THE EFFECT OF INCENTIVE SIZE ON RESPONSE AMPLITUDE DURING ACQUISITION AND EXTINCTION

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ABSTRACT

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By

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Research during the past twenty one years, using the double alley paradigm, has demonstrated that an instrumental response preceded by nonreinforcement is performed with greater vigor than a response preceded by reinforcement (i.e., the Frustration Effect, FE). Unfortunately, this paradigm is subject to a major confounding, demotivation, which precludes the assessment of the effect of size of incentive upon the FE. The purpose of Experiment 1 was to investigate the effect of nonreinforcement on performance as a function of size of incentive during training, using a paradigm that was not subject to demotivational confounding. Thirty male hooded rats were run in an apparatus designed to measure force of panel pushing. Each S was trained to push two panel doors in succession such that pushing the first panel door (operant response) allowed S to obtain reinforcement (a 45 mg. pellet) behind the second panel (goal response). The ITI was 30 sec and the maximum duration of a trial was 2 min. Once this sequence was established Ss were assigned to one of five different groups; they differed in the size of the single

pellet S received per trial:a 45, 97, 190, 300 or 500 mg pellet. All Ss were run under the appropriate size of reward for 10 days (10 trials per day). At the end of training Ss were extinguished, half of each group under a 30 sec. ITI and half under an 8 sec. ITI.

The results of the acquisition stage indicated a significant increase in force of responding over days but no significant relation was found between size of incentive and force of responding. It was concluded that pellet size may not be a main incentive variable and that other variables uncontrolled in the present study such as ingestion rate may be more important. A type of goal gradient effect was also found during acquisition as reflected in greater force on the goal than on the operant panel. There was a suggestion that the development of this effect is retarded by shifts in incentive and facilitated by large sizes of reward.

The results of the extinction stage indicated a significant decrease in force of responding which was not functionally related to incentive size. It was also found that an 8 sec. ITI significantly retarded the development of inhibition of the operant response. The opposite was true for the goal response. It was suggested that this differential effect of ITI on force of responding was a function of the response invigorating properties of the traces of frustrative nonreward which preceded the operant response.

The purpose of Experiment 2 was to test an implication of the results of Experiment 1, namely, that the force of

the response following nonreinforcement will increase if the time between nonreinforcement and the performance of the next response is short enough. A second aim was to determine if a relation exists between size of incentive and force of responding during acquisition and extinction using a more sensitive within subjects design.

Ten male hooded rats were trained to panel push using a procedure analogous to Amsels double runway paradigm. Each S had to push two panels in sequence with food reinforcement (i.e., a single 45, 97, 190, 300, or 500 mg pellet) behind the first panel (G1) and water reinforcement behind the second panel (G2). Incentive manipulations such as shifts in incentive and nonreinforcement occurred at G1. The effects of these manipulations were assessed at G2. All Ss received training and extinction with all five incentive sizes. The order was counterbalanced using a Latin square design.

The results indicated a significant increase in force on G2 and a significant decrease in force on G1 due to nonreinforcement. These performance changes reached an asymptote after 11 nonreinforced trials. Consistent with Experiment 1 size of reward was not significantly related to performance during acquisition or extinction on either G1 or G2. It was concluded that size of incentive, as manipulated in these experiments, is not related to the FE. It was further suggested that ingestion rate, independently manipulated, might be used to great advantage to elucidate the relation between incentive value and FE.

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By

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Daniel F. Tortora

A DISSERTATION

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DEDICATION

To Angie, Dawn and Danny

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INTRODUCTION

Research specifically related to the effect of individual nonreinforcements on instrumental responding was initiated by Amsel and Roussel (1952). It was already known that an instrumental response followed by a series of nonreinforcements would decrease in vigor. Their study demonstrated that a response preceded by nonreinforcement or frustration can be performed more vigorously than a response preceded by reinforcement. This frustration effect (FE) has been investigated rather extensively for the last 21 years using various types of apparatus and several experimental designs. The results of these investigations have led to some superficial inconsistencies and some major methodological problems which will be described later.

Amsel's theory of frustration (1958; 1962) which emphasizes the energizing function of frustrative nonreward has been a significant contribution to the field. Thus it is not surprising to find that the apparatus Amsel first used to study FE (Amsel & Roussel, 1952) has become as standard for research in frustration as the Skinner box is for research on schedules of reinforcement. This apparatus is the double runway. It was designed so the rat can perform an instrumental response (alley running) immediately following frustrative nonreward.

The double runway consists simply of two straight alley runways constructed so that the goal box (Gl) of the first alley (R_1) also serves as the start box (S_2) of the second alley (R_2). The general procedure is as follows: S (i.e., a rat) is placed in the start box (S_1) of the first runway. The start box (S_1) door is opened allowing S to traverse the first runway (R_1) and enter the first goal box (G_1). Reinforcement versus nonreinforcement in G_1 is the manipulation generating the frustration effect. After S has consumed the reinforcement or has been detained in G_1 for a period of time (during nonreinforced trials) the door in G_1 is opened allowing S to traverse the second runway (R_2) and enter the second goal box (G_2). Reinforcement is always available in G_2. An increase in running speed in R_2 after nonreinforcement in G_1 has been considered by Amsel (1958, 1962) as a demonstration of FE. According to Amsel, (1952, 1958, 1962) nonreinforcement (after a series of reinforcements) elicits primary frustration which adds to the general motivational complex increasing the vigor (speed) of the response it precedes (i.e., running in R_2).

Unfortunately the analysis of the frustration effect using the double runway is subject to major confounding, especially if size of incentive in G_1 is manipulated. Seward et al. (1957) were the first to point out that faster speeds in R_2 after nonreinforcement may be due to decreased speeds in R_2 after reinforcement. This interpretation of the "apparent frustration effect" was supported by a significant decrease in R_1 speeds when his subjects were prefed 1000 mg or 500 mg of food before traversing the first runway, meaning that a faster R_2 time when G_1 is empty than when it contains food, operationally defined as the frustration effect, may be due to demotivational factor. This result is a significant criticism of any work with the double runway since it is difficult if not impossible to unconfound demotivational and frustration effects when large incentives in G_1 are used. Thus, since the amount of demotivational confounding is positively related to the reward size, this confounding prevents a clear determination of the effect of size of reward upon the magnitude of FE. In fact, Amsel (1958) has suggested and Wagner (1959) has demonstrated that small reward sizes (100 mg) do not produce detectable demotivational effects. This restricts double alley research to small sizes of reward.

Magnitude of Reward and FE

Given the preceding criticism it is not surprising that investigations of the effect of size of reward on frustrative nonreward using the double runway have yielded inconsistent results. Unfortunately almost all of the research relating reward size to frustration have used the double runway. Table 1 summarizes the procedures and results of the double runway studies that have investigated magnitude of reward. Out of the nine studies presented, only three studies (Peckham &

TABLE 1. Summary table of studies investigating the frustration effect (FE) as a function of size of incentive experienced in G_1 or G_2. All the studies summarized in this table have used rats as subjects, a double alley apparatus, and a between subjects (BS) or within subjects (WS) design.

Investigator	Range of Incentive Sizes Used	Design	Results and Comments
Barrett, et al. (1965)	4, 8 or 10 45 mg pellets in G_1 2 45 mg pellets in G_2	BS	"FE" was unrelated to size of incentive given during acquisition.
Daly (1968)	1, 6 or 15 37 mg pellets in G_1 6 37 mg pellets in G_2	BS	"FE" was found in the 15 but not the 6 or 1 pellet groups. Groups were compared to a control that was never reinforced in G_1.
Krippner, et al. (1967 a)	5 or 10 45 mg pellets in G_1 1 45 mg pellet in G_2	BS	"FE" related to reward size with the 10 pellet Ss faster than the 5 pellet Ss on NR trials. On R trials 10 p. Ss were slower than 5 p. Ss.
Krippner, et al. (1967 b)	5 45 mg pellets in G_1 1, 5 or 10 45 mg pellets in G_2	WS	"FE" was found but no relation was found between incentive size and R_2 speeds on NR trials. R_2 speeds possitively related to size on R trials.
McHose & Gavelek (1969)	1 or 8 45 mg pellets in G_1 2 45 mg pellets in G_2	WS & BS	"FE" was found to be related to demotivation, i.e., on R trials R_2 speeds were slower after 8 p. than after 2 p. There was on difference in R_2 speeds on NR trials.

TABLE 1 (continued)

Investigator	Range of Incentive Sizes Used	Design	Results and Comments
McHose, et al. (1969) Experiment 1	1, 4 or 8 45 mg pellets in G_1 2 45 mg pellets in G_2	WS	"FE" was not found. R_2 speeds were equal on NR trials for all comparison.
McHose, et al. (1969) Experiment 2	4, or 9 45 mg pellets in G_1 2 45 mg pellets in G_2	WS	"FE" was found but R_2 speeds on NR trials were faster with 4 pellets than with 8 pellets.
McHose & Ludvigson (1965)	2 or 10 45 mg pellets in G_1 2 45 mg pellets in G_2	BS	"FE" was found but size of FE was inversely related to size of incentive. Results were probably due to demotivation.
Peckham & Amsel (1964)*	2 or 8 37 mg pellets in G_1 2 37 mg pellets in G_2	WS	"FE" was found to be directly related to incentive size but there was evidence of demotivation for the 8 pellet group.
Peckham & Amsel (1967)*	2 or 8 37 mg pellets in G_1 2 37 mg pellets in G_2	WS	"FE" was found to be directly related to incentive size but there was evidence of demotivation for the 8 pellet group.

* These two studies published in different journals and at different times may represent the same data.

Amsel, 1964, 1967 and Krippner, et al., 1967 a) have obtained results demonstrating a positive relationship between size of reward in G_1 and the amount of frustration measured in R_2 on nonreinforced trials. It must be pointed out that this relationship is critical for the Amselian interpretation of frustrative nonreward. The intensity of the frustration effect is postulated by Amsel to be related to the intensity of the fractional anticipatory goal response (rg-sg) which in turn is a function of the size of reward.

The lack of covariation between FE and incentive size found in the majority of studies presented in Table 1 can be best understood by a detailed look at McHose and Gavelek's (1969) study. This study has been chosen for this analysis since: 1. their results are representative of the six out of nine studies (see Table 1) not demonstrating a functional relationship between size of reward and the frustration effect; 2. all of the studies in Table 1 have used either between- or within- subject design; their study employed both designs.

In McHose and Gavelek's within subjects design, one group received differential reward conditioning in the first alley (R_1 and G_1) of the double runway. Large reward (8 45 mg food pellets) was consistently associated with one stimulus, S+ (i.e., a black or white alley), and small reward (1 45 mg food pellet) with the other stimulus, S- (i.e., a white or black alley), prior to the omission of reward, on test trials, in both S+ and S-. In their between subject design, different groups of Ss were trained on 8 45 mg (large) or 1 45 mg pellets. Their data demonstrate that the difference between large and small reward is not on the nonreinforced (N) trials but on the reinforced (R) trials where the 8 pellet condition yielded slower running speeds in R_2 than the 1 pellet condition. However, this difference cannot be attributed to frustration. The reduced speeds in R_2 after large reward in G_1 may be due to temporary satiation or to the other confounding aspect of the double alley i.e., the inhibitory effects of frustration in R_2 that obtain because S is reinforced with only 2 pellets in G_2 after being reinforced with 8 pellets in G_1.

FE Demonstrated in Other Types of Apparatus

Increased vigor of responding due to nonreinforcement (FE) has been demonstrated using types of apparatus other than the double runway. Many investigators (Amsel, 1962; Amsel & Ward, 1965; Goodrich, 1959; Haggard, 1959; Wagner, 1961; Weinstock, 1954) have studied the effect of nonreinforcement using a single runway. In these studies rats receiving 50% reinforcement ran slower than a group of rats receiving 100% reinforcement early in acquisition (12-30 trials). However, the partially reinforced group eventually caught up and reached a higher asymptotic running speed than the continuously reinforced group. This "cross-over" effect (PRAE) has been interpreted by Amsel (1958) and others

(Spence, 1960, Ch. 6; Wagner, 1961) as a demonstration of the invigorating effects of frustration. They have suggested that the frustrative nonreward under partial reinforcement adds to the general drive level of the organism. Whether this increased drive level will be inhibitory or excitatory relative to the continuously reinforced Ss depends on the response elicited by frustration. Early in training the response produced stimuli of conditioned frustration tend to elicit responses which are antagonistic to the approach response. At this point the partially reinforced Ss will run slower than the continuously reinforced Ss. As training continues, the instrumental running response becomes conditioned to these same anticipatory frustration cues (s_f). Thus frustration no longer elicits antagonistic responses but continues to produce an increase in drive level. The net effect, late in acquisition, is an increase in the performance of the partially reinforced Ss greater than that of the continuously reinforced Ss. These investigators have also shown that the "cross-over effect" occurs earlier as the distance from the site of frustration (goal box) is increased. Thus, start measures are the first to show this cross-over (12 trials). Running times cross-over later and later in acquisition as they are measured closer to the site of reinforcement. Goal times do not cross-over (i.e., the continuously reinforced group maintains its superiority over the partially reinforced group throughout acquisition).

Notterman and Mintz (1965), using a free operant situation have demonstrated that the force of bar pressing increases when rats are switched to a decreased density of reinforcement. Thus increasing the value of an FI schedule or switching to extinction may yield an increase in peak force of bar pressing. They present interesting but untestable evolutionary explanations for this phenomenon but appear generally disinterested in investigating it.

Kok (1971) investigated the effect of size of reward and nonreinforcement on the force and latency of a panel push response. She found that nonreinforcement decreased the force and increased the latency of this response. These changes in force and latency were not clearly related to the size of reward experienced during acquisition. Such a decrease in vigor of responding is not in accord with many of the previous investigations cited; however, it can be explained.

One difference between Kok's study and the previous studies reported relates to where the measurements were taken. In the double alley studies increased vigor of responding following nonreinforcement is obtained in R_2. The rat in this situation is running away from the site of nonreinforcement and running toward stimuli consistently associated with reinforcement. In the Notterman & Mintz (1965) studies one finds an increase in peak force following nonreinforcement on a bar horizontally displaced 8 inches from the site of reinforcement and nonreinforcement (i.e., the food cup). In the single runway, an increased vigor of responding is observed in the start measure which is maximally distant from the site of reinforcement and nonreinforcement (i.e., the goal box cues) and occurs early in the response chain. In the same apparatus, measures of responding in the presence of the cues directly associated with reinforcement (i.e., goal speeds) show a decrement in vigor of responding due to nonreinforcement. The empirical generalization appears to be that nonreinforcement can either increase or decrease the vigor of responding depending upon where the measure is taken. Measures of responding close to the site of reinforcement may show a decrement in vigor due to nonreinforcement. Measures distant (or distinct) from the site of reinforcement may show an increment in vigor due to nonreinforcement.

EXPERIMENT I

The present experiment combined the measures of operant force (Notterman & Mintz, 1965) and goal force (Kok, 1971) in a single study. This allowed for the energizing and inhibitory effects of frustrative nonreward to be studied simultaneously. To facilitate such comparisons the force of topographically identical responses was measured. This was accomplished by using an apparatus similar in conception to that of Kok (1971) which employed a panel push response. This apparatus consisted of a chamber with two panel doors located on one wall. An S had to push one door open (the operant response) in order to obtain food behind the other door (the goal response).

The independent variable was the size of incentive used during acquisition of the operant and goal response. Of primary interest was the relation between the size of reward and the changes in the force of responding during extinction. It must be pointed out that the problem of demotivation previously described for the double runway apparatus should not exist for this experiment. The apparatus is analogous to a straight alley runway with the operant response functionally similar to start measures and the goal response similar to goal measures.

Hypotheses

Operant and Goal Responses

It has been previously pointed out that operant response force increases (Notterman & Mintz, 1965), and goal response force decreases (Kok, 1971) due to nonreinforcement. Since the present study combined both measures, it was hypothesized that response force should increase from acquisition to extinction for the operant door and decrease from acquisition to extinction for the goal door.

The amount of predicted change in the operant and goal responses from acquisition to extinction should vary directly with the magnitude of reward used during acquisition. This hypothesis is based on Amsel's Theory (1962) of frustrative-nonreward since the magnitude of reward is postulated to be directly related to the intensity of the fractional anticipatory goal response (r_g) which in turn is related to the amount of frustration or R_f elicited by the removal of the incentive (nonreward).

Method

Subjects

The subjects were 30 naive male, hooded rats from Windsor Biological Supplies, approximately 150 days old at the beginning of training. They were housed individually throughout the experiment in a colony room adjacent to the running room. This room was illuminated 24 hours a day by overhead fluorescent lights.

Apparatus

The apparatus consisted of a testing chamber constructed of .635 cm plate aluminum, 30.48 cm high, 53.34 cm long, and 30.48 cm wide. When opened, two horizontally sliding aluminum doors on one wall of the chamber 22.86 cm apart, gave access to two identically constructed 8.89 cm by 13.34 cm galvanized sheet metal panel doors hinged at the top. Plates 1 and 2 depict the outside and inside view respectively of this apparatus.

Behind each panel door was a recessed plexiglass food cup 3.81 cm in diameter and 2.22 cm deep mounted on the floor of a three sided enclosure (See Plate 3). This enclosure prevented egress from the apparatus when the panel was opened and limited the swing of the panel to 60 degrees from vertical. Inside the chamber were two light fixtures, one over each door, designed to direct illumination over the general area of the door. There was also one light fixture behind each panel mounted on the far end of the panel enclosure. In the

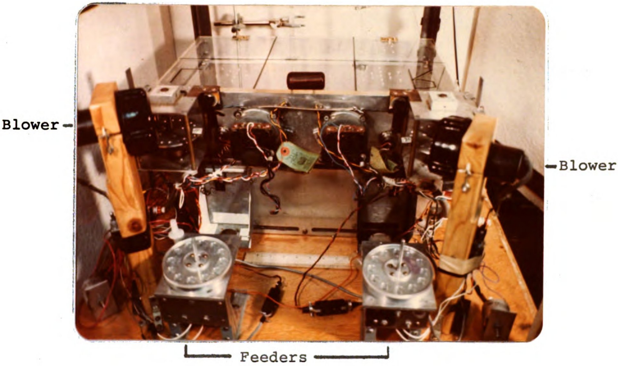
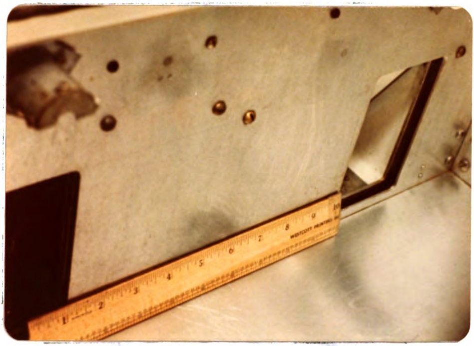


Plate 1. The outside view of the apparatus used in this experiment. In the foreground are two pellet dispensers. On the side of each dispenser are wooden frames used to hold blowers that served to reset the force transducing wheels. Directly in front of each dispenser are the three sided enclosures which contained the recessed plexiglass food cups. The *S* was placed into the apparatus by opening a plexiglass door mounted on the top.



Light Fixture

Enclosure

Enclosure

Plate 2. An inside view of the push-panel-wall as photographed from the rear of the chamber. Part of the three sided enclosure is visible on the right side of the photograph where a panel door has been propped open. The light fixture illuminating the vicinity of the panel doors can be seen in the top left side of the photograph.

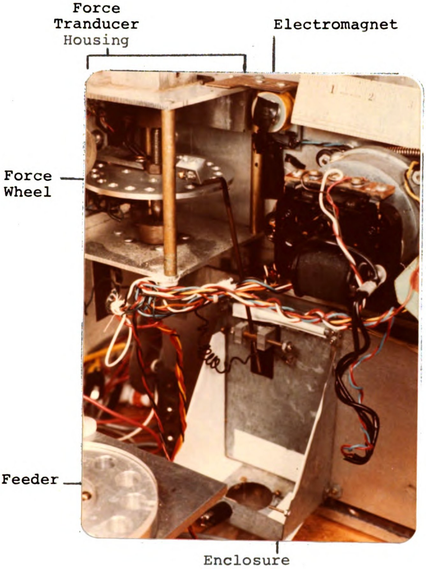


Plate 3. Plate 3 depicts a close up view of the force transducer (top left corner) and three-sided enclosure (bottom middle). There is a clear view of the rear of the panel door with the metal rod used to translocate the force to the wheels (center). As depicted the force transducer is reset and ready to be activated. When S pushes the panel the electromagnet (top center) would draw the rod back allowing the wheel freedom to move.

center of the wall opposite the wall containing the doors was a hole 5.08 cm from the floor of the chamber from which protruded a glass drinking tube that was attached to a 100 ml graduated cylinder. The floor of the chamber was made of .635 cm plate aluminum. On all four walls of the chamber there was a 1.91 cm ledge, 5.4 cm from the plexiglass top.

The force applied to the panels was transduced to a digital output and recorded on Hunter Klockounters (Model number 120 A). This transduction was accomplished in two steps. First, the initial force applied to the panels was translocated (by metal rods) to aluminum wheels mounted above the panels causing these wheels to rotate (See Plate 3). Great care was taken to construct two identical wheels, axels and axel housings. The tolerance for all parts of the apparatus connected with the measurement of force was .0002 in. This resulted in two wheels that rotated at the slightest applied force ($F < 1$ gram) and whose output was identical. The wheels contained 20 evenly spaced .635 cm holes on their periphery and four evenly spaced .635 cm holes near the center. Above these holes were mounted two photocells, a selenium photogenerative cell on the periphery and a cadnium sulfide photoresistive cell above the central holes. Below these holes were mounted two lights. The photocells generated a stream of electrical impulses as the wheels rotated (20 pulses per rotation) which were counted by the klockounters. This accomplished the transduction of force to a digital output. This transduction allowed the measurement of the initial force applied to the panels irrespective of the distance through which the panel was moved.

The functional relation between the amount of applied force and the output of the transducer is depicted in Figure 1. This function was generated by taking 1200 measurements, 200 at each of six known forces and recording the output of the transducer. The output of the transducer (T-units) is a linearly increasing function of applied force. There was no more than a 2 per cent error across all levels of applied force tested.

Latency was measured by the activation of the Hunter Photorelays (model number 330 S) connected to the central photocells. Through appropriate electromechanical programming these photorelays started and stopped Hunter Klockounters which measured latency to 1/100 of a second.

The apparatus was fully automatic. The vertical sliding aluminum doors were operated by electric motors. Food pellets were dispensed automatically to the food cups by means of solenoid operated feeders. The force wheels were reset automatically by means of blowers and electromagnets. The entire operation of the apparatus was programmed through electromechanical circuitry.

The testing chamber was closed in a sound attenuating box constructed of 1.91 cm plywood and two layers of 1.27 cm Celotex. This box was 85.09 cm wide, 82.55 cm deep and 105.41 cm high and had a plexiglass window near the top (See

Figure 1. Mean output of the transducer (T-units) as a function of applied force in grams for the left and right panel doors. The hatch marks above and below the points express the variance of measurement at each point. The line was fitted visually.

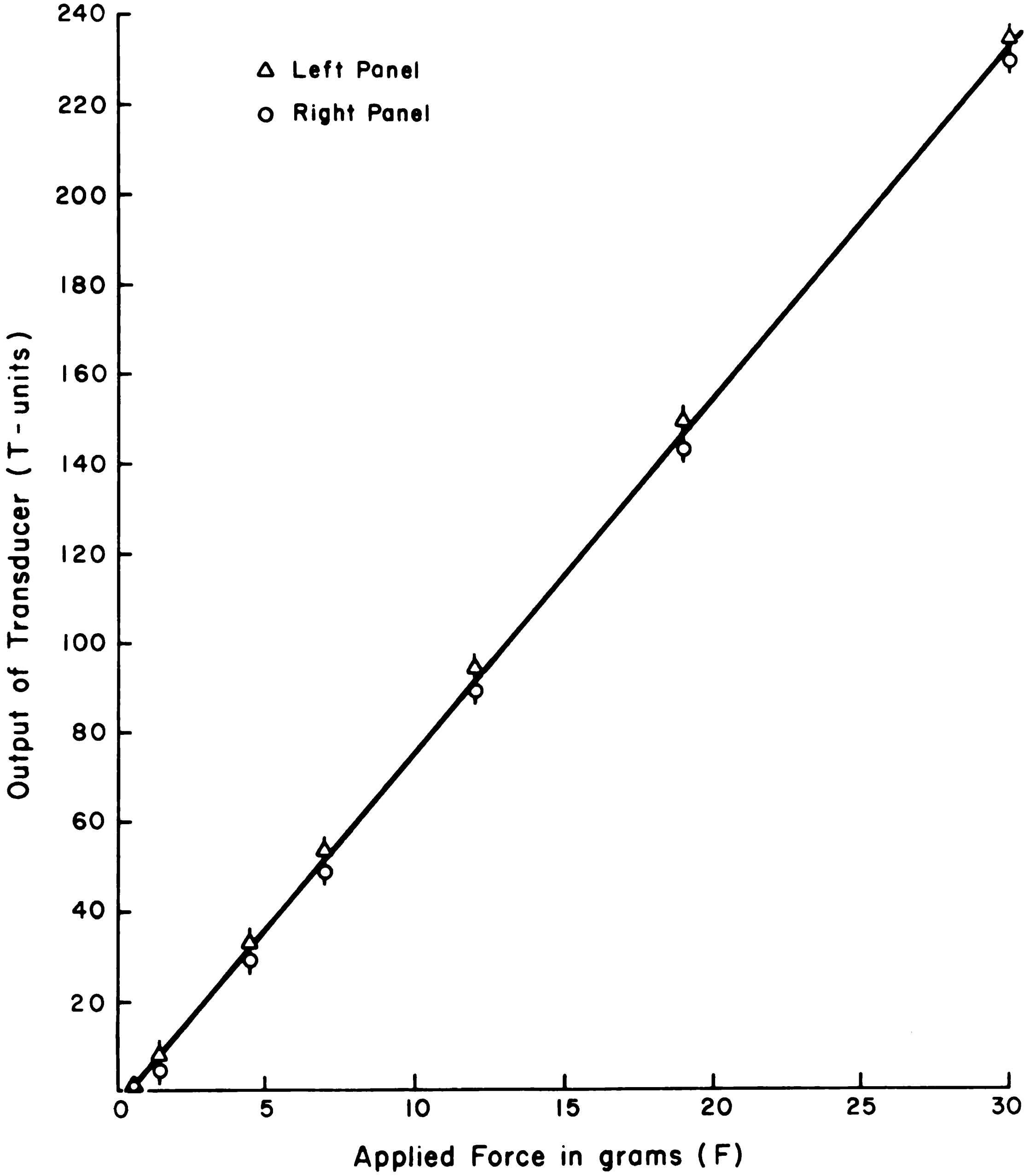

△ Left Panel
○ Right Panel
Output of Transducer (T - units)
240
220
200
180
160
140
120
100
80
60
40
20
0
5
10
15
20
25
30
Applied Force in grams (F)

Figure 1

Plate 4. The front view of the sound attenuating chamber used in this experiment. At the top center of the photograph can be seen the plexiglass window and the mirror which allowed an unobstructed view of S during running.

Plate 4). Above the experimental chamber was a mirror mounted at a 45 degree angle which allowed a clear top view of the inside of the chamber through the plexiglass window. A speaker was mounted at the top of the sound attenuating box for the presentation of 80 db white masking noise from a Grason Stadler Noise Generator (Model number 910 B). Further masking and ventilation was supplied by a blower mounted on one of the walls of the box. A 7½ watt red light bulb was mounted in back of the 45 degree mirror 45.72 cm from the top of the experimental chamber. This light provided diffuse indirect illumination during the intertrial interval.

Procedure

Upon receipt from the distributor, Ss were placed on ad libitum food and water for at least two weeks before being placed on deprivation. During this time the animals were weighed and handled daily.

At least three weeks before the start of training Ss were placed on food deprivation. Water was continuously available both in their individual cages and in the experimental chamber throughout the experiment. Food deprivation consisted of giving Ss 3.5 grams of Wayne Mouse Breeder Blox per day for the first week and from 10-15 grams thereafter. The food given was adjusted daily to maintain Ss at 80% of their ad libitum weight. During the experiment all Ss were weighed and fed their daily ration approximately one hour after being run in the chamber. Three days prior to any experience with the experimental chamber Ss were given 22-45 mg Noyes pellets (990 mg) each day in their home cage along with an adjusted ration of Wayne bloxs.

The rest of the procedure was divided into four distinct phases: Preliminary Training, Training, Reward Shift and Extinction.

Preliminary Training

This phase consisted of habituating Ss to the operation of the experimental chamber, training Ss to obtain food (Noyes pellets) from the food cups behind the panel doors, and to press the panel doors open when they were presented. During preliminary training each S received an equal amount of exposure to each panel door. This phase was terminated and training begun when S successfully completed one full day (22 trials) with the panel doors completely closed i.e., S performed 22 panel pushing responses (11 per door) and obtained 22 reinforcements on one day. This phase was completed for all Ss within nine days.

Training

Once a consistent approach and panel push response was established to both panels, training was started. The object of this procedure was to establish a sequence or chain of responces in which S must push one panel in order to obtain food (one 45 mg Noyes pellet) behind the second panel. The panel the S pushed first was analogous to the bar of a Skinner box and was designated the operant panel. The second panel, where food was obtained, is analogous to the food cup (or magazine) of a Skinner box and was designated the goal panel. The goal panel was illuminated by the overhead light and the enclosure light. The operant panel was not illuminated. In order to insure that intensity of illumination was the only relevant cue signalling the appropriate response, the position of the goal panel (and the position of the operant panel) was varied from right to left using the following 2 series: 1) LRLLRRRLLRLLRRLLLRRLRR 2) RLRRLLLRRLRLR-LLRRRLLRL. A different series was employed on alternate days. 22 trials were given each day. Reinforcement was one 45 mg Noyes pellet per trial.

This chaining procedure ensured that Ss made consistent approach and panel-push responses to the opening of the sliding doors. Thus on any trial the sliding door in front of the operant panel was opened first. When S pushed this panel, the sliding door in front of the goal panel was opened and a pellet of food was delivered to the goal food cup, The trail ended approximately 15 sec after the goal response or 2 min after the beginning of the trial by the closing of both sliding doors and turning off the door and enclosure lights. The intertrial intervals was 30 sec. The next trial started with the opening of the operant sliding door and the turning on of the lights over the goal door and inside the goal enclosure. This procedure continued until S reached a latency criterion of no more than two seconds for both the operant and goal response two trials in a row, with no failure to respond on that day. When this criterion was reached Ss were assigned to one of five reward shift groups, using trials-to-criterion as the basis for assignment such that each group was matched on mean trials-to-criterion.

The elaborate procedure just described was designed to prevent the occurrence of nonreinforcement during acquisition and can be considered analogous to errorless discrimination in an operant situation. This procedure also ensured that the present experimental situation was analogous to straight alley runway situations, thus allowing at least rough comparisons with runway data.

Reward Shift

There were five independent groups (6 Ss per group). Each group was gradually shifted to a different size of reward, except for one group which continued to be given one 45 mg Noyes pellet per trial. The other four groups were shifted to a single pellet reinforcement weighing either 97, 190, 300, or 500 mg (per trial). The gradual shift to larger sizes of reward was accomplished over a single session of 22 trials. This procedure was adopted because it was found with pilot Ss that an abrupt shift especially to the larger sizes of reward (190, 300, and 500 mg) was inhibitory. The Ss simply had not learned the appropriate behaviors necessary for the removal of the larger pellets from the food cup. The ITI, the maximum duration of a trial (2 min), and the time between obtaining the pellets and the end of the trial (15 sec) remained the same as in chaining. All Ss were run for 10 days, 10 trials per day.

Extinction

During extinction no reinforcement was given. All five independent groups were further subdivided, half of each group was extinguished under the original 30 sec ITI while the other half was extinguished under an 8 sec ITI. Otherwise there was no difference between reward shift and extinction procedures. All Ss were run in the chamber until they reached a criterion of 10 consecutive trials in a row on any one day without a response (i.e., operant or goal) within a 2 min period.

Results

Acquisition

The data were initially examined by plotting the relative frequency (per cent) distributions of force of responding for each of the major stages of the experiment. This measure has also been used by Notterman & Mintz (1965) in depicting force of responding. It involves expressing the frequency of each force category relative to the total frequency of responding for each group at each stage.

Figures 2-1 to 2-20 summarize this data on force of responding for the major stages of the experiment. First, one can see that force of responding as measured in this experiment is approximately normally distributed. This is probably due to the fact that the force measure was not subject to the ceiling and floor effects that hold for probability and latency, respectively. When these two pages of figures are scanned from left to right along any row (group) the change in the distribution of force as a function of training can be seen. Viewed this way there appears to be an increase in force across all groups as a function of training. The distributions become more negatively skewed as training proceeds from the last day of preshift to the last half of reward shift.

The effect of prolonged training alone without a shift in reward size can be seen by examining the 45 mg (nonshifted) group (see figure 2-1, 2-6, and 2-11). For this group training served to increase the difference between operant (Md = 65.41) and goal (Md = 81.36) responding having its greatest effect on the goal responding. This could be considered an example of the development of a goal gradient effect where the most vigorous responding occurs closest to the site of reinforcement.

This goal gradient effect is not as evident for the remaining groups. Although the goal response is usually produced with greater force than the operant response, the difference between the distributions is not as striking as seen in the 45 mg group. Comparing the medians for operant and goal force for each of the four remaining groups across experimental stages, we see a somewhat greater difference between these medians with the larger reward sizes (300 and 500 mg) than with the smaller sizes (97 and 190 mg) on the last half of reward shift i.e., Figures 2-11 to 2-15. This suggests that a shift in reward retarded the development of a goal gradient but that this retardation was overcome more readily with the larger sizes of reward. The relation between size of reward and force of responding can best be seen in the last half of reward shift, (see Figure 2-11 to 2-15). Examination of the medians suggests an inverse relation. This inverse relation appears more pronounced for goal than for operant force.

A more detailed statistical analysis of the speculations

Figure 2. Relative frequency distributions of the force of the operant (closed circles) and goal (closed triangles) responding. Columns represent progressive stages of the experiment and rows represent different groups. The median of each distribution is depicted by the open points on the graphs.

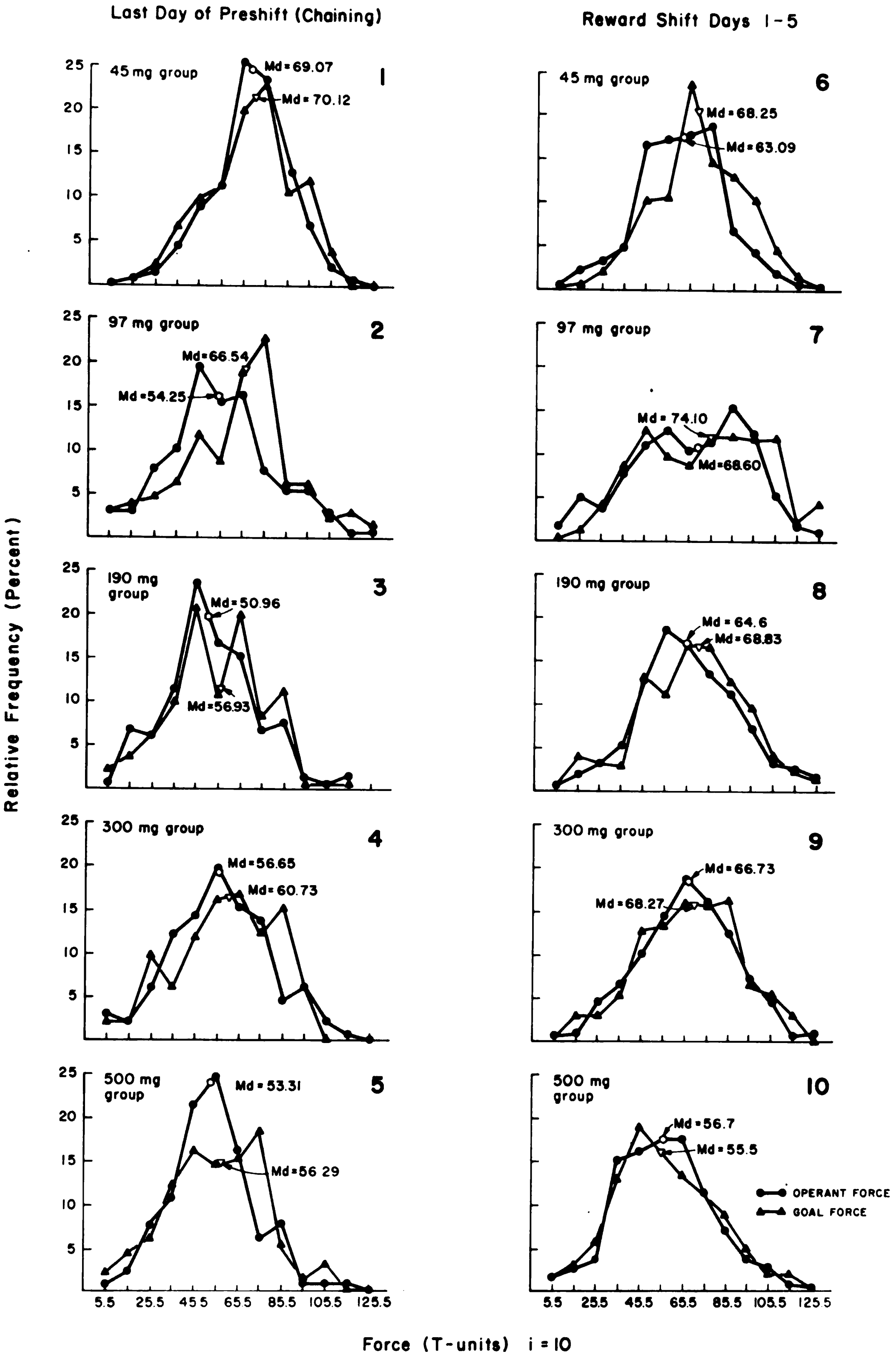

Last Day of Preshift (Chaining)
Reward Shift Days 1-5
Relative Frequency (Percent)
25
20
15
10
5
45 mg group
1
Md = 69.07
Md = 70.12
97 mg group
2
Md = 66.54
Md = 54.25
190 mg group
3
Md = 50.96
Md = 56.93
300 mg group
4
Md = 56.65
Md = 60.73
500 mg group
5
Md = 53.31
Md = 56 29
45 mg group
6
Md = 68.25
Md = 63.09
97 mg group
7
Md = 74.10
Md = 68.60
190 mg group
8
Md = 64.6
Md = 68.83
300 mg group
9
Md = 66.73
Md = 68.27
500 mg group
10
Md = 56.7
Md = 55.5
OPERANT FORCE
GOAL FORCE
5.5
25.5
45.5
65.5
85.5
105.5
125.5
Force (T-units) i = 10

Figure 2

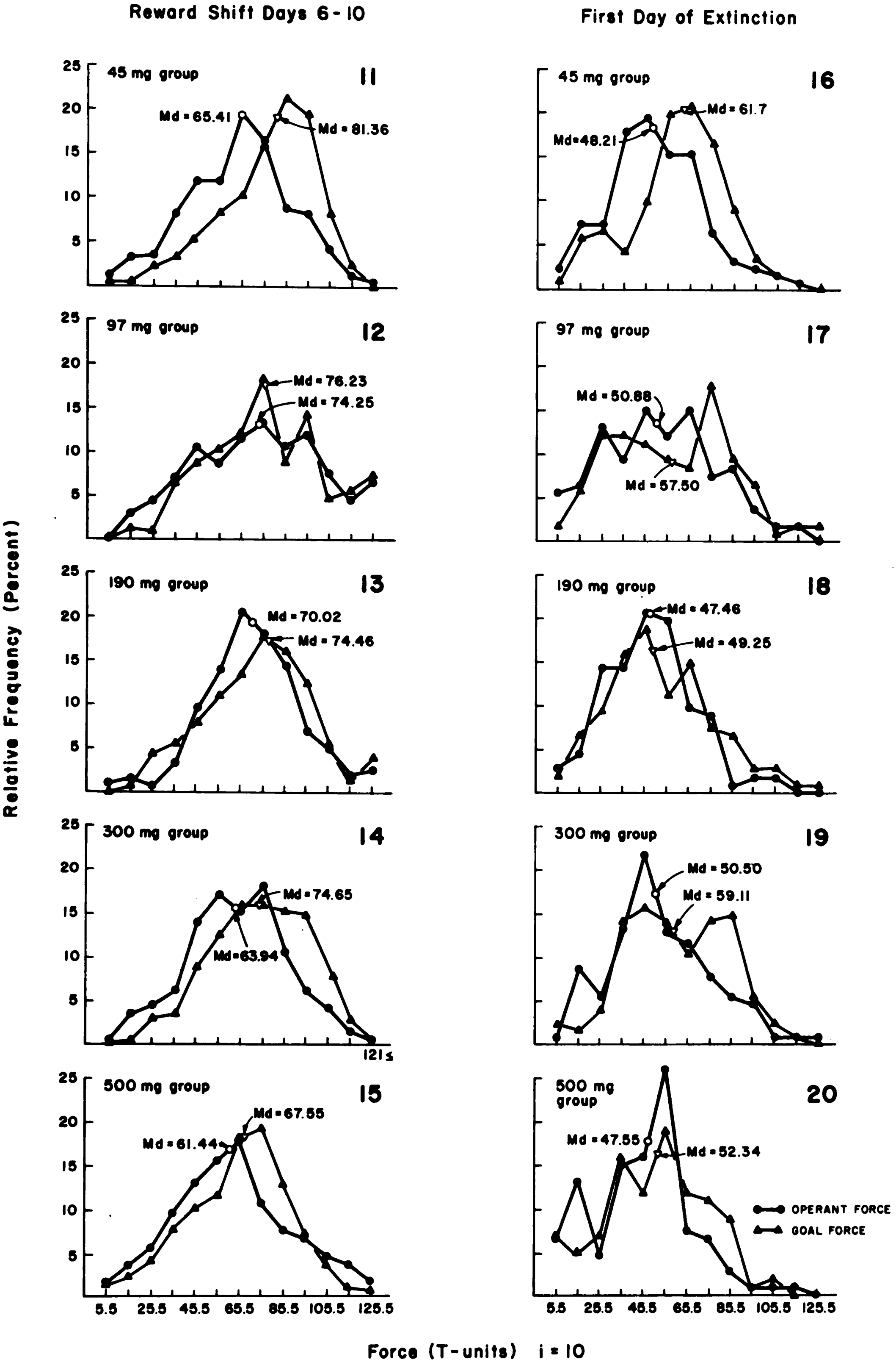

Reward Shift Days 6-10
First Day of Extinction
Relative Frequency (Percent)
25
20
15
10
5
45 mg group
11
Md = 65.41
Md = 81.36
16
Md = 48.21
Md = 61.7
97 mg group
12
Md = 76.23
Md = 74.25
17
Md = 50.88
Md = 57.50
190 mg group
13
Md = 70.02
Md = 74.46
18
Md = 47.46
Md = 49.25
300 mg group
14
Md = 74.65
Md = 63.94
121≤
19
Md = 50.50
Md = 59.11
500 mg group
15
Md = 61.44
Md = 67.55
20
Md = 47.55
Md = 52.34
OPERANT FORCE
GOAL FORCE
5.5
25.5
45.5
65.5
85.5
105.5
125.5
Force (T-units) i = 10

Figure 2

proposed by the inspection of figures 2-1 to 2-15 was performed by looking at the reward shift stage alone. This analysis is presented in Table 2. The mean force of responding for the first half (5 trials) of each day was used in the analysis to minimize the confounding of demotivational and incentive size effects. Figure 3 A and B depicts these data for the operant and goal responses, respectively, as a function of reward size and days of training.

The effect of reward size on force of responding was not statistically significant ($F = .3208$). However, force increased significantly for both operant and goal responses over days of training ($F = 6.6571$, $df = 9/225$, $p < .001$). The goal force was significantly greater than the operant force throughout reward shift ($F = 9.2167$, $df = 1/25$, $p < .005$) confirming the suggesting of a goal gradient effect proposed earlier. The significant reward size by type of response by training interaction ($F = 1.6657$, $df = 25/225$, $p < .05$) is probably due to the interaction of the suppressive effects of a reward shift *per se* and the facilitative effects of large reward upon the development of the goal gradient. No other interactions approached significance.

Extinction

The distribution of force of responding on the first day of extinction can be seen in Figures 2-16 to 2-20. Goal force remained greater than operant force the first day of extinction with the 45 mg group showing the greatest difference between these responses. There is also a decrease

Table 2. Summary table for the analysis of variance of force of responding for the reward shift stage of experiment 1 with size of reward, days of training, and type of response (operant vs goal) as independent variables. The dependent variable is the mean force for the first half of each day of training.

Source of Variance	SS	df	MS	F	P
Total	193100.6502	599			
Between Ss	103700.2352	29			
Reward Size (R)	5063.0202	4	1265.7551	.3208	ns
Error S (R)	98637.2150	25	3945.4886		
Within Ss	89400.4150	570			
Response (G)	3786.1863	1	3786.1863	9.2170	$< .005$
Days (D)	10465.8115	9	1162.8679	6.6571	$< .001$
RG	779.2140	4	194.8035	.4739	ns
RD	5238.2730	36	145.5076	.8330	ns
GD	862.5788	9	95.8421	1.2786	ns
RGD	1799.0196	36	49.9728	1.6657	$< .05$
Error S (R) G	10276.6432	25	411.0657		
Error S (R) D	39303.0037	225	174.68		
Error S (R) GD	16889.6844	225	75.0653		
Error within	66469.3313	475			

Figure 3. Mean force of operant (A) and goal (B) responding during reward shift as a function of size of incentive and days of training. The mean force on the last day of preshift and the first day of extinction is represented by the floating points on the left and right of the figures.

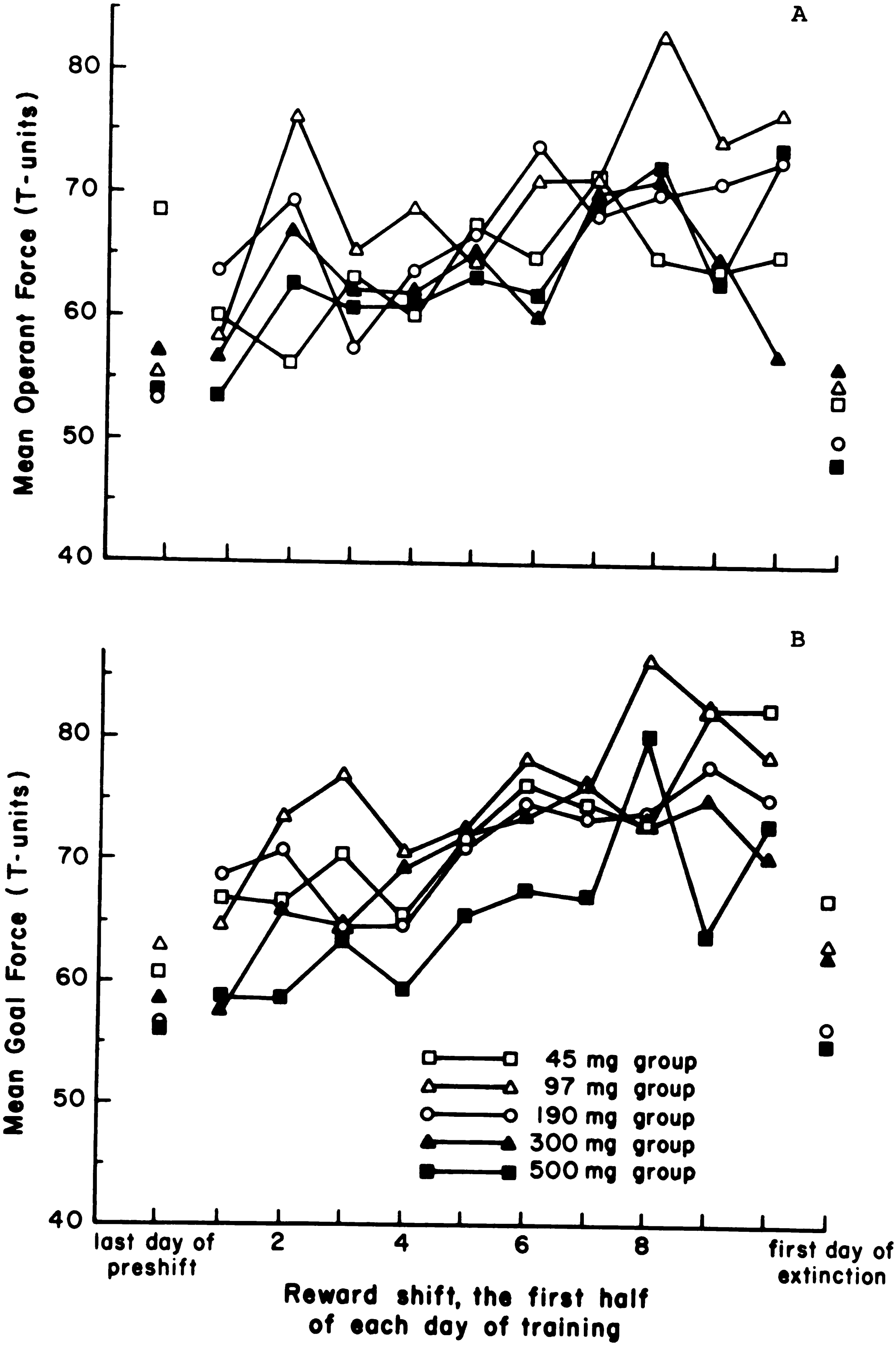

A
Mean Operant Force (T-units)
80
70
60
50
40
B
Mean Goal Force (T-units)
80
70
60
50
40
45 mg group
97 mg group
190 mg group
300 mg group
500 mg group
last day of preshift
2
4
6
8
first day of extinction
Reward shift, the first half of each day of training

Figure 3

in force of responding from reward shift to extinction. This is evident by the positive skewness of all the distributions during extinction. There does not appear to be any systematic relation between size of reward during reward shift and any changes in the shape of the frequency distribution during extinction.

In order to obtain a more detailed analysis of the immediate changes in force of responding the mean force of responding for progressive blocks of 4 trials on the first day of extinction was obtained for each subject. The first trial was treated separately since *S*s had not experienced nonreinforcement before making responses on this trial.Table 3 presents an analysis of variance on these data.

Consistent with the acquisition data reward size did not significantly affect force of responding on the first day of extinction (F = .2734). Surprisingly the effect of the duration of the intertrial interval was also not significant (F = .0538). The interaction between reward size and ITI was also nonsignificant (F = 1.0714).

The goal gradient effect seen during acquisition persisted through the first day of extinction. This is evident from the fact that the goal force was significantly higher than the operant force (F = 11.8975, df = 1/20, $p < .005$) and that the type of response by trials interaction (F = 5998) was not significant. There was also a significant decrease in force of responding over blocks of trials (F = 16.1688, df = 5/100, $p < .001$) for both responses over all groups.

Table 3. Summary table for the analysis of variance of force of responding for the first day of extinction of experiment 1 with size of reward, intertrial interval (30 vs 8 sec), type of response (operant vs goal), and trials as independent variables.

Source of Variance	SS	df	MS	F	P
Total	155494.9114	359			
Between Ss	59015.1923	29			
Reward Size (R)	2537.8966	4	634.4742	.2734	ns
ITI (I)	124.8680	1	124.8680	.0538	ns
RI	9944.4223	4	2486.1056	1.0714	ns
Error S (RI)	46408.0054	20	2320.4003		
Within Ss	96479.7191	330			
Response (G)	3291.2007	1	3291.2007	11.8975	$<.005$
Trials (T)	21291.8382	5	4258.3676	16.1688	$<.001$
RG	236.5696	4	59.1424	.2138	ns
RT	10058.2782	20	502.9139	1.9095	$>.1$
IG	423.7576	1	423.7576	1.5644	ns
IT	2596.9670	5	519.3934	1.9721	$>.1$
GT	403.6149	5	80.723	.5998	ns

Table 3 (continued)

Source of Variance	SS	df	MS	F	P
RIT	4389.3718	20	722.3825	2.7429	$<$ .005
RIG	399.7533	4	84.9383	.307	ns
RGT	2243.7576	20	112.1879	.8355	ns
IGT	2976.3453	5	595.2691	4.4228	$<$ .005
RIGT	2839.6944	20	141.9847	1.0549	ns
Error 1 S (RI) G	5532.5723	20	276.6286		
Error 2 S (RI) T	26336.8689	100	263.3687		
Error 3 S (RI) GT	13459.1293	100	134.5913		
Error within	45328.5705	220	206.039		

This is not in agreement with the original prediction that nonreinforcement would lead to an increase in force on the operant and decrease in force on the goal response. It appears that, at least early in extinction, nonreinforcement induced a general inhibitory effect on both responses.

The only other significant effects were the reward by ITI by trials interaction ($F = 2.7429$, $df = 5/100$, $p < .001$) and the ITI by type of response by trials interaction ($F = 4.4228$, $df = 5/100$, $p < .005$). Visual inspection of the data related to these interactions produced no psychologically meaningful interpretation.

The force of responding over the entire extinction stage of the experiment was also examined. It should be recalled that each *S* was run to an extinction criterion of 10 trials without a response. This is a stringent criterion requiring an *S* to go 20 minutes making a single response. Days to extinction criterion varied from a low of 2 days to a high of 24 days. Thus, for each *S* the total trials to the extinction criterion was divided into fifths and then the mean force for each *S* at each of these fifths was calculated. These means were used as the data points for subsequent analysis. Figures 4 A & B depict force of the operant and goal response respectively over progressive fifths of extinction as a function of size of reward. Table 4 presents an analysis of variance of these data.

Neither size of reward ($F = .46$) nor intertrial interval ($F = .0189$) produced significant results. As can be seen

Figure 4. Mean force of operant (A) and goal (B) responding during extinction as a function of size of incentive and fifths of extinction. The floating points on the left side of the graph represent mean force of responding on the last day of reward shift.

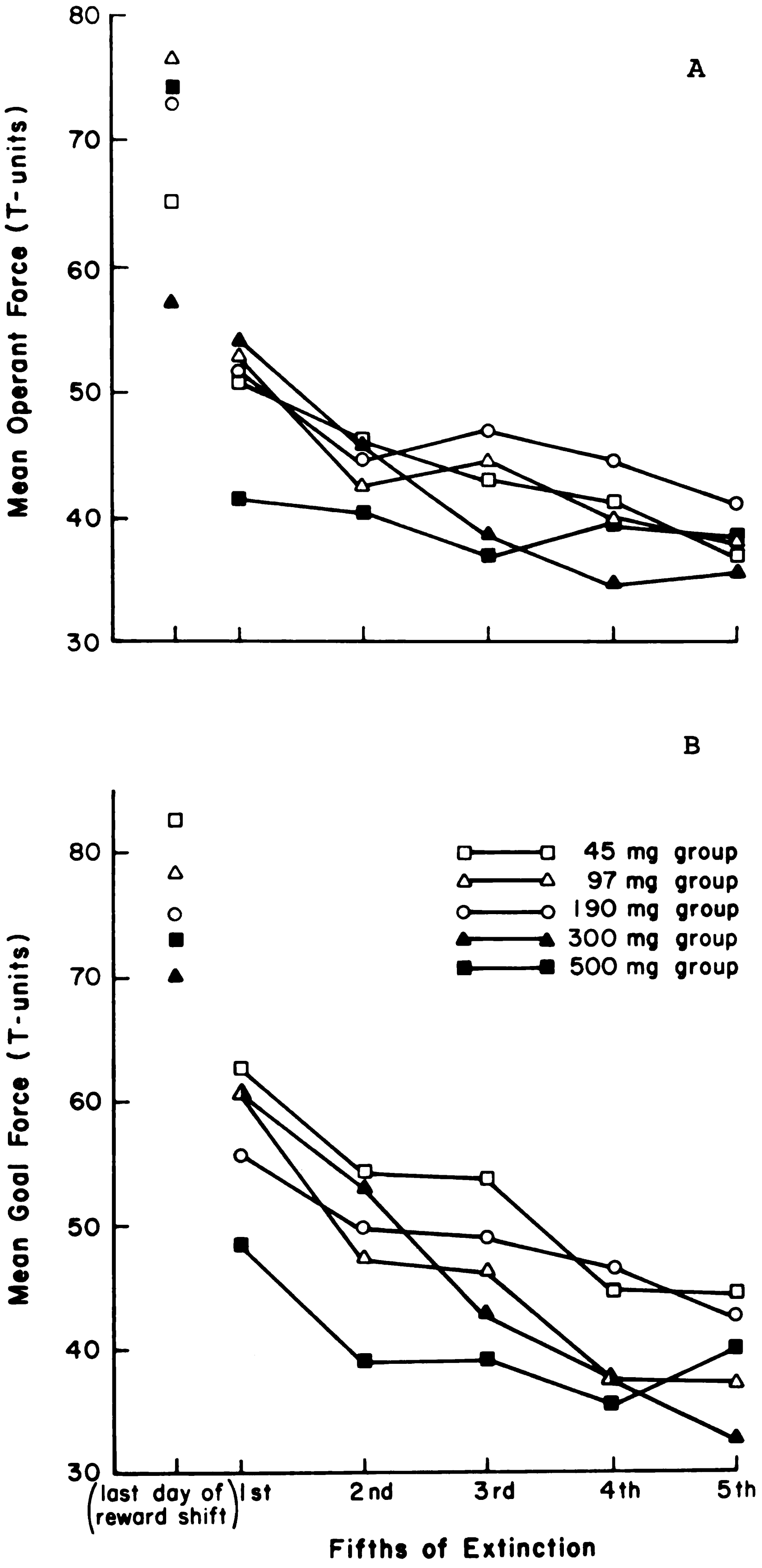

A
80
70
60
50
40
30
Mean Operant Force (T-units)
B
80
70
60
50
40
30
Mean Goal Force (T-units)
45 mg group
97 mg group
190 mg group
300 mg group
500 mg group
(last day of reward shift)
1st
2nd
3rd
4th
5th
Fifths of Extinction

Figure 4

Table 4. Summary table for the analysis of variance of force of responding for the extinction stage of experiment 1 with size of reward, intertrial interval, (30 vs 8 sec), type of response (operant vs goal), and fifths of extinction (blocks) as independent variables.

Source of Variance	SS	df	MS	F	P
Total	66246.6160	299			
Between Ss	37932.1419	29			
Reward Size (R)	2533.7908	4	633.4477	.4600	ns
ITI (I)	26.0781	1	26.0781	.0189	ns
RI	7829.9922	4	1957.4981	1.4214	ns
Error S (RI)	27542.2808	20	1377.1140		
Within Ss	28314.4687	270			
Response (G)	834.7673	1	834.7673	6.1840	$<.025$
Blocks (B)	8852.7632	4	2213.1908	21.8141	$<.001$
RG	525.2735	4	131.3184	.9728	ns
RB	2011.3368	16	125.7086	1.2390	ns
IG	273.0920	1	273.0920	2.0231	$>.10$
IB	164.3663	4	41.0916	.4050	ns
GB	487.7994	4	121.9498	11.2128	$<.001$

Table 4 (continued)

Source of Variance	SS	df	MS	F	P
RIB	1858.3340	16	116.1459	1.1448	ns
RIG	481.0297	4	120.2574	.8909	ns
RGB	408.3279	16	25.5205	2.3465	$<$ .025
IGB	110.8553	4	27.7138	2.5298	$<$ .05
RIGB	620.1344	16	38.7584	3.5637	$<$ .001
Error S (RI) G	2699.7664	20	134.9883		
Error S (RI) B	8116.5510	80	101.4569		
Error S (RI) GB	870.0715	80	10.8759		
Error within	11686.3889	180			

from the figure, however, goal force was significantly greater than operant force ($F = 6.184$, $df = 1/20$, $p < .025$). This difference decreased over progressive fifths of extinction with both responses decreasing in force to the same asymptote ($F = 21.8141$, $df = 4/80$, $p < .001$). It is no surprise therefore, that response type interacted significantly with progressive fifths of extinction ($F = 11.2128$, $df = 4/80$, $p < .001$). With Duncan's multiple range tests, goal force was found to be significantly different from operant force on only the first and second fifths of extinction ($df = 80$, $p < .05$).

The initial prediction of a differential change in force of responding as a function of type of response was partially supported by the significant ITI by response type by fifths of extinction interaction ($F = 2.598$, $df = 4/80$, $p < .05$). This interaction is depicted in Figure 5. As can be seen from the figure, force of operant responding decreases more rapidly with a 30 sec ITI than an 8 sec ITI. With a Duncan's multiple range test, the difference between operant force at the 8 and 30 sec ITI was significant at the fourth fifth of extinction ($df = 80$, $p < .05$). For the goal response the reverse is true. The 8 sec ITI caused a faster decline in goal force than the 30 sec ITI. With a Duncan's multiple range test the difference between goal force at the 8 and 30 sec ITI was significant at the second and third fifths of extinction ($df = 80$, $p < .05$). This interaction suggests that frustrative nonreward has opposing effects depending upon where it occurs.

Figure 5. Mean force of responding as a function of fifths of extinction, type of response and intertrial interval. Each point represents the mean for all five sizes of reward.

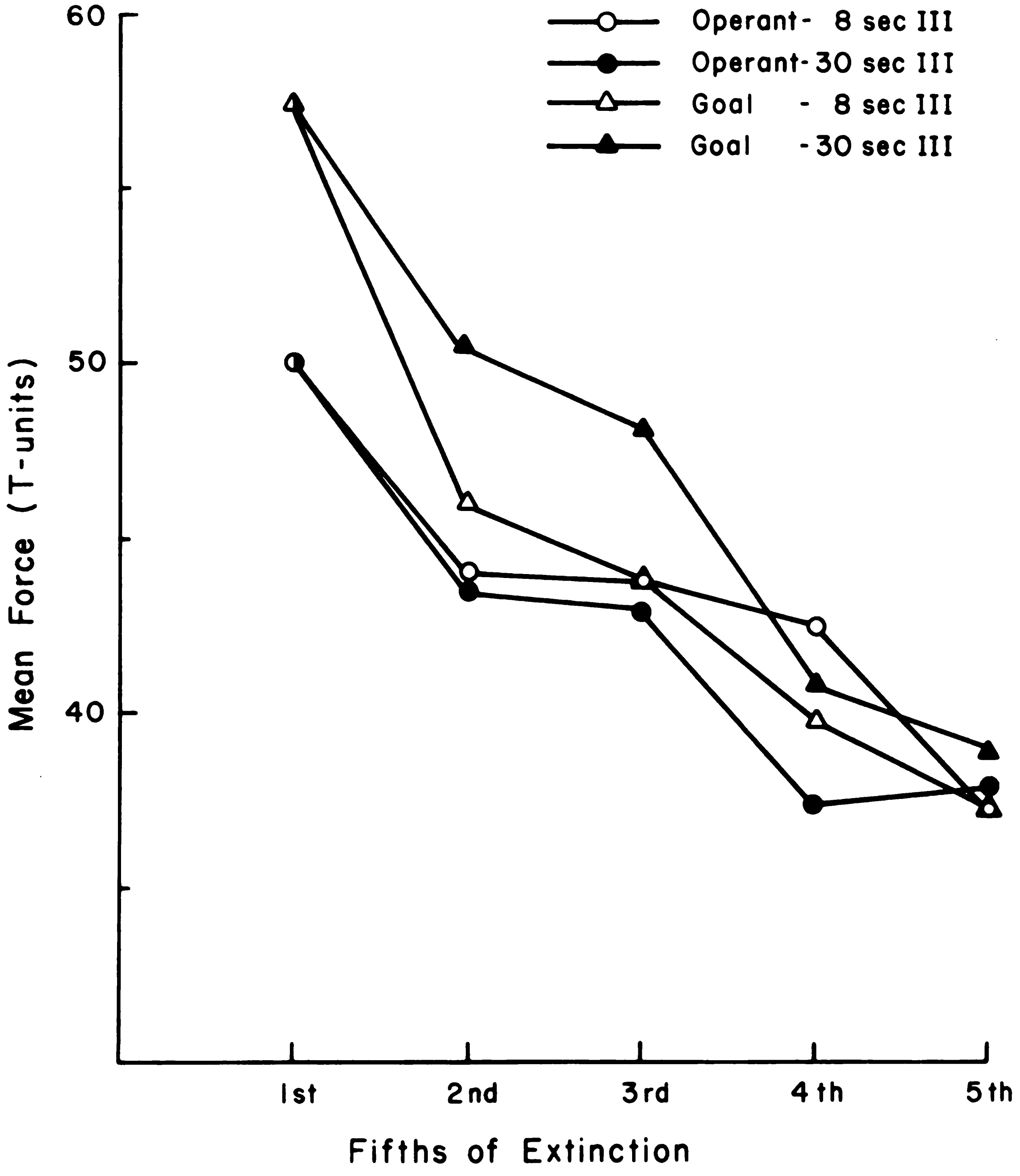

60
50
40
Mean Force (T-units)
Operant- 8 sec III
Operant-30 sec III
Goal - 8 sec III
Goal -30 sec III
1st
2nd
3rd
4th
5th
Fifths of Extinction

Figure 5

There were two other significant interactions found. They were the size of reward by type of response by fifths of extinction interaction (F = 2.3465, df = 16/80, $p < .025$) and the fourth order interaction (F = 3.5637, df = 16/80, $p < .001$). Graphic inspection of the data related to these interactions produced no interpretable relations.

The latency for both operant and goal responses were also recorded throughout the experiment. The mean latency and speed (i.e., the reciprocal of the latency) for each stage of the experiment was graphed in the same way as the force measure. Visual inspection of the graphs did not show any systematic differences. Thus, the latency measures were not subjected to further statistical analysis.

Discussion

Acquisition

Pubols (1960), after intensively reveiwing the literature on the effect of incentive magnitude manipulations on performance, concluded that "Asymptotic performance is an increasing function of incentive magnitude." A more recent review (Dunham, 1968) leads one to the same conclusion. Thus there appears to be ample evidence to justify Pubols conclusion. In the present experiment, however, there was a non-significant inverse relationship between reward size and performance.

One possible explanation of this result is that the gradual shift in incentive allowed the S to "adapt" to the new reward size, eliminating any performance changes, but a study performed by Wike (1970) makes this suggestion untenable. Using an L-shaped runway he increased reward size gradually over trials from one to four pellets. This resulted in an increase in running speed which was monotonically related to the size of reward.

Another possibility is that the required response (panel pushing) is not sensitive to the incentive manipulations used in this experiment. This possibility can not be completely ruled out, but since other expected effects were demonstrated using this measure, it is an unlikely explanation. Ss showed a significant increase in performance over days as well as a significant goal gradient effect. They also showed a significant decrease in performance over trials during extinction. This would lead one to suggest that panel pushing was sensitive to incentive manipulations.

A third possibility is that the massing of trials (ITI = 30 sec) caused a certain degree of satiation. This suggestion too, can not be completely eliminated but is made less plausible by two facts. First, the use of the mean force for only the first five trials of each day should have reduced the influence of demotivation. When mean force of responding for all ten days of Reward Shift is plotted against trials within a day (see Appendix A-1) one can see that there is no demotivation for all groups except for the last 5 trials of a day in the 500 mg group. Second, when the force on the first trial of each day is used as a measure essentially the same relations are seen. This measure, however, was deemed too unstable for further analysis.

The last possibility relates to the interpretation of changes in the performance measure. Perhaps a decrease in force of responding represents an increase in performance. This argument has been presented by Dilollo, Ensminger and Notterman (1965) to explain results similar to those of the present study. Using a small range of sizes of reinforcement (20 to 100 mg) they found that force of bar pressing was inversely related to reward magnitude. This result and interpretation was replicated by Notterman & Mintz (1965, p. 207).

The crux of their argument is that "the greater amount of reinforcements, the better the animal learns to make the requisite cutaneous and kinesthetic discriminations" (Notterman & Mintz, 1965, p. 210). Their force criterion for reinforcement was 8 grams and their S̲s were usually responding considerably above this level (eg. 18 grams for 20 mg group). Thus increased reward magnitude tended to cause their S̲s to perform more in line with the force criterion. The problem with the application of this "discriminative" interpretation to the data in the present study is that force of responding significantly decreases over extinction. For the discrimination hypothesis to be tenable: 1. force of responding should decrease over training as the cutaneous and kinesthetic discriminations are learned and 2. force of responding should increase during extinction as these same discriminations break down. Notterman and Mintz (1965) have obtained results in accord with the two above predictions.

It must be concluded that force of panel pushing is not directly related to the magnitude of the incentive as manipulated in this study. Perhaps the size of a single incentive is not the important variable. In the past (Pubols, 1960), most studies have manipulated incentive magnitude by varying the number of pellets of a constant size, and Kling (1956) presented some correlational evidence which suggests that with rats, rate of ingestion rather than incentive size is the significant variable. He found that with rats in a straight alley, fast ingestors ran faster than slow ingestors to the same amount of water.

Deaux (1973) is the first published study to actually manipulate ingestion rate. Rats were given equal volumes of water, half given the incentive at a fast rate (over a period of 1 sec) and half given the incentive at a slow rate (over a period of 5 sec). The high rate group was significantly superior to the low rate group (i.e., higher asymptotic performance) in a classical conditioning paradigm as well as in an instrumental runway paradigm. Ancillary to these findings was the fact that performance was inversely related to the number of consummatory responses (licks) made. In the present study, ingestion rate was uncontrolled. Perhaps larger pellets induce a slower rate of ingestion. This hypothesis deserves further investigation.

Extinction

It was stated in the introduction that decreases in the density of reinforcement generally lead to increases in the force of operant responding. This had been amply demonstrated by Notterman and Mintz (1965), but the question remains as to why this increase occurs. A motivational theory such as Amsel's (1968) which relies on the proposed response invigorating properties of frustrative nonreward could potentially explain this phenomenon. A discrimination hypothesis such as the one proposed by Notterman and Mintz (1965) which stresses the response shaping properties of reinforcements can explain this result equally well.

The main emphasis of this discussion is to see whether these hypotheses can be reconciled with the apparently contradictory results of the present study. It should be recalled that nonreinforcement produced a decrease in force of responding on the first day of extinction as well as throughout the entire extinction stage. Contrary to prediction, this decrease in force was apparent for both the operant and goal responses.

The discrimination or response shaping hypothesis suggests that reinforcement causes *S* to produce responses in line with the criterion for reinforcement by sharpening the appropriate kinesthetic and proprioceptive discriminations. Nonreinforcement causes the breakdown of these discriminations formed during acquisition. For this discrimination hypothesis to hold in this present experiment the decrease in force during extinction representing the breakdown in kinesthetic discriminative control should necessarily be preceded by a progressive increase in force during acquisition, where the kinesthetic discriminations are formed. Both the increase in force during acquisition and the decrease in force during extinction occurred in this experiment. Although the force requirement to open a panel was minimal ($F < 1$ gram) there could have existed another contingency that caused *S*s to progressively increase their force. Since *S*s were opening the panels and receiving reinforcement early in training with a much lower force it would be untenable to suggest that *S*s were approaching a high force criterion during acquisition. The only other hypothesis comes from observing *S*s making the response. To attain the reinforcement Ss must not only push the panel open (this they usually do with their nose) but also hold the panel open with the top of their head while retrieving the pellet. One might speculate that the necessity to sustain the panel push response over this period of time could be responsible for the progressive increase in force. This suggestion is supported by results reported by Notterman & Mintz (1965, p. 36). They found that reinforcing S for a longer than normal duration (.8 sec) of bar pressing caused a concommittant increase in force of responding as well as an increase in duration. In addition they found that any criterial manipulation that caused Ss to progressively increase their force of responding during acquisition yielded a decrease in force during extinction (Notterman & Mintz, 1965, Ch. 3). Thus it could be concluded that the decrease in force of responding during extinction in the present experiment was caused by the breakdown of discriminative control due to nonreinforcement.

The discrimination hypothesis does not however explain another significant finding of the present experiment, that is, the interaction between the type of response, fifths of extinction and intertrial interval. It should be recalled that the operant response force decreased much faster when Ss were extinguished under 30 sec ITI than under an 8 sec ITI, while force for the goal response decreased much faster for the 8 sec ITI than for the 30 sec ITI. This is understandable if it is realized that the operant response directly follows nonreinforcement at the goal during extinction. That is, on a trial during extinction S first performs the operant response then is nonreinforced at the goal and then, 8 or 30 sec later, must again perform the operant response. Presumably the 8 sec ITI allows for less decay of the effect of frustrative nonreward than the 30 sec ITI. This has two effects, a momentary invigorating effect of primary frustration and an increase in the build up of conditioned frustration which is generally inhibitory. According to Amsel (1968) if the stimulus trace of primary frustration is present while S is performing an instrumental response this would lead to the invigoration of that response. It can be postulated that for the 8 sec ITI enough excitory primary frustration was remaining to retard the development of inhibition for the operant response. However, since the goal response is not directly preceded by nonreinforcement, frustration would be dissipated by the time the goal response is performed. Thus, only the build up of inhibition can effect the GR, producing the more rapid drop in force with the 8 sec ITI. This suggestion is partially supported by the results of a study reported by Scobie and Fallon (1972). Using the reinforcement ommissions procedure of Staddon (1966), they found that increases in rate of responding occurred up to an 8 sec ITI, decreases in rate of responding occurred with longer ITIs. The implication of the present motivational analysis is that roughly a 0 sec ITI should produce an increase in force on operant responding and decrements in force on goal responding. Thus the increments of force of responding found by Notterman and Mintz (1965) using a free operant situation could be due to the very short interval between nonreinforcement and the next bar press which is characteristic of the free operant situation.

The two interpretations of incentive manipulations can only be separated by further research, manipulating the time between the occurrence of nonreinforcement and the occurrence of the next response.

Summary of Results and Conclusions

1. No significant relation was obtained between magnitude of incentive and force of responding. It was concluded that pellet size may not be a main incentive variable and that other variables uncontrolled in the present study such as ingestion rate may be of more importance.

2. A type of goal gradient effect was found as reflected in greater force on the goal than the operant panel, and there was a suggestion that the development of this effect is retarded by shifts in incentive level and facilitated by large sizes of reward.

3. The significant increase in force found during acquisition and decrease in force during extinction was supportive of the discriminative interpretation of Notterman & Mintz (1965). However, the differential effects of different intertrial intervals on the force of operant and goal responding during extinction was more easily interpreted with a motivational hypothesis (Amsel, 1962).

EXPERIMENT II

Introduction

The results of the previous experiment indicated that force of responding decreases with nonreinforcement, and that the rate of this decrease seems to be related to the type of response being measured and the length of the intertrial interval. The purpose of the present experiment was to test an implication of these results, namely, that the force of the response following nonreinforcement will increase if the interval between nonreinforcement and the performance of the next response is short enough. A second aim of the present study is to determine if a relation exists between the size of incentive used during acquisition and the force of responding during extinction.

A procedure analogous to Amsel and Roussel's (1952) double runway paradigm was adopted. As in the double runway and in Experiment I Ss performed two responses (panel pushes) in sequence. This experiment was different from Experiment I in that reinforcement was presented behind each panel. Food reinforcement (Noyes pellets) was presented behind the first panel (G1). Water reinforcement was presented behind the second panel (G2). It was also different from Experiment I in that incentive manipulations such as shifts in incentive size and nonreinforcement occurred at the first panel. The effects of these manipulations, i.e., invigoration of responding due to nonreinforcement, were assessed on the second panel. This allowed for roughly a zero sec interval between incentive manipulations and the performance of the next response instead of an 8 or 30 sec interval as in Experiment I.

This experiment differed from the double runway paradigm in two ways. First, water instead of food reinforcement was used at G_2 to reduce the effects of demotivation present in double runway paradigms. This procedure was adopted from a study similar to the present study (Levine & Loesch, 1967). As discussed in the introduction to Experiment I, demotivational confounding occurs in the double runway since performance post reinforcement is compared with performance post nonreinforcement. With the double alley paradigm, it is usually difficult to untangle the suppressive effects of previous reinforcement from the later invigorating effects of nonreinforcement (Seward, et al., 1957). Given the positive correlation between food and water intake (Adolf, 1947; Bolles, 1961) it can be predicted that the larger the size of food reinforcement behind the first panel (G_1) the greater is the response to water behind the second panel (G_2). This is opposite to demotivational counfounding.

Second, size of incentive was manipulated within subjects. All Ss received all sizes of incentive. This was done since it was observed in Experiment I that there existed large but stable individual difference in force of responding. This large variability might have masked of the effects of the size of incentive in the first experiment.

Method

Subjects

Ten naive, male hooded rats from Windsor Biological Supplies, approximately 120 days old at the beginning of training,served as subjects. The Ss were housed individually in a colony room adjacent to the running room. The room was illuminated 24 hours a day by overhead fluorescent lights.

Apparatus

The apparatus used was the same as used in Experiment I with only two modifications. First, the panel doors and the enclosures behind them were covered with Contact, an adhesive shelving material. The right panel and the interior of the right enclosure were covered with smooth white Contact. The left panel and the interior of the left enclosure was covered with black textured Contact. Second, a water dispenser was added to the apparatus. The water dispenser consisted of a solid cylinder of plexiglass 3.75 cm in diameter and 2.1 cm deep. This cylinder fitted snugly into the food cups. A graduated L-shaped hole was drilled into the cylinder terminating at the top and center of the cylinder with a small V-shaped depression .40 cm in diameter and .15 cm deep. The rest of the water dispensing devise consisted of a two gallon resevoir placed two meters above the water dispenser; surgical tubing to deliver the water to the dispenser; Skinner solenoid valves and adjustable stopcocks to meter the flow of water. With the appropriate arrangement of these parts a single drop of water could be dispensed to the depression at the center of the cylinder. The apparatus was arranged so that a Noyes pellet was delivered to the food cup behind one panel and a single drop of water was dispensed to the cylinder placed inside the food cup behind the other panel. The glass tube used to deliver water in Experiment I was removed.

Procedure

All *S*s were maintained on ad libitum food and water and placed on food deprivation as in the first experiment. After *S*s had stabilized at 80 per cent of their ad lib. weight and ten days before the start of training *S*s were also placed on 23.5 hours water deprivation. All *S*s were maintained at these levels of food and water deprivation throughout the experiment.

The rest of the procedure was divided into three phases: Preliminary Training, Training, and Reward Shift.

Preliminary Training

At the start of preliminary training *S*s were haphazardly assigned to two groups (n = 5). One group was trained to find food behind the black panel and water behind the white panel. These conditions were reversed for the other group.

Initially all *S*s were magazine trained with the appropriate type of reinforcement in each food cup. The Ss were then shaped to open the appropriate panel doors for both food (one 45 mg Noyes pellet) and water (one 1 ml drop) reinforcement, respectively. This procedure was continued until Ss made 10 reinforced panel pushes (i.e., 5 reinforced by food and 5 reinforced by water) in one 30 min session. Care was taken to insure that all Ss had equal experience with the food and water panels throughout this procedure.

Training

Once consistent approach and panel pushing responses were established to both food and water reinforcement, training was started. The purpose of this training procedure was to establish a sequence or chain of responses in which S would first open the food panel and then open the water panel. The food panel was analogous to the first runway and goal box of a double runway apparatus and was designated G_1. The second panel reinforced by water was analogous to the second runway and goal box of a double runway apparatus and was designated G_2. The enclosure light was illuminated behind each panel. However, the overhead light was on only over G_1.

A typical trial started with the opening of the sliding door in front of G_1 simultaneous with the delivery of a single 45 mg Noyes pellet to the food cup and the illumination of the light above G_1. When S pushed this panel, the sliding door in front of G_2 was opened and a single drop of water was delivered to the water dispenser. The trial ended approximately 15 sec after the G_2 response was made or two min after the beginning of the trial by the closing of both sliding doors and the extinguishing of the overhead and enclosure lights. The intertrial interval was 30 sec. All Ss were given 11 such trials per day for five days before reward shift was started.

Reward Shift

During this phase of the experiment all Ss received a series of five acquisition-extinction sessions under each of five sizes of reward: a single 45, 97, 190, 300, or 500 mg Noyes pellet. An acquisition session consisted of three days, ten trials per day under the appropriate size of reward in G_1. Each acquisition session was followed on the next day by an extinction session. This consisted of six reinforced trials (Er) followed by 22 nonreinforced trials (Enr) on G_1 in one day. Water (one 1 ml drop) was continuously available behind G_2 during both acquisition and extinction sessions. The order of administration of the acquisition-extinction sessions under the five sizes of reward was counterbalanced using a Latin square design. Two subjects were haphazardly assigned to each of 5 different orders, one S trained with a black G_1 and the other trained with a white G_1. The intertrial interval (30 seconds), the maximum duration of a trial (2 minutes) and the time between performing a G_2 panel push and the end of a trial (15 seconds) remained the same as in training.

As in the first experiment, the force for both G_1 and G_2 responses was measured throughout the experiment.

The latency of the G_1 response was the time between the beginning of the trial and the performance of the first (G_1) panel push response. The latency of the G_2 response was the time between the performance of the G_1 response and the performance of second (G_2) response. Both latencies were automatically recorded to 1/100 of a second on Hunter Klockounters. It must be pointed out that the G_2 latency was more indicative of time it took S to ingest the Noyes pellet obtained behind G_1 than of actual response time. Thus latency was not analyzed in this experiment.

Results

Figure 6 depicts the mean median force of responding over the six baseline reinforced trials (Acquisition-Er) and the 22 nonreinforced trials (Extinction-Enr) given on each extinction session as a function of size of reward and type of response. It was expected that performance on these six reinforced trials which immediately preceded the extinction trials would serve as the most accurate baseline from which to compare changes in performance due to nonreinforcement. Mean median force was used as the measure of performance because it appeared to be more stable than mean force. However, essentially identical results were obtained using either measure. Mean median force was calculated by obtaining for each subject the median force of responding for each acquisition and extinction session. Data points plotted represent the mean of these medians.

An analysis of variance of the results plotted in Figure 6 is presented in Table 5. As can be seen, force of responding on the first panel in the sequence (G_1) reinforced by food was significantly greater than force of responding on the second panel reinforced by water (G_2) both on reinforced (Er) and nonreinforced (Enr) trials ($F = 38.4720$, $df = 1/9$, $p < .001$). Unfortunately, the confounding of type of reinforcement and sequence of responding does not allow any

Figure 6. Mean median force of responding as a function size of incentive, type of response (G_1 vs G_2) and stage of testing (i.e., reinforced (Er) vs nonreinforced trial (Enr)).

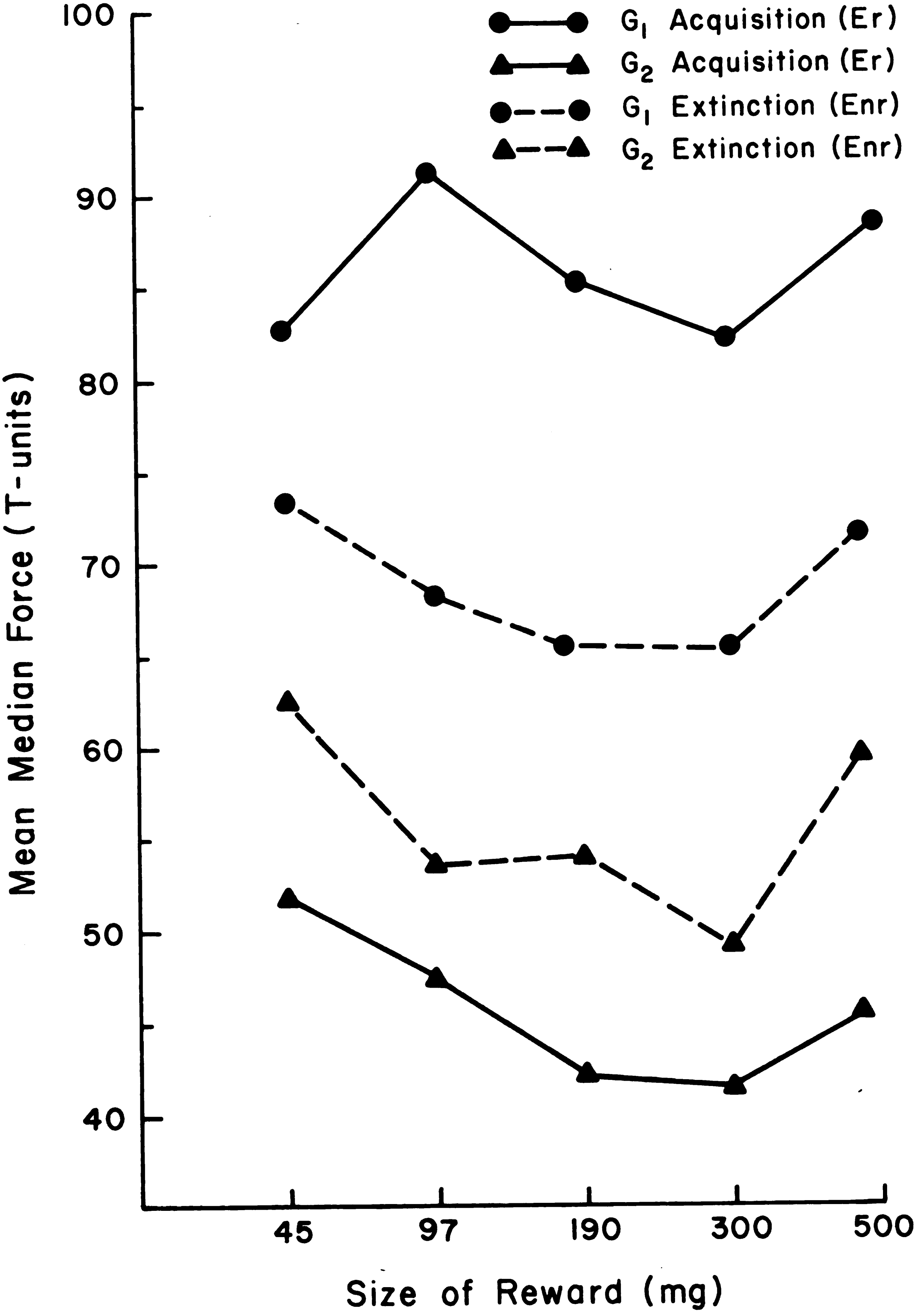

G$_1$ Acquisition (Er)
G$_2$ Acquisition (Er)
G$_1$ Extinction (Enr)
G$_2$ Extinction (Enr)
Mean Median Force (T-units)
100
90
80
70
60
50
40
45
97
190
300
500
Size of Reward (mg)

Figure 6

Table 5. Summary table for the analysis of variance of force of responding for the extinction sessions of experiment 2 with size of reward, stage of testing (Er vs Enr), and type of response (G_1 vs G_2) as independent variables.

Source of Variance	SS	df	MS	F	P
Total	913857.4600	199			
Subjects (S)	12272.0132	9	1363.5570		
Reward Size (R)	1632.6092	4	408.1523	.7072	ns
Error S x R	20777.4678	36	577.1519		
Stage (St)	723.5208	1	723.5208	3.5783	$>$ .10
Error S x St	1819.7722	9	202.1969		
Response (G)	34647.6488	1	34647.6488	38.4720	$<$ .001
Error S x G	8105.3542	9	900.5949		
R x St	369.0082	4	92.2521	.5004	ns
Error S x R x St	6636.1888	36	184.3386		
R x G	622.8452	4	155.7113	.5941	ns
Error S x R x G	9435.2918	36	262.0914		
St x G	9624.3938	1	9624.3938	58.4218	$<$ .001
Error S x St x G	1482.6592	9	164.7399		
R x St x G	157.8302	4	39.4576	.4913	ns
Error S x R x St x G	2891.0068	36	80.3057		

definitive interpretation of this difference, though from Experiment I it would seem that type of reinforcement is more important.

Consistent with the first experiment no significant relation between force of responding and incentive size was found (F = .7072). When G_1 and G_2 forces were analyzed separately the relation still remained nonsignificant (F = .5499 and .7505 respectively). Thus size of incentive as manipulated in this study produced statistically nonsignificant results. This is of particular interest since "incentive size" was manipulated within subjects. This type of design should be especially sensitive for two reasons. First, it removes stable individual differences as a source of error variance. Second, the exposure to many sizes of incentive should maximize any effects present, such as, contrast effects due to incentive shifts (Ehrendfreund, 1971).

Nonreinforcement in the present study yielded opposite performance changes depending on where the effects were measured. When frustrative nonreward immediately preceded the response to the G_2 panel push there was a significant increase in force of responding (FE) above the reinforced G_2 baseline ($F = 32.5411$, $df = 1/9$, $p < .001$). When frustrative nonreward did not directly precede the response, as with the G_1 panel push, there was a significant decrease in force of responding below the reinforced G_1 baseline ($F = 16.0849$, $df = 1/9$, $p < .005$). These effects yielded the significant goal by stage interaction ($F = 58.4218$, $df = 1/9$, $p < .001$).

To examine the progressive effects of extinction, the nonreinforced trials of each extinction session (approximately 22 trials) were divided into four quarters for each animal. The median force at each quarter of extinction was used as a measure. Figure 7 depicts the force of responding at G_1 and G_2 over progressive quarters of extinction with reward size as a parameter. Table 6 presents an analysis of variance of these data. As can be seen from this table, there was a significant goal (G_1 vs G_2) ($F = 9.9291$, $df = 1/9$, $p < .025$) and stage by goal interaction ($F = 9.5144$, $df = 3/27$, $p < .001$). These results can be more clearly seen in Figure 8. From this figure it can be seen that G_2 force is higher than G_1 force throughout extinction. The goal by stage interaction was probably due to the drop in force on G_1 and the increase in force on G_2 from the first to the second quarters of extinction. The functions appear to be parallel beyond the second quarter. Using the Duncans multiple range test the difference between operant and goal force is significant at the first quarter but is not significant at subsequent quarters ($df = 27$, $p < .05$). Thus it appears that the invigorating (G_2) and inhibitory (G_1) effects of frustrative nonreward reach asymptote at about 11 trials.

There was also a significant reward size by stage interaction ($F = 2.1054$, $df = 12/108$, $p < .05$). Visual inspection of this interaction yielded no psychological meaningful relation. All other effects produce _F_'s less than one.

Table 6. Summary table for the analysis of variance of force of responding for the extinction sessions of experiment II with size of reward, quarters of extinction (blocks), and type of response (G_1 vs G_2) as independent variables.

Source of Variance	SS	df	MS	F	P
Total	1743945.9289	399			
Subjects (S)	30249.9768	9			
Reward Size (R)	2919.2600	4	729.8150	.5425	ns
Error S x R	45514.7720	36	1345.3898		
Blocks (B)	918.1182	3	306.0394	.9936	ns
Error S x B	8315.9649	27	307.9987		
Response (G)	12378.6764	1	12378.6764	9.9291	∠ .025
Error S x G	11220.3809	9	1246.7090		
R x B	7182.4038	12	598.5337	2.1054	∠ .05
Error S x R x B	30703.0072	108	284.2871		
R x G	1042.6265	4	260.6566	.6057	ns
Error S x R x G	15491.0579	36	430.3072		
B x G	5156.5805	3	1718.8602	9.5144	∠ .001
Error S x B x G	4877.7662	27	180.6580		
R x B x G	1530.4217	12	127.5351	.6112	ns
Error S x R x B x G	22535.5367	108	208.6624		

Figure 7. Mean median force of responding during extinction as a function of type of response (G_1 vs G_2), size of reward and quarters of extinction. The floating points on the left of the figure represent mean median force for the 6 reinforced baseline trials given during the extinction session.

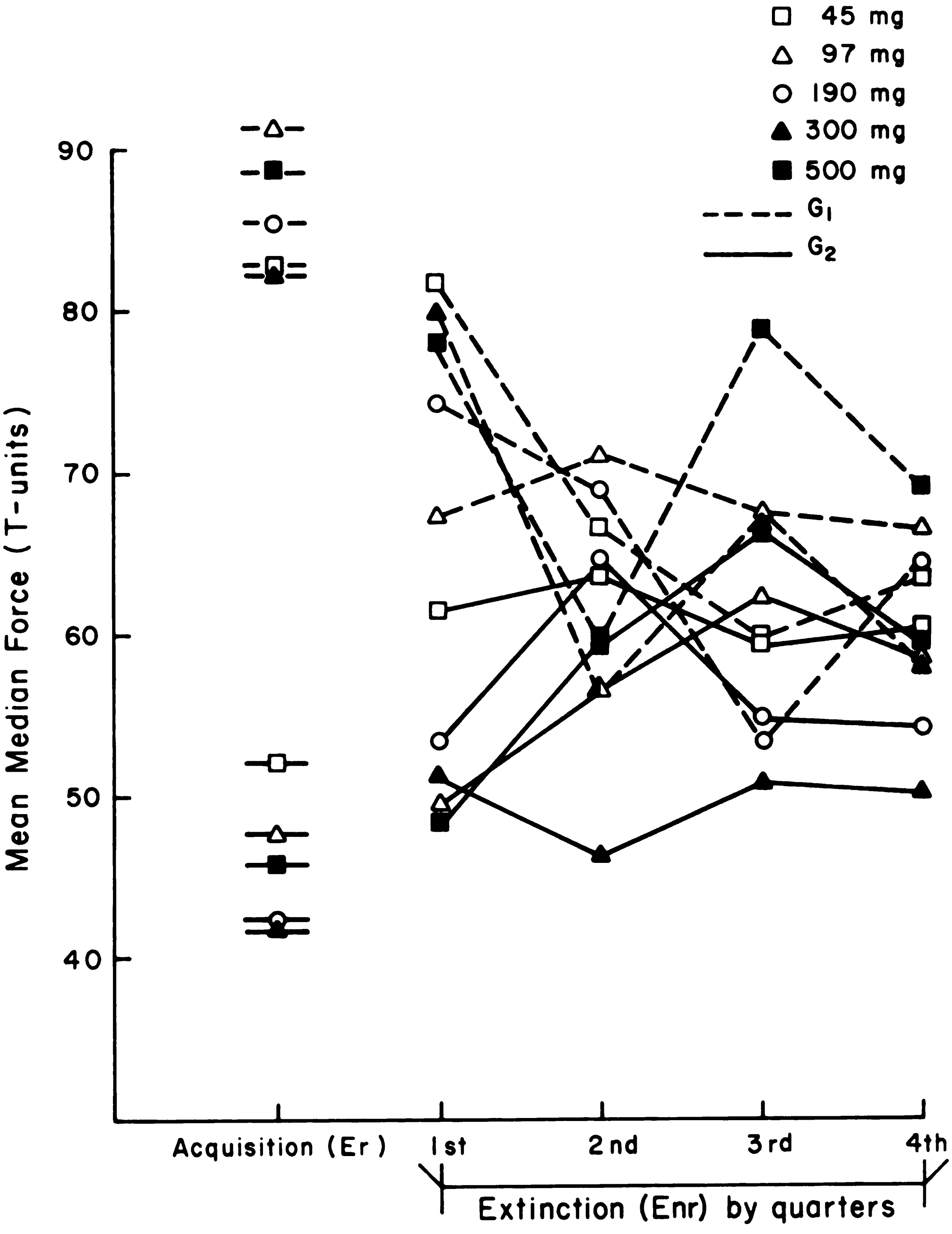
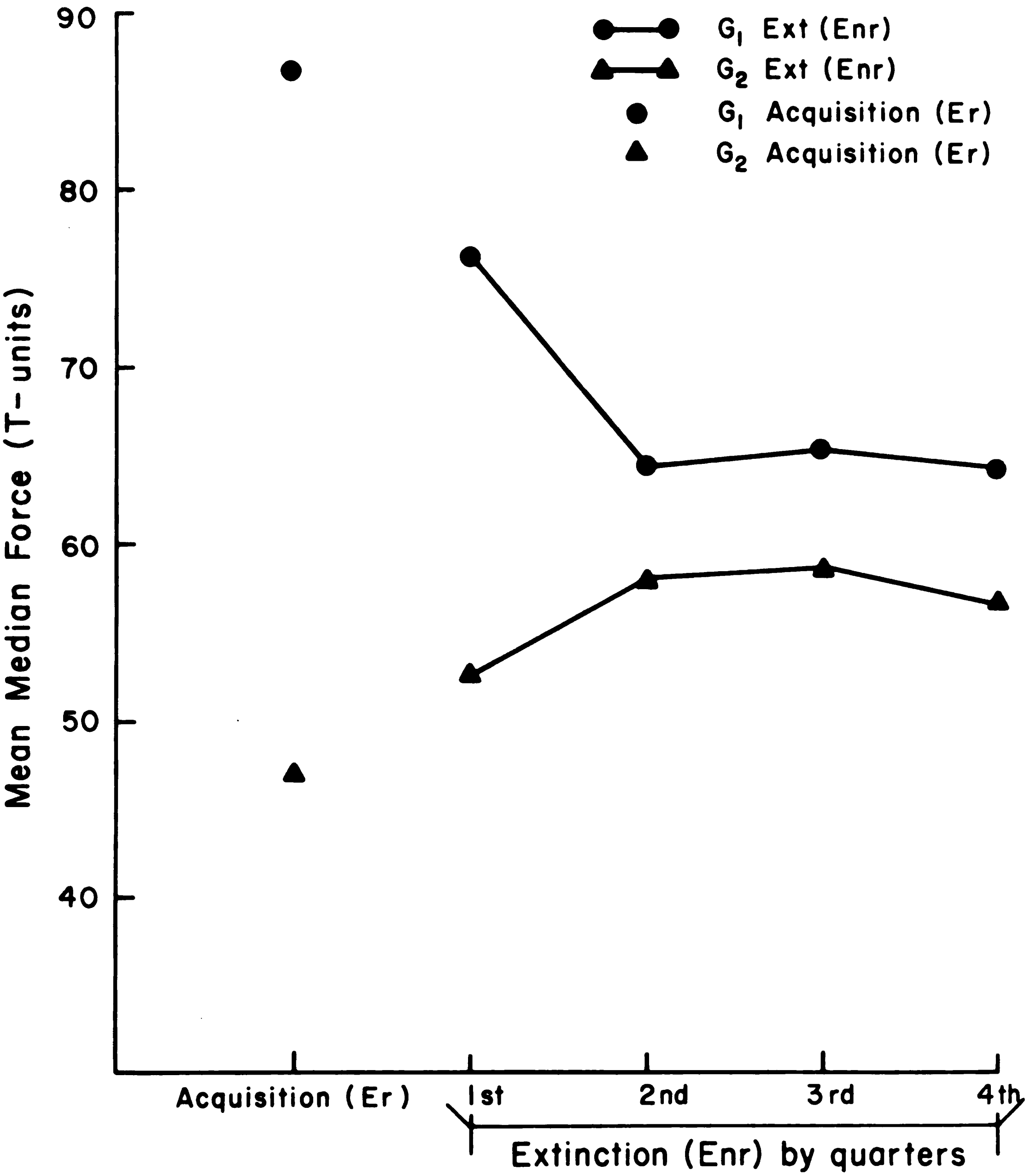

□ 45 mg
△ 97 mg
○ 190 mg
▲ 300 mg
■ 500 mg
G1
G2
90
80
70
60
50
40
Mean Median Force (T-units)
Acquisition (Er)
1st
2nd
3rd
4th
Extinction (Enr) by quarters

Figure 7

Figure 8. Mean median force of responding during extinction as a function of type of response (G_1 vs G_2) and quarters of extinction. Each point represents the mean for all five sizes of reward.



90
80
70
60
50
40
Mean Median Force (T-units)
G₁ Ext (Enr)
G₂ Ext (Enr)
G₁ Acquisition (Er)
G₂ Acquisition (Er)
Acquisition (Er)
1st
2nd
3rd
4th
Extinction (Enr) by quarters

Figure 8

Discussion

The force of responding during acquisition on G_1 in the present experiment was similar to the goal force measured during acquisition in the first experiment. Thus the results of the first experiment which employed a between subjects design have been replicated using a more sensitive within subjects design. There was no significant relation during acquisition between response force and incentive magnitude in either experiment and the nonsignificant decreasing relation between force and incentive magnitude seen in the first experiment was not seen in Experiment II. Thus it must be concluded, at least for force, an amplitude measure of response, that the actual physical size of the incentive is not relevant variable.

It has already been pointed out that most studies that manipulated incentive size have done so using number of pellets (Pubols, 1960; Dunham, 1968). For the most part, these studies have found an increasing monotonic function relating incentive magnitude to runway performance. Using force of bar pressing as a dependent measure Notterman and Mintz (1965) found a decreasing monotonic function relating incentive magnitude (i.e., number of pellets) to performance. The difference in the direction of the relation found when using bar pressing instead of alley running as an instrumental response may be related to differences in the reinforcement criteria implicit in each response. In the straight alley faster running leads to a decrease in delay of reinforcement. In the bar pressing situation increased force of responding only leads to a greater expenditure of effort. Thus improving performance in an operant situation may mean a decrease in force of responding, to conform to the reinforcement criterion.

Recent work with ingestion rate (Deaux, 1973) suggests that number of pellets may only indirectly cause performance changes. Deaux (1973) found that when equal volumes of water were given to rats at different rates, high ingestion rate *S*s were superior in performance to low ingestion rate *S*s. This occurred even when low ingestion rate *S*s produced more consumatory responses (licks) than high rate *S*s. The suggestion is that ingestion rate, an organismic variable, is the necessary condition for performance changes. Other incentive manipulations may have their effect indirectly by influencing ingestion rate. Preliminary data from our laboratory indicate that rats will consume 11-45 mg pellets (495 mg) approximately twice as fast as they consume a single 500 mg pellet. There is also a larger amount of intersubject variability in speed of consumption when *S*s consume a single large pellet than many small pellets. Thus, it is possible that neither size nor number of incentives directly affects performance, but do so indirectly by affecting ingestion rate to lesser or greater degrees.

The second major finding relates to performance changes due to nonreinforcement. In the first experiment it was found that extinction significantly decreased force of responding. This effect was replicated in the present experiment for G_1 force. It was also suggested in Experiment I that changes in performance during extinction were related to the interval between nonreinforcement and the performance of the next response. For the operant force (i.e., the response that directly followed nonreinforcement during extinction) an 8 sec ITI appeared to produce less decrement in force than a 30 sec ITI. This was interpreted as being due to the invigorating effects of the trace of frustrative nonreward. The implication was that a very short time between nonreinforcement and responding might lead to an increase in force of responding i.e., an FE, per Amsel (1952).

Experiment II tested this hypothesis. It was found that G_2 force increased from acquisition to extinction and that this increase asymptoted in about 11 trials. This is analogous to the frustration effect (FE) found traditionally in the double runway paradigms (Amsel, 1962). In accord most other studies there was no functional relation found between the FE and the magnitude of incentive (see Table 1). However, in previous studies any potential functional relation between incentive size and the FE was obscured by demotivational confounding (eg. McHose & Gavelek, 1969). In the present study, no strong evidence could be found to support this demotivational hypothesis (Seward et al., 1957). To support this hypothesis, force of responding on G_2 should have been a monotonically decreasing function of incentive size at G_1. That is, the larger the pellet consumed before pressing the G_2 panel the greater the presumed demotivation and the less the vigor of responding (Force) on G_2. This did not occur in the present experiment. There was no significant relation during acquisition between size of incentive and force of responding on G_2.

It has been previously pointed out that a positive relation between size of incentive and the FE is critical to Amselian frustration theory. To date no study, including the present one, has demonstrated this relation. Previous studies (see Table 1) have manipulated incentive size by varying the number of a constant sized pellet and the present study varied the weight of a single pellet. It has been suggested earlier that both these procedures may only indirectly affect incentive motivation by their effect on ingestion rate. Deaux (1973) has already demonstrated that ingestion rate can be independently manipulated. A procedure similar to his would have significant advantages over the previously mentioned procedures. First, since this variable is directly manipulated by E, the between subject variability in ingestion rate would be controlled. Second, when ingestion rate is varied the amount consumed can be held constant. This should completely remove any confounding due to demotivation. Thus, it appears that future research varying ingestion rate directly and holding amount consumed constant should have the greatest success in elucidating the relation between incentive magnitude and the FE.

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APPENDICES

APPENDIX A

Figure A-1. Force of operant responding during Experiment I as a function of trials in one day collapsed over all ten days of reward shift with reward size as a parameter.

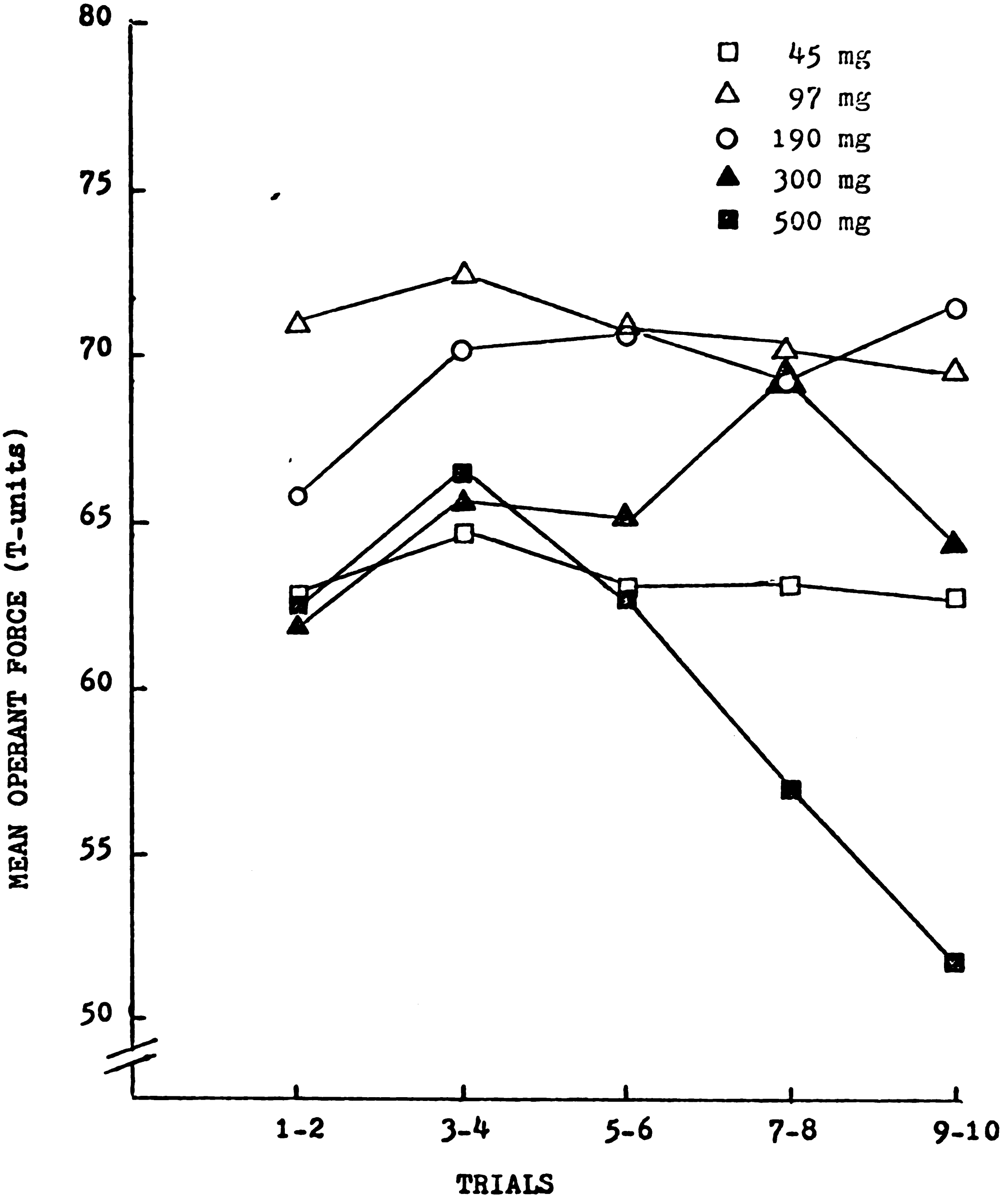
80
75
70
65
60
55
50
MEAN OPERANT FORCE (T-units)
1-2
3-4
5-6
7-8
9-10
TRIALS
□ 45 mg
△ 97 mg
○ 190 mg
▲ 300 mg
■ 500 mg

Figure A-1

APPENDIX B

Figure B-1. Mean latency of responding to both G_1 and G_2 during the acquisition and extinction stages of experiment 2 as a function of size of reward.

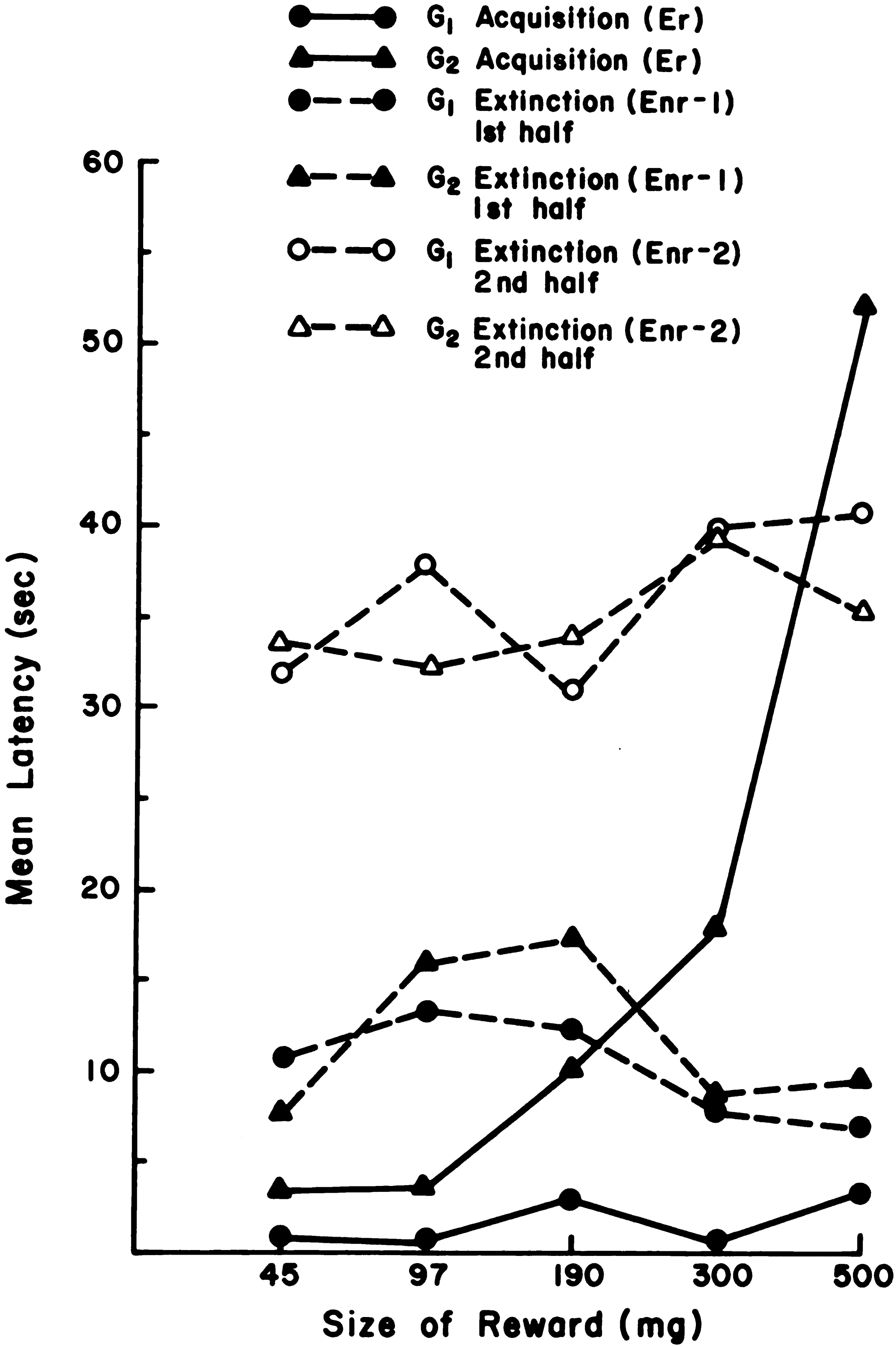
G₁ Acquisition (Er)
G₂ Acquisition (Er)
G₁ Extinction (Enr-1) 1st half
G₂ Extinction (Enr-1) 1st half
G₁ Extinction (Enr-2) 2nd half
G₂ Extinction (Enr-2) 2nd half
60
50
40
30
20
10
Mean Latency (sec)
45
97
190
300
500
Size of Reward (mg)

Figure B-1