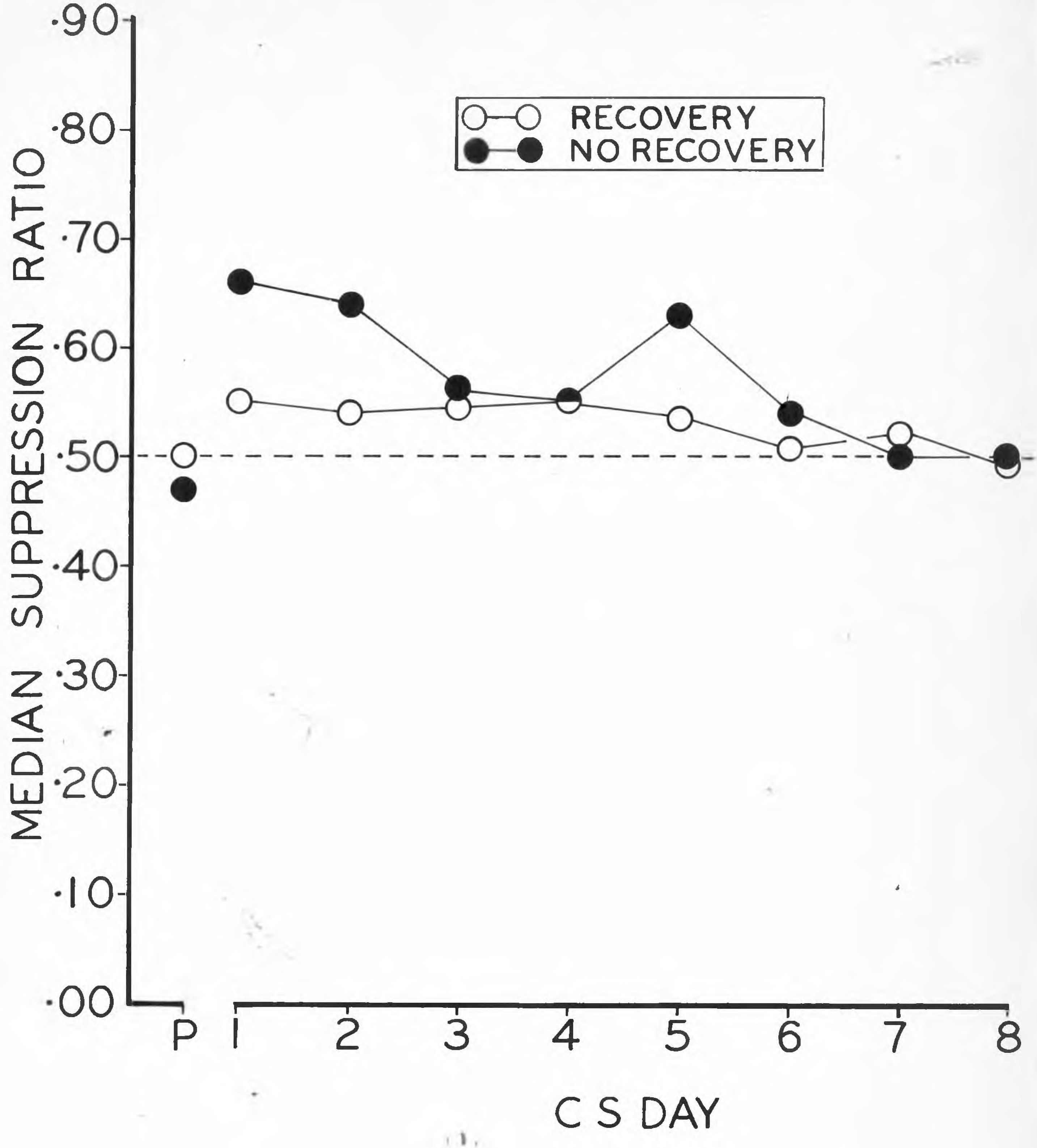

FIGURE 7

MEDIAN SUPPRESSION RATIOS AS A FUNCTION OF CS TRAINING DAY tendency for subjects with prior shock experience and lowered baselines to increase response rate in the presence of the CS is independent of any presentation of shock during the test.[9] Further, as Figure 7 makes clear, this tendency persists over several days, though gradually diminishing. Thus, we can assume that the persistance of this tendency over several days accounted for the observations in the preceding experiments, of a retardation in the development of suppression during CER training. Finally, it has again been made clear that this tendency to respond at a higher rate during the presence of the CS depends upon a lowered baseline; when, following the prior shock experience, the baseline rate is allowed to recover, the effect does not occur significantly.

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[9] This was already clear from the fact that in the earlier studies, the effect appeared on the <u>first</u> CS presentation.

CHAPTER FOUR

DISCUSSION

Pattern of Shock Intensity and the Apparent Adaptation Effect

The results of the experiments make clear that the "apparent adaptation effect," and the correlated super-normal ratios, are mediated through changes in baseline response rate. The patterns of shock intensity explored in Experiment I had differential effects on baseline rates; this makes it difficult to talk about pattern of shock intensity as an independent variable. We can say simply that, to the degree that baseline bar pressing was depressed by a given pattern, there was a tendency, during CER training, to respond at an accelerated rate during the presence of the CS. Thus, differences among groups in rate of acquisition of the CER follow from differences in the strength of this "speed-up" tendency.

This conclusion is indicated by the following facts. Within Experiment I, the groups with the lowest baselines at the start of CER training showed the highest super-normal ratios, and slowest acquisition of the CER. Within all three experiments there was a significant correlation between drop in baseline (from Day P to CER Day 1) and suppression ratio on CER Day 1; to the degree that an animal's baseline rate was depressed, it tended to accelerate its rate in the presence of the CS. When, however, in Experiment II, animals were allowed to recover their baselines after experience with "habituation" shock, they did not display super-normal ratios or a slow acquisition of the CER. Finally, Experiment III demonstrated that the "speed-up" effect was independent of CS-UCS pairings, as it persisted for several days when no UCS was employed during testing.

The experiments in one sense replicate Kamin's original observation of an apparent adaptation effect, in that acquisition of the CER after prior experience with shock was slow. The retardation in the development of suppression during CER training, however, did not appear to result from habituation to the UCS. Rather, it seems to have been the outcome of opposing reaction tendencies to the CS. The traditional tendency to suppress responding during the presence of the CS, under a standard CER training program, conflicted with the tendency to increase responding during the CS, when baseline responding was generally inhibited. The outcome was an attenuated CER.

Considering all the evidence, it is quite clear that what Kamin referred to as the "apparent adaptation effect" can be accounted for in terms of these two opposing tendencies elicited by the CS. Kamin seems to have been misled because he did not employ, during "habituation" training, the high shock intensities which were utilized in the present experiments, and consequently did not so radically alter the baseline rate of responding. As a consequence, reliable super-normal ratios were not present on CER Day 1 (although, in general, the experimental groups had ratios above .50), while the CS "speed-up" tendency was masked on later test days by the acquisition of suppression. The core of the argument, which seems to be fatal to an habituation interpretation, is that there is no need to assume that the tendency to suppress to the CS, considered by itself, is developing any more slowly after free shock than normally. Instead, it is more parsimonious to assume that this tendency is being counteracted. We are left, however, with the problem of accounting for the opposing tendency.

The "Speed-up" Tendency and Dis-inhibition.

There are occasional observations in the CER literature of increased responding during the presence of the CS, which appear to be similar to the phenomenon observed in our experiments. Valenstein (51) has reported a result that appears very comparable. Employing guinea pigs as subjects to study the effect of the drug, reserpine, in a CER situation, he found that the drug markedly decreased the baseline lever pressing rate. With the administration of sufficient dosages, responding almost entirely ceased. The point of interest, for our purposes, is that when this occurred, animals typically gave bursts of responding during the three minute CS period, i.e., displayed just the opposite of suppression. Valenstein (51, p. 224) has suggested that "the clicker (CS) serves to arouse the animal" so that when "an animal's general performance is suppressed as a result of a tranquilizer, the arousing aspect of the stimulus may, under certain conditions, play a larger role than its warning aspect."

This is quite different from another observation by Herrnstein and Sidman (19a) of increased responding during the presence of the CS in a CER situation. These authors trained monkeys to lever press for food, and then to lever press to avoid shock. In the latter situation, each response delayed the presentation of the shock by a fixed interval of time so that the higher the rate of responding, the fewer the number of shocks received. When, following shock avoidance training, CER training was superimposed on a food reinforcement schedule, the reaction to the CS was a response "speed-up." If, however, avoidance responding was extinguished prior to CER training, then the classical conditioned suppression effect was obtained. Thus, apparently, this example represents nothing more than the positive transfer of a learned response. Confronted with a new fear-eliciting situation (presentation of the CS in a CER program), the subject reacts by increasing response rate, as this behavior has successfully reduced fear in the past (i.e., reduced the number of shocks received during avoidance training).

Kamin, in a trace-conditioning CER study (23), found that under some conditions subjects would temporarily respond at a higher rate during the CS period than during its absence. This effect seems very relevant to that which we have encountered in our experiments. He observed that (23, p. 15): "During the early days of training, several Ss in the trace groups showed marked increases in responding during the CS....This never occurred on Day 1, nor within Days 6 to 10." Presumably, for the trace groups, the initial shocks (occurring before any associative connection between CS and UCS had been formed) acted as "free" shocks, depressing baseline response rate and, in turn, promoting increased responding during the CS period. During the later stages of training, however, such an effect would be eliminated by the recovery of baseline responding and the acquisition of conditioned suppression.

Strouthes and Hamilton (48), attempting to duplicate an earlier "CER-type" study by Mowrer and Aiken (34), found that their animals increased rate of responding when responding resulted in a brief presentation of a flashing light which had previously been paired with electric shock. Comparing the data for the two studies, it was found that the initial baseline bar pressing rate was substantially lower in the Strouthes, than in the Mowrer experiment. It should be noted that the light-shock pairings had occurred in the same apparatus in which the animal bar pressed, so that the shock experience quite probably had some inhibitory effect on bar pressing rate. The important point seems to be, however, that when the rate of baseline operant responding was low, response-contingent presentation of the fear-eliciting CS enhanced the rate (48), while when the baseline rate was high, the opposite reaction was observed (34).

There was an observation made during our Experiment I which is also pertinent. One animal in the Control group, apparently due to a temporary illness, had dropped to a very low baseline response rate by the beginning of CER training. On CER Day 1, this subject displayed a super-normal ratio of .75. It appears, therefore, that inhibition of responding due to illness may have a comparable effect to that which results from the administration of free shock.

The experiments which have been cited suggest that a low operant response rate will increase during the presence of an extraneous stimulus or CS. The effect appears to be quite general, so that response rate may be depressed by a drug (51), "free" shock (23, Experiments I, II, and III), "illness" (Experiment I), or unknown causes (48), while the extraneous stimulus may be a flashing light (48), white noise (23, Experiments I, II, and III), or a clicker (51).

This phenomenon appears similar to Pavlovian dis-inhibition (37a), the CS acting as an extraneous or dis-inhibiting stimulus to increase the response rate above its depressed level. Dis-inhibition, as Pavlov described it (37a), was a case of "inhibition of inhibition." It was demonstrated by the presentation of a "new extra agent" (extraneous stimulus) when an inhibitory process was present in the nervous system, so that (37a, p. 109) "the new extra agent inhibits the inhibition, and as a result there is a freeing of the previously inhibited action, i.e., a positive effect." Our experiments appear to offer almost classic examples of the phenomenon - Experiments II and III might serve as a prototype for demonstrating dis-inhibition in an "American" setting, where it has not often been studied. While our data offer no support for Pavlov's neurophysiological theorizing about dis-inhibition, the behavioral phenomenon is strikingly similar to that which he described. Further, the phenomenon is highly regular, being observed in almost all individual animals. Thus, it may be that the main contribution of our experiments on "habituation" is the development of a stable preparation for the study of dis-inhibition.[10]

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[10] Typically, from the time of Pavlov, Russian physiological psychologists have reported elaborate demonstrations of various in-

There are interpretations other than dis-inhibition which might explain our observation of a tendency to increase response rate during the presence of the CS. One such suggestion would be in terms of a learned discrimination. The day immediately preceding exposure to unsignalled (free) shock was, in all three experiments, pretest day. It is conceivable that an association is made between the four presentations of the CS on pretest day and the failure to receive shock in the presence of the CS, in contrast to each of the following days when four shocks are encountered but no CS. Thus, on CER Day 1, there might exist a tendency to respond at a normal pre-shock level during the "safe" CS period. While such an interpretation seems to unreasonably tax the discriminatory capacity of the rat, it could be easily tested by replicating our experiments but excluding the pretest.

In general, considering all the facts, the dis-inhibition interpretation seems to be the most plausible. A number of experiments might be performed, however, to confirm this explanation. The experiments would be designed to investigate the CS and the baseline inhibition parameters. Presumably, if baseline response rate were depressed by drugs, experimental extinction, or other procedures, there would still exist a tendency to increase response rate during the presence of an extraneous stimulus, whether it was a tone, flashing

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hibitory phenomena, including dis-inhibition. In general, American psychologists, concentrating on instrumental rather than classical conditioning, have not systematically duplicated the phenomenon.

light or the presentation of visual forms. If the extraneous stimulus acted as the CS in a CER program, one would expect retardation in the acquisition of conditioned suppression, to the degree that baseline response rate had been depressed, regardless of how the baseline inhibition had been brought about. In any event, the dis-inhibition interpretation would be on firmer footing if it were demonstrated that the behavioral effect we encountered was not specific to the white noise CS and the free shock technique.

An Apparent Sensitization Effect

Originally, one of the reasons for choosing the sequential patterning of shock intensities design of Experiment I, was the hope that some of the patterns might lead to sensitization, or an increased emotional responsiveness to electric shock. Such, of course, did not prove to be the case. However, there did appear during the course of the experiment some evidence for a sensitization effect. Response counts were made during the free shock phase of the experiment for the 3-minute intervals which later became the pre-CS, CS, and post-CS (post-shock) periods of CER training. During habituation days, post-shock suppression ratios could be computed in a manner analogous to CS suppression ratios during CER training. These ratios, which contrast response rate immediately following free shock to rate preceding shock, quantify the disruptive effect of free shock on bar pressing. The summary data for post-shock ratios computed for all groups for Habituation Day 2 and for the first trial on that day are presented in Table VIII. The comparison of interest is that between the Ascending and Irregular groups. These groups each received .25 ma. free shock on Day H-2. How-

TABLE VIII

Post-Shock Suppression Ratios on Habituation Day 2

		Ascending	Descending	Irregular	Control
TRIAL 1 (of Day H-2)	Mean	.51	.17	.33	.48
	Median	.50	.08	.39	.49
	Range	.45-.58	.00-.54	.00-.53	.33-.59
DAY H-2	Mean	.49	.37	.42	.48
	Median	.49	.33	.43	.49
	Range	.45-.55	.00-1.00	.34-.50	.42-.52

ever, on the preceding day, the Ascending group had received .25 ma. shock, while the Irregular group had received 1.00 ma. shock.[11] Thus, both groups, on the critical day, H-2, received the same weak shock. However, the Irregular group had had prior experience with relatively strong shock, while the Ascending group had had prior experience with weak shock.

Most conspicuously on Trial 1, but also over the entire second habituation day, the Irregular group showed more post-shock suppression

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[11] The Descending group received 4 ma. shock on Days H-1 and H-2, while the Control group received no shock. Thus the ratios for the Control group are "dummy" ratios.

than the Ascending group ($U = 8.0$, $p < .002$ and $U = 10.5$, $p < .02$, respectively). In fact, on Habituation Day 2, the Ascending group did not differ from the Control group (which did not receive shock), either on Trial 1 ($U = 38.5$, $p > .30$) or over the entire day ($U = 48.5$, $p > .80$).[12] It seems clear, then, that the same objectively weak shock may disrupt ongoing operant behavior, if it has been preceded by relatively intense shock, but not if it has been preceded by comparably weak shock. This can reasonably be referred to as a "sensitization" effect of prior experience with shock.

There is some reason to suspect that the crucial variable which produced this sensitization effect was the limited prior experience with intense shock. This would agree with the reports by Kellogg (25) and by MacDonald (35) of a similar heightened reaction that appeared after the first few exposures to noxious stimulation (electric shock or air puffs).[13] Like the phenomenon reported by Kellogg and by MacDonald, it appears that

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[12] It is interesting to note that in the Annau and Kamin study (3), .25 ma. shock never led to the acquisition of suppression during CER training, suggesting, as does the above post-shock analysis, that this level of shock is not very emotionally arousing.

[13] The clinical orientation to the sensitization phenomenon also seems to accept that limited exposure is critical. "Traumatization" is, almost by definition, an <u>isolated</u> experience that results in psychic injury.

the effect is short-lived (compare Trial 1 and the whole day) although it can span a relatively long time interval (at least 24 hours) between initial exposure to shock and testing for the effect.

To study sensitization further, it might be rewarding to look at three main variables: number of initial exposures to noxious stimulation, strength of the stimulation, and length of time between training and testing for the sensitized reaction. In terms of the number of exposures, it is quite possible that some number less than four (the number in our demonstration) would produce the maximal effect. Presumably, a higher shock level than the 1.00 ma. which we employed would also give more dramatic results. In regard to the last area, the effect (if any) of different time intervals remains largely unknown, although a sensitization effect may be demonstrated minutes (25, 35) or hours (our experiment) after exposure to noxious stimulation.

SUMMARY

Forty male hooded rats were randomly divided into four groups of 10 subjects each. Following preliminary bar pressing training, the three experimental groups were exposed to four "free" or unsignalled electric shocks during each ensuing two hour bar pressing session. This was continued for 10 daily sessions, during which time the control animals engaged in undisturbed bar pressing. All the experimental groups, by the conclusion of the free shock segment of the experiment, had had two days' experience with each of the five different shock intensities employed. The sequential pattern of the free shock intensities, however, was different for each of the three groups. Following the free shock days, all animals were given CER training for 10 days, with a three minute warning signal preceding a standard 1.0 ma. shock.

In agreement with earlier observations, it was found that subjects which had prior experience with shock subsequently were slow to acquire suppression during CER training. In contrast to earlier interpretations, however, this did not appear to be a case of adaptation or habituation to electric shock, but rather, the result of opposing reaction tendencies elicited by the CS. To the degree that baseline response rate was inhibited by free shock, there was a tendency to respond at a higher rate during the presence of the CS than during its absence.

The CS acted not only as an aversive warning signal (tending to decrease response rate), but also as a dis-inhibitor, to temporarily raise the rate of responding above its depressed level.

In two follow-up experiments it was found, that, if there was the opportunity to recover baseline response rate after free shock experience, then there was no significant tendency to increase response rate during the presence of the CS. When given CER training, these subjects acquired suppression normally. On the other hand, subjects not given baseline recovery training did show a retardation in the acquisition of suppression.

During the early free shock days of Experiment I, it was observed that weak shock significantly disrupted operant responding in the group which had previously had experience with relatively intense shock. The same weak shock did not affect bar pressing rate, however, when it had been proceeded by weak shock. Therefore, although there was no evidence that repeated exposure to noxious stimulation would lead to a habituation effect, there was some suggestion that the obverse - a sensitization effect - might occur after limited experience with intense electric shock.

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APPENDICES

APPENDIX A

RAW DATA FOR EXPERIMENT I

SUPPRESSION RATIOS FOR EACH RAT ON CER DAYS 1-10

	Subjects	P	CER Days 1	2	3	4	5	6	7	8	9	10
Ascending Shock Pattern	1	.54	.62	.53	.48	.22	.00	.23	.15	.39	.36	.02
	2	.50	.85	.88	.73	1.00	1.00	1.00	.68	.69	.69	.36
	3	.66	.60	.60	.65	.68	.27	.41	.36	.28	.15	.29
	4	.54	..64	.49	.44	.34	.29	.15	.07	.10	.12	.10
	5	.34	1.00	1.00	1.00	*	*	*	*	*	*	*
	6	.53	1.00	1.00	1.00	*	*	*	*	*	*	*
	7	.46	.65	.3[illegible]	.36	.00	.00	.00	.00	.00	.06	.01
	8	.54	.60	.57	.44	.18	.03	.12	.20	.04	.13	.09
	9	.52	.85	1.00	1.00	1.00	*	*	*	*	.54	.43
	10	.52	.93	.59	.36	.23	.19	.08	.15	.05	.03	.03
Descending Shock Pattern	1	.40	.62	.40	.09	.10	.02	.16	.00	.00	.00	.00
	2	.47	.62	.39	.31	.25	.18	.13	.23	.05	.06	.06
	3	.49	.54	.48	.31	.12	.02	.00	.01	.01	.01	.00
	4	.49	.58	.46	.39	.23	.18	.11	.07	.06	.01	.08
	5	.34	.51	.34	.02	.00	.00	.01	.02	.04	.10	.04
	6	.54	1.00	*	*	*	.15	.14	.08	.07	.11	.04
	7	.48	.49	.40	.05	.00	.01	.00	.01	.01	.02	.02
	8	.58	.47	.48	.14	.05	.00	.00	.01	.01	.00	.00
	9	.60	.64	.47	.49	.20	.43	.18	.23	.05	.07	.16
	10	.49	.51	.31	.03	.00	.00	.10	.00	.00	.00	.00
Irregular Shock Pattern	1	.57	.82	.92	.87	1.00	1.00	*	1.00	..86	.50	.34
	2	.44	1.00	*	*	*	*	*	*	*	*	*
	3	.51	.67	.47	.20	.03	.00	.02	.01	.03	.05	.02
	4	.49	.96	1.00	.60	1.00	1.00	.75	.50	.71	.16	.19
	5	.48	1.00	1.00	1.00	.50	.43	.00	.15	.06	.09	.10
	6	.52	.77	.57	.18	.04	.03	.02	.03	.04	.00	.00
	7	.55	.89	.74	.42	.08	.06	.03	.04	.01	.00	.11
	8	.55	.35	.58	.61	.54	.55	.32	.36	.29	.50	.33
	9	.63	1.00	*	1.00	*	1.00	*	*	.00	*	*
	10	.54	.57	.37	.26	.05	.09	.07	.01	.00	.02	.00
Controls	1	.47	.42	00	00	00	02	00	00	00	00	00
	2	.50	49	01	00	00	01	00	00	00	01	00
	3	.55	47	000	00	00	02	00	02	02	02	00
	4	.46	47	05	01	04	01	03	02	02	02	02
	5	.49	75	29	00	00	00	00	00	00	00	00
	6	.43	34	02	00	00	00	000	00	00	12	01
	7	.53	50	01	00	00	00	00	00	00	00	00
	8	.51	42	02	01	04	01	01	03	02	03	01
	9	.57	36	00	00	00	00	00	01	02	03	01
	10	.51	50	07	00	00	00	00	00	00	02	01

* Ratio indeterminate as no responses made during either pre-CS or CS period

NUMBER OF RESPONSES MADE DURING DAILY 12-MINUTE CUMULATED PRE-CS PERIOD

			Habituation Days									
	Subjects	P	1	2	3	4	5	6	7	8	9	10
Ascending Shock Pattern	1	169	193	201	201	197	187	184	135	87	79	59
	2	227	81	146	141	139	82	82	11	3	25	21
	3	37	72	83	92	99	99	73	34	17	18	19
	4	124	135	150	173	183	133	160	79	75	65	69
	5	142	192	172	108	160	85	76	44	13	35	16
	6	109	91	111	180	284	137	79	48	18	6	2
	7	186	119	95	176	146	111	116	59	46	37	12
	8	300	287	261	291	411	429	363	298	153	126	94
	9	134	103	83	102	78	65	42	48	18	18	10
	10	242	275	229	274	369	220	192	197	106	63	26
Descending Shock Pattern	1	235	78	11	2	14	4	0	0	136	131	153
	2	72	43	0	4	7	7	18	0	9	26	29
	3	159	108	111	31	11	13	30	58	67	99	126
	4	339	292	44	14	14	3	12	16	51	53	63
	5	121	62	0	0	0	0	0	0	41	131	130
	6	165	143	67	1	0	0	0	0	0	0	0
	7	48	28	16	0	9	5	21	28	37	61	77
	8	424	395	163	75	0	0	8	44	78	197	311
	9	55	29	15	0	0	10	22	33	45	36	64
	10	295	193	71	6	10	3	14	23	44	73	118
Irregular Shock Pattern	1	63	66	54	45	15	10	6	10	6	15	12
	2	267	82	117	149	87	31	33	22	14	6	4
	3	361	230	341	206	70	16	5	2	15	16	43
	4	202	151	112	64	15	0	12	15	50	23	22
	5	127	119	121	166	45	8	49	54	28	6	2
	6	161	164	111	121	102	66	46	37	50	72	50
	7	117	105	95	98	14	0	2	0	17	6	0
	8	109	120	97	98	94	93	82	66	93	76	64
	9	85	112	89	60	14	21	4	0	7	29	6
	10	102	178	151	194	[illegible]	9	32	63	56	127	58
Controls	1	99	132	108	126	116	112	125	[illegible]	138	112	110
	2	175	152	130	170	178	183	197	159	158	161	153
	3	138	138	167	141	213	189	161	131	145	154	167
	4	366	224	259	326	[illegible]	290	348	179	262	241	216
	5	259	[illegible]	156	213	328	201	138	70	68	42	51
	6	347	294	296	355	252	229	110	111	153	103	77
	7	135	132	86	132	149	100	114	137	124	151	118
	8	236	248	287	229	203	242	306	312	283	319	350
	9	118	119	110	202	222	276	159	207	173	240	177
	10	399	500	419	579	406	607	510	504	533	474	390

NUMBER OF RESPONSES MADE DURING DAILY 12-MINUTE CUMULATED PRE-CS PERIOD (Continued)

		CER Days									
	Subjects	1	2	3	4	5	6	7	8	9	10
Ascending Shock Pattern	1	52	60	52	31	33	41	50	43	48	53
	2	9	3	8	0	0	0	6	4	4	23
	3	21	16	19	6	16	13	18	18	33	20
	4	13	39	45	42	41	57	66	63	61	52
	5	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0
	7	24	32	21	30	45	49	49	40	67	74
	8	97	64	55	73	28	61	88	52	102	127
	9	4	0	0	0	0	0	0	0	5	15
	10	4	9	35	52	63	54	111	160	170	181
Descending Shock Pattern	1	147	106	97	45	51	48	80	126	92	118
	2	25	27	27	30	9	20	34	38	45	61
	3	151	151	137	108	145	138	153	122	145	44
	4	68	79	56	54	88	47	69	66	95	69
	5	132	136	110	103	87	81	117	99	117	102
	6	0	0	0	0	11	6	90	96	94	92
	7	57	71	57	63	67	58	69	71	55	50
	8	473	439	410	353	388	351	475	328	439	269
	9	76	115	65	55	36	40	23	36	28	31
	10	127	72	70	65	78	78	87	68	95	69
Irregular Shock Pattern	1	2	1	1	0	0	0	0	1	1	23
	2	0	0	0	0	0	0	0	0	0	0
	3	59	59	35	36	50	58	66	63	76	70
	4	1	0	2	0	0	4	3	2	32	87
	5	0	0	0	1	4	1	11	46	20	55
	6	21	41	37	42	33	40	64	44	72	60
	7	1	6	23	35	47	62	79	64	57	75
	8	77	61	33	42	44	41	41	43	24	32
	9	0	0	0	0	0	0	0	2	2	0
	10	52	26	44	38	70	95	137	149	163	106
Controls	1	80	67	34	34	43	41	52	49	39	38
	2	128	144	109	102	84	72	81	88	85	96
	3	109	73	24	94	107	116	142	113	110	78
	4	226	370	271	170	155	156	253	225	336	156
	5	13	5	12	8	7	32	40	25	22	6
	6	84	94	90	104	122	69	86	88	89	89
	7	106	125	53	31	75	52	56	69	73	76
	8	404	388	465	347	385	432	478	422	606	485
	9	234	150	73	53	44	46	76	63	72	67
	10	413	303	294	355	296	288	511	283	425	347

APPENDIX B

RAW DATA FOR EXPERIMENT II

SUPPRESSION RATIOS FOR EACH RAT ON CER DAYS 1-8

		CER Days								
	Subjects	P	1	2	3	4	5	6	7	8
Recovery Group	1	.48	.41	.06	.00	.00	.06	.00	.00	.00
	2	.56	.49	.13	.00	.00	.00	.01	.00	.00
	3	.51	.58	.45	.39	.23	.28	.14	.03	.08
	4	.47	.45	.04	1.00	.00	.02	.24	.03	.00
	5	.43	.45	.03	.00	.00	.00	.00	.00	.00
	6	.41	.33	.12	.16	.12	.14	.12	.18	.11
	7	.39	.49	.24	.00	.00	.01	.00	.00	.00
	8	.42	.48	.22	.18	.13	.07	.02	.03	.01
	9	.50	.44	.00	.00	.00	.00	.00	.00	.00
	10	.48	.47	.40	.01	.00	.00	.00	.02	.04
No Recovery Group	1	.46	.65	.50	1.00	*	.04	.04	.00	.02
	2	.43	.73	*	*	*	*	.00	.00	.00
	3	.53	.57	.00	.00	.18	.10	.13	.00	.00
	4	.49	.61	*	*	*	*	.05	.00	.11
	5	.49	.50	.53	.50	.47	.50	.06	.00	.00
	6	.46	.67	.00	.00	.20	.10	.21	.11	.08
	7	.52	1.00	*	*	*	*	*	*	*
	8	.51	.77	.60	.69	.79	.50	.40	.22	.20
	9	.55	.54	.58	.32	.01	.04	.00	.01	.17
	10	.50	.09	*	.00	.12	.01	.01	.00	.01

* Ratio indeterminate as no responses made during either pre-CS or CS period.

NUMBER OF RESPONSES MADE DURING DAILY 12-MINUTE CUMULATED PRE-CER PERIOD

	Subjects	P	Habituation Days 1	2	3	CER Days 1	2	3	4	5	6	7	8
Recovery Group	1	129	113	97	32	129	60	69	78	117	128	89	105
	2	39	26	137	42	90	59	64	133	229	167	225	403
	3	78	53	37	0	46	46	34	69	53	38	28	45
	4	251	255	279	86	166	49	0	37	54	61	70	98
	5	177	280	248	32	241	169	161	173	248	261	251	429
	6	310	350	106	1	330	226	201	121	111	120	93	162
	7	190	142	195	18	69	44	49	70	74	96	99	70
	8	456	277	122	5	118	46	40	47	38	90	84	88
	9	187	257	279	17	632	477	446	224	79	25	31	80
	10	114	126	91	108	179	135	96	120	169	122	83	98
No Recovery Group	1	92	87	59	1	33	3	0	0	53	46	51	58
	2	64	144	22	21	6	0	0	0	0	3	15	13
	3	50	75	75	37	32	3	4	50	45	59	46	58
	4	90	141	85	39	21	0	0	0	0	17	67	77
	5	141	138	205	148	167	139	148	146	111	116	105	118
	6	161	161	53	3	15	1	7	4	68	80	145	189
	7	114	38	2	0	0	0	0	0	0	0	0	0
	8	51	124	90	20	23	23	7	8	32	81	56	87
	9	39	58	69	60	74	47	52	91	52	44	67	62
	10	172	315	324	198	32	0	12	65	119	142	239	316

APPENDIX C

RAW DATA FOR EXPERIMENT III

SUPPRESSION RATIOS FOR EACH RAT ON CS DAYS 1-8

		CS DAYS								
	Subjects	P	1	2	3	4	5	6	7	8
Recovery Group	1	.51	.51	.59	.54	.52	.55	.52	.49	.52
	2	.49	.54	.52	.56	.58	.58	.51	.49	.49
	3	.53	.40	.39	.42	.57	.49	.47	.38	.31
	4	.55	.67	.80	.72	.74	.70	.62	.61	.57
	5	.49	.61	.61	.54	.54	.60	.41	.52	.49
	6	.56	.57	.43	.55	.65	.60	.47	.57	.53
	7	.48	.61	.56	.61	.41	.52	.51	.54	.51
	8	.46	.54	.48	.48	.48	.50	.50	.43	.40
	9	.46	.48	.32	.37	.42	.44	.45	.52	.41
	10	.51	.58	.56	.57	.56	.51	.58	.53	.49
No Recovery Group	1	.45	.57	.61	.53	.55	.51	.47	.48	.48
	2	.51	.66	.81	.49	.53	.50	.52	.49	.49
	3	.42	.73	.64	.59	.62	.58	.59	.54	.49
	4	.47	.75	.72	.79	.87	.64	.54	.60	.60
	5	.42	.86	.77	.63	.70	.60	.54	.63	.57
	6	.45	.59	.[illegible]5	.54	.48	.53	.57	.32	.52
	7	.47	.66	.81	.72	.65	.65	.65	.60	.50
	8	.49	.68	.59	.56	.53	.58	.53	.50	.52
	9	.52	.58	.50	.52	.47	.54	.47	.50	.47

NUMBER OF RESPONSES MADE DURING DAILY 12-MINUTE CUMULATED PRE-CS PERIOD

			Habituation Days			CS Days							
	Subjects	P	1	2	3	1	2	3	4	5	6	7	8
Recovery Group	1	168	230	139	0	180	132	175	158	119	138	166	168
	2	167	116	52	0	95	112	107	84	83	98	110	101
	3	112	197	105	3	479	629	555	204	412	353	457	288
	4	21	30	18	5	12	10	23	23	32	38	45	48
	5	87	55	40	2	78	78	104	95	127	214	161	126
	6	112	158	63	13	96	109	72	57	68	107	66	75
	7	34	23	52	34	24	18	13	38	39	39	32	41
	8	189	132	165	33	125	122	93	105	116	101	85	107
	9	206	124	71	12	90	86	129	92	100	104	100	144
	10	84	88	77	36	61	56	64	64	79	51	86	79
No Recovery Group	1	97	67	66	0	58	52	67	68	86	131	156	127
	2	576	459	69	0	246	49	637	788	783	665	875	753
	3	125	66	8	0	28	40	67	60	83	98	158	219
	4	53	60	48	0	34	33	21	18	56	65	88	90
	5	231	123	72	22	29	68	144	112	208	307	176	285
	6	46	78	11	14	33	65	61	61	69	65	61	76
	7	149	146	64	19	59	20	32	42	83	73	70	73
	8	393	290	147	67	101	149	259	323	329	407	341	425
	9	254	325	65	0	141	250	223	250	268	289	298	260