THE SPONTANEOUS RECOVERY OF CONDITIONED SUPPRESSION OF LICKING

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ABSTRACT

The spontaneous recovery of conditioned suppression of licking was systematically investigated. The subjects, 84 albino rats, received eight conditioning trials (two per day), 40 massed extinction trials, and were then randomly assigned to seven recovery groups. Independent groups (N = 12) were tested for the spontaneous recovery of conditioned suppression 3.5, 30, 60, 180 minutes, 24, or 72 hours after the last extinction trial. A seventh group remained in the conditioning apparatus for a 3.5 minute interval.

All the measures of recovery, i.e., suppression ratios, percentages of recovery, and number of responses produced during the period of the CS, indicated that the function relating the amount of recovery to the recovery interval was a rapidly rising, negatively accelerated function reaching its asymptotic level of 86.5 percent recovery within 24 hours. No differential effects as a result of remaining in the chamber during the 3.5 minute interval were found. Evidence was also found that the static cues of the conditioning situation spontaneously recover their ability to elicit the conditioned response. Recovery of static cues was viewed as supporting the position that conditioned suppression is the result of a Pavlovian conditioned fear response. The occurrence of spontaneous recovery was interpreted in terms of Pavlovian inhibition theory.

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CHAPTER I

INTRODUCTION

A Brief Review of the Conditioned Suppression Literature

The suppression of ongoing behavior to a conditioned aversive stimulus was first demonstrated by Estes and Skinner (1941). These investigators presented paired presentations of a neutral stimulus and a response non-contingent shock while rats were bar-pressing at a stable rate. After a number of such pairings, the presentation of the conditioned stimulus (CS) alone produced response suppression. This suppression was attributed to a learned emotional arousal or disturbance elicited by the aversive CS. Since an emotional disturbance is incompatible with the performance of an operant response, suppression of responding occurred. The term conditioned emotional response (CER) has since designated this paradigm.

The terms conditioned suppression and CER have been used interchangeably by most investigators (e.g., Beecroft, 1967). Recently, however, Davis (1968) has distinguished between the two terms. According to Davis, only those investigators who take some measure of autonomic activity are justified in calling the response a CER. In investigations using behavioral indicants alone, the cessation of responding in the presence of the CS should be designated conditioned suppression since any reference to emotional arousal would be inferential. However, since the authors of the articles which are discussed here have not distinguished between CER and conditioned suppression, for the purposes of this paper

the two terms will be used interchangeably. Since extensive reviews of the conditioned suppression and emotional conditioning literature are now available (Davis, 1968; Beecroft, 1967), the following review will be delimited and will illustrate some of the more relevant operations and variables which influence conditioned suppression.

Conditioning Techniques

Kamin and his associates have developed a standardized procedure for investigating the CER (e.g., Annau & Kamin, 1961). This technique uses the lever-press response, maintained on a variable interval 2.5 minute schedule with food reinforcement. Daily conditioning sessions are two hours long with four CS-unconditioned stimulus (UCS) presentations during each session. Typically CS duration is three minutes. The suppression of operant behavior is represented by suppression ratios which are defined by the formula $\frac{B}{A+B}$. A baseline of operant responding is obtained by recording the number of responses emitted during a three minute period immediately before CS onset (pre-CS) and is denoted by "A" in the formula. The number of responses during the three minute CS is denoted by "B". Therefore, a ratio of zero reflects total response suppression to the CS, a ratio of .5 reflects no suppression, and ratios greater than .5 denote "supernormal" periods in which the number of responses during the CS is greater than the number during the pre-CS.

Leaf and Muller (1965) devised a technique utilizing consummatory drinking to obviate the time consuming procedure of Kamin. However, this method does not enable the trial by trial analysis of acquisition or

extinction. Conditioning is conducted in a non-drinking situation and the drinking response is used only as a one trial test of the terminal degree of conditioned suppression.

Recently, James and Mostoway (1968), using consummatory drinking, developed a conditioning procedure which does enable the trial by trial analysis of the acquisition and extinction of conditioned suppression. This procedure involves the presentation of the CS-UCS pairings while water deprived rats are drinking their daily ration of water. During each daily ten minute session, either one or two conditioning trials may be given. The duration of both the pre-CS and CS periods is 30 seconds. This technique was employed in the present investigation.

Experimental Findings

Annau and Kamin (1961) investigated the effect of UCS intensity on the acquisition and extinction of conditioned suppression. Using UCS intensities of 0.28, 0.49, 0.85, 1.55, and 2.91 milliamperes, both acquisition and resistance to extinction were found to be positive monotonic functions of shock intensity. The same relationships were found by James and Mostoway (1968) using the licking-based CER procedure with UCS intensities of 0.1, 0.5, 1.0, and 2.0 milliamperes. This finding lends support for the use of this method in lieu of the Kamin procedure.

Evidence was reported by Kamin (1961) for the trace conditioning of the CER. The amount of conditioned suppression was found to vary inversely with the length of the trace intervals of 0, 1.0, 2.0, and 2.5 minutes. A later investigation (Kamin & Schaub, 1963) showed that CS

intensity strongly influenced the acquisition of a trace CER. For a one minute trace interval, subjects conditioned to a white noise CS of 49 decibels failed to display any suppression during the trace interval or to the CS itself, while a group conditioned to an 81 decibel CS showed considerable suppression during both periods. Another experiment reported in the same article investigated the effect of CS intensity on a delayed CER. The rates of acquisition for CS intensities of 81, 62.5, and 49 decibels were compared at a constant interstimulus interval of three minutes. The rate of acquisition was found to be a positive monotonic function of CS intensity.

Singh (1959) reported evidence that conditioned suppression had been achieved using a backward conditioning paradigm. However, Kamin (1963) in a series of two experiments found it impossible to obtain a backward CER. The evidence put forth by Kamin, using the standard conditioning procedure offers no support whatever for the possibility of establishing conditioned suppression through UCS-CS pairings.

The effect of unsignaled, "free" shock given prior to conditioning on the subsequent acquisition of the CER was explored by Brimer and Kamin (1963). In the first experiment, groups of subjects were administered free shock at intensities of 0.25, 0.5, 1.0, 2.0 and 4.0 milliamperes in ascending, descending, and irregular orders. A control group received additional lever-press training only. A significant retardation in acquisition was found in all experimental groups with the pattern of shock presentation significantly affecting baseline rates, the rates decreasing with the more intense stimuli. No differences were found

between the ascending and irregular groups, but these groups showed less response suppression than the descending group which in turn showed less than the control group. Also, evidence was found of sensitization to shock. That is, subjects which received an intense UCS followed by a weaker UCS displayed more behavioral disruption than those which received successive presentations of a weak UCS.

The second experiment in the series was conducted to discover whether recovery of baseline could be attained and, if so, whether normal CER acquisition could be demonstrated. After receiving three days of a 3 milliampere free shock, a recovery group was then given five days of additional lever-pressing experience without UCS presentations. A no-recovery group was placed in conditioning chambers in which a wall was inserted to prevent additional lever-press experience. The no-recovery group displayed a decrement in subsequent CER acquisition while the recovery group did not. Additionally, the baseline rate of responding was lower for the no-recovery group. Both of these experiments found a high proportion of supernormal suppression ratios, reflecting an acceleration in responding during the CS. However, since this was not found in the no-recovery group, it was concluded that the lowered baselines, rather than the free shock per se, were responsible for the supernormal ratios.

In a third experiment the tendency to accelerate during the CS was found when CS-only presentations were given after free shock. However, this tendency was also found to disappear over trials. The tendency to accelerate during the CS was interpreted in terms of Pavlovian

disinhibition. That is, the free shock produced inhibition of baseline responding and the CS acted as a disinhibitor of this tendency.

The generalization of conditioned suppression was first demonstrated by Ray and Stein (1959). Discrimination training was initially given with a tone of 1800 Hertz (Hz) serving as the CS+ and a 200 Hz tone as the CS-. Following this, test stimuli of 560, 980, 1120, and 1500 Hz were presented. The strength of conditioned suppression along the sound-frequency dimension was found to be an inverse function of the difference between the CS+ and the test stimuli. Hoffman and Fleshler (1961), omitting discrimination training, conditioned pigeons to suppress to a 1000 Hz tonal CS. The testing, conducted on stimuli ranging from 300-4000 Hz, disclosed a bidirectional gradient of generalization. Similar results have also been reported by Desiderato (1964) and Winograd (1965).

Geller (1964) failed to obtain the partial-reinforcement-effect (PRE) with conditioned suppression in goldfish. The experiment employed a 100 percent reinforcement group and a 50 percent group. The results indicated that the 50 percent group extinguished faster than the 100 percent group. This inconsistent finding was most likely due to the failure to control for the number of reinforced trials received by each group. All subjects received the same number of CS presentations, but the 50 percent subjects received reinforcement only on one-half of the trials. Thus, the 100 percent group received twice as many reinforced CS presentations. Therefore, the terminal level of conditioned suppression would be expected to be higher in the 100 percent subjects than in the 50 percent subjects. This could account for the greater resistance

to extinction shown by the 100 percent subjects. Geller (1964), however, referred to unpublished research that did demonstrate the PRE. More recently, Brimer and Dockrill (1966) successfully demonstrated the PRE with conditioned suppression in rats. In the first experiment, with the proper controls for the number of reinforced trials, a group conditioned on a 50 percent schedule extinguished slower than a group conditioned on a continuous reinforcement schedule. A second experiment, similarly designed, also demonstrated the PRE with a 25 percent group versus a 100 percent group.

Sensory preconditioning (SPC) of the CER was demonstrated by Parkinson (1968). Initially, 200 SPC training trials were given and consisted of the presentation of six seconds of 70 decibel white noise overlapped in the final two seconds by a two second pulsating light. A control group received 200 presentations of white noise only. The CER was then conditioned to the light and the test for SPC was conducted with the white noise. The magnitude of SPC was found to be weak and transient. Prewitt (1967) investigated the relationship between the number of SPC training trials and the amount of conditioned suppression. Subjects were given either 0, 1, 4, 16, or 64 SPC training trials. A positive monotonic function reaching asymtote at 16 trials was found.

Davenport (1966) achieved second-order conditioning of suppression in 38 out of 44 attempts and reported that the suppression was complete in several cases. When third-order conditioning was attempted partial suppression was attained in two out of four subjects. Second-order conditioning of the CER was also demonstrated by Kamil (1968) using a

450 Hz tone as the CS_1 and white noise as CS_2.

Differential conditioning of the CER has been demonstrated by Hammond (1966, 1967). In the first study, a 3000 Hz tone paired with shock served as the CS+ and a non-reinforced flashing light served as the CS-. The results indicated considerable suppression of responding during the CS+ and an enhancement of responding during the CS-. After attaining a differential CER in the second experiment, the CS- was combined with the CS+ during extinction for one group and a novel stimulus was combined with the CS+ in another group. The addition of the CS- to the CS+ during extinction produced greater alleviation of conditioned suppression than did the addition of the novel stimulus. The results were discussed in terms of the summation of Pavlovian excitation (CS+) and inhibition (CS-).

Conditioned suppression has generally been assumed to be an example of a Pavlovian conditioned fear response. Beecroft (1967) points out that to date, this assumption has found empirical support. The brief review presented above illustrates that the CER does in fact obey the principles of respondent conditioning. Therefore, the following review of the spontaneous recovery literature is restricted to classically conditioned responses.

Review of the Literature on the Spontaneous Recovery of Classically Conditioned Responses

Spontaneous recovery has been defined by Kimble (1961, p. 483) as "the return in strength of a conditioned response, whether partial or

complete, brought about by lapse of time following its diminution by extinction." The general procedure employed in the investigation of spontaneous recovery involves the conditioning of a response, its subsequent extinction, and the test for its recovery after a specified time interval by presenting the non-reinforced CS.

The spontaneous recovery of a conditioned response (CR) was first reported by Pavlov (1927). In this investigation a dog was conditioned to salivate at the sound of a metronome. After the CR was extinguished a rest interval of 20 minutes was given. Following this interval the CS was again presented and the CR was found to have "spontaneously" recovered to approximately 20 percent of its original strength. According to Pavlov, the recovery of the extinguished CR was the result of the dissipation of internal inhibition which was built up during extinction. Although no data were presented, Pavlov stated that in another subject complete spontaneous recovery had been attained by presenting a rest interval of sufficient length to allow the complete dissipation of inhibition.

The first systematic investigation of the spontaneous recovery of a classically conditioned response was conducted by Ellson (1939) with the galvanic skin response (GSR). All subjects were given eight conditioning trials with a tone serving as the CS and shock as the UCS. Following the eighth trial, two non-reinforced tone presentations were given to obtain a measure of the strength of the CR. Two more conditioning trials were then given. The CR was extinguished to the criterion that the average magnitude of three successive responses was equal to

or less than one-third of the average magnitude of the mean of the two conditioning test trials. After reaching this criterion, subjects were assigned to one of four groups. The groups were tested for spontaneous recovery 5, 20, 60, or 180 minutes after the last extinction trial. Ellson found the curve of recovery to be a rapidly rising, negatively accelerated function reaching asymptote within 20 minutes. In fact, when plotted, Ellson's data indicate that the 20, 60, and 180 minute groups recovered to a level greater than that during acquisition. However, this was probably a function of the method used to obtain the level of GSR conditioning. As previously mentioned, the average of two non-reinforced test trials was taken as the terminal magnitude of the CR. Since two additional conditioning trials were then administered, the actual level of conditioning cannot be determined. Thus, any attempt to obtain information regarding the amount of recovery in relation to the level of original response strength would be open to question.

Hovland (1937) in a classic study on the generalization of the GSR found that generalized CRs displayed a greater amount of spontaneous recovery than did the CRs themselves. The conditioned stimuli were vibro-tactual and the UCS was shock.

Liberman (1944) demonstrated that the amount of spontaneous recovery could be manipulated by varying interpolated activity between extinction and testing. The investigation consisted of three treatment groups which received identical training except during the 10 minute recovery interval. All subjects first received GSR conditioning, then eyeblink conditioning, followed by extinction of the GSR. One group

merely rested during the 10 minute interval and was then tested for the spontaneous recovery of the GSR. Of the two remaining groups, one received additional eyeblink conditioning trials during the final five minutes of the rest interval and the other underwent extinction of the eyelid response during the last half of the interval. Both groups were then tested for spontaneous recovery of the GSR. Liberman found significantly more GSR recovery in the group receiving interpolated eyelid conditioning than in either of the other two groups. Although there was no statistical difference between the interpolated extinction group and the rest-only group, the interpolated extinction subjects displayed less recovery than the rest-only subjects. The results were interpreted in terms of retroactive inhibition.

Virtually no published research was conducted on the spontaneous recovery of classically conditioned responses from the Liberman (1944) investigation until 1958 when D. A. Grant and his associates began investigating this phenomenon with the conditioned eyelid response. The first experiment reported by this group was conducted by Grant, Hunter, and Patel (1958). The recovery of the eyeblink was tested at intervals of 1, 2, 4, and 8 hours after extinction. The curve of recovery was similar to that found by Ellson with the GSR. The conditioned eyelid response was found to recover to an asymptotic level of 70-80 percent within 4 hours after extinction.

Howat and Grant (1958) were the first to explore the effect of massed versus spaced extinction on the spontaneous recovery of the conditioned eyelid response. All subjects were conditioned to a criterion

of eight CRs on 10 consecutive trials and then extinguished. The average intertrial interval for the massed condition was 7.5 seconds and 35 seconds for the spaced condition. Extinction was carried out until the criterion of no CR on five successive trials was attained. After extinction the subjects in each condition were randomly assigned to one of two recovery intervals; 20 minutes or 24 hours. The 24 hour groups displayed 20 percent more recovery than the 20 minute groups. Intertrial interval failed to produce any reliable differences in spontaneous recovery.

Beeman, Hartman, and Grant (1960) investigated the effect of massed and distributed trials during acquisition and extinction on the spontaneous recovery of the eyelid response. The same parameters were used in this study as in the Howat and Grant investigation. However, instead of conditioning subjects to a criterion, all subjects received 60 acquisition trials; massed for one-half and spaced for the other. Subjects were then further divided and given either 15 massed extinction trials or 30 spaced trials. The recovery interval was 24 hours and no reliable differences were found as a result of the distribution of acquisition or extinction trials.

The effect of massed and spaced acquisition on the recovery of the eyelid CR was investigated by Beeman and Grant (1961). The intertrial intervals during acquisition were 8 and 32 seconds. All subjects received 60 conditioning trials followed immediately by 15 extinction trials. The test for recovery was conducted 24 hours later. No effect due to the acquisition variable was found.

The recovery of the eyelid response as a function of the amount of acquisition and extinction training was investigated by Prokasy (1958). A 2 x 3 factorial design was employed. Subjects received either 20, 40, or 60 acquisition trials followed by 0, 10, or 30 extinction trials. The test interval was 24 hours for all conditions. In general it was found that an increase in acquisition training produced an increase in spontaneous recovery and that an increase in extinction training produced a decrease in recovery.

The effect of intermittent reinforcement during conditioning on the recovery of the eyeblink was initially reported by Hartman and Grant (1960). All subjects received 40 reinforced acquisition trials immediately followed by 20 extinction trials. Twenty test trials were administered 24 hours later. The reinforcement schedules were 25, 50, 75, and 100 percent reinforcement. Since the total number of reinforcements was held constant, groups received 160, 80, 54, and 40 acquisition trials, respectively. The average intertrial interval between reinforced trials was essentially constant. The greatest amount of recovery, 90 percent, was found in the 50 percent reinforcement group and the least, 66 percent, was found in the 100 percent group.

Froseth and Grant (1961) used the same intermittent schedules but held the number of conditioning trials constant at 80. Subjects were given 30 extinction trials immediately thereafter. The 30 spontaneous recovery trials were administered 24 hours later. Again, the greatest amount of recovery, 90 percent, was found in the 50 percent group, with the least, 57 percent, in the 100 percent group.

Hartman and Grant (1962), using the conditioned eyelid response, found that less spontaneous recovery occurred if subjects were told that the UCS would not be presented during the series of test trials. This effect was found both in subjects conditioned on a 50 percent reinforcement schedule and in those conditioned on a 100 percent schedule.

Differences between good and poor conditioners on the amount of spontaneous recovery were found by Franks (1963) using the eyelid response. Subjects were differentiated on the basis of the number of trials to reach the conditioning criterion of CRs on three successive trials. Extinction was then carried out to the criterion of the failure to elicit a CR on three successive trials. The test interval was 24 hours. It was found that subjects taking longer to condition, poor conditioners, displayed the most spontaneous recovery.

Evidence for spontaneous recovery in the planarian was found by Crawford and King (1966). After receiving 100 conditioning trials, subjects were divided into two groups matched for the frequency of the CR; body contractions during the initial two seconds of the three second CS. One group was given 40 extinction trials on the day following the termination of conditioning. A second group was given 20 extinction trials on that day and then 20 additional extinction trials for the test for recovery 24 hours later. The CR was found to have recovered approximately 70 percent of its original strength.

The Estes and Skinner (1941) study is to date the only investigation which has explored the spontaneous recovery of conditioned suppression. The authors reported that the CER displayed "almost" complete

recovery after 24 hours.

The best documented finding concerning spontaneous recovery is that it increases as a function of time between extinction and testing. It appears to rapidly reach an asymptotic level which is nearly equal to the original strength of the CR. Intermittent reinforcement during acquisition also appears to effect the rate of recovery (Hartman & Grant, 1960; Froseth & Grant, 1961). Beecroft (1966) states that spontaneous recovery does not appear to be influenced by the distribution of extinction trials. However, the intertrial intervals employed in the Howat and Grant (1958) and the Beeman, Hartman, and Grant (1960) investigations are open to question as to whether the difference between the massed (7.5 seconds) and the spaced (35 seconds) conditions actually constituted a rigorous test of their possible effects. Before a statement such as Beecroft's can legitimately be made, further research is necessary using intertrial intervals during extinction which are more disparate (e.g., one minute versus one day). It does not seem plausible that the rate of recovery would be unaffected by such intervals. Also, the effect of the distribution of such extinction trials on the asymptotic level of spontaneous recovery is yet to be determined empirically.

Statement of the Problem

The present investigation was conducted to provide a systematic analysis of the spontaneous recovery of the conditioned suppression of licking. The function relating recovery to the time between extinction and testing was expected to resemble those found for other classically

conditioned responses (e.g., Ellson, 1939; Grant, Hunter, & Patel, 1958). Specifically, it was predicted that the recovery function would rapidly reach an asymptotic level of near complete recovery and maintain this level for an extended recovery interval.

Most of the phenomena of classically conditioned responses have been systematically investigated with conditioned suppression. However, a systematic demonstration of the spontaneous recovery of conditioned suppression in the literature seems conspicuous by its absence. The present investigation was designed specifically to provide such a demonstration. It is possible that an investigation of this kind was not conducted before because of the unwieldy nature of such a study with the conditioning techniques previously available. The development of the James and Mostoway (1968) procedure for the conditioned suppression of licking provides an efficient method for investigations of this type, i.e., those which require the use of a large number of subjects.

As is evident from the review of the spontaneous recovery literature, conditioned responses appear to rapidly recover after undergoing extinction; at least when a massed extinction procedure is employed. Since a classically conditioned fear response is assumed to underlie conditioned suppression and since there should be a degree of parallelism between the same phenomena for the various conditioned responses, the spontaneous recovery of conditioned suppression should resemble the spontaneous recovery of other conditioned responses (e.g., the GSR, and the conditioned eyelid response).

CHAPTER II

THE INVESTIGATION

The subjects were 84 experimentally naive, male Holtzman albino rats, 300-350 grams in weight at the start of the experiment. There were 41 subjects in the first replication and 43 in the second. One conditioning chamber was used in the first replication and two in the second.

The apparatus consisted of two conditioning chambers (Scientific Prototype, Model A-100) modified for the purposes of the present investigation. The modifications included the removal of the magazine, food cups, and manipulandum. Two six-watt, 120 volt incandescent lamps (type 6S6) were mounted on the sides of the conditioning chambers, six inches above the grid floor. These lights provided one component of the compound CS. Continuous illumination of the chambers was provided by a single six-watt, 120 volt lamp (type 6S6) mounted on the rear clear Plexiglas panel of the chamber. The illumination in the chamber was reduced by black electricians tape attached to the Plexiglas panel. The tube of a water bottle, filled with tap water, protruded into the chamber through a hole in the front panel located two inches above the grid floor and two inches from the right side of the chamber. The chambers were individually housed in LeHigh Valley sound attenuated chambers (Model A-64).

Programming and recording equipment was located in an adjacent room. Subjects' licking responses were recorded via Grason-Stadler

Drinkometers (E4690A-1). The second component of the compound CS, white noise, was delivered by a Grason-Stadler Noise Generator (901A). The intensity of the white noise was calibrated at 82 decibels (re: .0002 dynes/cm^2) by a Brüel and Kjaer Sound Level Meter (type 4131/32) set on the linear fast scale. The UCS, a 1 milliampere scrambled shock, was delivered through the grid floors of the chambers by Grason-Stadler Shock Generators (E1064GS). The 30.5 second CS coterminated with the 0.5 second UCS.

The experiment proceded through four phases: preliminary training and habituation, CER conditioning, CER extinction, and the test for spontaneous recovery. All subjects were initially placed on water deprivation for six days. During this period water was available at their home cages for 20 minutes each day. Food was always available in their home cages throughout the investigation. After initiation of the experiment, the subjects' entire daily ration of water was consumed within the daily 10 minute sessions.

Pretraining and habituation to the potential CS were conducted during the first two sessions. Within each session, 10 CS presentations were given during alternate 30 second periods. The subjects' first lick started the programming equipment in the first replication, while in the second replication the programming equipment was started manually by the experimenter immediately after placing the rats into their respective chambers.

All subjects received eight conditioning trials, two within a session. During the first replication the subjects' twentieth lick

started the programming equipment while the experimenter started it in the second replication. The first trial of each session was presented randomly either 30, 60, or 90 seconds after the initiation of the session with the second trial occurring 3 minutes thereafter. A trial consisted of pre-CS, CS, and post-CS recording periods each of 30 seconds duration. Following the second trial subjects remained in the chamber and were allowed to drink for the remainder of the session.

Forty massed extinction trials were administered on the day following the eighth conditioning trial. The extinction trials were identical to those presented during habituation. To prevent satiation and thus enable the subsequent testing for recovery, the drinking tube was removed during extinction.

Following extinction, subjects were randomly assigned to one of seven groups with 12 subjects in a group. The test for recovery was conducted at intervals of 3.5, 30, 60, 180 minutes, and 24 and 72 hours after the last extinction trial. All subjects were removed from the conditioning chambers and returned to their home cages for the test interval. A seventh group remained in the chamber and was tested 3.5 minutes after extinction to evaluate the effect, if any, of the removal from the chamber during the recovery interval. During the recovery interval the 24 and 72 hour groups were given water at their home cages for 10 minutes each day. The test for recovery consisted of one 10 minute session identical to the conditioning sessions except the UCS was omitted.

CHAPTER III

RESULTS

An $\underline{A}$-test (Sandler, 1955) was used to assess the effect of the presentation of the CS during the second day of habituation. No significant difference was found between the number of responses produced during the period of silence and the number produced during the period of stimulation ($\underline{A} = .44$, df = 80, $p \geqslant .10$).

The data, in terms of acquisition and recovery suppression ratios, are presented in Figure 1. The analysis of the effect of the conditioning trials on performance is given in Table 1. The suppression ratios of the 3.5 minute group, which remained in the chamber for the recovery interval, did not differ significantly from the 3.5 minute group which was removed from the chamber for the recovery interval ($\underline{t} = 1.59$, df = 22, $p > .20$). The analysis of variance of the test suppression ratios for the six recovery groups is presented in Table 2. The Newman-Keuls test for between group differences (Winer, 1962) disclosed that the 30 minute group differed significantly from the 24 hour group ($p < .05$) and that the 3.5 minute group was significantly different from all the groups ($p < .05$).

The mean percentage of spontaneous recovery of conditioned suppression as a function of the recovery interval is presented in Figure 2. The percentages were calculated by subtracting each subject's suppression on the test trial from .5 and dividing this by .5 minus the subject's suppression ratio on the last conditioning trial. Both 3.5

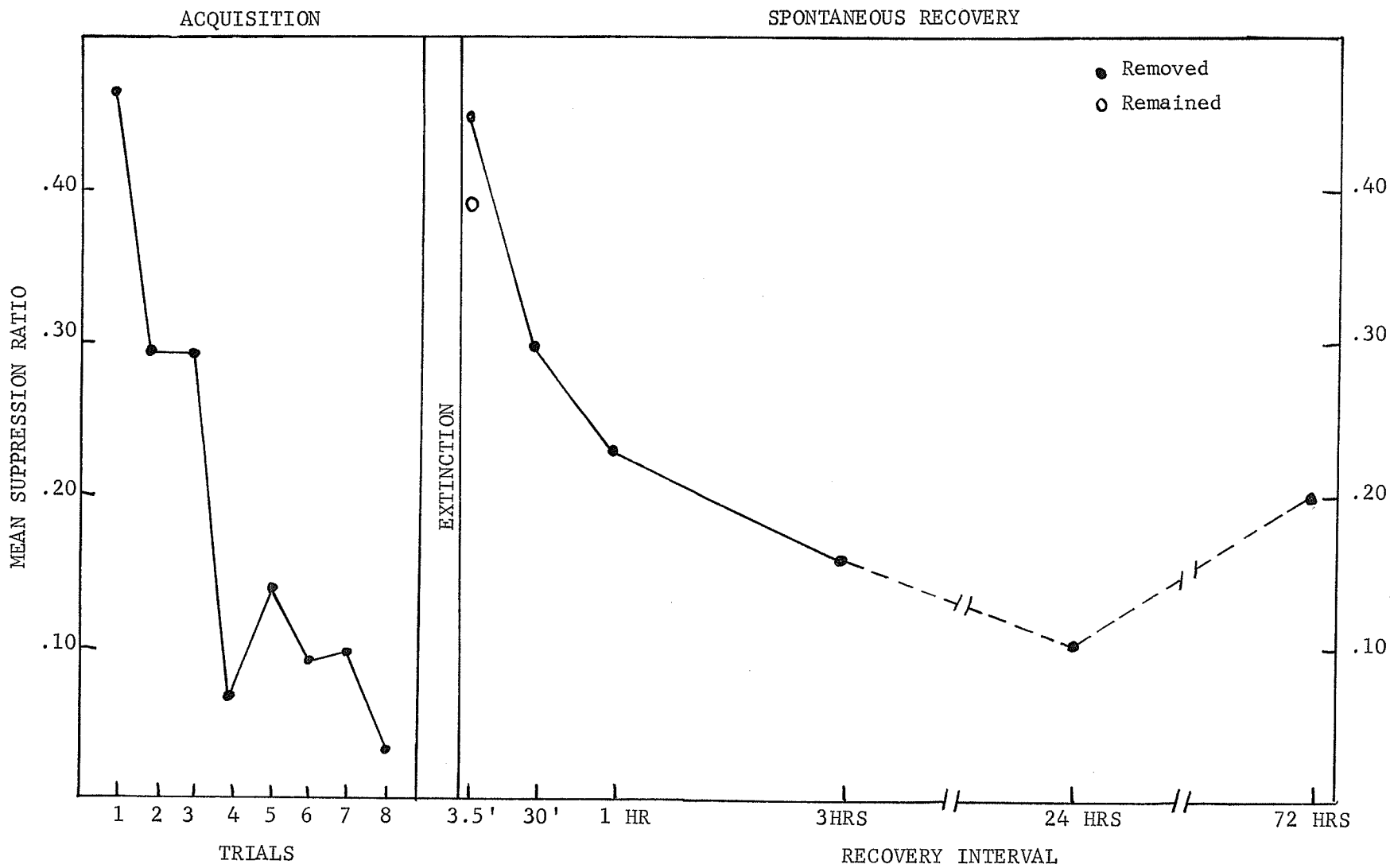

Fig. 1. The left panel depicts the mean suppression ratios for all subjects as a function of acquisition trials. The right panel shows the spontaneous recovery of conditioned suppression as a function of the time interval between the last extinction trial and the recovery test trial using mean suppression ratios as the measure of recovery.

TABLE 1

ANALYSIS OF VARIANCE OF THE SUPPRESSION RATIOS OF ACQUISITION

Source	df	SS	MS	F	p
Between Subjects	83	4.34805			
Within Subjects	588	31.13366			
Trials	7	13.25247	1.89321	61.53	.001
Error	581	17.88119	.03077		
Total	671	35.48171			

TABLE 2

ANALYSIS OF VARIANCE OF THE SUPPRESSION RATIOS OF THE TEST FOR SPONTANEOUS RECOVERY

Source	df	SS	MS	F	p
Recovery Interval	5	.85180	.17036	9.48	.001
Error	66	1.18619	.01797		
Total	71	2.03799			

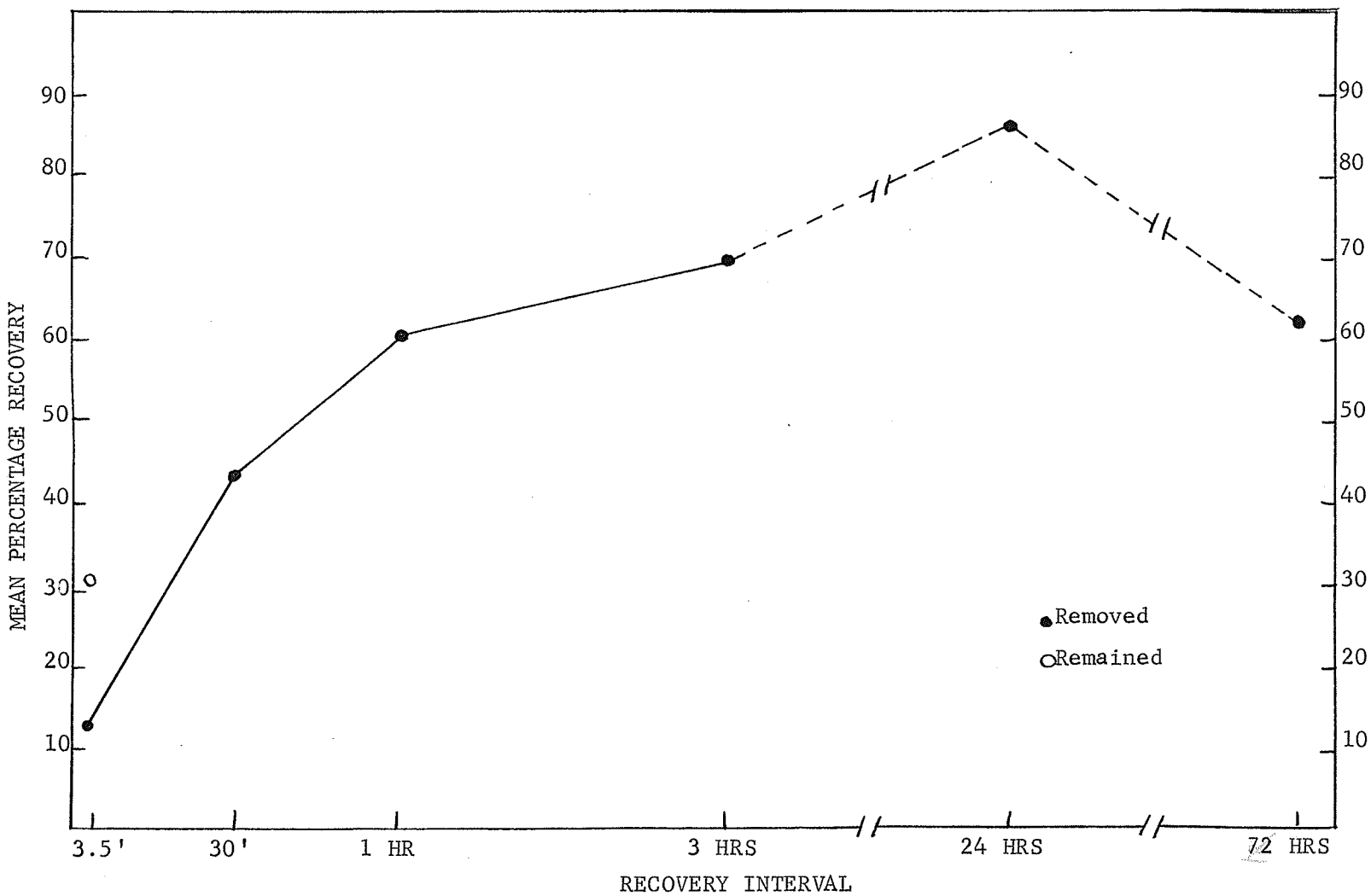

Fig. 2. Mean percentage of spontaneous recovery of conditioned suppression as a function of the time interval between the last extinction trial and the recovery test trial.

TABLE 3

ANALYSIS OF VARIANCE OF THE PERCENTAGE OF SPONTANEOUS RECOVERY

Source	df	SS	MS	F	p
Recovery Interval	5	37,389.18	7,477.84	8.67	.001
Error	66	56,901.96	862.15		
Total	71	94,291.14			

minute recovery groups displayed no differential amounts of spontaneous recovery ($t = 1.59$, df = 22, $p < .20$). The over-all analysis of variance of the recovery groups is presented in Table 3. The Newman-Keuls test revealed that the percentage of spontaneous recovery of the 3.5 minute group was significantly different from all other groups ($p < .05$) and that the 24 hour group was reliably different from the 30 minute group ($p < .05$).

The acquisition and spontaneous recovery of conditioned suppression using the number of responses produced during the period of the CS are presented in Figure 3 and the analysis of variance of the acquisition data is presented in Table 4. Again there was no difference between the two 3.5 minute groups ($t = 1.70$, df = 22, $p > .10$). Following the analysis of variance of the recovery groups, Table 5, the Newman-Keuls test was performed and revealed that the 3.5 minute group differed significantly from all other groups ($p < .05$) and that the 30 minute group varied reliably from the 72, 24, and 3 hour groups ($p < .05$).

The left panel of Figure 4 shows the mean number of responses produced during the period of the pre-CS as a function of acquisition trials and Table 6 presents the analysis of the data. The right panel of Figure 4 portrays the mean number of pre-CS responses of the recovery groups. A *t*-test revealed that there was no significant difference between the two 3.5 minute groups ($t = .66$, df = 22, $p > .60$). The analysis of variance of the six recovery groups is found in Table 7. The Newman-Keuls test disclosed that the 3.5 minute group significantly differed from the 72 hour group ($p < .05$).

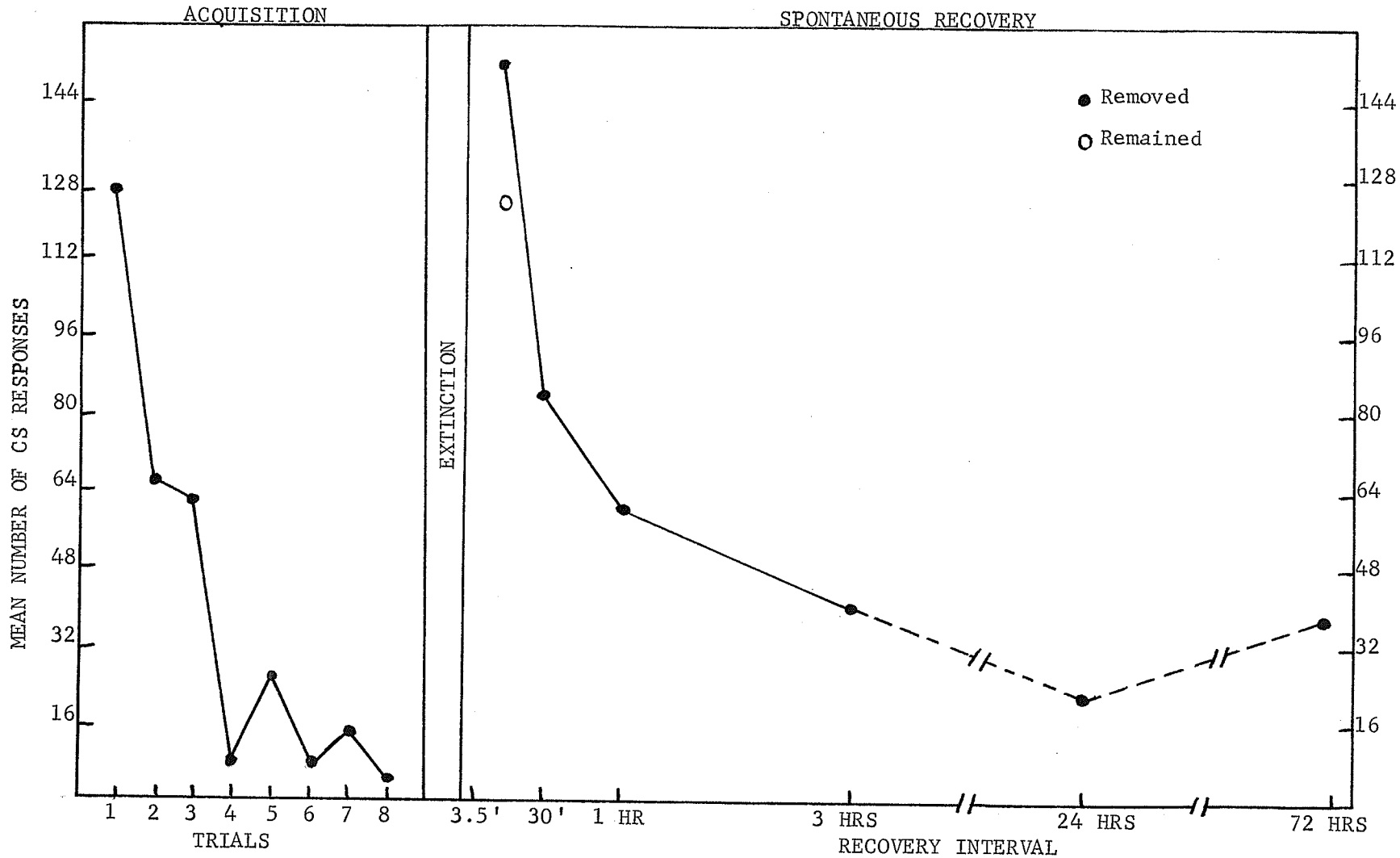

Fig. 3. The mean number of responses produced during the period of the CS as a function of acquisition trials is shown in the left panel. The right panel depicts the spontaneous recovery of conditioned suppression as a function of the time interval between the last extinction trial and the recovery test trial using the mean number of responses produced during the period of the CS as the measure of recovery.

TABLE 4

ANALYSIS OF VARIANCE OF THE NUMBER OF RESPONSES PRODUCED DURING THE PERIOD OF THE CS DURING ACQUISITION

Source	df	SS	MS	F	p
Between Subjects	83	265,225.23			
Within Subjects	588	1,707,299.33			
Trials	7	1,043,964.62	149,137.80	130.63	.001
Error	581	663,334.71	1,141.71		
Total	671	1,972,524.56			

TABLE 5

ANALYSIS OF VARIANCE OF THE NUMBER OF RESPONSES PRODUCED DURING THE PERIOD OF THE CS ON THE TEST FOR SPONTANEOUS RECOVERY

Source	df	SS	MS	F	p
Recovery Interval	5	133,095.3	26,619.1	15.43	.001
Error	66	113,848.6	1,725.0		
Total	71	246,943.9			

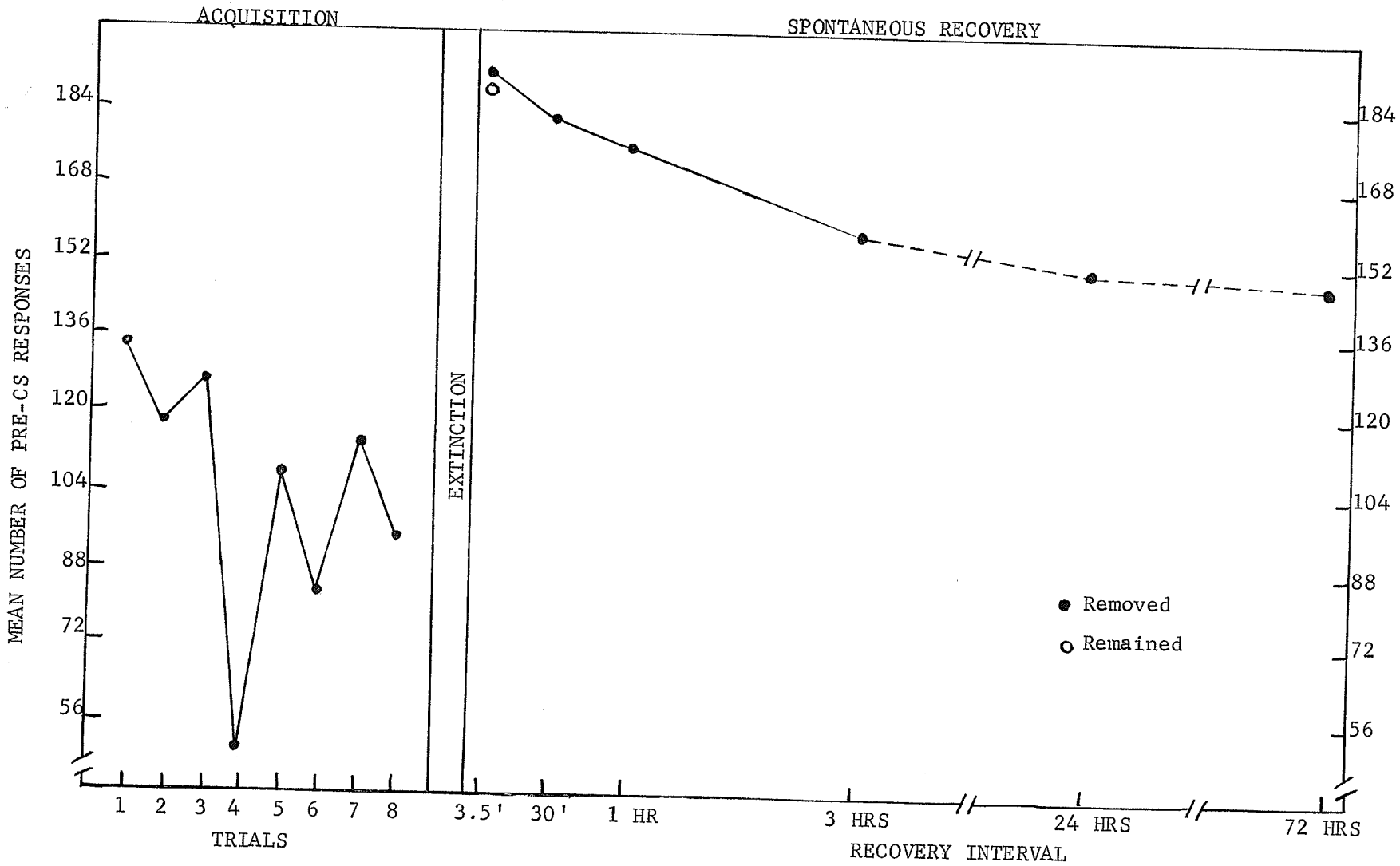

Fig. 4. The mean number of responses produced during the period of the pre-CS as a function of acquisition trials is depicted in the left panel. The right panel portrays the mean number of responses produced during the period of the pre-CS as a function of the time interval between the last extinction trial and the recovery test trial.

TABLE 6

ANALYSIS OF VARIANCE OF THE NUMBER OF RESPONSES PRODUCED DURING THE PERIOD OF THE PRE-CS DURING ACQUISITION

Source	df	SS	MS	F	p
Between Subjects	83	440,865.4			
Within Subjects	588	2,240,288.7			
Trials	7	438,714.1	62,673.4	20.2	.001
Error	581	1,801,574.6	3,100.8		
Total	671	2,681,154.1			

TABLE 7

ANALYSIS OF VARIANCE OF THE NUMBER OF RESPONSES PRODUCED DURING THE PERIOD OF THE PRE-CS ON THE TEST FOR SPONTANEOUS RECOVERY

Source	df	SS	MS	F	p
Recovery Interval	5	18,836.0	3,767.2	2.89	.025
Error	66	85,988.0	1,302.8		
Total	71	104,824.0			

CHAPTER IV

DISCUSSION

The conditioning procedure employed in this investigation resulted in the pronounced suppression of licking behavior in the presence of an initially neutral CS as indicated by two dependent measures: the suppression ratio and the number of responses during the CS. This finding partially replicates and supports the use of the James and Mostoway (1968) conditioning procedure. Also, the significant reduction in baseline responding (pre-CS) has been found by others to be a reliable counterpart of conditioned suppression (e.g., Annau & Kamin, 1961; Mostoway, 1968).

Whether the subjects remain in the apparatus during the recovery interval, at least for a very short interval, does not appear to differentially affect spontaneous recovery. No differences between the two 3.5 minute groups were found with any of the measures used. However, inspection of the figures indicates that possibly this factor could be a significant one and investigation at longer recovery intervals is suggested.

The suppression ratios, the most frequently used measure of conditioned suppression, indicate that the curve of spontaneous recovery is a rapidly rising, negatively accelerated function of the type found for other CRs (Ellson, 1939; Grant, Hunter, & Patel, 1958). It appears that conditioned suppression attains an intermediate level of recovery within 30 minutes and reaches its asymptotic level of recovery within

24 hours. Although a substantial, though non-significant, decrease in the amount of recovery at 72 hours was found, this group differed reliably only from the 3.5 minute group. This trend for a decrease in the amount of recovery between 24 and 72 hours, evident in all three measures, cannot be attributed to an increase in the thirst drive since there were no differences in baseline (pre-CS) responding in subjects tested 24 and 72 hours after extinction. Therefore, while further research is warranted at longer recovery intervals, it seems justified to assume that conditioned suppression reached its maximum level of recovery within 24 hours and maintained this level for at least 48 additional hours.

A more meaningful measure of spontaneous recovery may be the percentage of recovery since it is based upon within-subject changes in performance. As can be seen by comparing Figures 1 and 2, the curves of recovery very closely resemble each other. The between-groups analysis of the percentage data revealed the same differences found with suppression ratios. That is, the 3.5 minute group displayed significantly less recovery, 13.4 percent, than did any of the other groups and the 30 minute group displayed significantly less recovery (44.3 percent) than did the 24 hour group which attained a level of 86.5 percent recovery of conditioned suppression. Therefore, not only did conditioned suppression rapidly recover from extinction within a short time, but it also recovered a considerable amount of its original strength.

The use of the number of responses produced during the period of

the CS provides a measure of conditioned suppression supportive of the suppression ratios but caution must be exercised when examining these data. The between-groups analysis disclosed that significantly fewer responses were produced during the CS by the 3.5 minute group than by all other groups and that the 30 minute group produced significantly fewer responses than the 3, 24, and 72 hour groups. However, this measure does not provide information about the subjects' behavior when the CS was not present and subsequently conveys little information pertaining to the effect of the CS on ongoing behavior. In general though, the maximum amount of recovery was found to occur at 24 hours and the curve of these data resembles those of suppression ratios and percentage recovery.

An incidental finding of this study was that spontaneous recovery of baseline, pre-CS, suppression was a linear function of the recovery interval. The analysis of these data revealed that there were significantly fewer responses produced during the period of the pre-CS after the 72 hour interval than after the 3.5 minute interval. The McAllisters (McAllister & McAllister, 1962, 1965, 1968) have shown that fear is not only conditioned to a discrete CS, but also to the particular situational or static cues present. The conditioning which takes place to the static cues has been found to be weaker than that which takes place to the discrete CS (McAllister & McAllister, 1962). Since fear is assumed to be the CR which causes conditioned suppression, in the present experiment fear would be expected to be conditioned to the static cues of the conditioning chambers. The decline, during acquisition, in the number of

responses produced during the period of the pre-CS, Figure 4, may be viewed as representing the conditioning of fear to these cues. Mostoway (1968) demonstrated, through a trial by trial analysis, that the suppression of baseline responding extinguishes concommitantly with the extinction of the suppression of responding to the discrete CS. Comparison of the pre-CS data for the last acquisition trial and for the groups tested for recovery at the shorter intervals provides indirect evidence of the same effect in the present investigation. If fear is assumed to be conditioned to both the discrete CS and the static cues, and if the discrete CS spontaneously recovers its ability to elicit the CR of fear, so also, should the static cues recover their fear eliciting capability. The recovery of the static cues would result in the suppression of responding in their presence, just as response suppression occurs to the CS. The degree of suppression to the static cues would also be expected to be less than that to the discrete CS because of the initially weaker conditioning of fear to these cues. Since, in the present investigation, the number of responses produced during the period of the pre-CS was recorded prior to the presentation of the CS, the suppression of baseline responding, which was found to increase as a function of the recovery interval, must be the result of the spontaneous recovery of fear elicited by the situational cues. Also, the amount of baseline suppression was found to be small as would be expected. This finding is not only of empirical interest, but also has theoretical value in that it may be interpreted as supporting the position that conditioned suppression is the result of a classically conditioned fear response.

Inhibition theory of the type proposed by Pavlov (1927) provides an explanation of the results of this investigation. According to this view, the spontaneous recovery of conditioned suppression that was found here was due to the dissipitation of internal inhibition built up during extinction. As previously mentioned, Pavlov stated that complete recovery of an extinguished CR was possible. This investigation did find a substantial amount (86.5 percent) of recovery after 24 hours. It seems possible that total recovery of conditioned suppression could be attained, provided the test interval was long enough.

In summary, the function relating the amount of spontaneous recovery to the recovery interval was found to be a rapidly rising, negatively accelerated curve similar to that found for other CRs. This relationship was obtained when recovery was measured in terms of suppression ratios, percentage of recovery, and the number of responses produced during the period of the CS. Evidence that the situational cues recover their ability to elicit the CR was also found. In addition, this experiment supports the finding of Estes and Skinner (1941) that after massed extinction trials, conditioned suppression "almost" totally recovers within 24 hours.

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