THE QUANTIFICATION OF DRIVE III. PRIVATION OF FOOD AND WATER

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A THESIS

Submitted to the School of Graduate Studies of Michigan
State College of Agriculture and Applied Science
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The present thesis was concerned with a test of the Hullian theory of drive, using privation with respect to food and with respect to water. The position was formalized, and consequent theorems were tested.

A combined activity box and panel-pushing device was used in the present study. The panel-pushing device was so arranged to provide a measure of force of response, and of the number of trials to extinction.

Forty-eight male albino rats were used as subjects in the study, and were divided into two major groups:

1. Twenty-four animals deprived of water;
    a. Twelve animals given a large reward (0.20 cc)
    b. Twelve animals given a small reward (0.12 cc)
2. Twenty-four animals deprived of food;
    a. Twelve animals given a large reward (0.32 gm)
    b. Twelve animals given a small reward (0.08 gm)

All animals were given habituation training in the apparatus during the first five days of the experiment, while on an ad libitum feeding schedule. Activity level was recorded.

On days 6 through 13 all animals were trained on the panel-pushing task, under $22\frac{1}{2}$ hours of appropriate privation and reward. Each animal was given ten trials per day. Activity level was recorded on all 8 days, and force of response was recorded on the last 3 days.

At the completion of the training series the animals

went immediately to the testing series, where they were tested after different numbers of hours of privation, i.e., on 1, 2, 6, 12, $22\frac{1}{2}$ and 48 hours of appropriate privation. The order of presentation of privation levels was randomized for each animal. Each animal was given 4 trials per day. Activity level and force of response were recorded each day.

At the conclusion of the testing series each animal was extinguished on one of the above mentioned hours of privation.

The results are as follows:

1. Activity is not a reflection of privation, *per se*, but is rather dependent upon the amount and kind of reward in interaction with privation, and on a learned anticipation of reward.

2. A general concept of drive is not tenable, because the correlation between the food and water groups, when activity is constant, was not significant.

3. A drive concept is not tenable, because the water groups did not show the increase in behavior measures which the large food group showed.

4. There is a significant interaction between the kind of reward substance and the privation level.

5. There is a significant interaction between the amount of reward substance and the privation level.

The implications of the study for activity as a measure of drive, and for drive as an explanatory construct, were discussed.

The category of need was discussed, and an alternative interpretation of need, as interaction, was suggested.

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INTRODUCTION

The present thesis has two objectives: first, a formalization of the Hullian theory of drive; and, second, a test of the empirical adequacy of this theory of drive. This introductory chapter attempts to do three things: first, to isolate the Hullian theory of drive; second, to consider the theory of drive in the context of the larger theory of which it is a part; and, third, to consider the empirical research which bears on the task of testing the part-theory of drive.

The part-theory of drive finds its most complete elaboration in the _Principles of Behavior_ (16), and this book will be used as the source for the drive theory. The latest revision of the general behavior theory, of which the drive theory is a part, is presented in _A Behavior System_ (17). It is unfortunate that we have to go to two sources, but Hull did not deal with drive as completely in his _System_ as he did in his _Principles_.

Hull's theory of drive begins with the assumption that animals behave in such a way as to provide optimum conditions for survival. From this general assumption Hull arrives at the notion of _need_. Hull says:

> " ... when a condition arises for which action on the part of the organism is a prerequisite to optimum probability of survival of either the

individual or the species, a state of need is said to exist. Since a need, either actual or potential, usually precedes and accompanies the action of the organism, the need is often said to motivate or drive the associated activity. Because of this motivational characteristic of needs they are regarded as producing primary animal drives." (16, p. 57).

Drive is an intervening variable, and as such is not directly observable. However, if it is to be a satisfactory intervening variable it must be defined by reference to events which are themselves observable. Hull defines drive in terms of privation with respect to a need and the amount of energy expended by an animal in an effort to get the needed substance. Hull says:

> "Specifically, the amount of food need clearly increases with the number of hours elapsed since the last intake of food; here the amount of hunger drive (D) is a function of observable <u>antecedent</u> conditions, i.e., of the need which is measured by the number of hours of food privation. On the other hand, the amount of energy which will be expended by the organism in the securing of food varies largely with the intensity of the hunger drive existent at the time; here the amount of 'hunger' is a function of observable events which are its <u>consequence</u>." (16, p. 57-58).

Drive abstracts from the specificity of need. Needs are specific for certain classes of environmental supports. Drive abstracts away from this specificity and is the resultant of all of the needs operating at a given time. Hull says:

> "The drive concept, ... , is proposed as a common denominator of all primary motivations, whether due to food privation, water privation, thermal deviations from the optimum, tissue injury, the action of sex hormones, or other causes." (16, p. 239).

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The reader will note the use of the word energy in last quotation but one. This word energy will be interpreted to mean general activity in the present discussion. It is difficult to know just what Hull had in mind when he wrote this word, and an adequate test of the theory depends upon a correct interpretation. Whatever was meant by the word, it must be something observable, because it is to be one of the observables in terms of which the presence and amount of drive are to be determined. Furthermore, it cannot mean one of the four observables in terms of which reaction potential is measured, because this would introduce into the theory a nice tight circle. The word energy must refer to some observable which is independent of the remainder of the system.

By the term general activity we refer to what an animal does when placed in a specific apparatus for a determined length of time. The apparatus used will be the MSC activity box, and the animal will be the white male albino rat. It is necessary to define activity in terms of the situation, for as Reed has pointed out at the start of his review:

> Much of the research to be reviewed depends upon a general concept of spontaneous activity without regard to how the activity is measured. It will become evident in the course of the review that our concept of activity must be tied to the measure of it which we have used, ... (27, p. 393).

The elements of the Hullian theory of drive may be summarized as dummy equations* as follows:

Let: "f", "g" and "h" denote functions,

"a" denote magnitude of activity,

"d" denote magnitude of drive,

"n" denote magnitude of privation with respect to a need, then,

$$d = f(n) \tag{1}$$

$$a = g(d) \tag{2}$$

An interesting consequence of this position is that

$$a = h(n) \tag{3}$$

We may now consider the relation of drive to other concepts of the Hullian system. Hull considers that the performance of a particular pattern of behavior is dependent upon the strength of the effective reaction potential for that pattern of behavior. There are five variables which determine reaction potential in the Hullian system. One of these, drive, is the subject of the present thesis. The others are: 2, habit ($_SH_R$), which is determined by the number of reinforcements to the response being learned; 3, incentive motivation (K), which is dependent upon the quantity of incentive given as reward; 4, stimulus intensity dynamism (V), which is dependent upon the intensity of the stimulus; and 5, delay of reinforcement (J), which is

*We speak of dummy equations because the expressions used are not equations. The letters "f", "g", "h", etc. represent functions which are unknown; hence the expressions make no assertions. They are, rather, assertions of dependence, and the hope that some mathematical function will describe this dependence.

dependent upon the time interval between the making of a response and the receipt of reward. (18, p. 6-8).

Hull's basic equation for reaction potential,

$$_{S}E_{Rd} = D \times V_2 \times K \times {}_{S}H_R \times V_1(10^{-.15d}),$$

may be written as

$$_{S}E_R = C \times D \times K \qquad (4)$$

where C is a constant determined by lumping all of the variables except D (drive) and K (inceptive motivation) and holding them constant. We wish to point out here that C is a constant determined by holding each of the components of C constant. C could remain constant even if all of its components were not constant, if their variations compensated for each other. This latter method of holding C constant is not what is meant in the present formulation. This second method of holding C constant is fundamentally weaker than the method adopted for the present interpretation. It would have to be shown empirically that there were no interactions between the variables $_{S}H_R$, V and J before it could be legitimately used.

The equation for reaction potential as it will be used in the present study is represented by (4). D and K will be variables. D will be varied in the test of the part-theory of drive. K was chosen as a variable because of the possibility that there may occur interactions among the different values of the variables. As the Hullian system is set up today there is implicit the assumption that the components

of reaction potential are independent. However, this assumption may not hold when we deprive animals of food to set up drive, and then reward the animal with food for the performance of a given response.

If we now find some magnitude of water reward which is behaviorally equivalent to a given magnitude of food reward*, we may eliminate K from the above equation (4). If we, then, let "e" denote the magnitude of reaction potential we may rewrite (4), in terms of our previous notation as

$$e = cf'(d) \tag{5}$$

where c is a constant. An interesting consequence of (1) and (5) is

$$e = cg'(n) \tag{6}$$

<u>Drive as a function of privation</u>

The studies of Herenstein (15), Kimble (19), Yamaguchi (41) and Cotton (7) were direct tests of equation (6). These investigators all used food privation and food reward, and their results in general support the assertion of (6). Cotton's results, however, suggest a limitation on the generality of the Hullian theory. Cotton measured running time in a straight alley, and when he eliminated trials on which competing responses occurred, he showed that the decline in running time with increased privation approximates

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*Davis (8) has shown that 0.08 gms. of food reward was behaviorally equivalent to 0.20 cc. of water reward, using the panel-pushing device.

a straight line, rather than a negatively accelerated decreasing curve. Hull has used the results of Yamaguchi's study as a first approximation to the drive function, at least that based on food privation. The writer was unable to find any studies on water privation, comparable to these based on food privation.

E. E. Anderson (1) conducted an extensive correlational study on the interrelationship of drives in the male albino rat. He obtained intercorrelations among 47 different tests, using 51 male albino rats. Anderson concluded that in general neither the thirst nor the hunger tests correlated significantly. He states

> "intercorrelations between measures of different drives, on the whole, are somewhat sporadic in occurrence, and there is little evidence of any important 'general drive' factor influencing performance upon a large number of tests. There is however, some slight indication of relationship between such direct tests of different drives as eating, drinking, and copulation tests."

As the term 'food privation' and the term 'water privation' are used in the experimental literature, one receives the impression that the two are independent. This is not the case. Finger and Reid (10) and Verplanck and Hayes (37) have shown that when animals are deprived of food they automatically deprive themselves of water, and conversely. The results of the rather extensive study by Verplanck and Hayes has been confirmed by (31) and (5). It is thus seen that to deprive animals of food is to simultaneously deprive them of water, and conversely.

Activity as a function of privation

Equation (3), i.e., $a = h(n)$,

has been the object of a large number of experimental researches. The literature on activity as a function of the number of hours of privation is very extensive. Since there have been a number of excellent reviews of this material we will be primarily concerned here with studies which have been directly concerned with activity as a function of differences in privation. Of the general review articles we may mention the Bulletin article by Shirley (29) which includes work up to 1929, and the later Bulletin article by Reed (27) which covers the work between 1929 and 1947. Richter (28) has summarized the research on activity which has been done under his direction. Munn (26) has a summary of the work on activity which was completed up to the publication of his book.

The two methods that have mostly been used for the study of activity have been the running drum and the tambour- or spring-mounted cage. The running drum consists of two circular boards mounted on an axel shaft and separated by a sheet of wire mesh wound around their periphery. This basic design has been modified in a number of ways. One may vary the diameter of the boards, arrange the living cage so that the animal may enter the drum at its leisure, or confine the animal to the drum for given periods of time. One may record the total activity by attaching a counter to

the drum supports in such a manner that each revolution of the drum advances the counter one unit, or one may record activity as a function of time. Reliability measures using this device are on the order of .95, but it is unknown whether this value reflects the reliability of the measurement of activity or whether it reflects the consistency of different drums.

The tambour- or spring-mounted cage is a small cube of wire mesh mounted at three points on either a spring or an air tambour. The latter is the more effective because the air pressure provides some dampening effect. This piece of apparatus has also been modified in a number of ways to study various aspects of activity. Other devices that have been used to study activity are tilting cages, utilizing the movements of the animal to interrupt the beam of light which activates a photoelectric cell, a horizontal turntable, the pedometer, and various observational methods.

The most interesting thing about all of these methods is that they give different results, and modifications of one apparatus give still different results. It is thus necessary to know what kind of an apparatus was used to record activity before one may interpret the results.

With respect to food and water it is commonly accepted that privation will increase activity up to a point, after which further privation is accompanied by a decrease in activity, probably due to physical weakening of the animal.

Most of the attempts to quantify the relationship between the number of hours of privation and activity have been done with food privation. Using the Columbia Obstruction Apparatus, Warden (39) has shown the number of crossings of the charged grid drops off faster with water privation than with food privation.

Siegel and Steinberg (30) have utilized the movements of the animal to interrupt a beam of light which activates a photoelectric cell to study activity as a function of food privation. These investigators used privation intervals of 0, 12, 24, 36 and 48 hours, and their results indicate that activity increases as a negatively accelerated function of the number of hours of privation. With respect to this study it should be pointed out that the animals remained in their home cages all during the study and it is possible that the activity was influenced by expectancy of food.

Hall, Smith, Hanford, and Schnitzer (13) report the results of a study designed to determine the effects of a restricted feeding schedule on activity level. These investigators used 10 standard Wahmann activity drums, each mounted separately, and each provided with a small stationary living cage. All wheels were equated for frictional torque. Control animals had unrestricted access to food and water, while the experimental animals had unrestricted access only to water, being allowed access to food for one hour in the morning. The experiment was continued over a period of 20 days. These investigators report:

> "Although activity during the control condition remained relatively stable, mean daily activity during the experimental period rose to more than 1,400 percent of normal, reaching this level on the twelfth day of restricted feeding. The rise seemed to take the form of an exaggeration of the normal daily activity cycle, imposed upon a rising base line."

Campbell and Sheffield (4), utilizing an activity recording device constructed by Campbell (2), report the results of a study from which they conclude that "Starvation does not instigate activity; it only lowers the threshold for normal stimuli to activity." The apparatus was a small round wire mesh cage, pivoted at the center of the base so that it would tip a maximum of 1/8 inch. Four sensitive microswitches were placed at each of the four quadrants. Activation of any of the microswitches advanced an electromagnetic counter. The experimental animals were placed on an ad libitum diet for four days while in the apparatus. Then on the succeeding three days the animals were deprived of food, but not of water. On each of these three days the activity of the animals was recorded for ten minutes at noon, after which an environmental change was introduced and the animals' activity recorded again for ten minutes. An environmental change consistently produced an increase in activity, and the magnitude of the change in activity was correlated with the change in the environmental condition, but not with increased privation. The results of this study stand in striking contrast with the results of other studies in the area, and the reason for this may be found in the fact that "The apparatus usually fails to record certain small movements like scratching, but it records larger movements such as moving from one quadrant to another or shaking the cage." (4, p. 320). In other words, the method may not be very sensitive.

Thompson (36), using a rectangular elevated maze, has studied the exploratory activity of maze bright and maze dull rats, under three conditions of privation: 0, 24 and 48 hours of food privation. He reports that while exploratory activity in an unfamiliar situation declines as a function of time, food privation increases the amount of exploratory activity in which animals engage. Male rats show a steady increase in exploratory activity as privation increases from 0 to 48 hours, while for female rats the maximum of exploratory activity is reached after 24 hours, as measured. Maze bright and maze dull rats did not behave differently.

Montgomery (25), using an enclosed Y-maze has reported the results of a study which show that food or water privation significantly reduces the amount of exploratory activity, the maximum reduction occurring at 24 hours of food privation.

THE THEORY OF DRIVE

Preliminary considerations

It will be the purpose of the present chapter to set up the theory of drive in the notation of symbolic logic, so that testable consequences of this theory may be deduced as theorems. In this section on preliminary considerations, we shall attempt to relate the theory to conventional experimental methodology, to relate the theory to the more general problem of measurement, and in general to explain what the task of formalizing the theory of drive amounted to.

The first task is to relate the theory of drive to the conventional methodology of experimental psychology. Hull has stated his assumptions about drive in terms of individual animals. We find him using in the *Principles of Behavior* such phrases as "the organism", "an organism", "the individual" and "the individual or the species". It is obvious that Hull intended his speculations to apply to the animal as an individual.

On the other hand, the conventional methodology of experimental psychology is not conceived in terms of the individual animal. Groups of animals are used in psychological experiments, and conclusions are drawn in terms of the behavior of these groups of animals. Furthermore, all of the tests of Hullian notions have been in terms of group

behavior. Consideration of individual animals results in failure of the theory (7).

What is demanded here is some sort of an individual which has its genesis in a group, or in a class of individuals. Leonard and Goodman have provided such a conception in their calculus of individuals (22). This is the fusion-individual, or sum-individual, of a class of individuals. The fusion-individual has the same logical type as the individuals which are members of the class, but derives from the class itself. The notion _fusion_ is conceived as a heterogeneous relation between an individual -- the fusion-individual -- and a class. An individual is said to stand in that relation to a class, when everything that is discrete from the individual is discrete from every member of the class, and conversely. Their first postulate assumes that every class which has members has a fusion-individual, i.e., has a sum.

Therefore, in view of the above considerations, we will understand by the term _organism_, a sum-individual of a class of individuals. When we use the term animal we will understand the common-sense usage of the term, e.g., _a_ rat is an animal, _a_ dog is an animal, _a_ human being is an animal.

The theory of drive, as an empirical theory, is intimately related to measurement. We will want to speak about the amount of drive operative in a given situation. Or, to speak more precisely, we will want to speak about the magnitude of the drive of a given organism. The use of the phrase

<u>the magnitude of drive</u> in equations that represent empirical situations, implies that we have at hand some method of determining the magnitude of drive. The theory of drive is, in fact, an application of the general theory of measurement to a concrete situation, i.e., every measurement procedure is a model of the general theory of measurement. How this is accomplished can best be explained by showing the parallels between the notation of the general theory of measurement (22) and the notation of the theory of drive. Some discussion of the general theory of measurement will have to come first.

By the term measurement, we will understand the assignment of numbers as names of the properties possessed by objects. This definition of measurement differs from that commonly found in the writings of psychologists, in that it is more restrictive. The definition excludes, from the class of measurement procedures, the assignment of numbers as names of objects. Thus, the use of numbers in a nominal sense is not measurement. It is to be emphasized also, that measurement is an empirical procedure. Measurement is something that a person does, through the actual manipulation of events in the environment, in accordance, we would assert, with the above definition.

A theory of measurement has as its purpose, the elaboration of the nature of the relationships which must exist between: (1) the objects of measurement; (2) the class of properties with respect to which the objects are measured; (3) the number signs which are used as names of the magnitudes of these properties. The use of the phrase the _class of properties_ in (2), above, is to be noted. A measurement procedure, that is, a valid measurement procedure, is concerned with only a single class of properties. Examples might be heights, weights, numbers of moles on the body, Stanford-Binet I.Q.'s, etc. Comparison of any two such classes of properties, say for example, Stanford-Binet I.Q. and number of moles on the body, would require additional empirical knowledge, and would involve two applications of the theory of measurement.

The general theory of measurement (22) assumes three primitive ideas. These are: a class, K, of objects of measurement, e.g., buildings; a class, L, of properties which the objects of measurement possess, e.g., heights; and a relation, R, which takes members of K as arguments, e.g., smaller than. According to the examples, aRb would be interpreted as building a is smaller than building b. Later theorems show that R has _some_ of the properties of the less-than relation which holds between numbers.

Given the three primitives, three notions are defined. These are: a relation, S, taking members of K as arguments; a relation, Q, taking members of L as arguments; and a notation for the expression _the magnitude of the property_, _i.e._, _the member of the property-class_, _possessed by an_

object, i.e., "mag(a)". Later theorems show that S has some of the properties of the relation identity, which holds between numbers; Q is an ordering relation for mag(a), and corresponds to the relation less-than which holds between numbers.

Three primitive sentences, or postulates, are required. Postulate 1 asserts: if two objects, a and b, have the properties M and N, respectively, then M is identical with N if and only if a stands in the relation S to b. Postulate 2 asserts: R is transitive. Postulate 3 asserts: there is some property, M, which a possesses. Between them, postulates 1 and 3 assert that each member of K possesses one and only one member of L.

Theorems are then deduced which present interesting and important properties of the relations R, S and Q. Three of these theorems are particularly important because of the formal parallelism between them and the ordering axioms for the real number system. These three theorems show that Q is an ordering relation for mag(a). It is through these three theorems that the relationship between R and S and the number system is established.

The present theory of drive requires five distinct applications of the theory of measurement. That is to say, we will be concerned with five different classes of properties attributable to organisms, and also to animals. The animals considered will, of course, be rats; white, male, albino rats.

The five classes of properties will be: 1, privation with respect to food; 2, privation with respect to water; 3, general activity; 4, drive; and 5, reaction potential. To illustrate the parallelism between the general theory of measurement and the theory of drive we list in Table 14, below, the corresponding notation for the theory of measurement and one of our classes of properties. We chose privation with respect to food.

TABLE 14

PARALLELS BETWEEN THE NOTATION OF THE GENERAL THEORY OF MEASUREMENT, AND THE PRESENT THEORY OF DRIVE, IN THE CASE OF FOOD PRIVATION

Theory of measurement	Theory of drive
"a"	"a"
"mag( )"	"priv(,x)"
"mag(a)"	"priv(a,x)"
A class of qualities M, N, O, etc.	A class of privations M_1, M_2, M_3, etc.
$\text{mag}(a) .=_{Df}. (\imath M)(Ma)$	$\text{priv}(a,x) .=_{Df}. (\imath M)(Mx,a)$
Expressions like "mag(a)", "mag(b)" may be substituted for expressions like "M", "N" etc.	Expressions like "priv(a,x)", "priv(b,x)" may be substituted for expressions like "M_1", "M_2", etc.

Tables similar to 14 could be constructed to show the identical parallel relations between the notation of the theory of measurement and each of the other classes of properties used in the theory of drive.

Four primitive ideas are required for the theory of drive. These are need, general activity, reaction potential and drive. Of these four, the notion of need is most interesting. Need is a notion which Hull borrowed from common-sense for incorporation in his theory. Hull speaks of actual and potential needs (16, p. 57). We will consider that needs are dispositional properties of animals (6). That is to say, needs are constant. An animal has a constant need for such and such an amount of food per day. It makes no difference whether the animal has eaten its fill only ten minutes ago, he still needs a given amount of food per day. Similarly, in the case of water, an animal has a need for a constant amount of water per day; and for optimal conditions it needs this amount of water regardless of the state of its thirst at any given time. It will thus be seen, that we chose the notion of potential need, not the notion of actual need. Instead of speaking of the actual need of an animal for a given substance, we will speak of privation with respect to that substance. Thus, we hope to make the notion _need_ a little less ambiguous. Need will be conceived as a relation between an environmental support and an animal. The expression "xNa" is to be interpreted as x is a need of animal a.

Adequate treatment of the concept of need requires another symbol concerned with need, besides the relational symbol. We shall wish to speak of privation with respect to a need. For this purpose the expression "priv(a,x)" is used, and is to be interpreted as the magnitude of the privation of a with respect to the need x.

General activity is likewise conceived as a relation between the activity of an animal and that animal. The expression "yAa" is to be interpreted as y is the activity of a. When we use the term general activity, or when we speak of the magnitude of the activity of an animal, it will be understood that we refer only to activity as measured in the present situation. Any other use of the term activity is a use which is not included in the present system, and the present system makes no statement about any other use of the term activity.

We shall wish also to speak of the magnitude of the activity of an animal. For this, we will use the expression "act(a)", to be interpreted as the magnitude of the activity of a.

The notion of reaction potential was conceived, by Hull, as a relation between a stimulus and a response. He used it in the sense of a functor, i.e., a symbol taking number signs as values. Hull's use of the term reaction potential corresponded to the notation "mag( )" in the theory of measurement. Unfortunately Hull was not consistent in his usage (16, pp. 344-345). We are here interested in reaction potential only in the sense of the magnitude of reaction potential. We will be concerned with a notation for the magnitude of reaction potential only, and with only those other considerations which Hull's general system forces upon us. As was explained in the introduction, it will be necessary to assume that all of the variables, in the Hullian system, which determine reaction potential, except drive and the magnitude of reward, are constant over all of the experimental groups. Thus, the measures of drive which will be obtained are measures of relative drive. Differences which we will seek are relative differences.

The expression "ef(a)" is to be interpreted as the magnitude of the reaction potential of a. Likewise, the expression "dr(a)" is to be interpreted as the magnitude of the drive of a.

Three postulates are required for the theory of drive. These three postulates correspond to dummy equations (1), (2) and (5) in the introduction. The postulates are set up in the form of Carnap's bilateral reduction sentence (6), i.e.,

$$Q_1 . \supset . Q_2 \equiv Q_3$$

In each case Q_1 corresponds to the assumptions that are necessary for the assertion of $Q_2 \equiv Q_3$. In each case $Q_2 \equiv Q_3$ corresponds to the dummy equations of the introduction. We have made one modification of Carnap's usage. For Carnap, Q_3 represents a dispositional predicate. For the present usage, we have modified this interpretation. Q_2 and Q_3 are the same sort of notion, predicates taking definite descriptions as arguments. It is necessary to

assume that the descriptions exist in each case. For example, in the case of priv(a,x) it is necessary to assume that the property M, such that, a has M, exists. This assumption is made.

The first postulate is:

$$\overrightarrow{N'a} = \overrightarrow{N'b}.y\in\overrightarrow{N'a}:.(x):x\in\overrightarrow{N'a}.x \neq y.\supset.\mathrm{priv}(a,x) = \mathrm{priv}(b,x):.\supset.$$
$$\mathrm{priv}(a,y) < \mathrm{priv}(b,y) \equiv \mathrm{dr}(a) < \mathrm{dr}(b)$$

Postulate 1 says, in affect, that if two organisms, a and b, have identical needs, one of which is y, and if they have been equally deprived with respect to each of their needs except y, then the deprivation of a with respect to y is less-than that of b if and only if the drive of a is less-than that of b. Of course, y is the test need in this assertion, and it is necessary to assume that all of the organisms have all of their needs in common, as well as to assume that their privations with respect to all of their needs, except y, are equal.

The second postulate is:

$$(\exists u):.(v):\overrightarrow{A'a} = \overrightarrow{A'b}.v\in\overrightarrow{A'a}\supset u = v:.\supset.$$
$$\mathrm{act}(a) < \mathrm{act}(b) \equiv \mathrm{dr}(a) < \mathrm{dr}(b)$$

Postulate 2 says, in affect, that if two organisms, a and b, have all of their activities in common, and that they all do the same thing, implies that the magnitude of the activity of a is less-than that of b if and only if the drive of a is less-than that of b.

The third postulate is:

$$ef(a) < ef(b) \equiv dr(a) < dr(b)$$

Postulate 3 says, in affect, that the reaction potential of organism a is less-than that of b if and only if the drive of a is less-than that of b. This postulate comes directly from Hull, and it should be obvious that it is only true in the limited context of the present theory, where drive is the only variable which effects reaction potential.

The reader will note that in the consequences of the postulates we have used the relation less-than. The relation less-than is more powerful than the relation identity. We could have set the postulates up in terms of identity. Had we done this, we would be unable to assert any statement involving the less-than relation. The holding of identity can be derived from the holding of less-than, but not conversely. Since we wish to assert both kinds of statements, we must begin with the relation less-than. This consideration points out another parallel between the general theory of measurement and the present theory of drive. The theory of measurement was begun with the relation, R, which corresponds to the less-than relation. It will be remembered that the relation less-than is an ordering relation. Less-than orders the number domain which is its field. Identity, which is, never-the-less, a very useful relation, is not an ordering relation.

The arguments to the relation less-than, in the postulates will not be numbers. These are expressions like "the magnitude of the drive of", etc. Expressions of the form used are called <u>functors</u>. Functors are functions which take numbers as values. We speak of <u>the</u> magnitude of the privation of a with respect to x, when we have in mind some <u>unique</u> value of the magnitude of the privation of a with respect to x. Functors are a form of definite description, as the definition of priv(a,x) shown in Table 14 indicates. The general theory of singular descriptions is dealt with in <u>Principia Mathematica</u> in *14 and *30. We may make similar remarks about act(a), dr(a) and ef(a).

<u>Theory</u>

Let: "x", "y" and "z" be variables denoting possible needs
"u" and "v" be variables denoting acts
"a", "b", "c" and "d" be variables denoting organisms
"xNa" denote x is a need of organism a
"uAa" denote u is an activity of organism a
"priv(a,x)" denote the expression the magnitude of the privation of organism a with respect to the need x
"act(a)" denote the expression the magnitude of the activity of organism a
"dr(a)" denote the expression the magnitude of the drive of organism a

"ef(a)" denote the expression the magnitude of
the reaction potential of organism a.

An expression of the form "xNa" will be meaningful if and only if it takes a variable, or a constant, denoting a possible need as a member of the domain of N, and a variable, or a constant, denoting an organism as a member of the converse domain of N.

An expression of the form "uAa" will be meaningful if and only if it takes a variable, or a constant, denoting an act as a member of the domain of A, and a variable, or a constant, denoting an organism as a member of the converse domain of A.

An expression of the form "priv(a,x)" will be meaningful if and only if it takes in first argument position a variable, or a constant, denoting an organism, and in second argument position a variable, or a constant, denoting a need.

An expression of the form "act(a)" will be meaningful if and only if it takes as argument a variable, or a constant, denoting an organism.

An expression of the form "dr(a)" will be meaningful if and only if it takes in argument position a variable, or a constant, denoting an organism.

An expression of the form "ef(a)" will be meaningful if and only if it takes in argument position, a variable, or a constant, denoting an organism.

We will assume as logical vehicles: (1) <u>Principia</u>

Mathematica of Whitehead and Russell (40); and (2) The general theory of measurement of Leonard (21).

We will use the mathematical relations less-than ($<$), identity ($=$), and diversity ($\neq$).

The primitive sentences of the theory are:

P 1. $\overrightarrow{N}{}^{\prime}a = \overrightarrow{N}{}^{\prime}b \,.\, y \epsilon \overrightarrow{N}{}^{\prime}a :. (x) : x \epsilon \overrightarrow{N}{}^{\prime}a \,.\, x \neq y \,.\supset . \mathrm{priv}(a,x) = \mathrm{priv}(b,x) :. \supset .$

$\mathrm{priv}(a,y) < \mathrm{priv}(b,y) \equiv \mathrm{dr}(a) < \mathrm{dr}(b)$

P 2. $(\exists u) :. (v) : \overrightarrow{B}{}^{\prime}a = \overrightarrow{A}{}^{\prime}b \,.\, v \epsilon \overrightarrow{A}{}^{\prime}a \supset u = v :. \supset .$

$\mathrm{act}(a) < \mathrm{act}(b) \equiv \mathrm{dr}(a) < \mathrm{dr}(b)$

P 3. $\mathrm{ef}(a) < \mathrm{ef}(b) \equiv \mathrm{dr}(a) < \mathrm{dr}(b)$

The above propositions are consistent with a universe of: (1) two distinct sum-individuals, a and b; and (2) four distinct elements, c, d, e, and f.

Following are certain theorems derived from the primitive sentences, specifically for the purposes of testing in the present thesis:

Verbal statement of the theorems

On the hypothesis that two organisms have all of their needs in common, and that their degress of privation with respect to all of their needs, except the test need, are equal, then:

Th. 1. If their degrees of privation with respect to the test need are equal, then their drives are equal, and conversely.

Th. 4. If the degree of privation with respect to the test need of organism a is less-than that of organism b, then the reaction potential of a is less-than the reaction potential of b, and conversely.

Th. 5. If their degrees of privation with respect to the test need are equal, then their reaction potentials are equal, and conversely.

On the hypothesis that two organisms engage in the same activity, then:

Th. 2. If their activity is equal, then their drives are equal, and conversely.

Th. 8. If the activity of organism a is less-than the activity of organism b, then the reaction potential of a is less-than the reaction potential of b, and conversely.

Th. 9. If their activities are equal, then their reaction potentials are equal, and conversely.

On the assumption that all of the determiners of reaction potential, with the exception of drive, are constant for two organisms, then:

Th. 3. If their reaction potentials are equal, then their drives are equal, and conversely.

On the hypothesis that two organisms have all of their needs and activities in common, and that their degrees of privation with respect to all of their needs, except the test need, are equal, then:

Th. 6. If the degree of privation of organism a with respect to the test need is less-than the degree of privation of organism b with respect to the test need, then the activity of a is less-than the activity of b, and conversely.

Th. 7. If their degrees of privation with respect to the test need are equal, then their activities are equal, and conversely.

On the hypothesis that two organisms have all of their needs and activities in common, and that their degrees of privation with respect to all of their needs, except the test needs, are equal, then:

Th. 10. If the activity level of organism a is less-than the activity level of organism b, then the reaction potential of a is less-than the reaction potential of b, and conversely.

Th. 11. If the activity level of organism a is equal to the activity level of organism b, then the reaction potential of a is equal to the reaction potential of b, and conversely.

Theorems 10 and 11 are interesting, because the test needs can differ for a and b. For example, theorem 11 asserts that if two organisms are deprived with respect to different needs, and if their activities are equal, then their reaction potentials are equal.

Theorems of the present system are designated "Th". Theorems from the theory of measurement are designated "T", after Leonard's practice.

Th.1. $\overrightarrow{N'a} = \overrightarrow{N'b}.\ ,y \in \overrightarrow{N'a}:.(x):x \in \overrightarrow{N'a}.x \neq y.\supset.$

$priv(a,x) = priv(b,x):.\supset.$

$priv(a,y) = priv(b,y) \equiv dr(a) = dr(b)$

Dem.

P1.*4.11 $\quad Hp(N,x,y,a,b).\supset.$

$\sim[priv(a,y) < priv(b,y)] \equiv \sim[dr(a) < dr(b)]$ (1)

(1)[b/a,a/b] $\quad Hp(N,x,y,b,a).\supset.$

$\sim[priv(b,y) < priv(a,y)] \equiv \sim[dr(b) < dr(a)]$ (2)

(1).(2).*4.38 $\quad Hp(N,x,y,a,b).\supset:$

$\sim[priv(a,y) < priv(b,y)].\sim[priv(b,y) < priv(a,y)].$

$\equiv .\ \sim[dr(a) < dr(b)].\sim[dr(b) < dr(a)]$ (3)

(3).T6.64.*4.11.Dual.DN QED

Th.2. $(\exists u):.(v):\overrightarrow{A'a} = \overrightarrow{A'b}.v \in \overrightarrow{A'a} \supset u=v:.\supset.$

$act(a) = act(b) \equiv dr(a) = dr(b)$

Dem.

Same proof as Th.1., starting with P2.

Th.3. $ef(a) = ef(b) \equiv dr(a) = dr(b)$

Dem.

Same proof as Th.1., starting with P3.

Th.4. $\overrightarrow{N}'a = \overrightarrow{N}'b . \supset_y : y \in \overrightarrow{N}'a :. (x) : x \in \overrightarrow{N}'a . x \neq y . \supset .$

$priv(a,x) = priv(b,x) :. \supset .$

$priv(a,y) < priv(b,y) \equiv ef(a) < ef(b)$

Dem.

.1 and .3 $\supset$ QED

Th.5. $\overrightarrow{N}'a = \overrightarrow{N}'b . \supset_y : y \in \overrightarrow{N}'a :. (x) : x \in \overrightarrow{N}'a . x \neq y . \supset .$

$priv(a,x) = priv(b,x) :. \supset .$

$priv(a,y) = priv(b,y) \equiv ef(a) = ef(b)$

Dem.

Same proof as Th.2., starting with Th.4.

Th.6. $\overrightarrow{N}'a = \overrightarrow{N}'b . \supset_y : y \in \overrightarrow{N}'a :. (x) : x \in \overrightarrow{N}'a . x \neq y . \supset .$

$priv(a,x) = priv(b,x) :. (\exists u) :. (v) : \overrightarrow{A}'a = \overrightarrow{A}'b .$

$v \in \overrightarrow{A}'a \supset u = v :. \supset . priv(a,y) < priv(b,y) \equiv act(a) < act(b)$

Dem.

.1.P2.*11.02.31.*3.47.*4.21.$\supset$::

$\overrightarrow{N}'a = \overrightarrow{N}'b . \supset_y : y \in \overrightarrow{N}'a :. (x) : x \in \overrightarrow{N}'a . x \neq y . \supset .$

$priv(a,x) = priv(b,x) :. (\exists u) :. (v) : \overrightarrow{A}'a = \overrightarrow{A}'b .$

$v \in \overrightarrow{A}'a \supset u = v :. \supset :$

$priv(a,y) < priv(b,y) \equiv dr(a) < dr(b) :$

$dr(a) < dr(b) \equiv act(a) < act(b)$ (1)

(1).*4.22 $\supset$ QED

Th.7. $\overrightarrow{N'a} = \overrightarrow{N'b} . \; , y \in \overrightarrow{N'a} :. (x) : x \in \overrightarrow{N'a} . x \neq y . \supset .$

$\text{priv}(a,x) = \text{priv}(b,x) :.$

$(\exists u) :. (v) : \overrightarrow{A'a} = \overrightarrow{A'b} . v \in \overrightarrow{A'a} \supset u = v :. \supset .$

$\text{priv}(a,y) = \text{priv}(b,y) \equiv \text{act}(a) = \text{act}(b)$

Dem.

Same proof as Th.1., starting with Th.6.

Th.8. $(\exists u) :. (v) : \overrightarrow{A'a} = \overrightarrow{A'b} . v \in \overrightarrow{A'a} \supset u = v :. \supset .$

$\text{act}(a) < \text{act}(b) \equiv \text{ef}(a) < \text{ef}(b)$

Dem.

P2 and P3 $\supset$ QED

Th.9. $(\exists u) :. (v) : \overrightarrow{A'a} = \overrightarrow{A'b} . v \in \overrightarrow{A'a} \supset u = v :. \supset .$

$\text{act}(a) = \text{act}(b) \equiv \text{ef}(a) = \text{ef}(b)$

Dem.

Th.2. and Th.3. $\supset$ QED

Th.10. $\overrightarrow{N'a} = \overrightarrow{N'b} . y, z \in \overrightarrow{N'a} :. (x) : x \in \overrightarrow{N'a} . x \neq y . x \neq z . \supset .$

$\text{priv}(a,x) = \text{priv}(b,x) :.$

$(\exists u) :. (v) : \overrightarrow{A'a} = \overrightarrow{A'b} . v \in \overrightarrow{A'a} \supset u = v :. \supset .$

$\text{act}(a) < \text{act}(b) \equiv \text{ef}(a) < \text{ef}(b)$

Dem.

*3.31 $[(\exists u) : (v) : \overrightarrow{A'a} = \overrightarrow{A'b} . v \in \overrightarrow{A'a} \supset u = v / p,$

$\text{act}(a) < \text{act}(b) \equiv \text{ef}(a) < \text{ef}(b) / r,$

$\overrightarrow{N'a} = \overrightarrow{N'b} . y, z \in \overrightarrow{N'a} :. (x) : x \in \overrightarrow{N'a} . x \neq y . x \neq z . \supset .$

$\text{priv}(a,x) = \text{priv}(b,x) / q] :: . \supset :: .$

$(\exists u):.(v):\overrightarrow{A'a} = \overrightarrow{A'b}.v \in \overrightarrow{A'a} \supset u = v:.\supset.$

$act(a) < act(b) \equiv ef(a) < ef(b)::\supset::$

$\overrightarrow{N'a} = \overrightarrow{N'b}.\not{y},z \in \overrightarrow{N'a}:.(x):x \in \overrightarrow{N'a}.x \neq y.x \neq z.\supset.$

$priv(a,x) = priv(b,x):.$

$(\exists u):.(v):\overrightarrow{A'a} = \overrightarrow{A'b}.v \in \overrightarrow{A'a} \supset u = v:.\supset.$

$act(a) < act(b) \equiv ef(a) < ef(b)$ (1)

TH.8.(1).*3.22.35 $\supset$ QED

Th.11. $\overrightarrow{N'a} = \overrightarrow{N'b}.\not{y},z \in \overrightarrow{N'a}:.(x):x \in \overrightarrow{N'a}.x \neq y.x \neq z.\supset.$

$priv(a,x) = priv(b,x):.$

$(\exists u):.(v):\overrightarrow{A'a} = \overrightarrow{A'b}.v \in \overrightarrow{A'a} \supset u = v:.\supset.$

$act(a) = act(b) \equiv ef(a) = ef(b)$

Dem.

Same proof as Th.10., starting with Th.9.

STATEMENT OF THE PROBLEM

The problem for the empirical part of this thesis was to put to experimental test certain of the theorems derived in the section on theory. Using water privation Theorems 4, 5, 6 and 7 were tested. Using food privation Theorems 4, 5, 6 and 7 were tested. Finally Theorem 11 was tested.

In combination with the above, two magnitudes of food reward and two magnitudes of water reward were used in training the animals, to determine whether there was any interaction between the amount of reward and the degree of privation.

PREDICTIONS

Using Theorem 4 we have:

Hyp. 1. With food privation, the greater the level of privation, the greater the force of response (Test data).

Hyp. 2. With food privation, the greater the level of privation, the greater the number of trials to extinction.

Hyp. 3. With water privation, the greater the level of privation, the greater the force of response (Test data).

Hyp. 4. With water privation, the greater the level of privation, the greater the number of trials to extinction.

Using Theorem 5 in conjunction with Hull's postulate on the magnitude of reward, we have:

Hyp. 5. With food privation, the force of response of the small reward group will be less than the force of response of the large reward group (Training data).

Hyp. 6. With water privation, the force of the response of small reward group will be less than the force of response of the large reward group (Training data).

Using Theorem 6 we have:

Hyp. 7. With food privation, the greater the level of privation, the greater the activity level (Test data).

Hyp. 8. With food privation, the greater the level of privation, the greater the activity on extinction days.

Hyp. 9. With water privation, the greater the level of privation, the greater the activity level (Test data).

Hyp. 10. With water privation, the greater the level of privation, the greater the activity on extinction days.

Using Theorem 7 we have:

Hyp. 11. There will be no differences in activity among the four sub-groups in the training series.

Using Theorem 11 we have:

Hyp. 12. For a given level of privation of food or water, where the activity level of a food privation animal is equal to the activity level of a water privation animal, the force of response of the food privation animal is equal to the force of response of the water privation animal.

SUBJECTS

The subjects used in the present study were 48 experimentally naive male albino rats from the colony maintained by the Department of Psychology of the Michigan State College. The ages of the animals at the beginning of their use as subjects ranged from 100 to 120 days.

APPARATUS

The apparatus used in the present problem was especially constructed for the series of problems of which this thesis is the third. Davis (8) and Smith (34) used the apparatus in their studies, and with one minor modification the apparatus is the same as they reported. The apparatus itself consists of a combination activity chamber and panel-pushing device, so constructed that one may obtain from it a measure of the activity of the experimental animal, as well as measures of response latency and the force with which the animal responds. It consists of a 1/2 inch plywood box with overall dimensions of 20 x 16 x 11 inches.

Figure 1 presents a cross-section of the apparatus. The bottom of the activity chamber was a false floor which was supported by three springs near the edge, and by a rubber ball at its center. At the four corners of the false floor, small, attached, rubber balls served as stops, preventing the floor from tipping more than 1/4 inch.

A guillotine door at one end of the activity chamber, when raised, gave access to a hinged 4 inch by 2 inch panel. This panel was constructed of rectangular piece of plywood, 1/16 inch thick. At the upper end of the panel a small piece of 1/2 inch plywood, 2-1/2 inches long was attached. This formed the base for hinge.

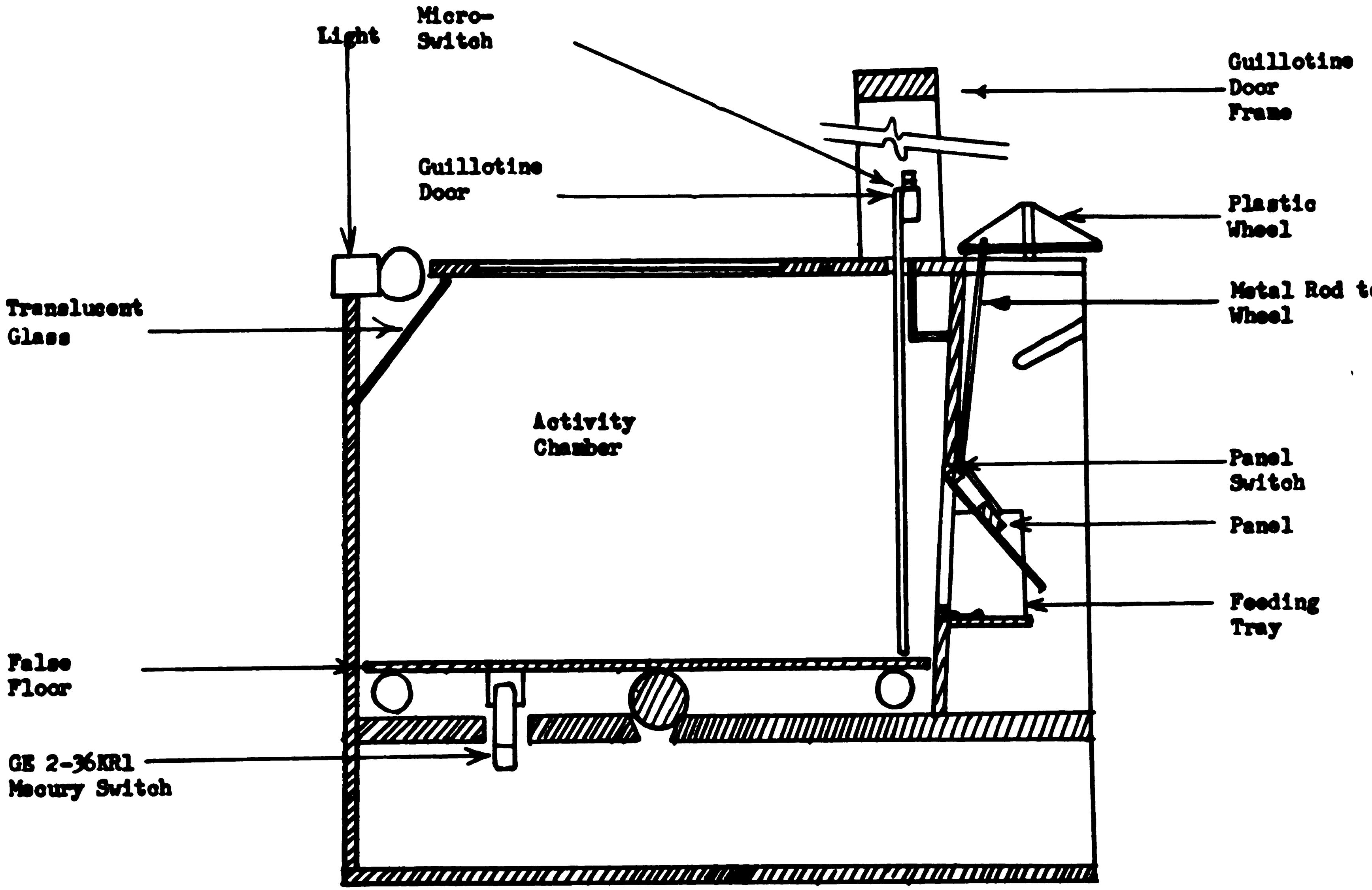

FIGURE 1. CROSS-SECTIONAL DRAWING OF APPARATUS

The flat grey interior was illuminated by a 7-watt bulb, located at the end of the box opposite the guillotine door. The bulb was covered by a piece of opal-flashed glass.

The box was entered from the top, through a 10-3/4 square inch hinged door. In the center of this door was a large clear-glass observation window.

Activity level was measured by a device consisting of a GE 2-36KRL mercury switch, suspended vertically beneath the false floor and connected in series with 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 floor to tip, causing the mercury in the tube of the switch to flow, momentarily making and breaking the circuit in accordance with the vigor and frequency of the movements of the animal.

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 placed that it "rode" back on the panel when the latter was pushed open, and at the same time the upper half of the rod came forward towards the activity chamber. By means of this rod, the force applied to the door was transmitted to a slender stick of wood which was glued to a light plastic wheel (a child's toy roulette wheel) mounted on a plastic axel. The force of the response, applied to the panel, was thus transmitted into rotary movement of the wheel.

The extent of movement of the wheel was read in degrees of angle. Because the wheel offered very little resistance to the metal rod, the initial movement of the panel caused it to turn out of the range of further movements of the rod. The extent of rotation of the wheel depended upon the initial force with which the panel was struck, not on the distance the panel was moved. Thus, force of response was read in degrees of rotation of the wheel.

Response latency is not considered in the present report because the experimenter feels that his own latency is confounded with the animal's response latency.

Single reward pellets were placed on a tray located 1/4 inch below the lower jamb of the panel. Metal walls were built up on either side of the tray to discourage exploratory behavior. The corners of these walls were bent toward the panel, forming stops to prevent the animal from forcing the panel and breaking it. On the tray itself, a small well of solder was constructed to hold the food pellet in place.

Water reward was administered through a curved glass tube attached by a rubber stopper to a burette. The burette was clamped to a standard ring stand, and the whole assembly was retractable. The tube was so adjusted that the end was located in the same position in which food pellets were placed.

PROCEDURE

That portion of the procedure which was common to all of the sub-groups will be presented first. We will then discuss the individual groups separately.

Habituation

All animals were handled for a period of 20 minutes on each of three days prior to their first experience in the apparatus. This handling consisted of stroking the animals, and allowing them to run about on top of a large table. On the fourth day each animal was placed in the activity box for a period of six minutes, during which time its activity level was recorded. These six-minute habituation trials continued for five days, or through the eighth day of the experimental series. This six-minute activity measure is standard for the entire experimental series. The activity measures obtained during the time period day 4 through day 8, inclusive, represent the initial activity levels of the animals under conditions of ad libitum feeding.

Training

On the ninth day each animal was given the regular six minutes in the box, during which time activity level was recorded. At the end of six minutes the guillotine door was

raised, allowing the animal access to the hinged panel. The panel was open to its fullest extent (approximately two inches) making the reward easily accessible to the animal. After the animal had taken the reward, the panel was closed, and the guillotine door was lowered. After a period of 30 seconds had elapsed, the guillotine door was again raised, presenting the animal with the open panel and the reward. This procedure continued for eight trials. On the ninth trial the panel was open only approximately 1/2 inch, so that the animal had to open the panel the rest of the way to obtain the reward. Another trial was given in the same manner, making a total of 10 rewarded responses for the day. The following day the entire procedure was repeated with the sole exception that for the first two trials the panel was open approximately 1/2 inch, and on the last eight it was closed all of the way. On the remaining six days of training each animal made 10 responses to the panel fully closed. At the end of training each animal had received 80 rewarded trials in the apparatus.

The six-minute activity level, before the trials of each training day, was recorded.

The force of the response for each trial was recorded on the last three training days.

All animals were trained on 22-1/2 hours of privation of the reward substance.

Testing

On the 17th day of the experimental series, testing was begun. The animals were randomly assigned to the particular privation level at which they would be tested on a given day. The appropriate privation manipulations were carried out (details to be specified below) and the animals were introduced into the apparatus. The six-minute activity level was recorded. Then the animals were given four rewarded trials on the panel, in exactly the same manner as on the last six days of training. The force of response was recorded for each of the four test trials. If a subject refused to respond for a period of six minutes it was removed from the apparatus, and the expression "NR" (no response) was recorded for that day's trials. Each animal was tested at each privation level considered, and the order of presentation of privation levels was randomized for each subject. Six privation levels were studied and there were seven testing days. The reason for the extra testing day is that one of the privation levels was 48 hours without food (water).

Extinction

On the 24th day of the series each animal was again assigned at random to one of the six privation levels. The animals were placed in the apparatus, the activity level was recorded, and extinction was begun. An extinction trial was conducted as was an ordinary testing trial, with the

exception that no reward was given the animal. Extinction trials were continued until an animal had refused to make a response for three consecutive minutes. An animal was considered to have responded if and only if it opened the panel and placed its nose in the position that it would have had to assume to get a reward. The force of each response was recorded, as well as the number of responses to criterion.

A summary of the procedure common to all groups follows:

Days 1 - 3	Handling, 20 minutes per day.
Days 4 - 8	Habituation in apparatus, six-minute activity level recorded.
Days 9 - 16	Training, 10 trials per day. Activity recorded on all days. Force of response recorded on days 14, 15 and 16.
Days 17 - 23	Testing, 4 trials per day under the appropriate privation conditions. Activity level and force of response recorded each day.
Day 24	Extinction, to a three minute criterion. Activity level and force of response recorded.

All animals were weighed at the beginning and end of the experimental series, and at least one other time during the series.

The main division of the present experiment is with respect to the privation substance. Half of the animals were deprived with respect to food and half were deprived with respect to water.

Of the 24 animals which were placed on food privation, 12 received a large reward pellet and 12 received a small reward pellet. The large pellets weighed, on the average,

0.32 gram. The small reward pellets weighed, on the average, 0.08 gram.

Of the 24 animals placed on water privation, 12 received a large water reward and 12 received a small water reward. The large water reward was, on the average, 0.20 cc. of water, and the small water reward was, on the average, 0.12 cc. of water.

On days 1 through 8 all animals were on an ad libitum feeding schedule. During the training series, the animals were on 22-1/2 hours food (water) privation. During the testing series, the animals were deprived for various numbers of hours, depending upon the particular random sequence of privations for any given animal. The privation levels studied were 1, 2, 6, 12, 22-1/2 and 48 hours. During the extinction series an animal was extinguished at only one of these six privation levels.

It was felt that any cumulative effect of privation would seriously impair the validity of the experimental results, so an attempt was made to keep the animals' weights as close to ad libitum weight as possible. To this end, one-half hour after each animal had completed his performance for a given day, it was allowed free access to a wet mash mixture and to water for a period of 45 minutes. During the testing series, animals were also allowed free access to the mash and water for 45 minutes just prior to the beginning of

their privation period. An exception to the general procedure is the case of 22-1/2 hours privation, where the single feeding time was lengthened to one hour.

Those animals deprived with respect to food (water) had water (food) available in their home cages at all times.

RESULTS

Activity level

The habituation activity levels of all 48 animals were broken out in terms of the sub-groups into which the animals would fall, and analysis of variance was done to determine whether there were differences in activity level with respect to the groups-to-be. The results of the analysis are presented in Table 1. There are no significant differences between groups-to-be. There are significant differences between the five habituation days. The general tendency is for activity level to decrease over the five-day habituation period (see Figure 2). The days-times-groups interaction term is not significant, indicating that all four groups-to-be behaved in the same way over the five habituation days.

Table 2 presents the results of an analysis of variance of the difference in activity level between the mean of the last two habituation days, and the first day of training. This analysis should indicate whether the change in privation, as such, is instrumental in bringing about an increase in activity. There were no differences between the four groups-to-be. The interaction term groups-times-days is not significant, indicating that all of the groups-to-be behaved in the same way. There is a significant difference between

TABLE 1

ANALYSIS OF VARIANCE OF THE HABITUATION ACTIVITY FOR THE FOUR GROUPS-TO-BE

Source of variance	d.f.	Sum of squares	F	p
Total	239	5,506,714.40		
Between animals	47	1,855,949.60		
Between groups	3	140,311.40	1.20	ns*
Between animals within groups	44	1,715,638.20		
Within animals	192	3,650,764.80		
Days	4	1,559,430.02	35.86	.01
Days x Groups	12	177,837.81	1.36	ns
Pooled animals x days interaction	176	1,913,496.97		

*ns denotes not significant

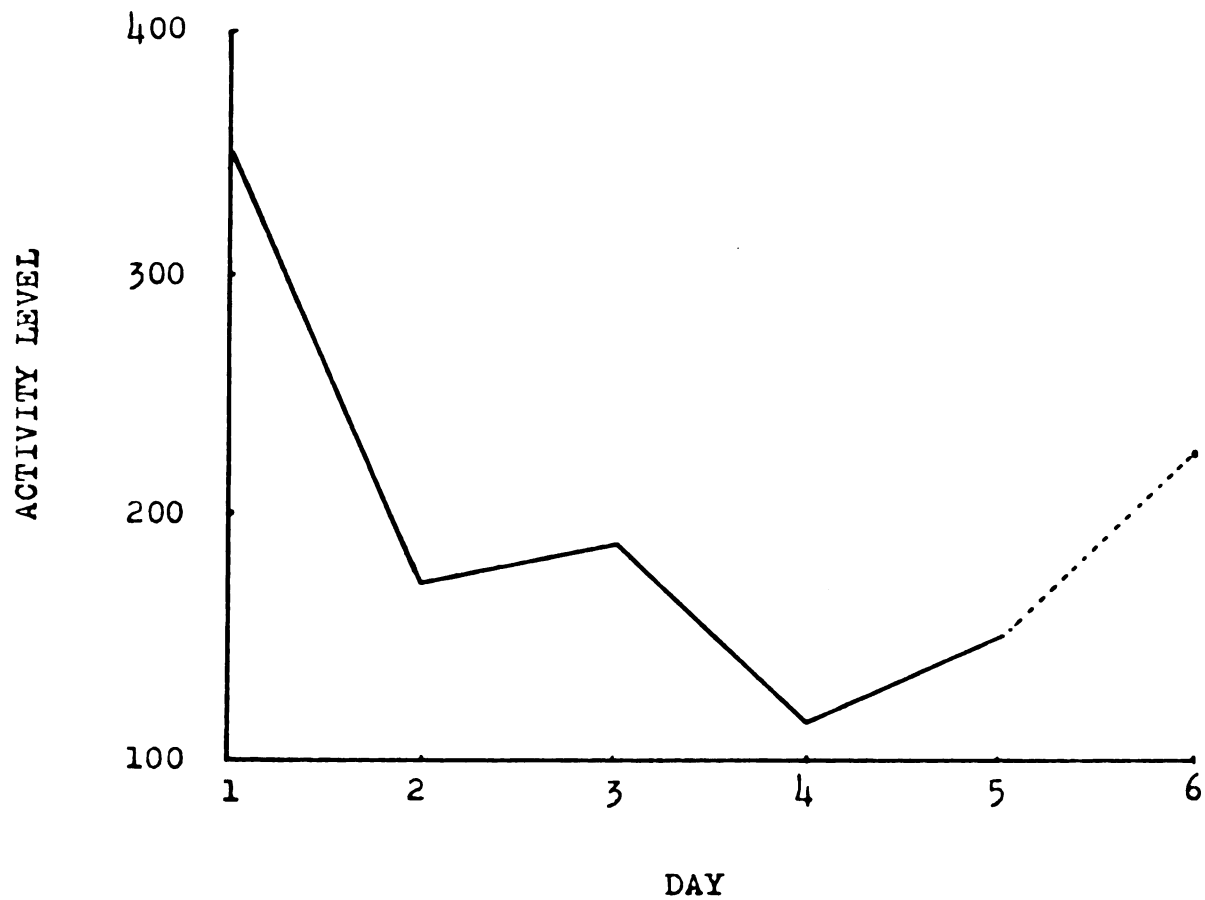

Figure 2. Activity level on each of the five habituation days, and on the first training day.

TABLE 2

ANALYSIS OF VARIANCE OF THE ACTIVITY DATA COMPARING THE FIRST DAY OF TRAINING WITH THE MEAN OF THE LAST TWO HABITUATION DAYS

Source of variance	d.f.	Sum of squares	F	p
Total	95	1,232,864.99		
Between subjects	47	705,139.49		
Between groups	3	39,178.49	<1	ns*
Between subjects within groups	44	665,961.12		
Within subjects	48	527,725.50		
Days	1	217,646.26	33.70	.01
Days x Groups	3	25,910.11	1.34	ns
Error	44	284,169.13		

*ns denotes not significant

days, indicating that the change from ad libitum feeding and watering conditions to 22-1/2 hours privation did significantly increase activity level.

The analysis of variance of activity on the training series is given in Table 3 (see also Figure 3). There are differences significant at the five percent level of confidence between: (1) the four sub-groups, (2) large and small reward, and (3) successive training days. The difference between sub-groups can be attributed to the difference between large and small reward, since the differences between food and water, and the interaction term food-water-times-large-small-reward, were not significant. Thus, hypothesis 11 is not denied by these results. There was a general tendency for activity level to increase with successive days of training, in the case of the large food reward group only.

The analysis of the activity levels on the testing series is given in Table 4. Inasmuch as there were differences in the training data, introduced by the use of two levels of reward, the analysis of the testing activity is a covariance analysis.

Table 4 shows significant differences between privation levels. The F-value for this factor was significant beyond the one percent level of confidence. More interesting than this result, however, is the finding of significant F-values for the two interaction terms food-water-times-privation

TABLE 3

ANALYSIS OF VARIANCE OF THE ACTIVITY DATA FOR THE TRAINING SERIES

Source of variance	d.f.	Sum of squares	F	p
Total	383	13,310,719.40		
Between animals	47	7,689,586.10		
Between groups	3	1,465,872.60	3.37	.05
Food vs water	1	323,292.16	2.23	ns*
Large vs small	1	930,234.44	6.42	.05
Food vs water x Large vs small	1	212,346.00	1.47	ns
Between animals within groups	43	6,223,713.50		
Within animals	336	5,621,133.30		
Days	7	231,818.50	2.09	0.5
Days x Groups	21	503,905.50	1.51	ns
Days x food-water	7	176,519.74	1.59	ns
Days x large-small	7	170,911.54	1.54	ns
Days x food-water x large-small	7	156,474.22	1.41	ns
Pooled animals x days interaction	308	4,885,409.30		

*ns denotes not significant

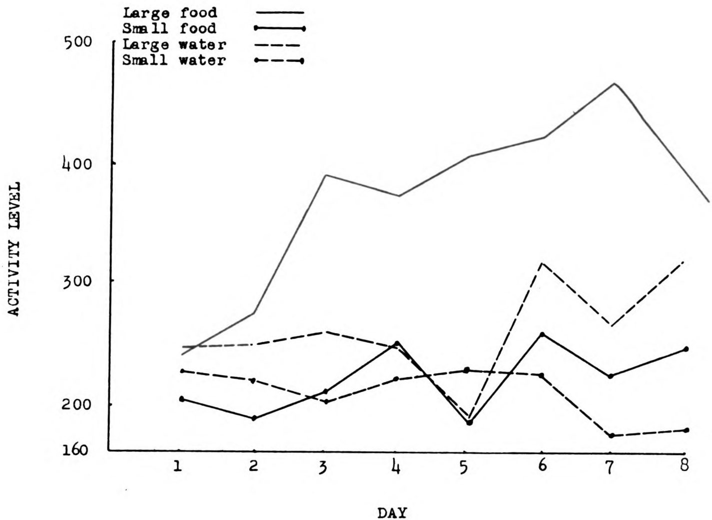

Figure 3. Activity level on each of the eight training days for four experimental groups.

TABLE 4

ANALYSIS OF CO-VARIANCE OF ACTIVITY LEVEL ON THE TESTING SERIES

Source of variance	d.f.	Sum of squares	F	p
Total				
Deprivation	5	692,590.40	12.97	.01
Animals	47	2,815,729.99	5.61	.01
Groups	3	179,291.98	1.50	ns*
Food-water	1	53,243.28	1.33	ns
Large-small	1	85,564.26	2.14	ns
Food-water x Large-small	1	21,321.37	<1	ns
Between animals within groups	43	1,715,892.77		
Animals x Deprivation				
Groups x Deprivation	15	604,557.10	3.77	.05
Food-water x Deprivation	5	291,407.12	5.46	.01
Large-small x Deprivation	5	182,989.30	3.43	.01
Food-water x Large-small x Deprivation	5	126,962.09	2.38	.05
Error	219	2,339,737.83		

*ns denotes not significant

level and large-small reward-times-privation levels. The significance of the food-water-times-privation level interaction term indicates that the food groups did not behave in the same way over the privation levels as did the water groups. Reference to Figure 4 and to Table 5 indicates that only the large food group deviated from the trend of the water groups. These data do not support either hypotheses 7 or 9.

The large-small-reward-times-privation level interaction term was significant for the same reason that the food-water-times-privation level interaction term was; i.e., the large food group deviates from the trend of the other groups. It is noteworthy that the large food group deviates from the trend of the other groups only with respect to the early privation levels. Table 5 is included to point up these differences in trend.

A remark on the reliability of measurement of activity is in order at this point. Johnson (19, p. 136) recommends the use of the error term and the individual mean square in estimating the reliability of measurement. We obtain an estimate of the reliability coefficient if we subtract from unity the ratio of the error mean square to the individual mean square. Using this procedure, with the results of the analysis of variance of the activity data for the training series, we have as an estimate of the reliability coefficient, $r_{xx} = 0.91$.

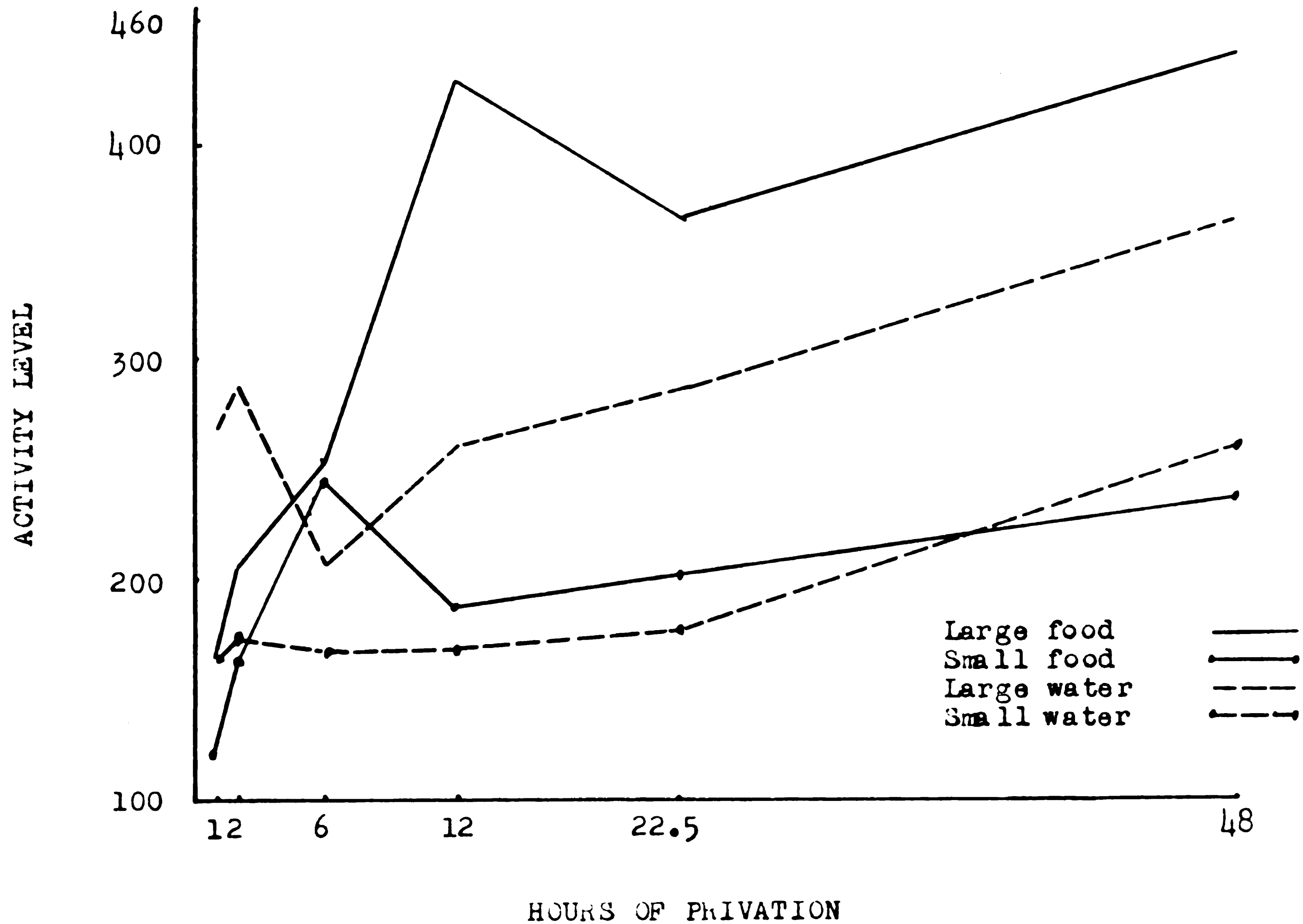

Figure 4. Activity level on each of six levels of privation for four experimental groups.

TABLE 5

PATTERN OF DIFFERENCES, SIGNIFICANT AT THE ONE PERCENT LEVEL OF CONFIDENCE, FOR THE TESTING ACTIVITY FOR THE FOUR GROUPS

	Water										Food									
	Small					Large					Small					Large				
	Hours of privation					Hours of privation					Hours of privation					Hours of privation				
	2	6	12	22.5	48	2	6	12	22.5	48	2	6	12	22.5	48	2	6	12	22.5	48
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.01	.01	.01
2		-	-	-	-		-	-	-	-		-	-	-	-		-	.01	.01	.01
6			-	-	-			-	-	-			-	-	-			.01	.01	.01
12				-	-				-	-				-	-				-	-
22.5					-					-					-					-

Table 6 summarizes the results of analyses of variance of activity on the extinction day. It is seen that none of the F-values is significant. Hypotheses 8 and 10 are not supported.

Force of response

For the training series, force of response was recorded only for the last three training days. The analyses of these data, using the mean force of response for each animal for each day, are given in Tables 7 and 8.

Table 7 presents the results of the analysis for the food groups. None of the F-values is significant, indicating no differences in force of response attributable to size of reward, and no differences in force of response on the last three days of training. The lack of significance in the interaction term groups-times-days, indicates that both groups behaved similarly on the last three days (see Figure 5). These results, with respect to size of reward, do not support hypothesis 5. These results, with respect to differences between days, indicate that the habit for the panel pushing response was at a maximum by the end of training. It was hoped that this would be the case for valid results on the testing data.

Table 8 presents the results of the analysis of variance of the force of response on the training series for the water reward groups. The total degrees of freedom here are 41

TABLE 6

SUMMARY OF THE ANALYSES OF VARIANCE OF ACTIVITY AT EXTINCTION

Source of variance	d.f.	F	p
Water-food	1	< 1	ns*
Large-small	1	< 1	ns
Groups	3	1.16	ns
Deprivation	5	< 1	ns

*ns denotes not significant

TABLE 7

ANALYSIS OF VARIANCE OF FORCE OF RESPONSE ON THE LAST THREE DAYS OF TRAINING FOR THE FOOD GROUPS

Source of variance	d.f.	Sum of squares	F	p
Total	71	3,154.089		
Between animals	23	2,054.842	< 1	ns*
Groups (Large-small)	1	3.167	< 1	ns
Between animals within groups	22	2,051.675		
Within animals	48	1,099.247		
Days	2	37.406	< 1	ns
Days x Groups	2	52.795	1.15	ns
Pooled animals x trials interaction	44	1,099.046		

*ns denotes not significant

TABLE 8

ANALYSIS OF VARIANCE OF FORCE OF RESPONSE ON THE LAST THREE DAYS OF TRAINING FOR THE WATER GROUPS

Source of variance	d.f.	Sum of squares	F	p
Total	41	3,445.736		
Between animals	13	1,821.169		
Groups (Large-small)	1	1,010.381	14.95	.01
Between animals within groups	12	810.788		
Within animals	28	1,624.567		
Days	2	78.832	<1	ns*
Days x Groups	2	350.917	3.52	0.5
Pooled animals x trials interaction	24	1,194.818		

*ns denotes not significant

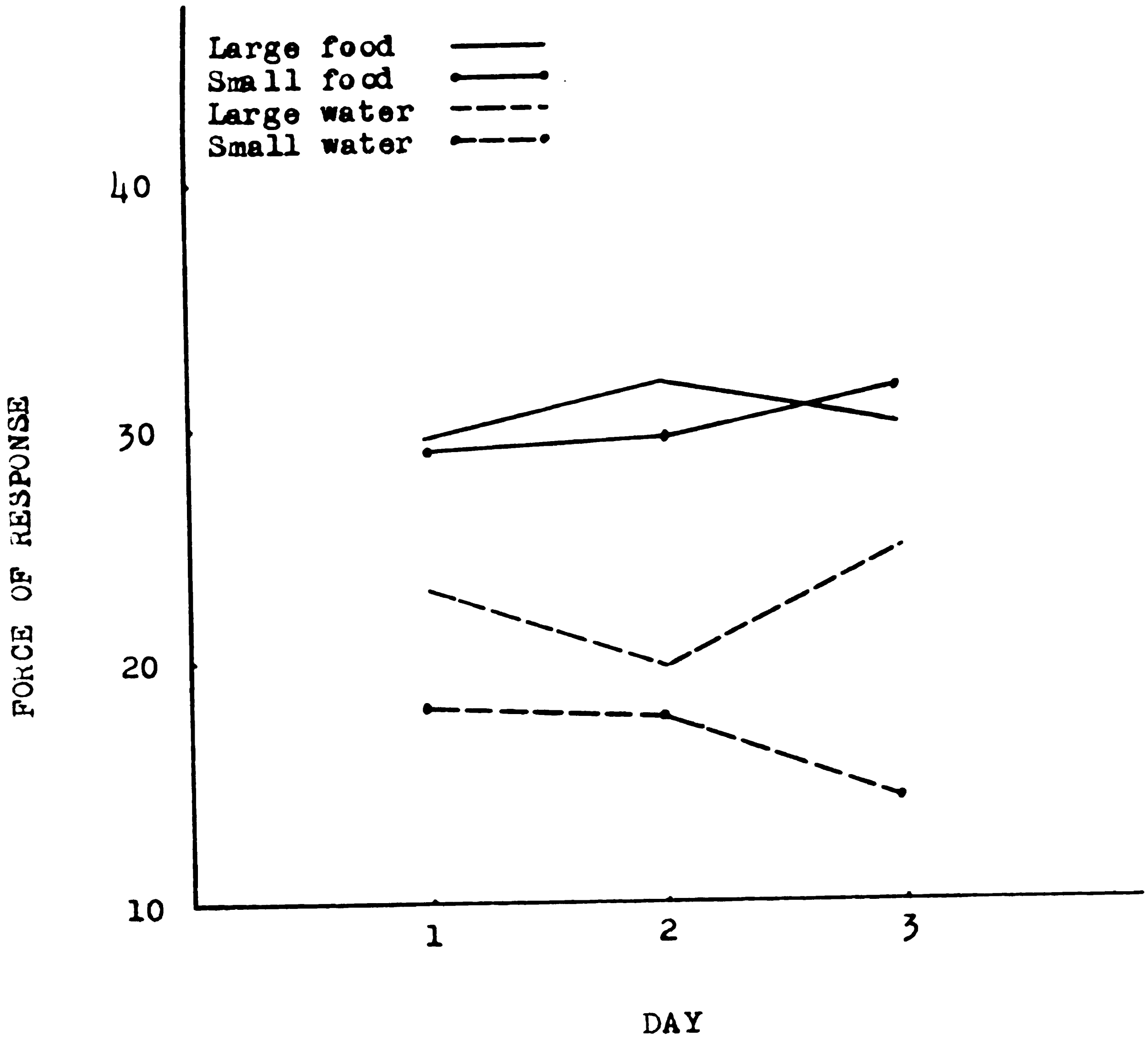

Figure 5. Force of response on the last three days of training for four experimental groups

instead of 71, as in Table 7. This is due to the fact that data for 10 animals were not available. The difference for size of reward is significant beyond the one percent level of confidence. This result supports hypothesis 6, since it is the small reward group which showed the smaller mean force of response. There were no significant differences over the last three days of training. The significance of the interaction term size of reward-times-days reflects the fact that the small reward group shows a steady decline in force of response over the last three days of training, while the large reward group does not (see Figure 5).

Estimates of reliability of measurement of force of response give $r_{xx} = 0.95$ for the food groups, and $r_{xx} = 0.91$ for the water groups.

Table 9 presents the results of the analysis of variance of the force of response on the training series. The original data were not homogeneous, and hence a square root transformation was used. The data for this analysis were obtained by averaging the four test trials for each privation level for each animal.

In Table 9 the F-value for privation levels was significant beyond the one percent level of confidence, indicating an increased force of response with increased privation. The only other significant F-value was the interaction term size of reward-times-privation level. This interaction term was significant because the large food reward group showed an

TABLE 9

ANALYSIS OF VARIANCE OF FORCE OF RESPONSE ON THE TESTING DATA

Source of variance	d.f.	Sum of squares	F	p
Total	287	301.4347		
Deprivation	5	37.448	15.16	.01
Animals	47	144.097	6.95	.01
Groups	3	5.203	< 1	ns*
Food-water	1	2.151	< 1	ns
Large-small	1	2.411	< 1	ns
Food-water x Large-small	1	0.641	< 1	ns
Between animals within groups	44	133.691		
Animals x Deprivation	235	119.889		
Groups x Deprivation	15	11.230	1.52	ns
Food-water x Deprivation	5	3.502	1.42	ns
Large-small x Deprivation	5	6.323	2.56	.01
Food-water x Large-small x Deprivation	5	1.405	< 1	
Error (pooled animals x deprivation)	220	108.659		

*ns denotes not significant

increase in force of response with increased privation, over the early privation levels, while the other groups did not. See Figure 6 and also Table 10. These results do not support either hypotheses 1 or 3.

Table 11 summarizes the results of analyses of variance of the number of trials to extinction. None of the F-values is significant. Hypotheses 2 and 4 are not supported.

According to hypothesis 12 there should be a strong positive Pearson product-moment correlation coefficient between the force of response of animals in the water groups and animals in the food groups, when the animals are matched according to activity level. Comparison of the activity levels of the food and water group animals disclosed 55 cases when the hypothesis of Theorem 11 was satisfied. Since the correlation of 0.12 is less than its standard error (0.13), hypothesis 12 is not supported.

The validity of the theory of drive

We are here concerned with empirical validity. The reader will recall that the consequences of the three primitive sentences were set up in terms of the relation less-than. This relation is an ordering relation, and implies linearity. In terms of our present experiment this means that there should be a linear relation between hours of privation and activity, and between hours of privation and force of response. Since significant differences were

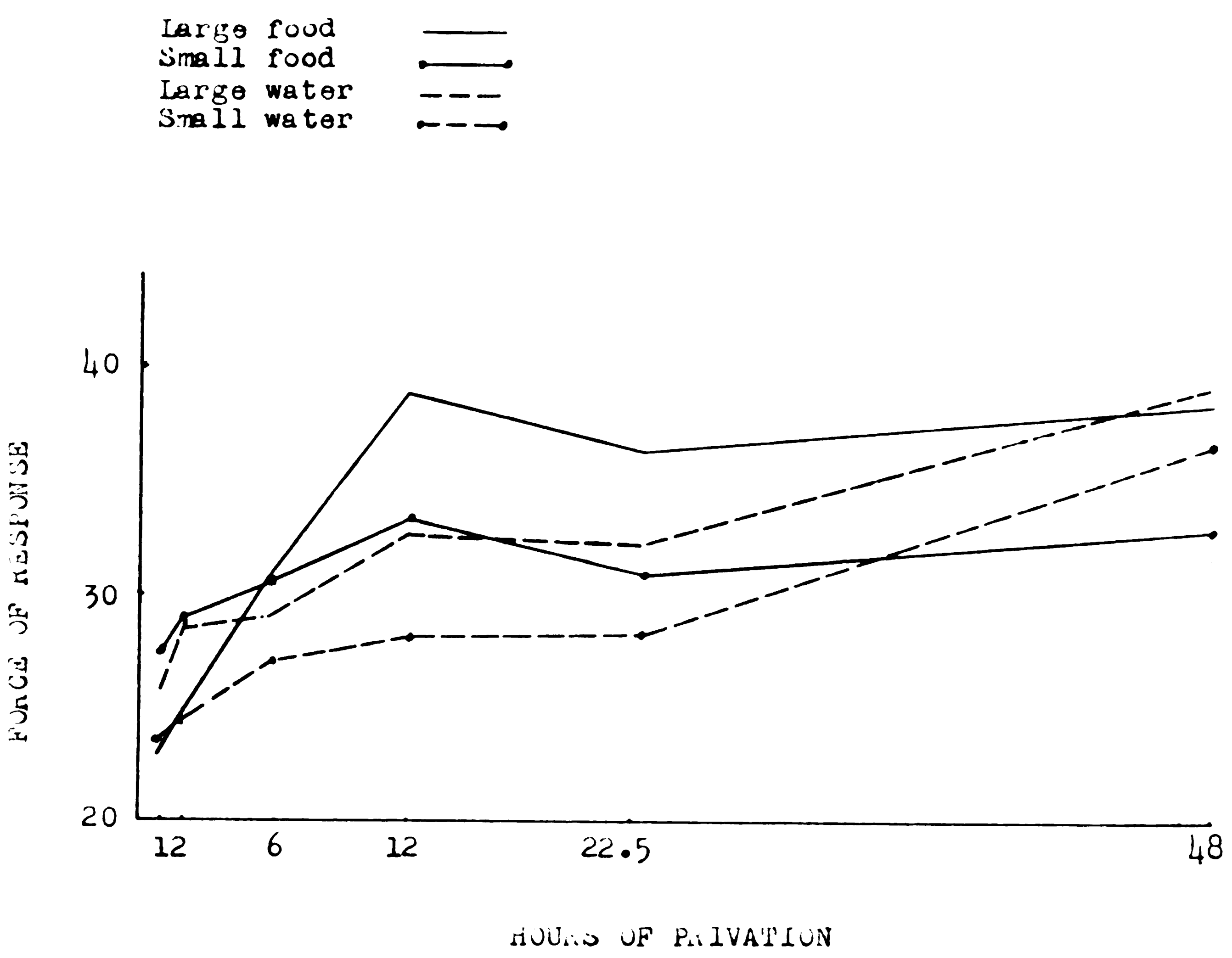

Figure 6. Force of response on each of six levels of privation for four experimental groups.

TABLE 10

PATTERN OF DIFFERENCES, SIGNIFICANT AT THE ONE PERCENT LEVEL OF CONFIDENCE, FOR THE TESTING OF FORCE OF RESPONSE FOR THE FOUR EXPERIMENTAL GROUPS

	Water										Food									
	Small					Large					Small					Large				
	Hours of privation					Hours of privation					Hours of privation					Hours of privation				
	2	6	12	22.5	48	2	6	12	22.5	48	2	6	12	22.5	48	2	6	12	22.5	48
1	-	-	-	-	.01	-	-	-	-	.01	-	-	-	-	-	-	-	.01	.01	.01
2		-	-	-	.01		-	-	-	.01		-	-	-	-		-	.01	.01	.01
6			-	-	.01			-	-	.01			-	-	-			-	-	-
12				-	-				-	-				-	-				-	-
22.5					-					-					-					-

TABLE 11

SUMMARY OF ANALYSES OF VARIANCE OF THE NUMBER OF TRIALS TO EXTINCTION

Source of variance	d.f.	F	p
Water-food	1	<1	ns*
Large-small	1	<1	ns
Groups	3	2.12	ns
Deprivation	5	1.15	ns

*ns denotes not significant

demonstrated between both of the test variables with respect to hours of privation, we are in a position to test the implications of the use of the relation less-than.

Table 12 presents the analysis of variance of deviations from linearity for the activity data of the testing series. It is seen that the F for deviations from linearity is not significant. Hence, the implications of the use of the less-than relation are supported for the activity data.

Table 13 presents the analysis of variance of the deviations from linearity for the force of response data of the testing series. It is seen that the F for deviations from linearity is not significant. Hence, the implications of the use of the less-than relation are supported for the force of response data.

In consequence, we may say that the present experiment is an adequate model for the theory of drive, at least within the range of privations used.

The least squares regression of the activity data on hours of privation is

$$a = 2.8446h + 202.1159$$

The least squares regression of force of response on hours of privation is

$$f = 0.0218h + 5.1889$$

TABLE 12

ANALYSIS OF VARIANCE OF DEVIATIONS FROM LINEARITY FOR ACTIVITY ON THE TESTING SERIES

Source of variance	d.f.	Sum of squares	F	p
Deprivation	5	694,074.230		
Linearity	1	627,183.095		
Deviat. fm. linear.	4	66,891.135	1.57	ns*
Error	220	2,340,056.82		

*ns denotes not significant

TABLE 13

ANALYSIS OF VARIANCE OF DEVIATIONS FROM LINEARITY FOR THE FORCE OF RESPONSE ON THE TESTING SERIES

Source of variance	d.f.	Sum of squares	F	p
Deprivation	5	37.4484		
Linearity	1	32.9334		
Deviat. fm. linear.	4	4.5150	2.29	ns*
Error	220	108.6587		

*ns denotes not significant

DISCUSSION

The discussion of the results of the present study will be divided into three sections. We will consider first the implications of the study for activity as a measure of drive. Secondly, we will consider the results of the study with reference to the concept drive. Finally, the notion of need will be considered.

Activity as a measure of drive

The fact that activity level drops during the five habituation days supports the findings of Smith (34), in the same situation. It seems to take approximately five days to establish a consistent level of activity, from which we may work. This reduction is certainly not the result of a reduction in privation, since the animals were on an ad libitum feeding schedule on all five days, but seems more due to the reduction in the amount of exploratory behavior in which the animals engage.

The finding of a significant increase in activity from the last two days of the habituation series to the first day of the training series, would seem to indicate that the increase in privation was responsible for the increased activity. There is, however, an alternative explanation. It is possible that the change in privation conditions,

independently of the fact that the change was an increase, resulted in increased activity. There are some studies which seem to suggest this (8, 9, 4), although their results are not a sufficient test. Some unpublished work from the Michigan State College laboratory bears more directly on this point*. Water privation was utilized, and activity was recorded over a ten-day period. Precautions were taken to see that the animals had no opportunity to associate water reward with the activity chamber. Four groups, of four animals each, were run. Two of the groups were on the same conditions of privation throughout the 10-day period, one group deprived for 3-5 hours, and the other for 18-20 hours. Two groups were switched on privation levels half way through the 10-day period; one group being switched from 3-5 to 18-20 hours privation, and the other being switched from 18-20 to 3-5 hours privation. Both of the groups which were switched on privation levels showed an increase in activity level from the first 5 days to the last 5 days. Neither group which remained at the same privation level showed any increase in activity from the first to the last 5 days. Furthermore, the difference between 3-5 and 18-20 hours of privation was not significant. These results support the assumption that the increase in activity level from the last days of habituation to the first day of training, in the

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*Behan, R. A. and Campbell, F. Activity under two levels of water privation, in the rat. Unpublished.

present study, was due to the change in privation conditions, and not to the increase in privation, as such.

The results of Smith (34) and Davis (8) pointed to the existence of an anticipatory learning factor as influencing activity. In the present study, the fact that the large food reward group showed an increase in activity during the eight days of training, points to the same conclusion. Also, the existence of significant interaction terms between food-water and privation level, and between large and small reward and privation level, points to the same conclusion. It might be thought that such a result would be the consequence of the particular apparatus used in the present study. That is, due to the fact that the activity measures were taken in the same apparatus in which the animals learned the panel-pushing response. This is doubtful, however, since the other three sub-groups did not show a similar increase in activity during the training series. If association with reward, as such, were a sufficient condition for an increase in activity, one would expect that these sub-groups would have shown an increase in activity parallel to the increase of the large food reward group. It would appear, from the present results, that some minimal amount of reward is necessary.

With respect to the results with activity on the testing series, it is obvious that activity is not determined by hours of privation of food or water. Here again, activity

level seems more dependent upon the amount of reward given in the situation, and the change of privation conditions. Only the large food group shows the increase in activity with increased hours of privation, and this only with respect to the lower levels of privation as contrasted with the higher levels.

It is well known that activity is a complexly determined aspect of the animal's behavior (10, 13, 26, 27, 28, 29, 30, 34, 39). The implication of the present series of studies, that the amount of reward that animals are given in a particular situation influences the amount of activity that the animals display in that situation, merely adds one more factor to be considered, if one attempts to use activity as a measure of drive. Drive is conceived as a unitary construct. To attempt to measure a unitary thing by reference to a multiply-determined aspect of behavior like activity, seems a little ridiculous.

There is also a question of precision of measurement. The results of the testing series suggest that there must be some substantial change in the level of privation, since differences occur only after 12 hours of privation. If drive is supposed to increase with each hour of privation, activity level does not reflect this fact. Further, it is believed that this insensitivity of activity to changes in drive is not due to the apparatus used. The rat could make the counter run very swiftly by merely sitting and scratching.

It is noteworthy that the writer could find no studies of activity as a function of privation where privation intervals were less than 12 hours.

The implications of the present study are that activity level would not be a satisfactory indicator of the magnitude of drive.

The theory of drive

The theory of drive presented in the second section of the present thesis has not stood the experimental test. Of the 12 hypotheses tested, 10 were not confirmed. Four hypotheses were derived from Theorem 4. Theorem 4 is to the effect that reaction potential will vary with hours of privation. Two hypotheses were concerned with privation with respect to food. Of these, hypothesis 1 used force of response as a measure of reaction potential, and hypothesis 2 used the number of trials to extinction as an indicator of reaction potential. Hypothesis 1 failed in the case of the small food reward group, but was supported in the case of the large food reward group. Hence hypothesis 1 fails. Hypothesis 2 failed in the case of both reward groups.

Two of the hypotheses derived from Theorem 4 were concerned with water privation. Of these, hypothesis 3 used the force of response as a measure of reaction potential, and hypothesis 4 used the number of trials to extinction as a measure of reaction potential. Both of these hypotheses failed for the large and the small water reward groups.

Theorem 4 was not supported.

Two hypotheses were derived from Theorem 5 in conjunction with Hull's postulate on the magnitude of reward. Hypothesis 5: with food privation, using the training data, the force of response of the small reward group will be less than the force of response of the large reward group. Hypothesis 5 was not confirmed. Hypothesis 6: with water privation, using the training data, the force of response of the small reward group will be less than the force of response of the large reward group. Hypothesis 6 was confirmed. The question arises, was the failure of Hypothesis 5 due to failure of the drive theory, or failure of Hull's postulate on the size of reward. The result with Hypothesis 5 is exactly what would have been expected if we had not used two sizes of reward in the two groups, hence the conclusion is that the failure of Hypothesis 5 is not due to the failure of the drive theory.

Theorem 5 was supported.

Four hypotheses were derived from Theorem 6. Two of these are concerned with food privation. Hypothesis 7: using the test series activity, the greater the privation the greater the activity. Hypothesis 7 was not supported in the case of the small food reward group. Hypothesis 8: using the extinction series activity, the greater the privation the greater the activity. Hypothesis 8 was not supported. Two of the hypotheses derived from Theorem 6

were concerned with water privation. Hypothesis 9: using the test series activity, the greater the privation the greater the activity. Hypothesis 9 was not supported. Hypothesis 10: using the extinction series activity, the greater the privation the greater the activity. Hypothesis 10 was not supported.

Theorem 6 was not supported.

Theorum 7 was tested with only one hypothesis, number 11. Hypothesis 11 asserted that there would be no differences among the sub-groups, with respect to activity, on the training series. The differences among the sub-groups that appear are due to the use of two sizes of food reward, hence Hypothesis 11 is not disconfirmed. In this connection see the discussion of Hypothesis 5, above.

Theorem 7 was supported.

A single hypothesis, number 12, tests Theorem 11. Hypothesis 12 failed.

Theorem 11 was not supported.

There is no consistent pattern of support and failure for the experimental hypotheses. If Theorem 11 had been supported, we could have said that those hypotheses involving the relation less-than failed, and those involving the relation identity were supported. However, Theorem 11 failed. We must conclude that there is something wrong with the theory of drive.

The theory of drive has three primitive sentences. The first of these reduces drive in terms of privation with respect to a need. The second reduces drive in terms of general activity. The third relates drive to the rest of the Hullian system. Postulates 2 and 3 are necessary for empirical test of the theory. We have already discussed activity, and noticed two draw-backs. First, activity is multiply-determined; and second, activity is not a sufficiently precise measure of drive.

We will not here concern ourselves with postulate 3, since it is forced upon us by external considerations.

Before we examine postulate 1, it will be necessary to consider some different usages of the term drive. There are three usages of the term drive which are common in present day psychology. The first of these is to consider that drive is a stimulus (12, 14, 24, 3). This is perhaps the oldest, and just beginning to come back into the literature. Before this notion of drive will become useful, it will be necessary to clarify the notion stimulus. Very little has been done along this line, and this usage of the term drive is outside the scope of the present thesis, hence we will go on to other uses of the word.

The remaining two usages of the term drive differ, not as to the function which drive plays in the explanation of behavior, but rather in the degree of abstractness with which the term is considered. Both usages depend upon the prior

assumption of need; assuming that it is possible to withhold some environmental support, and thus deprive the animal with respect to that environmental support, i.e., with respect to that need. The first notion of drive: drive(1), abstracts away completely from the specificity of need (16, 23, 37). As Munn puts it "... drives, as such are usually blind. They activate, it is true, but most of them do not, until learning has occurred, turn activity into appropriate channels." (26, p. 84). The second usage of the term drive: drive(2), is much less abstract than the first, and some individuals seem to use the term almost synonymously with the term need (33, 39). It differs from the concept need in that the drive activates the animal, but the activity is more or less specific, depending upon the need with respect to which privation occurs. For example, privation of water (food) results in water (food) seeking behavior on the part of the animal. We will confine our remarks to the latter two notions of drive.

The present thesis has its origin in a test of drive(1). However, as was pointed out, both drive(1) and drive(2) assume that privation with respect to a need results in the animal's being activated. In this sense the present thesis is a test of both notions. If Hypothesis 12 had been the only hypothesis denied by the present study, it would have been possible to fall back on drive(2). However, the denial of Hypotheses 7, 8, 9 and 10, also, makes this impossible.

Reference to Table 5 will make it plain that privation with respect to a need, per se, does not result in increased activity. Indeed, within the limits of the present study, it would seem that a learned anticipation and the amount of reward were the most important factors. Hence, the present experimental results legislate against both of the notions drive(1) and drive(2).

The category of need

This section will constitute an attempt at a speculative account of the reason for the failure of the theory of drive. The notion of drive rests upon the prior notion of need. The kinds of needs which psychologists assume are taken from the common-sense mythology of everyday life. In this respect psychology does not differ from the other sciences. The scientific enterprise is characterized by the fact that the scientist begins with common-sense. The contributions of science consist in the modifications of that with which they start.

With this observation in mind we may look to the notion of need as one of the sources of the present failure of drive. If the basic notion is faulty the derivative notion must also be faulty. In his treatment of the notion of need, Hyll may be taken as typical of psychologists in general. Hull considers the needs of animals as independent of each other. Animals have needs for food, water, air, avoidance of tissue injury, maintenance of an optimum temperature, defecation, urination, rest, sleep and activity. These of course are only the primary needs. Other psychologists, for example Lewin (23), would include a large number of other kinds, including some that are learned. Each of these needs acts independently, and then the results of the individual action is summated to give an over-all effect.

The thesis of the present section is that this notion of need is singularly simple-minded, and thus fallacious. It will be argued that the different needs listed above, as well as the learned needs that an individual may acquire, do not act independently of each other. The mode of action of needs is rather to be considered as an interaction. Furthermore, the conception that equal hours of privation with respect to a need results in equal drives, is likewise an over simplification. If needs interact with one another, then it is meaningless to speak of equal hours of privation with respect to a need. In other words, the denial of the independent action of needs necessitates a denial of the assumption that equal hours of privation with respect to a need result in equal effects.

The evidence for the above position is sketchy, and incomplete. However, there is some. The studies of Verplanck and Hayes (38), Finger and Reid (10), and Calvin and Behan (5) all indicate that there is an interaction effect between food and water privation. If animals are deprived

of food they automatically cut down their water intake, and also, if animals are deprived of water they automatically cut down their food intake. It is conceivable that there is no need for food or water, but that there is a need for an optimal food-water balance, and that the animal adjusts its intake of the one substance when deprived of the other, in such a way as to maintain this balance.

This interaction effect is conceivable, with respect to all sorts of nutritive substances. It is well known, now, that the proper utilization of organic food substances requires the presence of certain minerals in minimal amounts. Furthermore, it is not inconceivable that many kinds of substances might interact with each other _to constitute a need_.

It is thus seen, that the objection here is not to the notion of need, but rather to what constitutes a need, and how needs are classified. It should, however, be noted that a simple reclassification of needs will not allow one to go back to the rather simple minded assumption that equal hours of privation with respect to a need have equal effect on the animal, regardless of the need. For example, in the present study, the large food group showed no increase in activity until 12 hours of privation had elapsed. Animals deprived of water showed no increase in activity over the entire testing range. The force of response data yielded similar results, with the exception of the 48 hour privation level. On the other hand, animals deprived of air, become active immediately,

but only for short periods of time. Similar behavior patterns are seen in the case of certain learned needs. For example, the anxiety that arises when certain individuals are deprived with respect to learned needs may be the same kind of phenomenon.

The present notion would not be hard to test, in a preliminary way, at least with food and water. If there is an optimal food-water balance for the rat, and presumably for other animals also, then the ratio of food intake to water intake should be a constant, or should vary in a systematic way, under different conditions of privation. A number of studies have shown a consistent food-water intake ratio when animals are on ad libitum feeding schedules. They have also shown constant reductions in either food or water intake, when privation is with respect to water or food (5, 10, 11, 28, 31, 32, 35, 38). In other words, present evidence encourages the view, but is insufficient to maintain it systematically.

SUMMARY AND CONCLUSIONS

The present thesis was concerned with a test of the Hullian theory of drive, using privation with respect to food and with respect to water. The position was formalized, and consequent theorems were tested.

A combined activity box and panel-pushing device was used in the present study. The panel-pushing device was so arranged to provide a measure of force of response, and of the number of trials to extinction.

Forty-eight male albino rats were used as subjects in the study, and were divided into two major groups:

1. twenty-four animals deprived of water;
    a. twelve animals given a large reward (0.20 cc.)
    b. twelve animals given a small reward (0.12 cc.)
2. twenty-four animals deprived of food;
    a. twelve animals given a large reward (0.32 gm.)
    b. twelve animals given a small reward (0.08 gm.)

All animals were given habituation training in the apparatus during the first five days of the experiment, while on an ad libitum feeding schedule. Activity level was recorded.

On days 6 through 13 all animals were trained on the panel-pushing task, under 22-1/2 hours of appropriate privation and reward. Each animal was given ten trials per day.

The implications of the study for activity as a measure of drive, and for drive as an explanatory construct, were discussed.

The category of need was discussed, and an alternative interpretation of need, as interaction, was suggested.

Activity level was recorded on all 8 days, and force of response was recorded on the last 3 days.

At the completion of the training series the animals went immediately to the testing series, where they were tested after different numbers of hours of privation, i.e., on 1, 2, 6, 12, 22-1/2 and 48 hours of appropriate privation. The order of presentation of privation levels was randomized for each animal. Each animal was given 4 trials per day. Activity level and force of response were recorded each day.

At the conclusion of the testing series each animal was extinguished on one of the above mentioned hours of privation.

The results are as follows:

1. Activity is not a reflection of privation, *per se*, but is rather dependent upon the amount and kind of reward in interaction with privation, and on a learned anticipation of reward.

2. A general concept of drive is not tenable, because the correlation between the food and water groups, when activity is constant, was not significant.

3. A drive concept is not tenable, because the water groups did not show the increase in behavior measures which the large food group showed.

4. There is a significant interaction between the kind of reward substance and the privation level.

5. There is a significant interaction between the amount of reward substance and the privation level.

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APPENDIX

TABLE 1

ACTIVITY LEVELS ON THE FIVE HABITUATION DAYS FOR FOUR GROUPS-TO-BE

Day	Animal											
	1	2	3	4	5	6	7	8	9	10	11	12
						Small Food Group						
1	82	218	387	473	169	330	148	254	161	363	270	149
2	31	77	508	314	60	222	141	116	69	114	174	177
3	78	206	535	420	269	214	94	115	41	232	241	38
4	75	149	157	118	96	40	41	1	0	19	16	34
5	151	186	573	339	136	115	49	7	14	29	192	43
						Large Food Group						
1	783	391	705	541	380	465	570	568	196	114	114	84
2	31	257	380	90	118	188	533	263	150	236	126	25
3	261	455	182	253	115	64	205	187	51	90	277	129
4	153	202	81	142	29	130	103	63	86	247	66	226
5	218	168	359	268	153	102	67	97	84	54	340	81
						Small Water Group						
1	170	626	289	229	347	252	242	300	438	739	423	491
2	113	326	97	139	392	319	199	99	253	44	129	50
3	50	352	116	277	417	180	218	50	428	230	161	47
4	106	137	185	177	289	181	250	13	289	284	42	15
5	113	390	205	130	432	159	317	72	290	70	30	108
						Large Water Group						
1	325	358	322	477	415	429	417	599	397	171	356	157
2	207	400	30	104	222	93	110	215	81	154	90	201
3	10	318	43	240	200	70	184	292	110	193	136	53
4	18	123	132	97	247	98	121	57	114	161	121	103
5	63	259	104	90	366	96	83	28	36	54	41	95

TABLE 2

ACTIVITY LEVELS ON THE TRAINING DAYS FOR THE TWO FOOD GROUPS

Day	Animal											
	1	2	3	4	5	6	7	8	9	10	11	12
						Small Food Group						
6	50	236	396	379	371	200	96	39	50	299	181	177
7	176	204	121	439	425	154	70	144	88	207	71	166
8	194	310	400	443	575	142	100	21	36	259	46	11
9	204	218	343	436	287	230	323	106	8	293	375	229
10	95	261	286	357	230	134	182	123	60	137	51	306
11	461	113	266	579	360	295	186	104	95	266	71	330
12	253	278	85	503	573	74	296	208	9	211	86	160
13	335	469	164	655	400	24	199	35	26	134	181	349
						Large Food Group						
6	137	581	486	242	182	73	386	239	130	150	97	171
7	196	493	283	483	257	74	440	562	53	114	31	321
8	451	1747	593	154	315	309	624	240	10	61	132	65
9	903	739	311	142	234	241	391	448	311	301	164	314
10	638	744	589	444	475	233	613	367	106	161	239	239
11	688	540	495	484	454	387	802	453	191	135	267	140
12	803	794	637	463	313	493	841	441	167	80	260	319
13	478	474	259	446	286	323	944	678	344	62	95	83

TABLE 3

ACTIVITY LEVELS ON THE TRAINING DAYS FOR THE TWO WATER GROUPS

Day	Animal											
	1	2	3	4	5	6	7	8	9	10	11	12
						Small Water Group						
6	230	413	95	196	371	257	198	94	298	310	154	119
7	295	365	93	235	497	455	229	23	158	133	12	151
8	257	238	120	200	333	420	297	21	259	135	49	115
9	397	303	201	375	427	416	166	110	100	133	40	9
10	78	415	271	223	393	302	352	40	194	235	175	103
11	315	488	245	95	276	368	100	185	222	289	84	61
12	123	432	43	108	400	394	105	30	141	167	21	177
13	55	229	300	62	412	381	191	100	170	171	19	80
						Large Water Group						
6	381	353	389	430	195	69	73	50	222	249	348	198
7	213	73	120	119	474	333	324	447	468	146	166	121
8	332	416	273	256	246	535	294	100	181	103	156	224
9	241	282	270	211	232	531	331	239	173	178	92	215
10	74	160	135	156	285	329	111	229	203	150	290	168
11	160	403	302	237	370	436	442	210	370	264	400	231
12	247	624	242	378	39	315	393	109	295	238	115	216
13	288	617	325	408	338	481	326	254	256	184	208	179

TABLE 4

ACTIVITY LEVELS ON THE TESTING DAYS FOR THE TWO FOOD GROUPS

Hours of deprivation	Animal 1	2	3	4	5	6	7	8	9	10	11	12
						Small Food Group						
1	100	119	39	329	249	69	174	73	36	120	58	66
2	136	254	206	360	216	169	269	98	44	28	112	81
6	178	154	252	749	420	154	183	189	60	300	171	142
12	76	209	237	404	450	222	135	209	20	181	40	87
22.5	42	213	217	595	280	170	213	151	48	249	172	90
48	335	373	202	496	489	165	138	309	29	210	45	79
						Large Food Group						
1	500	289	130	105	188	63	283	199	50	77	81	63
2	404	374	127	179	288	80	126	388	151	142	91	124
6	450	513	172	279	388	151	198	366	134	140	40	229
12	830	648	449	488	426	207	330	599	276	411	275	260
22.5	715	516	490	337	720	247	269	750	310	167	65	173
48	652	338	366	530	441	307	704	553	367	308	201	563

TABLE 5

ACTIVITY LEVELS ON THE TESTING DAYS FOR THE TWO WATER GROUPS

Hours of deprivation	Animal											
	1	2	3	4	5	6	7	8	9	10	11	12
						Small Water Group						
1	17	516	69	135	381	194	195	18	100	228	86	39
2	389	175	224	222	481	85	329	11	50	39	29	45
6	93	243	89	79	525	530	59	7	233	71	33	88
12	12	539	150	135	330	307	150	4	175	204	25	33
22.5	68	251	165	271	296	224	179	26	226	130	69	222
48	274	295	253	511	390	315	147	97	249	327	269	263
						Large Water Group						
1	58	537	105	328	261	399	441	301	309	200	123	197
2	56	518	12	335	275	500	481	80	482	194	465	113
6	246	241	95	216	95	165	344	329	428	122	137	76
12	52	613	172	365	106	317	255	400	426	135	201	112
22.5	190	512	405	189	175	378	275	220	289	70	644	119
48	327	378	346	206	445	397	322	342	698	95	491	331

TABLE 6

MEAN FORCE OF RESPONSE FOR EACH ANIMAL OF THE FOUR GROUPS ON THE LAST THREE DAYS OF TRAINING

Day	Animal 1	2	3	4	5	6	7	8	9	10	11	12
						Small Food Group						
11	31.8	27.5	25.6	35.6	21.7	37.3	26.0	18.0	29.7	36.5	33.1	24.8
12	38.7	35.4	30.6	38.4	31.4	29.4	22.7	18.8	20.6	33.7	27.1	26.1
13	37.1	28.6	34.4	43.3	32.1	28.4	27.7	19.9	22.0	44.2	36.5	26.3
						Large Food Group						
11	25.1	42.9	19.6	24.3	25.4	32.9	34.1	23.7	32.0	36.3	30.1	22.4
12	22.6	39.4	23.3	44.1	29.7	35.5	40.7	34.5	28.7	28.6	32.2	23.2
13	25.3	19.9	24.0	31.8	22.9	33.3	31.9	35.0	37.8	41.4	32.7	21.4
						Small Water Group						
11	45.4	26.6	28.5	34.7	33.8	42.7	28.3	45.2	49.9	27.9	26.2	29.0
12	47.0	33.2	22.4	26.9	27.5	35.9	27.7	24.8	51.2	24.4	26.0	34.1
13	33.6	25.5	23.2	21.3	28.9	48.5	29.6	38.6	51.5	24.4	23.0	23.3
						Large Water Group						
11	48.8	26.7	38.9	35.6						44.2	38.9	46.5
12	25.8	35.8	36.9	34.7						36.1	30.6	37.3
13	25.4	62.8	41.0	38.8						39.8	47.3	40.7

TABLE 7

MEAN FORCE OF RESPONSE FOR EACH ANIMAL OF THE TWO FOOD GROUPS ON THE TEST SERIES

Hours of deprivation	Animal											
	1	2	3	4	5	6	7	8	9	10	11	12
						Small Food Group						
1	5.52	5.20	5.50	6.79	5.31	5.42	5.04	4.27	4.86	5.72	5.48	4.12
2	5.58	4.76	5.81	5.78	5.39	5.51	4.43	4.53	4.74	6.12	6.51	5.51
6	6.23	4.50	5.63	5.67	6.28	6.16	4.86	4.41	4.69	5.81	6.28	6.08
12	5.78	6.08	6.10	6.08	5.66	6.44	4.94	4.76	4.74	6.18	6.58	6.28
22.5	5.78	6.02	5.20	6.14	5.78	6.27	5.17	4.38	5.36	5.10	6.10	5.78
48	6.46	5.61	5.20	6.58	5.36	6.62	4.84	4.41	5.68	6.46	6.04	6.10
						Large Food Group						
1	4.44	5.27	4.32	6.02	4.92	4.55	6.56	5.00	3.63	5.54	2.83	4.66
2	4.87	5.12	4.18	4.61	4.66	4.87	4.30	7.45	6.46	5.25	2.83	5.68
6	4.87	5.50	4.33	5.00	5.17	5.57	6.59	7.01	5.25	5.41	5.94	6.10
12	5.85	5.32	5.76	6.18	6.16	5.61	7.82	9.41	5.50	5.70	6.81	4.90
22.5	6.54	5.85	5.76	4.87	6.62	5.46	6.89	7.07	6.42	5.48	6.29	5.33
48	4.98	5.29	4.87	5.32	5.68	5.74	8.35	8.84	7.37	6.78	5.22	6.14

TABLE 8

MEAN FORCE OF RESPONSE FOR EACH ANIMAL OF THE TWO WATER GROUPS ON THE TEST SERIES

Hours of deprivation	Animal											
	1	2	3	4	5	6	7	8	9	10	11	12
Small Water Group												
1	4.90	5.61	4.50	6.42	5.12	5.45	2.83	5.00	6.81	5.00	3.39	3.39
2	7.58	4.82	3.58	5.59	4.74	5.93	5.05	4.96	7.48	3.39	2.83	3.53
6	5.83	5.05	5.10	5.07	5.70	6.12	2.83	5.00	7.24	4.51	5.22	5.12
12	5.36	5.81	5.68	6.16	5.36	6.69	3.55	4.85	7.21	4.82	4.74	3.39
22.5	4.94	5.52	4.33	5.85	5.52	5.92	2.83	5.76	7.58	4.76	5.52	5.31
48	5.72	6.00	5.26	5.47	6.28	5.41	5.48	7.50	8.40	5.29	6.86	5.50
Large Water Group												
1	4.69	7.12	6.00	4.71	4.74	6.00	3.91	5.25	2.83	5.46	4.24	6.04
2	5.00	6.08	4.55	4.85	2.83	6.12	3.93	5.70	6.10	6.10	5.63	5.97
6	5.27	6.53	6.83	5.43	5.06	6.18	4.80	5.70	4.32	5.54	3.50	5.61
12	5.89	5.61	5.74	5.70	4.97	5.85	4.90	6.12	6.25	6.56	5.48	5.68
22.5	5.15	5.61	6.44	5.34	5.59	5.52	4.58	6.73	5.63	5.97	6.12	5.68
48	6.60	7.79	6.75	5.48	5.17	5.05	5.10	7.37	6.08	7.28	6.18	6.71

TABLE 9

MEDIAN LATENCY OF RESPONSE FOR EACH ANIMAL OF THE FOUR GROUPS ON THE LAST THREE DAYS OF TRAINING

Day	Animal											
	1	2	3	4	5	6	7	8	9	10	11	12
						Small Food Group						
11	0.41	1.26	1.57	1.69	1.65	0.77	0.31	3.40	2.50	0.42	0.48	0.59
12	0.59	1.25	0.80	0.69	0.64	2.09	0.34	13.12	49.72	1.31	0.33	0.35
13	0.18	1.67	0.46	0.64	0.67	0.17	0.34	0.74	9.64	0.32	0.14	0.51
						Large Food Group						
11	1.83	0.68	1.65	0.71	0.45	1.26	1.10	1.00	3.22	3.47	1.78	1.28
12	2.25	1.60	0.64	0.36	0.59	0.51	0.55	0.70	4.63	0.99	1.69	0.52
13	1.19	2.37	1.41	3.39	0.22	0.94	0.25	0.40	1.58	0.48	0.93	1.46
						Small Water Group						
11	0.33	0.69	0.91	0.69	3.91	0.51	1.68	0.10	0.39	0.47	1.39	1.73
12	0.35	1.03	1.50	1.50	1.11	0.32	1.91	0.25	0.16	0.53	8.27	8.34
13	0.81	0.85	1.28	6.03	4.94	0.36	0.84	0.21	0.25	1.23	3.21	16.60
						Large Water Group						
11	0.74	0.80	0.40	0.33						0.63	1.30	0.71
12	2.66	1.92	0.07	0.49						0.22	0.48	0.52
13	1.38	0.30	0.23	0.21						0.52	0.51	0.61

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TABLE 10

MEDIAN LATENCY OF RESPONSE FOR EACH ANIMAL OF THE TWO FOOD GROUPS ON THE TEST SERIES

Hours of deprivation	Animal											
	1	2	3	4	5	6	7	8	9	10	11	12
	Small Food Group											
1	0.28	9.15	12.59	0.16	0.54	8.14	0.33	26.50	3.04	1.39	0.17	9.56
2	0.29	9.98	3.25	0.19	0.72	1.83	3.68	5.39	7.57	0.28	0.27	2.54
6	0.16	14.87	0.32	0.57	0.49	0.41	0.29	6.28	6.33	0.27	1.18	2.28
12	0.24	0.64	1.15	0.51	0.32	0.57	0.29	3.84	5.70	0.66	0.13	3.20
22.5	0.33	1.42	0.26	0.26	0.64	0.77	0.17	8.24	2.78	0.52	0.25	0.28
48	0.33	0.75	0.66	0.74	0.66	0.89	0.35	5.26	4.62	0.61	0.18	0.80
	Large Food Group											
1	0.77	1.50	0.43	0.20	0.26	0.30	1.58	10.70	-*	1.87	-	0.66
2	0.69	0.73	0.71	0.17	1.91	0.48	127.50	1.20	1.69	1.18	-	0.43
6	0.31	0.95	0.71	0.40	0.39	0.31	3.20	0.95	5.42	2.04	6.61	0.47
12	0.14	0.43	0.27	0.22	0.24	0.36	2.60	0.45	0.35	0.38	47.98	0.65
22.5	0.21	0.71	0.17	0.25	0.91	0.31	6.50	0.40	3.03	0.65	0.31	0.60
48	0.38	0.83	0.38	0.23	0.26	0.20	2.10	0.10	0.22	0.32	10.06	0.68

*- indicates that the animal's median latency was greater than 5 minutes

TABLE 11

MEDIAN LATENCY OF RESPONSE FOR EACH ANIMAL OF THE TWO WATER GROUPS ON THE TEST SERIES

Hours of deprivation	Animal 1	2	3	4	5	6	7	8	9	10	11	12
						Small Water Group						
1	15.32	3.18	29.03	0.68	60.69	0.81	-*	2.36	0.25	5.79	-	-
2	0.36	1.02	-	0.61	-	1.05	1.58	0.21	0.25	-	-	-
6	1.27	1.21	2.51	16.08	4.23	1.55	-	9.98	1.82	5.32	22.16	88.33
12	1.69	0.65	1.09	0.40	0.75	0.35	-	1.52	0.19	0.69	13.19	-
22.5	16.12	0.77	1.60	0.88	1.31	0.38	-	0.12	0.10	0.32	0.86	73.12
48	2.36	0.38	0.43	3.02	0.94	0.51	0.94	0.10	0.40	0.60	0.42	2.64
						Large Water Group						
1	8.54	0.77	0.85	8.24	78.17	9.44	-	27.22	-	0.07	5.72	2.96
2	62.54	1.24	5.62	3.69	-	3.26	-	107.73	4.39	0.28	0.63	3.59
6	6.81	4.50	8.03	25.54	7.08	10.74	62.23	0.52	-	1.08	-	1.16
12	16.01	1.53	0.10	1.15	120.33	0.59	0.17	4.71	0.24	0.52	9.20	0.28
22.5	3.71	1.70	0.09	1.51	4.65	-	-	-	4.62	0.20	0.23	0.51
48	0.14	0.19	0.52	1.70	0.31	0.42	1.20	4.02	0.60	0.19	0.20	2.16

*- indicates that the animal's median latency was greater than 5 minutes