**THE EFFECT OF STRENGTH OF DRIVE
ON LEARNING**

BY

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PROFESSOR

To Dr. Sigmund Koch, who guided me throughout the experimental work and the preparation of this thesis, and to Mr. S. James Goffard who provided technical assistance, I offer my sincere thanks.

R.L.

INTRODUCTION

In what way is learning influenced by strength of motivation? Specifically, will a habit learned under "strong" motivation be more resistant to experimental extinction than the same sort of habit learned under "moderate" motivation? This is one aspect of the broad problem of the role motivation plays in the determination of behavior.

Since the passing of the early theoretical formulations involving a constancy hypothesis, an assumption of a point to point correspondence between specific situation and specific reaction, motivational variables have come to play increasingly important roles in theoretical descriptions of the determination of behavior. Early association theories had treated association between stimulus and response as a sufficient basis for the formation and utilization of habits. Somewhat later, field theorists like Lewin proposed motivational constructs, such as tensions and valences, as major components of their theories. Modern reinforcement theories, such as that of Hull, recognize the dependence of learning upon motivational variables, e.g., reinforcement through need-reduction. Therefore, it is evident that currently in-

fluent systematic theories take cognizance of the need to come to grips with motivational factors. But before entering into a further discussion of the motivation and learning relations in these modern theories, it shall be our purpose to briefly review the historical development of motivational theory.

The earliest formulations of the relation of motivation and learning were derived from studies which were aimed at the classification and ranking of needs and therefore bore a close resemblance to the attempts of "instinct theorists" to catalog instincts. In the typical sort of experiment, obstruction box or T-maze techniques were used to measure the relative strength of needs by means of quantifications of performance.¹

The relation of needs to learning was frequently investigated, particularly on the American scene, where learning came to be regarded as a foundation problem in psychology. Most studies involved the maze training of groups of animals under various motivational states, inferred from deprivation of food, water, sex satisfaction, etc. Comparisons of speed of performance, number of errors, and period of retention of the maze running habits were made and led to general statements such as those of Katz, "Dodson has shown that animal learning is dependent upon degree of hunger in the sense that, if reward is held constant, the greater the hunger the more rapid the learning. . . ." ² and

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¹Summaries of this early work will be found in Moss (12), Katz (6), and Young (18).

²Animals and Men, p. 157

Young, who concluded from an experiment by Ligon that "Considering the total experiment, it is apparent that the speed of learning varies in general, but not uniformly, with the duration of the food-privation period."³

General statements drawn from maze experiments, such as the statements of Katz and Young above, are useless for adequate theory construction in psychology for at least one basic reason. They fail even to attempt to distinguish the role of motivation in those modifications of the organism which are called learning, from the role of motivation in stimulating, energizing, and sustaining behavior. Measures of time and errors in a maze are performance measures and are useful for making some indirect inferences about learning, but they do not directly mirror the process of habit acquisition. Thus, on the basis of performance measures derived from training, it is impossible to differentiate effects of motivational level upon the acquisition of the maze running habits, from the effect of motivational level upon the energizing of already existing habits. Before quantitative experimental studies could begin to illuminate the complex problem area of the relations of motivation, learning, and performance, it was necessary to recognize that within that area at least two general sets of problems arise. These are the role of various motivational factors in the organismic processes which underly

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³Motivation of Behavior, pp. 116-17.

learning, and the effects of motivational systems in the utilization of already existing habits.

Gradually, theorists began to distinguish these two problem areas, and by 1935 Leeper was able to write that many psychologists, beginning with Lashley in 1929, had called for a distinction of the functional role of motivation in the processes of habit acquisition from the role of motivation in habit utilization, although this distinction had not been made in actual empirical studies (10).

It is important to note that theorists who accepted the distinction of motivational influences in habit acquisition and habit utilization did not thereby necessarily arrive at similar conceptions of those motivational effects. Several theorists have made tentative commitments in this area, despite the lack of definitive empirical evidence. Among these, we may conveniently point to the divergent general positions of reinforcement and field theories. While the theory of Professor Hull identifies reinforcement with need-reduction⁴ and lays great emphasis upon the primary role of reinforcement in habit acquisition, field theories, such as that of Professor Tolman, do not accept reinforcement as a necessary condition for learning, but rather point to the latent-learning studies as supporting their contention

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Hull's criticism of Pavlov and Guthrie for their failure to accept need-reduction as essential to reinforcement bring out this point (5, pp. 76-79).

that learning takes place without reduction of what is assumed to be the dominant drive, e.g., without food reward in the case of animals which have been deprived of food prior to their training in the maze.

The tentative and programatic nature of the commitments which various theories have made in the area of motivation and behavior should be recognized. The hesitancy of theorists to make determinate commitments would seem entirely justified in view of the complexity of motivational problems, and the paucity of relevant empirical information. Most of the empirical evidence available today concerns the hunger drive, yet neither physiologists nor psychologists have anything like an adequate set of data on hunger, only one of many drive systems. There seems to be no a priori basis for an assumption that all drive systems operate according to a single, simple quantitative function. But even if that assumption were true, there is as yet no evidence as to the form of the functional relation even for a single drive. Furthermore, after more complete evidence with regard to a single drive is obtained, it will be necessary to investigate differences which may be due to qualitative differences among drives.

We have already seen that the analysis of complex relations in the general area of motivation, learning, and performance demands that we distinguish two classes of problems, the role of motivational factors in the acquisition of habits, and the role of motivational factors in the utilization of already existing habits. The present experiment falls in the first of these

categories, but for purposes of establishing the context in its broadest scope, we shall briefly review the progress that has been made toward the clarification of the relation of motivation and performance. The advent of the Skinner box techniques and the elaboration of Hull's deductive theory provided a new impetus to empirical studies in this problem area, one of the pioneering investigations being the Perin experiment (14), which was closely related to the development of a crucial part of Hull's theory. By varying previous learning and current drive strength, Perin attempted to measure the influence of those variables upon performance. The results, which indicated that previous learning and current drive strength combine according to a multiplicative function to determine the tendency to perform a learned habit, served as a basic source for Hull's "postulate 7" on primary motivation. The Perin-Hull equations represent the first tentative statement of quantitative relations between habit strength, present drive, and behavior.

Further clarification of the determinants of the magnitude of response was provided by the Koch-Daniel (9) and Saltzman (15) experiments. Extrapolations of the Perin-Hull function were found to be grossly in error at low levels of current drive strength, and suggestive evidence on the question of "functional autonomy of motives" was secured. Contrary to the prediction of the Perin-Hull equations, when extrapolated, satiated animals did not perform the bar-depression habit, and it was found that short periods of food deprivation following satiation produced

large increases in response tendency.

Historically, most theorists have accepted the generalization that efficiency of performance of well-learned habits is in part determined by the level of motivation, e.g., the period of deprivation preceding performance. This generalization will play an important part in any discussion of the effects of strength of motivation in the learning situation, because behavior in the learning situation becomes performance as soon as more than one trial is given. Therefore, it has seemed advisable to review some of the basic quantitative studies of this motivation-performance relation. We have noted that the series of investigations beginning with the work of Perin have substantiated and expanded the historically accepted generalization.

We have briefly suggested that there are divergent current generalizations concerning the motivation-habit acquisition relations, e.g., the reinforcement position as contrasted to the sign-learning formulation. The aim of the present investigation is to seek quantitative empirical data bearing on the motivation-habit acquisition relations. We have suggested that there is no a priori basis for assuming that a generalized statement of relation will be found useful in this problem area, but similarly there is no reason to assume that such a broad formulation may not be obtained. Only experimentation can decide the matter.

We have suggested that early studies of the role of motivational variables in learning were of limited utility for theory construction, largely because of the failure of experimentalists

to distinguish adequately the acquisition of habits from the performance of already learned habits. However, when Hull published his theory of behavior, he offered as one of his central assumptions "postulate 3" which purports to state the conditions governing the acquisition of habits. In this postulate it is stated that growth of habit strength is a function of number of reinforcements, properties of the reward, stimulus-response asynchronism, and delay in reward. This explicit listing of the determinants of habit growth opened the way for quantitative studies of relations between these and other variables and the acquisition of habits. As we shall see, several experimenters specifically formulated their problems in an attempt to test the adequacy of Hull's list of determinants of habit acquisition. Particularly, the omission of drive strength, as a determinant of increment of habit resulting from reinforcement, stimulated research, since previously some relation between drive strength and learning had been generally accepted by many workers in the field of motivation.

Among the experiments which are to one degree or another relevant to the relation of strength of motivation and habit acquisition, there are various sorts of maze learning studies and also several investigations of bar-depression habits. Though all these experiments may be interpreted as falling within the same general problem area, they are far from identical as to either specific topic or methodology. It shall be our purpose below briefly to describe several of these motivation-learning

studies in order that the present experiment may be viewed in the context of the other attempts to obtain empirical information concerning the effects upon learning of variations in the strength of motivation.

We have previously presented a discussion of the general results of maze experiments in which the distinction between habit acquisition and habit utilization was not made. Of the several recent maze experiments which have been performed with the experimenter explicitly aware of the necessity for this distinction, we shall discuss first the Kendler study (8). Kendler's primary interest was in the problem of drive interaction, but concomitantly he sought to investigate the motivation-habit acquisition relation, as we see from his statement that, "The present experiments were designed to ascertain whether drive strength (D) was one of the variables determining habit strength (sHr). . . ." (8, p. 188). Drive was varied by varying the intensity of non-rewarded thirst co-existent with a standard degree of hunger, and the learning task was a T-maze habit, with habit acquisition measured by the number of trials required to attain a criterion of efficient performance and by the speed of relearning after a period away from the maze. In original learning the "high" drive groups tended to attain the criterion in fewer trials than the "low" drive groups. In relearning the maze under equated drive conditions, the animals that had previously been trained under "low" motivation tended to exceed the formerly "high" drive animals in speed of relearning, a fact attributed by Kendler to the higher number of reinforcements they had previously

received. He suggested that the results of this experiment support Hull's omission of drive strength as a variable determining habit acquisition.

About the same time that Kendler was finding strength of drive unrelated to habit acquisition, MacDuff (11) performed a T-maze experiment in which her intent was to investigate the relation of strength of drive during learning to the subsequent retention of the learned habit. In the Hullian terms used by Kendler, performance tests indicating retention would be equivalent to measures of reaction potential, which is assumed to be a function of habit strength. Using drive strengths of 12, 24, and 48 hours food deprivation, MacDuff tested the retention of maze running efficiency after 2 weeks and after 6 weeks, in both instances after equalization of drive. The results indicated that after the shorter interval, rats that had been trained under higher drive conditions slightly outperformed the 12 hour group, while after 6 weeks no differences were evident. MacDuff's obtained differences fell short of statistical significance, but because of their consistency she interpreted them to mean that drive during learning does effect retention, or transposing as we have indicated above, habit strength.

The third recent maze experiment which is relevant to the motivation and habit acquisition relation is an investigation of rats running a straightaway for a water reward. O'Kelly and Heyer (13) trained groups under three conditions of thirst: 12 and 36 hours water deprivation and 36 hours deprivation followed

1/2 hour before running the alley by a drink amounting to 2/3 of a normal 36 hour water intake. Then after 3 and 6 weeks, the 3 groups relearned the straightaway running habit with equalized thirst drive. When the relearning trial speeds were averaged for each group, statistically significant differences in running speed were found, with the 36 hour deprivation and the 36 hour pre-run drink groups exceeding the speed of the 12 hour rats. Even after 6 weeks, the 36 hour group was reported to be significantly faster than the 12 hour group. O'Kelly and Hoyer interpreted the results as a critical confirmation of MacDuff's somewhat inconclusive finding that drive intensity during training is a determinant of habit acquisition.

The last of the maze studies that we will discuss is the experiment performed by Seward and his associates (17), in which a single unit T-maze spatial discrimination was learned, then relearned to the opposite side under 2 drive conditions, and finally tested under equal drive levels. Three groups of rats were used, and thirst was the experimentally varied drive. All groups learned to run to one end box, and then in the second stage of the experiment the incentive was shifted to the opposite end box, and 2 of the groups were given "reversal" training. Before reversal training, one group was satiated for water and the other deprived for 22 hours, and these groups were given an equal number of forced runs. The third stage of the study involved all 3 groups with the animals allowed free runs in the maze under equal motivational conditions, and the number of

reversed choices recorded as the measure of habit strength resulting from the reversal training. The results showed that the control group that had received no reversal training performed the reversed spatial discrimination least well, the group re-trained under conditions of satiation performed better, and the group that had received reversal training after 22 hours deprivation performed best of all. Seward's conclusion was that, "for learning under such conditions the relevant drive is not necessary but it helps" (17, p. 14). In a published account this experiment has been interpreted as a demonstration that strength of drive during learning affects the degree of learning, or a further corroboration of the MacDuff and O'Kelly and Heyer conclusion (16). In the final section of this report we shall discuss the relevance of these experiments to the motivation and habit acquisition relation, but our purpose here is simply to report the findings and conclusions of the several maze experiments, and in so doing, to point out that only Kendler's finding supports Hull's omission of drive strength as a determinant of habit strength; while the other 3 investigators purport to have shown, to one degree of statistical significance or another, that drive strength is directly related to habit acquisition.

The second group of recent experiments which have been performed in an attempt to obtain empirical information bearing on the role of drive strength in the growth of habit strength is made up of Skinner box studies performed by Finan, Kendler, Heathers and Arakelian, and Cummings, all of which have been

reported in the journals, with the exception of the Cummings study. Finan's work stands out as the first approach to the problem through the use of a bar-depression habit, and it is important to note that his results were the only ones available to Hull at the time when Principles of Behavior was published.

Finan (3) deprived rats of food for 1, 12, 24, and 48 hours and then gave them ³⁰16 reinforcements in the Skinner box. All groups were next extinguished under equal ^{70%}hunger. Finan's results indicated that for the lower levels of hunger, there was a direct relation between strength of motivation and effectiveness of reinforcement. However this relation was not evident in the extinction scores of the 24 and 48 hour groups, those results being similar to each other and both falling between the scores of the 1 and 12 hour groups.

A detailed critique of the methodology employed by Finan was made by Cummings (1). Working in the early days of Skinner box research, Finan did not utilize the relatively more controlled techniques which were developed later. Cummings particularly noted certain uncontrolled factors in Finan's training procedure, as well as his use of inadequate satiation techniques, as providing the basis for a strong doubt that his experiment was methodologically sound. Similar considerations may have influenced Hull, who wrote that the results indicate "that reduction of need is a critical factor in the primary reinforcement process. . . ." ⁷ though omitting strength of motivation from his

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⁷Op. cit., p. 81.

list of determinants of the increment of habit strength resulting from training.

Kendler (7, 8) performed two Skinner box experiments which represent a further attack on the drive interaction problem. They also yield at least suggestive evidence on the question of whether drive strength is one of the variables determining the acquisition of habits. As in his maze work, Kendler varied drive by varying the intensity of non-rewarded thirst co-existent with a standard level of hunger. In the first part of the study, experiment I, the extinction tests were made under conditions of deprivation identical with those of the reinforcement situation, while in the latter part of the study, experiment II, extinction occurred after a uniform food deprivation.

Results of experiment I indicate that resistance to extinction increases as a function of drive strength, up to 12 hours additional thirst, when drive is the same during reinforcement and extinction. Extinction scores were lower for animals operating under 22 hours water deprivation.

The second experiment, with extinction occurring after all the animals had been equally deprived of food, produced no differences in measures of tendency to perform the bar-depression habit. Kendler interpreted the results of both Skinner box experiments as further support for Hull's omission of drive strength from the list of variables determining the increase of habit resulting from reinforcement.

Heathers and Arakelian (4) sought to determine the effect of

strength of motivation, at the time of extinction of a bar-depression habit, upon the effectiveness of that extinction. Four groups of rats that had previously acquired the bar-depression habit were extinguished under strong and weak levels of hunger. After a period of "spontaneous recovery" the tendency to perform the bar-depression response without reward was again measured. The levels of hunger at this second extinction were such that of the original 4 groups, one had been extinguished twice under weak hunger, another twice under strong hunger, one under first strong, then weak hunger, and the last under weak, then strong hunger. The measures obtained during the second extinction were considered to be indications of the effectiveness of the previous extinction.

Heathers and Arakelian's first finding was the commonly noted fact that hungrier animals produce higher resistance to extinction scores than do less hungry animals. But no significant relation was found between the scores from the second extinction and the hunger level during the first extinction. Their conclusion was, therefore, that strength of motivation at the time of extinction is not related to the long-range effectiveness of the extinction, i.e., to the change in habit strength.

Cummings undertook in 1946 to obtain a more critical empirical test of the effect of intensity of motivation during training on the efficiency of learning. Finan had concluded that there was a difference in the degree of learning produced by training

rats under 1 and 12 hours hunger, but that difference did not seem to hold for higher levels of motivation. The indeterminacy of his findings was further emphasized by the questions Cummings raised as to the adequacy of methodology employed in arriving at this non-continuous function. Neither of the other Skinner box studies is directly comparable to the Finan experiment, because, as we have seen, Kendler varied drive by using hunger and additional thirst, so that the lack of knowledge concerning drive interaction effects vitiates the significance of his results, while Heathers and Arakelian studied the effects of drive during a preliminary extinction test, not during habit acquisition. Thus, having good reason to question the probability that Finan's results were accurate, Cummings designed her experiment in such a way as to repeat Finan's problem but avoid shortcomings of his method. She gave 16 reinforcements to groups of rats that had been deprived of food for 3 and 16 hours, and then after equalizing the hunger level of both groups, she extinguished the bar-depression habit. Her groups were large, her satiation procedures rigorous, and her training techniques uniform. When Cummings compared measures of the speed of performance in the reinforcement situation, she found that the 16 hour group obtained the reinforcements faster than did the 3 hour group; that is to say, they performed faster during training. Furthermore, a higher percentage of the 16 hour group attained the training criterion, 81 per cent as opposed to 52 per cent. Although she found these differences in training behavior related to level of

motivation, her measures of resistance to extinction indicated that there was no subsequent statistically reliable difference in the habit which had been acquired during training.

The foregoing summary should make clear the indeterminacy of the empirical evidence bearing on the motivation-habit acquisition relation. We have previously noted that this lack of determinate evidence is paralleled by broad differences among theoretical formulations of the learning process. Further progress in theoretical treatments of the relations of motivation, learning, and performance can best be facilitated by such additional empirical studies as to clear up the uncertainty which results from the conflict of the maze findings of Kendler and others, as well as from the opposing conclusions of experimenters who have worked with Skinner box habits.

Among the Skinner box investigations, only the Cummings study attacked the problem in its most direct form with an approximation of adequate controls. If we therefore accept Cummings' results as valid, we are left with the following situation: variations in hunger strength of the order of 3 vs. 16 hours during the learning of a Skinner box habit, to a practice level of 16 reinforcements, produce no appreciable difference in the strength of the learned habit. But this does not necessarily mean that similar results would be obtained at all levels of hunger, and all levels of reinforcement. Indeed, so little is known of the significance for learning of variations of motivation, such as those produced by food deprivation periods of 3

and 16 hours, that it is possible to assume that over even such wide ranges of food deprivation, effects on habit acquisition may be functionally equivalent. But it is further conceivable that, at certain critical points, variations in food deprivation preceding training may produce different effects on habit acquisition. Thus we may say that Cummings compared what most experimenters would call "low" and "moderate" degrees of hunger and that the next logical step would be an extension of the exploration over a higher segment of the food deprivation continuum. It is primarily this that the present experiment was designed, at least partially, to accomplish. Whereas Cummings compared the effects of "low" and "moderate" hunger on learning, the present experiment seeks to compare the effects of hunger intensities which most experimenters would regard as "moderate" and "high."

The choice of periods of food deprivation within the areas of "moderate" and "high" intensities was influenced by several considerations. Among these were the findings of previous experiments that the elicitation of already learned habits, that is performance, is differentially affected by deprivation periods of the order of 12 and 48 hours (14, 7, 4) and additionally that 12 hours deprivation insures that a large percentage of the animals will attain the training criterion, thereby avoiding the possibility of a greatly different discarding rate between the two groups for failure to train.

If it is true, as seems possible, that the bar-depression

response becomes maximally learned after a few trials, some possibility may exist that habits of only slightly different strength might be built up under quite varied drive conditions, should the amount of training approximate the limit of practice. Thus, in order to create optimal opportunity for a difference in drive intensity during training to produce differential habit acquisition, it was considered desirable to establish a level of training which could be confidently expected to fall far short of the limit of practice. At the same time it would be necessary to avoid reducing the number of training trials to so low a level that a definite super-threshold habit would not be expected to result. On the basis of general considerations suggested by previous research (14, 1), it was felt that the above conditions would be more or less satisfied by allowing the animals 5 reinforcements.

The present experiment was frankly exploratory in nature with no specific hypotheses under test. The questions asked were, 1) If an equal number of reinforcements are given under "moderate" and "high" levels of hunger, will there be differences in the training performance? and 2) When hunger level is then equalized, will there be differences in the resistance to extinction of the two groups?

SUBJECTS, APPARATUS, AND PROCEDURE

It will be recalled that the present experiment was intended to investigate the question of whether or not strength of motivation during training affects habit acquisition in such a way as to be quantifiable through measures of the resistance to extinction of a bar-depression habit. A description of the subjects, apparatus, and procedure that were utilized in the attempt to answer this question will be presented below.

Subjects

The subjects in this experiment were 85 male albino rats from the Duke University psychology laboratory colony, the Duke Hospital experimental surgery laboratory colony, and the Albino Farms breeding company. The rats were obtained in groups of litter-mates which were then equally divided between the two experimental groups.

When they entered the experimental procedure at ages between 82 and 90 days, the weights of the rats ranged between 170 and 331 grams. Of the original 85 animals, one was discarded because of an infection and 19 were discarded because of their failure to meet either the habituation or training criteria, leaving 65

animals to complete the procedure, 32 in the 12 hour motivation group and 33 in the 48 hour motivation group.

Apparatus

The experimental apparatus consisted of two modified Skinner boxes of the sort described by Ellison (2) and an attached constant speed wax-paper polygraph recording unit. In order to insure that minute differences between the boxes would not produce variations in scores between the groups, an equal number of rats of each group was run in each box, and any particular rat had all his experimental experience in the same box.

Each box consisted of a partially soundproofed 12-inch cubical behavior compartment with a circular observation window in the top. Illumination of the interior of the box was provided by placing a 6-watt lamp on the observation window. Ventilation was achieved by directing a gentle stream of compressed air through the top of the behavior compartment. A water bottle attached to the side wall of the compartment made water available to the animal throughout his stay in the box.

Protruding through the wall of the behavior compartment opposite the entry door was a horizontal brass bar approximately 3 mm. in diameter and 55 mm. in length, L shaped with the longer segment parallel to the wall and approximately 1 cm. out from the wall. The bar was delicately pivoted so that a downward pressure of 10 to 15 grams would depress it and thereby close the contacts of a mercury switch, which in turn activated the

electric feeding device which was attached to the top of the box on the outside. Activation of the feeder caused one pellet of food to be released, to fall through a tube and into a 1-1/4-inch square feeding tray directly under the bar. A signal magnet on the polygraph unit and an electric impulse counter recorded each bar-depression.

The food pellets weighed approximately .07 gram each and were hard, cylindrical pellets compounded from ground Purina checkers and whole-wheat flour mixed with water according to the proportions and methods described by Koch and Daniel (9).

Procedure

The present experiment employed a 13-day procedure beginning with an initial 7-day period which was devoted to setting up a feeding rhythm. Each rat on feeding rhythm lived in an individual cage with water always available and with such environmental conditions as lighting, temperature, and noise level controlled within reasonably close limits. At the same time each day, the rat on feeding rhythm was provided with a small tray of food consisting of moist ground Purina checkers mixed with flour. After 1/2 hour the food tray was removed, typically with about half its contents uneaten, and then no food was available to the animal until the same time on the following day.

On the 8th and 9th days of the procedure the rats were fed in the Skinner box. On these occasions the food consisted of a large number of the standard food pellets which were heaped in

the food tray, and 1/2 hour was allowed for the rat to eat, this feeding occurring at the same hour of the day as the previous feedings.

TABLE I
Experimental Procedure

Day in Ex- perimental Series	Hours from Satiation	12 hour Group	48 hour Group
1-7		Feeding	Feeding
8-9		Box feeding	Box feeding
10	0	Habituation & Satiation	Habituation & Satiation
	12	Training	
11			
12	48 49	Satiation	Training Satiation
13	23	Extinction	Extinction

On the 10th day of the procedure, the animals were habituated to the sound of the feeding device and then satiated for food. At the regular feeding time, each animal was placed in the Skinner box with 3 pellets already resting in the tray. After these had been consumed the experimenter manually operated the feeding device, allowing one pellet to be released at a time. When a total of 20 pellets had been eaten, the animal was returned to his home cage for a 15 minute period, after which the

same procedure was repeated until another 20 pellets had been eaten. After finding and eating 40 pellets in the habituation situation, most of the animals had acquired a tendency to rush to the tray and search for the pellet immediately, when the feeding device made its click.

Satiation for food immediately followed habituation. In the present experiment all satiations were carried out in a manner similar to that described by Koch and Daniel. Moist food and water were made available to the rat for a period of 55 minutes. If eating had ceased by that time, food was offered to the animal by hand until no eating occurred for a period of two minutes. The animal was then considered satiated, and it was observed that in all cases the satiated animal curled up and went to sleep within a few minutes following the cessation of eating.

Table I summarizes the experimental procedure, and it will be noted that the time of satiation was considered to be "zero" hours hunger, the point from which all deprivation periods were calculated. Training, which consisted of 5 reinforcements of the bar-depression response, occurred for the "moderate" motivation group, Group I, 12 hours after satiation, and for the "high" motivation group, Group II, 48 hours after satiation.

During training each animal was given 5 reinforcements in the Skinner box. In order to insure that, upon entry into the training situation, the rat would orient toward the bar, a small quantity of moist food, approximately 1/10 of a gram, was smeared on the panel immediately above the bar. In most instances several

bar-depressions occurred before the rat was credited with his first reinforcement, the criterion for the first reinforcement being a bar-depression immediately followed by finding and eating the pellet. After the fifth reinforcement the rat was returned to his home cage where he remained until the second satiation, which occurred 49 hours after the first satiation.

The bar-depression habit was extinguished for all the animals 23 hours after the second satiation. During extinction tests the feeding device was disconnected so that depression of the bar resulted in only the very slight click of the impulse counter and signal magnet. A 5 minute no-response criterion was adopted as the standard of extinction.

Returning to Table I, it will be noted that the different periods of time between first satiation and training have the consequence of causing the second satiation and extinction to occur 37 hours closer to training for the 48 hour group. This procedure was chosen because, in view of the impossibility of varying only the period of deprivation preceding training, it seemed that any other procedural arrangement would involve an even more undesirable confounding of variables. Among the alternate possibilities would have been to have extinction follow 49 hours after the first satiation, or to return the animals to a feeding rhythm for several days between training and the second extinction. The first of the alternative procedures would have caused extinction to follow immediately after training for Group II, and 37 hours after training for Group I, with

the probable result that the hunger level of the two groups at extinction would be different due to the consumption of the pellets received during training. The second of the possibilities noted above would have involved lengthening the experimental procedure to 15 or more days, and it was felt that the advantage gained from the slightly more comparable extinction conditions would be outweighed by the possible deterioration of the bar-depression habit during the interval, with consequent increase in variability.

RESULTS

Since this experiment investigates the relation between motivation and habit acquisition by varying motivation during training and then equalizing motivation during extinction, the results fall into the two general categories of training and extinction data. In order to have a standard of comparison for the group scores at these stages, however, we must first present data bearing on the equivalence of the groups before the experimental variation of hunger strength.

Comparability of Groups

Measures obtained before the introduction of the experimental variable, level of motivation at training, should indicate whether or not our groups of animals were similar. Table II summarizes the information concerning this question, and it will be seen that comparisons of both the mean body weight of the rats and the mean weight of food eaten during the first satiation produce only slight differences. It is of particular interest that the means of food eaten at satiation are so nearly identical, 22.5 gms. and 22.7 gms., and that the critical ratio of these means is only .148, far short of significance at the 5 per cent

level. This near equality of food eaten during satiation gives us reason to assume that our "zero" hours food deprivation was closely similar for both experimental groups. We conclude, therefore, that with respect to body weight and food consumption during satiation, our groups were comparable at the start of the experiment.

TABLE II

Comparison of Groups With Respect to Body Weight
and Food Eaten at the First Satiation

Factors	Group I	Group II	C.R.
Mean body weight	244.8 gm.	239.2 gm.	.693
Mean weight of food eaten at the first satiation	22.5 gm.	22.7 gm.	.148

Training data

From the training data we seek the answers to two questions:
1) Did the two groups receive an equivalent amount of training as indicated by number of reinforcements? 2) Were there any differences in the speed of training for the two groups which operated under different strengths of motivation?

With reference to the first question it will be recalled

that each animal was allowed 5 reinforcements, but that in all cases, one or more bar-depressions preceded the first reinforcement. From the first statistic in Table III, we note that the mean number of bar-depressions during training, which is the same as the number of pellets eaten during training, was for the lower motivation group 10.2 and for the higher motivation group 10.6. The critical ratio of these means is .015 indicating that the difference in the number of bar-depressions is ascribable to chance. Therefore, our results indicate that both groups received an equivalent number of trials in training.

With regard to the second question above, Table III also gives the mean and median total training times for each group. It will be noted that while neither the means nor the medians differ for the two groups to the extent of statistical significance, both of these differences are in the same direction with the larger being the difference between the median training times, 6.9 minutes for the "high" motivation groups and 8.8 minutes for the "moderate" group.

The measure that has been used in similar Skinner box investigations (9, 14, 15), to indicate the rate of initial training performance, is the time from the first to the fifth reinforcement. Table III includes the mean time from the first to the fifth reinforcement for each of our groups, 3.4 minutes for Group I and 2.5 minutes for Group II, producing a critical ratio of 1.3, which has a probability value of about 10 per cent.

Table III

Mean Bar-Depressions During Training, Mean and Median Training Times, Mean Times Between 1st and 5th Reinforcement, Mean Latencies of the 5th Reinforcement, Number Failing Training Criterion, and the Critical Ratios of All Means and Medians

Statistic	12 hour group	48 hour group	C.R.
Mean number of bar-depressions during training	10.2	10.6	.015
Mean total training time	10.8 min.	9.2 min.	.49
Median total training time	8.8 min.	6.9 min.	.92
Mean time between 1st and 5th reinforcement	3.4 min.	2.5 min.	1.3
Mean latency of 5th reinforcement	.675 min.	.307 min.	2.72
Number failing training criterion	7	6	

A more detailed analysis of the difference in duration of actual training is obtained by comparing the latencies of individual reinforcements for each group. Figure I plots these "learning curves" in seconds. The form of the curves is similar although they do not overlap at any point. The increasing superiority of Group II as training progressed is quite evident, the gap between the curves opening from 7.8 seconds for the first

Mean Latency of Reaction of Two Groups of Rats
during Training in the Skinner Box

FIGURE I

reinforcement to 22.1 seconds for the 5th. Thus the mean latency of the 5th reinforcement for Group I is 40.5 seconds and for Group II 18.4 seconds. As noted in Table III, the C.R. of the difference is 2.72 which exceeds the requirement for statistical significance at the 1 per cent level.

Therefore, there is complete consistency among the several measures of training speed, and every obtained difference favors Group II. The discrete "learning curves," with a statistically significant difference in the latency of the fifth reinforcement, further point to the fact that the two groups operating under different motivational conditions performed at different speeds during training.

Extinction data

In this experiment a 5 minute no-response period was used as the criterion of extinction, and we may, therefore, compare the extinction performances of the two groups with reference to 1) the number of non-rewarded bar-depressions preceding the criterion, and 2) the period of time until the start of the 5 minute criterion period. Since, as we have indicated in the preceding chapters, performance is generally considered to be jointly determined by strength of motivation and strength of habit, and our groups entered extinction with approximately equal motivation, as inferred from an equal number of hours of food deprivation following the second satiation, any differences in these measures

of performance should reflect differences in the strength of the bar-depression habit.

TABLE IV
Mean and Median Extinction Responses to the 5 Minute
Criterion and Critical Ratios

Measure of bar-depressions preceding extinction	Group I	Group II	C.R.
Mean number of ext. responses to the criterion	20.3	22.8	.464
Median number of ext. responses to the criterion	12.5	14.0	.464

Table IV presents the means and medians of extinction responses to the 5 minute criterion. For Group I, the mean is 20.3 and the median 12.5, while for Group II, the mean is 22.8 and the median 14.0. The differences of both these measures yield critical ratios of .464, not significant at the 5 per cent level. Figure II is a comparison of the distributions of extinction responses for the groups. Comparisons of time measures to the criterion are presented in Table V. Mean extinction times are 10.4 minutes for Group I, and 12.2 minutes for Group II, while the medians are 9.4 for Group I, and 12.0 for Group II.

FIGURE II

Distribution of the Number of Extinction Responses Made by Each Rat to the 5 minute No-response Criterion.

The larger critical ratio is that derived from the difference between the median times, and that C.R. is .97, not large enough to achieve significance at the 5 per cent level.

Table V
Mean and Median Extinction Times to the Start
of the 5 Minute Criterion

Statistic	Group I	Group II	C.R.
Mean extinction time	10.4 min.	12.2 min.	.74
Median extinction time	9.4 min.	12.0 min.	.97

Table VI
Comparison of Weight of Food Eaten
at the Second Satiation

	Group I	Group II	C.R.
Mean weight of food eaten at the second satiation	26.2 gm.	24.4 gm.	1.36

Since split-litters were used in this experiment, one final comparison can be made between the extinction performances of

the two groups. Among the 65 animals that completed the experiment, there were 24 litter-mate pairs, with one member in each group, the other 17 rats being from litters with an odd number of offspring. Of the 24 pairs, the Group I rat exceeded the performance of his paired litter-mate in 10 pairs, the Group II rat out-performed the group I rat in the remaining 14 instances.

Therefore both the time and response measures of extinction performance suggest a slightly higher performance for the Group II animals, but since none of the figures yield significant differences, there is little reason to believe that any marked differences in habit strength existed as between the two groups.

It will be recalled from the preceding chapter that our procedures involved a different length of time between training and the second satiation, 37 hours for Group I and only 1 hour for Group II. Though as we have seen in Table III, both groups ate nearly the same number of pellets during training, the fact that these pellets were consumed so soon before satiation of Group II might suggest that those animals would eat slightly less than the others at that satiation. Table VI presents the mean weight of food eaten at the second satiation, 26.2 grams for Group I, and 24.4 grams for Group II. The C.R. of the difference is 1.36, which is less than the requirement for significance at the 5 per cent level. However, it is evident that, on the average, the Group II animals ate slightly less between the two satiations and might in consequence be expected to perform slightly more during the subsequent extinction test.

By way of summary, then, our results show a superiority in the speed of training performance of the "high" motivation group, and a near equivalence of the extinction performances of the two groups.

DISCUSSION

The role of motivation in habit acquisition has been studied by several investigators in recent years (1, 3, 4, 7, 8, 11, 13), and different theoretical interpretations have been given the incomplete empirical information which is available. It is now generally recognized that habit acquisition and habit utilization may relate differently to motivational factors, and while there is considerable agreement that strength of habit and current drive strength combine in some way to determine the level of performance of already learned habits (9, 14, 15), there is no such agreement on the role of drive strength in habit acquisition. Below we shall discuss the results of the present investigation as they bear on the general issue of the relation of drive strength and habit acquisition. Then, the attempt will be made to analyze our results with respect to the findings of previous investigations of this topic. Finally, suggestive information may be derived from a comparison of our results with results obtained in previous Skinner box experiments which utilized procedures relatively similar to our own.

Our results indicate that periods of 12 and 48 hours food

deprivation prior to training produce an effect on the rate of training performance but no marked effect on the strength of the learned habit. It will be recalled that Cummings found variations of 3 and 16 hours food deprivation related to speed of performance in training but not to habit strength. Therefore, both experiments produce evidence which suggests that strength of motivation is directly related to speed of performance during training but bears no relation to degree of learning. The procedure of the present experiment differed from that employed by Cummings in several respects, one of them being that the level of reinforcement in training was reduced from 16 to 5 trials, in the expectation that this change would create optimal conditions for obtaining any difference in habit strength which might be mediated by the strength of drive. The results show that despite this procedural change, no more conclusive differences in the strength of habit were obtained in the present experiment than in the Cummings study. Therefore, we must conclude that level of motivation during training, within the range of 3 to 48 hours food deprivation, is not a major determinant of the acquisition of habits. It will be recalled that the immediate point of departure of the present experiment was a question suggested by Cummings, namely whether or not at critical points on the food deprivation continuum, strength of motivation may exert an influence on learning. Certainly the results of this experiment favor ruling out such a possibility.

As was brought out in our introduction, there is marked

inconsistency among the various experimental findings bearing on the question of the relation of drive strength and habit acquisition. The findings of the Cummings experiment and the present study are in conflict with the conclusions of several other investigators. Let us examine this conflict.

Previous experimentation in the area of drive strength and habit acquisition problems has utilized essentially only two types of situations, the Skinner box and the maze. Of the relevant Skinner box studies only the results of the Finan experiment conflict with our own. This disagreement does not require further discussion in view of the several inadequacies of Finan's methodology brought out by Cummings and previously mentioned in this report. With regard to the conflict with the findings of maze investigators, it would, of course, be possible to hypothesize that Skinner box and maze habits are qualitatively different in such ways as to permit the role of drive in habit acquisition to differ between them. This hypothesis would seem, however, at the best a last ditch suggestion to be avoided until the possibilities for alternative explanations have been exhausted. Therefore, we will examine the maze findings of MacDuff, O'Kelly and Heyer, and Seward in more detail.

MacDuff investigated the relation of strength of drive during the learning of a multiple T-maze to the proficiency demonstrated in later relearning, under equal drive conditions. She found consistent though statistically insignificant differences in relearning, which she interpreted as suggesting that stronger

habits were acquired under 24 and 48 hour food deprivation than under 12 hours. MacDuff attempted to control the possibility of her 12 hour group receiving "massed practice," as compared to the others, by running her 12 hour group only every third reward period, a procedure which gives more rewards than performances, and thereby introduces an undesirable confounding of variables. Because of this procedural shortcoming, and the fact that her obtained differences were insufficient to attain significance at the 5 per cent level of confidence, MacDuff's results are not alone sufficient evidence to warrant the conclusion that drive strength at the time of learning is a major determinant of habit acquisition.

O'Kelly and Heyer attacked the same problem using different procedures. They trained 3 groups in running a straightaway under drive conditions of 12 hours thirst, 36 hours thirst, and 36 hours thirst with a pre-run drink, the last group being intended as a control on the massing of practice that occurred in the case of the 12 hour group. Their intention was to equate original training by discontinuing practice when the group median running time showed no improvement on 3 successive trials. Then, after 3 and 6 weeks, the 3 groups received 10 additional rewarded trials in the straightaway, and the group mean running times during this relearning were taken as indications of habit strength. O'Kelly and Heyer report large and significant differences in speed of relearning the straightaway, and their conclusion is that strength of motivation directly affects both speed of

training performance and the acquisition of habit. However, an examination of the experimental methodology reveals so many procedural shortcomings as to strongly suggest that the findings do not warrant such a generalization. This experiment attempted to equate original practice through the use of a criterion of improvement in running times, and it is obvious that unless this is achieved with accuracy, the study is worthless. O'Kelly and Heyer report, however, "that this criterion was not accomplished with any precision" (13, p. 469). Such an admission renders it unnecessary to read farther in the report, but that is not the only inadequacy of the experiment. With high variability other investigators have felt it necessary to use relatively large samples, but in this experiment relearning tests were made on groups as small as 7 rats, and extreme variability of scores was obtained. Even in original learning with 20 animals in the 12 hour group, we note that between the second and tenth training trials, the scores fail to improve, and in fact become slower. Helter-skelter variability, such as is found throughout those results which are reported by individual trials, suggests that either controls were lax, or the groups far too small for the production of reliable data. Therefore, because original training was not accurately equated, and because the degree of variability of results is excessive, O'Kelly and Heyer's conclusions seem to be unwarranted.

The last of the experiments, which seem at first inspection to conflict with our finding that strength of motivation is not

a prime determinant of the degree of habit acquisition, is the investigation performed by Seward and his associates. Inspection of this study reveals, however, that it is not relevant to the question of the effect of motivation on habit acquisition, despite Seward's attempts to make inferences bearing on the effect of drive on habit growth.

The explicit aim of the experiment was "to measure the relative ease of habit reversal by satiated and appropriately motivated rats" (17, p. 7). To do this, 3 groups of rats were first trained to go to one end box of the T-maze for a water reward. Then, the incentive was shifted to the other end box, and 2 of the groups were given forced runs, which were intended to allow them to learn the reversed location of the reward, the third group was a control. During this "reversal training," one group received its forced runs while sated for water, the other group while 22 hours thirsty. Finally, the third stage of the experiment consisted of allowing all 3 groups free runs, and the number of "correct" choices was tabulated for each group.

The results were that the control group made the fewest "correct" responses. The group given reversal training when sated did somewhat better, and the 22 hour group performed best of all.

Seward concluded that the sated animals had learned something, and the highly motivated animals had learned more. While this conclusion may be justified, the experiment is then a demonstration of the relative efficacy of latent learning and

reinforcement learning, and it throws no light on the relation of level of drive and habit acquisition, as contrasted to level of reward and habit acquisition.

We have analyzed the experiments whose results seemed most clearly to contradict our conclusion that level of motivation during training, within the range of 3 to 48 hours food deprivation, is not a major determinant of the acquisition of habits. Examination of the procedures employed in maze experiments leads us to the conclusion that there is no determinate evidence opposing our finding, and we have already seen that Finan's results were obtained under relatively uncontrolled conditions. Therefore, in the absence of further empirical data, we accept the hypothesis that strength of drive during learning is a determinant of speed of training but not of degree of learning.

Since several previous Skinner box experiments have utilized procedures to one degree or another comparable to our own, it may be useful for comparative purposes to examine the results of several studies together. It will be recalled that the results of the present experiment suggest that period of deprivation preceding training is a determinant of speed of performance during training, but not necessarily a determinant of amount of learning.

We have indicated that a sizeable number of studies devoted to motivation, learning, and performance relations have used closely similar Skinner box techniques. The experiments in question which are most directly comparable are the Perin-

Williams, Koch-Daniel, Saltzman, and Cummings studies. Although the first three of these are concerned with the relation of drive and performance, rather than drive and learning, certain of the sub-groups involved in the Perin-Williams experiment, and all the groups from the others, were run under conditions which make possible a suggestive comparison with our results.

The data comparisons which we shall make fall into the two categories of measures of initial training performance and measures of resistance to extinction. Table VII summarizes the data on measures of time from the first to fifth reinforcements, derived from five Skinner box experiments. These figures may be expected to be comparable since in the Koch-Daniel and Saltzman experiments, the attempt was made to duplicate Perin's procedures and apparatus, and both the Cummings study and the present experiment were patterned largely on this same procedural outline. From Table VII it may be seen that the slowest training performance of the several groups was obtained from Cummings 3 hour group, and that the three 23 hour groups, from experiments by Perin-Williams, Koch-Daniel, and Saltzman, performed during training at a faster rate, which was very similar, in fact, to the performance rate of the 48 hour group from the present experiment. Thus, within the range of variability that would be expected to result from the use of slightly different rats and techniques, the combined data suggest that speed of training performance is related to level of hunger, as defined by prior period of food deprivation. It should be noted that the figures

TABLE VII
Comparison of Initial Learning Data From
Several Skinner Box Experiments

Experiment	Hours food deprivation	Number of animals	Mean time from 1st to 5th re-inforcement
Cummings	3	40	5.19 min.*
Present experiment	12	32	3.43 min.
Cummings	16	40	4.37 min.*
Perin-Williams	23	460	2.28 min.**
Saltzman	23	120	2.56 min.
Koch-Daniel	23	32	2.57 min.
Present experiment	48	33	2.56 min.

* Approximate figure derived from a graph.

** Data from the two experiments is here combined.

for Cummings' groups were obtained by interpolation from values that she quoted for latencies in groups of four, and therefore they are approximations of obtained values.

To carry our comparison farther, Tables VIII and IX present measures of resistance to extinction obtained by Perin, Cummings, and the present experimenter, under the somewhat varied conditions of hunger at training and level of reinforcement that are indicated in the tables. Since the group differences in the Cummings study and the present experiment proved to be statis-

TABLE VIII

Comparison of Median Number of Responses to the 5
Minute Criterion From Several Experiments

Study	Hunger at training	Reinforce- ments in training	Number of animals	Hunger at extinct.	Median extinct. responses
Williams	23	5	35	22	9.0
Present exp.	12 & 48	5	65	23	13.25*
Perin	23	16	40	23	29.5
Cummings	3 & 16	16	80	23	14.5*

* An average of both experimental groups.

tically insignificant, we have averaged all the animals in each of these experiments.

Comparison of the data in Tables VIII and IX may be subjected to analysis from two points of view. One possibility would be to assume that the substantially negative conclusion of our own and the Cummings study, with respect to the determination of degree of habit acquisition by strength of hunger, is correct, and in line with this, to examine the implications of the comparisons with respect to level of reinforcement. The other possibility would be to adopt no pre-determined attitude concerning the efficacy of hunger in regulating habit acquisition, and to examine the implications of the material with respect to this question. By reference to Tables VIII and IX, it will be noted

TABLE IX

Comparisons of Mean Extinction Time Scores From the
Cummings Study and the Present Experiment

Study	Hunger at training	Reinforce- ments in training	Hunger at ex- tinction	Mean ex- tinction time
Cummings	3 & 16	16	23	11.6 min.*
Present exp.	12 & 48	5	23	11.3 min.*

*An average of both experimental groups.

that there are only very small differences between the resistance to extinction scores obtained by Cummings and by us, despite the fact that 16 and 5 reinforcements were used in the two experiments, respectively. One difference of procedure, however, may somewhat vitiate the significance of this comparison. Cummings removed the rats from the box after each of the first two bar-depressions during extinction, for a one minute period of "spontaneous recovery," a procedure Perin had used. The present methodology did not include this step. In general, one might expect that such an operation would depress the obtained measures of resistance to extinction. There is, however, no determinate way of evaluating the extent to which this procedural difference affects the significance of the comparison, and the comparison should, therefore, be regarded as having only suggestive significance.

The earlier Perin and Williams data, it will be recalled,

served as the chief source for Hull's discussion of primary motivation (5, p. 226-256). The Perin values have already been questioned at low levels of hunger (9, 15), and it remains to be seen whether or not the values Perin obtained, as functions of number of reinforcements, will stand under further experimental scrutiny. Table VIII may suggest part of the answer, since it contains Perin's value for 23 hours hunger and 16 reinforcements, which is markedly higher than Cummings' value for equal deprivation and reinforcement, although Williams' value for 23 hours hunger and 5 reinforcements is below the finding of the present experiment for these levels. Table IX suggests that not only do the Cummings study and the present experiment obtain closely similar values for number of extinction responses to the 5 minute criterion, but they also find time until the criterion very similar, although 16 and 5 reinforcements were used in the two experiments, which, according to the Perin function, should have produced sizeable differences.

If we should just hypothetically assume that strength of drive during training is a relevant factor in determining later resistance to extinction, the Cummings and Perin data in Table IX might be interpreted as due to the difference of 3 and 16 hours, as compared to 23 hours hunger, at training. Although this assumption is a possible one, it is highly improbable in the light of the agreement of our data and the data from the Cummings experiment.

Cummings and the present experimenter used the same apparatus,

and rats which seem to have been similar when compared on the basis of amount of food eaten at satiation, number of bar-depressions preceding the first reinforcement, and the measures presented above. But, despite the use of two considerably different levels of reinforcement, the two experiments obtain no compelling differences in resistance to extinction. This finding would be in marked conflict with the conclusion which Perin based on his own and Williams' data, to the effect that resistance to extinction is a positive growth function of the number of reinforcements. Therefore, one suggestion for future research which emerges from the comparison of the present findings with the results of earlier studies is the desirability of additional investigations of the role of level of reinforcement in the determination of habit strength.

Summary

The present experiment is concerned with the role of strength of motivation, during training, in the determination of strength of habit. Our procedure was to give equal training in the Skinner box to groups of rats under conditions of 12 and 48 hours food deprivation, and then to test the resistance to extinction of the learned habit. Our results indicate that strength of motivation at the time of training is a determinant of the rate of performance during training, but not an appreciable determinant of habit acquisition.

We discussed these findings in relation to previous studies

in the area of motivation and learning, and concluded that there is no determinate evidence which contradicts our results. Comparisons of our data with data from previous experiments were made, and these comparisons led to the following conclusions:

- 1) There is considerable evidence to support our suggestion that drive strength does affect rate of performance during training;
- 2) Drive strength during learning seems substantially unrelated to habit acquisition, within wide ranges of drive levels; and
- 3) Perin's assumption of an orderly exponential relation between number of reinforcements and growth of habit strength is called into question in view of the evidence from both the Cummings study and the present one.

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