THE QUANTIFICATION OF DRIVE
I. INCENTIVE VALUES OF FOOD AND WATER

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THE QUANTIFICATION OF DRIVE

I. INCENTIVE VALUES OF FOOD AND WATER

by

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A THESIS

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The present study was conducted in order to establish incentive values for food and water, and in an effort to determine the feasibility of quantifying the drive construct once such values were known.

A push-panel apparatus was constructed in which activity levels could be measured simultaneously with response amplitude and latency.

Thirty-six male, albino rats were divided into two major groups, both of which were subdivided again into three groups.

1. High Drive: (a) Large Food Reward
   (b) Small Food Reward
   (c) Medium Water Reward
2. Low Drive: (a) Large Food Reward
   (b) Small Food Reward
   (c) Medium Water Reward

Each of the 36 animals was habituated to the box, assigned to one of the subdivisions, trained to open the push-panel for either food or water, and then tested for a total of 40 trials, 20 trials under a high drive and 20 trials under a low drive. Half of the animals began their test series under a high drive and half began their test series under a low drive in order to counterbalance the trials. Activity level for six minutes before the exposure of the push-panel, and the latency and amplitude of each response was recorded. At the close of the test series, all animals were extinguished under either high drive or low drive.

The results were as follows:

1. Latency: Amount or type of reinforcement was not a significant variable with respect to latency. The incentive value of small food

reward, however, more nearly matched the incentive value of the amount of water employed. Such differences as do exist are largely confined to the first half of the test series. Early in the test series, latency appears definitely to be a function of the drive level under which it is measured, but not late in the series.

2. Activity Level: Activity level offered some promise as an independent measure of drive. Activity shows a consistent upward trend throughout the test series. This cannot be accounted for in terms of some generalized increasing drive but seems to be a consequence of learned anticipation. A significant negative correlation was obtained between activity level and latency. There was a significant difference between activity levels taken following long deprivation and those taken following short deprivation. Type of reinforcement was unrelated to activity.

3. Amplitude: The amplitude of the response as measured in the present study did not prove to be related to either the amount or type of reinforcement, or to the amount of deprivation.

4. Extinction: No difference was found between animals extinguished under high drive and those extinguished under low drive in number of responses to extinction.

5. One of the significant findings of the study was the discovery that differences often appear to be a consequence of the point in the test series at which measurements are taken, rather than a simple function of some variable such as drive or reinforcement.

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INTRODUCTION

A. DRIVE AS A CONSTRUCT

Two fundamental issues in contemporary psychology concern the nature of drive and the nature of reinforcement. There can be little doubt but that the adequacy of any future learning theory will depend upon the extent to which these two concepts are understood and their conditions described.

Although drive is frequently treated as a generalized drive state, its empirical definition in terms of antecedent conditions and resultant behavior is inadequate. To consider drive as a unitary, empirical construct implies that each measured value of drive will bear a constant relationship to certain behavioral consequences. In other words, regardless of the principal conditions under which drive is produced (privation of food, or water, or sex, etc.), the relationship of drive to the response variable in question should be the same. Since the current literature sheds little light on this matter, it is possible that drive may not be a genuine scientific construct.

The behavioral consequences of deprivation may be distinguished as to: (1) the general activity level and (2) learned performance. Often, activity and performance are observed to vary concomitantly, but performance shifts are also related to learning, fatigue, etc.. It is, therefore, often held that general activity is a better indicator of drive than is performance (31).[1]

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[1] It is important to note that activity amplitude does not necessarily reflect the "need" of an animal, however.

B. ACTIVITY LEVEL AND DEPRIVATION

A series of activity level experiments have been carried out over the past several decades, and they have demonstrated that there is a definite relationship between generalized activity level and the experimental manipulation of many features in the environment. While many reviews have been published in this area (18) (17) (36), the relevance of activity level studies to the present experiment make it imperative that we inspect a number of these studies and investigate the possibility of assessing drive level, not by the hours of deprivation of some relevant need, but by the general activity level which an animal manifests.

Specific activities in animals tend to be rhythmic. Such specific activities have been extensively investigated by Richter (21) (22). Where food is present at all times, for example, eating activity is still periodic, taking place every 3-4 hours. Richter has demonstrated that drinking, urination, defecation, and mating, all are characterized by a certain rather specific periodicity. P. T. Young (37) has reported studies conducted in his laboratory demonstrating a diurnal drinking pattern in the rat with periods of maximum drinking occuring in the late afternoon and at night.

Actually, it might be said that activity level always shifts as a result of some change in the physiological state of the animal, but frequently this shift appears to take place as the result of some specific change in the external world. For example, activity level is a function of temperature (13) (2), previous activity (26), and illumination (11) (3). In addition to these differences in general activity level which

appear as a consequence of those physiological and environmental conditions sighted above, there are many other conditions which have been correlated with activity. Among these are, for example: inheritance, endocrine condition, drug, cerebral injury, opportunities for sexual outlet, etc. Finally, perhaps the most important and interesting correlations for our purposes have been established between activity levels and the deprivation of some material substance which the organism requires for its existence, particularly food and water.

Whenever an animal is deprived of a needed substance its activity level rises. With reference to food it has been repeatedly demonstrated that just prior to their regular feeding periods, animals become very active, even though this period, if it were not regularly followed by food, would normally be an inactive one (21) (28). It has also been demonstrated that activity continues to rise up to about 96 hours of deprivation when an animal is deprived of food alone, but falls off at 72 hours if an animal is deprived of both food and water(22) (32). Warden (33), using an obstruction box, found that animals would cross a charged grid a greater number of times at 24 hours of deprivation of food than at any other number of hours of deprivation up to 6 days. Wald and Jackson (32) found that rats when deprived of many substances were increasingly active until satiated.

C. ACTIVITY LEVEL AND LEARNING

A number of years ago, several studies were conducted which bear directly on the problem of the relationship between activity level and

performance. In two of the earliest of these studies no appreciable relationship was demonstrated (24) (1). A later study, conducted by Tuttle and Dykshorn (30), indicated a definite correlation between activity level and learning. The Ns were small : 7, 6, 5, 7, 7 with correlations of .57, .60, .30, .64, and .82 respectively, and the data was derived from a study primarily concerned with the influence of gonadectomy. Rundquist & Heron (23) reanalyzed the data of Tuttle and Dykshorn. When groups were combined to achieve larger Ns and controls were introduced for sex and gonadectomy, a correlation of .30 was found for males and an r of -.15 for females between activity and learning. Using a different measure of learning, larger groups, and a t-test for significance rather than a Pearson r, Rundquist and Heron demonstrated marked differences in the learning and performance of active as compared with inactive rats. An interesting aspect of the Rundquist and Heron study in terms of the present investigation is the fact that these investigators shifted drive levels at the 23 and 32 trials in the series of 40. On the 23 trial the daily diet was cut to one half the normal diet and on the 32 trial it was raised to one and one-half times the normal diet. While this resulted in no significant shift in errors for the inactive animals there was a significant drop in errors for the active animals on the block of trials 24 through 31, as well as the block 32 through 40. This was particularly true of the block of trial 24-31, on which the daily diet was cut in half.

There would appear to be evidence here indicating that (1) active animals learn better than inactive ones, (2) active animals perform better than inactive ones, and (3) that shifting the deprivation levels

of active animals causes a marked decrease in errors and a significant increase in performance levels.

D. THEORETICAL INTERRELATION BETWEEN DRIVE, LEARNING, AND PERFORMANCE

It has been pointed out then that deprivation has an influence on activity level, and that activity level, in turn, apparently is functionally related to performance. Accordingly, it might now be asked, "How are these three complex factors interrelated?"

It is possible that the systematic investigation of deprivation, activity, and performance might ultimately lead to the development of a drive-construct, which would resemble those constructs found in the more exact sciences. If it could be demonstrated, for example, that regardless of the technique which was utilized to produce drive, a measure could be established which would predict its measurable consequence in performance, then "drive" would assume the status of a genuinely valid scientific construct.

Performance (sEr) is said by Hull to manifest itself in four ways, and was originally said to have been a function of drive (D) times habit strength (sHr). Accordingly, in any situation in which sEr was manifested, Hull's original postulates asserted that this sEr resulted from the interaction of at least these two complex factors. In order to determine which of these two factors influence an observed behavioral change, it would be necessary to control the other. The control of sHr involves the manipulation of environmental variables which have not thus far been discussed.

Within Hull's original system, sHr is assumed to be a function of several variables, particularly reinforcement. Hull (9) stated in his Principles that both the kind of reinforcement and its amount were learning (sHr) variables, influencing performance through learning. The empirical verification of this assumption has not been accomplished. Hull's reformulated postulates, therefore, now express the strength of sHr as a function of the number of reinforcements exclusively, and have recognized the influence of variation in amount or type of reinforcement by giving it the status of a "motivational" variable. In so far as learning is concerned, reinforcement is said to be an "all or none" affair. Performance, however, is apparently a definite function of the amount and type of reinforcement.

Effective reaction potential, at the termination of learning, is now believed to be a multiplicative function of a negatively accelerated increasing monotonic incentive function (K), drive (D), stimulus intensity (V), delay in reinforcement (J), and habit strength (sHr), i.e.,

$$SER: \; D \times V \times K \times J \times sHr.$$

E. ESTABLISHING DRIVE AS A CONSTRUCT

A critical question which arises in connection with this formula and the status of drive as a scientific construct is this: if performance is a function of all of these things, then how are we to detect the influence of drive alone on sEr? And, in this connection, the most difficult problems arise relative to the incentive function, K.

If the major problem consists of defining the conditions said to influence drive and of measuring the effect of these on performance

so as to establish drive as a construct, then what must be done to accomplish this? Briefly:

1. Animals must learn some prescribed task.
2. Once animals have learned this task, drive level—as produced by different types and degrees of deprivation—must be varied.
3. Ideally, drive should be measurable in units which are independent of those involved in its production.
4. Finally, throughout the experiment, the factors of V, J, K, & sHr must be controlled.

Let us consider these requirements individually and in greater detail.

1. Problems associated with the task to be learned. Learning (sHr) or habit strength must first be established and then held at a constant level in all groups. To accomplish this, animals must be trained for an equal number of trials in the performance of some specific task. What levels of drive and reinforcement should be used to accomplish this?

There is a growing body of evidence to indicate that drive level, as well as amount of reinforcement, is not a critical learning variable. With reference to the drive level under which a task is learned, Finan (6) in 1940 published evidence to show that rats learned better under 12 hours of deprivation than at any other level. Animals were trained to a criterion of 30 reinforced trials under different levels of deprivation and then extinguished with all animals under the same level of deprivation. While animals trained under 12 hours of food deprivation required more responses to extinction than those trained under 1, 24,

or 48 hours, the differences were not statistically significant except in those comparisons involving the 1 hour group. Actually, the evidence here for any real differences between groups is thus extremely limited.

In 1945, Kendler (12) published a study in which a relevant drive (hunger) was held constant at 22 hours and an irrelevant drive (thirst) was maintained at two different degrees, 12-22 hours, during learning. No evidence was obtained to show that degree of deprivation during learning effected the number of bar pressing responses to extinction.

In view of the contradictory implications of the studies of Kendler and Finan, Strassburger (29) undertook to do a genuinely definitive study of the problem.

While the study which Strassburger conducted was essentially a replication of Finan's, it was expanded, and he attempted to assess the strength of sEr after different numbers of reinforcements, as well as under different drive levels. The general conclusion of the study was that, although response was definitely a function of the number of reinforced trials during learning, no consistent relation existed between degree of hunger in conditioning and resistance to extinction.

From these studies, it can now be inferred that the problem of what drive should be used during learning, offers no particular difficulties. Deprivation level can, of course, be held constant through all groups during this phase of the experiment. It is interesting to note in this connection that it follows from the above studies that the results obtained on a study such as the one proposed here would be applicable to studies in which animals were trained under different levels of drive.

The same is largely true of reinforcement during learning. Our second problem in connection with the strength of sHr as it participated in the formula for sEr concerned the quantity of reinforcement which should be utilized during learning. While the evidence in this case does not lend itself to a straightforward interpretation, it now appears that learning is not influenced by the amount of reinforcement available to the animal per learning trial. Performance, however, definitely appears to be a function of this variable, and Hull's revised formula for sEr is the explicit recognition of this fact. The new formula holds that sHr depends only on the number of reinforced trials, whereas sEr is equal to the habit structure times certain other factors, one of which is K or quantity of reinforcement.

Grindley (7) demonstrated as early as 1929 that speed of running was related to the amount of reinforcement given an animal per trial, and in the years which followed Grindley's original study, several additional experiments were published in this area. Cowles and Nissen (4) correlated delay interval in chimpanzees with size of reinforcement. A later abstract, published by Fitts in 1940 (38) indicated that animals given 1 trial per day and rewarded with 10 grams per response to a bar pressing apparatus required more responses to extinction than those rewarded with .2 grams.

From these studies, it appears that amount of reinforcement has a universal influence on the rate at which learning takes place. Wolfe and Kaplon's study (35), published one year after the abstract reported by Fitts, casts considerable doubt on the universal application of this

assumption. With certain procedural modifications and using pop corn rather than rice, Wolfe and Kaplon repeated Grindley's original study. They demonstrated that one large piece of pop corn and a piece one-quarter its size were equally effective in producing lower running times, but that four one-quarter pieces were more effective than one one-quarter piece alone, and that four one-quarter pieces were even more effective than one large piece.

The problem of the amount of reinforcement and its role in learning was finally systematically attacked in 1942 by Crespi (5). Using a long runway and large differences in the amount of reinforcement, Crespi found significantly smaller running times in animals with the larger incentives. These differences in running times characterized both the learning and post-learning periods. Furthermore, it was demonstrated that a shift in incentive caused a corresponding shift in running time, so that, for example, large-incentive-fast-running animals, when shifted to smaller incentives, were observed to reduce the speed of locomotion, and vice versa.

Recently, it has become increasingly evident that while speed of response is definitely a function of the amount of reinforcement, it is doubtful that learning, *per se*, is correlated with this factor (19).

These studies make it reasonably evident that the amount of reinforcement, as well as the level of drive, is not a critical learning variable.

2. *The variation of deprivation after learning*. Because our second requirement involves the manipulation of an independent variable, no control difficulty is offered by the degree of deprivation.

3. The independent measure of drive. It is desirable that drive should be measured in response units which are both common to various types of deprivation and independent of the conditions involved in its production. These units should be so correlated with behavior that a knowledge of them will permit a trained observer to predict behavioral consequences. The studies reported in the area of general activity offer some evidence that these units might be supplied by an activity measure obtained either immediately before or during the learning and performance situations.

4. The control of variables contributing to sEr. The control of habit strength or sHr has been considered in (1) above. Attention was directed to the drive and reinforcement levels under which learning should take place (which should be used during learning). It is assumed that this factor can be adequately controlled by observing the considerations previously set forth.

Stimulus intensity dynamism (V) is controlled by the fact that all animals learn and respond in essentially the same environment.

Delay of reinforcement (J) operates to influence sEr as a consequence of the time intervening between the occurrence of the response and the reinforcement received. Since all animals would be trained under identical drive and reinforcement levels, there is little reason for assuming that J would differ from one group to another.

The importance of the incentive function (K) has been considered with reference to the influence of different amounts of reinforcement on learning and performance. With reference to amount, the difficulties are not particularly formidable. But, it will be recalled that ideally drive

should be produced not only with different amounts of deprivation, but also with different types of deprivation, e.g. food and water. This brings forth the last and most difficult obstacle blocking the way to a thorough and systematic attack on the problem of drive as it influences animal behavior.

It can readily be seen from the formula for sEr that in so far as quantity is concerned, this variable could be held constant from group to group and thereby controlled. But, the problem is to investigate the conditions said to influence drive and these conditions include more than just one type of deprivation. Although many other conditions are believed to influence drive, it would be both impractical and possibly even impossible to manipulate all of these, but the deprivation of water, as well as food, would certainly seem to be both feasible and desirable.

This being the case, the important question which now arises is: what quantity of water shall be used so as to be equal in reinforcing value to what quantity of food? The influences exerted on behavior by different deprivation levels of these substances will never be comparable unless we are certain that the quantity of reinforcement utilized to investigate learning and performance under different types of deprivation are of equal reinforcing value. In other words, everything must be controlled in the situation with the exception of the independent variable, D. This can only be done by substituting values of K which are constant from one type of deprivation to the next.

There is no evidence in the literature bearing directly on this problem.

Accordingly, we here are presented with a question which must be answered before the larger problem of validating the drive construct can even be attacked.

F. PURPOSE

The purpose of the present study is twofold:

(a) To determine the effects, which different quantities of food reward have on the learning and performance of hungry animals in a panel pushing apparatus as compared with the effect of a specific quantity of water reward on the learning and performance of thirsty animals in the same situation.

(b) To assess the extent to which the general activity level of an animal--as measured in the experimental situation--can be used to predict the strength or amplitude of a learned response, the speed of a learned response, and the number of such responses to extinction.

II. SUBJECTS

The subjects in this experiment were 36 male albino rats from the colony maintained by the Department of Psychology of Michigan State College. Ages ranged from 85 to 125 days, with a mean of approximately 90 days.

III. APPARATUS

In order to investigate the present problem an apparatus was constructed in which it was possible to measure activity level, response latency, response amplitude or force, and the number of responses to extinction. It consisted of a 1/2" plywood box with overall dimensions of 20" x 16" x 11".

Figure 1 presents a cross section of the apparatus. At the bottom of the activity chamber there was a false floor which was supported by 3 springs and a rubber ball at its exact center. At the four corners of this false floor, small, attached, rubber balls served as stops, preventing the floor from tipping any more than 1/4".

A guillotine door at one end of the activity chamber, when raised, gave access to a hinged, 4" x 2" panel. This panel was constructed of a thin rectangular piece of wood, 1/16" diameter; at the upper end of the panel was a small piece of 1/2" plywood 2 1/2" long, which formed a base for the hinge and brass strips. (See figures 1, 2, and 4.)

The flat gray interior was illuminated by a 7-watt bulb which was situated at the end of the box opposite to the guillotine door and was covered by a piece of opal-flashed glass.

Entrance to the box from the top was gained through a 10 3/4" hinged door, in the center of which was placed a large clear-glass, observation window.

Activity level was measured by a device consisting of a GE 2-36KR1 mercury switch, suspended vertically beneath the false floor and connected in series to a Gorrell and Gorrell 115 volt electric counter. The mercury switch was situated beneath the floor in such a manner that movement by the animal caused the liquid in the tube to move, momentarily making and breaking the circuit in accordance with the strength and number of movements. (See figure 1.)

A thin metal rod, hinged at the top of the panel was twisted so as to extend to the back of the panel in one direction and to the top of the box in the other. The rod was so designed that the lower half of it "rode" back on the panel as it was pushed open, and the upper half came forward toward the activity chamber. By means of this rod, the force applied to the door was transmitted to a slender stick of wood which was attached to a light, plastic wheel, mounted on a plastic axle. The force of the response, which was applied to the door, was thus transmitted into the movement of the wheel. The distance which this wheel moved was measured in degrees. Because the wheel offered very little resistance to the metal rod, the initial movement of the push-panel invariably caused it to turn out of range of further movements of the metal rod. That is, the degrees which the wheel was displaced depended upon the <u>force</u> with which the door was <u>first</u> struck, and not merely upon the distance through which the door was moved.

Response latency was measured by a Standard Electric Timer, connected in series through two switches. The first switch consisted of two brass strips, one being placed along the top of the push-panel, and

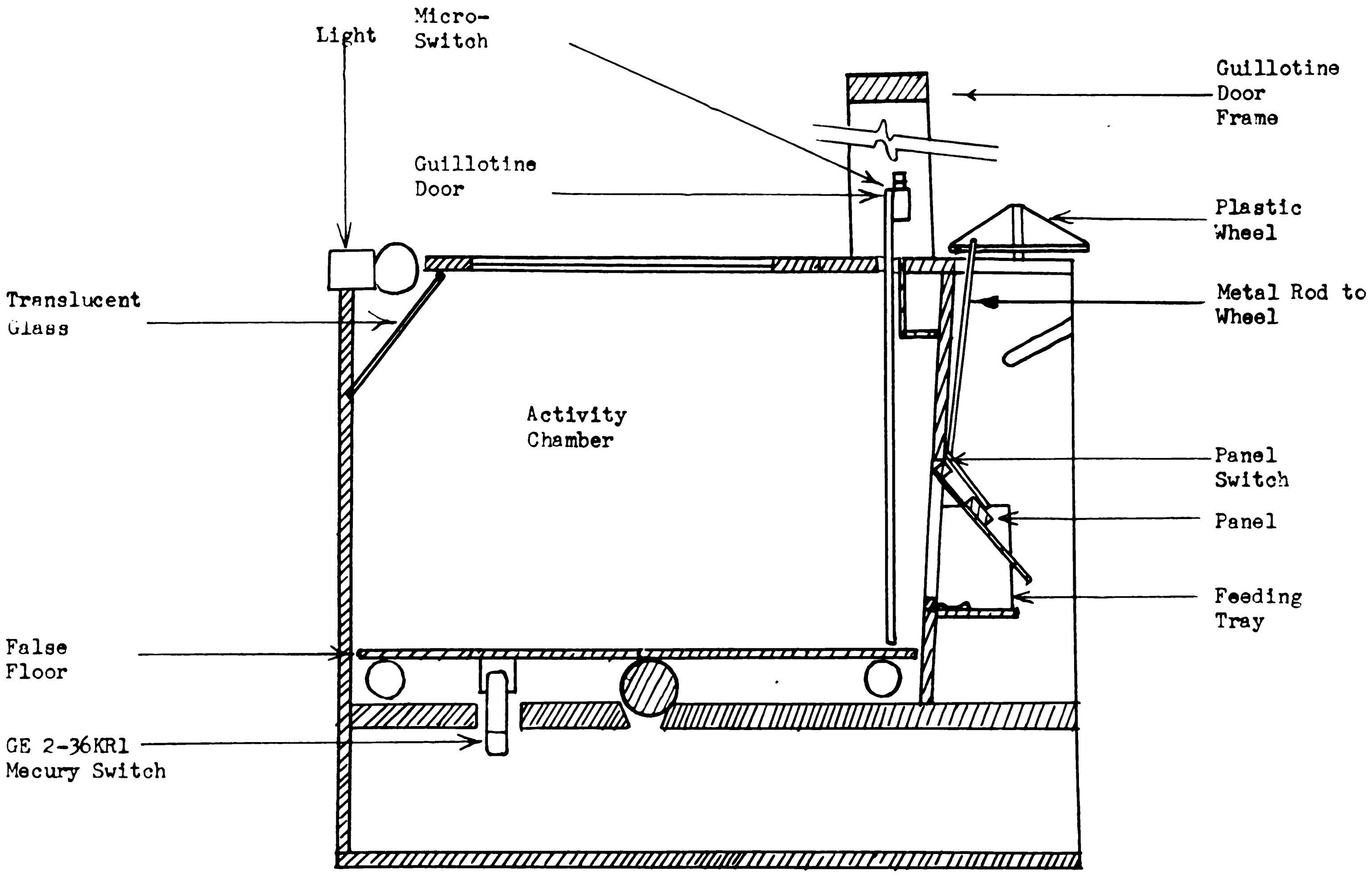

FIGURE 1. CROSS-SECTIONAL DRAWING OF APPARATUS DISCUSSED IN TEXT

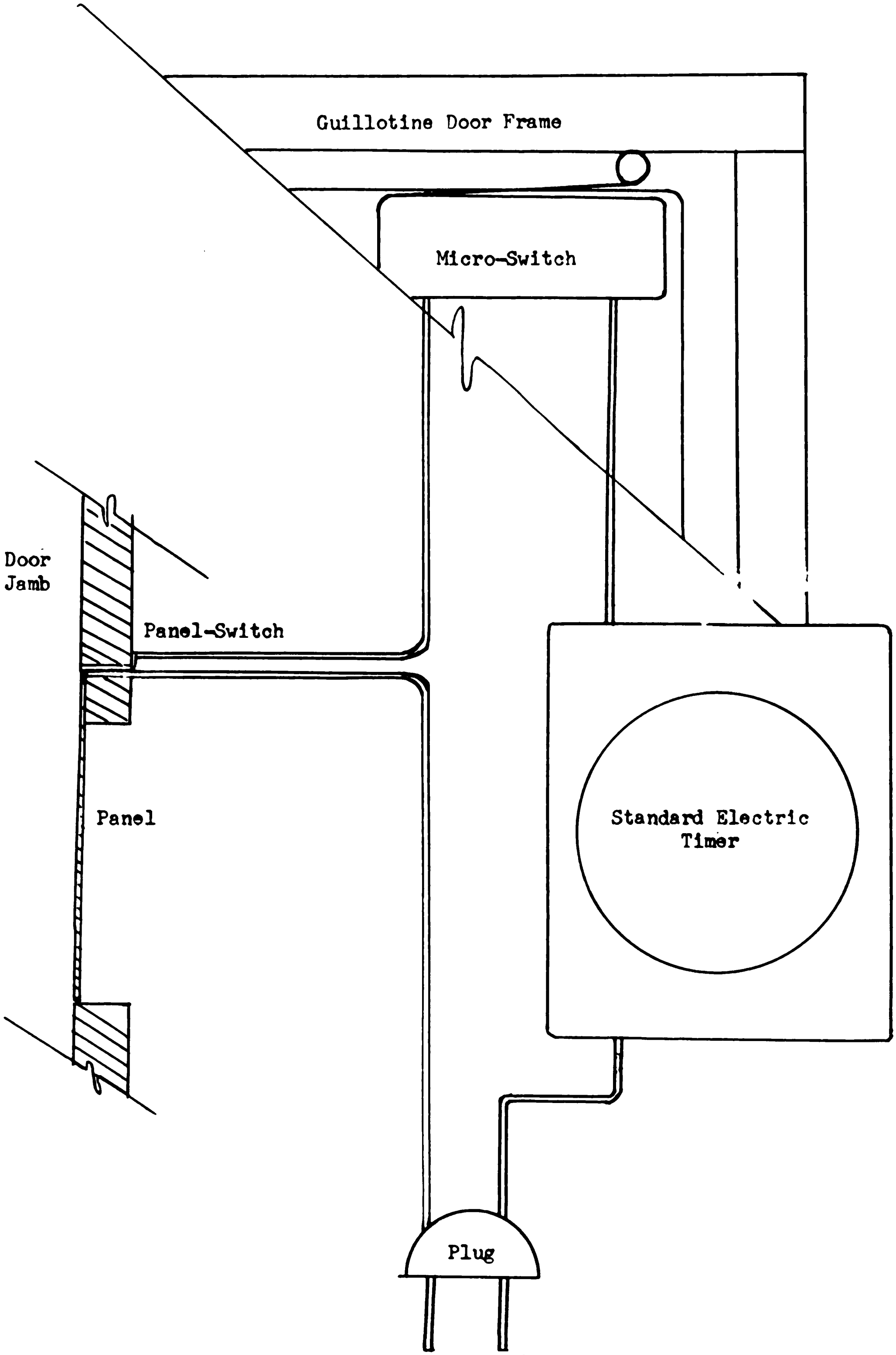

FIGURE 2. SKETCH ILLUSTRATING THE WIRING OF TIMER TO GUILLOTINE DOOR AND PUSH-PANEL

the other being attached to the upper push-panel jamb, directly above the strip on the push-panel. A second switch was attached to the top of the guillotine door. When the guillotine door was raised, this switch was closed. Thus, when the push-panel was closed and the guillotine door open, the circuit was closed. When the panel was opened by approximately 1/32", the switch was opened. This is illustrated in figure 2. Thus the timer started when the guillotine door was raised and stopped as the panel was being pushed open by an animal.

Single reward pellets were placed on a tray which was located approximately one quarter of an inch below the lower panel jamb. Metal walls were built up on either side of this tray to discourage exploratory behavior. The corners of these walls were bent towards the door, forming stops to prevent the animals from forcing the door and breaking it. This also reduced exploratory behavior. On the tray itself a small wall of solder was constructed to hold the food pellets in place. These construction details are illustrated in figures 3 and 4.

Water reward was administered through a curved tube supplied by a standard water bottle which was retractable. This is illustrated in figure 4. The water bottle was mounted on a rectangular piece of wood which was attached to a length of 1/2" dowelling. The dowel was inserted in slots, which were cut in both sides of the box behind the push-panel. When the dowel was rotated, the attached bottle also turned. Water reward could thus be presented or retracted by the experimenter.

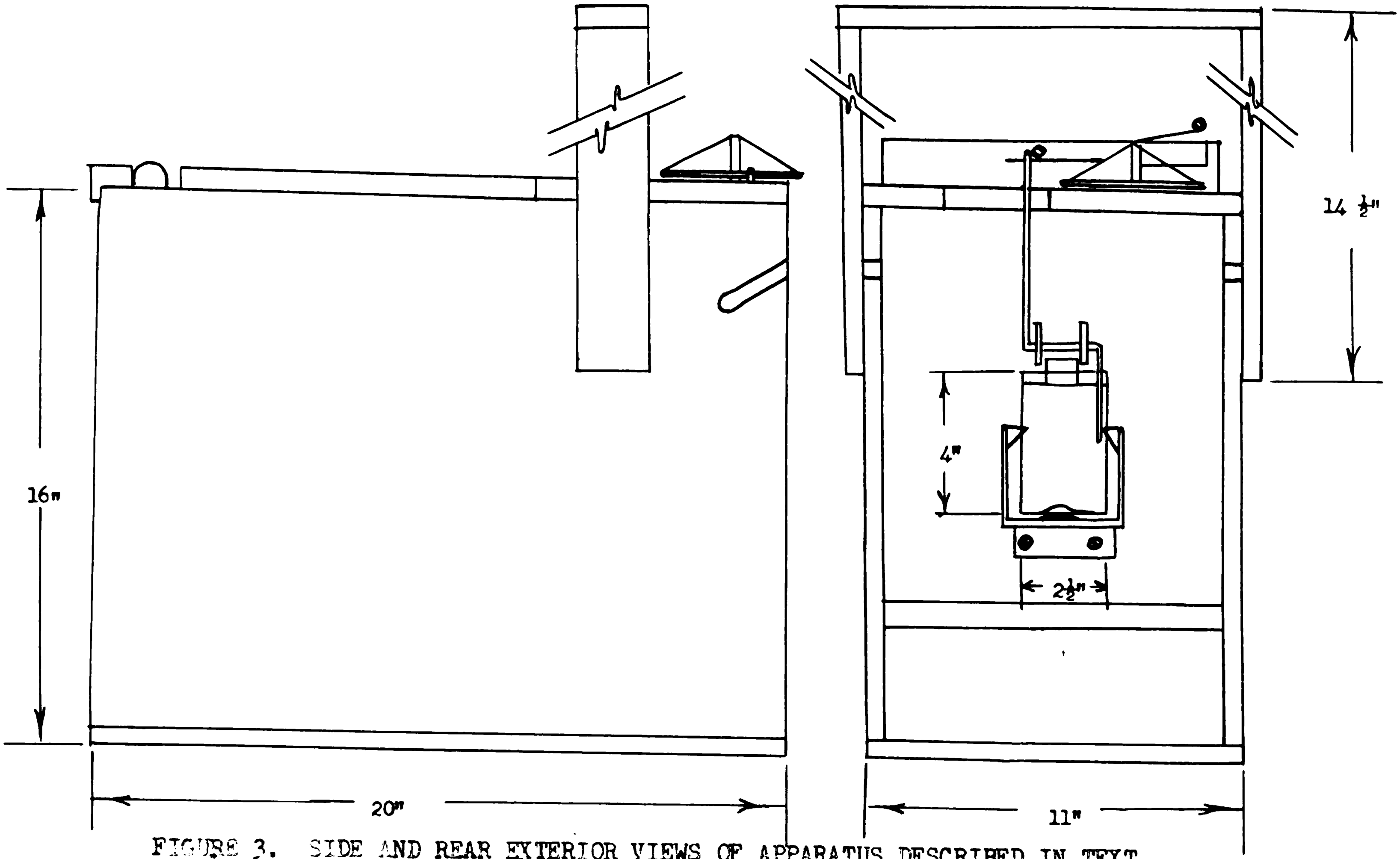

FIGURE 3. SIDE AND REAR EXTERIOR VIEWS OF APPARATUS DESCRIBED IN TEXT, SHOWING PARTICULARLY PUSH-PANEL, METAL ROD, PLASTIC WHEEL, AND FEEDING TRAY

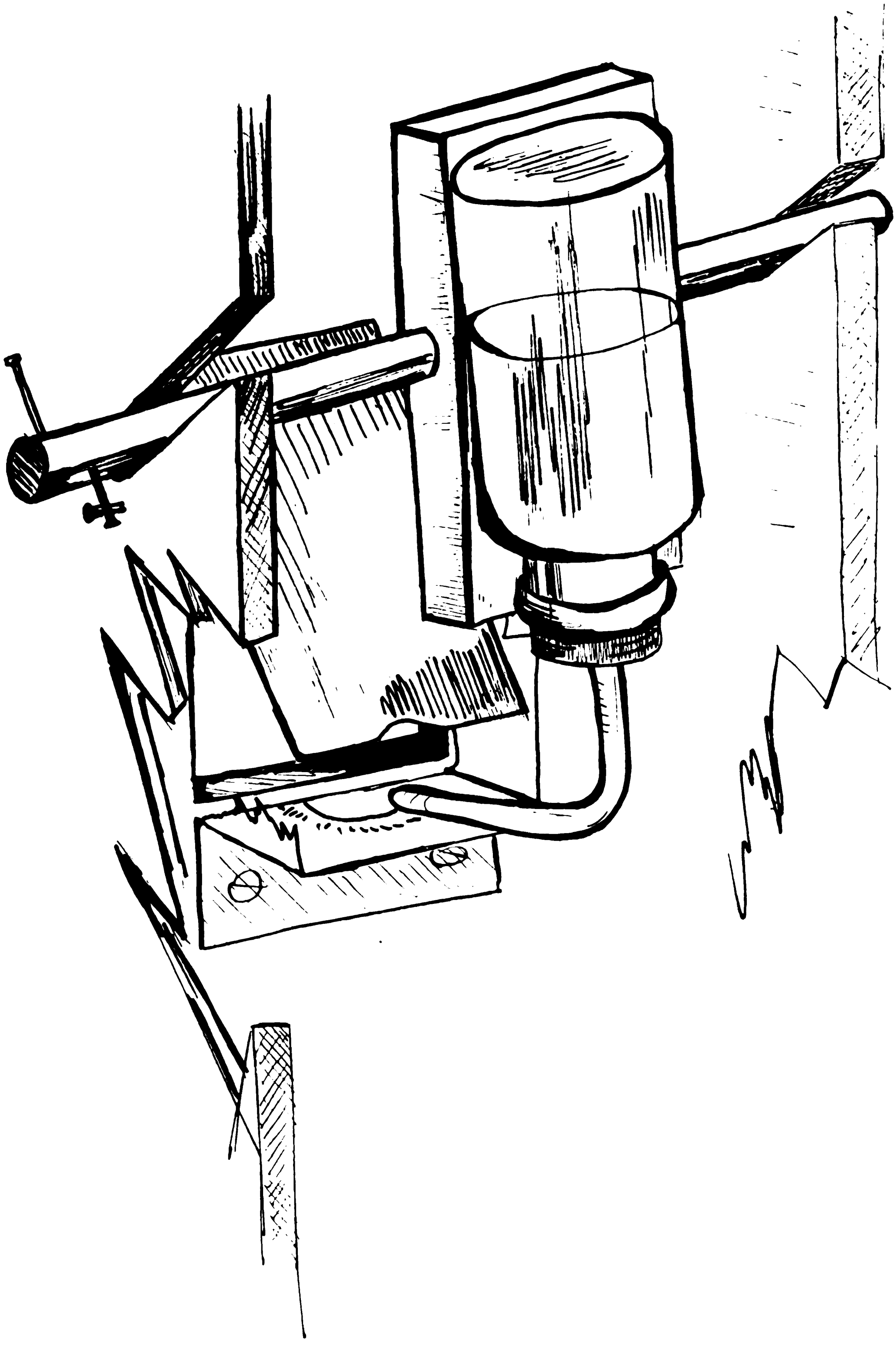

FIGURE 4. SKETCH OF WATERING DEVICE MOUNTED BEHIND PUSH-PANEL

IV. PROCEDURE

A. HANDLING

All animals were handled for three minutes a day for three days prior to the pretraining phase of the experiment. After handling, animals were placed on a large flat surfaced table and allowed to explore for a period of 30 minutes. During this entire three-day period, food and water were available at all times in the home cage.

B. HABITUATION

Animals in the present study may be conveniently divided into two major groups: (1) a thirst group (N=12) and (2) a hunger group (N-24). Each day for five days, animals from both groups were placed individually in the activity chamber of the drive level box for a six-minute period and their activity was recorded. Following this six-minute activity period, animals were placed in individual feeding cages where the relevant reward was made available after a delay of six minutes. In the case of hungry animals, this reward consisted of pellets of the same composition as those later used as reward pellets.

For the first three habituation days, animals remained in the individual cages for 30 minutes following the introduction of the food and water and were then returned to the home cage where 14 grams of food per animals and water were available. On the fourth and fifth habituation days, hungry animals were placed in the individual feeding cages

where—after a six-minute delay—their standard reward pellets were made available for a period of 15 minutes. These were followed by a wet mash, composed of 60% water and 40% ground Purina dog chow by weight. This mash was made available for an additional 15 minutes. Once or twice during this period, the mash was removed from the individual feeding cage and stirred. Following this, these animals were returned to their home cage where water was available for the next 24 hours but not food. In the case of hungry animals, this procedure insured against building up a large residual drive.

On the fourth and fifth habituation days, thirsty animals were placed in the individual feeding cages with Purina pellets immediately available, and water was made available after six minutes. These animals remained in the individual feeding cages for a period of 45 minutes and were then returned to their home cage where food was available for the next 24 hours, but no water.

Both hungry and thirsty animals were thus under a 24 hours relevant drive when introduced into the activity chamber on the fifth day of habituation.

C. TRAINING

For a three-day period, animals were trained to open the push-panel. Once per day, each of the anomals was placed individually in the activity chamber for a period of six minutes. At the close of this six-minute period, the activity level was recorded, the guillotine door was raised, and the push-panel was presented. This was done on each of the three training days in accordance with the following schedule:

Day 1: Door fully open for eight trials; door open 1/4" for two trials.

Day 2: Door fully open for two trials; door open 1/4" for eight trials.

Day 3: Door open 1/4" for two trials; door fully closed for eight trials.

Hungry animals were presented on each of these trials with reward pellets of a medium size (.20 gm.).[2] Thirsty animals were given access to the drinking tube (See figure 4) and allowed to drink for five seconds per trial.

Deprivation conditions for both groups were set up in the same way as on days four and five of the habituation period. That is, all animals were trained under a deprivation level of 24 hours. At the close of the third day's training, animals were placed in the individual feeding cages and treated as outlined above. Hungry animals were fed pellets for 15 minutes and mash for an additional 15 minutes. Thirsty animals were given access to food and water for 45 minutes.

D. TEST PERIOD

It was desirable that all animals be tested under high and low drive levels. Furthermore, these levels were to be roughly comparable for hungry and thirsty animals. It was also desirable to arrange the study so that low drive animals would be sufficiently motivated to respond to the door for the full number of test trials each day. The number of test trials was set at 10 per day for four test days. Each

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[2] Large pellets in the present study weighed .32 gm., and small pellets weighed .08 gm.

animal was given a total of 40 test responses, 20 successive trials at a low drive level, and 20 successive trials at a high drive level. Animals were counterbalanced in terms of the position of the blocks of twenty high and low drive trials. Half of the animals were tested under high drive first and then shifted to a low drive, and half of the animals were tested under a low drive first and then shifted to a high drive.

In order to insure that animals operating under a low drive would respond for the full ten trials, it was necessary to empirically determine the minimum length of time which must elapse following satiation before animals would make the necessary 10 test responses consistently. This value was determined to be five hours in the case of water deprivation and eight hours in the case of food deprivation. While many studies have apparently demonstrated that animals will respond under fewer hours of deprivation than those used in the present study, none of these studies have employed as strict a criterion of performance as was required in this experiment. Furthermore, the animals in the present study were under no residual drive and all measures are from *complete* satiation. It is interesting to note that, though some animals responded once or twice to the push-panel at drive levels below those employed, the problem consisted in finding a level which, while of a relatively low value, was still one at which all animals would consistently respond. Even at the relatively high number of hours of deprivation for "low" drive employed in the present study (8 hours hunger; and 5 hours thirst), two hungry animals, which were begun on the low drive, failed to complete all 10 responses on one of their two low drive days.

A further difficulty in the present study was the inevitable resistance offered by the push-panel. This resistance resulted from the attached device for measuring amplitude and may have tended to inhibit responses when the drive level was at a low value.

The 24 hungry animals were divided in two major groups, which were further subdivided for the purpose of counterbalancing.

(1) Lg (H-L): Animals in this group received one large pellet (.32 gms.) on each of the 40 test trials. On the first two test days (20 trials) these animals were tested under a high drive and on the last two test days these animals were tested under a low drive.

(2) Lg (L-H): As in the case of the above group, this group received one large pellet for all forty trials, but drive conditions were reversed, and animals were initially run under a low drive.

(3) Sm (H-L): This group was treated exactly like the Lg (H-L) group except that on all 40 test trials, these animals received a small pellet of food (.08 gms.).

(4) Sm (L-H): This group was treated exactly like the Lg (H-L) group except that on all 40 test trials these animals received a small pellet of food.

The 12 thirsty animals were given only one level of reinforcement but were split into two sub-groups for the purpose of counterbalancing.

(5) Md (H-L): This group received a reward of five seconds drinking time per trial on each of the 40 test trials. On the first two test days (20 trials) these animals were tested under a high drive and then switched to a low drive.

(6) Md (L-H): This group was treated exactly like the Md (H-L) except that deprivation levels were reversed.

All animals were run only once a day for 10 trials between the hours of 8 P. M. and 1 A. M.

Deprivation scheduling for hungry animals in a L-H group is illustrated in table 1, and deprivation scheduling for thirsty animals in a H-L group is illustrated in table 2.

E. EXTINCTION

For the purpose of extinction, all major groups were subdivided equally into two sub-groups, and the animals were extinguished under either or high or a low drive. For example, three of the animals in the Lg (H-L) group were extinguished to a three minute no response criterion under 48 hours of deprivation and three were extinguished to a three minute no response criterion under 8 hours of deprivation. Six minute activity levels were recorded before the extinction series was begun. The latency and amplitude of every trial was recorded. In some cases the activity was taken at two minute intervals throughout extinction. An error in assignment caused four of six animals in the Lg (H-L) group to be extinguished at 48 hours rather than three of six. In order to equalize the number of animals extinguished at 8 as compared with 48 hours, it was necessary to extinguish four of the six animals in the Sm (L-H) group at 8 hours.

During the entire process of running animals, it was the practice to assign animals randomly to groups. Systematic error was avoided to an even greater extent by running animals from the various groups simultaneously.

TABLE 1

DEPRIVATION SCHEDULE FOR HUNGRY ANIMALS IN A L-H GROUP

Condition	Day of Study	Number of Trials	Feeding Regimen
Training: 24 hrs. Drive	First Second Third	10 10 10	Fed to satiation 6 minutes after being trained.
Test:			
Low Drive (8 hrs.)	Fourth Fifth	10 10	Fed to satiation every running day 8 hrs. before testing and 6 minutes after testing.
High Drive (48 hrs.)	Seventh Ninth	10 10	Fed to satiation every running day 6 minutes after test trials.
Extinction			
8 or	Tenth or	Variable	Fed to satiation 8 hrs. before running.
48 hrs. drive	Eleventh		Fed 6 minutes after last run and extinguished 48 hrs. later.

TABLE 2

DEPRIVATION SCHEDULE FOR THIRSTY ANIMALS IN A H-L GROUP

Condition	Day of Study	Number of Trials	Feeding Regimen
Training: 24 hrs. Drive	First Second Third	10 10 10	Fed and watered to satiation 6 minutes after every day's training trial.
Test:			
High Drive (36 hrs.)	Fifth Seventh	10 10	Fed and watered to satiation 6 minutes after every running day and fed and watered to satiation at noon on days four and six and run 36 hrs. later.
Low Drive (5 hrs.)	Eighth Ninth	10 10	Fed and watered to satiation six minutes after test on days 8 and 9 and 5 hrs. before on these same days.
Extinction			
High (36) or Low (5)	Eleventh or Tenth	Variable	As above.

V. RESULTS

A. THE EFFECT OF DIFFERENTIAL REWARD ON PERFORMANCE

1. Latency. Table 4 summarizes the latencies for all 36 animals. Each block represents the performance of six different animals over a series of twenty trials. It can be observed that the values range from a total of 196.1 seconds for thirsty animals, which were begun under a high drive and shifted to a low drive, to 1068.2 seconds for thirsty animals which were begun under a low drive and then shifted to a high drive. The largest total difference is between the 12 animals which were run to a large food reward and the 12 animals which were run to a water reward. While the general trend of the data for animals rewarded with food is in accordance with our theoretical anticipations, that is, small reward animals exhibited considerably longer latencies than large reward animals, it was necessary to test the significance of this difference. Likewise, one of the major aims in undertaking the present study was to discover a quantity food reward which very nearly equalled a water reward of a fixed value. The differences between these total latencies were tested to determine which—if either—of our food rewards is not statistically different from the water reward.

The most obvious statistical tool to apply in the present problem was an analysis of variance. One of the basic assumptions in the use

of analysis of variance, however, is that the measures are independent.[3] An inspection of table 3 reveals that the individual measures in this experimental design did not comply with the assumption of independence.

The design, however, may be rearranged in such a way as to compare the totals for any given subject or group of subjects, and this results in a simple factorial design of the form illustrated in table 5. Since the subjects are randomly assigned to groups and measured independently of one another, their sums may be compared without violating the assumption of independence. Table 5 illustrates the comparisons which may be made legitimately when the influence of trials and drives is neglected.

The results of the analysis of variance applied to this design are summarized in table 6.

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[3] A second assumption involved in such an analysis is that the variance is homogenous. Bartlett's test of homogeniety of variance was applied and an uncorrected X^2 of 7.829 was obtained.

TABLE 3

DESIGN OF THE EXPERIMENT

		High Drive	Low Drive
		Trials	
	Subjects		
Large Food	1	1.............. 20	21.............. 40
	2		
	H-L3		
	4		
	5		
	6		
	7	21.............. 40	1.............. 20
	8		
	L-H9		
	10		
	11		
	12		
Small Food	13	1.............. 20	21.............. 40
	14		
	H-L15		
	16		
	17		
	18		
	19	21.............. 40	1.............. 20
	20		
	L-H21		
	22		
	23		
	24		
Water	25	1.............. 20	21.............. 40
	26		
	H-L27		
	28		
	29		
	30		
	31	21.............. 40	1.............. 20
	32		
	L-H33		
	34		
	35		
	36		

TABLE 4

SUMS OF INDIVIDUAL LATENCY MEASURES FOR ALL GROUPS

		High Drive	Low Drive	
Large Food	H-L	318.8	313.6	1344.90
	L-H	301.4	411.1	
Small Food	H-L	306.5	203.8	1607.4
	L-H	209.9	887.2	
Water	H-L	196.1	298.6	1795.5
	L-H	232.6	1068.2	
		1565.3	3182.5	Totals

TABLE 5

ARRANGEMENT OF EXPERIMENTAL DESIGN TO COMPLY WITH THE ASSUMPTION OF INDEPENDENCE OF LATENCY SCORES

	High to Low	Low to High
Large Food	= 632.4 = 6	= 712.5 = 6
Small Food	= 510.3 = 6	= 1097.1 = 6
Water	= 494.7 = 6	= 1300.8 = 6

TABLE 6

ANALYSIS OF VARIANCE OF LATENCY SCORES OF THREE GROUPS OF SUBJECTS TESTED UNDER DIFFERENT QUANTITIES AND TYPES OF REWARD

	SS	df	MS	F	P
Total Between Subjects	4978.99	35	142.26	1.59	
Groups	2298.10	5	459.62	5.14	.01
Procedure	1506.75	1	1506.75	16.86	.01
Size	213.41	2	106.70	1.19	
P X S	577.94	2	288.97	3.23	
Same Groups (Residual)	2680.89	30	89.36		

Two of these variances are significant at the .01 level of confidence: Procedure and Groups. This may be interpreted to mean that, regardless of the size or type of reward, animals begun under the high drive and then shifted to the low were significantly faster than those begun under the low drive and then shifted to the high. Despite the relatively large difference existing between animals rewarded with water and animals rewarded with a large food pellet, this difference did not prove to be statistically significant.

With reference to the difference between the individual groups, it is of interest to ask between which of any two of the groups in table 5 is the difference great enough to warrant the conclusion that they are significantly different from one another. Applying the formula

$$\text{diff } (M_1 - M_2) = \quad 2N \, (\text{Error}) \, t_{1,c}$$

to our data, it can be shown that a difference of 534 seconds between any two groups is necessary to reject the null hypothesis at the .01 level of confidence. Such a difference can be found only between animals rewarded with a large pellet in the low to high drive group and those rewarded with water in the low to high drive group.

2. *Amplitude*. Corresponding to each latency measure, there is a measure of amplitude. Thus we have two parallel problems, one concerned with amplitude and the other with latency. Everything relative to experimental design, which has been said thus far in relation to latency, applies to amplitude. Table 7 summarizes the results, and the analysis of variance for this parallel problem is given in table 8.

It will be noted that none of the observed differences is significant beyond the .05 level of confidence. The large difference between animals rewarded with water and those rewarded with food is, however, noteworthy.

Water reward animals appear to apply a stronger pressure to the push-panel than do the other animals. This may be the result of an artifact in the design of the apparatus or it may represent a true difference between the subjects which were tested.

Two considerations may help the reader to arrive at a conclusion relative to this problem.

Figure 4 illustrates the method whereby water reward was administered. From this drawing, it can be seen that the tip of the fired end of the watering tube was, in the case of water-rewarded animals, immediately over the point at which hungry animals found their food reward pellets. The push-panel, in other words, had to be opened in either case approximately the same distance, and it would therefore seem that the initial pressure applied was not controlled by a difference in the spatial point at which the two types of reward were found.

A second way, which might be suggested to account for the difference between animals is in terms of the manner in which reward was administered. While hungry animals obtained their pellets and retreated to eat them, thirsty animals had to hold the push-panel open while drinking. During this time in which thirsty animals held the push-panel open, the push-panel obviously did not remain perfectly stationary. It might be claimed justifiably that thirsty animals in holding the push-panel open caused the amplitude indicator to move forward. The peculiar arrangement of

the amplitude measuring device makes this seem unlikely, for once an animal had struck the door, the projecting thin wooden spoke on the plastic wheel invariably swung out of range of further movement of the metal rod attached to the push-panel.

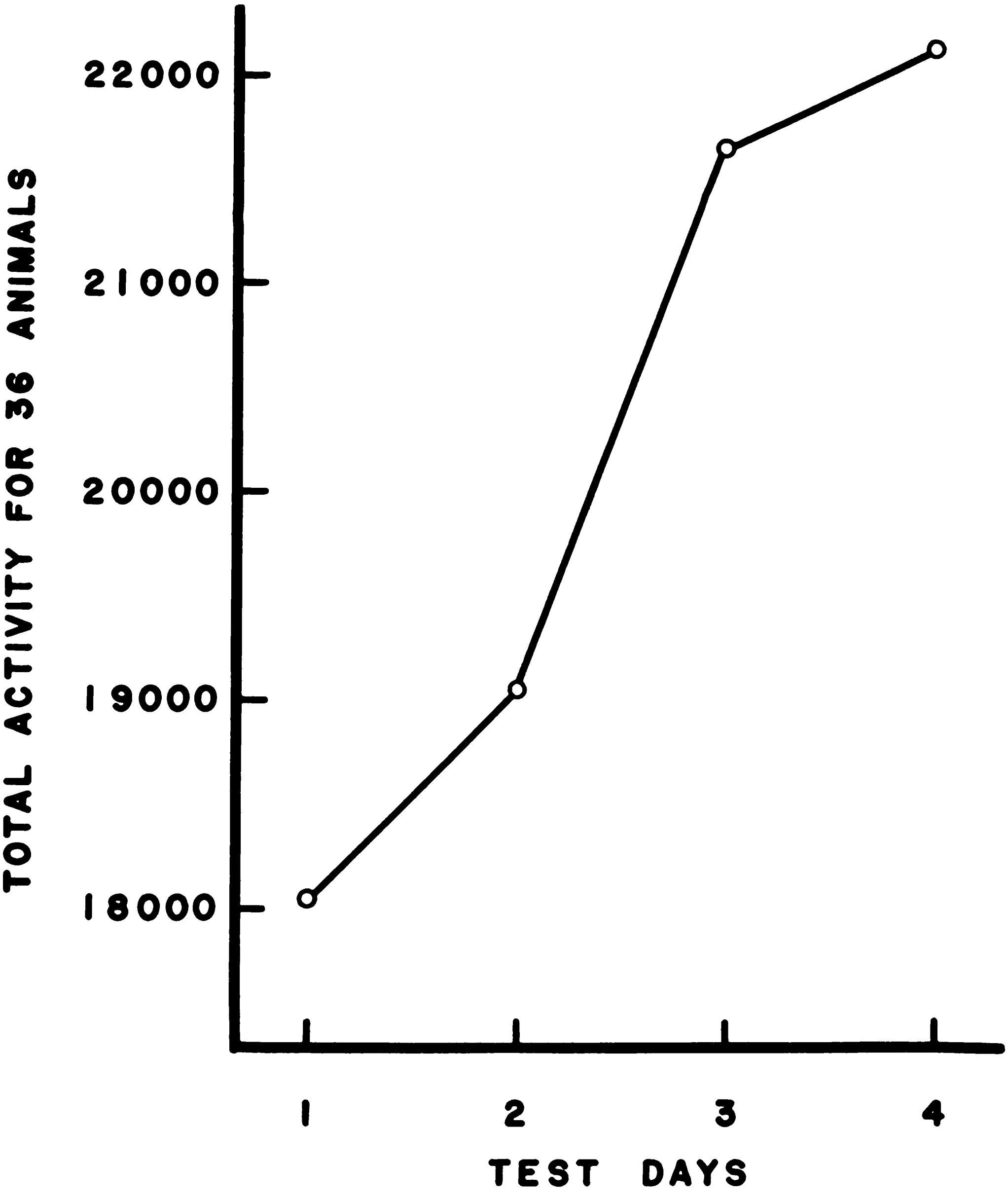

FIGURE 5. ILLUSTRATES THE STEADY RISE OF ACTIVITY LEVEL FOR ALL ANIMALS OVER THE FOUR TEST DAYS

TABLE 7

ARRANGEMENT OF EXPERIMENTAL DESIGN TO COMPLY WITH THE ASSUMPTION OF INDEPENDENCE OF AMPLITUDE SCORES

	High to Low	Low to High	Total
Large Food	6848	7448	14,296
Small Food	8031	9476	17,507
Water	16051	9382	25,433
	30,930	26,346	57,236

TABLE 8

ANALYSIS OF VARIANCE OF AMPLITUDE SCORES OF THREE GROUPS OF SUBJECTS TESTED UNDER DIFFERENT QUANTITIES AND TYPES OF REWARD

	SS	df	MS	F	P
Total Between Subjects	636,147.05	35	18,175.6	1.36	
Groups	234,675.5	5	46,935.1	3.51	.05
Procedure	17,773.4	1	17,773.4	1.33	
Size	136,919.98	2	68,459.9	5.12	.05
P X S	79,982.2	2	39,991.1	3.00	
Same Groups (Residual)	401,471.6	30	13,382.4		

B. THE EFFECT OF DIFFERENTIAL DEPRIVATION ON PERFORMANCE

1. *Latency*. According to the analysis set forth above, procedure contributed significantly to the variance observed in the present study. This may be interpreted to mean that a difference existed between those animals which began the test series under the high drive level and those which began the test series under the low drive level. Consequently, to test the effect of differential deprivation on response latency, it was necessary to compute two separate t's. One of these compared high drive and low drive animals which had begun their test series with the indicated drive, and the other t compared high and low drive animals which had completed their test series with the indicated drive. Thus, the difference between those animals begun under high and those begun under low were tested separately from those which completed their test series under high or under low.

The mean latency for the first 20 trials of 18 animals begun under the low drive level was 131.47. The mean latency for the first 20 trials of the 18 animals begun under the high drive was 45.63. A t calculated from this data was found to be equal to 6.77, which is significant at well beyond the .01 level of confidence.

The mean latency for the last twenty trials of the 18 animals which completed their test series under the high drive was 41.33 seconds. The mean latency for the last twenty trials of the 18 animals which completed their test series under the low drive was 45.32. This difference yields a t of .48 which is not significant.

2. Amplitude. An analagous circumstance to that reported for latency scores exists in the case of amplitude. A comparison made between amplitudes for high drive and low drive animals, which began their test series under these levels, revealed a mean difference of 230.83 degrees. The mean difference in amplitude scores between the high or low drive level on the terminal 20 trial test series was only 7.17.[4]

The largest of these two differences was tested by a t. This resulted in a standard error of 154.7 and a t of 1.49, which is not significant.

Since the distributions of amplitudes for initial and terminal test series are of approximately the same form, there is no doubt but what the smaller difference (7.17) would be far less significant than the larger (230.83), and a t test for this difference was, therefore, not computed.

C. ACTIVITY LEVEL AND PERFORMANCE

1. Increase of activity level per experimental day. With reference to activity level, a number of interesting comparisons may be made.

Figure 5 illustrates the fact that throughout the experiment there is a consistent trend towards an increase in activity levels, regardless of drive level. This curve is based on the total activity for each of the four experimental days. Since high and low drives contributed equally to the total activity on each of these four days, the effect of differential drive is to a large extent counterbalanced out.

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[4] This mean score is based on the sum of the amplitudes for each of the 18 animals contributing to that score. The amplitudes thus summed are the result of each animal's performance on a series of 20 trials.

2. Activity and the type of deprivation. Table 9 compares the mean activities for animals, which were run under hunger drives as compared with animals run under thirst drives. For convenience, comparisons were made between matched blocks of 12 animals. By this means, each of the 12 animals run under water deprivation could be matched with a corresponding animal run under food deprivation and a t test applied to the data. Because the thirst group consisted of 12 animals as compared with 24 animals in the hunger groups, it was necessary to match every thirsty animal with two different hungry animals. It is these data which are summarized in table 9.

To test the degree to which activity levels for hungry and thirsty animals were matched, it would be necessary to derive four separate t's from the data. If no significant differences existed, one could reasonably assert that type and length of deprivation were matched in terms of activity levels.

High and low drives for food and water deprivation in the present study were empirically "guessed at." Ideally, to test the effect of reward on performance these should have been perfectly matched. The application of a t test to the activity levels of hungry vs. thirsty animals is one of the ways in which the degree of the match can be estimated. The largest difference was found between one of the groups of hungry animals run under high drive and its control thrist group. The difference 50.0 yielded a t of .38, which is, of course, without significance.

TABLE 9

ACTIVITY LEVELS FOR HUNGRY AND THIRSTY ANIMALS COMPARED IN TERMS OF REINFORCEMENT AND HOURS OF DEPRIVATION

	Quantity Reinforcement	Hunger	Quantity Reinforcement	Thirst
High Drive	.32 gms.	628.5	.2 cc	(578.5 (
	.08 gms.	580.9		(578.5
Low Drive	.32 gms.	534.2	.2 cc	(493.3 (
	.08 gms.	496.2		(493.3

3. Activity and the Period of Deprivation. Animals in the present study were run under two values of drive. These have been called for convenience, high drive and low drive. It is assumed, here, that period of deprivation is directly related to the strength of drive. It is further assumed that activity level reflects the strength of drive which results from deprivation. One test of this is to compare the activity levels of the so-called high drive (long deprivation) animals with the low drive (short deprivation) animals, neglecting the type or amount of reward administered. Since all animals were run under both levels and counterbalanced, this may be done by employing a matched t. The two activity measures taken at low drive were summed, and the two activity measures taken at high drive were summed. A matched t, based on the difference between the means of 197.93, gives a t of 3.43, which is significant at beyond the .01 level of confidence. This indicates that high drive (long deprivation) animals give significantly higher activity level scores than do low drive or short deprivation animals.

4. Activity and Latency. It is interesting to compare latency and activity level in an effort to estimate the degree to which activity alone will predict the behavior of an animal. Figure 6, which is self-explanatory, illustrates the general trend of the data. The values on this graph were obtained by lumping all of the animals together, regardless of deprivation period, and considering them only in terms of activity level and latency. The animals were grouped by activity counts. Each 100 counts separated a new group. The N of each group varied, of course, and the latency for any given activity group was considered to be the mean of that group. It will be noted from the graph that the activity groups, which are based on

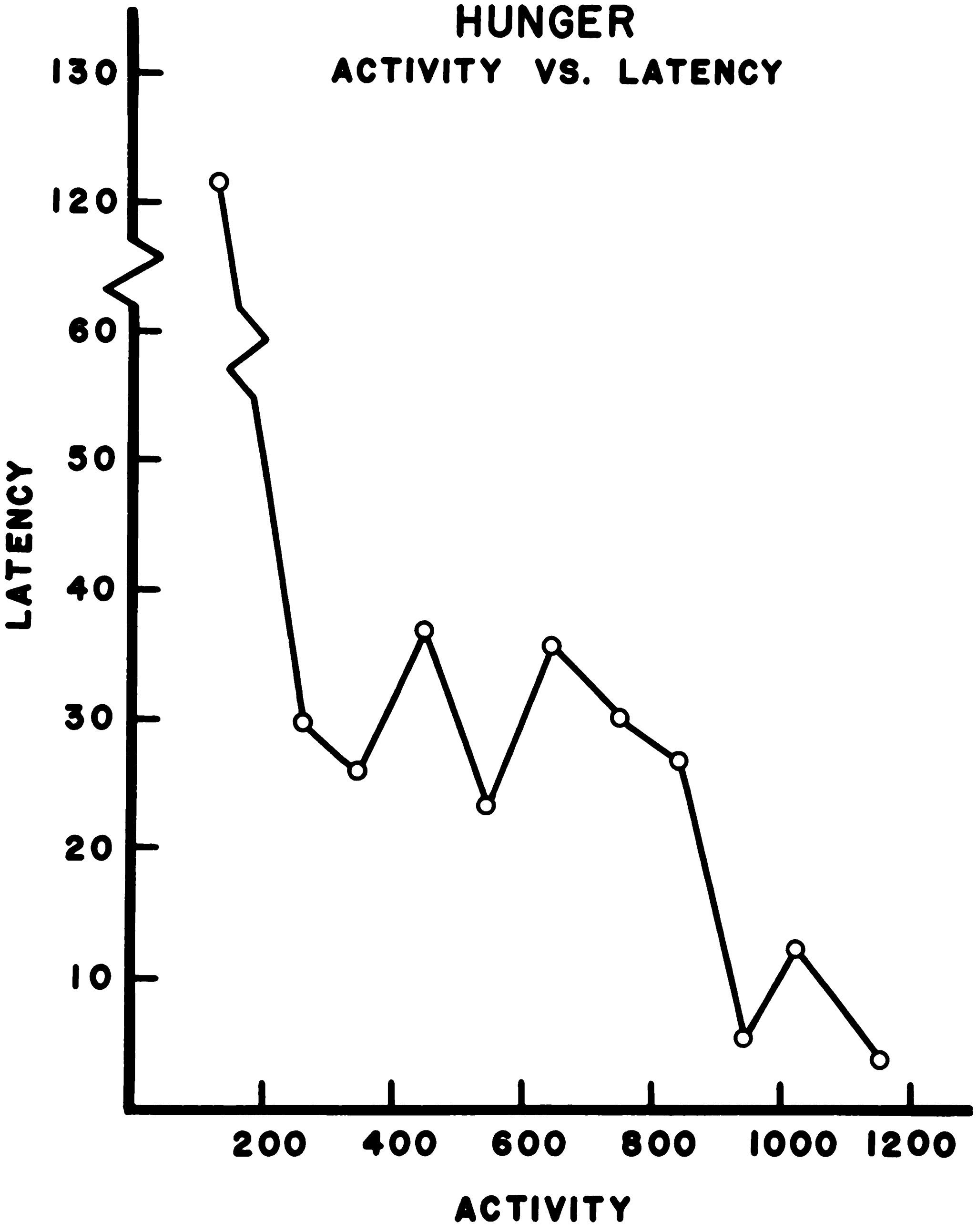

FIGURE 6. ILLUSTRATES THE DECLINE OF LATENCY WITH INCREASED ACTIVITY

small Ns, tend to conform to the notion that more active animals will respond faster than less active animals, whereas prediction breaks down in the middle of the activity range. Pearsonian rs were computed on the latency vs. activity data for high drive and low drive animals. An r of -.236 was obtained for high drive animals, and an r of -.428 was obtained for low drive animals. Homogeneity of variance was checked between these two groups and an x^2 equal to 1.48 which was obtained is not significant. Having established the fact that the samples were drawn from a common population, an estimate was obtained of the combined r. This equaled -.314, which when tested against the null hypothesis is significant at beyond the .01 level of confidence.

A second test of the prediction value of activity levels was also undertaken. Two frequency distributions of latencies were established. One of these was for the scores of animals under long deprivation and the other was for the scores of animals under the short deprivation period. A median activity level was established for both distributions. For the short deprivation period, this median activity was 1000, and for the long deprivation period this median activity level was 1142.86. In each case, scores exceeding the median of their distributions were called "high drive" scores (regardless of type or amount of deprivation) and scores falling below this median were called "low drive" scores, again regardless of type or amount of deprivation. For long and short deprivation periods, latency scores were thus dichotomized and could be tested with a matched t.

In the case of low drive or short deprivation scores, there was a difference between the high activity and low activity animals of 27.22. This difference, when tested, yielded a t for related measures of 1.15 which was not significant. The difference in the case of high drive or long deprivation scores amounted to only 5.34, and in view of the similarity of the distribution of the data in this case and that just reported, it seemed unnecessary to statistically test the difference.

D. EXTINCTION

1. Number of Responses to Extinction. Each of the six major groups of animals was equally divided. One half of the animals in each group was extinguished under the low drive. A simple analysis of variance was used to test the difference between these two populations. The resulting design is given in table 10.

Since the within group mean square exceeds the between group mean square, there is no significant difference between animals extinguished under a high drive and animals extinguished under a low drive.

The number of degrees of freedom, it will be noted, is 32 rather than 35. This results from the fact that three animals were eliminated from consideration. These animals were extinguished, by error, to a criterion of two, rather than three minutes. One of these animals was from the low deprivation group and two were from the high deprivation group.

Although the difference was not significant a mean difference existed between the groups of 7.9 responses. The high drive animals required a mean of 40.2 responses to extinction, whereas the low drive animals required a mean of 32.3 responses.

TABLE 10

ANALYSIS OF VARIANCE DESIGN TO TEST THE DIFFERENCE IN NUMBER OF RESPONSES TO EXTINCTION BETWEEN ANIMALS EXTINGUISHED UNDER HIGH DRIVE AND THOSE EXTINGUISHED UNDER LOW DRIVE

Source	S.S.	df	M.S.
Between	335.09	1	335.09
Within	16,285.28	31	525.33
Total	16,620.37	32	------

2. First Six Trials: Latency. The minimum number of trials, which any animal required to complete extinction, was six. Comparisons of the latencies on the first six extinction trials for all thirty-six animals were made and the results are shown in figures 7, 8, 9, and 10.

Figure 7 plots the sum of the latencies for all 18 animals run under each of the two drive levels. Figure 8 is a similar graph based, however, on the median latency for all 18 animals run on each of the two drive levels.

Both groups show an initial drop in response time and a gradual increase in latency thereafter.

3. First Six Trials: Amplitude. A similar analysis of the extinction data may be made in the case of amplitude. In figure 9, the total amplitude of the response of the 18 animals extinguished under high drive and the 18 animals extinguished under low drive are plotted.

High drive animals show a sharp increase in amplitude on trial two and then a gradual decline.

Figure 10 is a graph plotted with the same data but based on the median latency for the 18 animals in each of the two drive conditions.

Because medians are not influenced by marked shifts in data, the graphs plotted using the medians—rather than those based on sums—is probably the most satisfactory for indicateing the general trend of the data.

In general, the curves for high and low drives parallel one another both in the case of latency and amplitude.

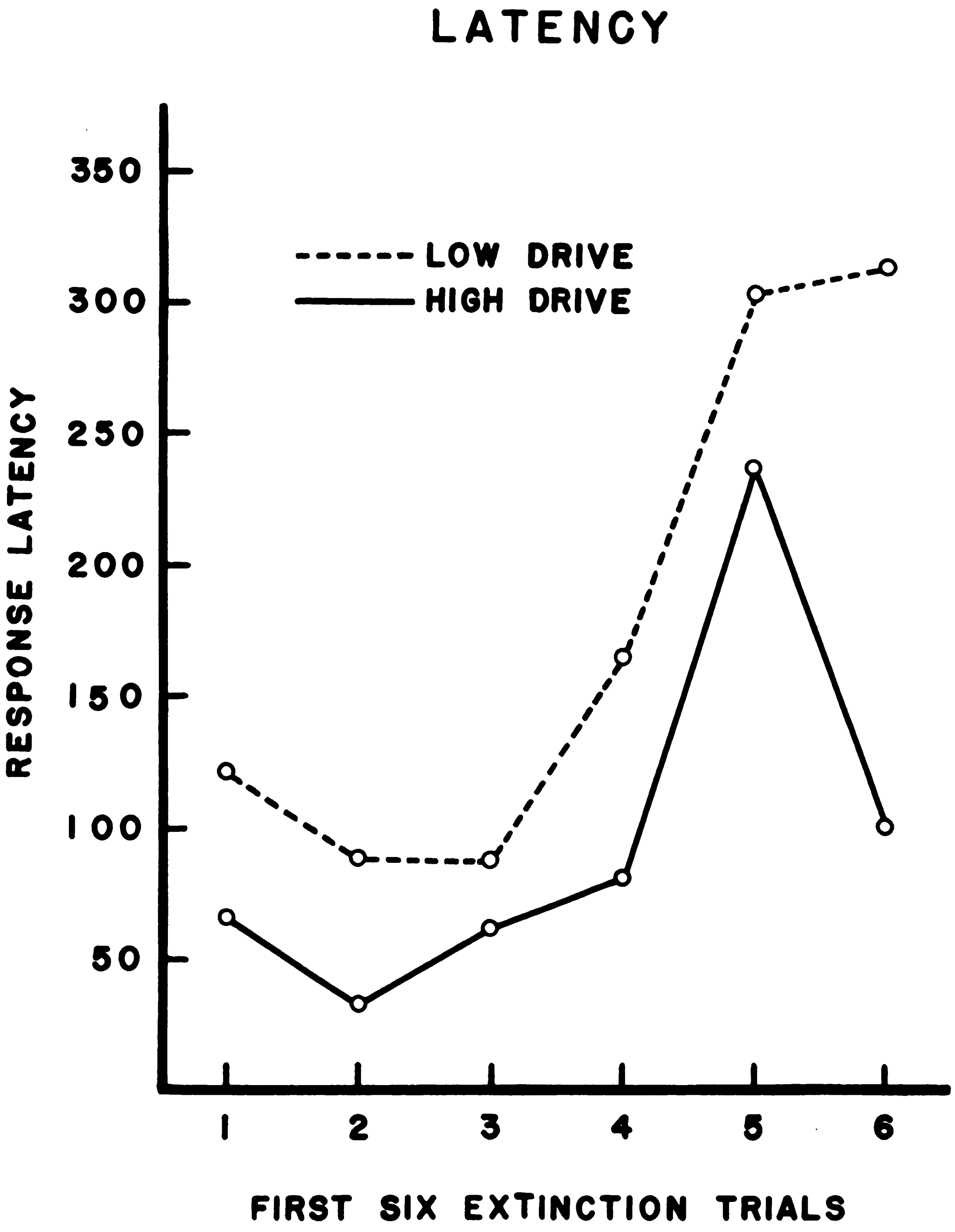

FIGURE 7. ILLUSTRATES THE DECLINE OF THE MEAN LATENCY ON THE INITIAL EXTINCTION TRIALS

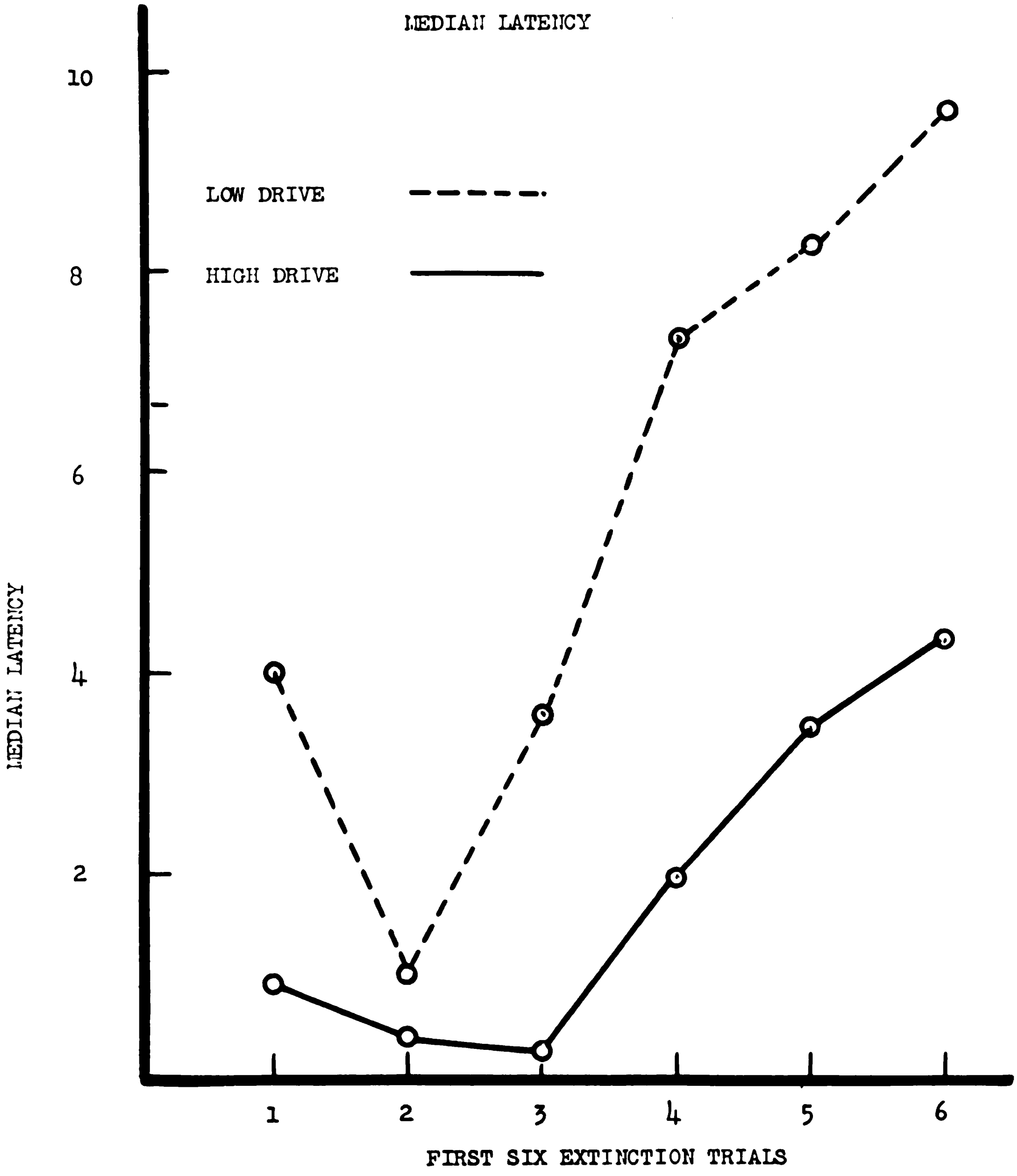

FIGURE 8. ILLUSTRATES THE DECLINE OF THE MEDIAN LATENCY ON THE INITIAL EXTINCTION TRIALS

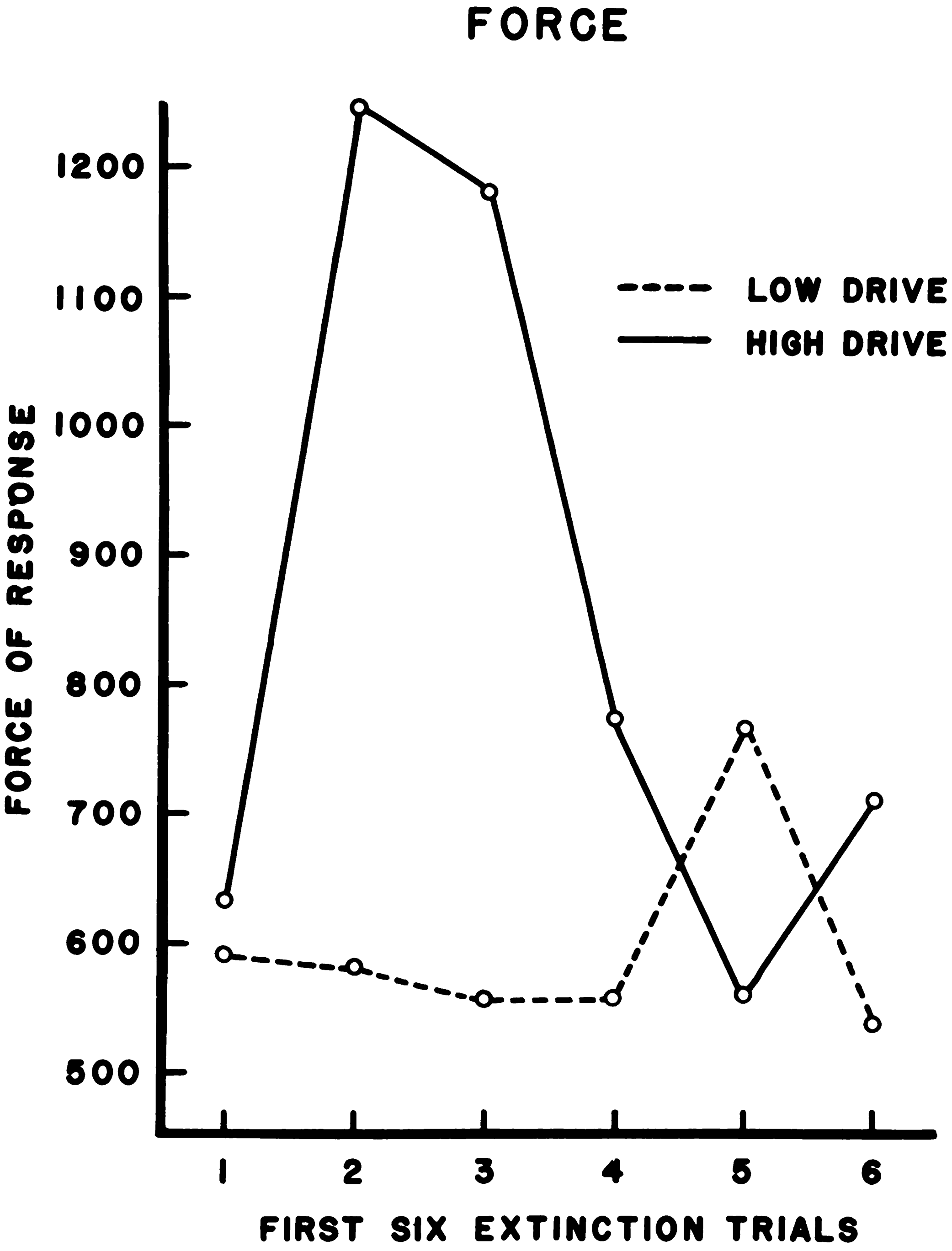

FIGURE 9. ILLUSTRATES THE RISE OF MEAN AMPLITUDE ON THE INITIAL EXTINCTION TRIALS IN THE CASE OF HIGH DRIVE ANIMALS

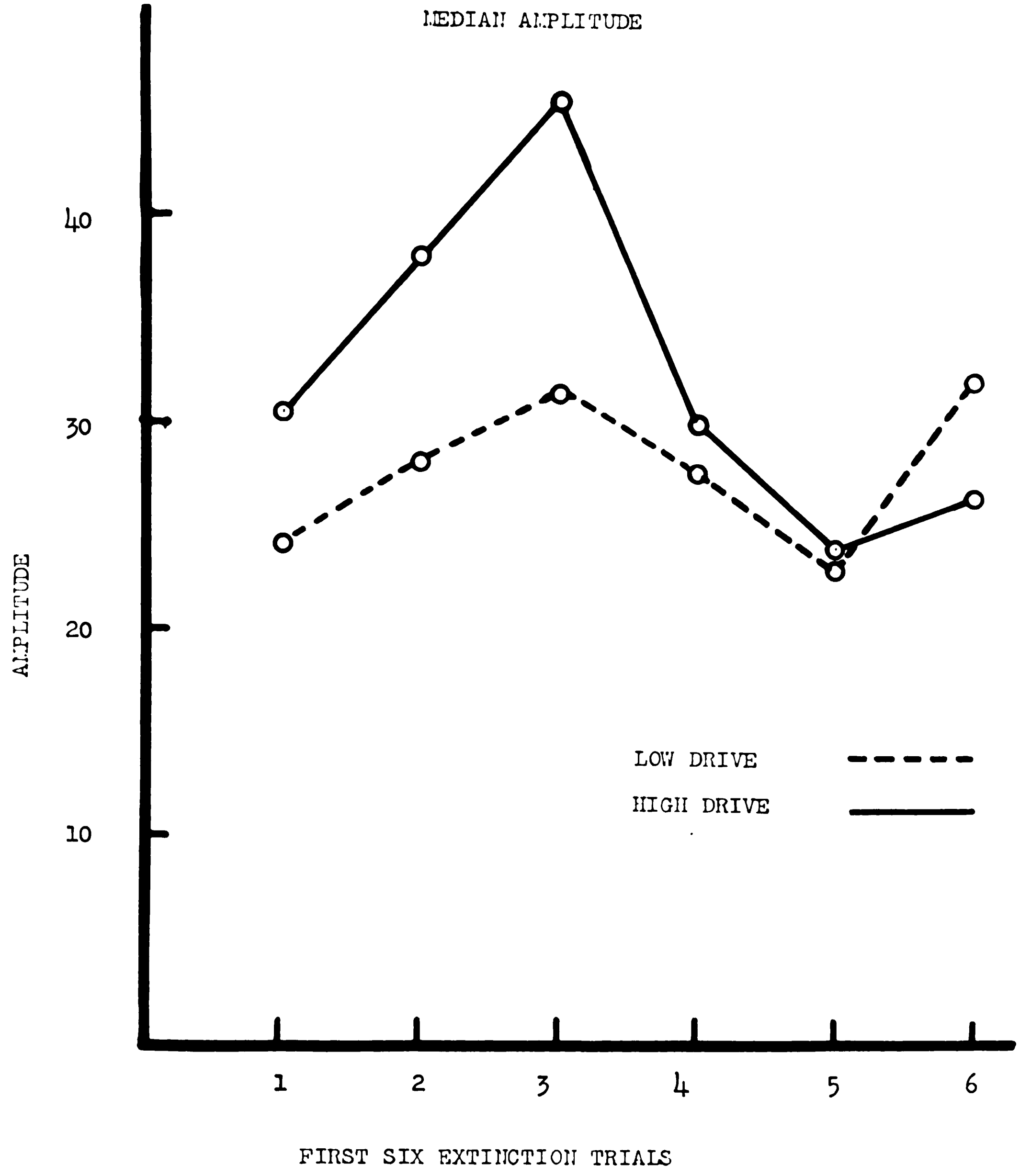

FIGURE 10. ILLUSTRATES THE MEDIAN RISE IN AMPLITUDE ON THE INITIAL EXTINCTION TRIALS IN THE CASE OF BOTH HIGH DRIVE AND LOW DRIVE ANIMALS

VI. INTERPRETATION

A. sEr AND THE SIZE OF REWARD

In the introduction it was pointed out that sEr is believed to be a function of a number of factors, one of which has been called the incentive component, K. K is held to be a negatively accelerated increasing monotonic function of the weight of food given as a reinforcement. In the present study, despite a weight-ratio of approximately 4x, animals rewarded with the larger pellets failed to respond significantly faster to the push panel than animals rewarded with the smaller pellets.

An inspection of table 4 reveals some interesting comparisons. Here it can be noted that small reward pellet animals are superior to large reward pellet animals in every cell except one, Low drive (Low to High). This implies that differences in performance, resulting from differential reward, depend not only upon the size of reward but also upon the total drive level under which animals are tested and the strength of the habit at the time of testing. Thus, one factor--such as habit--may mask the influence of other factors.

This is illustrated in the case of animals shifted from a high to a low drive. Both reward groups show a drop in response times as the animals are shifted from a high to a low drive, and this happens, despite the fact that for all animals combined high drive performance is significantly superior to low drive performance.

It might be asserted that animals which are run under a low drive the last two days are actually running under a low drive plus a residual motivation, resulting from two test days under long deprivation. This seems unlikely, for in this two-day period, these animals are satiated no less than four times, so that it would certainly seem that by the fourth day their running times would be somewhat depressed.

Some light is shed on this problem by reference to the curve illustrating the general rise in activity level over the four test days (see figure 5). With reference to this curve, it may be asked: Does this increase in activity result from a residual drive or is it the result of some learned anticipatory factor?

A partial answer to this question can be obtained by noting that the activity measures for the high drive animals show a smaller increase between day one and day two than do low drive animals. These low drive animals increase their activity count by a mean of 27.9, while high drive animals increase their activity count by a mean of only 12.6. This certainly cannot be accounted for in terms of a residual drive, for if a residual drive were building up, we would certainly expect it to be reflected in the activity of those animals undergoing the most marked physiological deprivation.

It thus appears that while deprivation and other similar functions, such as size of reward, do influence performance, the effects of these are often masked by strong learning. It follows from this that in the early stages of learning, the effects of motivation, K, and possibly other

factors as well will be most clearly distinguishable. To a large extent, the data gathered in the present study support this hypothesis.

The analysis of variance relative to these data indicates that the adopted procedure constituted a significant independent variable. This is an important finding, for an analysis of the data reveals that this difference results primarily from the longer latencies exhibited by animals which begin their test series under a low drive.

Assume, for example, that no measurements had been taken late in the series. In this case, marked differences would undoubtedly have been found to exist between the reward groups.

In other words, we have evidence here to suggest that the point in the test series at which measurements are taken may determine whether or not differences ever become apparent. All too often this important consideration is neglected in the psychological literature. We are inclined to assume that because differences exist utilizing one experimental procedure, they will necessarily be found when another procedure is adopted or vice versa.

In connection with the failure to uncover differences between large and small pellets, it should be pointed out that this is somewhat in opposition to our theoretical expectancies. Table 4 indicates that such differences as do exist are in the direction which would be predicted within a Hullian framework, however. Several factors may account for the lack of significant differences:

(1) The possible dominance of sHr in the equation for sEr. This has already been considered.

(2) The ratio of large reward to small reward may have been insufficient to permit a full realization of the potential differences in response time (39).

(3) The measure may have been too asymtotic. If, for example, the animals had had to run down a 20' runway as in the Crespi study (5), the differences might have been "stretched out" and thereby made more readily apparent, and

(4) It may be that in the present situation quantity of reinforcement actually made no difference at all.

B. sEr AND THE TYPE OF REWARD

One of the aims of the present study was to determine a quantity of food reward which equalled a fixed amount of water reward. Actually, the study indicates that no significant differences exist as the result of the amount of reward administered. Rather marked differences are present, however.

An inspection of table 4 indicates that in all but one of the cells the small food reward most nearly approximates the water reward. It would therefore seem that in the larger study, which is to be conducted, small pellets and five seconds drinking time would be roughly equivalent in reinforcing value.

C. DEPRIVATION AND sEr

1. Latency. The data tested with reference to latencies and deprivation tend in part to confirm out theoretical expectations. But, as we inspect

the data, we are struck by the fact that whether or not differences arise is again to a large extent a function of the point in the test series at which comparisons are made.

Reference to table 4 and the section entitled, "The Effect of Differential Deprivation on Performance," will illustrate this fact. Marked and significant differences occur between high and low drive animals up to 20 trials after the initial 30 training trials. These differences, however, are observed to be absent when latencies are compared beyond the 50th trial. Again it appears that the peculiar manifestation of the effect of a significant variable, such as drive, may depend to a large extent upon the strength of the habit at the time that measurements are made.

2. *Amplitude*. Deprivation, in the present study, appears to be totally unrelated to the amplitude of the response measured. This is, of course, in disagreement with the generally accepted Hullian beliefs concerning the amplitude of the response and sEr. It should be noted, however, that the studies cited by Hull to support the relationship of amplitude to sEr involve autonomic rather than skeletal response measures (9) (10).

It is interesting to note again that such differences as do exist are largely confined to the earliest of the two 20 trials test series. A difference of 230.83 was observed between high and low drives on the first series of 20 trials as compared with a difference of only 7.17 on the second twenty trial series.

D. EXTINCTION

1. *n as a Significant Indicator of sEr.* A second major point of conflict with contemporary Hullian theory exists with reference to the number of responses to extinction. According to the evidence collected in the present study, there is no basis for asserting that n is dependent in any way upon the drive level under which an animal is extinguished. n, in fact, appears to be completely unrelated to any variable which is controllable in the experimental situation.

The careful observation of animals under extinction and the correlated data reveals that beyond the first few trials, few, if any, really consistent generalizations can be drawn. Frequently, animals will come to a point where responses are delayed for as long as 160 or 170 seconds, and then, quite suddenly, there will occur a long flurry of responses, one immediately following another.

Most individual animals show no tendency towards a gradual decrease in latency. Especially those requiring a large number of responses to extinction. In fact, it quite often occured that the criterion latency came at the most unexpected points. Many animals would try to reach and to open the door through which they were admitted to the box, and other animals would continue to scratch themselves for the full three-minute criterion period. These observations, it seems to the author, can only be accounted for in terms of behavioral exploration and relearning.

What has been said about latency applies to the amplitude of the responses made, as well. Beyond the first several trials, no consistent trends are observable.

2. *The increase of D following removal of reward.* One of the most interesting observations which can be made with reference to the extinction data concerns the marked drop in the median latency and rise in the median amplitude on the second extinction trial. On the first extinction trial, animals have never experienced opening the door and the finding of no food, but on the second trial, this is not the case. Since this constitutes an instance of what is commonly called, "frustration," we are led to ask: Is this drop in latency and the increase in amplitude on trial two a function of "frustration," and if so, how does "frustration" enter the equation for sEr?

An inspection of the four figures, illustrating the trend of this data (figures 7, 8, 9, and 10) reveals several interesting and possibly significant facts.

(1) While high drive and low drive curves exhibit a marked similarity in form, in virtually every instance the point on the curves drawn for high drive are superior (performance-wise) to those drawn for low drive.

(2) Latency scores (especially in the case of high drive animals) approach a limiting asymptote, so that it is difficult to test the differences between trials one and two and draw meaningful conclusions. This is not true, however, in the case of amplitude scores, and

(3) At the time of this second extinction trial, animals have experienced 70 rewarded trials and 1x unrewarded trials in the experimental situation. The marked drop in latency and rise in amplitude following the first extinction trial certainly cannot be accounted for

in terms of a sudden rise in sHr. It seems more likely that there is, in this instance, a marked increase in drive, resulting from the addition of "frustration."

E. ACTIVITY LEVEL AS AN INDEPENDENT MEASURE

The consistent rise in total activity level which is noted on the four test days may be accounted for in one of two ways: either a residual drive (tissue need) is accumulating or else some learned "anticipatory factor" is operating in the situation. The first assumption may be tested by comparing total activities for high drive days one and two as compared with low drive days one and two. This we have already done, and it was pointed out that the increase for low drive animals was almost nine times that for high drive animals. If the increase in activity was the result of a high residual drive building up, it would certainly seem that his residual drive would be greatest on high drive days. But, such is apparently not the case. It seems more likely, then, that some learned anticipatory factor is operating here to increase activity. In one sense, this increase may reflect a change of motivation as well, but the change--it is important to note--is to be accounted for in terms of learning and not tissue need.

With reference to activity level and performance, few generalizations can be made. There appeared to be a genuinely significant difference between activity levels taken at high drive and those taken at low drive, but the prediction of performance on the basis of activity--either at the individual or group level--was limited. A significant correlation

between activity level and latency was established, tending to verify the graphic relationship illustrated in figures 7, 8, and 9.

While gross trends such as those observable in figures 7, 8, 9, and 10 are detectable, existing differences are overshadowed by the tendency for the vast majority of the data to center about a common range in activity level. Thus, when median latencies are established to separate arbitrary "high" and "low" drive levels, latencies cluster about the line of demarcation and tend to "flatten" the curve so that while marked differences may exist at the extremes, such differences are minimized and statistical differences do not appear.

VII. SUMMARY

The present study was conducted in order to establish incentive values for food and water, and in an effort to determine the feasibility of quantifying the drive construct once such values were known.

A push-panel apparatus was constructed in which activity levels could be measured simultaneously with response amplitude and latency.

Thirty-six male, albino rats were divided into two major groups, both of which were subdivided again into three groups.

1. High Drive:
   - (a) Large Food Reward
   - (b) Small Food Reward
   - (c) Medium Water Reward
2. Low Drive:
   - (a) Large Food Reward
   - (b) Small Food Reward
   - (c) Medium Water Reward

Each of the 36 animals was habituated to the box, assigned to one of the subdivisions, trained to open the push-panel for either food or water, and then tested for a total of 40 trials, 20 trials under a high drive and 20 trials under a low drive. Half of the animals began their test series under a high drive and half began their test series under a low drive in order to counterbalance the trials. Activity level for six minutes before the exposure of the push-panel, and the latency and amplitude of each response was recorded. At the close of the test series, all animals were extinguished under either high drive or low drive.

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The results were as follows:

1. Latency: Amount or type of reinforcement was not a significant variable with respect to latency. The incentive value of small food reward, however, more nearly matched the incentive value of the amount of water employed. Such differences as do exist are largely confined to the first half of the test series. With reference to drive level early in the test series latency appears definitely to be a function of the drive level under which it is measured. This does not hold true for differences measured late in the series.

2. Activity Level: Activity level, in the present study, offered some promise as an independent measure of drive. Individual and group predictions of performance based on activity are, however, of limited reliability. Some trends are observable. Activity shows a consistent upward trend throughout the test series. This, it was pointed out, cannot be accounted for in terms of some generalized increasing drive but seems to be a consequence of learned anticipation. A significant negative correlation was obtained between activity level and latency. Curves drawn comparing activity level with latency indicate a trend toward decreased latency with increased activity. This is particularly true of extremely high or low activity animals. An effort was made to test the difference between high and low activity animals using a t test, but no significant differences were detected. There was, however, a significant difference between activity levels taken following long deprivation and those taken following a short deprivation. Type of reinforcement was unrelated to activity.

3. Amplitude: The amplitude of the response as measured in the present study did not prove to be related to either the amount or type of reinforcement, or to the amount of deprivation.

4. Extinction: No difference was found between animals extinguished under high drive and those extinguished under low drive in number of responses to extinction. The lack of trends in the extinction data after the first few trials was discussed. Some drop in latency and rise in amplitude was noted on the second extinction trial, but this did not prove to be significant. The lack of significance may in the case of the latencies arise from the asymptotic level of the response.

5. One of the significant findings of the study was the discovery that differences often appear to be a consequence of the point in the test series at which measurements are taken, rather than a simple function of some variable such as drive or reinforcement. Habit in this respect, appears to be the dominant factor in the determination of sEr.

Recommendations for further research in the area of motivation:

1. In order to insure that animals will respond on every prescribed trial at low drive levels, the number of training trials should be increased to between 50 and 100. The number of test trials administered at each of the various drive levels can then be reduced from 20 to a much smaller number.

2. While there was no significant difference in the effect on performance of small reward, large reward, or water reward, water reward was most nearly matched by the small food reward. Any future study aimed

at the quantification of the drive construct, should adopt, therefore, the two incentive values for the different types of deprivation which are most nearly equal.

3. Certain changes in apparatus are recommended: (1) The large guillotine door should be moved nearer the wall which contains the push-panel in order to prevent animals from retreating into the intervening space. (2) The ball should be removed from the center of the false floor in order to obtain a more accurate activity count.

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