FRUSTRATION EFFECT AS A FUNCTION OF REWARD MAGNITUDE

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ABSTRACT

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OF REWARD MAGNITUDE

By

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The frustration effect is defined as an increase in response vigor immediately following non-reward after an expectancy of reward has been developed. Response vigor, usually running speed, is measured following trials in which reward has been eliminated and compared to running speed following reward. Frustration effect, according to one model, Amsel's theory of frustrative non-reward, has been studied using a double alley apparatus which has met with considerable criticism. The first criticism suggests that demotivational factors due to the intake of food on reward trials may be, in part, responsible for the superior running speeds following non-reward. The second criticism stems from possible inadequacies of tests of the effects of magnitude of reward and the effects of the degree of incomplete reduction of reward (to some non-zero level), as these tests are conducted in the double runway. An apparatus (panel-push) was used to eliminate some of the problems associated with the double runway. It was postulated that an increase

in response strength would occur immediately following the withdrawal of reinforcement and, further, that the size of this effect would be directly related to the magnitude of reward used in training.

Five groups of rats were trained with different amounts of reinforcement, either 20 mg, 45 mg, 97 mg, 190 mg, or 500 mg food pellets. Following 45 consistently rewarded trials the second stage of the experiment began. In this stage, which lasted for four days, the first three trials of each day were rewarded and the last five were non-rewarded. This design yielded four trials following reward and four trials following non-reward for these four days. The third stage of the experiment was regular extinction with a total of 25 non-rewarded trials.

The results showed a significant decline in response force within the first four trials following the initial withdrawal of reward. This effect was found to be related to magnitude of reward only in a limited (non-significant) fashion, and then only in terms of the drop from the response force level at the end of acquisition to its level at the end of extinction.

These results were interpreted as not supporting Amsel's theory of frustrative non-reward and were discussed from the viewpoint of elicitation theory. This discussion included a comparison of the panel-push apparatus with other types of apparatus previously used to test frustration theory.

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INTRODUCTION

Numerous experiments over the past two decades have been concerned with Amsel's theory of frustrative non-reward. Three major types of apparatus and several experimental designs have been used to examine the effects of non-reward after an expectancy of reward has been established. These different methods have produced a set of results which are not entirely consistent with each other.

The present experiment was an attempt to examine the effect of frustrative non-reward on the force or amplitude of a response as a function of the magnitude of reward used during original training. Latency of the response was similarly studied.

Amsel's Theory of Frustrative Non-reward

Amsel defined primary frustration as an increase in response vigor immediately following non-reward after an expectancy of reward (r_g) has been developed by consistent reinforcement for a number of trials.

> The addition of frustration to the motivational complex increases the strength of an immediately following, hunger-motivated response, presumably through an increase in generalized drive strength (Amsel and Ward, 1954).

In his review of the literature of frustrative non-reward, Amsel (1958, 1962) cited earlier allusions to "frustration effects" by Skinner, Hull, and others. Skinner (1950) observed that "when we fail to reinforce a response that has been reinforced . . . we set up an emotional response--perhaps what is often meant by frustration. . . ." Also, Hull (1952) stated that "abrupt cessation of a customary reinforcement will, at first, result in a slight rise in $_SE_R$ (excitatory potential or response tendency) due to emotion."

Similarly, Miller and Stevenson (1936) explained the agitated behavior of rats during extinction, which carried over from one trial to the next, by an emotional-motivational interpretation. This state, according to Bower (1962) is due to the discrepancy between expected and obtained rewards.

One of the basic assumptions underlying Amsel's frustrative non-reward hypothesis is that the strength of the anticipatory goal response (r_g) will directly influence the amount of the increase in response vigor following non-reward (Amsel, 1962). This concept, from Hullian theory, was viewed as related to frustration.

> Not rewarding a R will elicit frustration to the degree that earlier rewards of that R have lead to the conditioning of r_g to the cues in an instrumental response sequence (Hull, 1952).

Amsel dealt with another aspect of frustration which he referred to as conditioned frustration (r_f-s_f).

Conditioned frustration develops more slowly. This process may be conceptualized as resulting from the classical conditioning of the effects of non-reward to the cues associated with responding. This, Amsel calls the fractional anticipatory frustration reaction (r_f) which is analogous to fractional anticipatory goal reaction from Hull-Spence theory (Amsel, 1962).

Presumably, this r_f-s_f effect has been demonstrated most efficiently by Goodrich (1959). The initial inhibitory effect of partial reinforcement schedules in contrast to continuous (100%) reward schedules reversed itself after a number of trails. What resulted was that as asymptote was reached, the partial (50%) reward group ran faster than the 100% reward group. Amsel interpreted these results as evidence that the heightened motivational level associated with non-reward is gradually conditioned to the cues of responding. Goodrich's results will be described in detail later.

Criticism of Amsel's Experimental Procedure

A great deal of research has been stimulated by the theoretical assertions of the frustrative non-reward hypothesis. Some of the reports of this research have included varying degrees of criticism of the experimental apparatus in which Amsel first examined the frustration effect. These criticisms are primarily directed at two aspects of the theory.

First, Seward, Pereboom, Butler, and Jones (1957) suggested that demotivational factors, inherent in the double runway apparatus and design which involved the intake of food on rewarded trials, may be in part responsible for the faster running speeds following non-reward.

Second, some of the studies of the effect of reward magnitude on the amount of increase in response vigor following non-reward produced results which may be inconsistent with Amsel's assumption concerning the role of the anticipatory goal response (McHose & Ludvigson, 1965; McHose & Gavelek, 1969). Further, examination of the effects of reduction of reward magnitude to some non-zero level produced results which indicated that different amounts of reward in the two goal boxes of the double runway apparatus may lead to the development of dual expectations for the two goal boxes. Thus, utilization of different magnitudes of reward in the two goal boxes produced results which may not be entirely attributable to a frustration effect (Daly, 1968; McHose, 1970).

The first of these criticisms necessitates an examination of the type of apparatus used in the present research. The types of apparatus that have been used include the double runway, single runway, operant response apparatus, and a panel-push device in which both latency and force of response can be measured.

The second criticism will be elaborated and discussed within the discussion of the double runway apparatus since it is in this apparatus that most of the work related to frustration has been done.

Double Runway Apparatus

Demotivational Criticism

The double runway is the most frequently used apparatus in the study of frustration since it was the one in which Amsel's theory was first tested (Amsel & Roussel, 1952). It consists of two consecutive runways. Each is divided into three segments: start box (SB), alley, (A), and goal box (GB). The goal box of the first runway serves as the start box for the second runway. Running speed in each alley is measured by a series of photo cells.

Subjects are rewarded in both goal boxes during the acquisition stage of the experiment. This continues for 30-130 trials in order to build an expectation of reinforcement. Following these consistently rewarded trials, reward in the first goal box (GB-1) is eliminated (Peckham & Amsel, 1967; Krippner, Endsley, & Tacker, 1967) or in some studies reduced (Bower, 1962; McHose & Ludvigson, 1965). Periodically, non-rewarded trials are interspersed among the trials. This is usually referred to as the "post-shift" stage of the experiment.

The running speed in the second alley (A-2) following the non-rewarded trials in GB-1 is measured and compared to A-2 speed following reward in GB-1, from both the acquisition stage and the post-shift rewarded trials. It has been observed that the running speed for A-2 following non-reward is faster than A-2 running speed following reward in GB-1. It is this increase in running speed following non-reward that Amsel has termed the frustration effect (FE).

The first criticism of this interpretation of the increased running speed came from Seward et al. (1957). They concluded that at least a portion of the increase was due not to the motivational properties of frustration, but to the demotivational properties associated with the intake of food in GB-1 on rewarded trials. In their experiment A-1 speeds were calculated. On some trials subjects received either one-half or one gram of food just prior to entering the first start box. On other trials subjects were placed directly into SB-1 from their waiting cages with no prefeeding. Following prefeeding the A-1 running speeds were found to be significantly slower. They did not interpret this as necessarily resulting from decreased hunger, but perhaps from chewing and/or swallowing during the initial stages of the alley or, more likely, from a reduction in "the drive to eat."

To this, Amsel (1958) replied that the large magnitude of reward used in the Seward et al. (1957) study was responsible for the slower running speeds. He had considered this possibility in his earliest studies of FE and had ruled against this interpretation since the magnitude of reward used in his study was small, 100-125 milligrams (Amsel & Roussel, 1953).

Wagner (1959) in an attempt to clarify the situation, designed an experiment utilizing a control group which had never received reward in GB-1. Such a group would not develop an anticipatory goal response and would not experience frustration following non-reward. Nor would their A-2 running speeds be affected by demotivational factors. Therefore, Wagner suggested, if the increase in A-2 running speed was "entirely due to demotivational factors" of reward intake, then following non-rewarded trials the control group should run about equally as fast as the experimental group on its trials following non-reward. The results showed that the experimental group ran faster after non-reward than the control group which had never experienced reward in GB-1. He concluded that FE is "independent of any demotivational effects of feeding" (Wagner, 1959).

This extreme conclusion, however, does not necessarily follow from his data. Although Wagner has probably shown that demotivational factors are not the only effects involved, he has not ruled out the possibility that demotivation may be partially responsible. The criticism by Seward et al. did not reject such a possibility; they merely stated that the demotivational factors could not be eliminated as a partial explanation of the increase in A-2 running speed following non-reward as studied in the double runway.

Criticism Related to Studies of Effect of Reward Magnitude

A set of studies grew from attempts to examine the effect of magnitude of reward and the effect of incomplete reward reduction on the amount of FE. From reports on these studies came new criticisms of Amsel's experimental procedure.

As was stated earlier, if the magnitude of FE is directly related to the degree of anticipatory goal response, as it postulated in Amsel's theory, then magnitude of FE should also be directly related to reward magnitude used in training (Peckham & Amsel, 1967).

Results supporting Amsel were obtained in two studies by Peckham and Amsel (1964, 1967). These studies showed that A-2 speed increased more following non-reward for eight pellets in GB-1 than following non-reward for two pellets in GB-1. They concluded that this offered support for a direct relationship between FE and magnitude of training reward.

Krippner, Endsley, and Tacker (1967) obtained similar results but found that large GB-1 rewards depressed A-2 speeds following rewarded trials as compared with small GB-1 rewards following rewarded trials. Thus they suggested that large rewards may have a tendency to elicit staying in GB-1 rather than approaching GB-2 (as in keeping with the demotivational hypothesis). They interpreted their results as not completely supporting the FE hypothesis, and concluded that the discrepancy may be due to their use of a between subjects design as opposed to Amsel's within subject design.

McHose, Meyer, and Maxwell (1969) utilized a within subject design and obtained results "directly opposite to the predictions derivable from the model" (Amsel's frustrative non-reward theory), namely, that the small reward produced at least as large an FE as the large reward. They suggested that a comparison between the within subject and between subjects designs was necessary. McHose and Gavelek (1969) conducted such a study and found that performance following non-reward did not depend on reinforcement magnitude, irrespective of design. They interpreted this as damaging to Amsel's theory since the vigor of frustration response and the resultant increment in drive is assumed to vary directly with reward expectancy (reward magnitude). They concluded that the results of Peckham and Amsel's study (1967) which are in apparent support of the frustration theory, could (along with their own results) mean that the double alley tests of hypothesis are inadequate. The procedural inadequacies in question are described in the following studies.

Another variable concerned with frustrative non-reward theory that has been studied is the effect of reducing the reward in GB-1 to some non-zero level. Bower (1962) was one of the first to examine this variable. He hypothesized that if non-reward is frustrating and if this is due to the discrepancy between expected reward and obtained reward, perhaps the amount of FE would be related to the relative size of reduction of reward to a non-zero amount. He tested this using varying numbers of pellets in GB-1 in training and examined the effect of reducing these to the same amount of increase in running speed in A-2 following reward decrease was about proportional to the reduction in reward. He concluded that this finding may support either Amsel's theory of frustration or Spence's theory of incentive motivation which stresses the value of G-2 relative to G-1 and does not require the introduction of the concept of frustration. One incidental finding in this study was that rewards larger than eight pellets produced decrements in the speed of the next response.

In replicating Bower's procedures, McHose and Ludvigson (1965) found no support for the hypotheses that incomplete reward reduction produces a graded frustration effect. They interpreted their finding as indicating "that these A-2 speeds are simply function of absolute reward magnitude in GB-1, and that no frustration-drive increment from incomplete reward reduction need to be involved" (p. 495). They concluded that no existing theory, either that of Amsel, Bower, or Seward _et al_., can satisfactorily explain the results of their study. Similar results were obtained by Barrett, Peyser, and McHose (1965). They found that complete reward reduction facilitated A-2 running speed, but incomplete reward reduction did not. These two studies both found that post-shift speeds in A-2 were inversely related to absolute (post-shift) GB-1 reward magnitudes, but unrelated to expected reward magnitudes (i.e., magnitudes used in original training).

Daly (1968) also studied the role of incomplete reward reduction using a design similar to that of Bower. Goal box two contained six pellets throughout the study. The number of pellets in GB-1 was shifted in a between subjects design from 15 to 6, 15 to 1, and 15 to 0; and from 6 to 1, 6 to 0; or from 1 to 0. She also included control groups, 15 to 15, 6 to 6, 1 to 1, and 0 to 0. The observed increases in A-2 running speeds following the shifts were complicated by the effects of the size of reward used in training. The A-2 speeds following reward were slower than the A-1 speeds for the 15-pellet group. This was seen as due to an apparent inhibitory effect of six pellets in GB-2. Receiving six pellets in GB-2 after having received 15 in GB-1 produced an inhibitory effect on A-2 running speed. Receiving six pellets in GB-2 after having received one in GB-1 produced an excitatory effect. These effects increased over trials and occurred in the alley closer to the frustrating (smaller) reward. An important implication of all this is that groups which receive a smaller reward in GB-2 than in GB-1 have experienced frustration throughout acquisition and are, therefore, not an adequate test of FE.

At about the same time Meyer and McHose (1968) completed a study of the effects of reward increases in GB-1 of the double runway. They concluded that

> the fact that both reward increases and some reward decreases produced facilitation, but that no changes in reward have produced debilitation in A2, warrants the conclusion . . . that magnitude of change per se is responsible for the facilitative effects obtained in the present study and in the studies shifting to non-reward in GB-1 (p. 166).

Finally, McHose (1970) examined the relative effects of differential magnitudes of reward in GB-1 and GB-2 and concluded that the results were uninterpretable as a "frustration phenomenon" but were consistent with a discrimination contrast hypothesis as was also suggested by Daly.

One last variable studied in relation to frustration in the double runway is the role of number of previously rewarded trials in A-1 (Stimmel & Adams, 1969). Their procedure was different from those of the experiments previously discussed since these experimenters substituted regular extinction for the test period where randomly interspersed rewarded trials had been given. They found that although there was an increase in running speeds during the six days of non-reinforcement in GB-1, it did not occur until after five non-reinforced trials in GB-1. They interpreted these results as not supporting a frustration interpretation.

Operant Response

In the area of operant responding, Notterman and Mintz (1965) have examined the effect of frustration on the force of a bar-pressing response. Their study was quite extensive and indicated that response force increases during extinction. Notterman and Mintz discussed three major interpretations of the mechanisms causing the rise in response force during extinction trials.

The first explanation is a biological one. It is at least conceivable, according to Notterman and Mintz, "that the behavioral phenomenon of exerting additional force following non-reinforcement is a biological trait resulting from the process of natural selection" because exerting this extra force raises the probability of success after an initial failure. They see this as most closely associated with Amsel's conception of a "primary aversive motivational condition."

The second is a learning interpretation. Its major proponent was Schoenfeld (1950). He conceived of response force as made up of various subclasses of responses, that is, the various levels of response force may be viewed as subclasses of the response. He hypothesized that a:

> . . . wide sampling of response magnitudes or subclasses is reinforced during the early stages of acquisition and that each of these subclasses must then be separately extinguished. It is for this reason that higher forces as well as lower forces are observed during extinction.

If Schoenfeld was correct, the distribution of forces during extinction should be similar to the distribution during acquisition. This was tested by Goldberg (1959) using the apparatus of Notterman and Mintz. It was found that although the two distributions were very similar, there was a greater frequency of higher force responses during extinction. This was observed for each of the subjects in the experiment.

Observing this, Notterman and Mintz developed a third interpretation of the data which they call "incidental directional reinforcement," which they explained as follows:

> Biological organisms are exposed from birth to reinforcement contingencies in which they successively more vigorous responding tends to produce reinforcement. Thus, the animal learns, incidentally, that an increase in response vigor tends to increase the probability of reinforcement.

It is this interpretation which they feel underlies their experimental results, but they do not consider theirs to be a critical test.

In a lever-pressing experiment with rats, Cole and Van Fleet (1970) examined the effects of interoceptive and exteroceptive cues associated with differential reward schedules in a "Skinner box analogue of the double runway." They found no frustration effect for the latency data.

However, they did find a significant effect due to the reward--non-reward (R-NR) blocks of trials for the other measure, cumulative response time on a second lever. In other words, following trials where lever 1 was not rewarded, the subjects responded more efficiently, i.e., spent less time on lever 2. They found no significant interaction between reward schedules and the R-NR effect. To the extent that they obtained an R-NR effect, their results seem to be consistent with a frustration hypothesis.

Single Runway

Goodrich (1959) incidentally examined the conditioned frustration effect in relation to segments of the runway apparatus. Using a partial (50%) reinforcement group and a continuous (100%) reinforcement group, he studied the running speed in the start box, alley, and goal box. He found that in the early trials, the 100% group ran faster in the start box and alley than did the 50% reinforcement group. However, this phenomenon was reversed on later trials (a cross-over effect). This is in accordance with the postulates of Amsel's theory. Conditioned frustration (r_f--s_f) is assumed to gain control of the response later in a partial reward schedule and this tends to make the running speed at asymptote faster for the partial reinforcement group than for the continuous reinforcement group. The early-trial 50% reinforcement decrement persists for a greater number of trials as performance is measured closer to the goal region of the runway. In one of the two experiments discussed by Goodrich, this early trial partial reinforcement decrement at the goal region persisted for 60 trials. Goodrich ruled out the possibility of the relatively slower performance of the 50% group in the goal box region being due to subjects slowing down as they approached the empty food cup on non-rewarded trials by showing that goal speed was the same on rewarded and non-rewarded trials.

Goodrich concluded that although his results are in accord with the basic idea of conditioned frustration theory, the early appearance of cross-over suggests that other factors may be involved. In Amsel's study (Amsel, 1962), the faster speeds of the partial reinforcement group did not show up until some 20 or 30 trials had been run. In the Goodrich study the facilitation of running speed for the 50% group developed as early as trials 9-12. This earlier effect could be due to the narrow width of the Goodrich runway which may have discouraged competing responses, but Goodrich concluded that there exists no clear and adequate explanation of his results.

Panel Pushing

Robert Davis (1957) measured response force and latency as a function of drive level. During extinction, he observed a non-significant increase in response force for the second and third trials in the high drive group. This increase was attributed to frustration.

The Present Experiment

A panel push apparatus very similar to the one Davis used, was used in the present research in order to test the generality of Amsel's hypothesis and to eliminate many of the complications already mentioned that are involved in this area of research. It consisted of a chamber with a door which when raised provided access to a panel. The food cup was located just behind this panel. Measures of both response force and latency were possible on separate trials without handling the subject. Lowering and raising the door defined the end and start of a trial, respectively.

By measuring response force and latency the generality of Amsel's hypothesis of increased response region following non-reward could be examined. In the earlier studies cited above, response vigor was examined by measuring running speed (Amsel & Roussel, 1952; McHose & Ludvigson, 1965), and by measuring bar press response force (Notterman & Mintz, 1965). Thus, in the panel push apparatus the effect of non-reward on two new measures of response region could be studied.

In the double runway apparatus the subject remained in GB-2 until the door into A-2 was opened. This was necessary to eliminate the possible influence of handling the subject on what could be an emotional response. In the panel push apparatus also, the subject was not handled between trials.

If the lower A-2 running speed in the double runway following a large reward in 6B-1 was due to an increased tendency to remain in 6B-1, utilization of the panel push apparatus would eliminate this interfering response tendency, since approaching the panel on the next trial is not incompatible with the tendency to remain in the goal area, on rewarded trials.

Use of the panel push apparatus also eliminated the possibility of the development of dual goal box expectancies which Daly and McHose (1968) see as controlling A-2 running speed. In order to eliminate this problem each subject was exposed to only one size of pellet in the panel push apparatus, therefore making the subjects' expectancy level more clearly definable.

Thus, the present experiment, through utilization of the panel push apparatus eliminated the demotivational influences and the influences of dual goal box expectancies while studying the generality of Amsel's hypothesis to two new measures of response region.

Hypotheses

1. It was hypothesized that response vigor as measured by the force of striking the panel would increase immediately following the first non-rewarded trial. A positive result on this test would support Amsel's theory of frustrative non-reward.

2. The second hypothesis was that response force should decrease following the initial increase when non-reward is continued. This result would be in agreement with that of Davis (1957) in the panel push apparatus. This decrease would not directly contradict nor would it support Amsel's theory.

3. The amount of immediate effect of non-reward on response force was hypothesized to vary directly with magnitude of reward used in training. This would imply that the reward magnitude was positively related to magnitude of r_g, the anticipatory goal response, which Amsel viewed as controlling the amount of frustration aroused by non-reward.

4. The amount of ultimate decrease in response force during extinction was also hypothesized to be directly related to magnitude of training reward, This would be similar to the effect, most frequently attributed to Armus (1959), in which amount of reward in a runway situation is inversely related to the number of trials to extinction.

5. Finally, it was hypothesized that the magnitude of reward would have a direct influence on response force and latency during the acquisition of the panel push response. More explicitly, it was

predicted that as the magnitude of reward was increased, response force would increase and response latency would decrease.

METHOD

Apparatus

A panel push apparatus was used in which it was possible to measure response latency and force. It was constructed of one-half-inch plywood and its dimensions were 24 in. long, 12 in. wide, and 12 in. deep. A guillotine door at one end of the chamber, when raised, gave access to a 4 in. by 2 in. panel door hinged at the top. A thin metal rod, hung at the top of the panel, was twisted so that it extended to the back of the panel in one direction and to the top of the apparatus in the other direction. The rod was designed so that the lower half rested on the panel and rode back on the panel as this was pushed open. The upper half came forward toward the chamber with any movement of the panel. By means of this rod, force applied to the panel was transmitted to a screw which was attached to the side of a light wooden wheel which rotated on its center. The force of the response, pushing on the panel, could be measured by the displacement of the wheel, measured in degrees. Because the wheel offered little resistance to the metal rod, the initial movement of the panel caused it to turn out of the range of further movements of the rod. That is, the distance that the wheel was displaced depended upon the force of the initial push on the panel and not merely upon the distance through which the panel was moved.

Response latency was measured by a Standard Electric Timer, connected in series through two microswitches. The first switch was located at the top of the guillotine door. When the door was fully raised this switch was closed. This started the timer and defined the beginning of a trial. The second switch closed when a brass strip was displaced. The strip was located behind the panel so that when the panel was one-half opened the switch was opened. Thus, the timer started when the guillotine door was raised and stopped when the panel was pushed open.

Located behind the panel was a three sided enclosure. The floor of this held the small plastic cup in which the reward pellets were placed. The sides of this small enclosure prevented escape and discouraged exploratory behavior. The base of the microswitch, behind the panel, prevented the panel from swinging completely open, helping to prevent escape.

The interior of the chamber was unpainted as was the area behind the guillotine door. The top of the chamber was clear plexiglass which could be raised to give entrance to the box. The apparatus is shown in Figure 1.

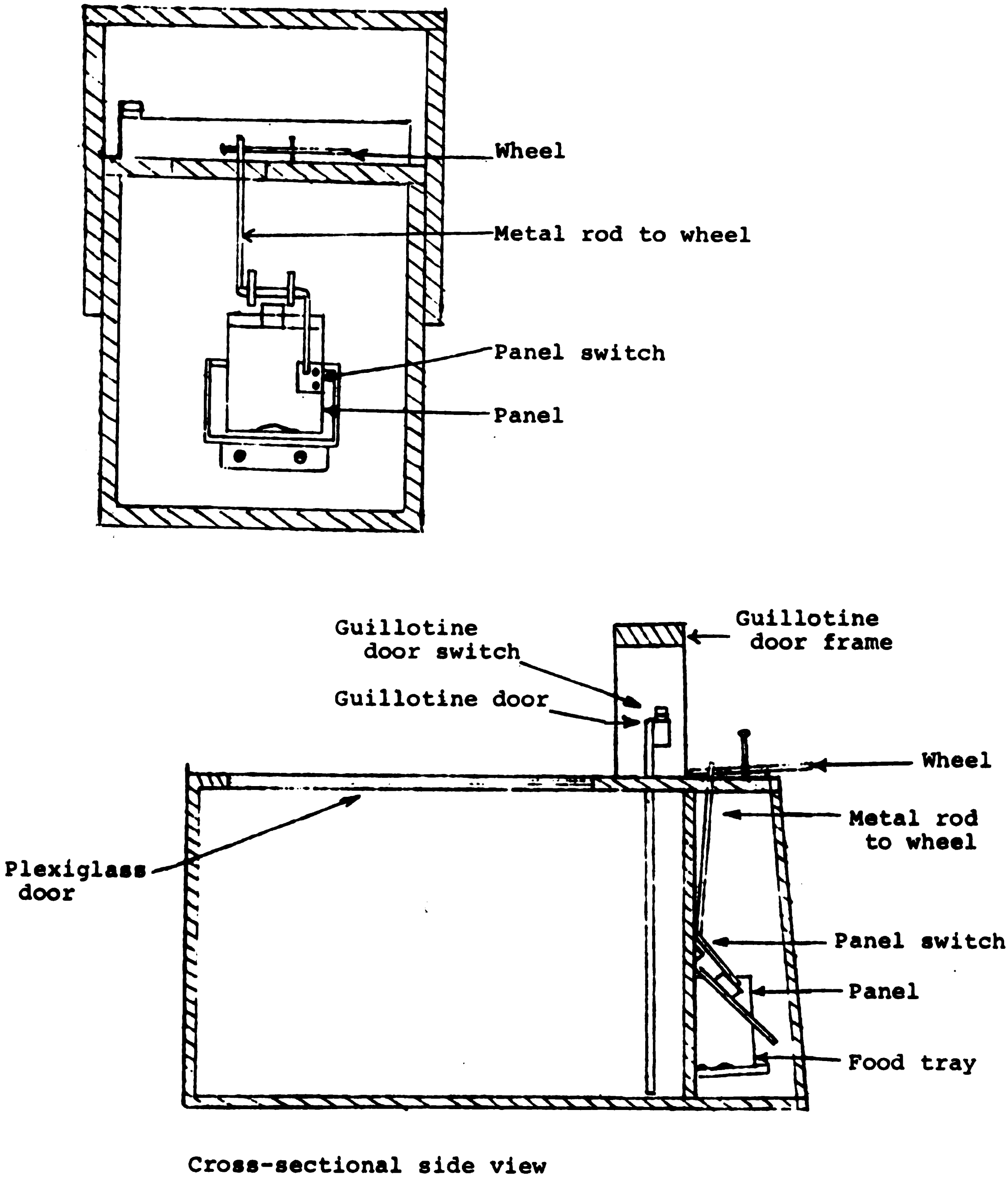

Figure 1. Drawing of apparatus discussed in text.

The experiment was conducted in a white room which was dimly lighted and relatively quiet. The rats were maintained in the same room in which they were run.

Subjects

Forty, male, albino rats from Spartan Research Animals, approximately 100-175 days old at the beginning of the experiment were used as *Ss*. They had been previously used for a study which had not called for food deprivation.

Overview of Method

Four subjects from the same group were housed in each cage. A 23-hour food deprivation cycle was maintained throughout the experiment. Following each day's trials for all groups, the *Ss* were given food in the home cage. Following the 1-hour free feedings, the remainder of the food was taken from the cage. Observation assured that 1-hour was enough time for all the animals to eat to satiation. This schedule was maintained to allow the smaller reward groups to maintain a level of deprivation approximately the same as the larger reward groups. Water was continuously available in the home cage.

The 40 subjects were divided into five independent groups with eight subjects in each group. On each training trial and on each rewarded trial during testing, each subject received one pellet of the size designated for his group. The sizes of pellets used were 20 mg, 45 mg, 97 mg, 190 mg, and 500 mg. These sizes were chosen since they are the standard pellet sizes available from Noyes. One pellet of various sizes was used rather than various numbers of the same size pellets since this eliminated the necessity of a subject repeatedly returning to the panel for the remainder of his reward. Usually, a subject would take the pellet back to the chamber to eat it. By using one pellet the subject would have to approach the panel only once, which permitted the effect of the absolute size of the reward pellet to be more clearly measurable.

Preliminary Training

The _S_s were placed on food deprivation for approximately three weeks prior to the first day of shaping. They received four blocks of mouse food (approximately 12 grams) in their home cages each day. After the first day of shaping, the _S_s were placed on the 23-hour food deprivation cycle which was maintained throughout the experiment.

Prior to the first shaping day, the _S_s received four days of hand habituating and habituation to the small waiting cages. This consisted of _E_ lifting the _S_, holding it for a few seconds and returning it to the waiting cage with a small chunk of food. The day before shaping began each _S_ was placed in the experimental chamber with the guillotine door open and given a small amount of food, of the appropriate size, in the chamber near the panel.

Shaping the panel push response lasted three days with five trials per day. The first day the panel was propped fully open with the appropriate pellet in the food cup for three trials and one-half open for two trials. The second day the panel was one-half open for the first three trials and one-fourth open on the last two. On the third day the door was propped one-fourth open for the first three trials and fully closed for the last two.

Acquisition sessions, five trials per day for nine days, were given seven days a week for all groups. The Ss were placed in the chamber from the waiting cages. Thirty seconds after Ss were placed in the chamber the guillotine door was raised and the first trial begun. A trial consisted of the approach to the panel which provided access to the food cup. When the Ss had withdrawn from the panel far enough for the guillotine door to be closed the trial was completed, and the inter-trial interval of 30 seconds was begun.

The second stage of the experiment was identical to the first, except that eight trials per day were given; the first three rewarded and the last five non-rewarded. Thus providing four trials prior to the withdrawal and four trials following the withdrawal of reward. Stage II lasted for four days.

The extinction stage (Stage III) was conducted similarly to the first two stages except that reward was completely eliminated. Extinction lasted five days with five trials per day.

RESULTS

At the end of the acquisition stage of the experiment, the two groups which received the largest reward, G-500 and G-190, showed the greatest response force. The other three groups showed the opposite effect. The smallest of these, G-20, showed the greatest response force, G-45 showed the next greatest and G-97 showed the lowest response force. The daily mean response force for each group for each day of acquisition is presented graphically in Figure 2. The analysis of variance on these data indicated that the effect of reward magnitude on response force was significant ($F = 4.52$; $df = 4, 35$; $p < .01$), although no direct relationship between reward magnitude and response force was found. The results of this ANOVA, given in Table 1, further indicated that the effect on response force of days of training was not significant ($F < 1$), and no significant interaction effect between days of training and reward magnitude was observed ($F < 1$).

Latency of response in acquisition appeared to be related to magnitude of training reward. The longest response latencies were observed for the two smallest reward groups, G-20 and G-45, but the response latencies

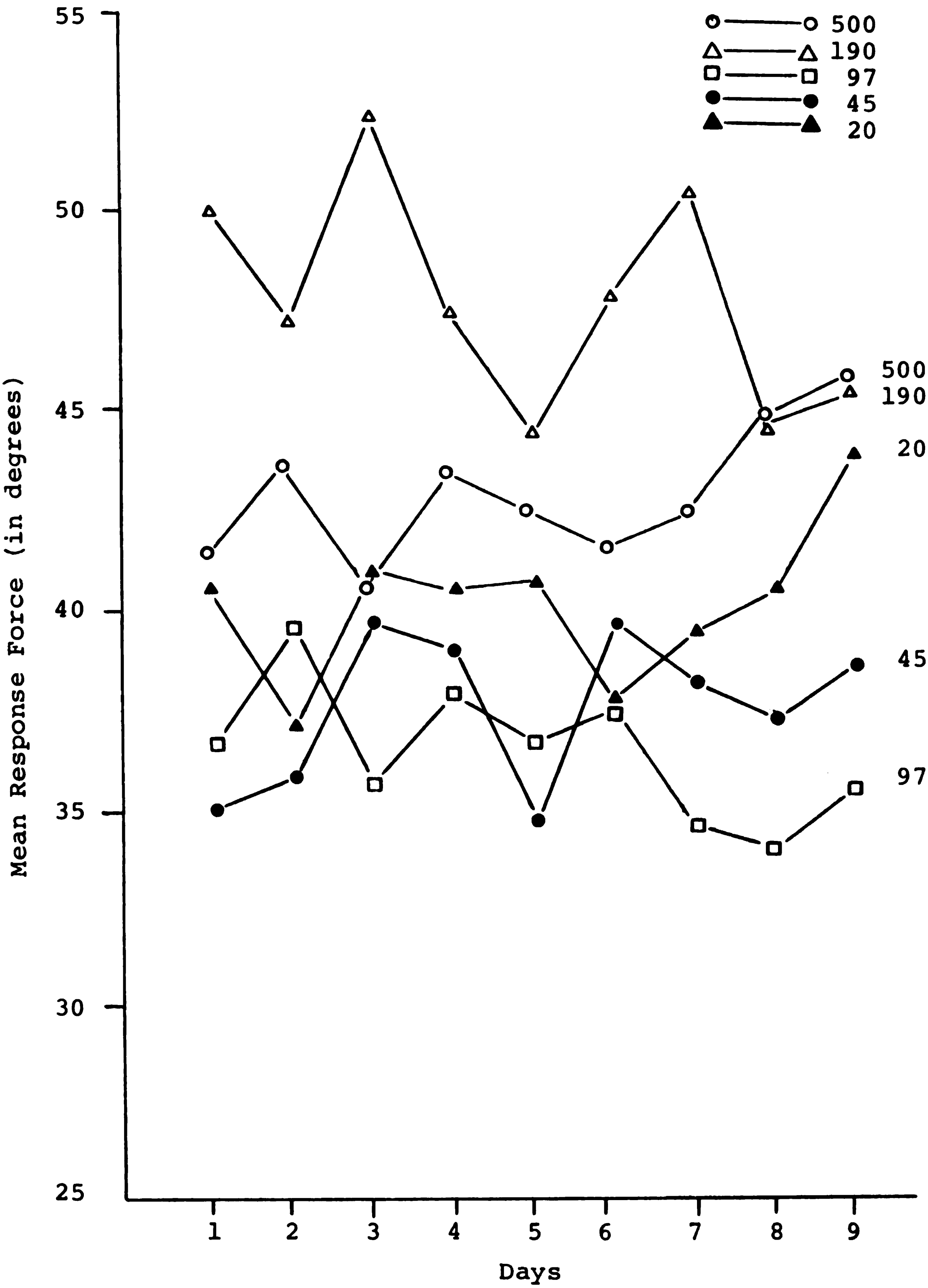

Figure 2. Mean response force in training by groups over days.

Table 1. Analysis of variance on effects of reward magnitude, days of training, and the interaction of these, with response force as the measure, Stage I.

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Squares	F	p
Reward magnitude	147,973.93	4	36,993.4825	4.5246	<.01
Error	286,163.27	35	8,176.0937		
Days	4,175.21	8	521.901	<1	ns
Reward magnitude by days	29,656.765	32	926.7739	<1	ns
Error	352,291.355	280	1,258.1834		

of the other three groups were approximately equal. The mean response latencies for each group for each day of acquisition are shown in Figure 3. The analysis of variance on these data indicated that the Effect of reward magnitude on response latency was significant ($F = 5.28$; $df = 4, 35$; $p < .01$).

As may be seen in Figure 3, response latencies for all groups grew shorter with days of training. The effect of days on response latency was found to be significant ($F = 10.43$; $df = 8, 280$; $p < .01$). Although the effect of the interaction between days of training and reward magnitude was not significant, the relationship was in the predicted direction. The response latencies of the three largest reward groups reached asymptote more quickly than G-45 and G-20, further, the asymptote for the three large reward groups was lower. The results of the analysis of variance for these response latency data are given in Table 2.

Each of the four test sessions (Stage II) consisted of three reinforced trials followed by five non-reinforced trials. Figure 4 shows the mean response force of each group for each trial of the first day of the test stage. Contrary to the prediction, a decline in response force was observed in four of the five groups from trial four to trial five, the trial immediately following the first non-rewarded trial. However, this immediate decrement was

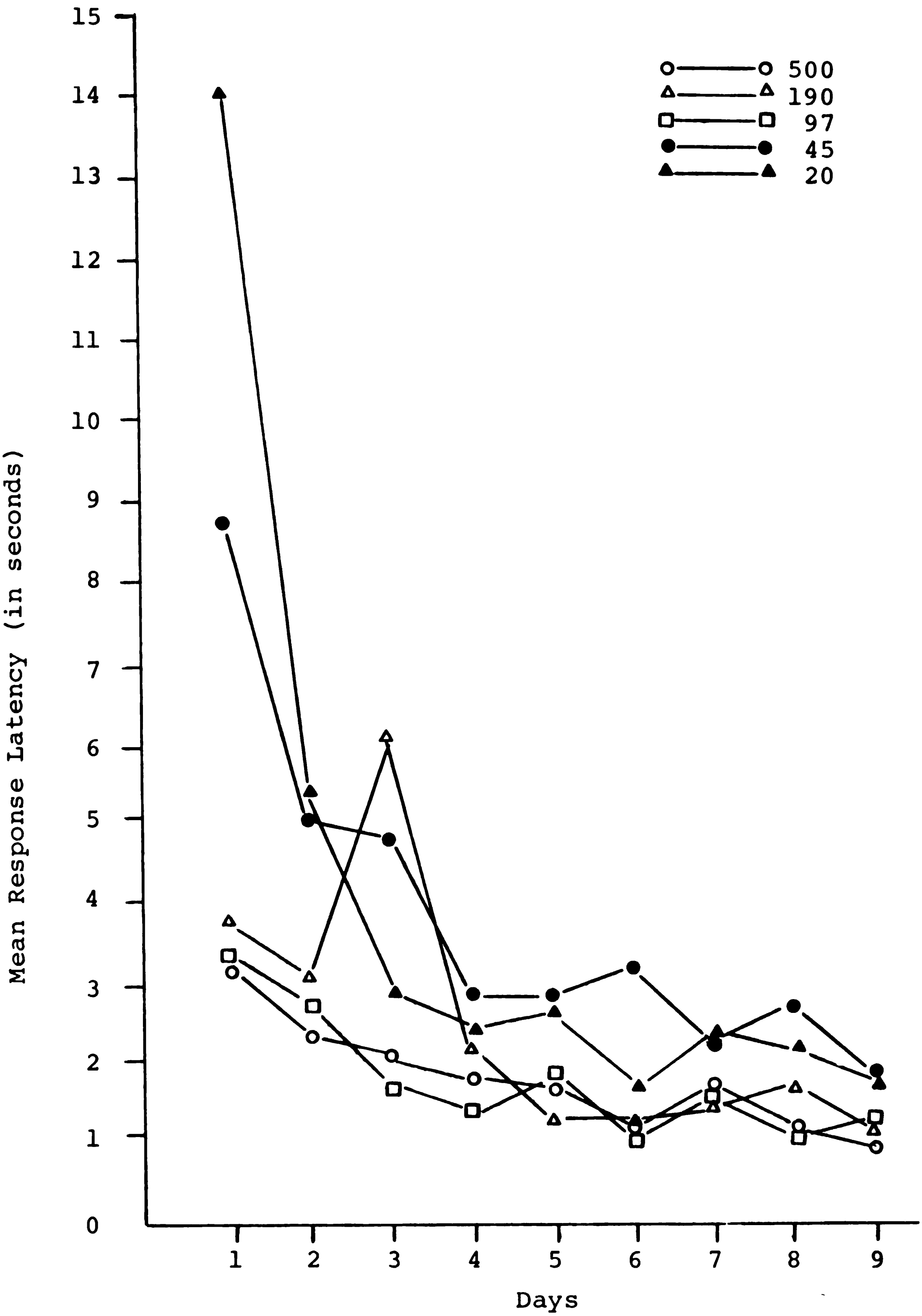

Figure 3. Mean response latency in acquisition by groups over days.

Table 2. Analysis of variance on effects of reward magnitude, days of training, and the interaction of these, with response latency as the measure, Stage I.

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Squares	F	p
Reward magnitude	8,307.213	4	2,076.8032	5.2388	<.01
Error	13,874.9662	35	396.4276		
Days	22,901.3404	8	2,862.6675	10.4273	<.01
Reward magnitude by days	16,836.9553	32	526.1549	1.9164	ns
Error	76,869.7861	280	274.5350		

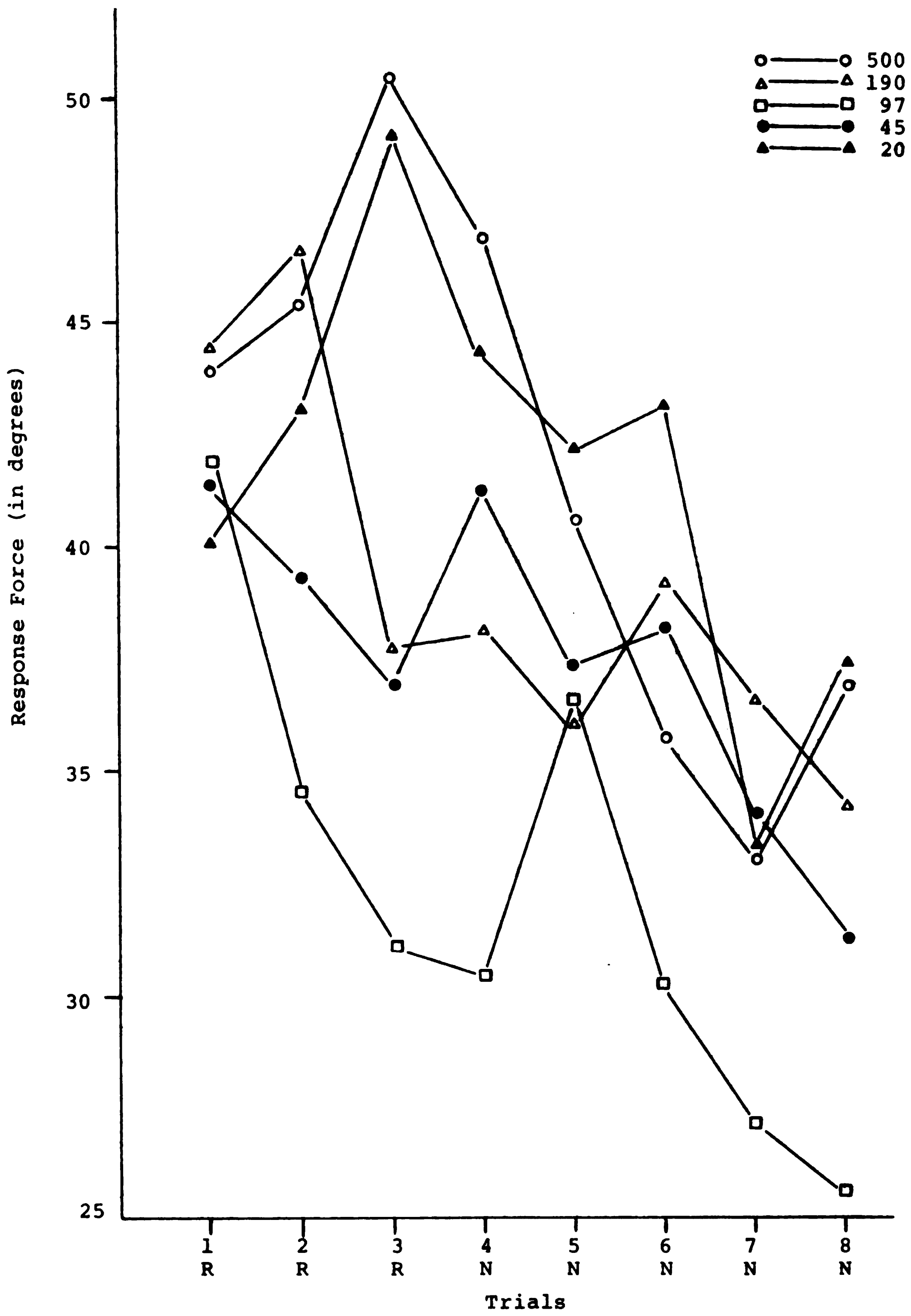

Figure 4. Mean response force on first day of testing by trial.

too small to be entirely attributed to the effects of non-reward.

The eight trials were divided into two blocks for further analysis. Block I consisted of those trials which followed reward (trials one through four) and Block II consisted of those trials which followed non-reward (trials five through eight). Figure 5 shows the mean response force for each group for the two trial blocks on the first day of testing.

A decrease in mean response force comparing Block I to Block II was observed for all groups. An analysis of variance on these data (Table 3) found that the effect of blocks was highly significant ($F = 18.87$; $df = 1, 35$; $p < .01$). That is, the mean response force for each group was lower following withdrawal of reward, i.e., for trials five through eight of each test session.

The effect due to magnitude of training reward on response force was found to be non-significant ($F = 2.07$; $df = 4, 35$; $p > .10$), although the greatest drop from Block I to Block II was observed in the mean response force of G-500, the largest reward group. A direct relationship between size of training reward and amount of response force decrement was not observed.

Results for the other three days of testing were very consistent with those of the first day which are given above. The mean response force for Block II was lower than the mean response force of Block I for each group on each

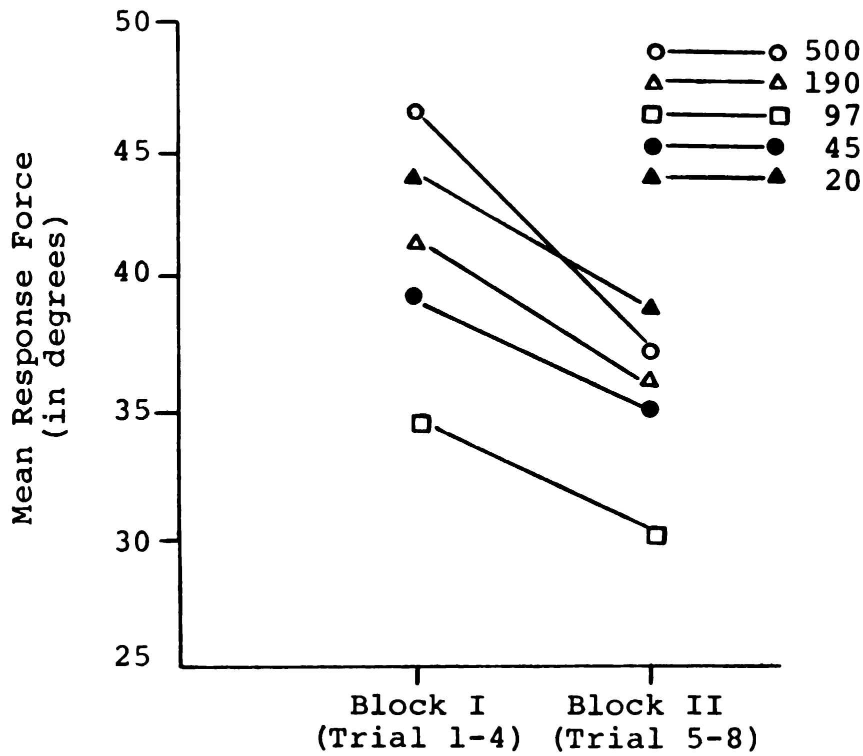

Figure 5. Mean response force for each group for first day of test stage by trial blocks.

Table 3. Analysis of variance for effects of reward magnitude, blocks of trials (following reward and following non-reward) and the interaction of reward magnitude and blocks, with response force as the measure, day 1, test stage.

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Squares	F	p
Reward magnitude	15,049.625	4	3,762.406	2.07	ns
Error	63,606.562	35	1,817.330	--	--
Blocks of trials	11,068.512	1	11,068.512	18.87	<.01
Reward magnitude by blocks of trials	1,440.425	4	360.106	.61	ns
Error	20,526.562	35	586.473	--	--

day of testing. These data are presented graphically in the Appendix along with the results of the ANOVA for each day.

The response latency data for the test stage were similar to those of response force. On the trial immediately following withdrawal of reward for the first test day, the average latency over all groups stayed at approximately the same level as for the first four trials. Individual groups showed slight declines or rises, but these tended to average out when the groups were combined. The mean response latencies for each group for each trial of the first day of the test stage are shown graphically in Figure 6. As can be seen from this figure, the mean response latencies lengthened considerably within the four trials following withdrawal of reward.

The eight trials were divided into two blocks, as was done for the response force data analysis. An increase in mean response latency between Block I (following rewarded trials) and Block II (following non-rewarded trials) was observed for all groups. The effect of blocks on response latency was found to be significant ($F = 13.82$; $df = 1, 35$; $p < .01$). The mean response latencies for each group for Block I and Block II on the first day of testing are shown in Figure 7. The results of the ANOVA for the effects of blocks of trials, reward magnitude, and the interaction between blocks and reward magnitude used in training are

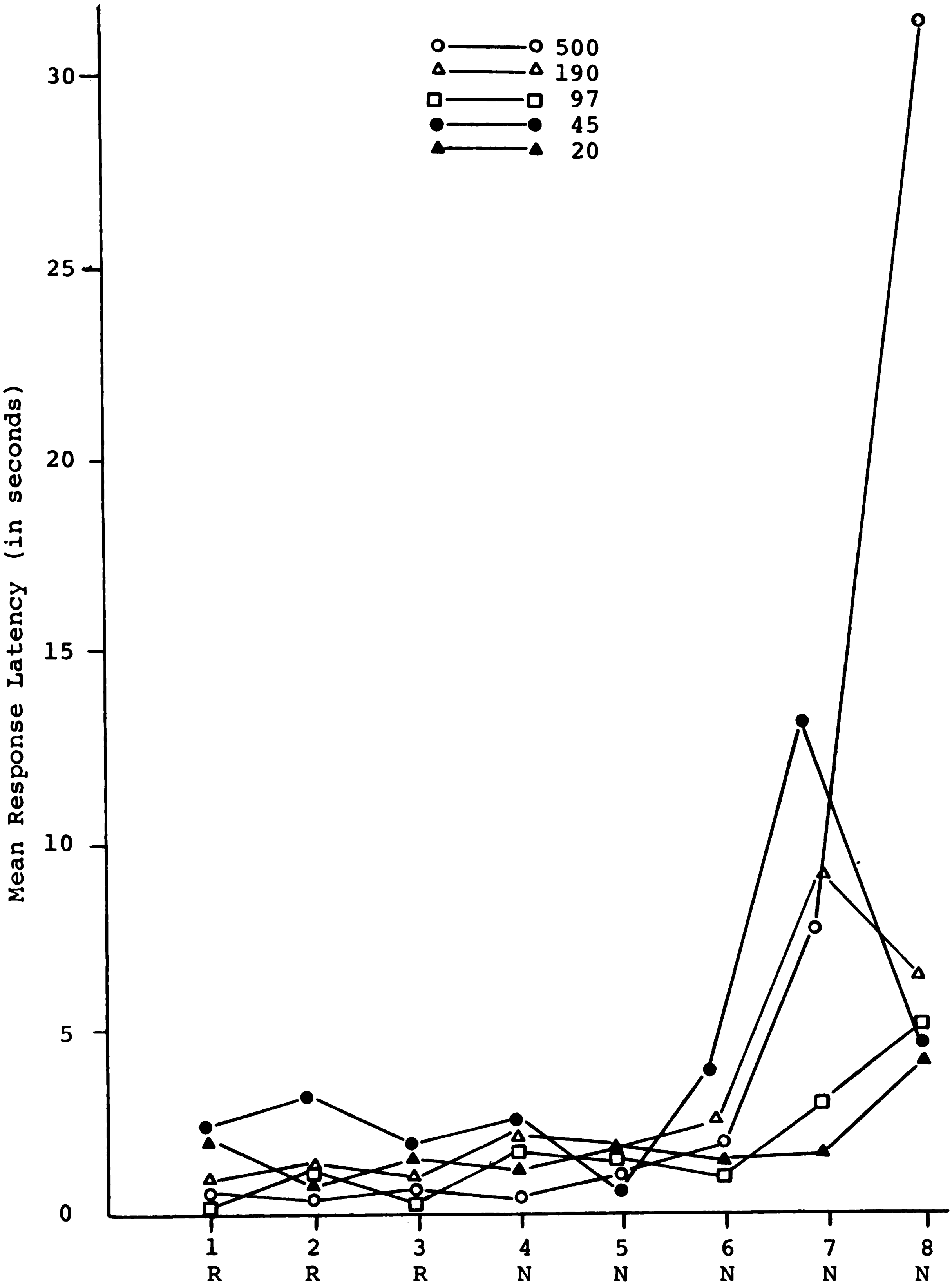

Figure 6. Mean response latency for each group for each trial on day 1 of test stage.

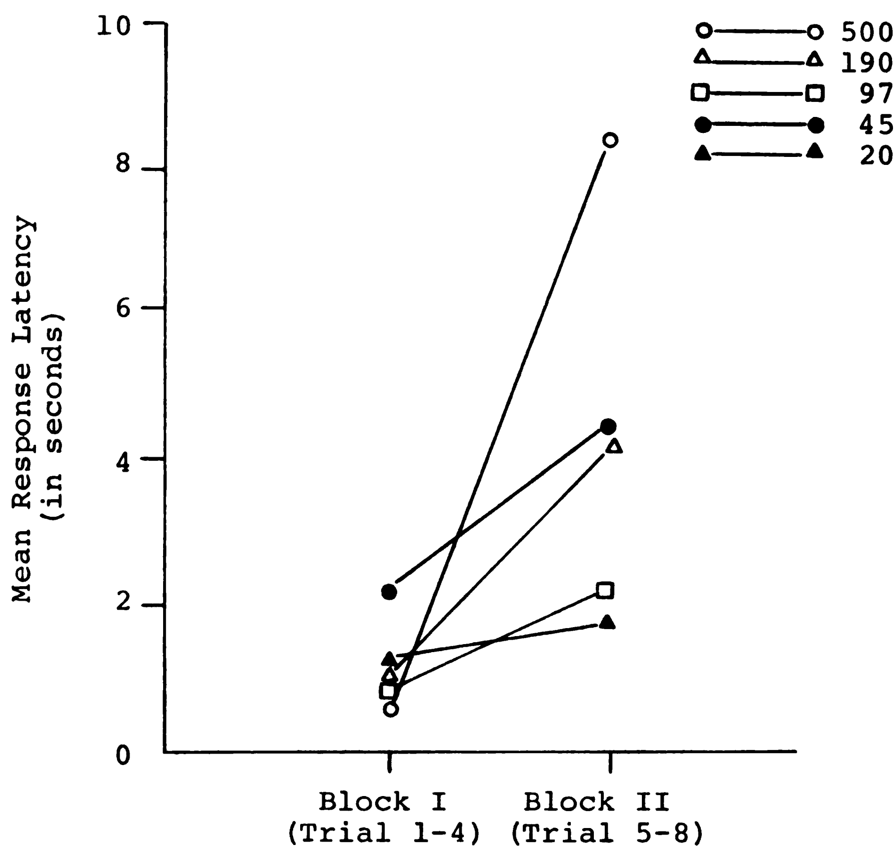

Figure 7. Mean response latency for each group for first day of test stage by trial blocks.

given in Table 4, the only significant effect was due to blocks.

The relationship between magnitude of training reward and amount of increase in response latency from Block I to Block II can also be seen in Figure 7. The greatest increase in response latency from Block I to II was observed for the largest reward group, the next largest from the next largest reward group. Although a perfect direct relationship was not observed, the results tentatively suggest a relationship. The effect due to reward magnitude used in training was found to be non-significant in the test stage ($F = 1.72$; $df = 4, 35$; $p > .10$).

The results observed for the other three test sessions were consistent with the results of the first. Mean response latency increased from Block I to Block II for each day for each group. These data are presented graphically along with their respective ANOVA results in the Appendix.

A decrease in response force was observed from the last day of extinction for all five groups. The effect of stage of experiment was found to be highly significant ($F = 30.29$; $df = 1,35$; $p < .01$). The ANOVA for these data are presented in Table 5, and the mean response force for each group on the last day of acquisition, the first day of extinction, and the last day of extinction are presented graphically in Figure 8.

Table 4. Analysis of variance for effects of reward magnitude, blocks of trials (following reward and following non-reward) and the interaction of reward magnitude and blocks, with response latency as the measure, day 1, test stage.

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Squares	F	p
Reward magnitude	2,763.183	4	690.80	1.72	ns
Error	14,033.089	35	400.95	--	--
Blocks of trials	4,627.338	1	4,627.338	13.82	<.01
Reward magnitude by blocks of trials	3,323.289	4	830.822	2.48	ns
Error		35	334.759	--	--

Table 5. Analysis of variance for effects of reward magnitude, stage of experiment, and the interaction of these, with response force as the measure (end of acquisition and end of extinction).

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Squares	F	p
Reward magnitude	12,145.3000	4	3,036.325	1.2369	ns
Error	85,911.1875	35	2,454.6053		
Stage of experiment	99,757.8125	1	99,757.8125	30.2851	<.01
Reward magnitude by stage of experiment	16,966.00	4	4,241.50	1.2876	ns
Error	115,288.1875	35	3,293.948		

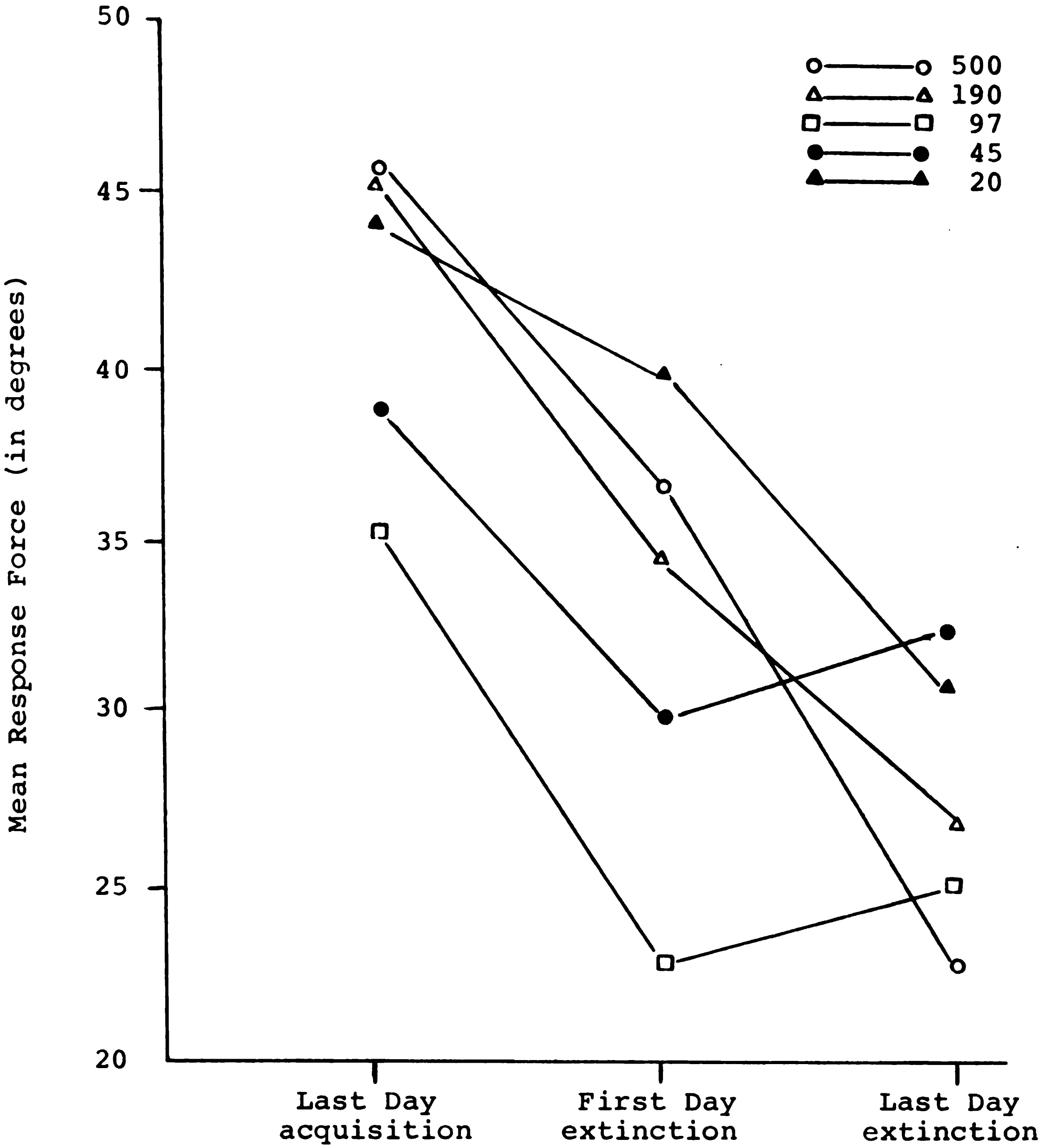

Figure 8. Mean response force for each group on last day of acquisition, first day of extinction (following test sessions), and last day of extinction.

Although the reward magnitude by stage of experiment (in last day of acquisition on last day of extinction) interaction was not significant (F = 1.28) it was observed that the larger the magnitude of training reward, the greater the decrement in mean response force during extinction. This relationship was observed for all but one group. The smallest group, G-20, showed a response force decrement in extinction larger than that of G-45 and G-97. The decreases in mean response force for each group were as follows: G-500, 22.9; G-190, 18.1; G-97, 10.3; G-45, 6.3; and G-20, 13.0. However, as noted above, these differences among groups are not significant.

Response latencies for all groups increased considerably comparing acquisition with extinction, as predicted. At the end of acquisition, prior to any experience with non-reward, all five groups showed mean response latencies between .5 seconds and 2 seconds, by the first day of extinction the response latencies were between 5 seconds and 23 seconds, and on the last day of extinction they were between 8 seconds and 46 seconds. These data are presented graphically in Figure 9.

An analysis of variance indicated that the effect of the stage of experiment (i.e., increase in response latency from end of acquisition to the end of extinction) was highly significant (F = 267.63; df = 1, 35). The ANOVA for these data are presented in Table 6.

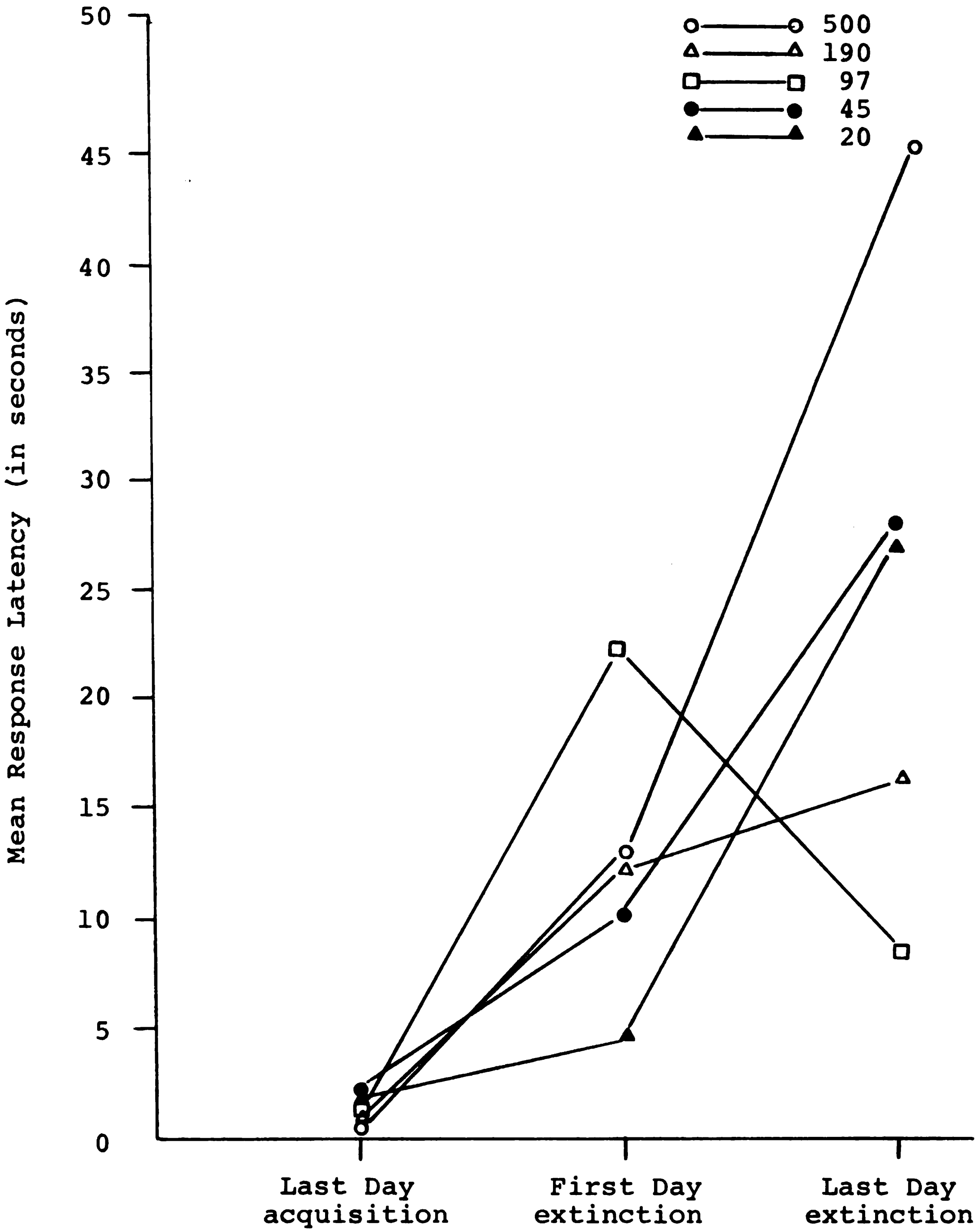

Figure 9. Mean response latency for each group on the last day of acquisition, first day of extinction, and last day of extinction.

Table 6. Analysis of variance for effect of reward magnitude, stage of experiment (acquisition and extinction), and the interaction of these effects with response latency as the measure.

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Squares	F	p
Reward magnitude	77,896.1355	4	19,474.0339	1.596	n.s.
Error	427,038.5521	35	12,201.1015		
Stage of experiment	291,037.9696	1	291,037.9696	267.63	<.01
Reward magnitude by stage		4	19,930.1510	18.33	<.01
Error	38,061.8574	35	1,087.4816		

The interaction between reward magnitude used in training and stage of experiment (end of acquisition or end of extinction) was also found to be significant as may also be seen in Table 6. Although direct relationship between amount of reward and change in response latency was not observed the largest increase in response latency during extinction was observed for the largest reward magnitude group, G-500.

DISCUSSION

A decrease in response force following withdrawal of reward was observed rather than the predicted increase in response force. This decrement was small at first, but it continued during the four trials following non-reward during each day of the test stage. These results are obviously not in agreement with Amsel's theory of frustrative non-reward. It is possible, however, that a reasonable interpretation of the diverse effects is available in a theory proposed by Denny, namely, elicitation theory (Denny, 1967, 1971, 1971; Denny & Aditman, 1955).

In elicitation theory it is postulated that extinction occurs because of effective competition by competing responses (R_c) in the same or similar stimulus situations. The effectiveness of the competition between $S\text{-}R_o$ and $S\text{-}R_c$ is a function of the degree of incompatibility of R_o and R_c. A further postulate of elicitation theory is that an elicitation hierarchy describes the hierarchy eliciting value of all the stimuli in a stimulus situation. The response of the stimulus-response tendency which is momentarily strongest is the one that occurs (Denny, 1970).

Adelman and Maatsch (1955) studied the role that the type of R_c elicited by non-reward played in the extinction process. They allowed three separate groups to extinguish under one of the following conditions:

a) allowed to jump out of the goal box onto a two-inch ledge for twenty seconds;
b) allowed to recoil from the goal box for a period of twenty seconds and retrace;
c) stayed in the goal box for twenty seconds--regular extinction.

The results indicated that extinction occurs most rapidly when the response elicited by non-reward was directly incompatible with R_o. That is, the recoil group extinguished fastest since recoil was directly incompatible with approach; and the jump out group which was allowed to escape from the goal box and spent the 20 seconds in another stimulus situation, extinguished the slowest. In fact, they hardly extinguished at all within 100 massed extinction trials. It was concluded that the jumping response was directly elicited inside the goal box and conditioned to these cues. The jump-out response was not incompatible with approach and was assumed to be an extension of this response chain.

The panel push apparatus, as previously described, does not allow S to excape from the goal area behind the panel by continuing on in the same forward direction. The situation is like regular extinction or the "recoil" condition in the Adelman and Maatsch study. The available responses when reward is eliminated are limited to remaining near the empty food cup or recoiling from it. Recoiling, the most likely response, according to elicitation theory, is directly incompatible with the R_o of approaching the goal. We would expect, with repeated non-rewards, that as R_c is frequently and consistently elicited, it becomes conditioned to S and interferes with R_o, and as non-reward continues, and R_o is interfered with, the force of R_o should decrease.

An increase in response latency was observed following withdrawal of reinforcement. This increase occurred within the first four trials following onset of non-reward in the test stage and continued through extinction. This increase in response latency of R_o also could be attributed to the effective competition of R_c. As non-reward is repeated R_c would be more consistently elicited and R_o would become less likely to occur. Therefore, the latency of R_o would tend to increase just as force of R_o would tend to decrease.

The assumption that incentive size, since it is assumed to partially control the strength of r_g, will be directly related to the amount of frustration effect, found only limited support in the present study. In part, this may be due to the type of reward magnitude used, size of pellet rather than number of pellets. The results were in the predicted direction (the larger reward groups showed larger decreases in response force in extinction) except for the smallest group (G-20). The eliciting value of one

20 mg pellet may be so small as to yield a response strength for R_o which could easily be outweighed by competing responses. This could result in faster extinction and greater response force decrement for this group as opposed to the larger reward magnitude groups. Except for the 20 mg group, the relationship observed between the amount of decrease in response strength and the reward magnitude used during acquisition was in keeping with the predictions based on the Armus (1959) effect.

As expected latency of responding decreased significantly with days of original training, as the criterion response (R_o) effectively competes with other responses, latency decreasing more quickly the larger rewards, although the three largest reward groups were almost exactly equal in performance. This is perhaps not unexpected in light of research which indicated that the effect of incentive size has little effect on the speed of acquisition of simple responses unless the incentive size is extreme.

Let us also see if this theory can shed light on some of the results in the double runway. This apparatus permits S to make responses following non-reward which are not necessarily incompatible with approach, being somewhat similar to the jump-out condition of the Adelman and Maatsch (1956) study. Here, it was found that a jump-out response elicited by non-reward, when an anticipation of reward had been developed, was learned faster than a jump-out response reinforced with familiar food. Thus, a combination in which elicitation of the response of running away from an empty goal box is joined with the elicitation of approach to food in GB-2, would predict a strong response in A-2, as generally is found in the double alley.

The results obtained by Notterman and Mintz (1965), namely, that frustration increases the amplitude of the bar press response, can also be seen as consistent with the elicitation position. In the operant situation, the food tray is separate from the bar, and the instrumental bar-pressing response represents an available alternative response, an elicited, tangential R_c occurs when the food tray is empty. Such a directly elicited response could increase the force with which the bar is pressed during the first part of extinction. Although this directly elicited component of the total R_c complex is incompatible with approach to the food tray it is quite compatible with the operant bar-press and the two summate. In the present study, on the other hand, panel push is an integral part of approach to food, closely associated in time with a directly elicited withdrawal response. Thus, it is congruent for frustration to increase the force of the operant in the Notterman and Mintz study and decrease the force of the operant in the present study where the operant is a part of the approach response to food.

This interpretation is also compatible with Goodrich's finding in the single runway apparatus that the faster running speeds for partial reward groups were not observed for many trials in the area closest to the goal as compared with the 100% reward group. Competing responses which are elicited by the empty goal cup would compete more effectively with that part of the running response chain which is closest to the goal cup.

The results of the present experiment were interpreted as not supporting Amsel's theory of frustrative non-reward. A decrease in response force was observed rather than the increase which would be predicted from Amsel's theory. These results and the results of earlier studies were examined in terms of the competing response view of extinction (of elicitation theory). The analysis of the effects of the magnitude of reward used in training only partially supported the hypothesis that this variable is related to response force decrement in extinction (inversely related, as is the case in the present experiment).

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APPENDIX

Table A. Analysis of variance on effects of reward magnitude, blocks of trials, and magnitude by blocks interaction with response force as the measure, day 2, Stage II.

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Squares	F	p
Reward magnitude	18,427.55	4	4,606.8875	2.6131	n.s.
Error	61,705.4375	35	1,763.0125		
Blocks	11,737.0125	1	11,737.0125	18.12	$<.01$
Blocks by magnitude	1,765.0500	4	441.2625	.68	ns
Error	22,670.4375	35	647.7265		

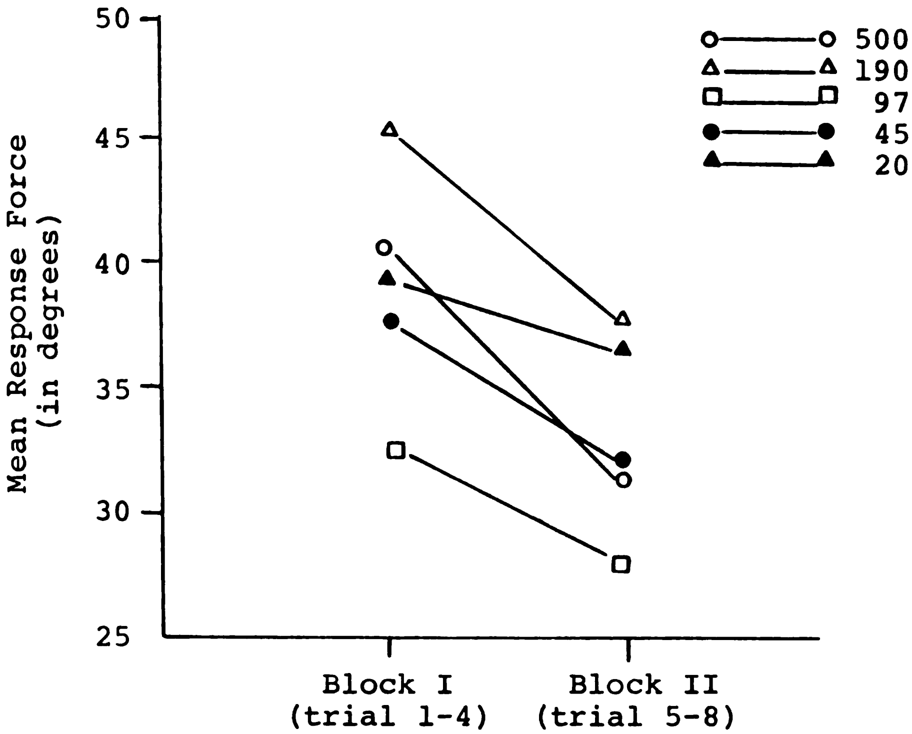

Figure A. Mean response force for each group for second day of test stage by trial blocks.

Table B. Analysis of variance on effects of reward magnitude, blocks of trials, and magnitude by blocks interaction with response force as the measure, day 3, Stage II.

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Squares	F	p
Reward magnitude	8,156.1750	4	2,039.0438	1.27	ns
Error	56,194.3125	35	1,605.5518		
Blocks	7,087.6125	1	7,087.6125	8.51	<.01
Blocks by magnitude	930.5750	4	232.6438	.28	ns
Error	29,146.3125	35	833.7518		

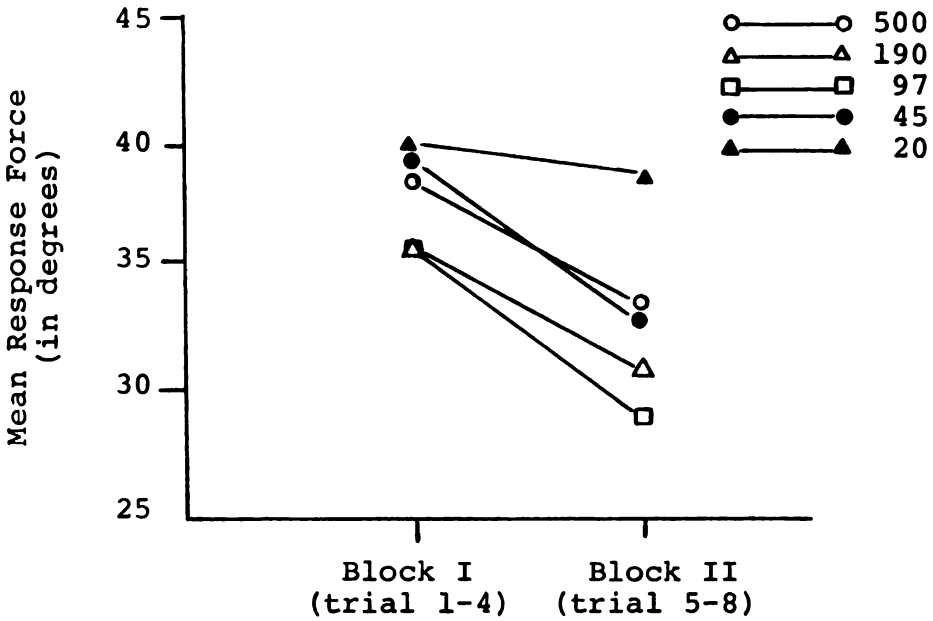

Figure B. Mean response force for each group for third day of test stage by trial blocks.

Table C. Analysis of variance on effects of reward magnitude, blocks of trials and blocks by magnitude interactions with response force as the measure, day 4, Stage II.

Source of Variance	Sums of Squares	Degrees of Freedom	Mean Squares	F	p
Reward magnitude	14,360.825	4	3,590.2063	2.799	n.s.
Error	44,893.125	35	1,282.6607		
Blocks	20,930.45	1	20,930.45	31.09	<.01
Blocks by magnitude	10,044.1750	4	2,511.0438	3.73	n.s.
Error	23,529.3750	35	672.27		

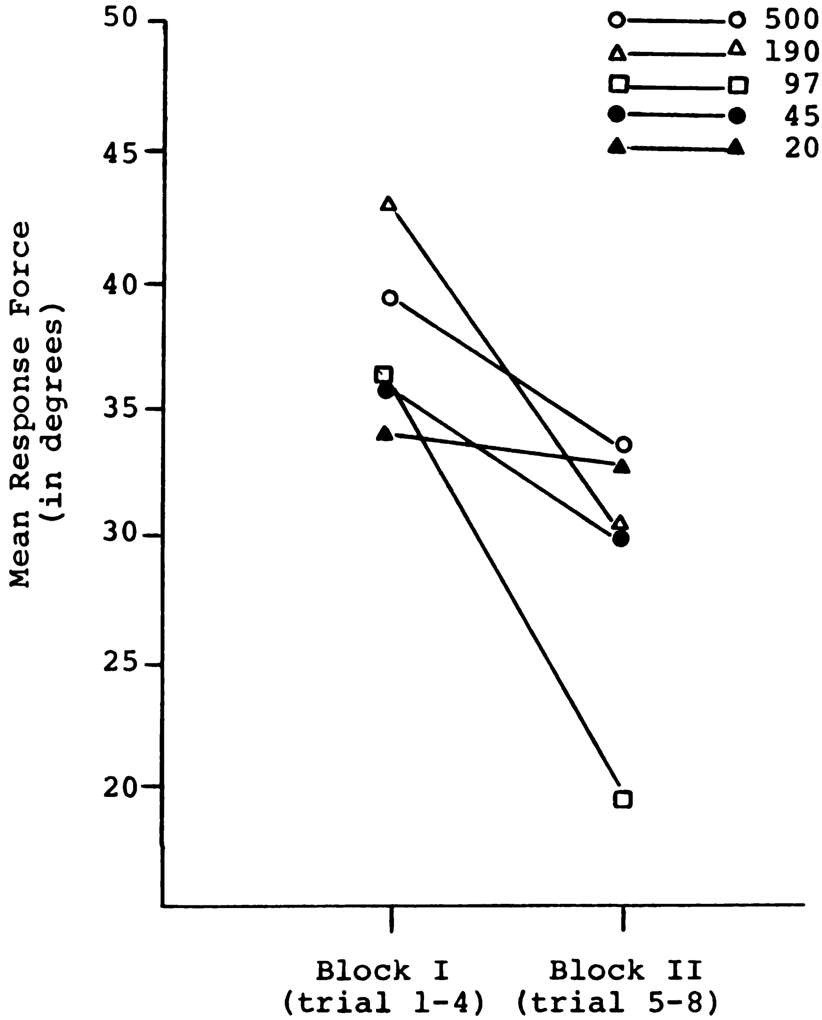

Figure C. Mean response force for each group for third day of test stage by trial blocks.

Table D. Analysis of variance for reward magnitude blocks of trials and magnitude by blocks interaction with response latency as the measure, day 2, Stage II.

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Squares	F	p
Reward magnitude	3,137.9470	4	784.4868	.5066	n.s.
Error	54,196.1282	35	1,548.4608		
Block	11,329.2760	1	11,329.2760	8.7226	<.01
Blocks by reward magnitude	76,605.9958	4	19,151.499	14,7451	<.01
Error	45,459.252	35	1,298.8358		

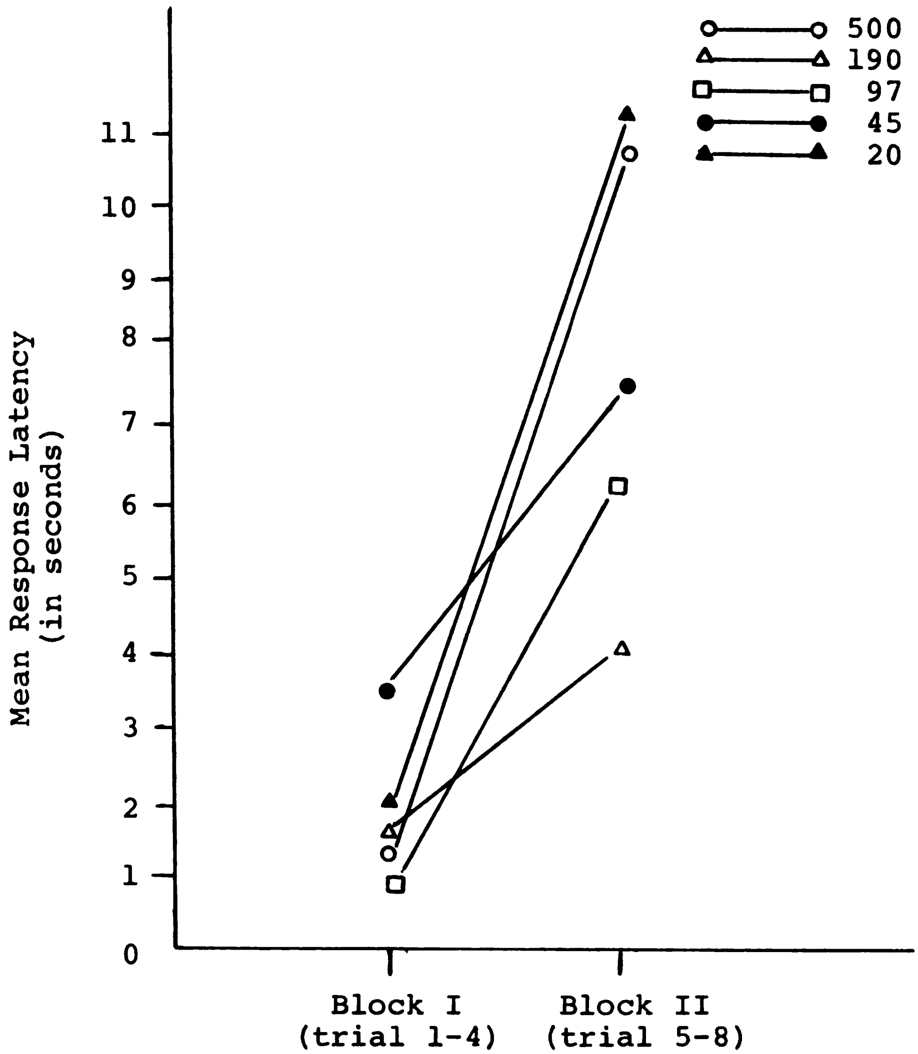

Figure D. Mean response latency for each group for the second day of test stage by trial blocks.

Table E. Analysis of variance for effects of reward magnitude, blocks of trials and magnitude by blocks interaction with response latency as the measure, day 3, Stage II.

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Squares	F	p
Reward magnitude	10,041.3479	4	2,510.337	.95	ns
Error	92,609.4291	35	2,645.9837		
Blocks	26,801.0829	1	26,801.0829	11.29	<.01
Blocks by magnitude	9,980.5263	4	2,495.1316	1.05	<.01
Error	83,075.1088	35	2,373.5745		

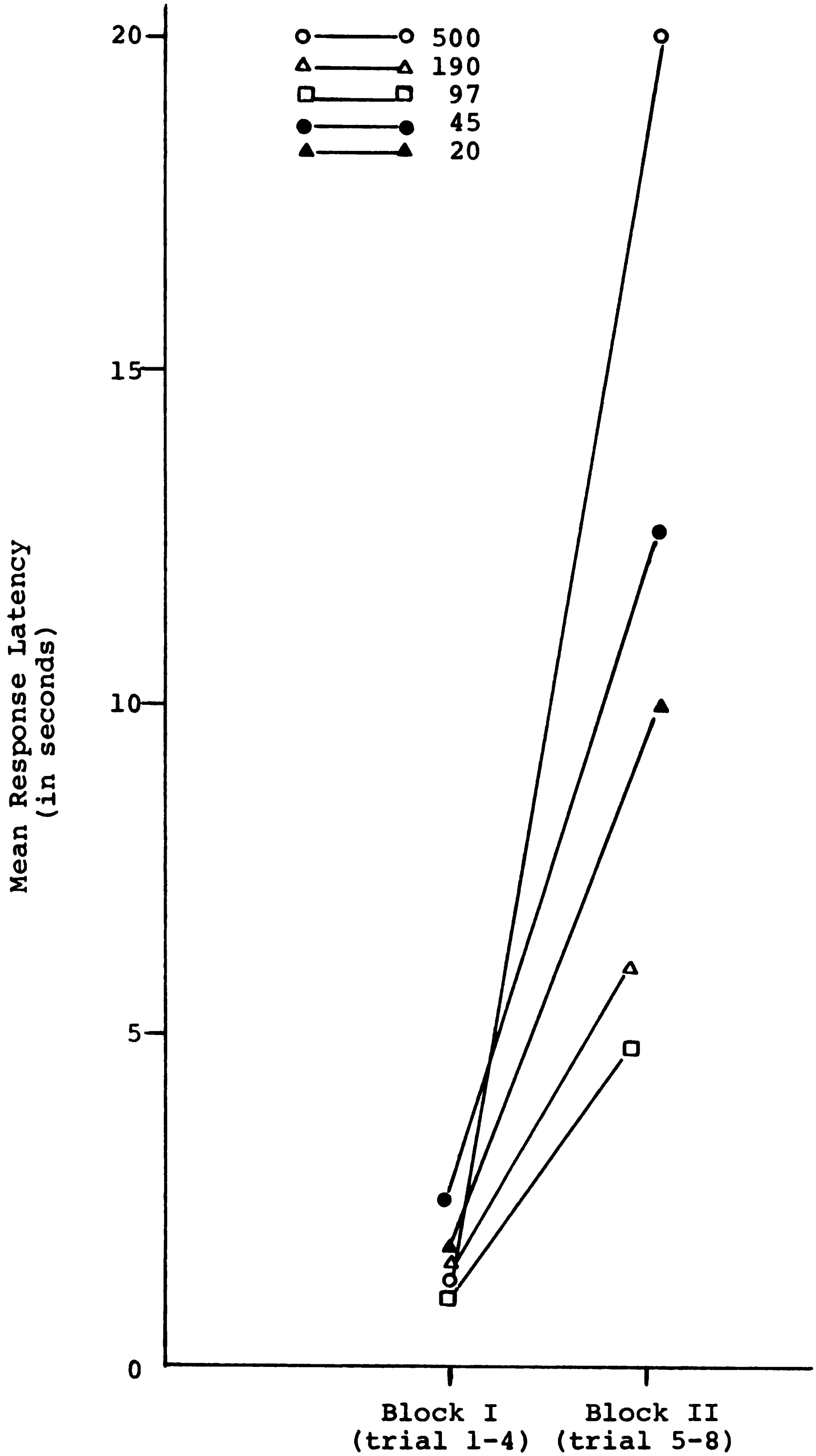

Figure E. Mean response latency for each group for the third day of the test stage by trial blocks.

Table F. Analysis of variance for effects of reward magnitude, blocks of trials and blocks by magnitude interaction with response latency as the measure, day 4, Stage II.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	F	p
Reward magnitude	3,153.6867	4	788.4217	.2249	ns
Error	122,677.8238	35	3,505.0807		
Blocks	34,972.8116	1	34,972.8116	11.24	<.01
Blocks by magnitude	5,274.0599	4	1,318.5150	.42	ns
Error	108,868.7757	35	3,110.5364		

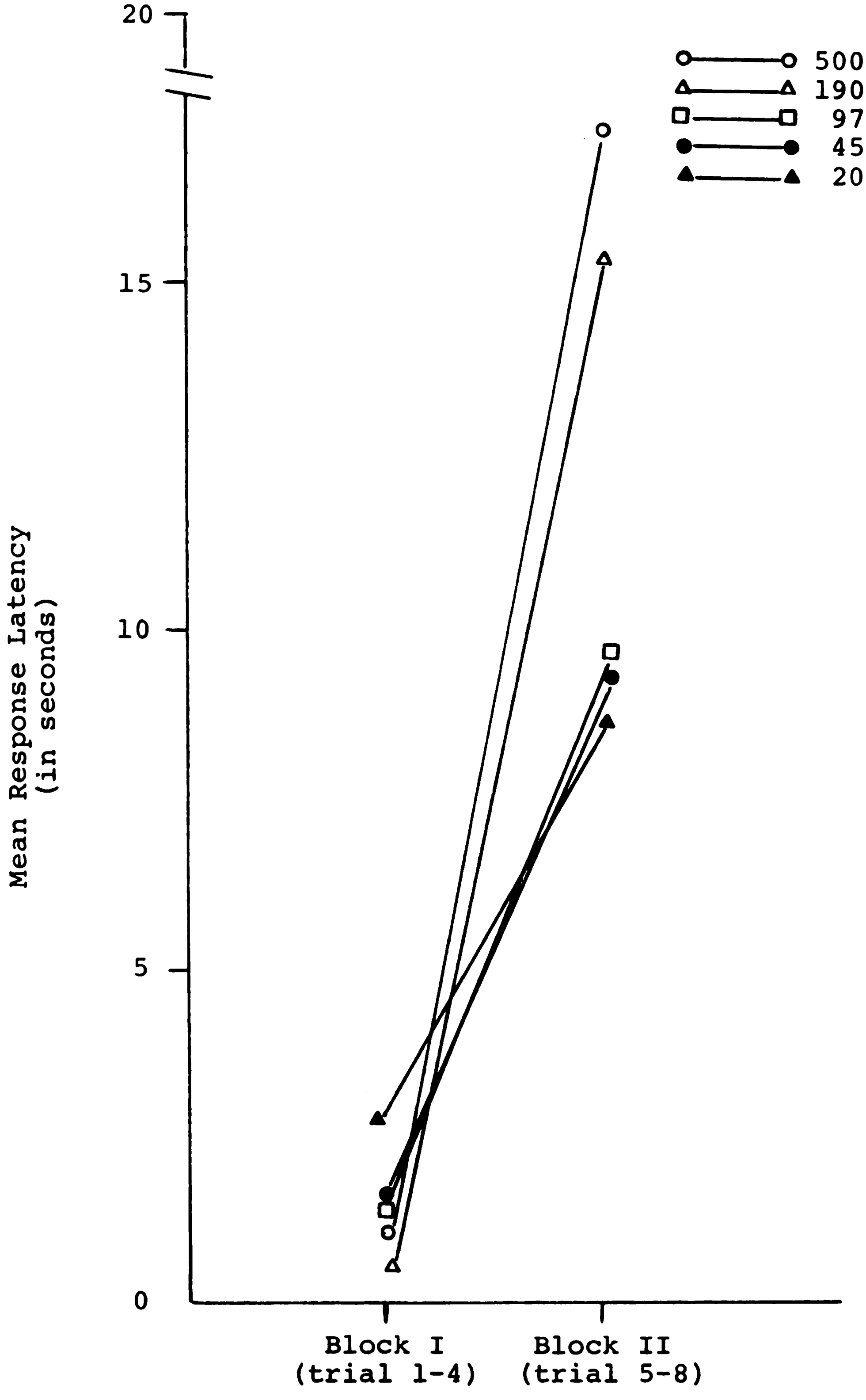

Figure F. Mean response latency for each group for fourth day of the test stage by trial blocks.