THE EFFECTS OF US INTENSITY ON THE CONDITIONED EMOTIONAL RESPONSE

THE EFFECTS OF THE INTENSITY OF THE UNCONDITIONED STIMULUS ON THE ACQUISITION AND EXTINCTION OF THE CONDITIONED EMOTIONAL RESPONSE

By

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A Thesis

Submitted to the Faculty of Graduate Studies

in Partial Fulfilment of the Requirements

for the Degree

Master of Arts

McMaster University

May 1960

MASTER OF ARTS (1960) McMASTER UNIVERSITY
(Psychology)

TITLE: The Effects of the Intensity of the Unconditioned Stimulus on the Acquisition and Extinction of the Conditioned Emotional Response

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NUMBER OF PAGES: 57, v.

SCOPE AND CONTENTS:

The effects of intensity of the unconditioned stimulus (US) on the acquisition and extinction of the conditioned emotional response (CER) in rats were investigated. The US intensities studied were 0.28, 0.49, 0.85, 1.55, and 2.91 ma. Both acquisition and extinction of the CER were found to be monotonic functions of US intensity, with the higher US intensities producing more rapid acquisition and more resistance to extinction. The lowest shock intensity failed to produce suppression. The 0.49 ma. subjects typically showed a partial recovery of normal operant behavior after development of a fairly profound CER. The results were interpreted as consistent with the supposition that the CER is acquired in accordance with Pavlovian laws of classical conditioning.

ACKNOWLEDGEMENT

The author wishes to express his gratitude and thanks to Dr. L. J. Kamin whose countless hours of friendly guidance made this study possible.

Thanks are also due to J. Bartlett, C. Brimer, J. Hay, T. Ryan and J. Walker for devoting many hours to the execution of the experiment.

CONTENTS

INTRODUCTION AND HISTORY

The problem of anxiety has long been familiar to the clinician, but its history in the psychological laboratory is fairly recent.

In 1941 Estes and Skinner (18) in a paper entitled "Some quantitative properties of anxiety", ascribed two defining characteristics to this concept: 1) it is an emotional state somewhat resembling fear, 2) the disturbing stimulus which is principally responsible does not precede or accompany the state but is "anticipated" in the future.

The more important of the two aspects of anxiety seems to be the concept of anticipation, and the way in which a stimulus can acquire this property of eliciting fearlike anticipation has been conceptualized by Schoenfeld in a mechanistic way, by the following paradigm (37):

$$S_1 \longrightarrow S_2$$

where S_1 is initially a neutral stimulus or a stimulus which the organism does not approach or recede from, S_2 any noxious stimulus which the organism tries to terminate or avoid, and $\longrightarrow$ indicates the passage of time. After repeated paired presentations S_1 becomes a conditioned stimulus in Pavlovian fashion, capable of eliciting some of the respondents, largely autonomic, to S_2. That is, some of the responses made originally to the unconditioned stimulus are now elicited by the conditioned stimulus. While these respondents, which include such effects as heart rate changes, defecation, etc., could be directly measured, one can instead measure anxiety, by its disruptive effects on ongoing behavior. This latter technique is likely to produce more easily quantifiable results.

The experiment devised by Estes and Skinner (18) incorporated this reasoning in the following way. This experiment, the first in a lengthy and continuing line of research, will be described in some detail.

Twenty-four male albino rats were conditioned to bar press for a food reward in a Skinner box on a fixed interval schedule of 4 minutes.[1] The rats were run one hour daily for two weeks in order to establish stable response rates. Following this training, emotional conditioning took place. The noxious stimulus to be anticipated (the unconditioned stimulus or US) was an electric shock delivered through the grids of the

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[1] Ferster and Skinner (19) define a fixed interval schedule as one in which the first response of an organism after a designated interval of time is followed by a reinforcing stimulus. A fixed interval schedule normally generates a stable state in which a pause follows each reinforcement, after which the rate of responding accelerates to a terminal (usually moderate) value at the time of reinforcement.

Skinner box to the feet of the rat, and the neutral stimulus, (or conditioned stimulus CS), preceding the shock was a tone which was produced by phones attached to a 60 cycle AC transformer.[2] The rats were run under a high hunger drive for one hour in the box during which the tone and shock - CS-US combination was presented twice. The tone lasted for 3 minutes and was terminated by the shock. The first presentation of the CS-US showed that the mean periodic rate of bar pressing of the rats was not disturbed. The procedure above was followed for six days after which the tone was lengthened to 5 minutes and only one CS-US trial (emotional conditioning) was given a day for the next two days. The strength of the emotional conditioning or the CER (conditioned emotional response) was calculated as the ratio of the number of responses made by the rat during the CS to the average number of responses made during the same fraction of the hour in a control experiment when no emotional conditioning took place. According to Estes and Skinner, the result of this procedure was the conditioning of a state of anxiety to the tone, which was manifested by a decrease and later almost complete cessation of bar pressing during the presentation of the tone. A number of other behavioral effects were observed by the authors:

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[2]The CS and US are terms adopted from Pavlov and classical conditioning where US stands for a stimulus which elicits a reflex in the animal and is preceded by a neutral stimulus CS. After repeated CS-US pairings the CS alone is capable of eliciting the reflex previously only elicited by the US.

a decrease in the rate of bar pressing occurred after the delivery of shock, creating a slight depression in the cumulative record.[3]

Following this depression, which never completely disappeared, a compensatory increase in rate of responding was found until the rat's cumulative curve had reached the extrapolation of the curve preceding shock.

The effects of the conditioning on a low hunger drive group were not observable because of the low response rates associated with low drive, but when the drive level was raised by greater food deprivation producing also higher response rates, it became clear that these rats had learned to suppress during the CS, as well as the high initial drive group.

Withholding the food reinforcement produced an extinction curve for bar pressing as expected, but the anxiety was not extinguished.

Estes and Skinner tried extinguishing of the CER by turning the tone on at the usual time (27 minutes after the animal had been put in the Skinner box) and leaving it on for the rest of the experimental hour. This produced fairly rapid extinction of the CER, the mean period required for

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[3]The cumulative record consists of recording additively the responses of a rat as a function of the passing of time. A pen steps up one fixed step on a paper which is moving at a steady speed at 90° to the direction which the pen moves. The result is usually a line diagonally across the paper made up of small steps of responses, but if the rat does not respond a straight line parallel to the direction of the paper's motion will be drawn.

recovery of bar pressing was found to be 8.6 minutes and 9.1 minutes with a somewhat lower hunger drive group. On the following day, however, the rats on the presentation of the CS, showed spontaneous recovery of the CER.

Although this experiment pointed to an excellent technique for quantitatively measuring anxiety, it seems to have been forgotten for 10 years and when it was reintroduced, it was to be used primarily as a tool to investigate problems with a clinical reference.

The purpose of the present study was to examine the effects of different shock intensities on the acquisition and extinction of the CER. There are two classes of studies on the CER, one class uses the CER as was mentioned above, merely as a measuring instrument, and the second class under which the present research falls, explores the parameters of the CER phenomenon itself. In the following pages, a review of previous studies of both types, will be undertaken. Those studies employing the CER as a technique will be considered first.

In 1951 Hunt and Brady (22) published a paper on the effects of electro convulsive shock - (ECS) on the CER. Since ECS was used in the clinics to treat patients with acute anxiety and since the CER which was presumably due to anxiety was present in the experimental situation, a logical method seemed available to study a clinically relevant problem in the laboratory. There were, however, a number of methodological difficulties to be overcome, and they were handled in different ways at different laboratories. The immediately following section will be devoted to a description of the different techniques used to establish a CER. While a number of specific studies will be cited, their purposes and results will be left for a subsequent section.

Hunt and Brady published a whole series of papers on the effects of ECS on the CER and the basic methodology employed, with some variations, followed the procedure outlined below which, as will be seen, is quite different from the original Estes and Skinner procedure.

Ninety day old male albino rats were trained to bar press in a Skinner box for a water reward during daily 15 minute runs. The animals had free access to food but were restricted to 30 minutes of water per day, 15 minutes after the daily session. After they learned to bar press, the animals were put on a variable interval (VI) reinforcement schedule ranging from 30 seconds to 4 minutes with a mean at 1 minute.[4]

The emotional conditioning trials took place not in a Skinner box, but in a specially constructed "grill box" slightly larger than the Skinner box, with a grill floor, no

[4] A variable interval schedule is one in which the interval between reinforcements is varied in a random or near random order.

bar for reinforcements and no water cup. An earphone was attached to transmit the CS and a transparent wall permitted observation. This special grill box was introduced by Hunt and Brady in order to cut down a generalized fear reaction to the Skinner box, due to the shock, which might result in the rat "freezing" or refusing to bar press at all. The reason for this precaution seems also due to the fact that the rats were placed in the training boxes for only 15 minutes per day and this would not give them sufficient time to recover from generalized fear of the Skinner box.

On each day there were two emotional conditioning trials in a 15 minute session and also one bar pressing run of the same duration. The 2 experimental situations were handled by different persons, took place in different rooms and were separated by at least 6 hours. The CS was a clicking noise of 3 minute duration (16 times per second) and did not disrupt the rate of bar pressing when presented alone. The US consisted of a make break 1.5 ma (150V, 60 cycle) AC electric shock delivered to the grill once just before and one just after CS termination.

Although the shock seemed to disrupt bar pressing when first delivered, recovery was rapid.

The emotional conditioning trials were as follows:

The animal was placed in the grill box and allowed to explore for 3 minutes, when the CS was introduced, terminated 3 minutes later by the US. Three minutes later another CS-US sequence took place and after three minutes more, the animal was removed from the box. After 3 days of emotional conditioning, the animals were tested with a reinforced presentation of the CS (CS-US) in the Skinner box while they were bar pressing. Hunt and Brady found that 8 conditioning trials were sufficient for most rats to produce the effect observed by Estes and Skinner. Eight or nine unreinforced presentations of the CS (CS no US) produced extinction of the CER.

The amount of suppression during the CS in some of the later studies in this series, was measured by the "inflection ratio" $\frac{B - A}{A}$ where A is the number of bar presses made during the 3 minutes before the CS and B is the number of bar presses made during the 3 minute CS. Complete cessation of bar pressing results in a -1.00 ratio and a 100% increase yields + 1.00. Unchanged output results in 0.00. However, in the earlier studies the emotional reaction was usually observed as an "all-or-none" stoppage of bar pressing during the CS, accompanied by defecation.

Kamin (28) in a later study on suppression, employed a different method of measuring the suppression ratio. Using the same denotations for the time interval, A for pre-CS 3 minutes, B for 3 minute CS, Kamin's ratio was $\frac{B}{A + B}$.

This ratio gives a 0.00 value with complete suppression, a value of 0.50 with no suppression and 1.00 with no responding in period A but responses being made during the CS. The ratio employed by Kamin, with an upper limit of 1.00, is particularly advantageous when the experimental procedures - as was the case in Kamin's study - sometimes produce accelerated responding during the CS. The relation between the two ratios is simply expressed.

If $Z_1 = \frac{B - A}{A}$ or Brady's ratio

and $Z_2 = \frac{B}{A + B}$ or Kamin's ratio

the relation between the two expressed in terms of Z is:

$$Z_2 = \frac{Z_1 + 1}{Z_1 + 2}$$

or in other words, Kamin's ratio equals Brady's ratio + one divided by Brady's ratio + 2.

The significant differences between Estes and Skinner's method and that of Hunt and Brady, as can be seen from the above outline, are in the lengths of time the animals were run daily, and the use of a grill box for emotional conditioning instead of the Skinner box. The second point is really a consequence of the first, or the short experimental session.

Hunt and Brady (9) also found that whether the rats were emotionally conditioned in a quiet semi-dark room or in a well lighted room filled with the noise of the conditioning apparatus, did not make any difference in the characteristics of the emotional response. Using a blinking light as a CS brought about the same results as a tone CS. (6)

Hunt and Brady abandoned the grill box and used a Skinner box in a 1952 study (25) both for the emotional conditioning and for testing the strength of the CER. The emotional conditioning trials took place on alternate days during 12 minute runs, with the CS introduced at the beginning of the fourth minute. On days between conditioning trials, the animals were allowed to bar press without the tone or shock being presented. This procedure was adopted for the same reasons as the grill box had been, namely to avoid generalized fear reactions to the Skinner box due to the shock received during the very short 12 minute daily run. In later experiments, the experimental session was reduced to 9 minutes, with the CS introduced at the beginning of the fourth minute, and ended by the US at the end of the seventh minute. Sometimes, due to the requirements of the experimental design, the 8 emotional conditioning trials were given over a period of 31 days interspersed with simple bar pressing runs in the Skinner box. The temporal distribution of the emotional conditioning trials did not effect the nature of the phenomenon.

In later studies, the experimental session extended to 2 hours and 8 emotional conditioning trials were given during a session (27). Using monkeys, Sidman (38) used 2, 6, 72 hour experimental sessions and sequences of 5 minute CS-on, followed by 5 minute CS-off. Termination of the CS was always, of course, coincident with delivery of the US. None of the different approaches seemed to affect the nature of the CER, though no study has been reported on the most effective temporal distribution of the CS-US sequences in a given experimental session, or on the most effective length of session.

Other investigators also adopted the technique, but each of these used his particular method of establishing the CER.

In 1951, Libby, (30) in a paper described the effect of number of CS-US pairings and of CS-US interval on the acquisition of the CER. The CS was a 10 w, 110 V light bulb raising the illumination of the training box, from 0.04 ft. candles to 0.85 ft. candles. The US was a somewhat less than 2 ma electric current delivered to the feet of the rat. The experimental session lasted for 45 minutes. Libby's procedure varied somewhat from Hunt and Brady's because the rats received the emotional conditioning trials first, and were trained to bar press only later. In the third phase of the experiment, the effect of the CS was tested on the bar pressing response. The emotional conditioning trials took place in the same experimental chamber, essentially a Skinner box, as the bar pressing and testing sessions.

The reversal of Hunt and Brady's procedure, by giving emotional conditioning first followed by bar pressing training, did not seem to affect the testability of the CER in any way, the suppression effect was observed in the bar pressing situation, even though it had been acquired after the emotional conditioning trials. A somewhat similar procedure was adopted by Geller, Sidman and Brady (20) for testing the hypothesis that ECS only affects the more recently acquired habits.

Mowrer, Solomon and Aiken (31, 32) used a version of the Estes and Skinner technique in two experiments designed to compare the adequacy of the contiguity vs. drive reduction theories of conditioned fear. The technique adopted by these authors was similar to the early Hunt and Brady studies in that a white box with no reinforcement bar was used for emotional conditioning and the testing of the CER. The CS was two electric lights blinking at 4 cycles per second for 3 seconds, and the US was 0.9 ma electric shock. The results were congruent with those of Hunt and Brady with their grill box- Skinner box combination. The rats were tested under a kind of "secondary punishment" schedule, which involved presenting the CS for 3 seconds every time the rat pressed the bar, for a period of twenty-five minutes. To the extent that response production of the CS inhibited bar pressing, the CS was regarded as having fear producing qualities. Since this type of test as a necessity is an extinction trial for the CER every time the rat presses the bar, it is not a very strong measure of the CER except on the early bar presses.

The previous section was devoted entirely to a review of the different methods used to establish the CER. Although all these studies were based on the original Estes and Skinner model, none of the investigators used exactly the same procedure and there were constant procedural changes even within the same laboratory. As will be seen in the next section, devoted to the results of the experiments outlined methodologically so far, most of these studies used the CER as "index" behavior on which different conditions thought to affect anxiety could be conveniently superimposed. Parametric studies of the CER have only recently begun, and studies on the functions of the US are especially lacking.

The early studies of Hunt and Brady are all concerned with the effects of ECS on the CER. In their first paper (2) the effects of a series of 21 ECS treatments over a period of 7 days, following emotional conditioning were observed. The rats on a retest after ECS showed none of the usual signs of anxiety such as defecation etc., to the CS, while a control group retained the CER completely. A control study (9) which established the CER only in the grill box produced the same results.

ECS treatments given immediately after emotional conditioning, eliminated the CER when it had been acquired to a blinking light CS, just as effectively as when a tone was used (10).

Testing the permanency of the effectiveness of the ECS treatments, the rats were retested for the CER, 30, 60 and 90 days after the ECS treatments (3). It was found that after 30 days the CER reappeared, and the rats showed again the overt signs of anxiety to the CS. The treated rats, however, extinguished the CER when the CS was not followed by shock more rapidly than the control or untreated rats.

The next study (4) was designed to study the effectiveness of ECS if given 30, 60 and 90 days after the emotional conditioning trials. The results showed that after even only 30 days, ECS had no effect on the CER but again the treated animals extinguished faster.

When animals that had been given ECS treatments were run on 9 extinction trials immediately after the treatment, even though as yet they did not show signs of anxiety to the CS, the CER failed to reappear on retests 30, 60 and 90 days later (25). To Hunt and Brady, this indicated the importance of re-educative therapy after ECS in the clinical situation.

Giving ether anaesthesia which prevented convulsions, just prior to the ECS treatment, made this treatment entirely ineffective (26). This result seemed to point to the necessity of having convulsions rather than just the electricity passing through the rat's head as the effective attenuator of the CER. As a result of these studies, convulsions were induced audiogenically in the rats (14). The amount of interference with the retention of the CER proved to be directly related to the number of convulsions a rat had experienced. Convulsions induced by CS_2 (carbon disulfide) also proved effective in overcoming the CER (27).

Since the initial ECS treatments proved effective only temporarily, more treatments were tried prior to and after the 21 intensive treatments (15). Additional treatments given prior to the intensive ECS attenuated the CER while if given after the 21 treatments the CER did not reoccur 30 days later. The problem of best temporal spacing of the ECS treatments for most effective attenuation of the CER was studied also, and the optimal spacing was found to be from 1 per hour to 1 every 24 hours. At lesser or greater intervals the treatments were not as effective.

Following a paper by Duncan (17) which postulated that the effects of ECS were specific to the most recently learned habits, Geller, Sidman and Brady (20) investigated this possibility with regard to the past work of Hunt and Brady. Since the rats had learned to bar press first and received their emotional conditioning trials later, it was possible that the ECS would only effect the more recent CER and not bar pressing. In order to investigate this hypothesis, the previous procedure was reversed: The emotional conditioning trials were given first in Skinner boxes with inoperative levers, and 7 days of bar pressing were instituted only after 8 emotional conditioning trials per day for 2 days had taken place. The results were the same as before. The ECS treatments removed the CER just as effectively as before, while leaving the more recently learned bar pressing response unaffected.

Other factors beside ECS were also considered in relation to the CER. Brady and Nauta, (13), found that lesions in the septal forebrain region of the rat produced gross increases in emotional behavior as well as a reduction in the strength of the previously conditioned emotional response. Animals with extensive lesions in the habenular complex of the thalamus were found to extinguish the CER more rapidly than control animals, though there was no difference in the rate of acquisition of the response. The effects of drugs were also considered, specifically reserpine, morphine and amphetamine. Brady, (7), found in a study of the CER in monkeys that the administration of amphetamine in a dose of 2 mg per kg increased the total lever pressing output more than 100% during the 1 hour experimental session. This increase seems to have occurred completely in the no-CS periods and there was actually a decrease in the rate during the CS. Reserpine on the other hand, in a dose of 0.2 mg 1 kg had the opposite effects. The total rate decreased by about 50% but the rate during the CS went up, indicating some decrease in anxiety. Hill (21) following a series of studies in anxiety reduction in human subjects by the injection of morphine, adopted the Estes and Skinner method to study the effects of morphine in animals. Using a 4 minute tone as CS and 40-60 volts AC as US, Hill obtained the usual CER on rats bar pressing for food in a Skinner box. With the injection of morphine, the rats continued to bar press during the CS.

These studies complete the investigations concerned with the use of the CER as an exploratory clinical tool. Although all these studies have dealt with the CER, the knowledge they contributed of the parameters affecting this phenomenon, was incidental to the main point of interest: the reduction of anxiety. Some important points were still gained from these studies, namely that the CS can be varied qualitatively and in duration, considerably, without decreasing its effectiveness, and that the US can also vary considerably in strength though how this influences the CER has not yet become clear. In the next section, the more basic approach will be considered, the approach which was aimed at investigating the parameters that control and maintain the CER.

Libby (30) in 1951, investigated the effects of varying CS-US pairings on the acquisition of suppression, in two experiments. The CS was light from a 10 watt bulb and the US was 2.0 ma electric shock. In the first experiment CS-US intervals of 0, 1, 4, 7, 10, 20, 30 seconds were tested and were administered 10 times to the rats. On the test day the subjects were given: 1) 10 minutes of regular reinforcement in the Skinner box, in the dark, 2) 10 minutes of regular reinforcement in the presence of the CS, and 3) 25 minutes of reinforcement in the dark. The measure of suppression was the difference in bar pressing rate between the first 5 minutes in the dark and the first 5 minutes in the light as well as the full 10 minutes in dark and light. The results indicated a rapid rise in effectiveness of the light to the 7 - 10 second intervals in producing suppression. There was a loss in effectiveness beyond the 20 second interval. The weakness of this study was that the test for the strength of the CER presented the CS for 10 minutes which following the work of Estes and Skinner, must have led to rapid extinction of the CER and as a result, a not very effective measure of its strength.

In the second experiment, the groups of rats were given 0, 5, 10, 20, 40, and 80 pairings of the CS-US, using a 7 second CS, over a period of 10 days. The results indicated that on the first day, the depressant effect of the CS was at its maximum in the 40 pairing group, but on the second day, it shifted to the 20 pairing group. Libby explained the presence of such a maximal effect in terms of possible adaptation to the shock by the animal.

The positive reinforcement schedule of the experimental subjects is another important parameter of the CER. Unpublished data by Goy, cited in Brady and Hunt (11), indicate that the CER is more difficult to conditioned on a continuous and fixed ratio reinforcement[5] schedule than on variable interval. Extinction also takes place faster on these difficult schedules than on VI.

A more complete set of data on extinction was presented by Brady in 1955 (5). Twenty-four rats were conditioned to bar press and then received 8 emotional conditioning trials, 10 adaptation runs (bar pressing but no CS-US) and finally one more emotional conditioning trial. The animals were divided into 6 groups, each group on a different reinforcement schedule and were trained on this schedule for 60 days. On day 61 to 71 the animals were tested for the retention of the CER by unreinforced presentations of the CS. The animals on ratio schedules extinguished fastest, those on

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[5] In continuous reinforcement the animal receives one reinforcement for every bar press. On a fixed ratio every nth response is reinforced.

interval schedules slowest, and those on continuous reinforcement midway between the two groups. The recovery of the ratio group following the first bar press in the presence of the CS was much more abrupt than in the other groups. Invariably when a ratio schedule animal emitted a response it continued to respond at a pre-CS rate until the next reinforcement. The interval schedule animals showed no such tendency. This "locking together" of responses is characteristic of the ratio schedules in which the animal's own behavior becomes the discriminative occasion for reinforcement and each response generates a successor until reinforcement occurs. The continuous reinforcement group could be regarded as a special 1 to 1 ratio group and could be expected to acquire some of the responding characteristics of that group.

The characteristics of responding under these reinforcement schedules would explain the order in which the different groups extinguished. The results of this experiment shed further light on Goy's data since similar conditions presumably would prevail on acquisition with regard to the animal's tendency to respond.

An interesting recent development in the comparative study of the CER is its relationship to the intracranial self stimulation technique developed by Olds (34). Cats with electrodes implanted in the caudal nucleus can be trained to bar press at very high rates if reinforced by a brief electric current passing through the electrodes. Subsequently these animals are trained to lever press also for a water reward and the emotional conditioning is superimposed on this. The familiar suppression phenomenon soon appears in the bar pressing response with the presentation of the CS. When these animals are next switched back to bar press for the electrical self stimulation, the presentation of the CS has absolutely no effect on the cat's behavior (8). It has been found further impossible to superimpose the CER on cats bar pressing for electrical stimulation only.

Stein, Sidman and Brady (41) investigated the relation between duration of the CS and non CS periods in the maintenance of the CER. The results indicated that, roughly, in programs, where the CS duration was short in relation to the CS-off interval, good suppression was achieved, while in programs in which the CS-on interval was longer than the CS-off interval, there was poor suppression. The number of reinforcements obtained by rats under different programs proved to be about the same, or 90% of the maximum number obtainable during the experimental run. An estimate of the number of reinforcements that would have been lost if the animal had suppressed completely in the stimulus period correlated 0.92 with suppression scores, indicating that the degree of suppression decreases to the extent that suppression reduces opportunities for positive reinforcement. In other words, the relative duration of the two periods has significance only because it correlates highly with the reinforcements missed measure. These results are very interesting because they represent the conflict arising out of two opposing drives: hunger and anxiety. To complete a study like Stein, Sidman and Brady's, the relation between the relative strength of these drives and the degree of suppression would have to be investigated. Some unpublished data by Brady (6) did shed some light on this problem.

A recent study by Kamin (28) investigated the temporal relations between the CS and US without affecting the length of the inter-trial interval. This was achieved by a trace conditioning procedure where the CS-US interval remained always the same but the duration of the CS within this interval was varied. The duration of the CS was 0.5, 1, 2, 3 minutes using a 3 minute CS-US interval and 0.8 ma shock of 0.5 seconds duration as the US. Suppression was measured by a ratio $\frac{B}{A + B}$ where B is the number of responses made during the CS-US interval and A the number of responses made during 3 minutes preceding the CS. The results indicated that suppression did develop for all groups except the .5 minute group. The 3 minute group developed the most marked suppression while the 1 and 2 minute groups showed intermediate levels of the CER. Perhaps the most interesting finding was that long trace intervals, in the order of minutes, did lead to suppression.

Kamin compared his results to trace conditioning of the salivary reflex of dogs by Pavlov, where a three minute CS-US interval and a one minute CS was used successfully, whereas in American studies of the classical conditioning of such responses as the eyeblink, and finger flexion, a CS-US interval greater than a very few seconds is never employed.

Three recent studies by Sidman were concerned with superimposing the usual suppression training procedure on a base line rate of bar pressing produced by Sidman's avoidance training procedure. Sidman, Herrnstein and Conrad (39) first trained 3 rhesus monkeys in an avoidance situation in which the monkeys had to press a bar to avoid a 5 ma shock which otherwise came on every 20 seconds. A lever press by resetting a timer which after 20 seconds delivered shock, postponed shock for 20 seconds. This procedure produced a stable rate of bar pressing in the monkeys on which the usual emotional conditioning, 5 minute clicker inevitably followed by shock, was superimposed. Each CS-US interval was followed by 5 minutes of simple avoidance scheduling. The result was that the bar pressing rate of the subjects initially increased considerably both during the clicker-on and clicker-off periods. Subsequently a decline in baseline rate took place, but the rate during the clicker-on period remained higher than in the clicker-off period in apparent contradiction of suppression. The authors explained this in terms of the "free" shock presumably changing the previously established avoidance schedule from a fixed 20 second interval to a variable interval, where the shock would come before or after the 20 seconds were up. This, as in a positive or food reward situation, would result in a speed up in the rate of bar pressing.

In the next paper Herrnstein and Sidman (21) trained the monkeys first on suppression, second on avoidance and third on suppression again. The result was that during the first part of the experiment the monkeys learned to suppress bar pressing during the 5 minute CS but in the third part, responding during the CS occurred at a higher rate than in its absence.

In another part of this experiment, the authors tried to reverse this effect by using monkeys that had been used in the first study. The avoidance training was extinguished in these animals and they were put on a food reward bar pressing situation on which the CER was superimposed. The usual suppression took place in about 5 sessions with no speed up during the CS. In order to separate the two procedures, (avoidance and suppression) even more, Sidman (38) placed two levers in the experimental chamber. One lever was connected to a 4 minute VI circuit delivering orange juice (1 ml) and the other lever was used for an avoidance schedule. It was hoped that after both response rates had stabilized the introduction of the suppression schedule would lead to the acquisition of the CER on the juice reward bar, and at the same time, activation of the avoidance bar during the CS. The results showed that the CS facilitated both lever pressing responses, and that the avoidance schedule exerted control over both responses. The desired objective of separating the two responses and conditioning the animal to suppress on the juice reward lever, while speeding up on the avoidance lever during the CS, was only attained when the juice lever was put on a fixed ratio schedule which broke the control of the avoidance schedule over this lever.

Again the importance of the reinforcement schedule on which the CER is superimposed is revealed in this study. The avoidance schedule generated the dominating response, to avoid shock and the juice reward response became subordinated to this "more important" response. This only prevailed until the ratio schedule was instituted which as was mentioned earlier is characterized by a "locking together" of responses so that if one is emitted, the whole chain follows until reinforcement occurs. Only this type of response schedule was strong enough to overcome the domination of the avoidance schedule over both responses.

A recent study by Ray and Stein (36) studied generalization of conditioned suppression. Rats were emotionally conditioned to an 1800 cps CS and a 200 cps tone was also presented in the experimental period but never reinforced with shock. A discrimination was established with suppression to the 1800 cps tone and no reaction to the 200 cps stimulus. On a test for generalization of suppression to tones between these two values, it was found that the amount of responding to the test frequencies was an inverse function of their similarity to the 1800 cps CS. This, of course, is perfectly congruent with the many demonstrations of generalization in Pavlovian conditioning.

The last experiment in this section is an interesting comparison of the differential effects of suppression and punishment schedules on behavior. Hunt and Brady (24) using rats in a Skinner box conditioned one group as previously on the CER but the other group followed a different procedure. During the 3 minute CS, every time rats in this group pushed the bar, the shock generator was activated, punishing the rat for making the response during the CS. The rat was never punished in the CS-off period. It was found that the punishment group did not suppress as well as the CER group, and furthermore, did not show, except during the first few shocks, the signs of anxiety so characteristic of the CER group during the CS. The punishment group also extinguished the suppression much faster than the CER group.

This experiment suggests that suppression of behavior through direct punishment of the response may be accomplished with considerably less emotional "side-effects" than are observed when behavior is suppressed by punishment which is not response-contingent.

In order to clarify the findings of the research previously outlined, a brief summary of the results will be considered.

The original Estes and Skinner paper in 1941 (18) showed that a brief tone followed by shock introduced in a bar pressing situation, leads after a few repetitions of tone and shock, to suppression of bar pressing in the presence of the tone. Most subsequent studies on suppression from then on, were carried out by Hunt, Brady, Sidman and their followers, and the majority of these studies had to deal with the effects of ECS on suppression. Hunt and Brady found that a series of 21 ECS treatments attenuates the CER (23, 9). The effect of the treatments tends to disappear after 30 days (3) but can be made more permanent by giving the rats additional ECS treatments (15), or by running them on extinction trials immediately after treatment, (25). From further studies it became apparent that the ECS treatments were made effective in attenuating the suppression by the concurrent convulsion, and convulsions produced audiogenically or by CS_2 were just as effective (14, 27). Furthermore, the CER could be attenuated by reserpine and morphine (7, 22), while amphetamine had the opposite effect (7).

Incidental to the study of the effects of ECS, factors about the nature of the CER were revealed by these studies, as well as others dealing with the CER. The CS could be light or tone (6), and the length of the CS-US interval could vary from 3 seconds to 5 minutes (31, 32, 38). If a trace conditioning procedure is adopted the suppression tends to take place in the interval between CS termination and the onset of the US (28). The relation between degree of suppression and the length of the CS was found to be directly related to the reinforcements missed measure if the animal had suppressed during the CS. In other words, a long CS led to poor suppression, while a short CS led to good suppression. The suppression phenomenon was not restricted to rats, but was successfully imposed on cats as well as monkeys (38, 8).

Studies related to the reinforcement schedule on which the CER was superimposed, showed that the CER was more difficult to condition and extinguish on continuous and fixed ratio schedules than on variable interval (11, 5). Animals on an intracranial self reward schedule did not condition at all (8) and if they were trained previously on a food reward schedule to suppress, switching them to an intracranial schedule made the suppression disappear.

The opposite of suppression was obtained by Sidman and Herrnstein (39), when the CER was superimposed on a Sidman avoidance schedule. The author postulated that the speed up in responding during the CS came from a change of the previous FI schedule to a VI schedule by the unavoidable shock. Finally Ray and Stein (36) on a study of stimulus generalization in suppression found that the generalization was in accordance with Pavlovian laws, namely the subjects suppressed most to stimuli closest to the training stimulus and least to stimuli far removed from the training stimulus.

What conclusion can one draw about the CER from these studies?

Estes and Skinner looked at it as "anticipation of shock" with a state of anxiety being conditioned to the tone, the anxiety being manifested by a decrease in the rate of bar pressing during the CS. Schoenfeld (37) postulated that the CS elicits the respondents to the US which one would presume are in conflict with bar pressing. The CER accordingly can be considered as a classically conditioned state of anxiety in accordance with Pavlovian laws. The parametric studies considered so far, support this contention. Studies which have shown that the CS can last from 3 seconds to 5 minutes (31, 32, 38) and the trace conditioning procedure employed by Kamin (28) in which the animals conditioned to the interval between the CS termination and US onset are certainly consistent with a notion of classical conditioning. The last study considered above, on generalization, has already been mentioned as consistent with a Pavlovian conditioning interpretation.

With these considerations in mind, it would be expected that the effect of intensity of the US on acquisition of the CER would be analagous to the effects of US intensity on the acquisition of classical conditioning. The present study was undertaken to reveal the relationship between different levels of US intensity and the acquisition and extinction of the CER.

The last section of this survey of the literature concerning emotional conditioning shall deal with studies of the US, or specifically with studies of the effect of different US intensities on the acquisition of emotional behavior. In the case of the present study, electric shock was used as the US and thus most of the papers considered will deal with this specific though widely applied aversive stimulus.

The earliest study relevant to this area is the Yerkes and Dodson experiment of 1908 (43) in which these workers measured the number of trials it took their subjects (mice) to reach a criterion of learning a discrimination between different brightnesses of grey paper in the apparatus which later became the "Yerkes box". The subjects were rewarded with food for correct choices and punished with electric shock for wrong ones. The results indicated that with an easily discriminable situation, or with great difference between the two shades of grey, increasing shock made the mice learn faster. An optimum was reached, however, beyond which an increase in shock intensity produced slower rather than faster learning. These authors also found that when the difficulty of the discrimination was increased, the optimum was reached at lower shock intensities, from which they concluded: "An easily acquired habit - - - may be readily found under strong stimulation, whereas a difficult habit may be acquired readily only under relatively weak stimulation" (43). This finding later became known as the Yerkes-Dodson law. Plotted on a graph this law becomes a U shaped function and later studies confirmed this function for discrimination learning.

Turning specifically to the study of the US intensity in classical conditioning, the most detailed paper is by Passey in 1948 (35) who studied the influence of US intensity on the acquisition of a conditioned response. This study which serves as a standard reference, used the eyeblink response as the unconditioned reflex and a puff of air directed against the cornea as the US. The CS was a tone of 500 cps and lasted for 450 ms. Passey used 4 groups of 10 subjects and the intensities employed with different groups of subjects were the following: 7.5, 18, 44, 88 pounds per square inch. The results indicated that the rate of acquisition of the conditioned eyeblink reflex was a direct function of the log of US intensity. The size of the response was also a direct function of the US intensity. The results of Passey did not yield a U shaped curve. Whether this was due to the different nature of the learning situation or the small range of the US intensity did not become clear from the study.

The most thorough study of shock intensity came from yet another area, avoidance learning. Kimble (29) used rats as subjects in a study of shock intensity in avoidance learning. The experiment consisted of two parts. Part 1 was a measure of the rat's innate response to varying values of inescapable shock.

Responses were classified by observers as: 1) no response, 2) flinch-startle response when the rats' feet did not leave the electrified grid, 3) jump. The shock intensities starting at 0, were presented in ascending and descending steps of 0.1 ma to 0.9 ma maximum. The voltage was approximately 230 V. Two curves were obtained, one for flinch and one for jump responses. The flinch responses went to a maximum at 0.3 ma and then reached zero at 0.6 ma. The jump responses started from zero at 0.1 ma and reached over 90% of all responses at 0.9 ma.

In the second experiment on avoidance learning, the rats were put into a box with a movable wheel inserted in one end, and an electrifiable floor. The CS was a muffled buzzer which came on 5 seconds before the shock. If the rat turned the wheel during this 5 second interval, the shock did not come and the CS went off. If S did not respond, the shock and tone stayed on until response occurred. The CS came on after a 3 second period of no responding. If a response occurred during this period, the CS did not come on. The shock intensities were 0.2, 0.5, 1.0 and 2.0 ma and each intensity was assigned to a group of rats. Kimble found that the response latency decreased as a negatively accelerated function of shock intensity, or the stronger the shock was, the shorter the time for a response to occur. During extinction, no statistically significant residual effects remained. The function obtained by Kimble was not U shaped as the one by Yerkes, possibly because the shock intensities Kimble used did not reach a high enough level. Also, of course, Kimble's study is not directly concerned with discrimination learning. Avoidance learning, although it does involve instrumental responding to the CS, also involves classical emotional conditioning to the CS.

Brush (16) in 1957 also studied shock intensity in avoidance learning, using dogs this time. The apparatus was a modified Mowrer-Miller shuttle box consisting of two identical compartments separated by a barrier. A drop gate rested on this barrier. The CS consisted of raising the gate and simultaneously extinguishing a light above S's compartment. The US was electric shock delivered to the dog's feet through grids. The mean shock intensities used were 0.70, 2.06, 3.10, 4.82 and 5.59 ma at 550 V AC. The conditioning trials were as follows: After a five minute acclimation period the CS was presented, followed 10 seconds later, by the US. Both remained on until the animal had jumped the barrier in an escape response, or if it did not, the CS-US was turned off 2 minutes after the onset of the CS. If the dog jumped before shock came on the CS was terminated and the dog did not get shocked, the dog had made an avoidance. The gate was lowered after the dog had jumped. The dogs were given 10 trials a day until they had met the acquisition criterion of 10 straight avoidances in a day. The failure to learn criterion was failure to respond on 10 CS-US trials in one day and the extinction criterion was 10 consecutive failures to respond to the CS.

The findings indicated that the percentage of animals learning increased with higher shock intensities up to 4.82 ma, and decreased thereafter. The US intensity had negligible effect on the rate of acquisition, or on resistance to extinction of those dogs which did acquire the response, although the mean speed of response in extinction and the asymptotic speed of escape were found to be inverted U shaped functions of shock intensity. Several measures of acquisition and resistance to extinction suggested that U shaped relationship to shock intensity might exist here also, although these trends were not significant.

A study by Boren, Sidman and Herrnstein (2) employing the Sidman avoidance procedure described previously, also studied the effects of US, shock intensity on avoidance behavior. Briefly again, the rat was shocked every 20 seconds unless it pressed a bar, which by resetting a clock, delayed the shock for 20 seconds at every bar press. Altogether, 4 rats were used and these were initially trained to a shock intensity of 1.2 ma in 3 to 6 hour sessions. The shock intensity was then lowered step by step with nine sessions devoted to each step to stabilize bar pressing rates, until the rats did not maintain escape behavior (pressing the bar in order to terminate shock). The shock intensity was consequently increased in steps, above the original value until lethal or near lethal levels were reached. The order of presentation was 1.2, 0.5, 0.1, 1.7, 2.5, 2.6, 3.2, 3.7 ma. As the shock intensity increased, the escape latency and the number of shocks received by the rats decreased while the avoidance rate and the resistance to extinction increased. The largest changes in the functional relations occurred at the low to medium shock intensities and further increase in intensity added little to the effect. Boren, Sidman and Herrnstein point out that the relationship obtained was not a U shaped one as in some earlier studies but suggest that this might be due to the particular reinforcement schedule used in the experiment. Barry and Harrison (1) reinforcing escape behavior intermittantly obtained a maximum in the rate of responding but when the reinforcement was continuous the response rate function was negatively accelerated, and approached an asymptote.

The studies just cited have dealt with avoidance behavior in relation to shock intensity. Some studies have been published, relevant to the effects of shock intensity on the CER. These studies, however, do not give a detailed description of the phenomenon but only a sketchy picture of the relationship between US intensity and the CER.

Singh (40) using rats, investigated (among other things) the effects of only two very low shock intensities, 0.20 ma and 0.25 ma on the acquisition of suppression. The rats were trained to bar press for a water reward in a black Skinner box and received the emotional conditioning trials in a white Skinner box. A 3 minute flashing light was the CS followed by 2 seconds of shock or preceded by the shock. Singh found that fear conditioning was greatly increased by greater emotional reactivity (as independently measured by defecation in an open field test) and by stronger shock.

Females were more susceptible to this effect than males and whether the CS preceded or followed the US did not matter.

Since Singh used only two US intensities at the low extreme, his study sheds little light on the general nature of the effects of US intensity.

Nottermann and Marton (33) conducted an experiment on the study of stress using the CER as a stressful situation. A 3 minute light CS was followed by 1 second of shock which came on 1 second before the CS was terminated. Nottermann used 3 levels of shock intensity, 0.5, 1.3 and 3.0 ma. The measure of suppression was the ratio of bar presses during the CS, to the number of bar presses before and after CS. From the results of his study, Nottermann concluded that the light acquires depressant qualitites as a function of shock intensity. Nottermann's major interest was the physiological changes (such as increased size of adrenal glands) caused by what he called stress, the CER, and as a result his data provide no details on the relationship between US intensity and suppression.

In a paper presented to the Eastern Psychological Association in 1955, Brady and Susla (6) outlined an experiment in which 6 levels of shock intensity were used. This seems to be the most nearly adequate study of shock intensity with the CER but unfortunately it has never been published. Personal communication with Brady has established that the shock intensities employed were 0.25, 0.5, 0.75, 1.0, 1.50 and 5.0 ma.

Following 30 emotional conditioning trials the animals received 30 unreinforced presentations of the CS. By the third training trial all animals in Groups V and VI (1.5 and 5.0 ma) showed almost complete suppression to the CS. The animals in Groups I and II showed very little suppression even after 30 trials. Groups III and IV required 15 trials before they acquired complete suppression. On extinction there was a significant difference between Groups III and IV which extinguished partially by the fourth extinction trial, and Groups V and VI which remained suppressed until the tenth trial. No evidence of a U shaped function of shock intensity was revealed by this study. It should be noted, however, that the only measure employed by Brady in this study was the presence or absence of "virtually complete suppression". There is no information given on possible differences among groups in relative degrees of suppression. This information might be very difficult to obtain when the highest shock intensities are employed, since, using a very short daily session, it is quite likely that total freezing - no bar presses either before, during, or after the CS might have occurred.

Although drawn from different learning situations, the US intensity studies have yielded much valuable information. The discrimination study of Yerkes and Dodson (43) revealed learning as a U shaped function of shock intensity. Passey (35) using human subjects in a classical conditioning situation found the rate of conditioning to be a direct function of log US intensity instead of the U function obtained by Yerkes and Dodson. Avoidance learning, which may be regarded as containing elements of both classical conditioning and discrimination learning, was studied by several investigators in relation to US intensity. Kimble (29) using rats and measuring response latency as a function of US intensity, found this response to yield a negatively accelerating curve with increasing US intensity. Brush (16) using dogs in a Mowrer-Miller shuttle box did obtain inverted U shaped functions in measuring the mean speed of response in extinction and the asymptotic speed of escape. The percentage of animals learning the criterion also was a U shaped function of shock intensity. One reason why Kimble may have failed to obtain a U shaped function may be in the measure, response latency he used, or the range of US intensities may not have been extensive enough.

The study of Boren, Sidman and Herrnstein (2) using rats in a Sidman avoidance procedure, also failed to obtain the U function on the measure of escape latency, avoidance rate, and resistance to extinction. The authors suggest that this might be because of the particular reinforcement schedule employed in the experiment.

The first two studies mentioned on the CER do not present sufficient data to permit a valid comparison with the previous studies. Nottermann (33) concludes that the CS acquires depressant properties as a function of US intensity and Singh (40) using only two very low shock intensities, found differential rates of suppression, the more intense US leading to greater suppression.

The unpublished report of Brady and Susla (6) using 6 shock intensities indicates with very little detail, 3 levels of suppression. The lowest shock intensities yielded almost no suppression. The middle ranges required 15 trials before complete suppression resulted and the high US intensities groups suppressed almost immediately. On extinction, significant differences were found between these groups. The function obtained by this study was not U shaped.

In the present experiment, a detailed investigation was made of the effects of 5 US intensities on the acquisition and extinction of the CER. Since there has been no report of classical conditioning yielding a U shaped function when related to US intensity, a direct monotonic relation between degree of suppression and US intensity was expected in this study.

METHOD

Subjects: The subjects were 40 experimentally naive male hooded rats approximately 5 months old.

Apparatus: The aparatus consisted of 4 standard No. 3125A Grason Stadler Skinner boxes enclosed in a sound insulating metal chest. One wall of the Skinner box contained the food receptacle, the response lever and two lights (not used in this experiment) as well as a loudspeaker attached on the outside. The floor was made from steel grid bars which were connected to a multiple contact plug leading to a Grason Stadler E1064GS shock generator. The circuit in the shock generator was a high voltage, high resistance circuit in order to reduce the effects of changes in the rat's resistance on current flow. The amperage in the shock circuit was changed by varying the size of resistances in series with the rat. The output of the shock generator was fed into a scrambler of 18 points arranged in 9 pairs. A commutator successively reversed the polarity of each pair changing the shock pattern approximately every 0.3 seconds on 60 cycle operation.

The shock was delivered in such a way that the rat could not avoid it by standing on any particular pair of grid bars or by maintaining contact with the walls or lever.

Shock intensity settings of 0.25, 0.5, 1.0, 2.0, 4.0 ma on the shock generator were used with a 0.5 second duration. To estimate the actual amperage received by the rat, the voltage drop across a 10,000 ohm resistor in series with the rat was measured. The resistance of several rats in each Skinner box in an ascending and descending series of shock intensity measurements was recorded. The average value of these measurements was taken arbitrarily as the amperage delivered to the rats. The values delivered at each of the above settings were calculated to be .28, .49, .85, 1.55, 2.91 ma with relatively minor variation from rat to rat.

The CS was a 3 minute white noise produced by a Model 901A Grason Stadler noise generator which fed into the loudspeakers on one side of the Skinner boxes. The noise level inside this box with the exhaust fan operating, was about 69 db measured by a General Radio Sound Survey Meter, and the CS raised the level to 70 db.

The rest of the apparatus, in a separate room, consisted of standard Grason Stadler operant conditioning units with automatic programming procedures and counting of responses.

Procedure: The animals were put on a 24 hour feeding schedule and reduced to about 75% of ad lib body weight. When this was reached, the animals were trained to bar press first by receiving 40 "free" pellets on a 1 minute VI schedule ("magazine training"), then the automatic delivery was stopped, and the bar activated on a continuous reinforcement schedule with animals being allowed another 80 response-produced pellets. A total of 8 hours of bar pressing practice on 2½ minute VI in two hour sessions over the next four days was used to stabilize response rates. The animals were always fed a few minutes after the experimental session. On the next day (Day P) the rats were pretested with the unreinforced presentation of the CS at 20, 45, 95 and 112 minutes during a 2 hour session in the Skinner box while on a 2½ minute VI schedule. The suppression training (Days 1 - 10) followed the same sequence, except the shock was introduced, and the rats received 4 CS-US pairings at the US intensity assigned to each particular subject, in the same temporal sequence as on the pretest day while still on a 2½ minute VI schedule. On Day 11 extinction trials began with unreinforced presentations of the CS until the rat had met the extinction criterion, of two consecutive trials with a ratio of 0.50. The strength of the CER was measured by the ratio used by Kamin (28) or $\frac{B}{A + B}$ where B was the number of responses emitted by the rat during the CS and A the number emitted during the 3 minutes prior to the CS. The ratio $\frac{B}{A + B}$ equals 0.00 with complete suppression (no response during CS-US interval), equals 1.00 with no response prior to the CS-US interval but some responding during the CS, and the ratio equals 0.50 with equal rates of responding during both intervals. The number of responses made during interval A and interval B were recorded for each CS-US sequence on Foringer print-out counters. For most purposes, however, only a single ratio was computed for each rat for each experimental day, the ratio being based on the cumulated responses made in four CS-US sequences.

Design: The design allows a simple test of the effect of intensity of the US. There were 5 independent experimental groups of 8 subjects each, randomly constituted. The sole differences between groups was intensity of the US, which was 0.28, 0.49, 0.85, 1.55, 2.91 ma with different groups.

RESULTS

The raw data of the experiment can be found in Appendix A. The raw data were divided into three classes of measurements: acquisition, extinction and changes in the baseline during acquisition. The results for acquisition shall be considered first.

From the raw data, which consists of a daily suppression ratio calculated for each rat (pooling all four daily trials), the median suppression ratio for each day of training for each experimental group was computed. These median ratios are presented in Figure 1. From the figure it can be seen that the acquisition of the CER is a monotonic function of the US intensity. The .28 ma group oscillated around a ratio of .5 or showed no tendency to suppress throughout the ten days of acquisition. The .49 ma group as Figure 1 indicates, achieved an intermediate level of suppression by Day 4 but from thereon, recovered considerably. Two of the rats in this group had ratios of 0.00 on Day 5 but only one of them remained completely suppressed until Day 10.

The .85, 1.55 and 2.91 ma groups all suppressed virtually completely by Day 2 and remained almost completely suppressed until Day 10. For purpose of statistical analysis,

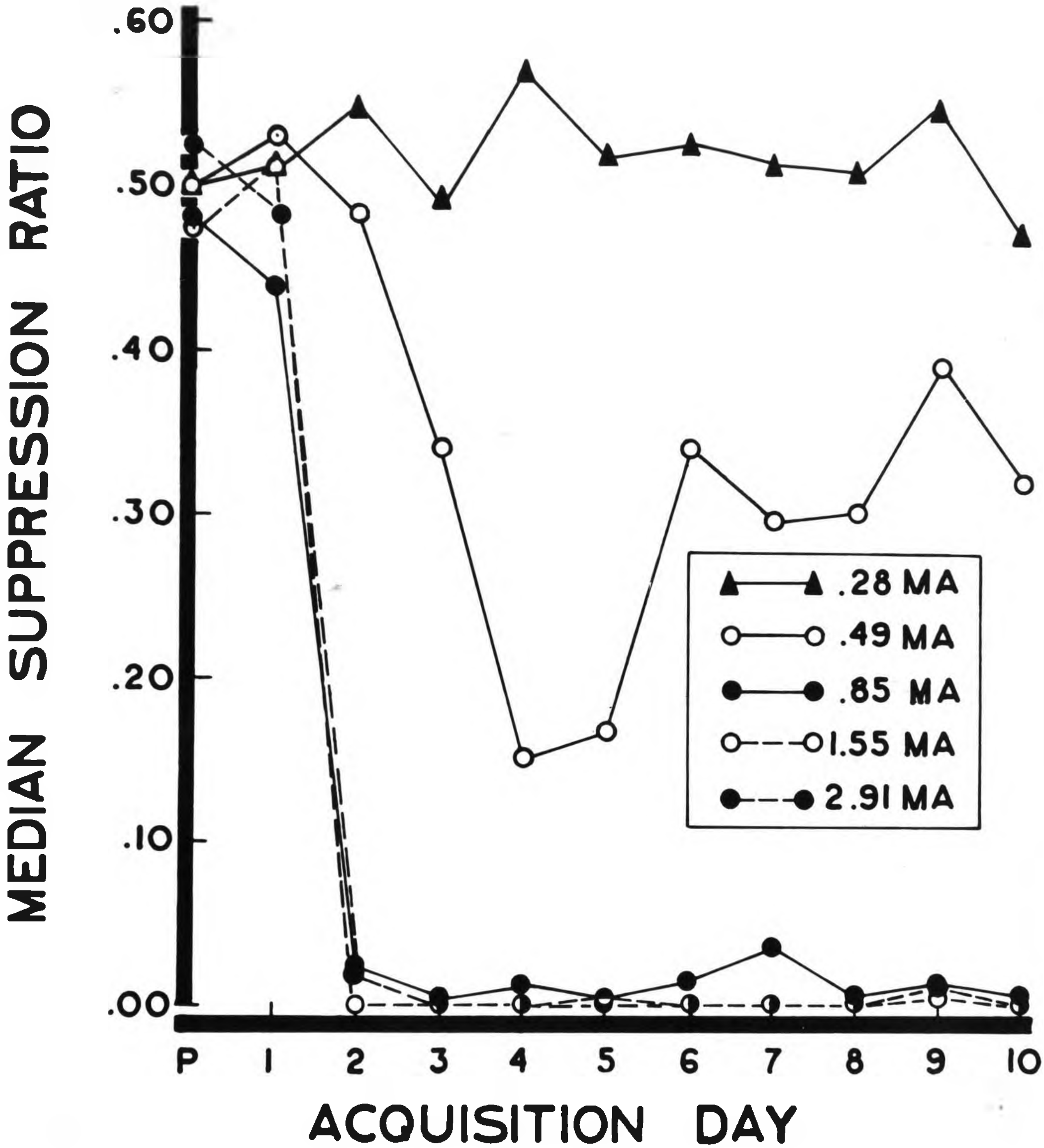

Fig. 1 - Median Suppression Ratios during Acquisition as a Function of Shock Intensity.

attention was focused on performance during acquisition Days 6 to 10 when suppression is relatively asymptotic. For each rat, the mean suppression ratio for Days 6 to 10 was computed. These mean ratios were then analyzed as a function of shock intensity. The means, medians and ranges of these ratios are presented as a function of shock intensity in Table I.

TABLE I

Means, Median and Ranges of Mean Suppression Ratios for Days 6 to 10 as a Function of Shock Intensity.

Measure	US Intensity in Milliamperes				
	0.28	0.49	0.85	1.55	2.91
Means	0.51	0.24	0.03	0.02	0.00
Median	0.51	0.26	0.01	0.00	0.00
Ranges	0.46 - 0.54	0.00 - 0.46	0.00 - 0.09	0.00 - 0.07	0.00 - 0.02

These data submitted to a Kruskal-Wallis ranked analysis of variance yielded a value of H significant at well beyond the 0.001 level indicating a marked effect of shock intensity.

Because of the skewed distribution of the data and the heterogeneity of variance, non-parametric tests were used to analyze the data. The differences between adjacent values of shock intensity were tested by the Mann-Whitney U test (one-tailed). The difference between the .28 and .49 ma groups was significant at $p = < 0.005$, between the .49 and .85 groups at $p = < 0.005$, between the .85 and 1.55 ma groups at p 0.06 and not significant between the 1.55 and 2.91 ma groups ($p = 0.36$).

Turning now to extinction data, Figure 2 shows the median suppression ratios as a function of extinction days for different shock intensities. The 0.28 ma group was not in fact given extinction training because this group did not acquire suppression, even after 10 days of acquisition. It will be recalled that when a rat reached a ratio of 0.50 for an entire extinction day before Day 10, he was discontinued, and for all subsequent days given a ratio of 0.50. The curves in Figure 2 are based on this procedure. Whenever the median ratio for a group reached 0.50, the curve was discontinued. Inspection of the curves makes it clear that extinction is a monotonic function of US intensity. There is no crossover in the curves and more separation is observable between the high shock intensities than in acquisition.

For statistical analysis, an arbitrary extinction criterion was adopted and each rat given a score for number of trials required to reach the extinction criterion. The criterion was 2 consecutive trials (CS presentations) during which the animal had a ratio of 0.50 or greater. The extinction score

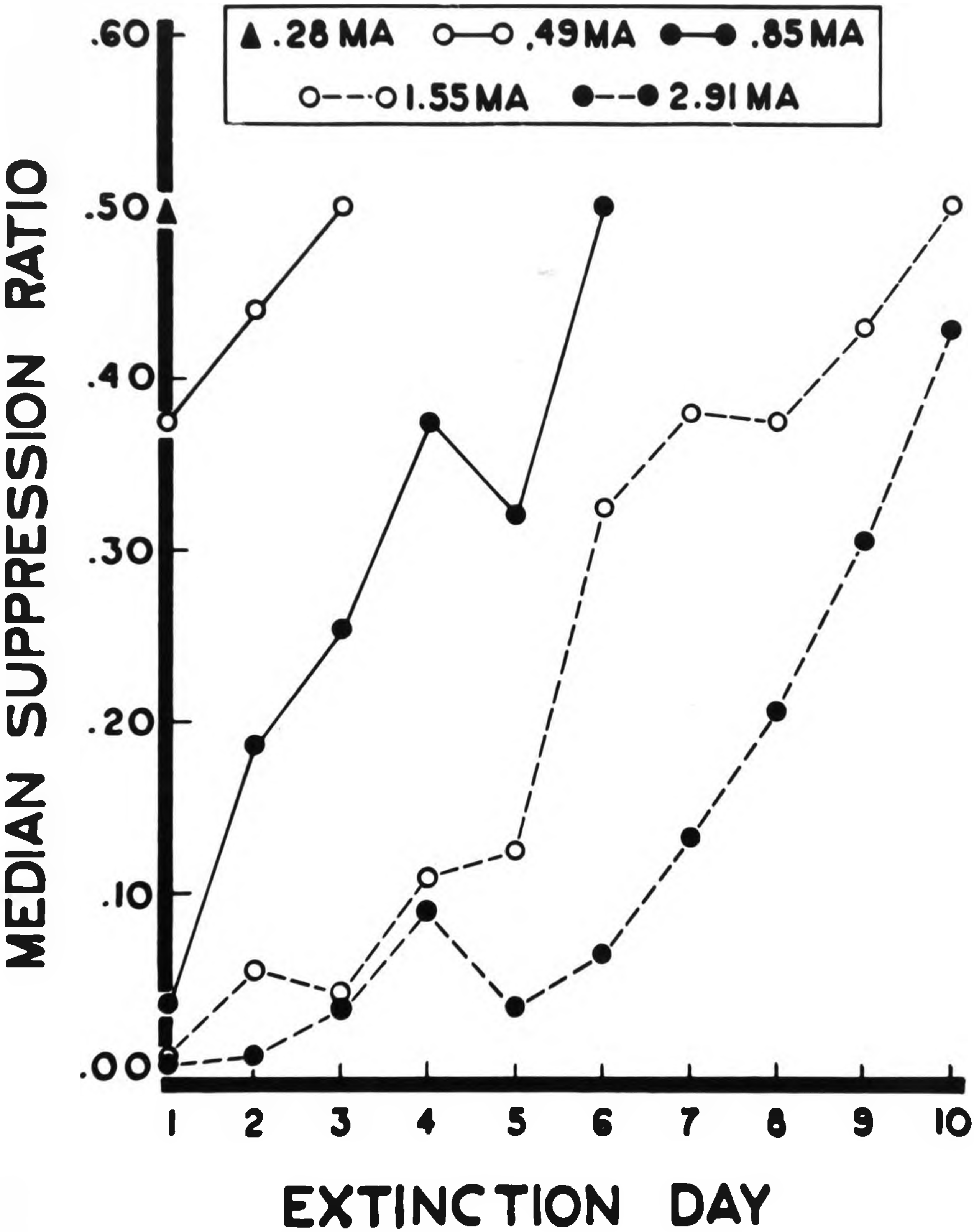

Fig. 2 - Median Suppression Ratios During Extinction as a Function of Shock Intensity

was thus the number of the trial on which the rat achieved the criterion. When the rat failed to achieve extinction criterion within 10 days of the extinction training, his extinction score was "40+".

Table II presents the mean, median and ranges of extinction scores as a function of shock intensity.

TABLE II

Means, Medians and Ranges of Extinction Scores as a Function of US Intensity

Measure	US Intensity in Milliamperes			
	0.50	0.85	1.55	2.91
Mean	6.50	18.12+	30.50+	34.25+
Median	6.0	17.5	35.0	39.0+
Range	2-11	7-40+	15-40+	10-40+

The Kruskal-Wallis ranked analysis of variance showed a significant effect of experimental treatment, i.e., shock intensity, at the 0.01 level.

A series of Mann-Whitney U tests (one-tailed) indicated a significant difference between the 0.48 and 0.85 ma groups ($p = 0.007$), but the difference between the 0.85 and 1.55 ma groups had a p value of only 0.097 and there was no statistically significant difference between the 1.55 and 2.91 ma groups ($p \approx 0.37$). Although there are no statistically significant differences among the highest shock intensities, it is interesting to note that the number of rats receiving a 40+ as the extinction score, were two rats in 0.85 ma group, two rats in the 1.55 ma group and four animals in the 2.91 ma group.

The possibility exists that, had extinction training been carried on until all animals met the criterion, significant differences among the higher shock intensities might have been obtained.

Finally, an interesting observation concerns the single animal in the 0.49 ma group which showed a prolonged and complete suppression during acquisition. While during acquisition this animal was indistinguishable from animals in the high shock intensity groups, unlike these animals it extinguished very rapidly, meeting the extinction criterion on the trial.

Also one must note the changes which occurred during acquisition in the baseline rate of bar pressing against which the suppression ratio is computed. The baseline was computed for each animal, for each day, by cumulating the number of responses made during the four 3 minute periods which preceded the CS. In order to decrease the heterogeneity of variance for these data, the raw data were transformed by a square root transformation. These data were the basis of Figure 3, which presents changes in the animals' baseline responding as a function of shock intensity for Days 1 through 10 of acquisition.

It is of interest to note that the three highest shock intensity curves in Figure 3 do suggest a definite U shape over time, especially the 2.91 ma group. Thus with the higher shock intensities, there is a tendency for baseline responding to decrease early in training, and then gradually recover. The baseline data were submitted to a Lindquist Type III analysis of variance with shock intensity and days as main effects. The analysis is summarized in Table III.

TABLE III

Summary of Analysis of Variance of Baseline Responses

(Square Root Transformation)

Source	df	Mean Square	F	p
Shock Intensity	4	421.4738	3.28	<.025
Error (b)	35	128.3636		
Days	9	29.5295	4.17	<.001
Days X Shock Intensity	36	17.0037	2.40	<.001
Error (w)	315	7.0797		

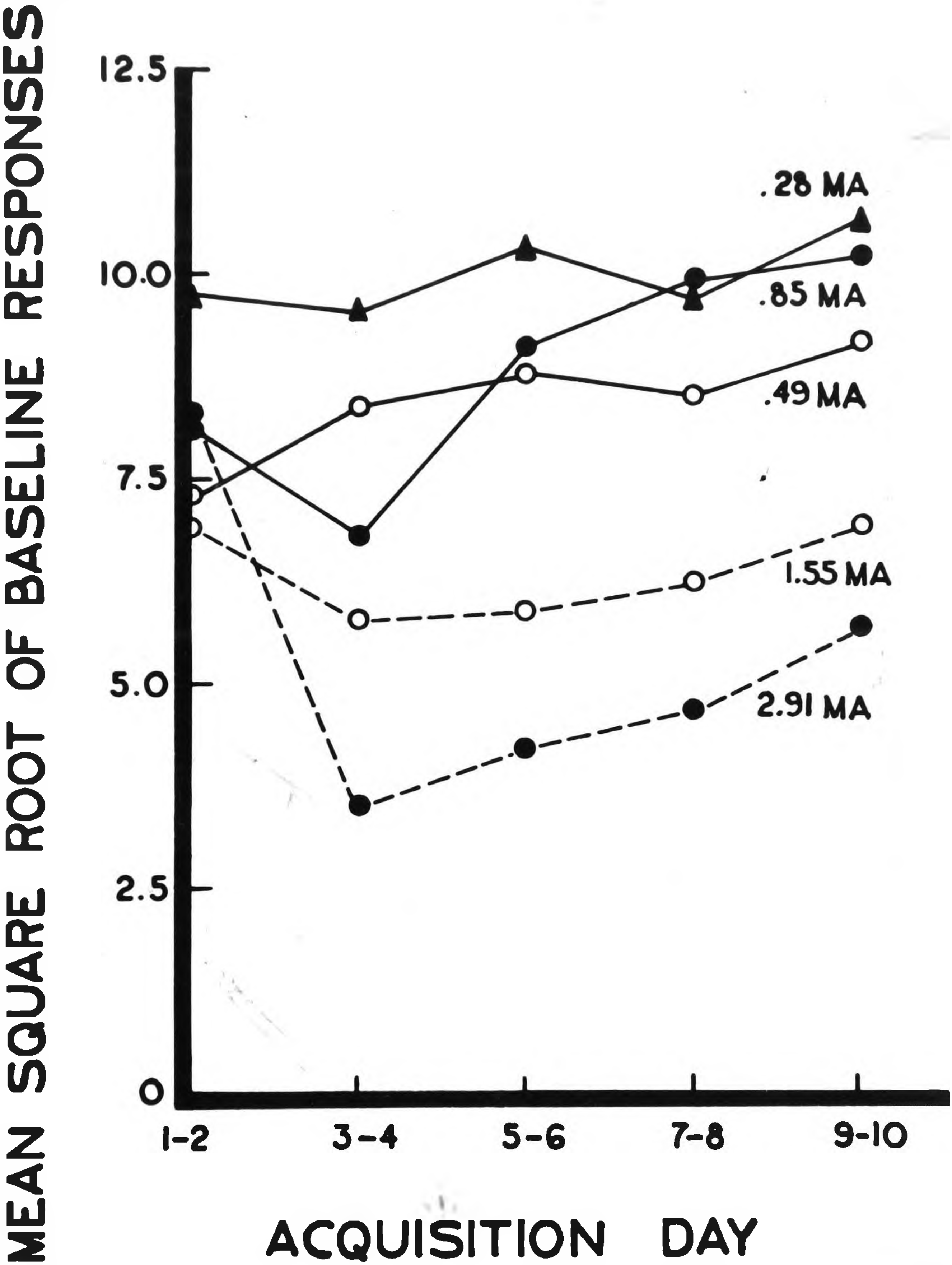

Fig. 3 - Mean Square Root of Baseline Responding During Acquisition as a Function of Shock Intensity.

The effects of shock intensity and of days are significant, as is the interaction of days and shock intensity. Inspection of Figure 3 makes it clear that the significant effect of shock intensity is due to a lowering of the baseline for the highest shock intensity groups. The significant interaction between days and intensities reflects the tendency for the initial drop in baseline responding to be specific to the high shock intensity groups.

The fact that the baseline was differentially affected by varying shock intensities does not effect the validity of comparing suppression ratios across shock intensity groups. The suppression effect is defined in essence, by the proportionate reduction in responding during the CS, compared to whatever the baseline response rate might be. It can be noted in any event, that the lower baseline of the high shock intensity groups could not have contributed to their lower suppression ratios. One or two "random" or "accidental" responses made by these animals when evaluated against their low baselines, would have inflated rather than lowered their suppression ratios.

In some cases it happened during acquisition that, on a given day for a given rat, the baseline would become zero, because of a generalized fear reaction by the rat, which would result in total "freezing". In all such cases of course, the animal also made no responses during the CS.

For these rats which did not respond at all, a suppression ratio of 0.00 was assigned for the days on which there was no responding, following Hunt and Brady's practice. No animals "froze" in the 0.28 and 0.49 ma groups, one animal "froze" in the 0.85 ma group (for two days), two animals "froze" in the 1.55 ma group (one for eight days, the other for four days) and five animals "froze" in the 2.91 ma group (two for one day, two for two days and one for five days). The reason for assigning the 0.00 ratio to these animals was that invariably the ratio on days before and after the "freezing" was either 0.00 or very close to it.

The "case history" of one animal provides an interesting check on the reasoning employed in assigning suppression ratios of 0.00 to animals which froze. This subject, in the 1.55 ma group, froze completely during the last eight days of acquisition. However, on the second day of extinction training, he resumed bar pressing. Then, when the CS was presented, he made no responses. This animal's suppression ratio remained at 0.00 for a long bank of extinction trials during which normal bar-pressing occurred between CS presentations. Thus, although the complete freezing during acquisition masked the existance of suppression at that time, the suppression was clearly exhibited - without any further shocks - when the baseline responding recovered.

DISCUSSION

The results of this experiment indicated that the acquisition and extinction of the conditioned emotional response are monotonic functions of shock intensity. Rats conditioned to 0.28 ma did not acquire suppression at all, an intermediate level of suppression occurred at 0.48 ma, and 0.85 ma, 1.55 ma and 2.91 ma each led to virtually complete suppression on the second day, with no recovery. There was, as well, a direct monotonic relationship between shock intensity and resistance to extinction of the CER.

It can be said that the results of this experiment in general agree with previous studies on shock intensity in other learning situations. Stronger shock leads to more rapid and profound acquisition of the response, although even at the highest shock intensity (2.91 ma) used in this experiment, there was no indication of the Yerkes and Dodson U function (43). There is, however, no reason to expect such a U shaped function in classical conditioning, and it is assumed that the CER can be considered as a classically conditioned emotional response.

That the CER is controlled by the same factors as Pavlovian conditioning is suggested by other studies in the field. Kamin's (28) trace conditioning data seem to point in this direction, as well as Ray and Stein's (36) experiment on the generalization of the CER to CS's varying in similarity to the CS employed in training.

Some of the results obtained in this experiment seem to deserve special attention. It is of interest to note that none of the 0.28 ma animals showed any sign of suppression. This fact is surprising when one considers Singh's results (40). The animals in our 0.28 ma group did display, on being shocked, an easily observable "flinch" response like that reported by Kimble (29), and yet the CS did not acquire suppressant properties. In contrast to this, Singh, using only 0.20 ma and 0.25 ma, not only found that his animals acquired the CER, but that the 0.25 ma group showed more suppression than the 0.20 ma group. It is difficult to explain this difference in results between the two experiments unless some unclarified procedural differences exist between them. In this connection it should be noted that Singh reported that it made no difference in his factorially designed study whether the US was presented just before or just after the 3 minute CS. This surprising finding suggests that Singh's procedure may have produced a behavioral effect quite different from the classically conditioned CER. On the other hand the failure of our 0.28 ma group to suppress is consistent with the unpublished data of Brady and Susla (6). One possibility is that Singh's rats were not as motivated to work for a water reward as our severely deprived rats were motivated to work for food. Presumably, a consequence of this would be that it would be easier for Singh to establish suppression, even with weak shock as the US.

In order to clarify the nature of the 0.28 ma shock intensity which produces an obvious flinch response in the rat and yet no suppression, some animals that had finished the CER experiment were put on a punishment schedule like that outlined by Hunt and Brady (24). Briefly, in this procedure, during the CS every bar press results in immediate shock, but in the CS-off period no shock is delivered. The VI food reinforcement schedule is, of course, always in effect. This procedure interestingly enough produced very rapid though never complete inhibition of responding during the CS in most rats, with a 0.28 ma punishment. Despite the fact that in the early trials the rats received a good number of shocks, their behavior was quite different from that of the CER group, trained at the same shock intensity. Instead of the usual signs of anxiety, such as crouching and defecation, the punishment rats displayed an almost "I don't believe it" behavior and, after each shock, jumped back from the bar, but almost immediately advanced again to press it or almost press it down. In later trials, when these rats had suppressed, the signs of anxiety still did not develop during the CS.

The above findings suggest some interesting possibilities for the application of aversive stimulation to control behavior. The results suggest that a level of noxious stimulation may exist, which is enough to stop (through punishment) ongoing behavior without creating anxiety. The implications of this translated into the human situation could be far reaching, especially in education.

Another finding of interest was the behavior of the 0.49 ma group. The U shape of the curve in Figure 1 for this group suggests some kind of adaptation by this group to the shock. One can postulate that somehow as acquisition proceeds, the shock begins to lose its aversive properties and the CS becomes less anxiety producting.

It could be visualized that the animals, given enough time, would have recovered completely to a ratio of 0.50, and become completely indifferent to the shock.

The failure of the relatively minor differences between the high shock intensity groups to be statistically significant can be attributed to the small N, and with more subjects the small differences obtained might have been statistically significant.

Finally, turning to the baseline data, the depression of the baseline and its subsequent recovery in the three high shock intensity curves is of some interest. Although the animals in these groups suppress to the CS virtually completely by Day 2, the baseline rate continues to drop until Days 3 - 4, before beginning to recover. This depression may be due to the generalized fear reaction of the animals to the experimental situation as a whole. The CS is presumably the most anxiety eliciting, but the overall situation is also feared. As the acquisition training continues, the animals learn not to fear the CS-off periods, since they never lead to shock, and baseline rates of bar pressing increase, to the normal level. The lower shock intensities seem not to lead to such a generalized fear, and the baseline curves remain relatively level throughout acquistion.

SUMMARY

The effects of US Intensity on the acquisition and extinction of the Conditioned Emotional Response were investigated, employing 40 male hooded rats in a Skinner box. The US intensities studied were 0.28, 0.49, 0.85, 1.55, and 2.91 ma. Both acquisition and extinction of the CER were found to be monotonic functions of US intensity, with the higher shock intensities producing more rapid acquisition and more resistance to extinction. The lowest shock intensity employed (0.28 ma) failed to produce any suppression of operant behavior, although it did produce a "flinch-like" response in the rat. The 0.49 ma subjects showed typically, a partial recovery of normal operant behavior during the CS, after first acquiring, during the early days of training, a fairly profound CER.

The results were interpreted as consistent with the supposition that the CER is acquired in accordance with Pavlovian laws of classical conditioning.

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APPENDIX A

SUPPRESSION RATIOS FOR EACH RAT FOR DAYS 1 - 10

OF ACQUISITION AS A FUNCTION OF US INTENSITY

	Subjects	Days P	1	2	3	4	5	6	7	8	9	10
US Intensity .28 ma	1	.56	.60	.56	.49	.49	.57	.48	.42	.50	.60	.56
	2	.55	.52	.61	.49	.69	.54	.58	.57	.45	.55	.54
	3	.47	.58	.55	.48	.54	.51	.53	.53	.59	.57	.48
	4	.50	.51	.50	.45	.57	.50	.52	.48	.41	.45	.46
	5	.48	.40	.48	.61	.57	.51	.53	.49	.47	.48	.50
	6	.54	.41	.55	.59	.63	.50	.52	.52	.55	.52	.45
	7	.47	.46	.57	.51	.48	.53	.51	.61	.54	.60	.46
	8	.50	.53	.54	.50	.68	.55	.53	.51	.52	.54	.46
US Intensity .49 ma	1	.55	.61	.52	.57	.55	.53	.60	.54	.58	.49	.52
	2	.47	.52	.48	.42	.09	.26	.43	.32	.35	.47	.39
	3	.54	.54	.50	.46	.43	.52	.53	.50	.49	.46	.38
	4	.41	.51	.45	.24	.00	.00	.00	.00	.06	.36	.24
	5	.44	.61	.22	.02	.00	.01	.00	.00	.00	.00	.00
	6	.67	.70	.54	.51	.40	.40	.37	.37	.42	.42	.46
	7	.45	.49	.48	.26	.21	.00	.00	.00	.17	.18	.26
	8	.53	.54	.45	.12	.05	.07	.31	.27	.25	.26	.12

SUPPRESSION RATIOS FOR EACH RAT FOR DAYS 1 - 10 OF ACQUISITION AS A FUNCTION OF US INTENSITY

	Subjects	P	1	2	3	4	5	6	7	8	9	10
US Intensity .85 ma	1	.52	.42	.00	.00	.00	.00	.00	.00	.01	.01	.00
	2	.47	.33	.02	.02	.01	.00	.01	.01	.00	.02	.01
	3	.79	.53	.00	.00	.00	.02	.02	.06	.00	.01	.00
	4	.49	.51	.27	.00	.01	.00	.09	.21	.12	.07	.03
	5	.58	.42	.03	.00	.03	.04	.00	.02	.00	.00	.00
	6	.40	.46	.02	.00*	.00*	.00	.01	.05	.00	.00	.02
	7	.44	.13	.22	.12	.14	.06	.12	.02	.03	.02	.03
	8	.47	.48	.37	.01	.25	.01	.08	.10	.13	.16	.10
US Intensity 1.55 ma	1	.60	.57	.00	.00	.00	.00	.00	.00	.00	.01	.00
	2	.46	.37	.02	.01	.06	.01	.03	.02	.01	.01	.01
	3	.45	.46	.00*	.00*	.00*	.00*	.00*	.00*	.00*	.00*	.00*
	4	.46	.55	.00	.00*	.00*	.00*	.00*	.00	.00*	.00	.00
	5	.58	.53	.39	.18	.15	.07	.05	.14	.13	.10	.02
	6	.49	.58	.00	.10	.00	.05	.06	.06	.00	.00	.01
	7	.39	.36	.00	.00	.00*	.02	.00	.00	.00	.03	.00
	8	.49	.50	.34	.00	.00	.00	.00	.00	.00	.00	.00
US Intensity 2.91 ma	1	.47	.52	.00	.00	.00	.00	.00	.00*	.00	.03	.00*
	2	.58	.56	.02	.00	.00*	.00*	.08	.00	.01	.03	.00
	3	.53	.38	.02	.00*	.00	.00	.01	.00	.00	.00	.00
	4	.52	.29	.00	.00	.00	.00	.00	.00	.00	.02	.01
	5	.47	.49	.00	.00	.00	.00*	.00	.00	.00	.00	.00*
	6	.54	.40	.20	.00*	.00*	.00	.00	.00	.00	.00	.00
	7	.55	.48	.20	.00*	.00*	.00*	.00*	.00*	.00*	.00	.00
	8	.51	.49	.24	.03	.00	.00	.00	.00	.00	.04	.00

* Rat frozen for the experimental session

SUPPRESSION RATIOS FOR EACH RAT FOR DAYS 1 - 10

OF EXTINCTION AS A FUNCTION OF US INTENSITY

US Intensity	Subjects	Days 1	2	3	4	5	6	7	8	9	10
US Intensity .49 ma	1	.57	.50								
	2	.42	.44	.51							
	3	.46	.51								
	4	.39	.48								
	5	.31	.25	.50							
	6	.36	.43	.49							
	7	.14	.22	.47							
	8	.15	.45	.47							
US Intensity .85 ma	1	.02	.02	.06	.25	.14	.38	.43	.40	.39	.44
	2	.01	.01	.04	.00	.02	.00	.00	.02	.00	.00
	3	.04	.35	.46							
	4	.19	.42	.37	.52						
	5	.00	.00	.14	.16	.00	.51				
	6	.16	.47	.							
	7	.02	.00	.00	.00	.01	.00	.00	.00	.00	.02
	8	.13	.42	.49							

SUPPRESSION RATIOS FOR EACH RAT FOR DAYS 1 - 10

OF EXTINCTION AS A FUNCTION OF US INTENSITY

	Subjects	Days									
		1	2	3	4	5	6	7	8	9	10
US Intensity 1.55 ma	1	.00	.00	.07	.13	.23	.06	.18	.27	.37	.00
	2	.08	.20	.24	.20	.17	.31	.42	.45	.52	
	3	.00	.02	.00	.00	.00	.34	.34	.30	.16	.50
	4	.00	.00	.00	.02	.02	.00	.05	.00	.00	.27
	5	.04	.09	.02	.10	.08	.47				
	6	.00	.18	.30	.40	.50					
	7	.01	.03	.00	.00	.00	.00	.00	.28	.00	.00
	8	.01	.23	.40	.54						
US Intensity 2.91 ma	1	.00	.00	.00	.00	.00	.00	.01	.00	.00	.00
	2	.00	.07	.08	.10	.03	.34	.34	.37		
	3	.00	.00	.01	.00	.04	.05	.13	.13	.28	.25
	4	.17	.32	.49							
	5	.00	.00	.00	.00	.00	.00	.03	.00	.08	.16
	6	.03	.01	.01	.08	,00	.00	.14	.23	.25	
	7	.00	.00	.06	.24	.36	.09	.05	.18	.33	.36
	8	.11	.39	.49							