AN EXPERIMENTAL STUDY OF THE RELATIVE VALUES OF REWARD AND PUNISHMENT IN HABIT FORMATION

BY

JOHN D. DODSON

A DISSERTATION

SUBMITTED TO THE FACULTY

OF THE

GRADUATE SCHOOL OF SCIENCE,

LITERATURE AND ARTS OF THE

UNIVERSITY OF MINNESOTA IN

PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE

OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF PSYCHOLOGY

APRIL 1918

I hereby desire to acknowledge my indebtedness to Major Robert M. Yerkes for his supervision and valuable suggestions in carrying out this experimental study.

J.D.D.

INDEX

RELATIVE VALUES OF REWARD AND PUNISHMENT IN HABIT FORMATION

*****

Problem. The first need of the student of animal behavior, under laboratory conditions, is some form of stimulation which will serve as a motive for the proper performance of the required act. The forms of stimuli most commonly used are rewards and punishments. But there are differences of opinion among students of comparative behavior as to which of these two motives facilitate most the learning process. At the suggestion of Professor R. M. Yerkes the writer has undertaken to answer, for at least a a sensory habit in one species of animals, this important question.

History. The use of reward and punishment as motives for securing desired forms of behavior is as old as the companionship of human and infra-human organisms. Wherever man has attempted to establish habits of subserviency in lower animals he has resorted primarily to one or both of these motives for action. But the close of the last century and the beginning of the present have seen an awakening of a broader interest in animal behavior than that of subserviency - an interest in the comparative behavior of living organisms. With the interest in comparative behavior and the use of laboratory methods naturally came the question of motive to secure the desired behavior.

If one ignores a few experiments done by Romanes, Lubbock, Gaber, Preyer, Loeb and Verworn (1881 to 1890) whose interests were primarily physiological and not psychological, he may begin his history of comparative experimental behavior with E. L. Thorndike whose " Animal Intelligence" appeared in 1898. He reduced his subjects to a state of "utter hunger" and placed them in a box from which they might escape by working some form of simple door-fastener. The motive used to get the animal to react to this situation was the placing of food on the outside of the box. These experiments brought forth a considerable amount of adverse criticism. These criticisms were directed either against the placing the animal under abnormal conditions as a means of control or against reducing them to a condition of " utter hunger". But these objections did not seriously affect the interest in comparative behavior; and many valuable experiments have been performed in our psychological laboratories, especially Harvard, Chicago, Johns Hopkins and Clark.

Within the next decade after the appearance of Thorndike's monoghaph, Yerkes, in the Harvard Psychological Laboratory, had devised a means of using punishment as a motive for the proper performance of a required act. He says,[11] " My experiments with the dancer differ from those which have been made by most students of mammalian behavior in one important respect. I have used punishment instead of reward as the chief motive for the proper performance of the required act. Usually in experiments with mammals hunger has been the motive depended upon. The animals have been required to follow a certain devious path, to escape from a box by working a button, a bolt, a lever, or to gain entrance to a box by the use of the teeth, claws, hand, or body weight and thus obtain food as a reward. There are two very serious objections to the use of the desire for food as a motive in animal behavior experiments - objections which in my opinion renders it almost worthless in the case of many animals. These are the discomfort of the animal and the impossibility of keeping the motive even fairly constant. However prevalent the experience of starvation may be in the life of the animal, it is not pleasant to think of subjecting it to extreme hunger in the laboratory for the sake of finding out what it can do to obtain food. Satisfactory results can be obtained in an experiment whose success depends chiefly upon hunger only when the animal is so hungry that it constantly does its best to obtain food, and when the desire for food is equally strong and equally effective as a spur to that action in the repetitions of the experiment day after day. It is easy enough to get almost any mammal into a condition of utter hunger, But it is practically impossible to have the desire for food of the same strength day after day."

But the use of punishment as a motive for the performance of a required act did not escape adverse criticism. Watson says, [10] " It is not fair to talk of the cruelty and inhumanity of keeping the animal hungry, as has been done by several writers, until there is some factual support for the charge. There is not the slightest difficulty in keeping the animal in perfect condition and at the same time hungry enough to work properly. We have found no animal which does not work well when food is used as the general stimulus.**** We repeated the maze experiment on the dancer with food as a stimulus. So far as we could judge the method was as satisfactory, from the standpoint of the rapidity of learning and from that of the well being of the animal, as the punishment of Yerkes.**** This punishment method has not worked any too well. It has been criticised by Hamilton who found that it made his dogs restless and hesitant, by Lashley, who found it made rats, where association was difficult, after a time refuse to work."

In spite of the difficulties of using reward and punishment as stimuli for the performing of any desired act, there are many valuable experiments in animal behavior for which one or both of these are not only desirable but almost absolutely necessary for the performance. This being true, it is very profitable that the experimenter knows which is the most favorable to habit formation.

English

During the years, 1907 and 1908 Dr. Yerkes and the writer attempted to work out, in the Harvard Psychological Laboratory, the problem as to the relation of strength of stimulus to rapidity of habit formation.[12] The subject used for this experiment was the dancing mouse; the habit for the dancer to acquire was a simple visual discrimination between two boxes of different light intensity. We used three degrees of difficultness of discrimination, easy, medium and difficult; and three strengths of stimuli, weak, medium and strong. The data secured led to the following conclusions:

1."In the case of the particular habit which we have studied, the rapidity of learning increases as the amount of difference in the brightness of the electric boxes between which the mouse is required to discriminate is increased. The limits within which this statement holds have not been determined."

2. "The relation of the strength of electdical stimulus to rapidity of learning or habit-formation depends upon the difficultness of the habit, or, in the case of our experiments, upon the conditions of visual discrimination."

3. "When the boxes which are to be discriminated between differ very greatly in brightness, and discrimination is easy, the rapidity of learning increases as the strength of electrical stimulus is increased from the threshold of stimulation to the point of harmful intensity. Our results do not represent, in this instance, the point at which the rapidity of learning increases begins to decrease, for we did not care to subject our animals to injurious stimulation. We therefore present this conclusion tentatively, subject to correction in the light of future research. Of its correction we feel confident because of the results which the other sets of experiments gave."

4. "When the boxes differ only slightly in brightness and discrimination is extremely difficult the rapidity of learning at first rapidly increases as the strength of stimulus is increased from the threshold, but, beyond an intensity of stimulation which is soon reached, it begins to decrease. Both weak stimuli and strong stimuli result in slow habit-formation. A stimulus whose strength is nearer to the threshold than the point of harmful stimulation is most favorable to the acquisition of a habit."

5. "As the difficultness of discrimination is increased the strength of that stimulus which is most favorable to the acquisition to habit formation approaches the threshold. This leads us to infer that an easily acquired habit, that is one which does not demand difficult sense discriminations or complex associations, may readily be formed under strong stimulation, whereas a difficult habit may be acquired readily only under relatively weak stimulation."

Professor Laurence W. Cole repeated the above experiment on the chick with the discriminatory conditions somewhat changed to fit the needs of his subjects.[2] His results led him to the following conclusion:

"In conclusion, it is evident that within the limits of the stimuli which I used, the number of trials required by the chick to learn to choose consecutively the darker of the two unequally illuminated screens, when discrimination is easy, decreases with an increase of stimulus. Under medium difficulty of discrimination the above law holds true only for the lower intensities of the stimuli which were used or, in other words, the optimal stimulus recedes towards the threshold from 590 to 480.[6] The above law for the condition of easy discrimination holds true for that of difficult discrimination if we consider only the record of the chicks which succeeded in learning to make the discrimination. If, however, we consider only the chicks which failed, the optimal stimulus recedes once more to a point nearer the threshold of stimulation than in case of medium discrimination. In other words, with difficult conditions of discrimination, strong stimuli divided the chicks into two groups, those which succeeded in learning to discriminate by reason of more right choices at the beginning of the training series and consequently fewer pain stimuli, and those which failed because of fewer right choices and more pain stimuli in the earlier trials. So far as I determined the sensitiveness of chicks, it may be said that on the average the more sensitive chicks learn more rapidly both for strong and weak stimuli."

Mildred A Hogue and Ruth J. Stocking did some work in Johns Hopkins Psychological Laboratory on the relative values of punishment and reward as motives.[4] Their subjects were a mixed breed of black-and-white rats. The problem for the rats was to learn to discriminate between two lights of different intensity always choosing the one and avoiding the other. The experimenters divided their subjects into three groups of two rats each and trained two with punishment, which was a "light electric shock", two with reward, which was "milk-soaked bread", and two with a combination of reward and punishment.

Of the two rats trained with reward and punishment one finished in 490 trials, or the 49th day, the other in 550 trials, or on the 55th day; but the first of these made a perfect record on the 30th, 31st, 34th, 37th, 40th, 43rd and 44th days; the latter made a perfect record on the 48th day. Of those trained with punishment one finished in 550 trials; the other had not finished when the experiment was discontinued on the 60th day; but later made a perfect record on the 37th, 50th and 51st days. Neither of the animals used with reward finished or made a perfect record during the entire series. From these results the experimenters came to the following conclusions:

"It seems evident from this experiment that a combination of punishment and reward-motives is more effective in bringing about visual discrimination in the rat then is either punishment or reward used alone. It seems evident, also that punishment is more affective than reward, at least in so far as the rate of learning is concerned."

Whatever else the above experiments may or may not have proved, they demonstrate beyond a question of doubt that no experimenter can arbitrarily choose a single strength of stimulus or degree of hunger and say he has the most favorable condition for training any living organism. The experiment on the relative value of punishment and reward as motives shows almost nothing of the relative value of these two motives. The strength of electrical shock used may have been the most unfavorable to the learning process while the degree of hunger was the most favorable, or the strength of shock may have been the most favorable while the degree of hunger was the most unfavorable. It seems likely from the results that both the electrical shock and the degree of hunger were too weak to keep the animals up to their greatest capacity. To meet this difficulty, at least in some measure, we have worked out a curve for the relative values of different strengths of shock and a curve for the different degrees of hunger.

Subject Used. As the white rat possesses the desirable qualities of lending itself readily to laboratory methods and treatment, and of breeding rapidly we chose it as our subject. All individuals used in this experiment were bred in the Harvard Laboratory for Animal Psychology from a pure albino " pet rat stock" secured from Miss A. E. C. Lathrop, Granby Massachusetts. They were fed, when not being used as subjects, at 8:30 in the forenoon and at 5:00 in the afternoon each day. The morning meal consisted of mixed grains and the afternoon meal of bread soaked in milk. A constant supply of water was provided by means of automatically feeding bottles which also served as weights to keep the doors closed.

Apparatus. The control box, figure 1, was 55 cm. long by 39 cm. wide by 20 cm. deep. It was divided into a nest box, A, 15 cm. long by 21 cm. wide, an entrance chamber, B, 20 cm. long by 21 cm. wide, two electric boxes, D, D, each 15 cm. long by 10 cm. wide and two alleys, E,E,each 55,cm. long by 8 cm.wide. The nest box opened into the entrance chamber by a small doorway,F, closed by a vertically sliding door. The right electric box opened into the right alley and the left into the left alley by the doorways,G,G,which were closed by colorless glass doors. The alleys opened into the nest box by means of swinging wire doors,H,H, which a rat could easily push open and enter the nest box but could not could not pass back into the alley. Small food receptacles,I,I, were inserted into the side at the rear of the control box. These receptacles could be removed and the openings closed by small metal doors. On the floors of the electric boxes were series of copper plates connected in a circuit with a No.6 Columbia dry cell and a calibrated Porter inductorium. The current was kept constant at 1.5 amperes by means of a resistance coil. Fastened to the rear of the control box was a lamp stand,J.

Room and Light. The experiment was done in a dark room lighted by a "Champion" 16 watt ground glass tubular lamp K,fig.1,the lighting capacity of which was

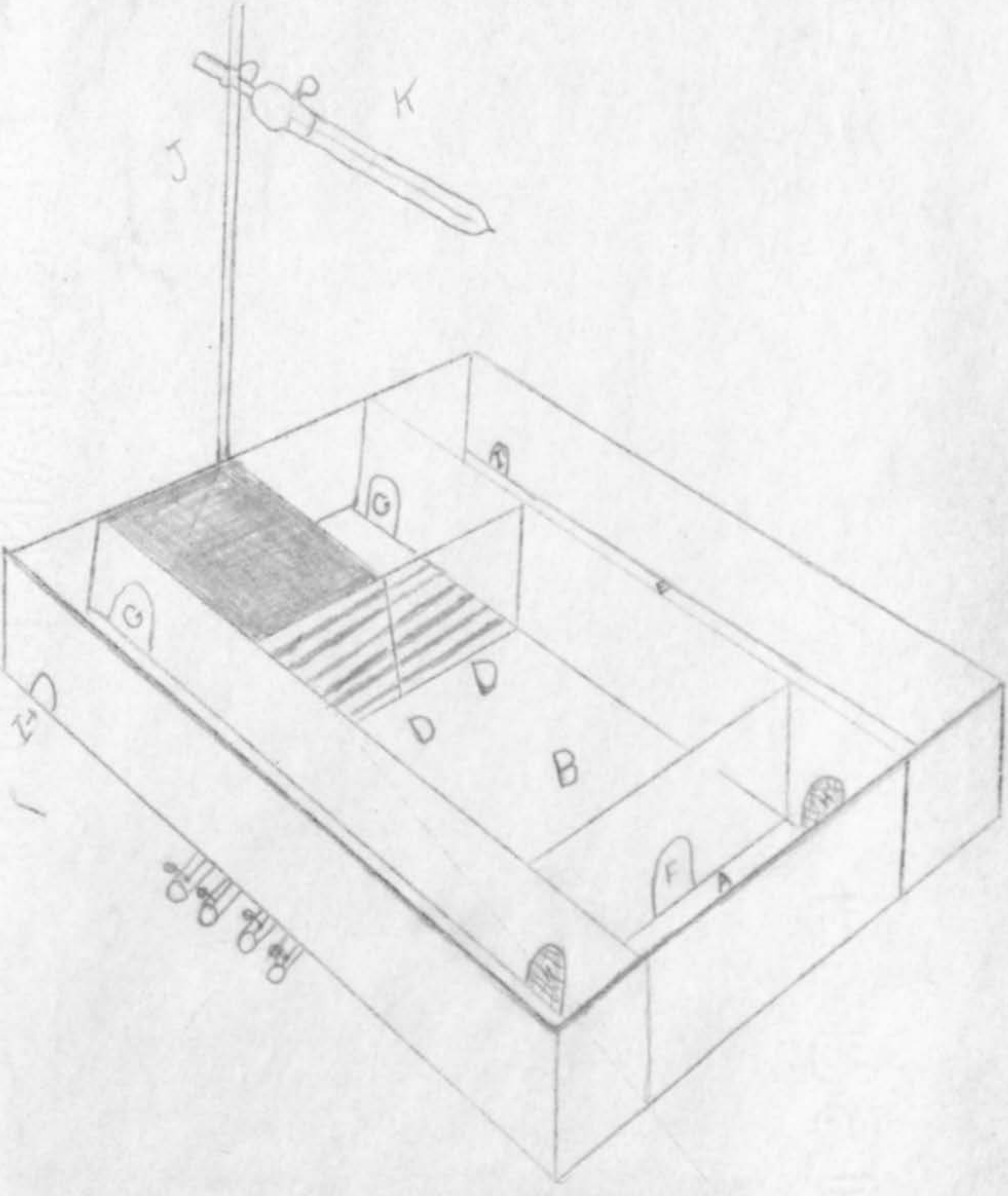

Fig.1.Control Box. A,nest box; B,entrance chamber; D,D,electric boxes; E,E,alleys;F, G,G,H,H,doorways; I,I,food receptacles; J, K, lamp stand and lamp.

reduced by a resistance coil to 0.61 candle power. The lamp was attached to the stand at a distance of 80 cm. from the bottom of the control box and so placed that the front of the electric boxes cast a perpendicular shadow. One of the electric boxes was made dark by placing a cardboard just the size of the top of the box over the box. This cardboard was shifted from one box to the other in the order shown in record blank, table 1. Thus the problem for the rat was to learn to discriminate between a box the lighting of which was 0.95 candle-meter and a box the lighting of which is such as was reflected from the dark surface of the control box through an opening 10 cm. by 15 cm. at the front of the electric box, and to choose the light box.

Method: (1) Time and Number of Trials — Each subject was given ten trials every third day. This unusually long time between training periods was necessary to make it possible to use a hunger period of forty-eight hours. In order to eliminate differences due to tendencies of varied activity of the rat at different hours of the day, all experiments were done between three and five o'clock in

Subject .... Age .... Reward or Punishment .... Date ....

Date	Tests → / Series ↓	1	2	3	4	5	6	7	8	9	10	R	W	T	REMARKS
	1	r	r	l	r	l	l	r	l	r	l				
	2	l	l	r	r	l	r	l	l	r	r				
	3	r	r	l	r	l	l	r	l	r	l				
	4	l	l	r	r	l	r	l	l	r	r				
	5	l	l	r	l	r	r	l	r	l	r				
	6	r	r	l	l	r	l	r	r	l	l				
	7	l	l	r	l	r	r	l	r	l	r				
	8	r	r	l	l	r	l	r	r	l	l				
	9	r	l	l	r	r	l	l	r	r	l				
	10	l	r	r	l	l	r	r	l	l	r				

Memory Tests

		r	r	l	r	l	l	r	l	r	l				
			l	r	r	l	r	l	l	r	r				

TABLE 1

the afternoon. The animals trained with electrical shock were given their trials from three to four o'clock and those with hunger from four to five. The habit was considered perfected when the subject made ten correct choices on the same day. While this is a smaller number of correct choices than is usually required in like experiments we did not care to require an animal to retain the habit for so long a time as six or nine days.

(2) Care of Subjects. Subjects which were trained with electrical shock were fed twice daily just as the animals which were not being used. The subjects which were trained with hunger were fed the same only during the period of training. The group trained with twenty four hours of hunger was fed the last time, before the experiment, at three-thirty in the afternoon of the day prior to the day of the experiment. Thirty minutes after feeding the rats were transferred to a cage in which no food was ever put and kept there until the time of the experiment. The group trained with thirty-one hours of hunger was fed at eight thirty A.M. and transferred at

at nine thirty A.M. of the day prior to the day of the experiment. The group trained with forty-one hours of hunger was fed last at ten and transferred at ten-thirty P. M. two days before the day of the experiment. The fourth group trained with forty-eight hours hunger was fed at three thirty and transferred at four P.M. two days before the day of the experiment.

(3) Training with Electric Shock. At the beginning of each experiment all doors of the control box were closed except the one at the exit of the light box. The food receptacle had been removed on the day before and all food cleaned off the box and the openings closed. The subject was placed in the nest box and allowed to pass into the choice box where it faced the dual possibility of entering the light or dark electric box. If it chose the light box it could pass out at the exit and through the alley to the nest box without receiving any shock; but if it chose the dark box it received an electric shock and it had to return through the entrance chamber and the light box in order to get to the nest box. The shock was given to the animal after it had entered the electric box instead of as

it entered as is the usual method. This was to make the place of punishment as nearly comparable to the place of food as was possible.

(4) Training with Food. At the beginning of the series of experiments with food, food was placed in the receptacles and all doors closed as in case of the training with electric shock. If the subject chose the light box it found toasted corn flakes soaked in cream in the food receptacle. The rat was given about ten seconds in which to eat then the experimenter made it pass on through the alley into the nest box ready for another trial. If the animal chose the dark box it found the door closed and had to return into the entrance chamber and pass out through the light box.

(5) Timing of Subject. The experimenter kept the time in seconds that the subject took from the moment it entered the entrance chamber until it entered one of the electric boxes.

(6) Selecting of Subjects. In order to eliminate family differences each litter of rats was divided equally; and one group trained with hunger and the other with electric shock.

PRELIMINARY EXPERIMENT

At the beginning of this experiment certain preliminary questions still remained to be answered. The most important of these were (1) The advisability of giving light-dark preference series and (2) the earliest age at which rats are sufficiently well developed to undergo periods of starvation as long as forty-eight hours without being reduced to physically unfit conditions for experimentation.

Subjects used for this series of experiments were fifty-six days old on the day of the experiment began. Each rat was given one-half hour a day for five days preceding the experiment proper in the control box with doors opened, with the cover of the electric box removed and food in the receptacles . This gave the animals an acquaintance with the box and the place where food might be found in case of hunger.

Special Conditions of Series I. A series of experiments as here used includes all subjects, both hunger and electric shock, which were trained at the same time. The electric shock used for the first series was seventy-five units [6]; and the length of the period of hunger was twenty-four hours. The difficultness of discrimination was the same in all experiments - being fairly easy.

Special Conditions of Series II. The strength of the electric shock used for the second series was two-hundred and fifty units; and the length of period of hunger was thirty-one hours.

Results. Detailed results of the above series of experiments are given in tables 2 to 5. These tables also give the results of the retraining of the same subjects after a period of twenty-one days from the day on which each animal perfected the habit. The retraining of each group of rats was done under the same conditions as the training, and the habit was considered re-established when the subject made ten successive right choices.

Construction of Tables. At the top of each table are the numbers of the subjects * trained under the conditions stipulated in the heading of the table. The first vertical column gives the series number; in the other columns appear the number of errors made in each series of trials by the several subjects; the average number of errors made by males and females; the general average made by both males and females; and in the last column the total average time of choice.

---

* Even numbers refer to males and odd to females.

TABLE 2

RESULTS WITH PUNISHMENT OF 75 UNITS

No. of Series	Males										
	No. 34		No. 38		No.42		No. 44		No.46		
	W.	AV.T.	W.	Av.T.	W.	Av.T.	W.	Av.T.	W.	Av.T.	Av.E
1	5	17.9"	7	4.7"	6	1.6"	4	3.4"	6	3.6"	5.6
2	4	11.5	6	1.5	4	2.0	3	3.1	4	2.0	4.2
3	1	3.4	4	1.6	1	1.7	3	2.	5	2.1	2.8
4	0	6.0	0	2.1	0	1.6	2	2.0	4	1.8	1.2
5							1	2.0	1	2.0	.4
6							1	1.6	0	2	.2
7							0	3.8			0
	Retraining										
1	1	3.4	5	1.3	7	3.6	3	3.0	0	1.5	3.2
2	1	2.5	3	1.5	2	2.8	0	2.1			1.2
3	0	2.0	0	2.2	0	1.4					0.

No. of Series	Females								Total
	No.35		No.39		No.41				
	W.	Av.T.	W.	Av.T.	W.	Av.T.	Av.E.	Gen.Av.	Av.T.
1	6	15.0"	6	4.7"	5	5.2"	5.6	5.62	6.9"
2	3	11.7	4	2.1	6	6.9	4.2	4.33	4.6
3	0	6.7	5	3.3	4	4	3	3.88	3.1
4			0	4.5	5	6.0	1.4	1.36	4
5					6	2.0	2	1.5	3.3
6					3	8.	1.	.5	3.8
7					4	4.2	1.33	.5	4.7
8					0	5.0	0	0.	4.4
1	0	3.6	1	3.4	0	3.2	0.33	2.13	2.8
2			0	4.5			0	.75	2.2
3								0.0	1.8

TABLE 3

RESULTS WITH HUNGER OF 24 HOURS

No. of Series	Males No. 36 W.	Av.T.	No. 40 W.	Av.T.	No. 48 W.	Av.T.	Av.E.
1	6	2.7	5	3.7	6	3.0	5.66
2	3	2.1	5	2.5	6	2.	4.66
3	5	1.3	2	3.0	6	1.2	4.33
4	4	1.9	2	1.3	2	0.9	2.66
5	2	1.6	2	1.0	1	1.1	1.66
6	4	1.1	2	1.1	2	1.0	2.66
7	3	1.2	1	1.2	2	1.1	2
8	2	1.1	3	1.0	6	1.5	3.66
9	3	1.2	0	1.0	2	1.1	1.66
10	2	1.1			4	1.4	2
11	2	1.0			1	1.0	1
12	1	1.2			2	1.0	1
13	2	1.2			2	1.0	1.33
14	1	1.0			3	1.2	1.33
15	0	1.0			2	1.0	.66
16					0	1.0	0.0
				Retraining			
1	2	1.0	2	1.0	4	1.4	2.66
2	1	1.1	0	1.0	1	1.2	.66
3	6	1.1			0	1.1	2
4	4	1.0					1.66
5	0	1.2					

	No. 37 W.	Av.T.	No. 43 W.	Av.T.	No. 45 W.	Av.T.	No. 47 W.	Av.T.	Av.E.	Gen.Av.	Av.T.
1	4	7.0	5	1.5	5	2.4	4	1.8	4.5	5	3.2
2	8	2.5	3	1.6	2	1.4	2	1.2	3.75	4.14	1.8
3	5	1.3	2	3.0	6	1.2	1	1.1	4.	4.14	1.4
4	3	2.5	4	1.7	3	1.5	2	0.8	3.	2.88	1.5
5	5	1.7	4	1.0	6	1.0	0	1.0	3.75	2.86	1
6	5	2.4	4	2	2	1.0			2.75	2.71	1.6
7	3	2.0	3	2	6	1.0			3	2.57	1.6
8	3	2.5	5	1.5	5	1.2			2.75	3.45	1.6
9	2	1.2	6	1.0	2	1.0			2.5	2.14	1.1
10	0	1.5	4	1.0	5	1.1			2.25	2.14	1.2
11			0	1.0	1	1.0			.25	0.57	1.
12					2	1.1			.5	.71	1.1
13					2	1.0			.5	.86	1
14					1	1.1			.25	.71	1.1
15					1	1.1			.25	.43	1
16					2	1.0			.5	.28	1.1
17					0	1.0			0.0	0.0	1.0
						Retraining					
1	5	1.3	3	1.2	0	1.0	2	1.0	2.5	2.57	1.1
2	1	1.0	3	1.0			0	1.0	.75	.71	1
3	2	1.2	3	1.2					1.0	1.43	1.2
4	0	1.2	1	1.4					.25	.71	1.2
5			3	1.1					.75	.43	1.2
6			0	1.0					0.0	.00	1.0

TABLE 4

RESULTS WITH ELECTRICAL SHOCK OF 250 UNITS

No. of Series	Males No. 60 W.	Av.T.	No. 62 W.	Av.T.	Av. Er.
1	6	6.1	7	1.5	6.6
2	2	1.6	2	2.1	2
3	5	2.0	1	1.0	3
4	3	1.6	1	2.1	2
5	2	1.1	0	1.2	1
6	3	1.2			1.5
	0	1.4			0
	Retraining				
1	3	1.0	0	1.0	1.5
2	1	1.0			.5
3	3	1.1			1.5
4	0	1.6			0

Females

No. of Series	No. RO W.	Av.T.	No. 51 W.	Av.T.	No. 53 W.	Av.T.	No. 61 W.	Av.T.	Av.E.	Gen.Av.	Av.T.
1	4	3.5	5	4.0	4	6.0	5	4.0	4.5	5.16	4.2
2	4	3.2	4	3.7	2	2.8	3	1.6	3	2.83	2.5
3	5	2.0	1	1.0	4	3.0	2	2.4	2.75	2.83	2.6
4	3	1.6	4	1.8	1	1.3	0	1.9	2	2	2.1
5	0	30	3	1.5	0	1.1			1	.87	1.4
6			3	1.4					0.75	1.0	1.3
7			0	2.6					0.00	0	2
	Retraining										
1	4	1.0	2	1.3	5	1.0	1	1.8	3	2.5	1.2
2	2	1.1	1	1.3	6	1.0	2	1.3	2.75	1.	1.1
3	0	1.1	0	1.1	0	1.2	0	1.1	0	0.5	1.1
4										0.0	1.6

TABLE 5

RESULTS WITH HUNGER OF 31 HOURS

No. of Series	Males No. 64		No. 70		
	W.	Av.T.	W.	Av.T.	Av. E.
1	6	1.0	2	1.3	4
2	4	.9	1	1.3	2.5
3	7	1.4	0	.9	3.5
4	3	.8			1.5
5	1	.7			.5
6	3	.8			1.5
7	1	.6			.5
8	0	.7			.0
			Retraining		
1	1	.8	1	.8	1.
2	2	1.1	0	1.0	1.
3	1	.9			.5
4	2	.8			1.
5	1	1.0			0.5
6	0	1.0			0.0

	Females No. 55		No. 57		No. 63		No. 65				
	W.	Av.T.	W.	Av.T.	W.	Av.T.	W.	Av.T.	Av.E.	GeN.AV.	Av.T.
1	6	2.5	3	1.3	6	1.0	4	1.0	4.75	4.5	1.3
2	5	1.4	6	1.0	4	1.0	4	1.0	4.75	4	1.1
3	5	.8	1	.7	5	1.3	6	1.3	4.25	4	.9
4	3	.8	2	.8	2	.7	1	.7	1.5	1.5	.7
5	0	.7	1	.8	4	.7	2	.7	1.75	1.33	.7
6			0	.7	4	.7	2	.9	1.5	1.5	.7
7					3	.6	1	.7	1.0	.83	.7
8					4	.6	4	.8	2.	1.33	.7
9					2	.6	1	.7	0.75	.5	.7
10					5	.7	0	.7	1.25	.83	.7
11					2	.7			.5	.32	.8
12					0	.6			0.0	.0	.6
					Retraining						
1			2	1.0	5	1.0	5	1.0	4	2.6	.9
2			1	1.4	2	.9	0	.7	1.5	1.	1.2
3			5	1.2	1	.8			2	1.4	.9
4			4	1.0	0	.8			1.66	1.2	.8
5			0	0.9					0	0.2	.9
6										0	1.0

Conclusions: 1. On the whole subjects showed no marked preference between the light and the dark box but the experimenter found four rats, all belonging to the same litter, which were decidedly positive phototropic. Two of these animals always chose the light box and the other two took the light box eight out of ten trials. But this must not be taken to have any bearing on the question of light or dark preference in rats under ordinary light conditions for the light used in this experiment was not only very weak being 0.65 candle power but was softened by the ground glass bulb.

2. When the experimenter attempted to use a period of hunger of forty-eight hours he found that rats fifty-six days old could not undergo so long a period of starvation but were by the third or fourth series physically unfit for use.

3. The above facts led us to establish two preference series of ten trials each and to use subjects older than fifty-six days.

EXPERIMENT PROPER

Subjects used in the experiment proper were seventy-eight days old on the day that the training series began. Each animal was given one-half hour daily in the control box for five days preceding the training series in order that the subject might become familiar with the box and the place where food might be found. In addition to this each subject was given two preference series of ten trials each on the two days preceding the training series.

Special Conditions of the Experiments. The experiments were done in four sets, each set consisting of a group of animals trained with electric shock and a group trained with hunger. For the first set the strength of electric shock was one hundred and fifty units and the length of the period of hunger was forty-eight hours. For the second set the strength of electric shock was one hundred and fifteen units and the period of hunger was thirty-one hours. For the third set the strength of electric shock was seventy-five units and period of hunger twenty-four hours. For the fourth set the strength of electric shock was sixty units and the period of hunger forty-one hours.

Retention. On the twenty-first day after the subject had perfected the habit a retention series of ten trials was given. This series was given under the same conditions and in the same manner as the training series except the subject was neither given food for right choice nor electric shock for wrong choice.

Retraining. Three days after the retention test retraining was begun and each individual was retrained in the same way that it had been trained. The habit was considered perfected, as it was in the training series, when the rat made a perfect series of ten successive trials.

Results. Detailed results of training, retention and retraining are given in tables 6 to 13 inclusive. These tables are constructed on the same plan as the tables in the preliminary experiments.

Curve of Learning. Figures 2 and 3 show the characteristic differences in the curves of learning and curves of re-learning with electric shock and hunger. These curves represent the average number of errors made in each training series as given in the next to the last column of tables 6 to 13 inclusive.

TABLE 6

RESULTS WITH ELECTRIC SHOCK OF 150 UNITS

No. of Series	Males: No. 74 W.	Av.T.	No. 76 W.	Av.T.	No. 82 W.	Av.T.	No. 84 W.	Av.T.	No. 86 W.	Av.T.	Av.E.
A	5		4		4		8		6		5.4
B	7		6		5		6		5		5.6
Q	6	3.0	5	4.0	5	1.8	5	3.0	4	2.0	5
2	4	3.6	4	6	3	1.9	4	2.4	4	4.5	4.2
3	4	2.1	1	4.5	5	1.2	5:	2.2	6	1.9	4.2
4	4	1.6	1	4.0	2	1.3	5	1.9	2	1.6	2.8
5	2	1	3	3.8	0	1.1	5	6.8	3	2.2	2.6
6	2	1	0	5.5			2	9.0	0	3	.8
7	2	2.5					3	5			1.0
8	3	3.7					2	5			1.0
9	3	4.5					2	5.8			1.
10	0	3					0	13.7			0.0
1	4	3.0									
Retention											
1	4	3.0	0	4.6	6	2.4	1	9.0	1	3.5	3.4
Retraining											
1	3	2.6			4	1.9	2	4.4	1	4.5	2
2	4	3.1			1	1.1	0	4.8	2	3.6	1.4
3	2	2.8			1	1.6			0	3.0	.6
4	0	4.6			0	1.6					

No. of Series	Females: No. 71 W.	Av.T.	NO. 73 W.	Av.T.	No. 81 W.	Av.T.	No. 85 W.	Av.T.	Av.E.	Gen.Av.	Av.T.
A	U		6		3		6		5.5	5.44	
B	7		4		6		6		5.75	5.77	
1	5	5.0	7	1.8	4	2.0	7	3.0	5.75	5.33	2.8
2	4	2.0	2	2	5	1.5	3	3.1	3	3.33	3.8
3	2	6.5	2	2.0	3	1.2	4	1.2	2.75	3.58	2.2
4	3	1.7	1	1.4	1	1.3	1	1.6	1.5	2.11	2.3
5	1	1.4	2	3	2	1.1	0	2.2	1.25	2	2.2
6	0	4.0	2	6.0	0	1.0			0.5	0.66	2.2
7			0	4.2					0.0	.56	2.6
8										.56	1.0
9										.56	8.3
10										0.0	5
P.E. 3.9											
Retention											
1	0	1.2	1.	4.5	2	1.2	2	1.2	1.25	1.88	2.5
Retraining											
1			1	4.5	0	2.1	0	3.9	0.25	1.22	3.4
2			0	3.1						.77	2.2
3										.33	3.1
4										0.0	3.1

TABLE 7

RESULTS WITH HUNGER OF 48 HOURS

No. of Series	Males No. 72 W.	Av.T.	No. 78 W.	Av.T.	No. 80 W.	Av.T.	No. 88 W.	Av.T.	No. 90 W.	Av.T.	Av.Er.
A	6		4		6		8		6		6
B	4		4		5		5		5		4.6
1	3	1.4	6	5	9	4.0	5	1.0	5	1.0	5.6
2	7	1.0	7	1.4	3	1.2	3	.7	7	1.0	5.4
3	5	1.4	4	1.1	3	1.0	5	1.0	2	1.0	3.8
4	5	1.0	3	1.4	5	1.0	4	1.0	6	1.0	4.6
5	5	1.4	3	1.5	5	0.8	3	0.8	4	1.6	4.0
6	2	.8	2	1.1	4	1.0	2	1.1	3	1.1	2.6
7	3	2.0	5	1.6	4	1.0	2	.8	6	1.0	4.
8	3	1.3	2	2.3	5	1.0	2	.9	3	1.0	3.
9	6	1.3	2	2.0	4	.9	5	1.0	6	1.2	4.6
10	5	1.2	9	1.5	3	0.7	2	.9	4	1.8	4.6
11	4	1.3	4	1.6	3	.8	2	.7	4	1.4	3.4
12	6	2.5	2	6.2	0	1.5	3	.8	3	1.8	2.8
13	2	1.2	2	2.4			1	.9	4	1.3	1.8
14	1	1.3	3	1.2			4	.7	4	1.1	2.4
15	0	1.0	2	1.0			4	.7	4	1.0	2
16			0	1.0			1	.8	4	1.4	1
17							1	1.0	0	1.0	0.2
18							0	.6	-		0.0
Retention	1	1.3	4	1.1	5	1.1	0	.5	6	0.9	3.2
Retraining 1	0	0.5	2	.6	3	.8			3	.7	1.6
2			3	.7	4	.7			2	.7	1.8
3			1	.6	0	.6			2	.5	.6
4			3	.7					1	.6	.8
5			0	.7					0	.5	0.0

P.E. 5.9

TABLE 7 CONTINUED

RESULTS WITH HUNGER OF 48 HOURS

No. of Series	Females No. 75 W.	Av.T.	No. 77 W.	AV.T.	No. 87 W.	Av.T.	No. 89 W.	Av.T.	Av.E.	GeN.Av.	Av.T
A	4		5		7		5		5.25	5.66	
B	6		7		6		7		6.5	5.44	
1	3	1.5	5	1.4	4	1.0	2	3.0	3.5	4.99	2.1
2	5	1.1	5	1.2	5	1.3	2	1.2	4.25	4.79	1.2
3	1	1.2	6	1.1	6	1.1	5	1.3	4.5	4.11	1.1
4	3	1.8	4	1.1	6	1.0	6	1.0	4.75	4.66	1.2
5	3	1.7	3	2.1	3	1.1	4	.7	3.25	3.66	1.3
6	1	2.5	2	1.2	3	1.3	1	.8	1.75	2.22	1.2
7	3	1.2	4	1.2	2	0.9	1	.8	1.75	3	1.1
8	5	1.7	4	1.6	2	1.1	2	.7	3.25	3.11	1.2
9	4	1.1	4	1.0	3	1.0	5	1.0	4	4.33	1.2
10	4	2.0	6	1.1	2	1.1	2	.8	3.75	3.11	1.2
11	4	1.2	3	1.5	4	1.0	0	.8	2.75	3.11	1.2
12	0	1.0	2	1.0	2	1.6			1.	2.	2.0
13			0	.8	3	1.7			0.75	1.33	1.7
14					3	.7			.75	1.66	1
15					4	1.1			1.00	0.88	1
16					1	1.1			.25	.66	1
17					1	.8			.25	.22	1
18					0	.6			0.	0.	0.6
Retention											
1	2	1.0	5	1.2	1	.6	7	1.0	3.75	3.44	.9
Retraining											
1	3	1.1	5	.6	3	.6	2	.6	3.25	2.33	.7
2	1	.9	0	.7	2	.5	4	.6	1.75	1.77	.6
3	0	.8			0	.5	3	.7	.75	..66	.6
4							4	.6	1.0	.88	.6
5							3	.7	.75	.33	.7
6							0	.7	0.00	0.00	.7

TABLE 8

RESULTS WITH ELECTRIC SHOCK OF 115 UNITS

No. of Series	Males: No. 92 W.	Av.T.	No. 98 W.	Av.T.	Av.E.
A	5		4		4.5
B	8		5		6.5
1	5	1.5	5	1.5	5.
2	4	3.0	5	2.3	4.5
3	2	5.5	1	3.5	1.5
4	3	4.5	0	3.6	1.5
5	3	3.3			1.5
6	0	4.8			0
Retention					
	2	2;4	0	4.0	1
Retraining					
1	3	3.5			1.5
2	2	1.9			1
3	2	2.4			1
4	0	4.			0

No. of Series	Females: No. 91 W.	Av.T.	No. 95 W.	Av.T.	No. 99 W.	Av.T.	W.	Av.E.	Gen.Av.	Av.T.
A	3		7		6			3.3	5	
B	8		8		7			6.3	6.2	
1	5	3.5	5	1.1	5	2.3		5	5.	2.3
2	5	4.2	5	3.4	4	1.8		4.6	4.6	3.1
3	3	2.9	4	3.2	4	1.5		3.66	2.8	2.1
4	0	2.6	3	2.0	4	1.1		2.33	2.	1.9
5			7	2.0	3	1.9		3.33	2.6	1.9
6			3	6.3	4	2.9		2.33	1.4	4.2
7			2	2.	3	1.8		1.66	1.0	1.9
8			2	3.2	2	1.7		1.33	0.8	2.4
9			0	2.1	0	1.8		0.0	0.0	1.9
Retention										
	3	2.0	2	2.8	2	2.3		2.33	1.8	2.5
Retraining										
1										
1	4	2.4	3	3.6	3	2.0		3.0	2.6	2.4
2	1	2.0	0	1.6	0	1.9		0.33	0.4	1.9
3	0	2.0						0.0	0.6	2.
4									0.0	4.

P.E. 6.8

TABLE 9

RESULTS WITH HUNGER OF 31 HOURS

No. of Series	Males						
	No. 94		No. 96		No. 100		
	W.	Av.T.	W.	Av.T.	W.	Av.T.	Av.E.
A	6		5		5		5.3
B	4		7		7		6
1	5	1.0	4	1.0	5	1.8	4.66
2	4	.6	5	.6	4	1.1	4.33
3	6	.7	5	.8	3	1.0	4.66
4	2	.8	1	.8	3	.9	2
5	3	.6	0	1.0	4	.9	2.3
6	3	.7			4	.8	2.3
7	2	.9			4	1.0	2
8	4	.6			2	1.2	2
9	4	1.1			2	1.0	2
10	4	.9			0	1.0	1.3
11	4	1.0					1.33
12	2	.8					1.66
13	3	1.0					1.
14	0	.8					
	Retention						
1	3	.5	7	1.4	4	.9	4.6
	Retraining						
1	3	.7	2	.8	3	.8	2.6
2	3	.6	3	.8	1	.7	2.3
3	3	.5	4	.9	0	.7	2.3
4	0	.6	2	.8			.6
5			0	.9			.0

TABLE 9(Con.)

RESULTS WITH HUNGER OF 31 HOURS

No. of Series	No. 93 W.	No. 93 Av.T.	No. 97 W.	No. 97 Av.T.	Av.E.	Gen.Av.	Av.T.
				Females			
A	5		5		5	5.2	
B	3		6		4.5	5.4	
1	3	1.0	3	1.0	3	4	1.1
2	4	.5	4	.6	4	4.2	.7
3	1	.7	4	.5	2.5	3.8	.7
4	3	.7	5	.6	4	2.8	.8
5	2	.7	2	.6	3	2.6	.7
6	2	.7	2	.6	2	2.2	.7
7	1	.6	1	1.2	1	1.6	.9
8	2	.7	0	.6	1	1.6	.7
9	2	.6			1	1.6	.9
10	1	.7			0.5	1.	.9
11	0	.7			0	0.8	.8
12						.4	.8
13						.6	1.0
14						.0	.8
				Retention			
1	5	.8	5	.8	5	4.8	.8
				Retraining			
1	0	.7	6	.7	3	2.8	.7
2			6	.6	3	2.6	.6
3			5	1.1	2.5	2.4	.8
4			3	1.0	1.5	1.	.8
5			2	.7	1	.4	.8
6			0	1.0	0	.0	1.0

P.E. 6.

TABLE 10

RESULTS WITH ELECTRIC SHOCK OF 75 UNITS

No. of Series	Males: No. 102 W.	Av.T.	No. 106 W.	Av.T.	No. 108 W.	Av.T.	No. 110 W.	Av.T.	Av.E.
A	5		7		6		5		5.75
B	5		5		6		6		5.5
1	4	3.2	5	1.8	4	4.7	4	4.2	4.25
2	4	2.1	3	2.2	2	4.2	5	2.7	3.5
3	1	3.0	1	5.2	1	2.7	0	2.0	.75
4	3	5.5	0	3.5	0	1.9			.75
5	0	4.0							0.0
					Retention				
1	5	2.7	0	8.0	0	1.1	2	3.9	1.75
					Retraining				
1	4	3.9					0	2.3	1
2	0	4.0							0.0

	Females: No.101 W.	Av.T.	No.103 W.	Av.T.	No.105 W.	Av.T.	No.107 W.	Av.T.	No.115 W.	Av.T.	Av.E.	Gen.Av.	Av.T.
1													
A	5		6		6		4		6		5.4	5.55	
B	6		5		7		8		4		6	5.33	
1	7	2.6	5	2.5	5	2.6	6	2.3	4	3.3	5.4	4.88	2.82
2	4	5.0	4	3.0	5	2.5	6	2.0	1	2.4	4	3.77	1.1
3	2	6.5	1	2.4	5	1.9	3	3.5	1	3.3	2.4	1.66	1.2
4	0	1.3	0	5.4	4	5.6	5	2.3	0	1.4	1.8	1.33	1.7
5					3	1.6	5	4.0			1.6	.88	4.
6					3	1.9	4	3.7			1.4	.77	1.1
7					0	2.2	5	3.2			1.	.55	2.7
8							2	3.9			0.4	.22	3.9
9							0	2.8			0	.00	2.8
							Retention						
1	2	5.4	3	4.5	2	1.7	4	2.5	2	3.0	2.6	1.88	3.6
1							Retraining						
1	6	2.0	6	2.1	1	1.6	3	2.7	1	2.6	4.4	2.4	2.8
2	2	2.6	2	1.8	4	1.5	2	1.4	0	1.9	2.2	1.1	2.2
3	1	4.3	0	2.1	0	1.3	0	1.8			0.2	1.1	2.4
4	0	4.8									0.	0.0	2.8

P.E. 2.9

TABLE 11

RESULTS WITH HUNGER OF 24 HOURS

No. of Series	Males No. 104 W.	Av.T.	No. 112 W.	Av.T.	No. 114 W.	Av.T.	No. 116 W.	Av.T.	Av.E.
A	6		5		7		5		5.75
B	5		4		5		5		4.75
1	5	3.3	4	1.5	7	1.7	4	4.2	5
2	5	2.7	4	3.2	5	1.7	4	3.2	4.5
3	6	2.7	4	1.4	4	1.4	6	2.4	5
4	6	3.1	6	1.9	1	1.4	5	2	4.5
5	4	1.1	5	1.4	3	1.3	3	1.6	3.25
6	4	1.2	4	1.1	4	1.2	3	1.8	3.25
7	4	0.8	2	1.1	3	1.2	4	1.9	2.5
8	4	1.6	2	1.2	3	1.3	2	1.4	2.75
9	2	1.6	5	1.7	6	1.6	5	1.6	4.5
10	1	.9	1	1.1	1	1.4	1	1.1	1
11	1	.8	1	1.2	0	1.1	5	2.0	1.75
12	0	.9	3	1.1			3	1.5	1.5
13			4	1			3	1.8	1.75
14			3	1.0			4	1.2	1.75
15			5	1.8			4	2.2	2.25
16			1	1.3			2	1.3	.75
17			0	1.0			2	1.1	.5
18							2	1.0	.5
19							0	1.0	.0
Retention									
1	3	1.1	4	1.5	2	1.6	6	1.1	3.75
Retraining									
1	1	1.2	2	1.5	4	1.2	1	0.9	2.0
2	3	1.2	3	1.0	4	1.2	3	.9	3.25
3	2	1.2	1	.9	4	1.2	2	.8	2.25
4	1	1.3	1	1.1	2	1.1	3	1.0	1.75
5	0	1.0	2	1.2	2	1.0	2	1.0	1.5
6			0	1.0	1	.8	0	1.0	.25
7					0	.8			0.0

TABLE 11(Con)

RESULTS WITH HUNGER OF 24 HOURS

No. of Series	Females No.109 W.	Av.T.	No.111 W.	Av.T.	No.113 W.	Av.T.	No.117 W.	Av.T.	No.119 W.	Av.T.	Av.E.	Gen.Av.	Av.T
A	5		4		5		5		4		4.8	5.11	
B	6		5		5		6		6		5.6	5.77	
1	6	4.0	6	2.2	6	5.5	4	4.3	6	3.4	5.6	5.33	3.3
2	4	2.0	7	2.1	3	.7	5	1.9	6	1.3	5	4.77	2.1
3	3	3.5	4	1.7	1	1.2	3	2.3	3	4.0	2.8	4.33	2.2
4	2	6.0	5	3.0	4	1.5	2	2.2	5	1.8	3.6	4	2.5
5	5	1.6	4	2.5	1	.9	1	2.1	3	1.5	2.8	3	1.4
6	3	1.6	2	2.9	3	.8	2	3.0	5	1.4	3	3;11	1.7
7	2	1.1	2	1.9	2	1.0	1	1.9	3	1.1	2	2.22	1.3
8	2	1.9	6	1.7	1	1.1	3	1.5	4	1.4	3.2	3	1.4
9	1	1.2	4	1.7	1	.7	4	2.0	3	2.0	2.4	3.33	1.4
10	1	1.2	1	.6	0	.6	1	.8	1	1.0	.8	.88	1.0
11	0	.7	2	.9			0	.6	3	1.2	1.	1.33	1
12			3	1.3					4	3.0	1.4	1.44	1.5
13			4	1.1					2	1.2	1.2	1.55	1.2
14			1	1.9					0	.9	.2	.88	1.2
15			3	1.7							.6	1.33	1.9
16			4	1.9							.8	.77	1.5
17			2	1.4							.4	.66	1.2
18			4	1.1							.8	.66	1.2
19			1	1.2							.2	.11	1.1
20			0	1.0							0.0	0.0	1.0
							Retention						
1	0	1.0	3	1.2	5	1.0	2	1.4	6	1.0	3.2	3.44	1.2
							Retraining						
1			4	1.5	1	.8	4	2.0	3	1.0	2.4	2.22	1.2
2			5	2	1	.7	5	1.8	3	1.0	2.8	2.77	1.2
3			5	1.8	0	.7	5	1.8	2	.9	2.4	2.22	1.3
4			4	1.2			3	1.4	4	.7	2.2	2	1.0
5			3	1.1			3	1.7	2	1.2	1.6	1.44	1.0
6			2	1.0			2	1.1	1	1.0	1.0	.66	1.3
7			0	.8			0	1.0	0	1.0	0.0	.00	.9

P.E.7.6

TABLE 12

RESULTS WITH ELECTRIC SHOCK OF 60 UNITS

No. of Series	Male No.118 W.	Av.T.	Females No.121 W.	AV.T.	No.123 W.	Av.T.	Av.E.	Gen.Av.	Av.T.
A	5		3		3		3	3.66	
B	4		8		6		7	6.00	
1	4	1.2	4	1.5	3	1.3	3.5	3.6	1.5
2	6	1.1	2	2.7	4	1.6	3	4	1.8
3	5	1.7	1	3.1	4	1.3	2.5	3.6	1.3
4	4	1.7	1	2.8	5	1.5	3	3.3	2.
5	4	3.0	2	4.5	4	1.6	3	3.33	3
6	2	4.5	0	3.6	3	1.9	1.5	1.66	3.3
7	2	2.3			4	2.1	2	2	2.2
8	1	4.3			2	1.9	1	1	3.1
9	0	3.6			1	2.	0.5	0.33	2.8
10					0	1.8	0	0.0	1.8

P.E. 5.7

TABLE 13

RESULTS WITH HUNGER OF 41 HOURS

No. of Series	Males No.124 W.	Av.T.	No.126 W.	Av.T.	Av.E.	Females No.125 W.	Av.T.	No.127 W.	Av.T.	Av.E.	Gen.Av.	Av.T.
A	7		2		4.5	6		3		4.5	4.5	
B	5		5		5	6		5		5.5	5.25	
1	5	1.1	4	1.1	4.5	3	1.0	6	1.2	4.5	4.5	1.1
2	5	.7	5	.7	5	2	.8	4	.8	3	4	.7
3	4	.5	5	.6	4.5	5	.5	2	.6	3.5	4	.6
4	4	.6	3	.5	3.5	4	.6	1	.6	2.5	3	.6
5	2	.5	6	.5	4	2	.5	1	.5	1.5	2.75	.5
6	2	.5	3	.5	2.5	2	.5	0	.5	1.	1.75	.5
7	4	.5	2	.5	3	3	.6			1.5	1.75	.5
8	0	.5	1	.6	.5	1	.8			.5	.5	.7
9			1	.6	.5	1	.8			.5	.5	.7
10			0	.7	.0	0	.7			.0	.00	.7

P.E. 5.6

The curve marked 150 units is based on the average number of errors for the subjects trained with an electric shock of 150 units and the curve marked 48 hours is based on the average number of errors for subjects trained with hunger of 48 hours, and-so-on for the other curves. Figure 4 shows the relative values of different strengths of electric shock, the relative values of different degrees of hunger and the relative values of both electric shock and hunger in the learning process.

Summary of Tables. Table 14 contains the summary results of the experiment proper. It gives (1) the average number of trials and the probable error made by males, by females and the general average and probable error for both males and females in the formation of a perfect habit in case of four strengths of electric shock and four degrees of hunger, and the average time for choice in each case; (2) it gives the number of males and the number of females and the total number of subjects which made a perfect retention test after twenty one days, the average number of errors made by males and the average made by females and the general average for both males and

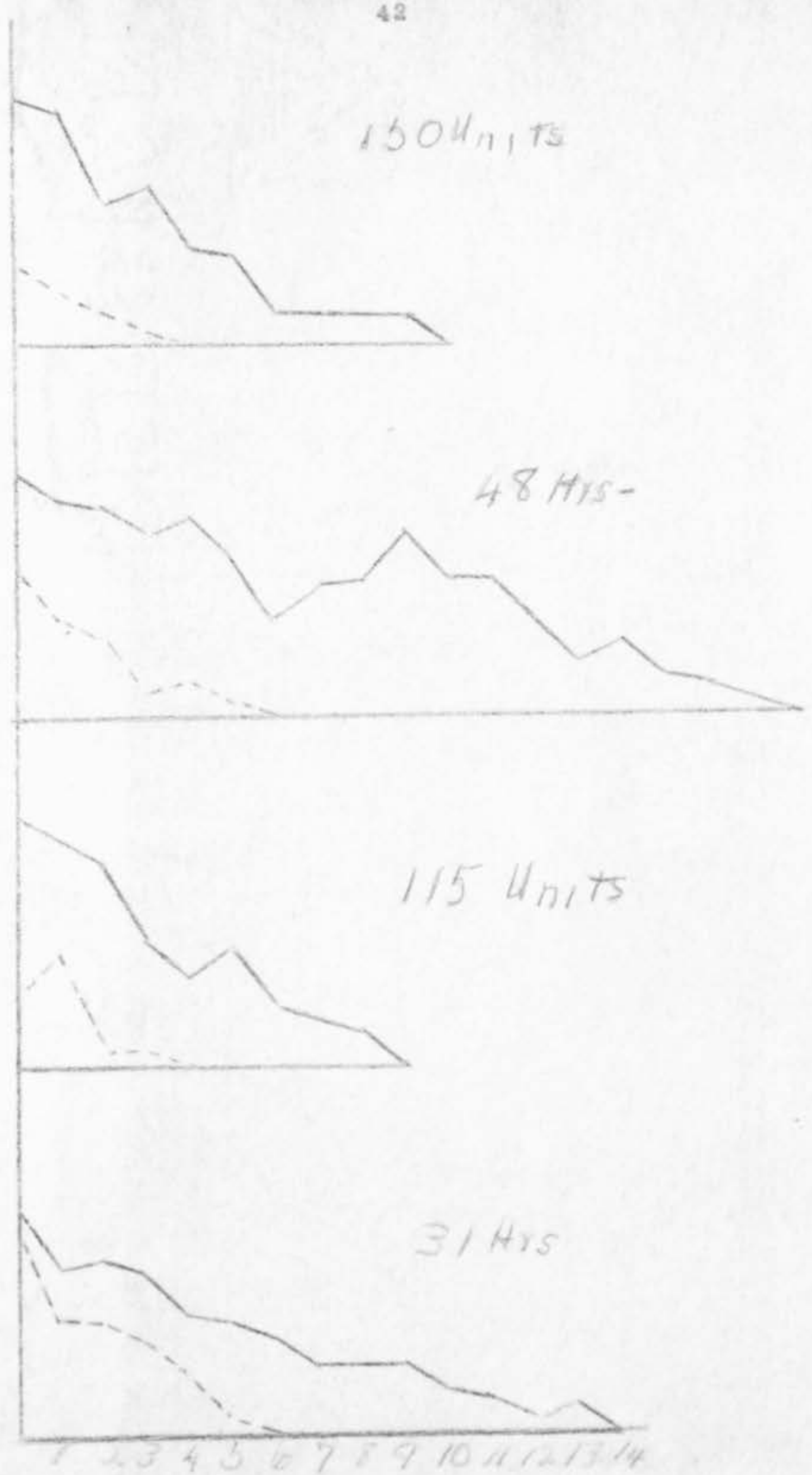

Fig.2. Curves of learning and relearning. Ordinates represent series of ten tests, abscissae average number of errors. Solid line in each case is the learning and broken line the relearning curve. The first point on abscissae is average of the preference tests in learning curve and the retention test in relearning curve.

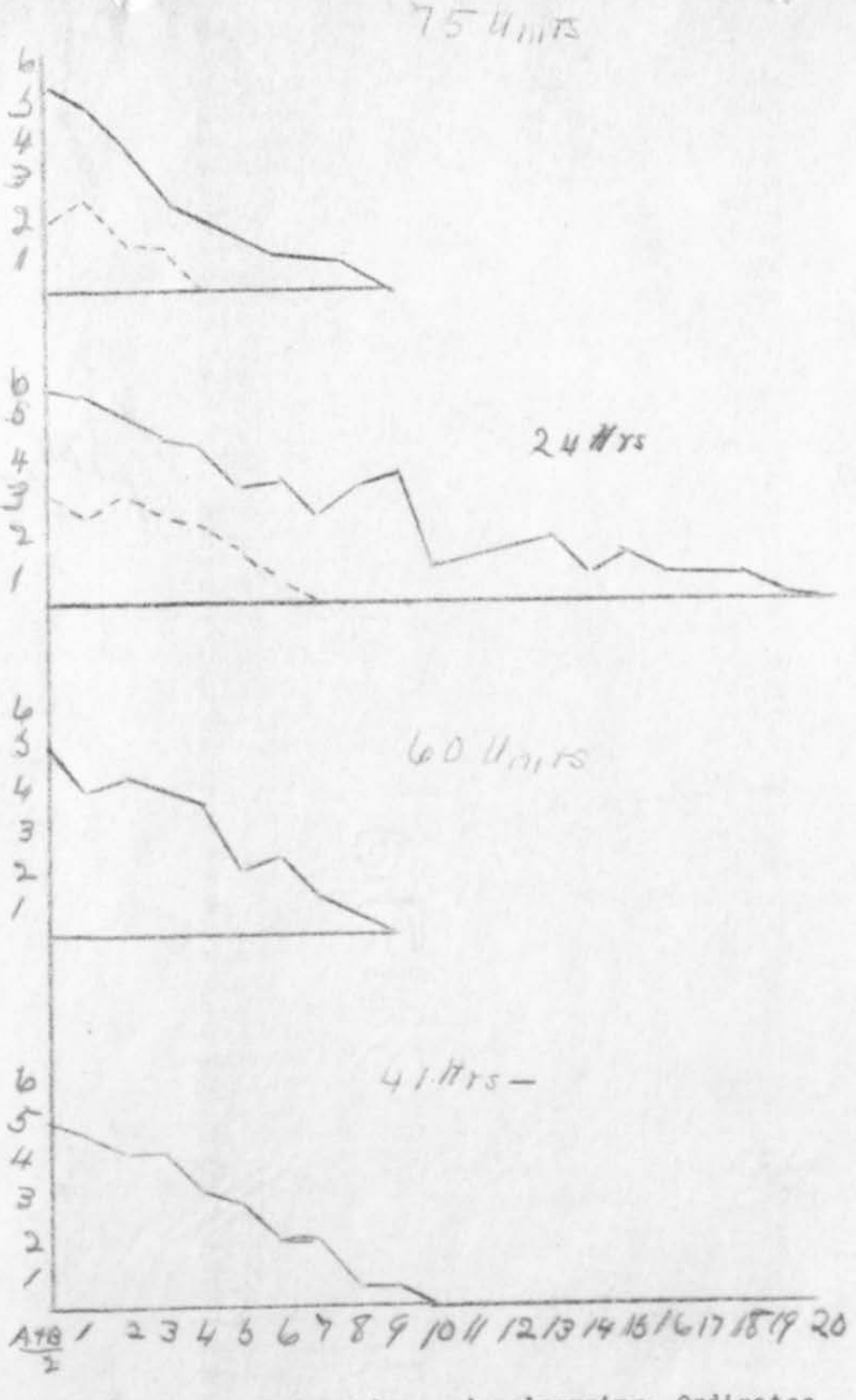

Fig. 3. Curve of learning and relearning. Ordinates represent series of ten tests, abscissae average number of errors. Solid line in each case is the learning and the broken line the relearning curve. The first point on the abscissae is average of the preference tests in learning curve and the retention test in relearning curve.

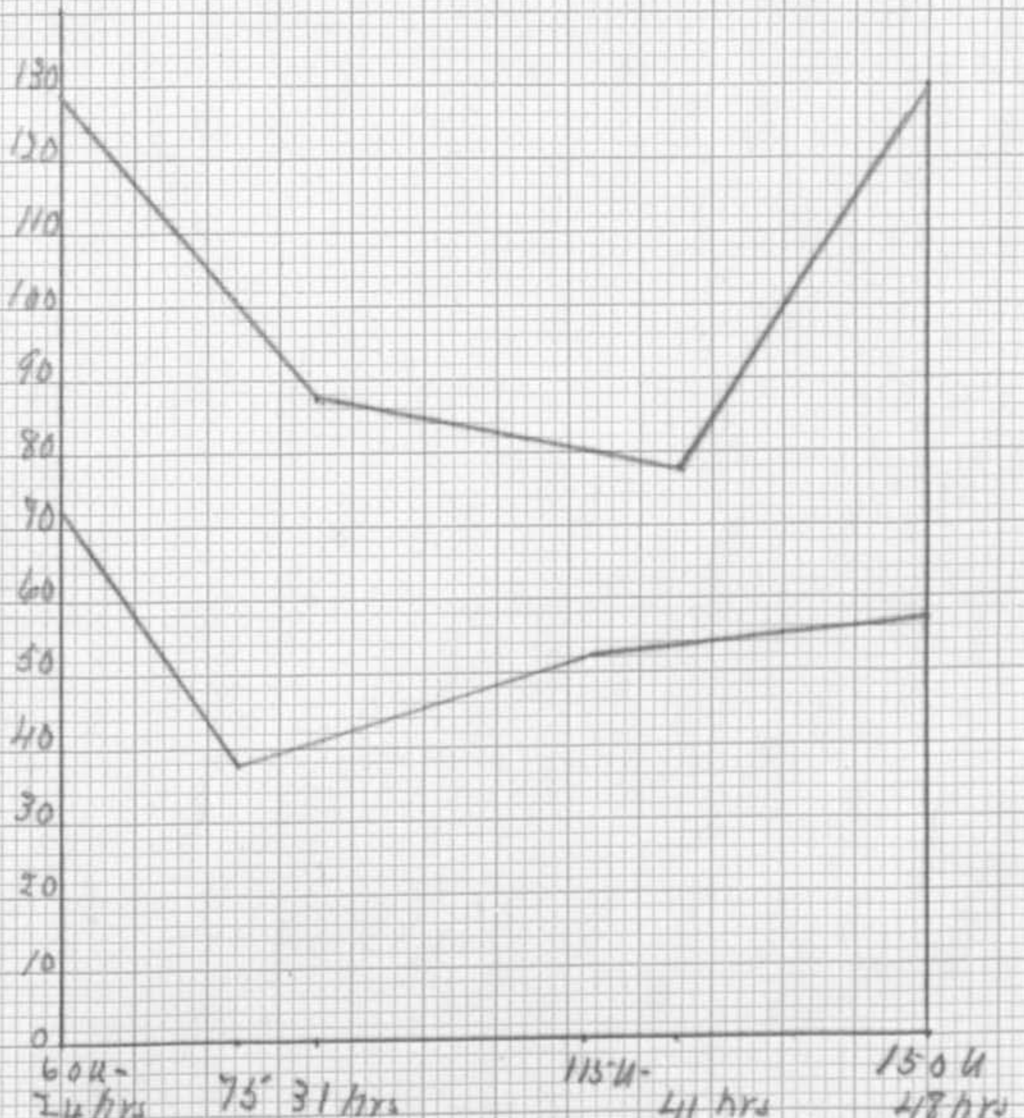

Fig. 4. Curves of relative values of hunger and electric shock. Ordinates represent strength of stimuli, abscissae the total number of trials for learning. Upper curve is relative values of hunger and lower of electric shock.

females in the retention test, and the average time for choice; (3) it gives the average number of trials required by males, the average number of trials by females and the general average for both males and females for the relearning of the habit, and the average number of choices in the relearning process.

Differences in Learning in Males and Females.

As may be seen in table 14 there is a difference in the rate of learning with males and females but this difference is neither consistent not conclusive. In all cases with hunger the average number of trials required for perfecting the habit is less for females than for males but with electric shock the average with seventy five units and one hundred and fifteen units was less for males. The retention tests show no difference in retention of males and females when trained with different degrees of hunger but a difference in favor of the males four to one when trained with electric shock. The retraining results are even less consistent than in case of training. But having observed rather closely the behavior of all subjects the experimenter would hesitate to say that there is no sex difference. This difference, however, is not necessarily a difference in the capacity of the two sexes to

TABLE 14

SUMMARY OF RESULTS OF EXPERIMENTS

	Original Training						
Reward	Av. NO. trials						
Hours	Males	P.E.	Females	P.E.	Gen.Av.	P.E.	Av.Total T.
24	137.5	11.6	122	11.6	128.83	7.6	1.5
31	86.6	13.6	85	7.1	86	6.	0.8
41	80	4.8	70	9.7	75	5.6	0.66
48	146.7	7.	125	9.2	136.67	5.9	1.2
Punishment in Units							
60	80	9	70	8.8	73.33	5.7	2.3
75	30	2.3	46	4.9	38.88	2.9	2.4
115	40	4.6	63.33	9.7	54.00	6.8	2.6
150	64	6.3	50	2.3	57.77	3.9	3.6

Reward	Retention Tests						
	Number of Individuals making perfect record			Average Erross		General Av.Er's	Total Av.T.
	Males	Females	Total	Males	Females		
24	0	1	1	3.75	3.2	3.44	1.2
31	0	0	0	4.6	5	4.8	.8
48	1	0	1	3.2	3.7	3.44	.9
Punishment							
75	2	0	2	1.75	2.6	1.88	3.6
115	1	0	1	1	2.33	1.8	2.5
150	1	1	2	2.4	1.25	1.88	2.5

	Retraining			
	Av. No. of Trials		General Average	Av.Total Time
Reward	Males	Females		
24	50	40	44.4	1.1
31	30	26	28	0.9
48	20	25	22.2	0.6
Punishment				
75	2.5	20	12.2	2.5
115	15	13.3	14	2.6
150	20	2.5	12.2	2.9

profit by experience but probably a difference in physiological make-up which causes the most favorable condition of learning to vary in a characteristic manner for the two sexes. Females on the whole seemed more anxious for food than the males in all four sets of experiments. This may account for the difference for the rate of learning with hunger.

Interpretation of Curve of Relative Values of Hunger. If the reader will examine the curve of learning (fig.4) for different degrees of hunger he will find that there is a constant increase in the rate of habit formation up to forty-one hours of hunger but a sudden decrease from forty-one to forty-eight hours of hunger. The first part of the curve needs no explanation for the difference in the rate of habit formation when a subject is putting its whole energy in the accomplishment of the act and when it is more or less indifferent towards the performance is fairly well established. Rats which pass from the door between the entrance chamber and nest box in sixty-six-hundredths of a second were making about the greatest speed possible for such animals. The scratching reflex or any other distracting influence seldom interfered with their choosing. But the rats which took one and five-tenths seconds had time to scratch occasionally or explore the entrance chamber. But the rapid decrease in the rate of learning for animals of forty-eight hours of hunger is not so apparent. Nor can this decrease be accounted for in terms of poor physical condition of the subjects. At the end of the series of experiments all these animals were in good physical condition though they had somewhat less flesh than their mates which had been trained with electric shock.

Had one who did not know their physical condition been observing the manner of choice of this group of rats he would have immediately come to the conclusion that they were not hungry. They neither rushed to get food nor ate eagerly when they had reached it. Their behavior was very much the same as that of subjects which had gone for only twenty four hours without food. It is true that the carriage of the rat was somewhat different. Dr. J. A. Carlson's careful experiments on hunger in man and dogs account for the behavior of this group of animals in a most satisfactory manner. Dr. Carlson has demonstrated rather conclusively that the sense of hunger is due to "certain types of contmactions in the empty or nearly empty stomach. That these contractions stimulate nerves in the sub-mucosa or muscularis." He demonstrated experimently that these contractions persist almost constantly after the first day of hunger in man: and in young dogs until a short time before death from starvation. In describing his own experience for a period of five days of hunger he says, "the sensation of hunger was almost constant after the first day of starvation - somewhat more severe during the first two or three days. The most severe sensations were at periods of gastric contractions. Appetite ran practically parallel with sensation of hunger. It increased during the first two or three days and diminished on the fourth and fifth days. Instead of an eagerness for food there was an almost indifference to food despite the persistent hunger call of the empty stomach.

The writer could not give a more exact description of the behavior of these rats after forty-eight hours of hunger than the above. As the average time of choosing indicates this group of subjects was slightly more active than the group which was trained with twenty-four hours of hunger but they were not eager for food. Still their behavior was indicative of some disturbing factor: they assumed the hump of a starving animal. They largely abandoned it immediately after eating but assumed it again as the hunger period advanced. This disturbing element was due, no doubt, to the continued contractions of the empty stomach. It seems probable from Dr. Carlson's description of his sensations during a starving period, that these rats had sensations of hunger but were not eager for food. As may be seen from next to the last column, table 7, and from the curve of learning representing this column, this distuвbing factor was so great that it seemed most probable even as late as the hundredth trial that these animals would never finish the learning process. But from the hundredth trial on the animals were more eager for food. There are two possible explanations for this change: (1) As the subjects grew older they were better able to stand long periods of starving; (2) the organism doubtless tended to adapt itself to its conditions.

Dr. Carlson says, "That the young and growing individual experiences greater hunger than the adult or aged individual is common knowledge." This being the case it is most likely that the period of eagerness for food ends earlier in the young than in the adult individual. When one examines the retraining of the group of animals trained with forty-eight hours of hunger he finds this most interesting fact, that this group retrained more rapidly than the other groups. That it made better average time in choosing than any other group used throughout the experiments is, also, to be noticed. During the retraining these subjects showed great eagerness for food. These facts go to substantiate the indications in the latter part of the training series; viz, That rats as they grow older are better able to under-go long starving periods and that the period of eagerness for food is extended; and that the organism may tend to adapt itself to its conditions. While the first of these is sufficient to account for the facts it is very probable that the second entered into the situation.

Values of different Strengths of Electrical Stimuli.

The experimenter determined roughly the minimum stimulus to which the white rat would respond with the control box used in this experiment. Six males and six females of the same age as the subjects for the experiment were used for this purpose. With 18 units these rats gave no observable signs of response but with 25 units all animals tested gave slight movements indicative of feeling the shock. Thus it is fairly certain that with well developed rats the threshold of sensation for subjects of seventy-eight days of age is between 18 and 25 units with the apparatus used in this experiment. This is from 10 to 15 units below the threshold for the experimenter.

As may be seen from table 14 subjects trained with an electric shock of sixty units perfected the learning process on an average of 73.33 trials; subjects trained with seventy-five units on an average of 38.88 trials; subjects trained with 115 units on an average of 54 trials; and those trained with one hundred and fifty units perfected the process on an average of 57.77 trials. Thus seventy five units proved to be the most favorable strength of stimulus for the learning process in rats of seventy-eight days of age. This is also a very favorable strength of stimulus for animals of fifty-six days of age.

Individual differences were very marked with the two weaker strengths of stimuli. All subjects reacted to a stimulus of 75 units very vigorously with the exceptions of numbers 105 and 107. Number 105 would get out of the electric box fairly rapidly but 107 did not seem much disturbed by the shock and took its time in getting off the electric plates. The experimenter is convinced that the difference in time taken for 107 to perfect the habit and the time taken for 110 to perfect the same habit is not primarily a difference in the learning capacities of the two subjects but a difference in favorableness of the conditions of learning. With a stimulus of 150 units probably number 107 would have even surpassed 110 in the learning process. There is little doubt that a stronger stimulus would have been more favorable to the learning of both 107 and 105. Both of these subjects were slightly lighter than the other rats of this group but the runt of the entire series was trained with hunger of twenty-four hours and surpassed any of the other animals trained with this degree of hunger. The fairly weak stimuli were more favorable to the observation of individual differences than stronger stimuli as the stronger stimuli called forth vigorous reaction in the least sensitive subjects.

How may we account for the increase in the number of trials required for the habit formation as the strength of stimulus increased from about 75 units up to one hundred and fifty units? One hundred and fifty units is far below the point of injury to the subject. The only thing to account for this difference that was observable to the experimenter was less nervousness on the part of subjects trained with 75 units than subjects trained with the stronger stimuli. Subjects trained with 75 units approached the electric box more cautiously and sometimes put their noses into the dark box then withdrew and entered the light box while subjects trained with stronger shock would rush into one of the boxes seemingly trying to escape from the situation by running over the grill. Thus it seems that the primary cause for the differences in length of time required for rats to perfect the habit of always choosing the light box when trained with a rather weak stimulus and when trained with stronger stimuli is due to the disturbing factor of excitation.

Comparison with Earlier Results. Do the above results agree with the results found in previous experiments on the relative values of different strengths of stimuli in habit formation? Were one to examine the results given by the different experiments without taking into consideration the nature of the subjects used he would conclude that the results are almost diametrically opposed. But when one takes into consideration the differences in the natures of the animals it seems that the results point to a common principle. As every one who is acquainted with the dancer knows, this animal is not especially sensitive to its environment. It dances in the presence of danger with the same indifference to its environment that it does in its cage. It enters an electric box where it may receive a strong shock almost as readily as it does a box where there is no form of punishment. Ordinary changes in its environment affect its behavior very little. On the other hand the rat is extremely sensitive to its environment. The slightest movement in its presence may call forth the native tendency of flight with the suddenness of a simple reflex. Subjects trained with electric shock had to be forced through the door between the nest box and the entrance chamber, and here in the presence of the electric boxes the primary motive for choice seemed to be to escape from the situation. If, as all these experiments indicate, there is a point of interference as the strength of stimulus is increased this point should be reached much sooner with the rat than the dancer. And the interference due to excitement will appear much earlier in the series of difficultness with the rat than with the dancer. Thus the most favorable strength of stimulus for habit formation in the rat should be weaker than the most favorable strength of stimulus for the dancer and interference due to excitation should be more noticeable in the rat than in the dancer.

Summary of Facts to be Explained. The above results present certain obvious facts which need interpretation. Why should rats of similar heredity and environment perfect a like habit in so widely different lengths of time when trained with different degrees of hunger? Why should subjects of similar heredity and environment perfect a like habit in so widely different lengths of time when trained with different strengths of electric shock? Why should subjects with the same heredity and similar environment perfect a like habit in so widely different lengths of time when trained with hunger and when trained with electric shock as motives? Subjects trained with the most favorable condition of hunger perfected the habit in very nearly one-half the number of trials that subjects trained with the least favorable conditions of hunger did. Subjects trained with a shock of 75 units perfected the habit in slightly more than one-half the number of trials that subjects trained with 150 units did. Subjects trained with the most favorable electric shock perfected the habit in about thirty-nine trials while it took subjects trained with the most favorable condition of hunger seventy-five trials.

Some Laws of Learning which Have Been Suggested.

Thorndike in his Educational Psychology gives three primary laws of learning.[8]

(1) Exercise.-"To the situation,'a modifiable connection being made by him between a situation S and a response R,' man responds originally, other things being equal, by an increase in the strength of that connection. To a situation,'a modifiable connection not being made by him a situation S and a response R, during a length of time T,' man responds originally, other things being equal, by a decrease in the strength of that connection."

Corollary to the first part of the law of exercise:"the degree of strengthening of a connection will depend upon the vigor and duration as well as the frequency of its making."

(2) Effect.-"To the situation,'a modifiable connection being made by him between an S and an R and being accompanied of followed by a satisfying state of affairs' man responds, other things being equal, by an increase in the strength of that connection. To a connection similar,save that an annoying state of affairs goes with it or follows it, man responds, other things being equal, by a decrease in the strength of the connection."

(3) Readiness.-" By original nature a certain situation starts a behavior series: this involves not only actual conduction along certain neurones and across certain synapses, but also the readiness of others to conduct."

Watson criticizes the conception that pleasure tends to stamp-in desireble acts and pain to stamp-out the undesirable acts, and offers two principles,"recency" and "frequency" as possible explanation for the mechanical process in learning. He says,[10]" It is our aim to combat the idea that pleasure or pain has any thing to do with habit formation or that harmfulness or harmlessness has any thing more to do with the situation." Again

"We may confess at once that we have no new principles to offer in solving the problems involved in learning, but we hope that by stating our problem carefully and by clearing away the misconceptions referred to, we shall be able to show in a convincing way that the mechanical principles with which we are already familiar and which can experimentally be shown to act in the way we maintain are sufficient to yield the solution of those problems. We shall call these principles (1) frequency and (2) recency."

Holmes says,[5] " Profiting by experience in an animal of primitive type of intelligence we conceive, then, to take place as follows: The creature is endowed with the capacity for responding to beneficial stimuli by aggressive, outstreaching movements, and to injurious stimuli by movements of withdrawal, retreat and avoidance. All these are matters of pure instinct. Given the power of forming associations between responses, the animal acquires new habits of action by repeating those responses which arouse instinctive acts of a congruous, and discontinuing those responses which arouse instinctive acts of an incongruous kind."

Peterson has recently suggested "completeness of response" as a fundamental principle in the explanation of the learning process. He says,[7] "That the animal in the performance of an act is constantly in a state of muscular tention due to mutually reinforcing, mutually inhibiting tendencies and that these tentions are released only when the proper reactions have been made and the desired act been performed."

Haggerty gives a physiological interpretation of the learning process in the following laws[3] "A physiological state is not self-contained but tends to radiate to other physiological states both those which form with it a series of states like a habit chain and also to other physiological states which have never formed a series."

Frequency. That the frequency of repetition of a desired act is of value in perfecting the habit may hardly be successfully denied, but that it is a dynamic factor may be doubted. Its importance varies with the nature of the habit and the motive used for promoting the learning process. That it fails to offer any thing like a complete explanation for habit formation is shown by the following facts: (1) It took rats trained with a shock of 75 units an average frequency of twenty four right choices to 14 wrong while it took rats trained with 24 hours of hunger a frequency of 85 right choices to 42 wrong to perfect the same habit. (2) It required subjects trained with a shock of 60 units an an average frequency of 54 right choices to 23 wrong choices while it took subjects trained with 75 units an average frequency of 24 right to 14 wrong choices to perfect the same habit. (3) It required subjects trained with 41 hours of hunger an average frequency of 45 right choices to 23 wrong while it required those subjects trained with 24 hours of hunger an average frequency of 85 right to 42 wrong choices to perfect the habit. Thus we see that the proportion of right to wrong choices is greater in all cases where it took the subject a greater number of trials to complete the learning process.

Recency. The importance of recency as a factor in the formation of a habit like frequency varies with the nature of the habit. But it does not help to explain the differences in the results in this experiment. The recency in all series of experiments was the same and as to the recency between trials there was practically no difference.

Vigor. The importance of the vigor with which an animal performs and act has been underestimated by some students of behavior. The more nearly the whole active organism is directed towards the accomplishment of the act the more rapidly will the act be perfected. The subjects which chose most quickly and made the greatest effort to reach the food learned in about one half the time that it took for those subjects which did not seem anxious to get to the food. This is evidently an important factor in accounting for the difference in the time taken for animals trained with 24 hours hunger and animals trained with 41 hours hunger to perfect the same habit. It also has its bearing in the interpretation of the difference in the average number of trials taken by animals trained with 30 units and those trained with 75 units. The former stimulus was too weak to keep the subjects up to their greatest efficiency. The directing of all energy in a single channel means efficiency in acquiring any habit. Animals trained with the more favorable conditions were not often interfered with by the scratch reflex and like inhibitory processes.

Satisfyingness and Annoyingness. Thorndike tells us "that improvement is the addition or subtraction of bonds of the addition or subtraction of satisfyingness and annoyingness." But how the satisfaction of eating of food after an animal has performed an act can lap back and in some way stamp in the act is not very easy to understand. Likewise it would be a hazardous science that would say that the satisfaction an animal gets from eating after 41 hours of hunger is more effective in stamping in a desired act than eating after 48 hours of hunger, or that the annoyingness of an electric shock of 150 units is less effective in stamping out an undesirable act than that of 75 units. The above illustrations are sufficient to show that the principles of satisfyingness and annoyingness are of no significance in an explanation of the results of this experiment.

Other Principles. Though the principles of congruity and incongruity, completeness of response and the law of irradiation are suggestive and are doubtless of importance in the explanation of the learning process, the writer is unable to give a satisfactory interpretation of this experiment on basis of one or all of these principles.

The seeming simplicity of the mechanical principles of a simple type of learning grows into complexity when one attempts to account for habit formation under different conditions. The writer does not hope to give a panacea for all habits nor does he care to add another guess to the physiological changes which take place, but desires some kind of interpretation for the results obtained in the above experiments. Any part or even all of the principles which have been mentioned do not give a satisfactory explanation of the facts. There are at least two other factors which seem of importance.

Native tendencies. Something of the importance of the native tendencies of the organism in the learning process has been recognized in a very general way by a number of students of behavior, but the writer here refers to specific tendencies. The specific native tendency with which the learning process is linked seems of vital importance in determining the length of time for perfecting any habit. Subjects trained with the most favorable strength of electric shock perfected the same habit in slightly over half the time that subjects trained with the most favorable degree of hunger. Most probably this is due not to a difference in the values of pleasant and unpleasant stimuli but to the fact that in one case the process is tied-up with the tendency of flight and in the other it is tied-up with the food seeking tendency. The tendency of flight is a very strong tendency and takes predominance over the food seeking tendency when both are stimulated. The rat which is seeking food, on the approach of an enemy takes to flight and ceases the search of food for the time being. Were these comparisons between sex and flight tendencies the results might be very different. The stronger the pull or drive of the tendency with which an act is linked-up the less likely is the individual to be attracted from the performance of the act. The subject which is very hungry is seldom interfered with by the scratch reflex while the subject which is only slightly hungry is frequently interfered with by it; but the subject trained with electric shock is less frequently interfered with than is the very hungry subject. This means that the native tendency of flight holds the subject up to a more efficient performance of the act than does the food seeking tendency.

Disintegration. The physiological process which takes place in the nervous system in the learning process is not definitely known but whatever it is it may be interfered with, or there may be a tearing down process taking place along with the building up process. It is in this rather broad sense that the writer uses the term disintegration. The factors which cause disintegration may vary from a minimum to a point where the tearing down process is equal to the building up process. Subjects trained with a shock of 150 units learned less rapidly than subjects trained with a shock of 75 units doubtless because of disintegration due to too great excitement of the situation. That is the disintegrating and integrating processes were more nearly equal in the former case than in the latter. Subjects trained with hunger 24 hours hunger would not infrequently be headed directly towards the light box when the scratch reflex would predominate over the food seeking tendency and the animal would stop and scratch and then go in the direction which it might be headed regardless of right or wrong. Subjects trained with 48 hours of hunger were more active than subjects trained with 24 hours of hunger but learned less rapidly probably because of the interfering effect of the strong contractions of the stomach. The physiological disturbance during the first 80 trials was so great that it seemed that the animals would never finish with 48 hours of hunger, but about this time the subjects seemed to adapt themselves to the condition.

Relation of Rate of Learning to Retention. Our results show no marked difference in the three groups tested for retention in the relative values of different degrees of hunger for the retention of the habit. Of the nine subjects trained with 48 hours hunger one made a perfect retention test; of those trained with 24 hours hunger one made a perfect retention test; and of those trained with 31 hours hunger there was no perfect retention test. Likewise groups trained with electric shock showed no special difference in retention. Two subjects for each of the strengths of shock, 150 and 75 units made perfect records for retention and one for 115 units shock. These facts indicate that subjects trained with electrical stimuli retained better than subjects trained with hunger. In all cases where individuals were trained with electrical stimuli they showed recognition of the situation.

Thus it seems that the time required for the formation of a habit has little to do with the retention of the habit but the strength of the native tendency with which the habit is linked is of some importance.

Retraining. The retraining series are on the whole in harmony with the training series. Animals trained with 24 hours of hunger relearned the habit on an average of 44.4 trials; those trained with 31 hours hunger retrained on an average of 28 trials; subjects trained with 48 hours retrained on an average of 22.2 trials; subjects trained with 75 units of shock retrained on an average of 12.2 trials; those trained with 115 units retrained on an average of 14 trials; and subjects trained with 150 units retrained on an average of 12.2 trials. The fact that subjects trained with 48 hours of hunger relearned more rapidly than any of the other groups is due to the increased age and adaptation of the organism to long periods of starvation. Just as one should expect there is no significant difference in the time taken for the three groups trained with electric shock to relearn the process for the retraining time was too short.

Conclusions: 1. In case of hunger the rapidity of learning increases as the hunger increases but the maximum hunger is reached in rats of 78 days of age some where between 41 and 48 hours. After the maximum hunger is reached there is a rapid decrease in the rate of learning as the period of starvation is increased.

2. With a discrimination problem of the difficultness used in this experiment the rate of learning increases as the strength of stimulus increases from the threshold up to about 75 units, which is a comparative weak stimulus, and gradually decreases as the strength of stimulus is increased beyond this point.

3. The electric shock is more favorable to the learning process in the white rat than is hunger in case of a simple discrimination problem.

4. The important factors in accounting for the differences in rate of learning in this experiment are: vigor of performance, frequency of repetition, native tendency with which the process is linked and the disintegration due to interfering tendencies.

5. The time taken for the forming a habit

has but little to do with its retention but the tendency with which it is linked may be of considerable importance.

BIBLIOGRAPHY

1. Carlson, J.A. The Control of Hunger in Health and Disease.

2. Cole, L.W. The Relation of Strength of Stimulus to Rate of Learning in the Chick. Journal of Animal Behavior, Vol.I. pp.11.

3. Haggerty, M.E. The Laws of Learning. Psychol. Rev., Vol.20, pp.411.

4. Hogue, Mildred, and Sticking, Ruth. A Note on the Relative Values of Punishment and Reward as Motives. Journal of Animal Behavior, Vol.II. pp.43.

5. Holmes, S.J. Studies in Animal Behavior. Badger Co., 1916.

6. Martin, E.G. A quantitative study of faradic stimulation. Amer. Jour. of Physiol. Vol.22.

7. Peterson, J. Completeness of Response as an Explanatory principle in Learning. Psychological Rev., Vol.23.

8. Thorndike, E.L. Educational Psychology, Briefer Course. Teachers College, N.Y.

9. Washburn, Margaret F. The Animal Mind, Second Edition.

10. Watson, J.B. Behavior - an Introduction to Comparative Psychology. Henry Holt & Co., N.Y.

11. Yerkes, R.M. The Dancing Mouse. Henry Holt & Co., N.Y.

12. Yerkes, R.M. & Dodson, J.D. The Relation of Strength of Stimulus to Rapidity of Habit Formation. The Journal of Comparative Neurology and Psychology, Vol.28.