NUMBER OF REINFORCEMENTS, NUMBER OF ACQUISITION TRIALS, AND PERCENTAGE OF REINFORCEMENT IN HUMAN LEARNING

RESISTANCE TO EXTINCTION AND RATE OF LEVER-PULLING IN HUMAN SUBJECTS AS A FUNCTION OF:
(1) NUMBER OF CORRECT ACQUISITION TRIALS AND PERCENTAGE OF REINFORCEMENT, AND
(2) NUMBER OF REINFORCEMENTS AND PERCENTAGE OF REINFORCEMENT

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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
October 1963

MASTER OF ARTS (1963)
Psychology

McMASTER UNIVERSITY
Hamilton, Ontario.

TITLE: Resistance to extinction and rate of lever-pulling in human subjects as a function of: (1) number of correct acquisition trials and percentage of reinforcement, and (2) number of reinforcements and percentage of reinforcement.

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NUMBER OF PAGES: vi, 55

SCOPE AND CONTENTS:

Two experiments were carried out.

The first study was designed to investigate the effects of percentage of reinforcement and the number of correct acquisition trials, when combined, on the number of responses to extinction and rate of lever-pulling of human subjects.

The second study was designed to investigate the effects of percentage of reinforcement combined with number of reinforcements on the same dependent variables.

Analysis of the data revealed: (1) resistance to extinction in both experiments, was inversely related to the percentage of reinforcement; (2) resistance to extinction was inversely related to the number of reinforcements but was not affected by the number of correct acquisition trials; (3) the mean rate of responding was inversely related to the number of reinforcements but was not affected by either percentage of reinforcement or number of correct acquisition trials; and (4) the number of responses per unit of time increased during acquisition and decreased during extinction in both studies.

The results were discussed in relation to theories stemming from previous partial reinforcement studies.

ACKNOWLEDGEMENTS

The author wishes to express his thanks and appreciation to Dr. D.W. Carment, thesis director, for his generous assistance, guidance, and encouragement throughout all phases of the research.

Thanks are also due to Drs. P.L. Newbigging and A.H. Black for their advice.

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CHAPTER ONE

INTRODUCTION

The partial reinforcement effect or PRE is an empirical generalization that has been fairly well established in a variety of situations for both human and infrahuman subjects. The bulk of the research, however, has been with animals. It may be stated: "All other things equal, resistance to extinction after partial reinforcement is greater than after continuous reinforcement when behavior strength is measured in terms of single responses." (Jenkins & Stanley, 1950)

However well this generalization may be founded, the theoretical notions put forward to account for the phenomenon have been none too adequately supported by the experimental data collected to date.

The two theories which receive the most support are the expectancy and discrimination theories. Briefly, the first theory maintains that partial reinforcement results in an expectation of irregular reinforcement and that continuous reinforcement results in an expectancy of regular reinforcement. (Humphreys, 1939) The second theory suggests that "resistance to extinction is a function of the similarity of the acquisition stimuli to the extinction stimuli". (Lewis & Duncan, 1960) The more similar the two conditions, the greater the resistance to extinction.

The second theory seems to best explain the data obtained from experiments using human Ss, and so it was within this framework that the present two studies were conceived.

An attempt was made, in each of the following studies, to better understand the dynamics of the PRE when different percentages of reinforcement are factorially combined with certain other variables considered important in the learning process. One of these variables is the number of acquisition trials, and the other is the number of reinforcements received during the acquisition period.

An attempt will be made to relate the findings to the discrimination hypothesis which, along with other theories, is outlined more fully in the historical section.

CHAPTER TWO

HISTORICAL REVIEW

For many years psychologists have been aware of important differences between the effects of continuous and partial reinforcement in learning situations. Continuous reinforcement refers to that condition wherein every trial or every response in a series is followed by a reinforcement. In contrast, partial or intermittent reinforcement refers to that condition whereby reinforcement is given at least once, but not after all of the trials or responses in a series. Thus, in any learning study, the conditions of reinforcement may range anywhere from 0% (pseudo-conditioning; extinction) to 100% (continuous) reinforcement.

Jenkins & Stanley, in their 1950 review of partial reinforcement studies, outlined the following empirical generalization stemming from a comparison of partial and continuous reinforcement data: "All other things equal, resistance to extinction after partial reinforcement is greater than after continuous reinforcement when behavior strength is measured in terms of single responses". (p. 222) This generalization was arrived at on the basis of investigations dating back to 1939. To-day, it remains largely as valid as it was then.

In this section will be outlined those studies which are relevant to the above generalization as well as the theories which have developed with the research. Somewhat heavier emphasis will be given to certain of these theories in that the writer believes them to be more directly related to the studies which are described in the following section. Also, this review will be concerned most with those experiments involving a free-responding or a semi-operant situation (i.e., a free-responding condition within the limits imposed by instruction) and using human subjects. Animal experiments and classical conditioning studies will be mentioned only when they seem directly concerned with the same independent variables that are manipulated in the studies presented in the next section.

In addition to distinguishing between partial and continuous reinforcement, one may also distinguish among the various ways in which reinforcements can be delivered. The two major parameters are: (1) according to a temporal basis, and (2) according to a response basis. Only those studies concerned with reinforcing on a response basis shall be dealt with here.

The studies which the writer intends to review in this section are those concerned with the following independent variables either alone or in combination: (1) percentage of reinforcement, (2) number of acquisition trials, and (3) number of reinforcements. The dependent measures are resistance to extinction and rate of responding.

I Percentage of Reinforcement

Jenkins & Stanley (1950) summarized the data from 17 studies (11 using animal subjects; 6 using humans) which compared the effects of partial and continuous reinforcement on extinction. These studies were consistent in demonstrating that resistance to extinction is greater following partial reinforcement than following continuous reinforcement. Jenkins & Stanley state: "Resistance to extinction is usually greater after partial reinforcement, and typically, response strength in conditioning is less for the same case. For example, periodic reinforcement yields a lower rate of responding in conditioning then does continuous reinforcement (at least when the periodic interval is fairly long); this lower rate appears to carry over into extinction. When the letter is prolonged, the periodically reinforced subjects ultimately exceed the continuous ones in total number of responses, although rate of response early in extinction may be greater for the continuous subjects. With a truncated extinction, however, the situation may be reversed. When the higher response strength characterizes the partial reinforcement instance in conditioning(as in fixed ratio situations), the potential effect of this variable cannot be ignored. From a practical standpoint, as has been pointed out, the relative response strengths in performance may be of little consequence as long as the desired behavior occurs occasionally." (p. 218) This statement was based in part on the observations of Skinner (1938), as well as on the strength of the 17 studies.

One of the most provocative of these partial reinforcement experiments is Humphreys' (1939) study of "expectations". The subject's task was to indicate, by marking a record sheet, whether or not a second light was to come on following a signal light. Seventy-eight subjects were run through the sequence: 100% condition were extinguished and then used immediately as the 50% reward group. He found that with 100% reward, learning reached a 98% level. With the random series of 50% reinforcement, learning does not take place.

Detambel put forth a cogent criticism of Humphreys' study saying that his instructions prepared the subjects so that whenever the subject's "yes" was followed by the second light, the "yes"-response was strengthened. Whenever the second light failed to occur following a "non"-response, this alternate behavior was reinforced. Thus, during the extinction period, the complete absence of the second light strengthened the "no"-response to such an extent that it reached a level near 100% frequency, while the competing response of "yes" was never reinforced and hence approached zero. In addition, Humphreys had no way of evaluating the effects of order in his design.

Detambel tested his hypothesis in a situation consisting of a pair of keys and one light. A correct response was a key closure that turned on the light. The subjects were instructed to press the key they thought would turn on the light. Two groups parallel to Humphreys' were run (100% and 50% reinforcement, with Key A correct in training and Key B correct in extinction) along with a 50% and a 100% reinforcement group exposed to no reinforcement in extinction. A minimum of 120 extinction trials was given, with 25 subjects in each of the four groups.

When the procedure resembled Humphreys', the extinction curves were similar to his. Striking differences were found when reinforcement of the incompatible response was omitted in extinction; both curves dropped towards a chance level (50%), with the 100% reinforcement curve dropping the quickest. These findings clearly support Detambel's contention that Humphreys' procedure was contaminated by the introduction of an incompatible response so that extinction consisted of the differential weakening of one response and the strengthening of the other. (Jenkins & Stanley, 1950)

Following the initial studies of partial reinforcement which used only two percentages (50% and 100%) of reinforcement during acquisition, many investigators explored further along the dimension of percentage of reinforcement and employed several percentages of a wide range in their experimental designs. Many of these studies resulted in a ∩-shaped relationship between resistance to extinction and percentage of reinforcement in acquisition. The remainder of this section will be concerned with these investigations.

Grant, Hake & Hornseth (1951) in a verbal conditioning situation used 0%, 25%, 50%, 75%, and 100% reinforcement. They found that the percentage of positive responses during acquisition was an increasing function of percentage of reinforcement.

During extinction, the response rate dropped off rapidly for the 100% group, with increasing resistance to extinction for the 75%, 50% and 25% groups. The 25% group was the most resistant to extinction. As the 0% group (pseudo-conditioning) did not make many positive responses during acquisition, there was almost no resistance to extinction. Thus the results yielded a ∩ -shaped curve.

Grant & Schipper (1952), using the same percentages of reinforcement, counted the percentage of CR's in the acquisition and extinction periods of an eyelid conditioning situation. The CS was light and the UCS an airpuff. The results indicated that during acquisition, the percentage of CR's was an increasing function of percentage of reinforcement with the greatest response strength for the 100% group. During the extinction period, however, they found the greatest resistance to extinction was for the 50% and 75% groups, falling off for both the 25% and 100% groups. Again this yielded a ∩ -shaped curve.

Using 0%, 11%, 33%, 67%, and 100% reinforcement in another study, Lewis & Duncan (1957) asked their subjects to state an "expectation" of winning for each trial of a 9 trial acquisition series. The expectancies were quantified and the results showed them to be a direct function of percentage of reinforcement both during acquisition and extinction. The 100% group yielded the least resistance to extinction while the expectancy for this group dropped off very rapidly at the same time. The 0% group also showed a slight drop, suggesting a ∩ -shaped function.

Four of the above studies demonstrated a ∩ -shaped function when different percentages of reinforcement during acquisition were tested for effects on resistance to extinction. (Grant, Hake, & Hornseth, 1951; Grant & Schipper, 1952; Lewis, 1952; and Lewis & Duncan, 1957)

Because of the non-monotonic function Grant & Schipper hypothesized that two processes must be operating. The first is a discriminative one. The higher the percentage of reinforcement, the more the acquisition series should "stand out" from the extinction series, and the less the resistance to extinction should be. A discrimination process thus results in a decreasing function as a result of percentage of reinforcement. The second process is a learning one. For equal numbers of trials below some limit, and with a response starting close to zero response strength, the greater the percentage of reward, the greater the response strength should be. Thus, the learning process produces an increasing function while the descrimination process produces a trend in the opposite direction. The combination of these two should result in a ∩ -shaped function.

Lewis postulated that if Grant & Schipper were correct, the point of inflection of the ∩ would need to vary with the degree of learning. Hence he suggested that several percentages of reinforcement needed to be combined with several numbers of acquisition trials in the same experiment to verify this conjecture.

II <u>Number of Acquisition trials and Percentage of Reinforcement</u>

Lewis & Duncan (1956a, 1958a) using human subjects, in two studies combined different numbers of acquisition trials with different percentages of reinforcement. Although they found no interaction during extinction between the two variables, the larger number of acquisition trials in both cases, resulted in quicker extinction. Capaldi, in 1957 using human Ss and again in 1958 using rats, found the same thing; the more acquisition trials, the faster the extinction. Capaldi, however, found this rule to hold only for regular reinforcement, while Lewis & Duncan found it for irregular reinforcement as well.

Yaresower, Vlases, & Friedman (1960), using college students, assigned their subjects to one of six groups. They received either 10 or 30 presentations of a tone (CS) paired with a shock (UCS) on 10%, 30%, or 100% of the trials depending upon their respective group. Maximum resistance to extinction of a GSR with 10 acquisition trials occurred at the higher reinforcement percentages while an increase in the number of acquisition percentages caused maximum resistance to extinction at the lower reinforcement percentages. These results partly support a hypothesis favoring two processes involved in partial reinforcement effects.

Murillo & Capaldi (1961) adopted the hypothesis that extinction is reduced following increased training if, and only if, such increased training includes overlearning trials. With undergraduates as subjects, they tested this hypothesis using regular reinforcement (every 3rd trial was positive) and four levels of acquisition trials 12, 24, 48, and 60. The results supported the hypothesis; as the amount of training increased, resistance to extinction decreased. Murillo & Capaldi maintain that mere learning of a pattern of reinforcement or other relevant response is not sufficient to result in reduced resistance to extinction. The critical factor or factors responsible for reduced resistance to extinction seem to occur in the over-learning trials.

Senko, Champ, & Capaldi (1961) point out that whereas Murillo & Capaldi (1961) found reduced resistance to extinction following increased training under certain conditions, Williams (1938) and Perin (1942) had demonstrated just the opposite. Taken together, the results suggest that a ∩ -shaped function might describe the relationship between amount of training and resistance to extinction. To investigate this hypothesis, Senko, Champ, & Capaldi assigned 18 subjects (human) to each of 8 groups. Each group received a fixed, but different number of 100% reinforced acquisition trials immediately followed, in each case, by 20 trials of extinction training. The numbers of acquisition trials given were 0, 1, 3, 6, 12, 20, 40, or 80 trials.

The results supported the hypothesis that the relationship between amount of training and resistance to extinction is described by a ∩ -shaped function, and both agreed and disagreed with the results of Murillo & Capaldi (1961). Agreement centres about the fact that increased training resulted in reduced resistance to extinction. However, in the Murillo & Capaldi study reduced resistance occurred only after the event pattern was well learned, whereas in the present study it began to ovcur with the 6-trial group, prior to the time that 100% positive response occurred. Senko, Champ & Capaldi state: "The most plausible explanation for this descrepancy would appear to involve factors concerned with differences in the type of event pattern employed in the two studies." (p. 351) These differences may well be attributed to the fact that Murillo & capaldi used partial but regular reinforcement whereas Senko, Champ & Capaldi used continuous reinforcement.

Carment & Miles (1962), using college students, factorially combined three different levels of acquisition trials (8, 16, and 64) with three percentages of reinforcement (12½%, 25%, 50%), in a simple lever-pulling situation, a task they placed in the category of almost pure performance. Their dependent measures were the number of responses to extinction and the rate of responding during acquisition and extinction.

The results indicated that as the percentages of reinforcement increase, trials to extinction decrease. Also, it was noted that as acquisition trials increase, responses to extinction decrease. There was no interaction and no sign of a ∩ -shaped function.

These results are in accord with the findings of Murillo & Capaldi and support the notion of two processes operating in studies yielding a ∩ -shaped function. Carment & Miles suggested that a follow-up study should be done involving a more complex learning task. This suggestion encouraged the first of the two studies reported in this thesis.

III Number and Amount of Reinforcements

Humphreys (1943) based a bar-pressing study of rats on groups with equal numbers of reinforced responses. Two groups each received 18 reinforcements, one for making 18 responses, the other for making 52. Two other groups received only 7 reinforcements, one for making 18 responses and the other for 7. When the two groups were matched on the total number of trials (18 responses), it was found that the continuously reinforced rats were slightly superior in extinction behavior; but they also had two and one-half times as many reinforcements. Earlier studies had already indicated increasing resistance to extinction with increasing numbers of reinforced responses (Williams, 1938; Perin, 1943). This case clearly indicates a confounding of the contribution of number and pattern of reinforcements.

In a study designed to measure the effects of magnitude of reward when varied with different percentages of reinforcement, Lewis & Duncan (1957) combined four amounts of reward (1, 10, 25, and 10 cents) with five percentages of reinforcement (0%, 11%, 33%, 67%, 100%).

The results showed that resistance to extinction decreased as the percentage of reward was increased. The 50 ¢ reward group was the most resistant to extinction and varied significantly from the other three response groups. However, the other three groups did not differ significantly from one another. There was no interaction between percentage and amount of reinforcement.

In a similar study, Lewis & Duncan (1962) varied five percentages of reinforcement (0%, 11%, 33%, 67%, and 100%) with two magnitudes of reward, 1¢ and 5¢. They found neither the amount of reward nor the interaction between amount and percentage to be significant.

Hulse (1958), however, using rats in an enclosed alley with magnitudes of .08 gm. and 1.0 gm. pellets, found greater resistance to extinction with the larger sized pellets. These experiments differ too much in design to permit any reasonable accounting for their differences.

Logan, Beier, & Kincaid (1956) studied the effects on extinction of varying the magnitude of reward from trial to trial. That is, the animals (rats) were reinforced on every trial, but the amount of reward varied from trial to trial. They found that this procedure increased resistance to extinction.

Lewis & Duncan (1961) studied the effects of variable magnitude of reward on human subjects, and found no increased resistance to extinction as a function of the variability of the reward. However, they did find consistent though not significant evidence that the pattern of reward variability may affect resistance to extinction in that the pattern yielding the greatest stimulus change from acquisition to extinction resulted in fewest plays to extinction.

Yamaguchi (1961) tested for the effect of partial, continuous and varied magnitude reinforcement on acquisition nd extinction, using rats as subjects. The various groups exhibited similar acquisition performance but showed significantly different extinction effects. The partial reinforcement and the varied magnitude groups were more resistant to extinction than the continuous reinforcement group, with the varied magnitude reinforcement group lying intermediate between the other two groups in terms of this measure.

Although the evidence from these studies is none too consistent, it seems likely that increasing the number and / or the amount of reward during acquisition does lead to increased resistance to extinction, (Williams, 1938; Perin, 1943; Humphreys, 1943; Huke, 1958), as least as far as animal subjects are concerned. It also appears likely that varying the magnitude of reward during acquisition on a continuously reinforced basis leads to resistance to extinction superiority over a continuously rewarded group with non-variable reinforcement. (Logan, Beier, & Kincaid, 1956; Yamaguchi, 1961) Again this finding is best supported by animal studies.

IV Factorial Designs With Three Independent Variables

Hulse (1958) investigated the role of percentage of reinforcement (100% and 46%), amount of reinforcement (1.0 gm. and .08 gm.), and duration of goal-box confinement (10 sec. and 60 sec.) as parameters of a running response in rats.

The animals were given 1 trial per day and in all received 6 pretraining, 24 training, and 19 extinction trials.

The results during extinction were as follows: (a) partial reinforcement produced greater resistance to extinction than continuous reinforcement, but the differences were much greater if large as compared with small rewards were used during training; (b) large as compared with small rewards produced greater resistance to extinction if partial reinforcement was used, but less resistance to extinction if continuous reinforcement was used; and (c) if goal-box confinement times were changed from training to extinction was less than if no such change occurred.

Wagner (1961), also using rats and a runway situation, factorially combined two levels of acquisition trials (16 and 60), and two amounts of food reward(.08 gm. and 1.0 gm.) with two percentages of reinforcement (100% and 50%). Of primary interest during extinction were the effects of size of reward and number of acquisition trials on the magnitude of commonly obtained superiority of the partially reinforced as compared to continuously reinforced Ss. (This well-established superiority of partially reinforced groups to continuously reinforced groups in resistance to extinction is often referred to as the "partial reinforcement effect" or PRE). The extinction results showed that whereas the PRE did not vary with number of prior acquisition trials, it was markedly greater following 1.0 gm. than following .08 gm. rewards. The increased PRE with larger rewards reflected not only greater resistance to extinction of partially reinforced Ss but also less resistance to extinction of continuously reinforced Ss with large as compared to small rewards. These results confirm those of Hulse (1958). The number of acquisition trials in this study did not seem to be a factor when combined with different percentages and amounts of reinforcement.

Theory

Numerous theories have been proposed to account for the partial reinforcement effect and to relate the independent variables to certain parametric laws.

Lewis (1960) ennumerates seven theories developed to explain the PRE: (1) response-unit, (2) aftereffects, (3) expectancy, (4) secondary reinforcement, (5) competing response, (6) mediating response, and (7) discrimination.

The response-unit hypothesis as put forward by Skinner (1938) and Mowrer and Jones (1945) is that if more than one response is required to obtain a reinforcement, then the whole block of non-reinforced trials ending with a reinforced trial should be treated as one unit, strengthened by the reinforcement. Their results indicate fewer response units in extinction for partially reinforced groups, although more single responses occur. This theory was based largely on data obtained from fixed-ratio reinforcement procedure in a free-responding situation; it has not been able to explain as well the data obtained under other reinforcement conditions, particularly those employing a discrete trial design.

The aftereffects theory of Sheffield (1949) distinguishes between the aftereffects of reinforcement as opposed to the aftereffects of nonreinforcement. Sheffield's contention was that the greater resistance to extinction after partial reinforcement is based on the conditioning of the aftereffects of non-reinforcement in the stimulus compound during training. In extinction following partial reinforcement, the stimulus situation through generalization is more like conditioning than after continuous reinforcement. The stimulus change from training to extinction is much greater for the 100% rewarded group than for the partially rewarded group. The hypothesis was tested by comparing extinction after massed and distributed training on the assumption that the aftereffects of reinforcement or nonreinforcement in conditioning would be dissipated by spaced training. The results were in agreement with the hypothesis: Massed training produced significantly greater resistance to extinction for partial over continuous reinforcement, while distributed practice reversed the findings slightly.

Wilson, Weiss, and Amsel (1955), and Lewis (1956) were unable to obtain the same results as Sheffield, however, when they duplicated her design. Tyler (1956) found greater resistance to extinction following partial reinforcement than following continuous after a 15 minute acquisition interval, and Weinstock (1954, 1958) on two occasions, found the PRE even when acquisition trials were spaced 24 hours apart.

Probably the most convincing evidence against the after-effects theory came from Tyler, Wortz, & Bitterman (1953) who reasoned that if Sheffield were right, then alternating reinforcement with nonreinforcement in a simple pattern should give a greater PRE than a random pattern, since alternation would maximize the number of times nonreinforcement follows reinforcement. Their results were just the opposite, showing that random reinforcement results in greater resistance to extinction than does alternating reinforcement.

The above results were all obtained from animal studies; even so, it is even more difficult to argue in favor of the after-effects theory to account for data obtained from research with humans. It seems likely that any explanation offered by the after-effects theory could equally as well, and perhaps even better, be explained in terms of the discrimination hypothesis which will be outlined later.

The expectancy theory which appears to have developed from Humphreys' (1939) study, which has already been outlined, states simply that continuous reinforcement results in an expectancy of regular reinforcement and partial reinforcement results in an expectancy of irregular reinforcement. Since it is easier to change from a regular expectancy of one kind (that rewards occur on every trial) to a regular expectancy of another kind (that rewards do not occur on any trial), than it is to change from an irregular expectancy (rewards occur on only some of the trials) to a regular expectancy, continuous reinforcement results in quicker extinction than does partial reinforcement.

Lewis argues against the adequacy of such an interpretation as, "Perhaps every study...could be reinterpreted according to an expectancy notion, and that is the main weakness of such a view. There seems to be no way of disproving it." (p. 23)

The secondary reinforcement hypothesis appears to have been introduced into this area by Denny (1946), who argued that on reinforced trials the goal-box stimuli are associated with primary reinforcement and therefore should acquire secondary reinforcement power. On nonreinforced trials and during extinction, secondary reinforcement should be taking place which therefore retards extinction.

The main attack on this theory came from the Texas group, Bitterman, Fedderson, and Tyler (1953), and Elam, Tyler, and Bitterman (1954). They found that rats receiving their reinforced trials in one goal-box and their nonreinforced trials in another goal-box, extinguished faster when placed in the goal-box in which they had previously been rewarded than in the goal-box which was used for nonreinforced trials. According to the secondary reinforcement hypothesis, the results should have been just the opposite.

It seems unlikely from the evidence that the secondary reinforcement hypothesis in itself is sufficient to explain the PRE; at its best it is difficult to distinguish from a discrimination hypothesis, according to Lewis. (Lewis, 1960, pp. 20-21)

Weinstock (1954) introduced a "competing response" theory to account for the increased resistance to extinction following partial reinforcement as opposed to continuous. He contends that for partially reinforced Ss, these competing responses are made during acquisition on the nonreinforced trials; they "habituate" and drop out. Thus when extinction begins, since these competing responses have already dropped out, the instrumental response is able to continue strongly. No habituation occurs during acquisition for the continuously reinforced group, so that the onset of these competing responses during extinction results in a rapid decline of the instrumental response.

Stanley & Clayton (1955) assumed on the basis of Weinstock's theory that if ratio of reinforcement were held constant, resistancy to extinction should be a direct function of the opportunity provided for the extinction of competing responses. They tested this inference with an overall ½ ratio of food reinforcement of a running response in rats. They believed that, within limits, the occurrence and extinction of competing responses in the goal-box on nonreinforced acquisition trials should be a direct function of goal-box confinement on these trials. The results opposed Weinstock's hypothesis as the acquisition delay group was not more resistant to extinction than the immediately rewarded group.

Tyler (1956) has pointed out that Weinstock's theory does not explain why random reinforcement results in a greater PRE than alternating reinforcement.

Hulse & Stanley (1956) presented a theory much like Weinstock's but without the "habituation" concept. They maintained that subjects learn to do something other than eat during nonreinforced acquisition trials. This "something else" they learn under partial reinforcement occurs during the extinction period and prevents the conditioned eating response from being rapidly extinguished. However, this notion also runs into difficulty when Freides' (1957) data are considered. Freides found that goal-box behavior (approaching food) could extinguish while a runway response remained strong.

Wilson, Weiss, and Amsel (1955) and Amsel (1958) have argued for a mediating response to account for the PRE. During partial reinforcement an emotional response (frustration) develops on the nonreinforced trials, and becomes conditioned to the instrumental response which preceded it on the reinforced trial. During extinction, the partially reinforced group whose instrumental responding is accustomed to competing with the emotional responding on reinforced trials, persists. The continuously reinforced group during acquisition, however, has had no emotional response conditioned to its instrumental response; hence, on extinction trials, the instrumental responding decreases quickly.

This theory appears to be best supported by animal studies involving discrete trial situations. It does not appear to be adequate, however, in explaining many of the findings of research using humans as subjects. For example, it is difficult to see how a mediation theory would explain the fact that increasing the number of acquisition trials with partial reinforcement leads to reduced resistance to extinction.

The discrimination theory, which appears to have been first advanced by Mowrer & Jones (1945), states that resistance to extinction is a function of the similarity of the acquisition stimuli to the extinction stimuli; the more similar the stimulus conditions in the two situations, the greater the resistance to extinction. This theory has received much support from the data of both animal and human studies and appears to be especially adept at explaining the latter.

Longenecker, Krauskopf, and Bitterman (1952) and Tyler, Wortz, and Bitterman (1953) showed that random reinforcement resulted in greater resistance to extinction in rats than did a simple alternating pattern. They argued that this must be the result of some serial patterning that occurs with alternation, enabling subjects to discriminate the acquisition series and to stop responding quickly when it ceases.

"In several studies Lewis & Duncan (1956a, 1956b, 1957, 1958a, 1958b) found that 0% reinforcement showed more resistance to extinction than 100% reinforcement, and more than most other percentages of reinforcement." (Lewis, 1960, p. 18) They argued that 0% reinforcement during acquisition was more like extinction than the acquisition series with any other percentages of reinforcement were, and thus <u>should</u> result in a longer extinction period.

The situation here, employing a "one-armed bandit", differed from most others in that almost no learning was involved. All Ss knew how to pull a lever on entering the experimental room. In one of these studies (1958a) they found that extinction was quicker following a long acquisition series. Capaldi (1957, 1958) confirmed these results. Lewis & Duncan attributed this effect to the pure performancy situation in which a relatively long acquisition series would serve to make the initial stimulus situation more stable, and hence more discriminable from extinction.

These results and those of Carment & Miles (1962, described above) suggested that different levels of acquisition trials should be combined with different percentages of reinforcement in a design which required the Ss to learn a more complex task. The first factorially combined (1) number of correct acquisition trials and percentage of reinforcement (implying that now a specific response must be made as opposed to just pulling a lever as in the Lewis & Duncan and Carment & Miles situations), and (2) number of reinforcements and percentage of reinforcement. Again, the dependent measures were resistance to extinction and rate of lever-pulling.

It should be noted that little mention has been made in this section about rate of responding as a dependent measure. The reason for this is that most of the literature which reports rate as a dependent variable appears to be centered around the work of Skinner and his followers. These studies have been concerned largely with animals and the purpose behind them appears to be an interest in the effects of delivering reinforcements according to various schedules. (Ferster and Skinner, 1957) Under all conditions of the two experiments reported in this thesis the schedules of reinforcement remain the same (variable ratio) and therefore are not considered in the statistical analyses. For this reason a history of "Skinnerian" studies is not included in this thesis.

The use of rate measures in these studies was justified on two counts: (1) the equipment (cumulative-recorder) was handy and easy to set-up, and (2) it was deemed worthwhile to study any effects which might result as a function of the three independent variables used, particularly in view of the paucity of previous studies of the PRE which have included this measure.

Carment & Miles (1962) found the rate of responding to be significantly affected by the number of acquisition trials ($p < .05$). It was hoped that this finding would be further substantiated by the following experiments.

The next section will describe the method and apparatus employed in this study.

CHAPTER THREE

METHOD

Subjects and Apparatus:

Two separate but similar experiments were conducted. First, those aspects which were the same will be detailed and then the differences will be outlined.

The subjects used in each experiment were 120 male and female students enrolled in introductory and second year psychology courses at McMaster University. Each subject was randomly assigned to one of twelve experimental groups so that there were 10 subjects in each group.

The apparatus consisted of a Gerbrands-Lindsley operant conditioning panel connected to Grason-Stadler automatic programming and timing units in an adjoining room. Briefly, the operant conditioning panel is a 2' x 2' structure mounted at a 60° angle against a wall. Two levers, projecting from the right and left of the panel can be pulled straight out to a distance of about ten millimeters. When released, the lever is returned to a starting position by a variable tension spring. Above each lever there is a stimulus light and in the middle and below the levers, a receptacle is located into which the reinforcements are delivered. Above the panel a digital counter was located which recorded the cumulative number of reinforcements that the subject received. This was for the subject's information. To the right of the panel was a switch connected to a light in the recording room so that the subject could signal when he wished to quit. In both experiments a reinforcement was one poker chip.

The reinforcement dispenser is similar to a vending machine. Following a correct response, a reinforcement is delivered down an aluminum chute into the illuminated receptacle in the experimental room. A hand-operated switch in the recording room activates the two 100 watt bulbs (stimulus lights), which are situated above the levers on the instrumental panel and which serve as the signal for the subject to begin responding.

Procedure:

Each subject was run individually. After entering the experimental room he was seated comfortably before the instrumental panel and given the following instructions:

"This experiment is designed to compare the ability of people to learn. By pulling these levers in a certain way you can make poker chips drop into this receptacle. This is how to operate the levers. Just pull them up and a spring will pull them back by themselves. You do not have to hold them. Be careful not to pull both levers at the same time. You may pull in any manner you wish as long as you pull only one lever at a time.

Your task is to make as many chips as possible fall down.

This counter will record the number of chips that drop into the receptacle so that you can keep track of the number you have earned. In other words, you can judge your progress by the counter and the number of chips that fall. I am not going to tell you when to quit; you must decide this for yourself. However, if you stop before you have earned as many chips as possible it will count against you. It will also count against you if you keep pulling after you have earned all the chips you can. If you want to get a good score, it is important that you consider carefully when you should stop. When you decide to stop, just flip this switch down, like this, to let us know you have finished. Them, I will record your score.

Start pulling when these panels light up, and then pull for as long as you wish. Try to make as many chips as you can. Any questions? Okay, the lights will come on in a moment."

If there were any questions the instructions were repeated. The experimenter then left the subject alone in the experimental room.

Experimental Design:

The design of both experiments required that the subject learn to make a correct response. The designated response was one right-handed pull followed in succession by two left-handed pulls on the levers. (RLL) All other responses were recorded but did not "pay-off".

Experiment I

In this study four percentages of reinforcement, 25%, 50%, 75% and 100% were factorially combined with three levels of correct acquisition trials, 8, 16 and 32. That is, there were four percentages of reinforcement and three conditions under which the subjects had to make a required number of correct responses during the acquisition period in order to obtain the maximum amount of reinforcement. Thus, one trial was a correct response, (R11), irrespective of the total number of lever-pulls made during that interval. The number of reinforcement received during acquisition, then, was allowed to vary.

Experiment II

The second experiment differed in design only in that the number of correct acquisition trials was not controlled and the n number of reinforcements received during acquisition was experimentally varied. This time, four percentages of reinforcement, 25%, 50%, 67% and 100% were factorially combined with three levels of numbers of reinforcement, 4, 8 and 12 poker chips.

In some instances in each experiment, subjects quit before completing the acquisition series. These subjects were randomly replaced and their data are not included in these studies.

The dependent variables in both experiments were: (a) the number of responses from completion of acquisition to quitting (trials to extinction), (b) the mean rate of responding during acquisition and extinction, and (c) the number of responses made per vincentized tenths of time in both acquisition and extinction.

CHAPTER FOUR

RESULTS & PRELIMINARY DISCUSSION

In this section the results of each experiment will be presented and discussed separately.

Experiment 1

a) Responses to extinction:

The two dependent measures used were the total number of lever-pulls (a single lever-pull was considered a response) made during the extinction period and the number of correct responses (RLL) emitted during the same period. The raw data were transformed into logarithms to reduce heterogeneity of variance and then subjected to a standard treatments by levels analysis of variance.

Tables I and II summarize these results.

Table I about here

Table II about here

It can be seen from the two tables that the analyses based on total number of responses made to extinction and total number of correct responses made during the same period reveal the same

TABLE I

Analysis of Variance of Total Lever-pulls to Extinction

Source	df	ms	F	P
Percentage of Reinforcement (P)	3	4.26	21.20	$<.001$
Acquisition trials (A)	2	.08	—	—
P X A	6	.11	—	—
Within cells (error)	108	.20		
Total	119			

TABLE II

Analysis of Variance of Correct responses to Extinction

Source	df	ms	F	P
Percentage of Reinforcement (P)	3	3.26	16.95	<.001
Acquisition trials (A)	2	.37	1.95	—
P X A	6	.12	—	—
Within cells (error)	108	.19		
Total	119			

factors to be significant. In both cases this is the percentage of reinforcement during acquisition. ($F = 21.20, 16.95$; d.f. = 3 and 108; $p < .001$) This is illustrated graphically in figure 1.

Figure 1 about here

It can be seen that as the percentage of reinforcement increases, the total number of responses made during extinction decreases. The trend for number of correct responses to extinction is nearly identical and hence is not presented.

b) Rate of responding:

A second response measure employed in this study was the subject's rate of responding. This was obtained for each subject by dividing the number of responses made by the total time taken to make them. The average of these data was then determined separately for the subjects under each experimental condition, first for the acquisition period and then for the extinction period. Analysis of these data indicated that there were no differences among these mean response rates attributable to either number of correct acquisition trials or percentage of reinforcement.

c) Number of responses per unit of time:

Finally, the acquisition period for each subject was divided into ten equal parts and the number of responses made during each tenth determined and averaged for all subjects under each ex-

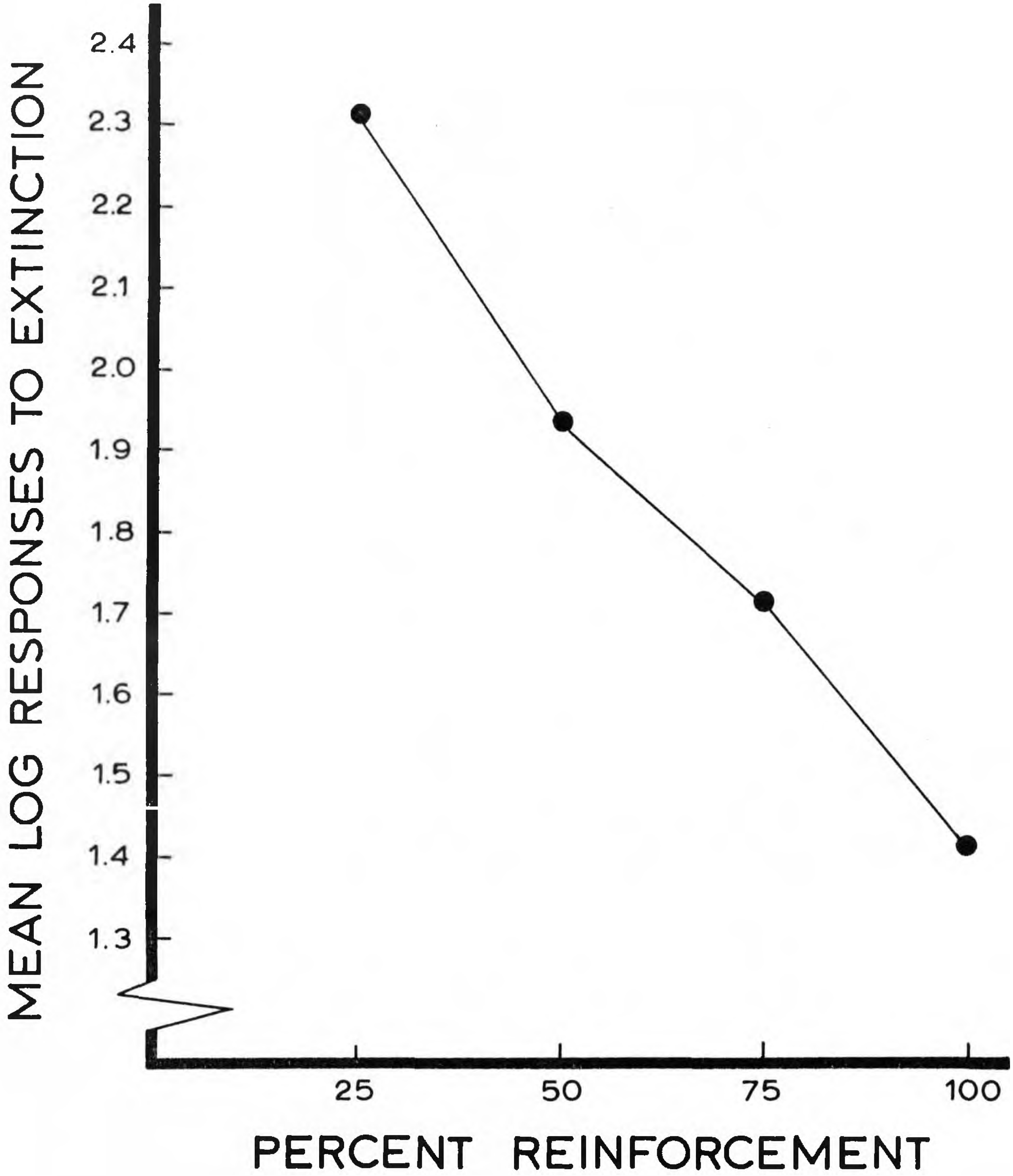

Figure 1. Mean log responses to extinction as a function of percentage of reinforcement for combined groups 25%, 50%, 75%, and 100%.

perimental condition. This allowed a comparison of the groups which would reveal any changes which might be present in the number of responses made as acquisition progressed.

A similar procedure was carried out separately for the extinction period.

When the acquisition responses were plotted[1] across time there was a significant increase in the number of responses made per vincentized tenth of time. ($F = 65.04$; d.f. = 1 and 108; $p < .01$) The trend analysis revealed no significant differences between the slopes of the three trends. These slopes are shown in figure 2.

Figure 2 about here

Figure 3 shows the data averaged across percentages of reinforcement. Again, there is a general increase in number of responses made per vincent tenth of time during the acquisition period, ($F = 2.77$; d.f. = 3 and 108; $p < .025$)

Figure 3 about here

During extinction the number of responses per vincent tenth when plotted with percentage of reinforcement as the parameter,

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[1] The differences between the lines on the ordinate reflect the different total number of responses made by the groups under each of the experimental conditions plotted.

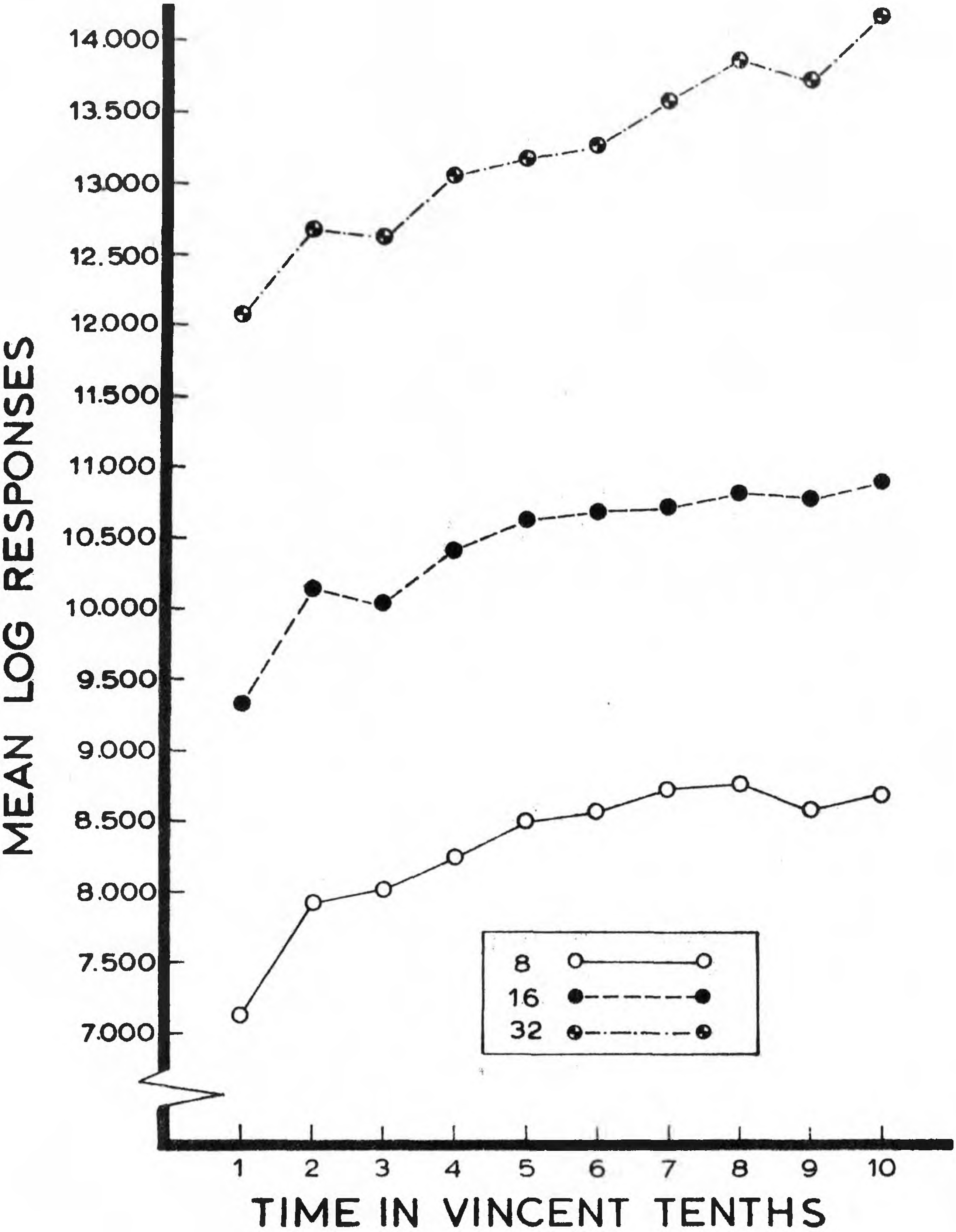

Figure 2 The mean number of responses per vincent unit of time during acquisition with the number of correct acquisition trials as the parameter.

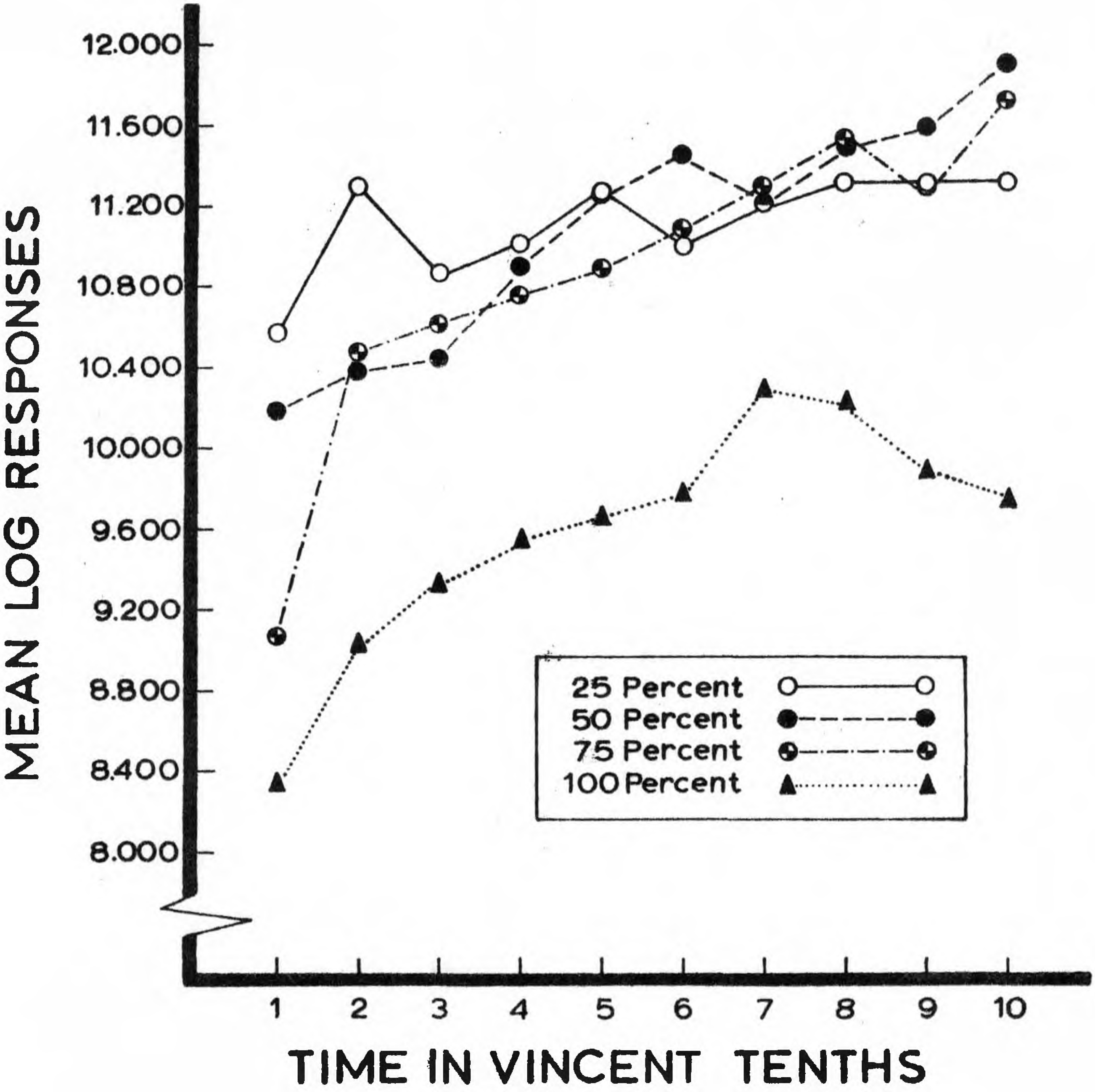

Figure 3. The mean number of responses per vincent unit of time during acquisition with percentage of reinforcement as the parameter.

reveal a general downward trend ($F = 33.95$; d.f. = 1 and 108; $P < .01$). That is, the number of responses made per vincent tenth gradually decreases during this period. However, the trend analysis revealed no significant differences among the slopes of the four trends. This is illustrated in figure 4.

Figure 4 about here

When plotted with the number of correct acquisition trials as the parameter, however, there is a significant difference found in the curvature of these lines. ($F = 3.63$; d.f. = 2 and 108; $P < .05$) Figure 5 shows that in the 8 acquisition trial group there is an initial increase in the number of responses made which then rather rapidly declines; whereas in the 16 and 32 groups there is a general decline until the last two blocks of trials whereupon the number of responses made drops off rapidly.

Figure 5 about here

Discussion:

In this first study it was demonstrated that an inverse relationship holds between the number of responses emitted during the extinction period and the percentage of reinforcement of a correct response during acquisition. That is, as the percentage of reinforcement increased, the number of responses to extinction

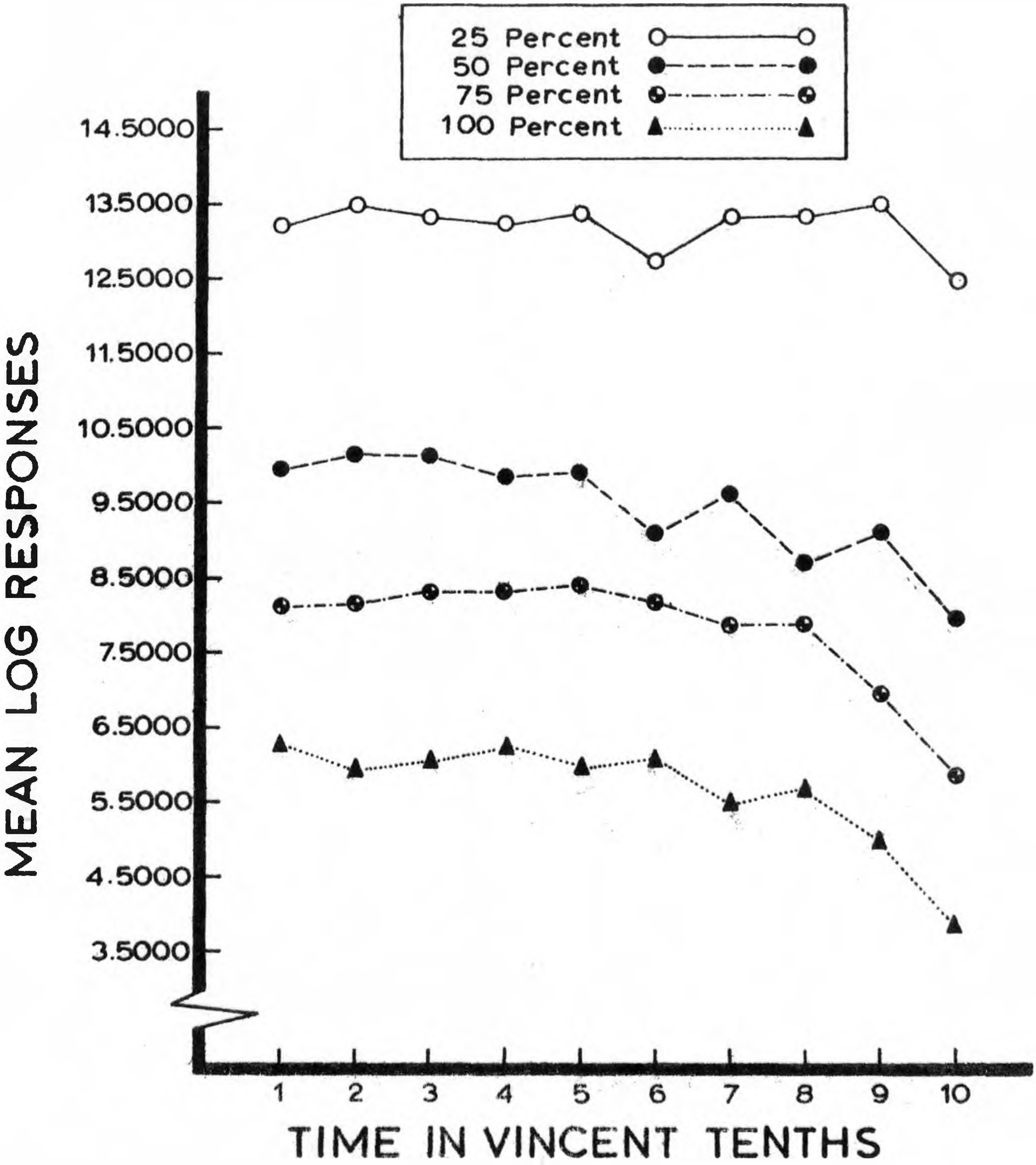

Figure 4. The mean number of responses per vincent unit of time during extinction with percentage of reinforcement as the parameter.

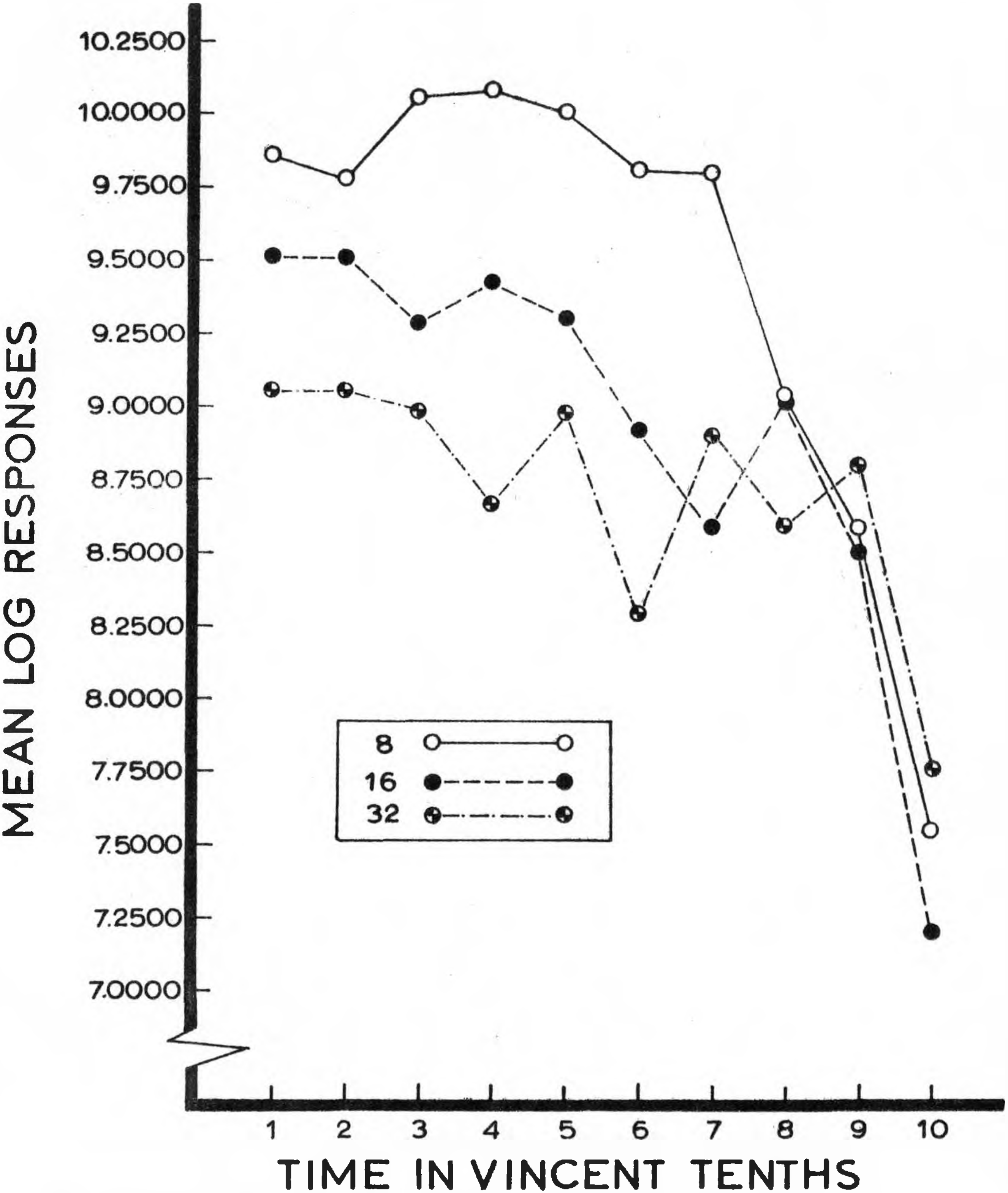

Figure 5. The mean number of responses per vincent unit of time during extinction with the number of correct acquisition trials as parameter.

decreased. Similarly, it was shown that using the total number of single responses emitted during extinction as a criterion measure gave the same results as did the total number of correct responses made during that period as the criterion measure. No effect attributable to the number of correct acquisition trials was found. This finding led to the next experiment in which the combined independent variables were the percentage of reinforcement of the correct response and the number of reinforcements received during the acquisition period. Thus, in the next study the number of reinforcements were experimentally varied.

Experiment II

a) Responses to extinction:

Again, the two dependent measures used were the total number of lever-pulls (responses) emitted during the extinction period and the number of correct responses (RLL) made during the same period. The raw data were transformed into logarithms, as before, and then subjected to an analysis of variance.

Table III shows the results for the total number of

Table III about here

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responses to extinction and table IV demonstrates the results for

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Table IV about here

TABLE III

Analysis of Variance of Total Lever-pulls to Extinction

Source	*df*	*ms*	*F*	*P*
Percentages of Reinforcement (P)	3	.10	6.93	<.001
Number of Reinforcements (R)	2	1.43	9.92	<.001
P X R	6	.18	1.29	——
Within (error)	108	.14		
Total	119			

TABLE IV

Analysis of variance of Correct Responses to Extinction

Source	df	ms	F	P
Percentages of Reinforcement (P)	3	1.08	8.03	<.001
Number of Reinforcements (R)	2	.64	4.76	<.025
P X R	6	.27	1.93	——
Within (error)	108	.14		
Total	119			

the number of correct responses to extinction.

Both these tables demonstrate similar significant differences which can be attributed to the percentage of reinforcement of the correct response in acquisition. ($F = 6.93$, $F = 8.03$; d.f. = 3 and 108; $P < .001$) In addition, these analyses reveal that the number of reinforcements received is a significant factor in determining both the total number of single responses and the number of correct responses made in this period. In both tables a significant effect of number of reinforcements is found. ($F = 9.92$, $F = 4.76$; d.f. = 2 and 108; $P < .001$, $P < .025$) There was, however, no difference between those groups receiving 8 and 12 reinforcements; hence, the significance must be accounted for by the difference between the groups receiving 4 reinforcements during acquisition, and the other two groups.

Figure 6 illustrates the mean log responses to extinction

Figure 6 about here

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as a function of the percentage of reinforcement. Since the plot of the correct responses to extinction is essentially the same it is not presented here.

It is clear that as the percentage of reinforcement increases, the number of responses to extinction decreases. The most marked deviation in these data is for the groups which were reinforced 67% of the time. It should be noted that it is this 67%

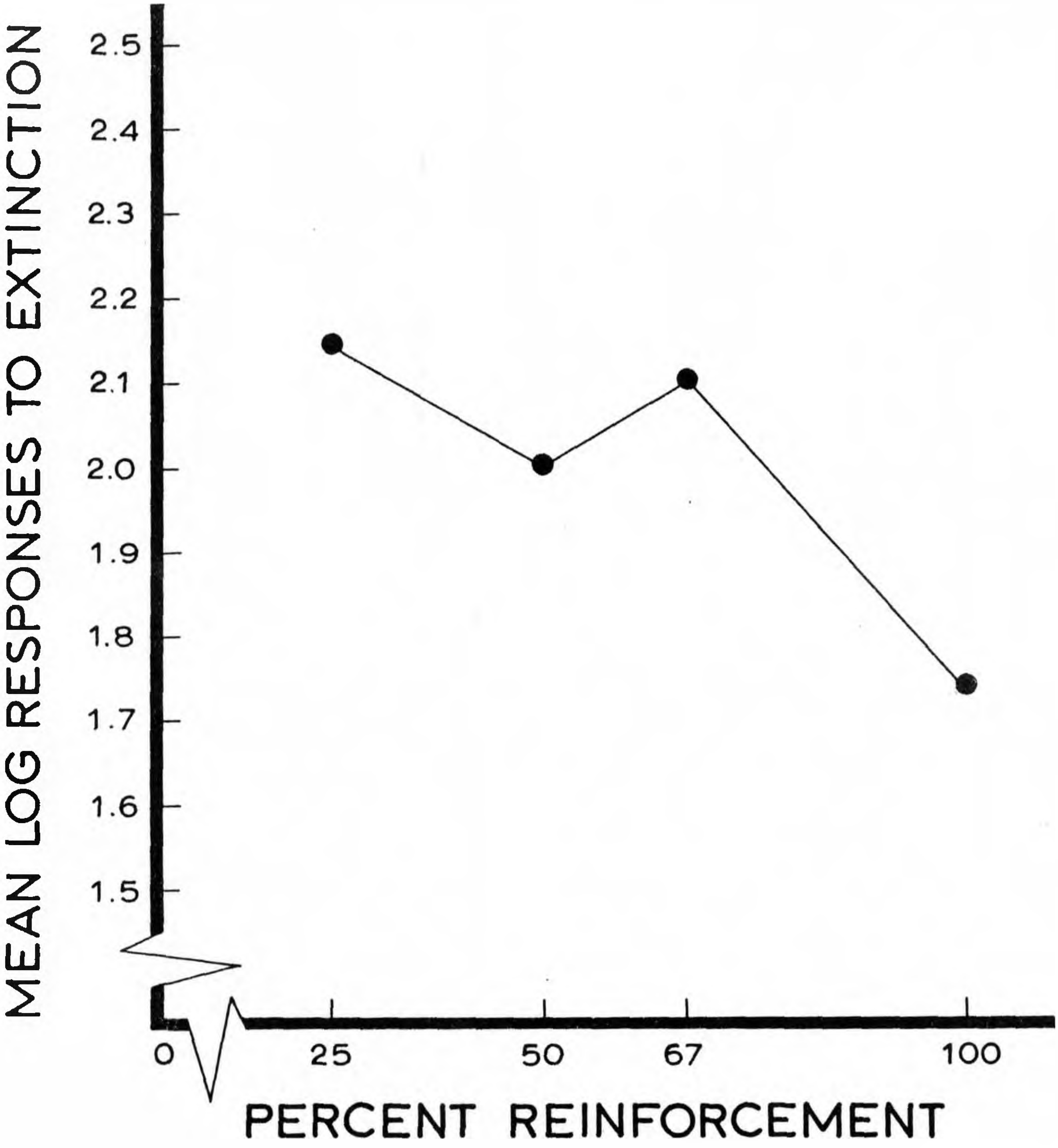

Figure 6. Mean log responses to extinction as a function of percentage of reinforcement for combined groups 25%, 50%, 67%, and 100%.

condition which breaks the general downward trend.

Figure 7 shows the mean log responses to extinction plotted

Figure 7 about here

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with number of reinforcements received during the acquisition period as the parameter.

Here we see that generally as the number of reinforcements increases, the number of responses made during extinction decreases.

b) Rate of responding:

An analysis of variance performed on the mean rates of responding for each group revealed a significant effect attributable to the number of reinforcements received during acquisition. ($F = 3.78$; d.f. = 2 and 108; $P < .05$) This analysis is shown in table 5.

Table 5 about here

As the number of reinforcements increased, the mean rate of responding during the extinction period decreased for all groups. The mean rate of responding was not affected by the percentage of reinforcement.

c) Number of responses per unit of time:

Again in this experiment, the raw data were divided into vincent tenths for both acquisition period and extinction period, separately. Again, it was noted that there was an increase in

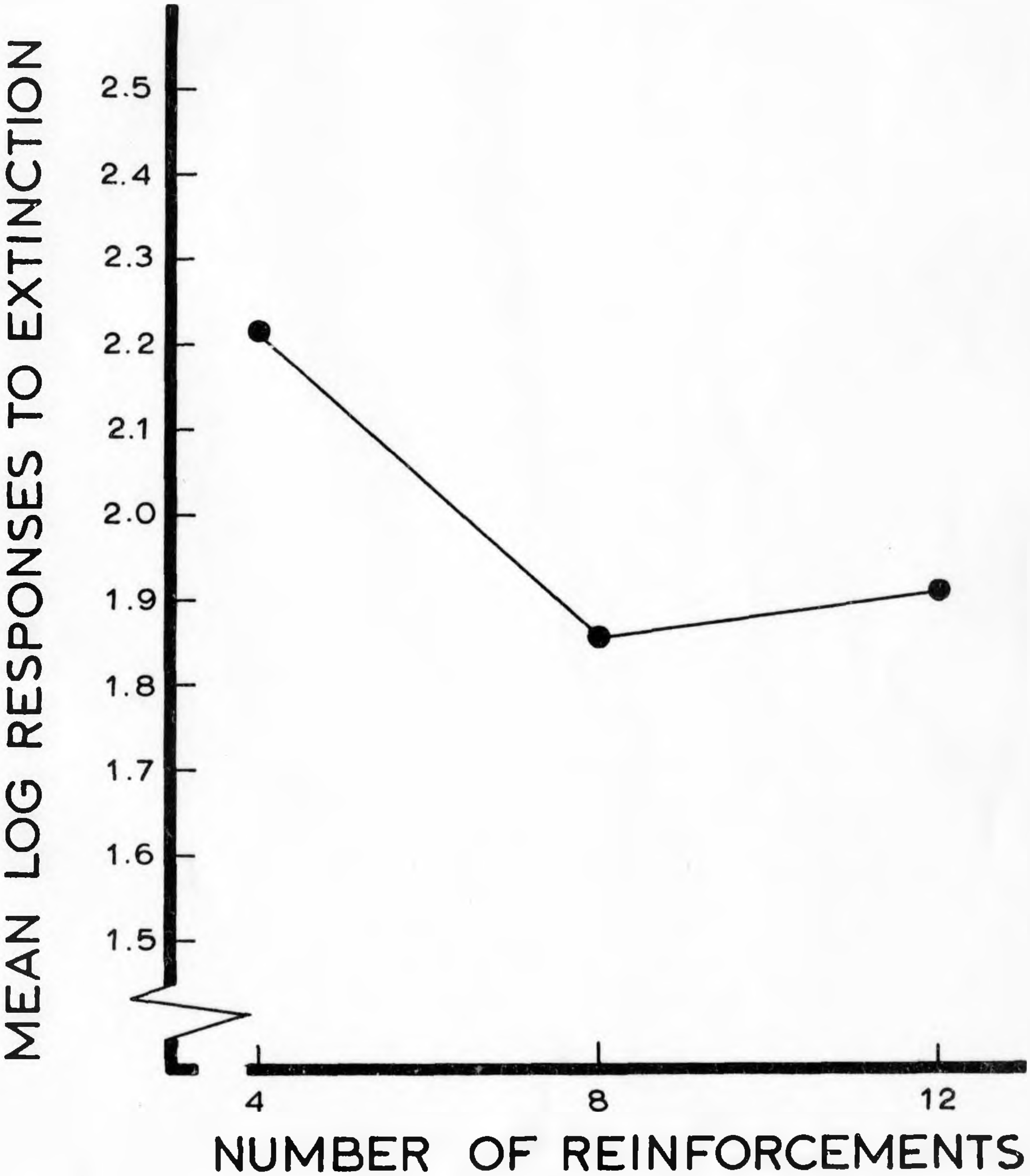

Figure 7. Mean log responses to extinction as a function of the number of reinforcements for combined groups 4, 8, and 12.

TABLE V

Analysis of Variance of Rates of Responding

Source	*df*	*ms*	*F*	*p*
Percent Reinforcement (P)	3	.07	—	—
Number of Reinforcements (R)	2	1.02	3.78	$<.05$
Interaction (P X R)	6	.39	1.44	—
Within (error)	108	.27		
Total	119			

the number of responses made during acquisition per vincent tenth of time, but a trend analysis revealed no significant differences between the slopes of the four lines.

Figures 8 and 9 show these trends.

Figure 8 about here

Figure 9 about here

And once again, during the extinction period there was a gradual decrease in the number of responses made per vincent tenth of time but no significant differences between the slopes of the lines.

Figures 10 and 11 depict these lines.

Figure 10 about here

Figure 11 about here

Discussion:

The results of this experiment complement those of experiment 1. Whereas in the first experiment the number of correct acquisition trials was not a relevant variable when combined with

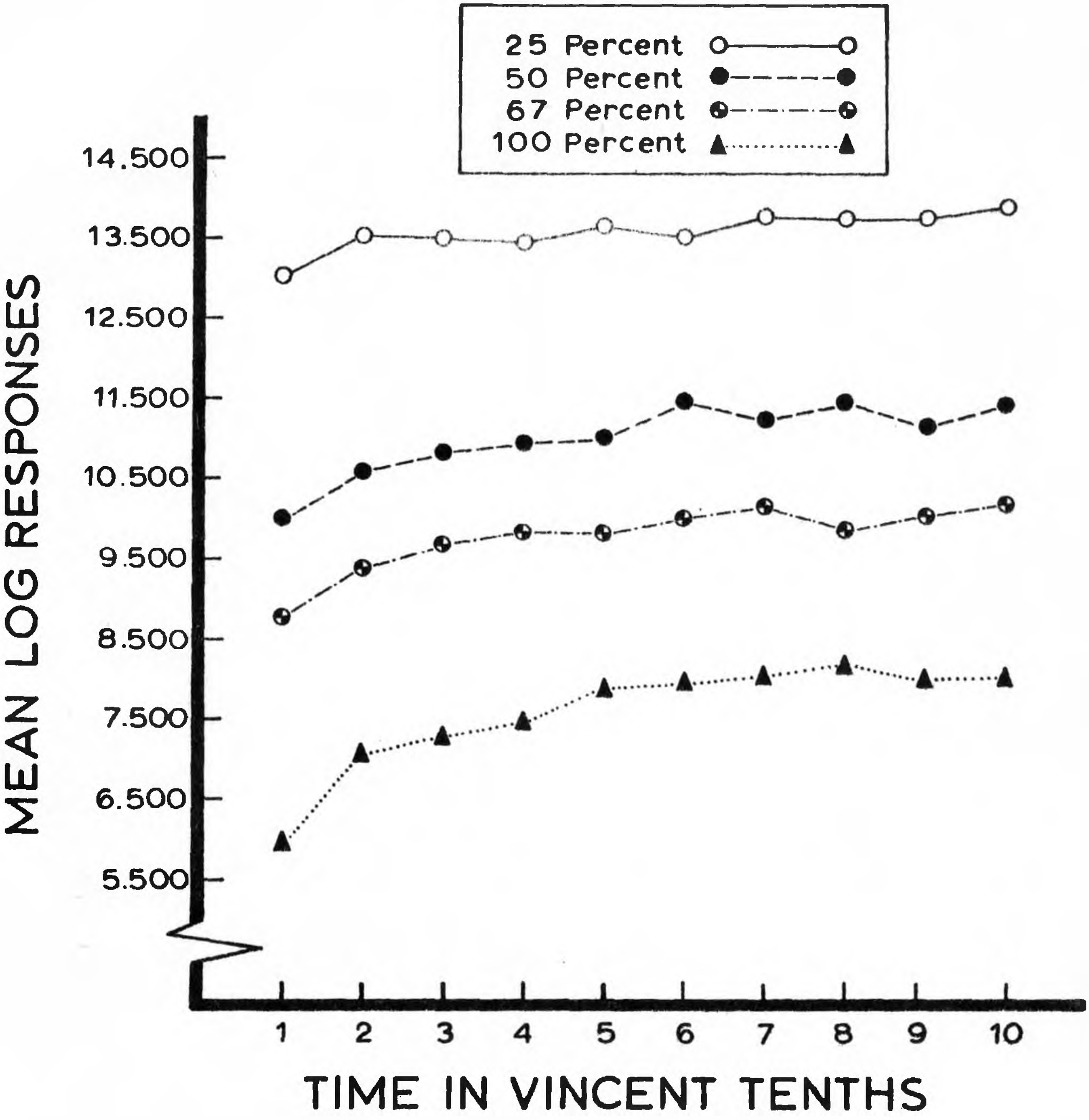

Figure 8. The mean number of responses per vincent unit of time during acquisition with percentage of reinforcement as the parameter.

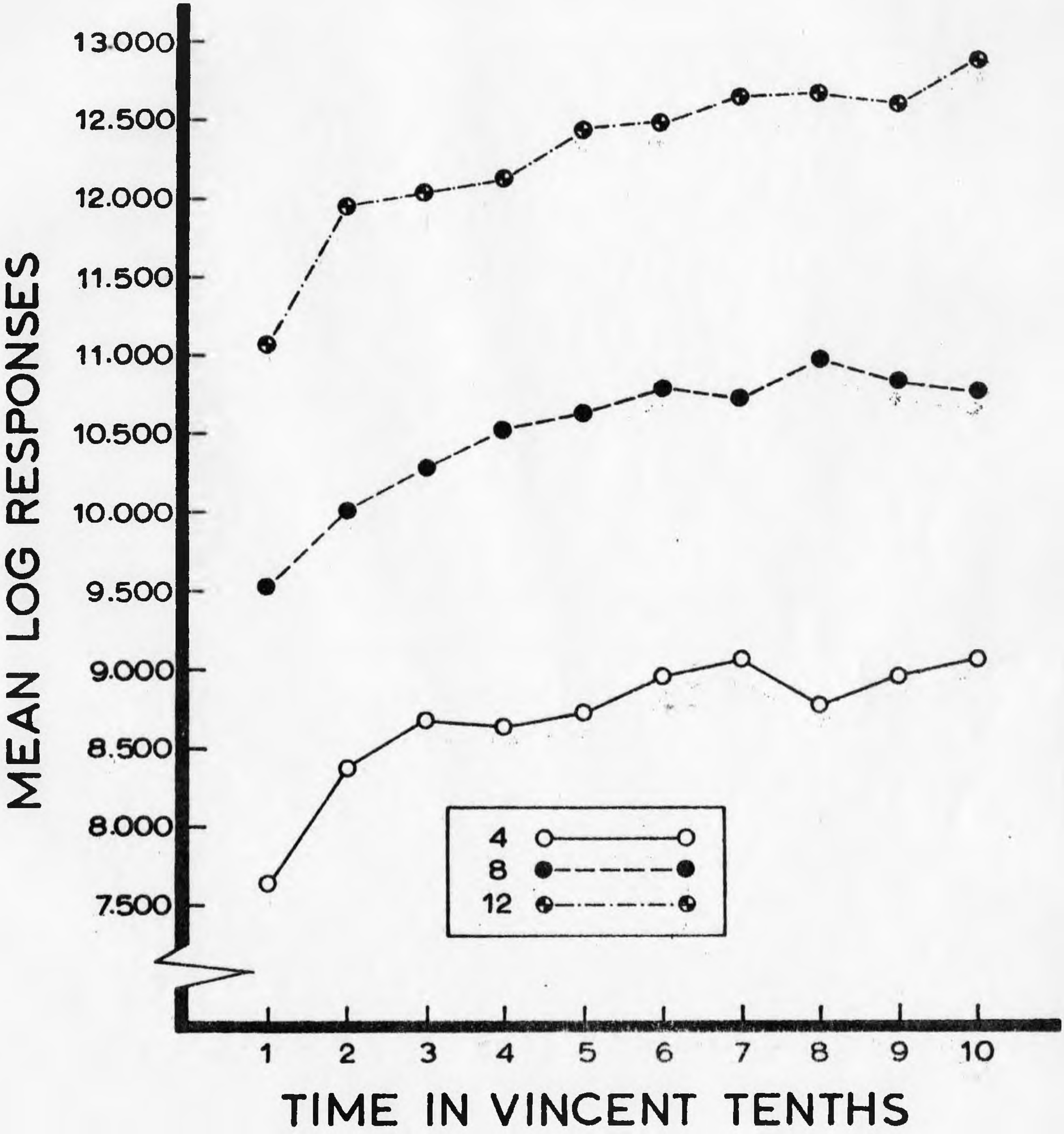

Figure 9. The mean number of responses per vincent unit of time during acquisition with number of reinforcements as the parameter.

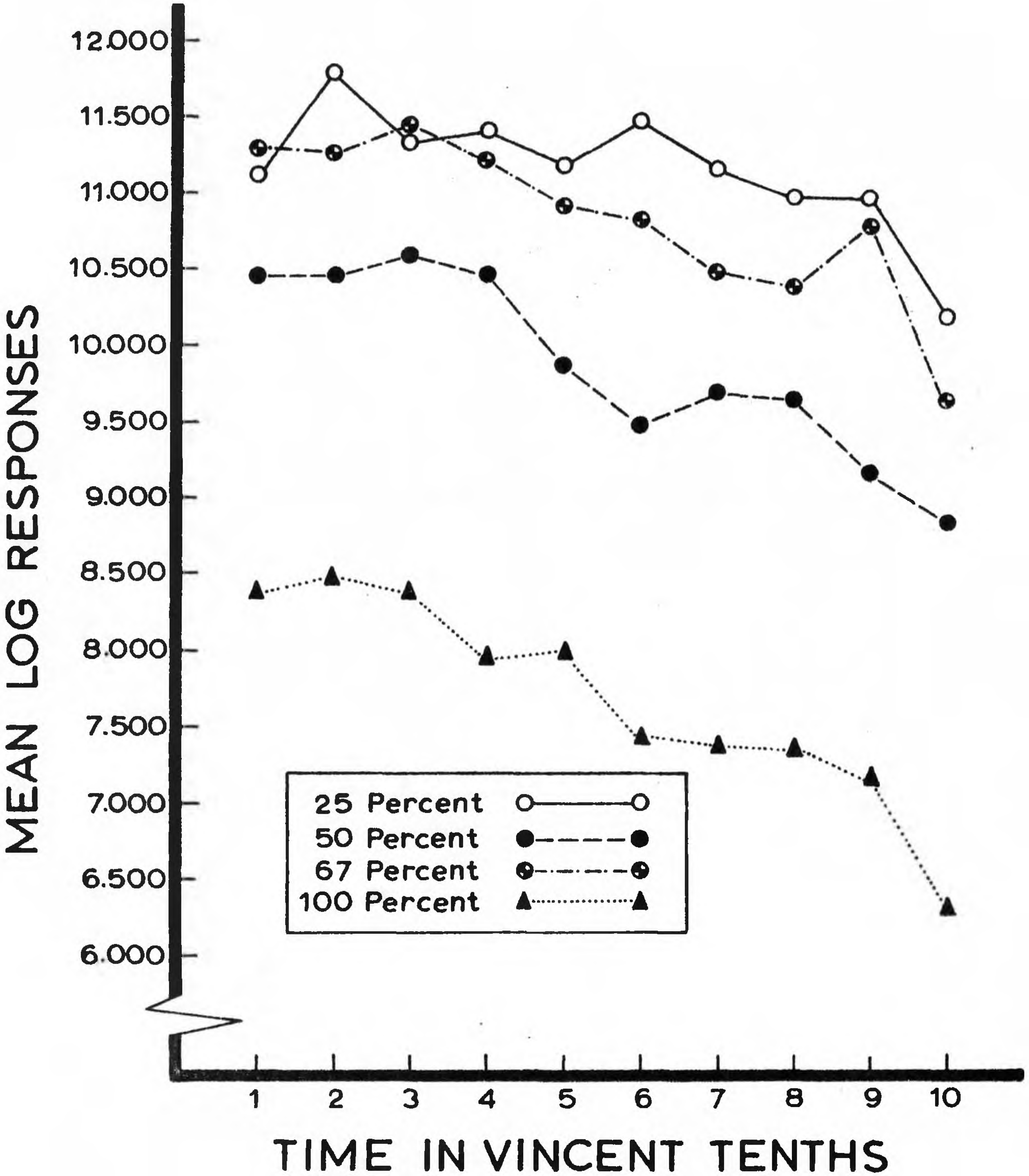

Figure 10. The mean number of responses per vincent unit of time during extinction with percentage of reinforcement as the parameter.

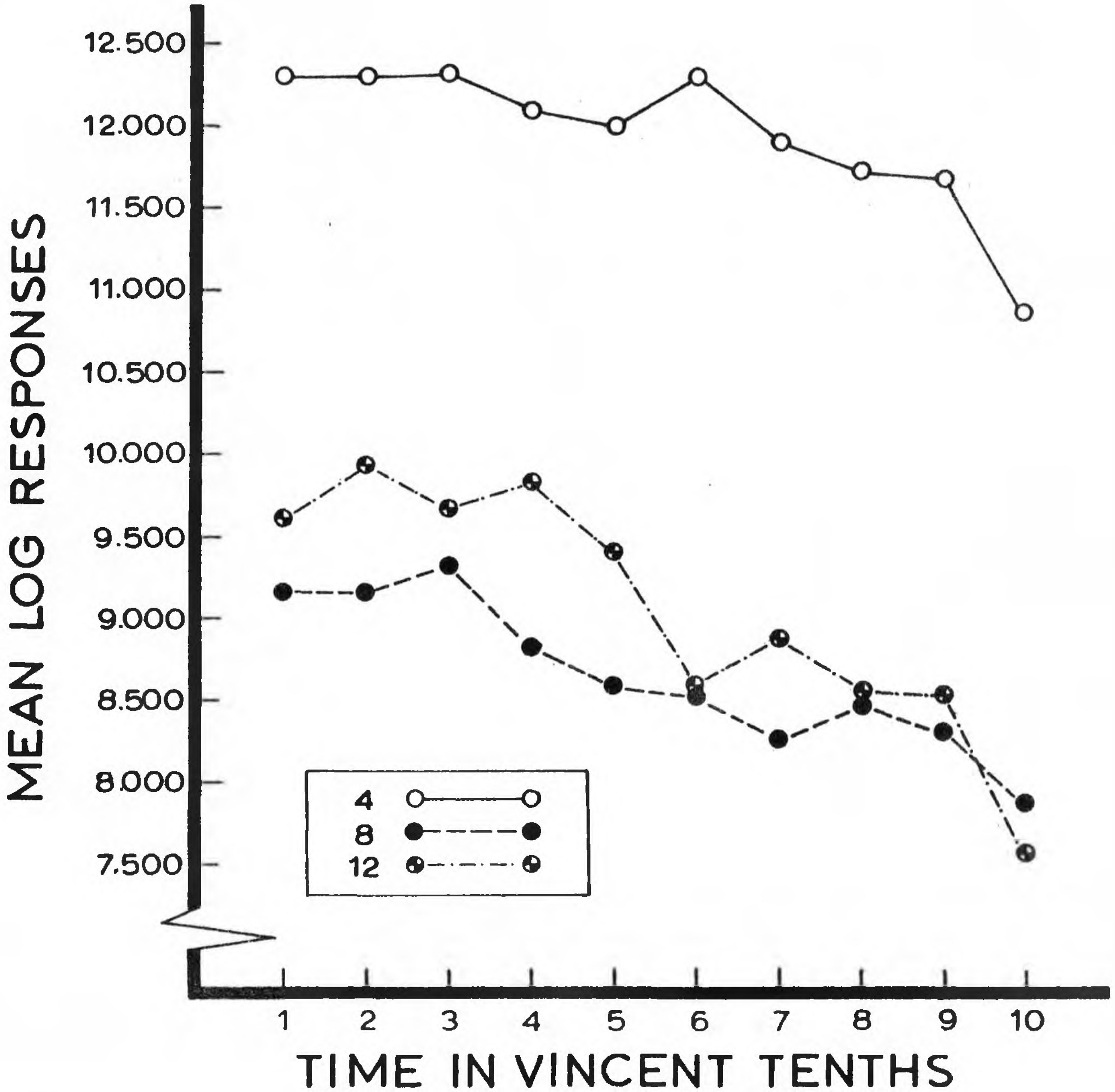

Figure 11. The mean number of responses per vincent unit of time during extinction with number of reinforcements as the parameter.

different percentages of reinforcement, this experiment demonstrates that the number of reinforcements is. As the number of reinforcements obtained during acquisition increases, the number of responses made during extinction decreases. The same inverse relationship as found in experiment 1 holds between the percentage of reinforcement during acquisition and the number of responses made during extinction. As the percentage of reinforcements during acquisition increases, the number of responses emitted during extinction decreases. Again, the same factors were significant whether the number of single responses was used or the number of correct responses was used as the criterion measure.

In addition, the mean rate of responding was not affected in the first experiment by either the percentage of reinforcement or the number of acquisition trials, whereas in this experiment, an inverse relationship between mean response rate and the number of reinforcements during acquisition was found. In other words, as the number of reinforcements received during acquisition was increased, the mean rate of responding during extinction decreased. Again, there was no effect on the mean rate of responding due to percentages of reinforcement.

It was also noted in both studies that the number of responses made per vincent tenth of time tends to increase gradually during the extinction period.

CHAPTER FIVE

DISCUSSION

Grant & Schipper (1952) have suggested that the ∩ -shaped function frequently found in partial reinforcement studies is based on the interaction of two separate processes: a discrimination process and a learning one. As percentage of reinforcement is increased the more the acquisition series should "stand out" from the extinction series, resulting in less PRE. This is the discrimination process and should result in a decreasing function as a result of percentage of reinforcement. However, with a response starting out close to a zero response strength, the higher the percentage of reinforcement for equal numbers of trials below some limit, the greater the response strength and the greater the PRE. Thus the learning process results in increasing resistance to extinction, and the combination of the two processes produces a ∩ -shaped function.

In a situation which they classed as almost pure performance, Lewis & Duncan (1958a) and Garment & Miles (1962) failed to obtain such a ∩ -shaped function. They explained its absence as owing to the fact that their subjects were not required to learn; hence the only process operating was a purely discriminative one. Their results showed the familiar PRE to be a direct function of the percentage of reinforcement.

Additional support was given to this notion by the fact that resistance to extinction, in these experiments, decreased as the number of acquisition trials was increased. It was argued that increasing the number of acquisition trials serves to make the acquisition series more distinct from the extinction series, thus reducing resistance to extinction.

The studies on which this thesis is based were carried out in an attempt to expand on the work of Carment & Miles and Lewis & Duncan using essentially the same procedure but with a more complex learning task involved.

In the present experiments, an acquisition trial was defined as one correct response (RLL). This meant that learning now had to take place in contradistinction to the Lewis & Duncan and Carment & Miles situations.

One problem remained which had been outlined by Jenkins & Stanley (1950) as a general dilemma characterizing the partial reinforcement situation: the relationship between number of trials (or responses) and number of reinforcements. They pointed out that a partial reinforcement group can be matched with a continuously reinforced one on either number of trials or number of reinforcements, but not both. If, for example, 50 reinforced responses are to be given and a 50% reinforcement schedule is employed, this group will have 100 trials, and the 100% group will undergo 50 trials. "The experimental question revolves around a determination of the relative effects on behavior of nonreinforced trials as contrasted with reinforced ones." (p. 200)

This explains the reason for the two experiments offered in this thesis. The experimenter was interested in observing the relative effects of the number of reinforcements as well as the number of acquisition trials on resistance to extinction. A question left unanswered by the Lewis & Duncan and Carment & Miles studies was whether the increased resistance to extinction observed following a long acquisition series was in fact attributable to the increased number of trials, or to the increased number of reinforcements during acquisition.

As Jenkins & Stanley noted, it is not possible to study these variables in one design. Hence, the first experiment did not control the number of reinforcements, but experimentally varied the number of acquisition trials, whereas the second experiment did not control number of acquisition trials but experimentally varied the number of reinforcements received during acquisition. In most other respects the two experiments were essentially the same (allowing for slight differences in the percentages of reinforcement used). It was believed then, that taken together, these studies should indicate more precisely the nature of the relationship existing between percentage of reinforcement, number of acquisition trials, and number of reinforcements.

a) Responses to extinction

The results of the first experiment indicate that the number of acquisition trials is not a vital factor in determining resistance to extinction. The typical PRE was obtained as a direct decreasing function of the percentage of reinforcement; nor was there any interaction between number of acquisition trials and the percentage of reinforcement.

This finding suggested that perhaps the important variable during acquisition was not the number of trials, but the number of reinforcements delivered during acquisition.

This conclusion was supported by the findings of the second experiment which demonstrated that resistance to extinction was significantly affected by both the percentage of reinforcement and the number of reinforcements. There was no interaction. However, as the percentage of reinforcement was increased, resistance to extinction decreased. Likewise, as the number of reinforcements increased, resistance to extinction decreased.

It should be noted that in this experiment the PRE as a function of the percentage of reinforcement was not as clear-cut as that obtained in the first experiment. Whereas in the first study, resistance to extinction decreased as the percentage of reinforcement increased, the general downward trend in the second experiment was interrupted by the 67% reinforcement group, which did not make fewer responses to extinction than the 50% group. However, each percentage level represents the mean of three different treatment groups and when these means are plotted separately (see appendix) it is evident that one very deviant group (4 reinforcements, 67% reinforcement) accounts for most of this difference. The mean for the 67% group, calculated without the inclusion of the 4, 67% group, falls well below that of the 50% group in resistance to extinction.

The results of these two experiments suggest that the number of reinforcements received and the percentage of reinforcement during the acquisition period are important variables in determining resistance to extinction. However, it appears that the number of acquisition trials in itself is not enough to influence the number of responses emitted during extinction.

It should also be noted that similar significant findings were discovered whether the response measure used was single lever-pulls (responses) to extinction or correct responses (RL) to extinction. Both measures gave the typical PRE and demonstrated that resistance to extinction increases as the percentage of reinforcement during acquisition decreases. This finding discredits the response-unit hypothesis of Mourer-Jones and adds greater support to the discrimination hypothesis.

b) Rate of Responding

In both experiments the number of responses per unit of time increase during acquisition and decrease during extinction.

This finding may be interpreted in terms of response strength being greatest at the end of the acquisition period thus accounting for the fastest rate at this point. Also, as extinction progresses and response strength declines, it is to be expected that the number of responses emitted would also decline.

It may also be possible to interpret these over-all findings in terms of "frustration-produced drive". The frustration resulting from non-reinforced trials following reinforced ones can be expected to be at its highest peak immediately following the last reinforcement (the end of acquisition). Hence the drive-level should also be highest at this point. As extinction progresses, frustration dissipates and the drive-level is lowered, thus lowering the number of responses per unit of time.

Whereas the first experiment did not reveal the mean rate of responding to be significantly affected by either the number of acquisition trials or the percentage of reinforcement, the second experiment showed it to be significantly affected by the number of reinforcements. As the number of reinforcements during acquisition increased, the mean rate of responding in extinction decreased.

In terms of frustration theory, then, the more reinforcements acquired by the subject during acquisition, the fewer the non-reinforced trials he experiences. Thus with each new reinforcement the frustration level is lowered so that during the extinction series the rate of responding is also lowered.

It seems fairly obvious that rate of responding has not been used enough as an experimental measure in studies using human subjects to account for the results of this study on very solid theoretical grounds. There is little evidence in the literature to allow for any long-range predictions in terms of one theory or another. However, response rate does appear to be a very powerful measure of the effects of the kind of independent variables used in these studies, and it is recommended that more use be made of it was a dependent variable in future studies.

A summary of the findings of this thesis follows in the next section.

CHAPTER SIX

SUMMARY

This research was designed to test the effects of percentage of reinforcement, number of acquisition trials, and number of reinforcements on a lever-pulling response in human subjects.

Two separate experiments were carried out: the first factorially combined four percentages of reinforcement during acquisition (25%, 50%, 75%, and 100%) with three numbers of acquisition trials (8, 16, and 32); the second factorially combined four percentages of reinforcement during acquisition (25%, 50%, 67%, and 100%) with three numbers of reinforcements (4, 8, and 12) received during acquisition.

The design in each case required that the subject learn to make a specified response in order to receive a reinforcement.

The dependent measures were the number of lever-pulls to extinction and the overall rate of responding first during acquisition and secondly during extinction, and the number of responses made per unit of time in acquisition and extinction.

The results showed resistance to extinction to be an inverse function of both the percentage of reinforcement and the number of reinforcements received during acquisition. There was no effect attributable to the number of acquisition trials.

These findings were interpreted in terms of a discrimination hypothesis, both the percentage of reinforcement and the number of reinforcements received, when increased, making it easier for the subject to discriminate between the end of acquisition and the beginning of extinction.

The number of responses made per unit of time, in both experiments, was found to increase as acquisition proceded and to decrease as extinction progressed.

In the second experiment it was found that mean rate of responding during extinction was an inverse function of the number of reinforcements received during acquisition; however, there was no effect attributable to either the percentage of reinforcement or the number of acquisition trials.

It was suggested that the above findings might be explained in terms of either response-strength or frustration-produced drive hypothese; however, the literature using rate as a dependent measure in this type of design is too scanty to allow extensive speculation. Certainly these results warrant more use of rate as an independent variable in future studies.

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APPENDIX

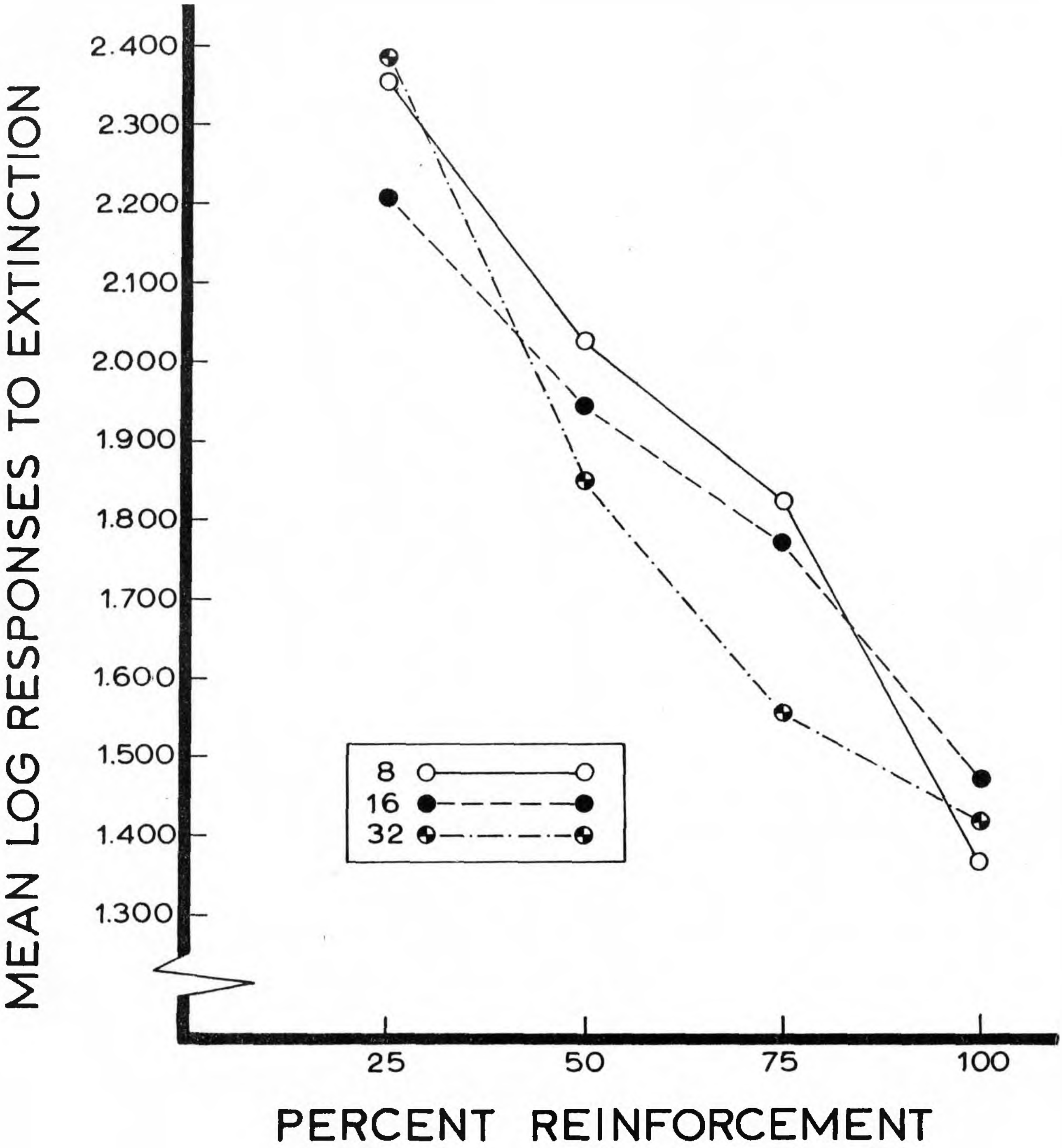

Figure 1. Mean log responses to extinction as a function of percentage of reinforcement for all groups.

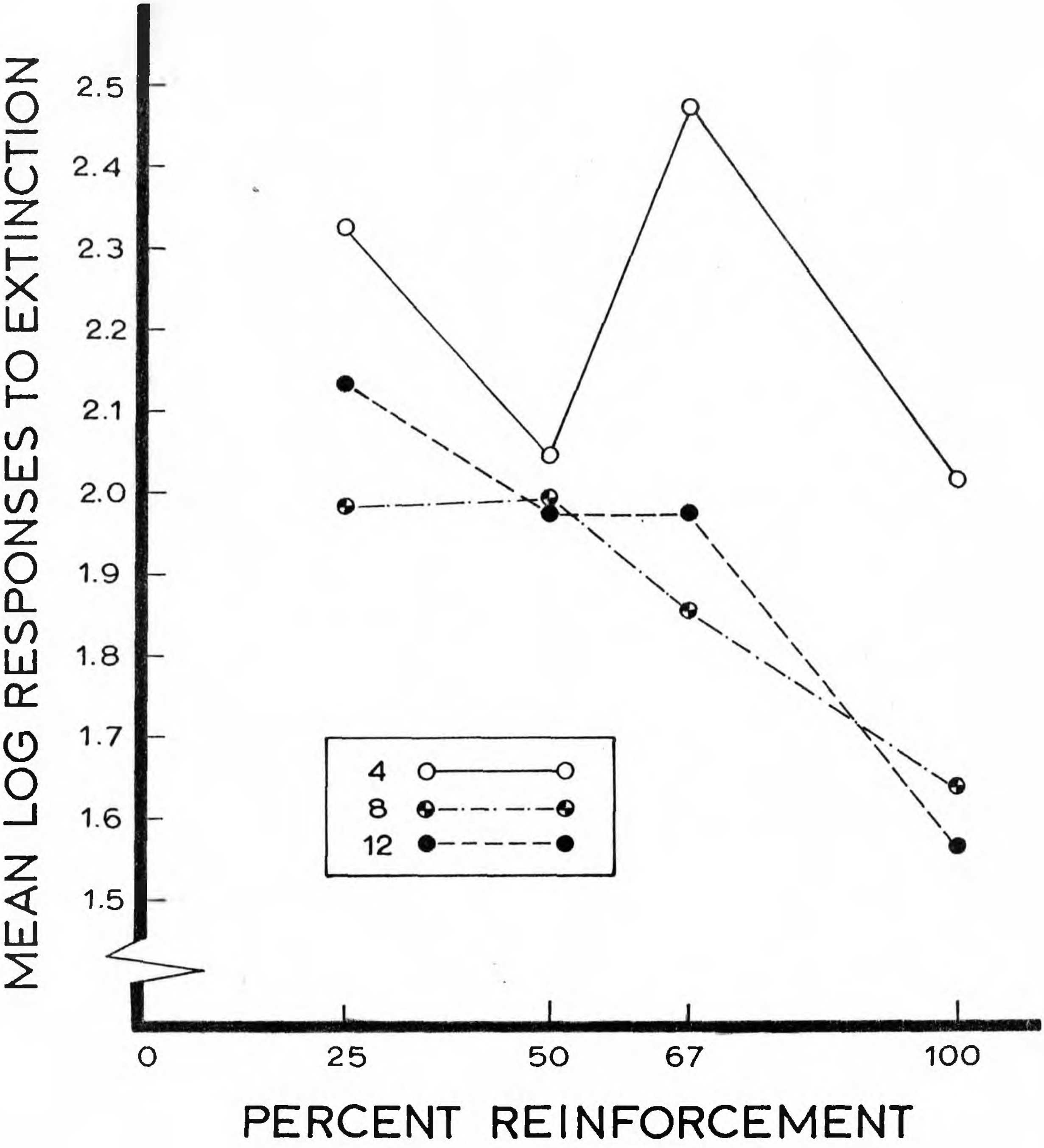

Figure 2. Mean log responses to extinction as a function of percentage of reinforcement for all groups.

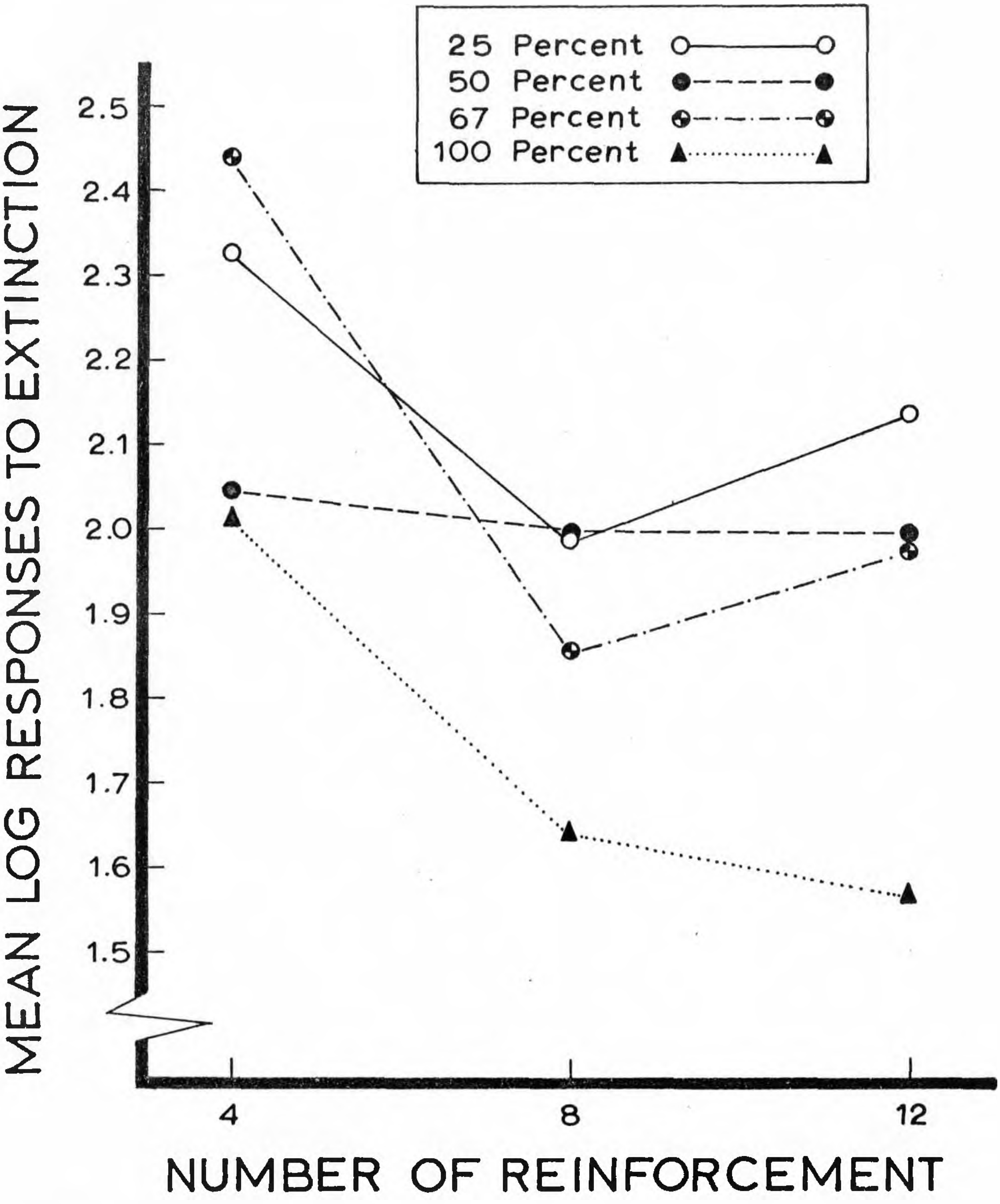

Figure 3. Mean log responses to extinction as a function of the number of reinforcements for all groups.