THE EFFECT OF AGE ON HABIT FORMATION IN THE ALBINO RAT.

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DISSERTATION

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Degree of Doctor of Philosophy

by

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CONTENTS.

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INTRODUCTION.

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The problem concerning the relation of the age of an animal to its learning capacity forms the basis for the investigation herein discussed. Experiments were begun in the Psychological Laboratory of The Johns Hopkins University during the winter of 1912, and continued until the spring of 1915.

HISTORICAL.

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So far as the writer has been able to determine, practically no experimental work has been undertaken on the relation of age to learning ability, although the importance of the problem has been generally conceded.

In the field of human psychology, Munn[1] carried out a series of "substitution tests" on children in the grades, on normal school pupils, and on two elderly persons, to determine the relative rapidity of gain in ability to make the required substitutions. Her records were taken in the terms of time, and showed that although the children gained much more rapidly than the adults, their actual rate of speed at the beginning was lower, and they did not reach the same level of effi-

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1. Munn - Curve of Learning, Archives of Psychol. No. 12, p. 37.

ciency within the limits of the experiment. Only two elderly subjects were obtained, hence too much reliability cannot be attributed to the results from the last group, but apparently, while their initial rate is intermediate between that of the children and the normal school pupils, they fail to reach the final rate attained by either of them. Munn gives neither the average nor the rate of gain for this last group, but the former was easily obtained, and appears in the table below.

Adults - first test - 42 sec. last test - 14 sec.
Children- " " -184 sec. " " - 32 sec.
Old persons" " - 72 sec. " " - 39 sec.

Gain in first 5 tests:

Adults 16 seconds Children 34 seconds

Gain in second 5 tests:

Adults 5 seconds Children 14 seconds

It would appear from these results that, if the rate of improvement is the question considered, children learn about twice as fast as adults.

Turning to the field of animal behavior we find a somewhat larger amount of experimental work on the matter under discussion, although practically all of it occurs as a side issue to some other problem. Slonaker[1] undertook a study of the normal activity of the white rat at different ages, hoping to "ascertain how the age of greatest activity compared with that at

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1. Slonaker, J.R., The Normal Activity of the White Rat at Different Ages, Journ. Comp. Neur. & Psych. 17, (07 , 342-59.

which the rats were most capable of education." His conclusions which relate particularly to the subject of this discussion are as follows:

"1. White rats of difference ages show a marked difference in their activity.

2. The very young rat and the very old rat are each noticeably inactive.

3. These experiments indicate that the age of greatest activity ranges between 87 and 120 days.

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7. From these preliminary experiments no correlation can be made between the age at which they are most active and the age at which they learn most rapidly."

In a later paper[1] he places the age of greatest activity for the males at ten months, and for the females at twelve and five-tenths months.[2] The daily activity increases with the advance in age until a certain age is reached, after which there is a gradual reduction till death occurs.[3] "The female is much more active than the male."[4] In this paper, as in the earlier one, no attempt is made to correlate amount of activity with capac-

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1. Slonaker, J.R., The Normal Activity of the Albino Rat from Birth to Natural Death, &c., Journ. An. Behav. II, ('12), 20-42.

2. Loc. cit., p. 30.

3. Loc. cit., p. 26.

4. Loc. cit., p. 42.

ity to learn.

Yerkes[1] raised the question of the relation of age to habit formation in the dancing mouse. He worked first on the acquisition of the white-black discrimination habit, and later on the learning of simple labyrinth pathways. The indices of modifiability as given by the number of training tests required to complete the habit for dancers of one and four months respectively, show that the males learned the white-black discrimination habit more quickly at one month (30 days) than at four months (120 days) while the reverse was true of the females.[2] The female was superior to the male, however, in the formation of the labyrinth habit.[3] In later work[4] he finds that male dancers ten months old learn the labyrinth more rapidly than those one to two months old, while there is practically no difference in rapidity of learning of one to two month and ten month females. The old dancers are somewhat superior to the young in their ability to learn the labyrinth paths.[5] With regard to the sensory habit he says:

"**1.** The dancer at one month of age acquires a particular white-black visual discrimination habit more rapidly than do older individuals. From the first until the seventh month there

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1. Yerkes, R.M., The Dancing Mouse, The Macmillan Co., 1907.

2. Loc. cit. p. 274.

3. Loc. cit. p. 275.

4. Yerkes, R.M., Modificability of Behavior in its relation to the Age and Sex of the Dancing Mouse, Journ. Comp. Neurol. and Psychol. 19, (1909) 237-271.

5. Loc. cit. pp. 266-267.

is a steady and marked decrease in rapidity of habit formation; from the seventh to the tenth month the direction of the change is reversed. These statements hold for both sexes.

2. Young males acquire the habit more quickly than young females, but between the ages of four and ten months the females acquire the habit the more quickly."[1]

Haecker,[2] in work on the Mexican axolytl, found that the habit of distinguishing between wood and meat when offered to the animals in forceps, was learned with far greater difficulty by the young (nine month) individuals than by the old ones, whose age is not given.

Watson[3] in his Animal Education, discusses work both on habits involving simple motor ability and on those requiring skill in manipulation. He concludes that "a young rat will solve for the first time more quickly than a mature rat any problem conditioned on mere random activity, but that a problem involving associative activity and manipulation is more easily solved by the older animals." He found that with the simple saw-dust box the average time of entrance for the old rats was 85.50 minutes, while that for the young ones was 6.87 minutes and says further, "there is a gradation in the number of use-

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1. Loc. cit. p. 269.

2. Haecker, Arch. f.d. ges. Psych., 25, 1-35.

3. Watson, J.B., Animal Education, University of Chicago Press, 1903.

less movements made by rats at different ages. At thirty-five days of age, when physical activity appears to have reached its highest stage, the percentage of useless movements is largest. As the rats grow older, this superabundant activity disappears, and in its place comes direction of activity."

To summarize the main points in this brief historical survey, we may note:

First:- That there is disagreement as to the age of greatest activity, Slonaker putting it first between eighty-seven and one hundred twenty days, and later at ten months for the males and twelve and five-tenths months for the females, while Watson believes it to be at about thirty-five days;

Second:- That Yerkes finds the labyrinth habit more easily learned by the old dancers than by the young, while if Watson's interpretation is correct the reverse should be true;

Third:- Yerkes concludes that the female is superior to the male in learning the labyrinth.

APPARATUS AND PROCEDURE.

Albino rats were chosen as subjects in this investigation for several reasons: Slonaker, Watson and Yerkes worked with rodents, and we desired to compare our results with theirs. Nearly two hundred animals were required for actual experimental work and many more than that had to be kept on hand to provide for replacing any who might become unfit for work, and to allow for the usual losses through death and sickness. It has

been found that white rats are easier to breed, handle, and care for in large numbers than any other small mammal. For reasons which will appear later, we adopted the circular maze as our problem since it is generally conceded that the rat is pre-eminent among animals in his ability to thread a labyrinth, while his satisfactoriness as a subject for experimental work is attested by the number of experimenters who have employed him in various capacities.

The rats were bred in our own laboratory as needed, in-breeding being carefully avoided and all possible care being taken to maintain uniformity of breeding conditions. All of the rats were weaned at from eighteen to twenty-three days,* and the sexes were separated at thirty-five to forty days and kept separate thereafter. The living cages were protected from mice and gray rats by screened compartments constructed of pine and 1/4 inch wire mesh. Every two weeks the cages were thoroughly cleaned, the shelves washed with a disinfecting solution, and the rats dipped in a one per cent solution of "kreso" to prevent the rise and spread of vermin. The animals were carefully watched and treated immediately upon the appearance of parasites, so that they were kept continually in a healthy condition. The diet consisted of milk-soaked bread given every day, and a mixture of cracked corn and sunflower seed every other day. They seemed to thrive on this somewhat restricted diet, so that no additions were made to it

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* No bad effects were noticed from this early weaning and the rats were found to be extremely active as early as the 16th day. See Slonaker, op. cit. p. 350.

although both Basset and Ulrich used carrots and fruit occasionally.

The rats were handled freely from birth, and consequently were perfectly tame and evinced no fear of the experimenter. Special care was taken to tame any rat seeming a little wild, before beginning work with him, since it was believed that fear and timidity might cause irregularities in behavior, a belief which was substantiated during the course of the experiment.

It was desired in this work to obtain not only a record of time but also a distance record of the learning process, since it was felt that this might throw considerably more light on the factors involved in learning than had yet been obtained. The maze problem seemed to offer greater possibilities in this line than either sensory problems requiring a long and tedious course of preliminary training or problems of manipulation permitting of movements in two dimensions which would be practically impossible to trace. We therefore selected as our problem the learning of the circular maze.

Heretofore, the only data possible on such a problem have been in terms of time and errors, the time being the only reliable record since it is practically impossible to evaluate and standardize errors.[1] With regard to this Miss Hicks[2] says: "The prevalent practice of omitting all total and partial re-

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1. Watson, J.B., Noddy and Sooty Terms, Carnegie Pub. No. 103, p. 249, note 1.

2. Hicks, V.C., The Relative Values of Different Curves in Learning, Jour. An. Behav. I, 138-156.

turns from the error record, and of making no attempt to evaluate varying degrees of error gives a curve which is not only worthless but false" (p. 156). She says further: "The total distance criterion presents so many difficulties as to render it impracticable for ordinary work. One difficulty lies in the matter of taking records accurately. The rats, after a few trials, run so rapidly that it is extremely difficult for one person to observe and record at the same time. To do this, it is necessary to mark off the maze into small segments and commit to memory some scheme of representation so that records can be jotted down in a purely automatic manner. The work of transcribing this record into distance terms and computing the same is very laborious. Eliminating these practical difficulties, the distance criterion is in some ways an ideal one." (italics mine.) There can be no divergence of practice as to what shall be omitted or included and results obtained by different experiments upon the same maze will be strictly comparable." (page 154) "The distance and error criteria are fundamentally alike. The distance curve is the better representative of the progressive approximation of the act towards automatic accuracy. It portrays all the details of this eliminative process and it approximates the ideal of uniformity and regularity of descent. However, it is impracticable from the standpoint of recording and manipulating the data."

These practical difficulties in "recording and manipulating the data" have been overcome, at least where small animals are the subjects used in the maze. The total distance can be

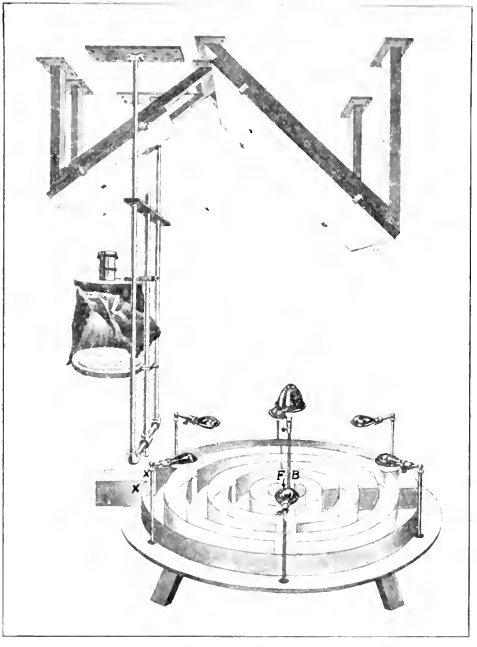

Plate I - The Maze.

obtained accurately by means of the camera lucida attachment designed by Prof. Watson (see Plate I) for use with his circular maze. This maze has a wooden base 150 cm. in diameter and six aluminum runways 15.5 cm. high and 10 cm. wide. The entrances to the alleys are 10 cm. wide, and are at alternate ends of a quadrant arc. The radial stops in alleys 1 to 5 are also placed at alternate ends of a quadrant arc, the stop in each alley being directly opposite its entrance. Thus it is possible for a rat to run only 1/2 the circumference of a runway in either direction before being forced to turn. This is not true of alley 6, where no stop is employed. The central circle, or food compartment is 20 cm. in diameter. A 3/4 inch mesh, wire top prevents the animals from escaping without interfering with observations of their movements. The camera lucida attachment consists primarily of two mirrors and an achromatic lens. The arrangement is as follows: A large plate glass mirror is fastened by supporting framework at an angle of 45° with its center directly above and 1.8 meters from the center of the maze. A somewhat smaller mirror is placed facing the first and making an angle of 90° with it at such a distance away that the light reflected downward falls outside the maze area. In the path of this reflected light is placed a single achromat, 6 cm. in diameter and of 50 cm. focus, in a mounting provided with rack and pinion adjustment which is fitted into the center of a wooden disc 30 cm. in diameter. Below this at the focus of the lens is placed a second wooden disc of the same diameter as the first, which serves as a holder for the paper upon which

the image of the maze is reflected. Both of these discs are attached to iron collars which slide independently up and down the rod CR, thus making it possible to vary the size of the image. A small curtain of dull black velvet attached to the upper disc serves to exclude all extraneous light from the recording table and as a further aid in sensitizing the eye, a large curtain of dark material encircles the space occupied by lens and recording apparatus as well as the experimenter's chair. This curtain also serves the purpose of completely hiding the experimenter from the animals while they are running in the maze.

Illumination is obtained by means of six 40 watt tungsten lamps placed symmetrically around the maze and one 150 watt tungsten in the center. These lights are mounted on brass rods and fitted with aluminum shades blackened on the upper surface. The central shade is circular, those for the peripheral lights are half shades.

The floor of the maze is covered with white linoleum, which can be thoroughly scrubbed whenever necessary. The entrance to the starting box is supplied with a hinged door which can be securely fastened after the animal has been placed inside. The exit is provided with a sliding door which is raised by means of a cord, and closes of its own weight when the tension on the cord is released, thus making it impossible for a rat to return into the starting box after it has once entered the maze.

By means of the two mirrors (M and M'), and the lens (L),

Fig. 1 - Tracing of the actual path followed by a rat at one stage of the learning process.

Fig. 2 - Chartometer.

an exact image (I I) of the maze is thrown on the recording table where the experimenter can follow every movement of the animal during any passage through the maze. Actual records of these trips are made by tracing on the record sheet with a soft pencil the successive movements of the rat. (See Fig. 1) These tracings, measured with a chartometer (Fig. 2) shown by calibration to be accurate to within one per cent, form the basis for the distance record. Since the maze is 6.4 times as large as the image, the distance record obtained in centimeters by the chartometer, must be multiplied by 6.4 to obtain the actual distance traversed in the maze. For example, if the distance indicated by the chartometer is 121 centimeters we obtain the actual distance run thus, 121 cm. x 6.4 = 7744 cm. The values given in the tables represent the actual distance covered by the rats. Both chart and maze distances were tabulated, and the multiplications made to obtain the latter were checked on the adding machine. In addition to the distance record, such charted pathways also furnish accurate account of the excess effort expended, enabling a comparison as to the frequency and extent of the several possible errors as well as a record of the exact steps in their elimination. It can be determined whether a certain error is lessened at each trial and finally disappears, or whether it is dropped out all at once. In short, we have an accurate method of tracing the several factors involved in the learning of the maze problem, and a basis for the analysis of the learning process which has heretofore been lacking.

The exact method employed in this research concerning the

relation of age to the learning ability was as follows:

One week preceeding the day on which the animal was to begin work, food was removed from the living cage and the rat was fed each day in the center of the maze which was temporarily partitioned off from the remainder, making it impossible for him to roam at will through the maze. The first day, he was allowed to eat for forty-five minutes; the second day, for thirty minutes; the third day, for twenty minutes. The feeding time was then diminished five minutes on each succeeding day, so that the day before beginning the problem, the rat had been fed for five minutes in the food box of the maze.[1] Two things were accomplished by this procedure - 1st: The rat was rendered quite hungry, a necessary step, since food was the stimulus used, but the shock which would have resulted from entire absence of food was avoided. 2nd: It became accustomed to some extent to experimental conditions.

On the day when the problem was actually begun, the temporary partition was removed from the maze, a dish of milk-soaked bread placed at the center and the rat placed in the starting box (S. B. Plate 1). The instant it emerged into the maze proper, the door (indicated but not shown in the illustration), was closed behind it making return into the starting box impossible, the stop watch was started and the tracing begun. Twelve or fourteen minutes might be required to reach the

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1. Grain was given in the cage each day at the end of the feeding period.

food, and as many as sixteen sheets of paper have been necessary to trace the pathway during a single trial. At the moment of entrance into the food box (F.B.), the watch was stopped, the time noted, and the animal at once removed. This constituted one trip or one trial. The rat was immediately introduced for a second trial, in which the same procedure was followed except that on reaching the food it was allowed to eat for five minutes before being removed. The feeding period was carefully timed with the purpose of keeping the hunger stimulus as uniform as possible. A short ration of grain was thrown into the living cage, and no more food was allowed until the next day's work. Basset[1] had given grain only twice a week, and noted in consequence a disturbance in behavior on the day following that on which grain was given. Ulrich[2] fed his animals in the cage after work, which may account for their slowness in learning the maze as compared with the rats used in this problem.

Two trials were given each day until the problem was learned, i.e., until in six trips made on three consecutive days no error was made from start to finish. In both Basset's and Ulrich's work, a time norm was set, and although no useless

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1. Bassett, G. C., Habit Formation, &c., Behavior Monograph 2, (1914), No. 4.

2. Ulrich, Work unpublished.

movements were made, unless the act was performed within the limits of the time set, it was not considered perfect. For the purposes of this experiment such a norm was not desirable, since one of the points under investigation was the relative final rate of efficiency attained by rats of different ages. Elimination of all useless movements for three days was therefore considered as sufficient evidence that the problem had been learned. The number of trials required to reach this level of efficiency varied with each rat, the extreme limits being fourteen, and one hundred twelve trials. In a single trial any distance greater than 4.5 meters, which is the length of the errorless pathway from the entrance to the food, represents excess effort on the part of the animal.

If a rat remained in the maze for fifteen minutes without reaching the food box he was taken out and replaced in the entrance box for a second attempt. Distance and time were recorded in the same way as for a successful run, i.e., if the first effort to reach the food proved unavailing after fifteen minutes, and the second attempt was successful after eight minutes, the total time for the first trial would be twenty-three minutes and the total distance the combined distance of the two attempts. Should the rat fail on the second effort also, it was fed for three minutes in the maze with the food box partitioned off as for preliminary feeding, and tried again the following day.

The time and distance records for each trip were carefully tabulated, and form the basis for the conclusions which ap-

pear later. In many cases the actual tracings were kept for reference.

EXPERIMENTAL RESULTS.

It was planned to work with five groups of rats, twenty-five, sixty-five, two hundred, three hundred and five hundred days old respectively, since it was thought that these ages represented fairly well the successive stages in the growth and development of the animal; twenty-five days for youth, sixty-five days for sexual maturity, two hundred days for maturity, three hundred days for age, and five hundred days for old age. The attempt was made to have thirty rats in each group, but sickness and unavoidable accidents among the animals have brought the number somewhat lower. It has been found extremely difficult to obtain rats for the last group (500 days). Although Slonaker finds the average length of life of the white rat to be thirty-four months,[1] and Donaldson gives it as three years, from three hundred to four hundred days is the maximum longevity for most of the rats used in this laboratory, and up to this time only ten have lived to work at the five hundred day age, one of these dying apparently of old age before the problem was learned.[2]

The groups used, with the number of rats in each group

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1. op. cit. Journ. An. Behav. pp. 37-38, tables.

2. Dr. Watson has informed the writer that his experience was quite similar, very few of his rats living to be more than 500 to 600 days old.

were as follows:-

Age at which work began	Number of rats in the group
25 days	27
65 "	27
200 "	28
300 "	28
500 "	10

Throughout the experiment two conditions have been rigidly complied with. 1st: Every animal was started on the problem upon the exact day at which the proper age was reached. This procedure was followed even when it necessitated starting eighteen rats on the same day, in order that experimental conditions might be kept strictly comparable.

2nd: Every animal was run twice every day from its first trial until the last, even though at one stage of the work this required having as many as fifty-eight rats under observation at one time. Such strict continuity of trials precluded the introduction of any factors aside from those involved in the learning process proper. Removal from experimental conditions for even one day would not only cause a change in the physiological tonus of the organism, but would also bring in the matter of retention. So far as was possible the rats were run at the same hour each day, but where large numbers were being used it was impossible to adhere strictly to this rule, although rats accustomed to run at night did not do so well if used in the morning and vice versa; which was probably attributable to the acquiring of a certain food rythm that might not be broken with impunity. Thus it was found that while a difference of an hour

in the working time, and hence the feeding time caused no noticeable change in the behavior of the rats, marked disturbance resulted from a delay of four or five hours.

In general, the behavior of individuals of each group on first entering the maze was the same. The rats showed great hesitancy in leaving the starting box, returned to it frequently after finally entering the maze proper, and endeavored to push up the sliding door; they were also to leave a familiar alley for one unexplored, became excited when a stop was encountered, trying repeatedly to push it aside or to gnaw through the mesh top, and made frequent efforts to escape from the maze. Departure from this type of behavior was noticed among the very old rats and the very young ones. Many of the former evidenced no excitement whatever, often sleeping for several minutes between periods of activity, while the latter were far more active than the rats of any other group, and showed no hesitancy in entering unfamiliar portions of the maze.

The time usually decreased very rapidly, the distance less so, during the first three or four trials. For example, on its first trial, rat 34 of the 300 day group required eleven minutes and forty seconds to reach the food and the distance covered was forty-nine and six-tenths meters. On its second trial, seven minutes six seconds were required, and the distance run was thirty and nine-tenths meters; at the fourth trial success was attained after 1 minute nineteen seconds; the pathway traversed measuring ten and two-tenths meters, while for the sixth trial the time record was only forty-nine seconds, the distance eight and six-tenths meters. By the tenth or fifteenth trial the decrease in

both time and distance become much more gradual, and continued so until the problem was learned. The rat referred to above required on the fifteenth trial twenty-four seconds, and ran seven and two-tenths meters, on the thirtieth trial the trip occupied fourteen seconds and covered five and six-tenths meters. This particular animal completed the problem at the sixty-sixth trial when the time record was seventy and two-tenths seconds and the distance record four and five-tenths meters, which, it will be remembered, constitutes a perfect run.

The data set forth above may be conveniently tabulated thus:

Trial	Time required to reach food	Distance run in maze before reaching food. (The true pathway 4.5 M.)
1st	11 min. 40 sec.	49.6 meters
2nd	7 " 6 "	30.9 "
4th	1 " 19 "	10.2 "
6th	49 "	8.6 "
15th	24 "	7.2 "
30th	14 "	5.6 "
66th	7.2"	4.5 "

This rapid decrease in time and distance at the beginning of the problem was characteristic of all groups, and is clearly shown in the initial drop in all the curves.

The Twenty-five Day Rats.

Work on this group began at twenty-five days when the rats were so small that they could crawl through the mesh top of the maze, and could touch the sides of the alleys only by running from side to side, while other rats could remain in the center of the path and touch both walls of the runways with

their vibrissae. These rats were weaned at eighteen days, and were fed in the maze for five days preceding the experiment, the forty-five and thirty minute feeding periods being omitted. For the first day or two after starting the problem, they were allowed to eat for six or seven minutes instead of five minutes at the end of each day's work, since it developed that a shorter ration had a weakening effect on animals so young. The little rats were exceedingly active, and on entering the maze ran so rapidly that it was very difficult, but never impossible, to trace their movements. For the most part they showed great eagerness to escape from the starting box, some even acquiring the habit of lifting the door partway with the nose, and as a rule they had no hesitancy in entering unexplored portions of the maze, in this respect differing from most of the rats in this experiment. The error of circling the food box occurred more often with rats of this group than with those of any other, the explanation being, perhaps, that in their over-eagerness to reach the food they acquired such momentum than they ran past the entrance to the food box.

Twenty-seven rats were experimented with at this age, eleven males and sixteen females, eight strains being represented, as follows:

	WM 1/9/14	Y(CF) 2/9/14	G 3/9/14	AL 3/9/14	XL 3/15/14	YL 3/20/14	XW 11/1/14	YW 11/1/14	All
Males	0	2	1	1	1	3	1	2	11
Females	2	1	1	1	3	5	3	0	16
Total	2	3	2	2	4	8	4	2	27

The first letter indicates the father, the second letter the mother, of the litter. Individual rats were distinguishable from each other by a convenient system of ear marks, and on every cage was a tag showing the experimental number, parentage, date of birth, sex and ear mark for each rat contained therein. Thus, W M 1/9/14 R-♀ 4, would be deciphered, rat number four, female, right ear straight, born January ninth, 1914, mother M, father W.

The number of trials required by animals of this group in learning the problem varied from fourteen to fifty-one, the absolute time from four and nine-tenths seconds to nine and one-tenth seconds, the total time from sixty-four minutes to six hundred forty-nine minutes; and the total distance from one hundred thirty-nine meters to four hundred eighteen meters.

The "absolute time" is the average time for the last six trials, represents the limit of efficiency in speed for a given group, and varies among individual rats within the group as well as for the groups themselves. Thus, the record time for the twenty-five day group was made by a rat which could run from entrance to food box in four seconds, but no other rat attained this speed, and one in particular could not make the run in less than eight seconds. The last six trials were all without error and would seem to afford a fair basis for judging the average final efficiency, which for this group was five and seven-tenths seconds. The absolute distance is the same for each group, since the last six trials are errorless, and the true pathway measures approximately four and five-tenths meters.

The enormous number of figures involved, makes the showing of individual records inexpedient. An exact copy of the daily record for rat number fifteen of the twenty-five day group, from the first to the last trial appears as Table I. The averages and totals for each rat which appear in Table II are obtained by adding and averaging the daily records for each rat. Trial, time and distance variation for each animal are also given. The total time, total distance, total number of trials and the absolute time of the twenty-seven rats were added and averaged to give the average total time, the average total distance, the average number of trials, and the average absolute time for the group.

The speed is the average number of centimeters traveled per second throughout the learning process, and is obtained by dividing the total time into the total distance. For the twenty-five day group these averages were:

Trials	Time		Distance	Speed
	Absolute	Total		
30	5.7 sec.	224 min.	271.6 meters	20.1

The curves shown in Fig. 3 are based on the figures in columns 2, 4 and 6 of Table II. Only one rat finished in less than fifteen trials, and this is indicated on the first point of the curve. Three rats finished at between fifteen and twenty trials, one at seventeen and two at eighteen trials each, the average being seventeen as indicated on the curve. Betwe..

TABLE I.
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Run in day time — Rat 15 - 26 days

Day	Trial	Time	Seconds	Distance Chart	Distance Maze	X L 3/15/14 ♂ male
1 4/9/4	1	1′7.8″	67.8	195	1248.0	Elim. 4-5-6
	2		37.2	140	896.0	" 3-4-6-wrong turn-1
2 4/10	3		15	106	678.4	Elim. 1-3-4-5
	4		10	70	448.0	Perfect
3 4/11	5		25.8	158	1011.2	Elim. 1-2-4-5-6-Lost in 3
	6		17.4	120	768.0	" 2-4-5-6-w.t.1-3
4 4/12	7		11.8	72	460.8	" 2-3-4-5-6-w.t.1
	8		18.6	106	678.4	" " " "
5 4/3	9		10.4	70	448.0	Perfect
	10		25.8	120	768.0	Elim. 2-4-5-6-w.t.1-3
6 4/14	11		6	70	448.0	Perfect
	12		18	132	844.8	Elim. 3-4-5-6-w.t.1-2
7 4/15	13		5.6	70	448.0	Perfect
	14		6.2	70	44.8	"
8 4/16	15		11.8	99	633.6	Elim. 2-3-4-5-6-ret.-1
	16		32.4	129	825.6	" 2-3-4-5-6-ret., w.t.1

TABLE I (Continued)
-1-

Run in day time — Rat 15 - 26 days

Day	Trial	Time	Seconds	Distance Chart	Distance Maze	X L 3/15/14 B_ male
	17	7.8	5.4	70	448.0	Perfect
9 4/17	18		7.4	83	531.6	Elim. 2-3-4-5-6-w.t.1
	19		5.4	70	448.0	Perfect
10 4/18	20		5.2	70	448.0	"
	21		5.4	70	448.0	Perfect
11 4/19	22		6	72	460.8	Elim. 2-3-4-5-6-too far 1
	23		5.2	70	448.0	Perfect
12 4/20	24		9	101	464.4	Elim. 2-3-4-5-6-w.t.-1
	25		5	70	448.0	Perfect
13 4/21	26		5.6	70	448.0	"
	27		7.6	72	460.8	Elim. 1-2-3-4-6-w.t.-5
14 4/22	28		5.4	70	448.0	Perfect
	29		5	70	448.0	"
15 4/23	30		5.2	70	448.0	"
	31		4.8	70	448.0	" Finished 4/25/14
16 4/24	32		4.4	70	448.0	" 34 Trials
	33		4.6	70	448.0	"
17 4/25	34		5.6	70	448.0	"

twenty and twenty-five trials three rats finished, at twenty-three, twenty-four and twenty-four trials respectively; the average is twenty-three, and the third point on the curve indicates that three rats finished at twenty-three trials. The same procedure is followed in drawing the time and distance curves except that they are necessarily more condensed. Three rats required approximately four hundred seconds each in which to learn the problem, (numbers 11, 15 and 24), and the first point on the time curve indicates this fact. The fourth point shows that six rats consumed from fifteen thousand to twenty thousand seconds (average for the six seventeen thousand seconds), in their total number of trials. The fifth point in the distance curve is interpreted to mean that six rats covered between three hundred thousand and three hundred fifty thousand centimeters, (average for the six, one hundred seventy thousand), in learning the maze. It might be well to notice at this point that all of the curves appearing in this paper are constructed on this same plan.

The trial curve, (Fig. 3-A) for this group reaches the apex at about thirty, which is the average number of trials for this age.

Two maxima appear in the time curve, (Fig. 3-B) at eight hundred seconds, and at seventeen hundred seconds respectively. A point intermediate between the two would give the time average for the group, approximately thirteen hundred seconds.

The apex of the distance curve, (Fig. 3-C), is at three hundred thousand centimeters, which is not far from the group

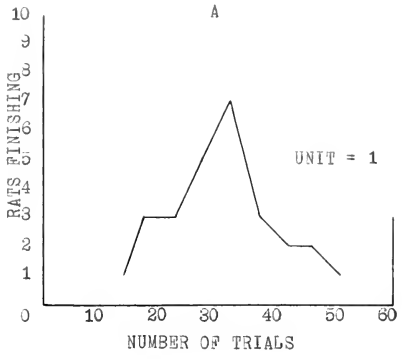
TABLE II - 25 DAY RATS.

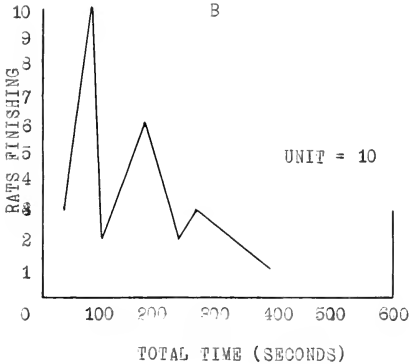
-:-

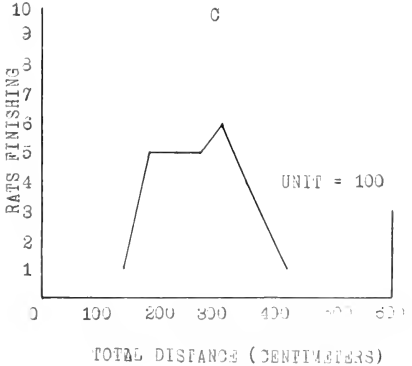
11 males - 16 females

Rat	Trials	Trial Dev.	Time(secs)	Time Var.	Distance (cm)	Dist.Var.	Absolute T.
♂							
4	18	12	2541.4	-1196.3	18035.2	9127.1	5.7
6	45	-15	1903.4	- 558.3	38666.8	-11504.5	5.1
8	32	2	959.8	385.3	36732.4	-9570.1	5.3
10	28	-2	699.6	645.5	23770.4	3891.9	5.0
15	34	-4	423.2	921.9	19424.0	7738.3	4.9
16	27	3	1592.2	-247.1	30016.4	-2044.9	5.5
19	40	-10	721.2	623.9	29207.2	11030.7	5.5
24	24	6	388.4	956.7	16131.6	-2854.1	6.1
27	51	-21	1588.0	-242.9	41816.0	-14553.7	5.6
36	30	0	1603.2	-258.1	28454.4	-1292.1	9.1
37	30	0	1632.8	-287.7	23070.4	4091.9	5.5
♀							
1	23	7	2623.2	-1278.1	37819.2	-10656.9	7.2
2	26	4	562.2	782.9	21913.6	5248.7	5.5
5	14	16	3897.2	-2552.1	30348.8	- 3186.5	5.2
9	38	-8	723.6	621.5	27129.6	32.7	5.4
11	18	12	401.4	943.7	13900.8	13261.5	5.7
12	32	-2	2381.0	-1035.9	32648.8	- 5486.5	6.1
13	46	-16	999.4	345.7	30407.0	- 3244.7	4.9
14	24	6	519.6	825.5	18553.6	8608.7	5.6
17	26	4	612.8	732.3	18771.4	8390.9	5.6
20	34	-4	945.6	399.5	25779.2	1383.1	5.3
21	36	-6	900.6	444.5	26208.0	954.3	5.1
22	32	-2	536.2	808.9	23979.2	3183.1	5.4
25	36	-6	597.6	747.5	30882.8	- 3720.5	5.2
28	28	2	2643.2	-1298.1	36672.0	- 9509.7	5.2
31	44	14	1838.2	- 493.1	30332.2	- 3169.9	5.2
41	17	13	2082.8	- 737.7	23212.8	3949.5	7.6
Totals	822	197	56317.8	20370.7	733383.8	161686.5	153.5
Averages	30	7	1345.1	754.4	27162.3	5988.3	5.7
Average for ♂	32	7	1277.5	574.9	27711.3	7063.6	5.7
Av.for ♀	29	8	1391.5	877.9	26784.9	5249.2	5.6

TWENTY FIVE DAY RATS Fig. 3







average of two hundred seventy thousand.

The average mean variations for the group are:

Trials.....	30 ± 7	23% Variation
Time.....	224 min. ± 125 min.	55% "
Distance.....	271.6 m. ± 59.8 m.	22% "

The distance variation is the least, which confirms the statement made above, to the effect that distance is the most reliable measure of learning ability in such a problem as the present one. No very close relation seems to obtain between the number of trials required for finishing the problem and the total amount of time or distance. Thus the rat which finished in fourteen trials had the highest total time record in the group, and a high distance record, while the rat which finished in fifty-one trials had the highest distance record, but a mean time record. The lowest time record was made by a rat finishing in twenty-four trials whose distance record was also low; the lowest distance record, by a rat requiring eighteen trials for the problem, whose time was lower than the average. Reference to the columns in the table which show the mean variation for each rat in time, distance, and trials will emphasize the lack of regularity just mentioned. Except where the time values are very high, time and distance bear a fairly constant ratio to each other. The exceptions occur when the time record is increased on account of failures (each of which means a count of 900 seconds) in the first part of the learning process. In a trial which has one or more failures as a com-

ponent part, the distance run is never proportional to the time spent, since if the rat does not refuse to run altogether after several vain efforts to reach the center, it will make frequent halts at the radial stops and at the entrance to the maze. It appears that we have here additional evidence for considering the distance as a more accurate measure of the learning process than the time.

According to the averages which appear below, the females of this group are superior to the males in number of trials required to learn, and in final efficiency (absolute time), but inferior in total time consumed, total distance covered, and speed attained throughout the learning process, so that on the whole the males may be considered as slightly superior to the females.

	Trials	Time Absolute	Total	Distance	Speed
Males	32	5.7 sec.	213 min.	277.1 m.	21.6 cm.per sec.
Females	29	5.6 "	232 "	267.8 "	19.2 " " "

The time variation of the males is less than that of the females, while the reverse relation exists regarding the distance variation, as shown below:

	Time Variation	Distance Variation
Males	96 min.	79.6 m.
Females	146 "	52.4 m.

Sixty-five Day Rats.

These rats began the problem when sixty-five days old, and were fed in the maze for one week before actual experimentation began. They were lively, but did not show the superabundant activity of the twenty-five day group, and were not so speedy. Twenty-seven rats were run, sixteen males and eleven females, representing nine strains as follows:

	EJ 11/1/13	EL 11/10/13	EL 12/3/13	WM 1/8/14	Y(CF)3/4/14	GJ 3/12/14	AL 3/14/14	XL 3/15/14	Total
	0	3	2	4	3	0	1	1	16
	3	0	0	3	2	1	0	2	11
Total	3	3	2	7	5	1	1	3	27

Trials varied from fourteen to sixty-five, absolute time from four and seven tenths to eleven and eight tenths, total time for sixty-four minutes to seven hundred thirty-one minutes; and total distance from ninety-one and eight tenths meters to seven hundred fifty meters. Here as in the preceding group, we can trace no close connection between number of trials and time or distance. The rat which finished in the fewest number of trials had a low time record and the lowest distance record for the group, while the one requiring the greatest number of trials had the highest time and distance records. So far the relation seems very close. But the lowest time record was made by a rat finishing in twenty-two trials, whose distance record was high, while two other rats which finished at twenty-two trials had very high time and distance records. The next to the highest

distance record was by a rat finishing in fifty-four trials, while the next to the highest time record was made by one which finished in twenty-two trials. In general, where the trials run very high (65, 54) or very low (14, 16) the distance corresponds rather closely, but for the trials lying between these extremes no such correspondence can be traced. The ratio between time and distance in this group is by no means constant. (See Table III.) The group averages are:

Trials	Time Absolute	Total	Distance	Speed
31	6.8 sec.	219 min.	260.6 m.	19.8 cm.per sec.

There are two maxima in the trial curve for this group, (Fig. 4-A), at twenty-two and thirty-seven respectively, and the group average lies midway between the two at thirty-one.

The time curve (Fig. 4-B), shows the highest point at six thousand seconds and one almost as high at twelve hundred seconds, while the average number of seconds for the group was eleven hundred.

For the distance curve, (Fig. 4-C), there is a clearly marked maxima at twenty-six, which corresponds exactly with the group average of twenty-six hundred cm. The average mean variations for the group are:

Trials.....31 ± 9.....29% Variation

Time.....219 min. ± 105 min.....48% "

Distance...260.6 m. ± 83.2 m.....32% "

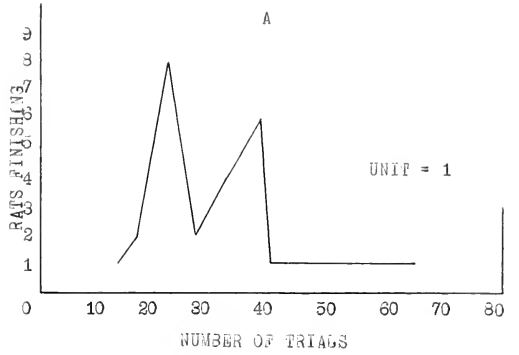
TABLE III - 65 DAY RATS.

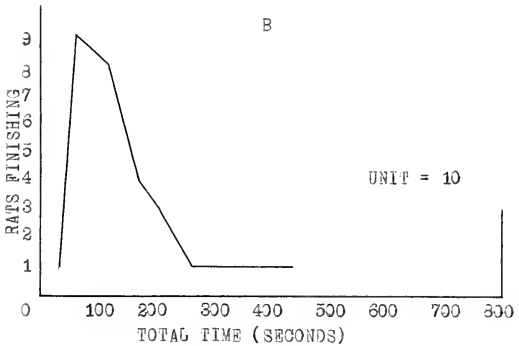
-:-

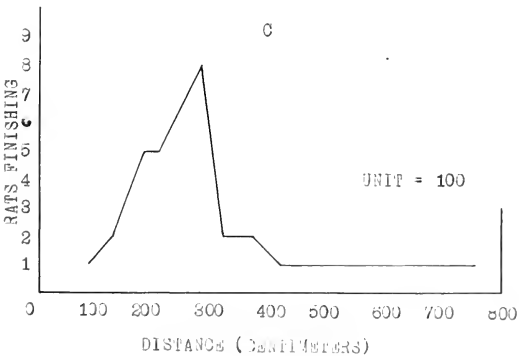
16 males - 11 females

Rat	Trials	Trial Dev.	Time(Secs)	Time Var.	Distance (cm)	Dist.Var.	Absolute T
26	14	17	454.0	858.1	9184.0	16880.2	11.8
4	16	15	496.0	816.1	11603.2	14461.0	9.9
5	22	9	2378.0	-1065.9	26675.2	- 611.0	6.5
6	24	7	452.4	859.7	18182.4	7881.8	6.3
7	22	9	645.2	666.9	16454.4	9609.8	6.6
8	30	1	385.8	926.3	19718.4	6345.8	6.6
9	38	- 7	981.4	330.7	25117.6	946.6	7.2
10	26	5	519.2	792.9	19481.6	6582.6	5.6
11	18	13	1184.8	127.3	18899.2	7165.0	5.8
12	34	- 3	1724.8	-412.7	30498.8	-4434.6	6.4
13	22	9	721.0	591.1	16626.4	9437.8	5.6
14	22	9	2700.4	-1388.3	29484.8	-3420.6	5.9
20	36	- 5	1051.8	260.3	29491.2	3427.0	6.9
21	46	-15	1436.4	124.3	33280.0	7215.8	5.9
22	21	10	1344.0	- 31.9	21305.6	4758.6	6.6
24	38	- 7	1982.0	- 669.9	39326.0	-13261.8	10.6
1	30	1	1327.4	- 15.3	23033.6	3030.6	8.2
2	54	-23	1651.8	- 339.7	42368.0	-16303.8	7.9
3	21	10	1542.0	- 229.9	19603.2	6461.0	7.1
15	28	3	2028.0	- 715.9	28921.6	- 2857.4	5.5
16	36	- 5	1139.4	172.7	25177.6	886.6	5.3
17	36	- 5	454.4	857.7	20819.2	5245.0	4.7
18	65	-34	4388.4	-3076.3	75001.6	-48937.4	5.5
19	32	- 1	1312.0	0.1	25638.4	425.8	4.9
23	38	- 7	815.8	496.3	28409.6	2345.4	7.6
27	40	- 9	1714.6	- 402.5	35584.0	- 9519.8	6.4
28	20	11	597.4	714.7	13849.6	12214.6	6.7
Totals	830	250	35428.4	16943.5	703735.2	224667.4	184.0
Averages	30.7	9	1312.1	627.5	26064.2	8321.0	6.8
Av. for	26.8	9	1153.6	620.1	22833.0	7277.5	7.1
" "	36.5	10	1542.8	628.3	30764.2	9657.0	6.3

SIXTY FIVE DAY RATS Fig 4







Here again the distance variation is seen to be less than the time variation.

Comparison of the male and female records in the group show that while the absolute time of the females is less than that of the males, in other respects the male showing is the better.

Trials	Time Absolute	Total	Distance
Males.....27	7.1 sec.	192 min.	228.3 m.
Females.....36	6.3 "	257 "	307.6 "

Comparison of the time and distance variation for the males and the females shows that the former have a lower variation than the latter in both particulars.

Time Variation	Distance Variation
Males.....103 min.	72.7 m.
Females.....107 "	96.5 "

Two Hundred Day Rats.

These rats were put to work when two-hundred days old, having been fed in the maze for one week preceding the beginning of the problem. They were more erratic than those of any other group used, being jerky and irregular in their movements. Often after making a perfect run in six or seven seconds a rat would

drop back to one, two or three minutes with many errors. This behavior was not noted in any other group except in one or two isolated cases.

Twenty-eight rats were used, fifteen males and thirteen females, eight families being represented as follows:

	BD 7/30/15	CC_2 7/30/15	WG 8/24/15	BD 9/28/15	BH 9/18/15	BH 9/28/15	H 9/28/15	XL 9/28/15	Total
	1	1	3	1	2	3	2	2	15
	0	2	2	2	4	2	0	1	13
Total	1	3	5	3	6	5	2	3	28

Trials varied in number from fourteen to one hundred twelve, absolute time varied from five and two tenths seconds to twenty-four and one tenth seconds, total time from eighty-two to nine-hundred forty-nine minutes, and total distance from one-hundred twenty-five and five tenths meters to nine-hundred and twelve meters. As for previous groups trials bear little relation to time or distance, but the proportion between total time and total distance is fairly constant. (See Table IV) The lowest trial record was fourteen, and the time and distance records for the rat making this record were also low. The lowest time record, as well as the lowest distance record was made by a rat finishing in twenty trials. The rat requiring the largest number of trials (112) had a time record but little higher than one which required only thirty-four trials, while its distance record was next to the highest. The highest time record was that of a rat which finished in one hundred seven trials, with the next to the highest distance record, the highest distance

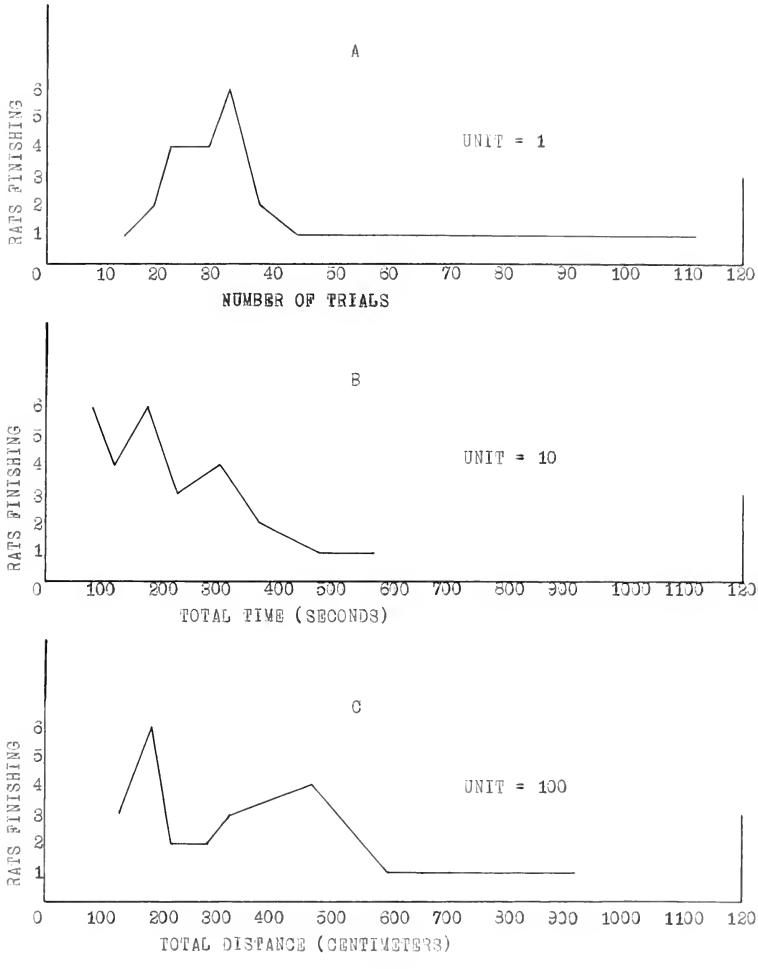
TABLE IV - 200 DAY RATS.

-:-

15 Males - 13 females

Rat	Trials	Trial Dev.	Time (Secs)	Time Var.	Distance (cm)	Dist. Var.	Absolute T
♂							
2	18	24	810.2	1298.9	15010.4	18900.7	8.7
5	28	14	1548.2	560.9	21[illegible]	11978.7	8.6
8	44	- 2	1767.0	342.1	30275.2	3635.9	10.7
9	26	16	646.3	1462.8	16672.0	17239.1	5.7
10	20	22	496.4	1612.7	12559.2	21351.9	6.8
11	20	22	1548.6	560.5	18387.2	15523.9	7.4
23	30	12	1191.0	918.1	22828.8	11082.3	7.0
24	30	12	1564.8	544.3	28355.2	5555.9	7.6
29	104	-62	2636.1	- 527.0	64632.2	-30721.1	17.3
30	107	-65	4735.6	-2626.5	91293.8	-57382.7	24.1
31	64	-22	1877.2	231.9	47627.2	-13716.1	6.5
33	32	10	1343.8	765.3	25446.4	8464.7	8.5
34	22	20	1084.6	1024.5	18240.3	15670.8	10.5
36	32	10	777.8	1331.3	18675.2	15235.9	8.1
38	14	28	732.8	1376.3	12569.6	21341.5	7.9
♀							
3	26	16	1280.4	828.7	19744.0	14167.1	9.4
4	112	-70	3014.0	- 904.9	69781.6	-35870.5	7.4
6	18	24	1825.2	283.9	13475.2	20435.9	8.0
7	54	-12	3851.1	-1742.0	51143.4	17232.3	7.2
15	32	10	2409.0	- 299.9	31522.8	2388.3	5.2
17	56	-14	2995.8	- 886.7	46335.8	12424.7	6.5
18	79	-37	3663.4	-1554.3	59373.2	25462.1	6.6
19	49	- 7	2031.4	77.7	44944.4	11033.3	5.4
20	27	15	5694.8	-3585.7	32960.0	951.1	8.7
21	32	10	2440.0	- 330.9	35686.0	1774.9	6.1
25	35	7	2990.6	- 881.5	35897.6	1986.5	7.8
27	22	20	963.4	1145.7	19043.6	14867.5	7.8
35	37	5	3135.8	-1026.7	45104.8	11193.7	7.3
Totals	1170	568	36294.9	28731.7	949517.5	437589.1	238.8
Averages	41.7	21	2109.1	1026.1	33911.1	15628.1	8.5
Av. for ♂	39.4	23	1517.3	1012.2	29633.6	17186.7	9.7
" " ♀	44.5	19	2791.9	1042.2	38847.1	13060.5	7.2

TWO HUNDRED DAY RATS Fig. 5



record by one finishing in twenty-seven trials, whose time was considerably above the average.

The averages for this group are:

Trials	Time Absolute	Total	Distance	Speed
42	8.6 secs.	351 min.	339.1 m.	16 cm. per sec.

The apex of the trial curve, (Fig. 5-A,) lies at thirty-three, while the average for the group is forty-one, but the explanation of the apparent discrepancy is to be found in the records of the six rats who required from fifty-six to one hundred twelve trials to learn the problem, thus running the group average up. No well defined apex can be found in the time curve (Fig. 5-B) the group average, twenty-one hundred seconds showing rather as a depression, nor could it be divined by a glance at the distance curve that the average lay in the neighborhood of thirty-three thousand cm.

The average mean variations are:

Trials.....42 ± 21.....52% variation

Time.....852 min. ± 171 min.....48% "

Distance.....339.1 m. ± 156.2 m.....46% "

The distance variation is again the least.

If the averages for the males and females be compared, it appears that the former are somewhat superior to the latter except in absolute time. The averages are:

Trials	Time Absolute	Total	Distance
Males.....39	9.7 sec.	219 min.	296.3 m.
Females.....45	7.2 "	465 "	388.4 "

In the matter of mean variation, the males have the lower time variation, but the female distance variation is lower. The figures are:

Time Variation	Distance Variation
Males.....169 sec.	171.8 m.
Females.....173 "	130.6 "

Three Hundred Day Rats.

This group consisted of twenty-eight rats from ten families, thirteen males and fifteen females, who began the problem when three hundred days old.

AD-	W 5/5/12	BD 5/5/12	WF 5/25/12	BF 5/25/12	WF 6/5/12	BF 6/6/12	CF 6/6/12	BL 6/6/12	CF 6/6/12	Total
0	1	0	1	0	4	1	2	2	2	13
1	4	1	1	2	2	2	1	1	0	15
Total 1	5	1	2	2	6	3	3	3	2	28

They were fed in the maze for ten days before the beginning of

the problem, preliminary feeding being thus extended because it was found that rats so old contracted digestive troubles unless the decrease in food supply was made more gradual than for the younger animals. They were allowed to eat for from six to eight minutes instead of five, at the close of each day's work, since they ate much slower than the younger rats, and could not obtain sufficient nourishment in the shorter time. These rats differed markedly in behavior from those in any of the preceding groups in that they were lethargic, inactive, and often went to sleep in the maze instead of working at their problem. A few of the animals of this group were from The Wistar Institute, and were somewhat timid and difficult to handle, but even among animals bred in this laboratory the same disinclination to work was noted, although with our own rats it id not last so long. When the rats finally begun to work, they went about it differently from those of other groups. They were very deliberate, followed the culs de sac out to the bitter end whereas the other rats often turned back toward the true path before reaching the alley stop, furthermore, they did not hesitate to enter the unexplored runways as did most of the other rats, in this last respect resembling the twenty-five day rats.

The trials varied from fourteen to eighty-four, absolute time from five and eight tenths seconds to thirty-five and two tenths seconds, total time from one hundred nine minutes to two thousand two hundred seventy-four minutes, and total distance from one hundred seventeen and three tenths meters to six hundred nine and six tenths meters.

No connection between number of trials and time or distance was found, and the ratio of total time to total distance did not appear to be constant. (Table V). Thus, the lowest number of trials (14) was made by a rat whose total distance was next to the lowest, but whose time record was higher than that of one rat finishing at sixteen trials and those of two rats finishing at thirty-eight trials each. The greatest number of trials (84) was made by a rat whose time record was exceeded by eighteen others, while its distance record was exceeded by four others. The lowest time record as well as the lowest distance record was made by a rat which finished in sixteen trials, the highest time record by one requiring twenty-four trials, whose distance record was an average one. The highest distance record belongs to the rat with next to the highest number of trials whose time is also next to the greatest.

Group averages were:

Trials	Time Absolute	Total	Distance	Speed
41	11.6 sec.	743 min.	367.5 m.	8.2 cm. per second

The apex of the trial curve (Fig. 6-A) lies at twenty-eight, although the average is forty-one. The large number of rats finishing after thirty trials however easily accounts for the apparent discrepancy. Two maxima are found in the time curve, (Fig. 6-B), at seventeen hundred and twenty-eight hundred respectively, but again the general average is raised by the twelve

TABLE V - 300 DAY RATS.

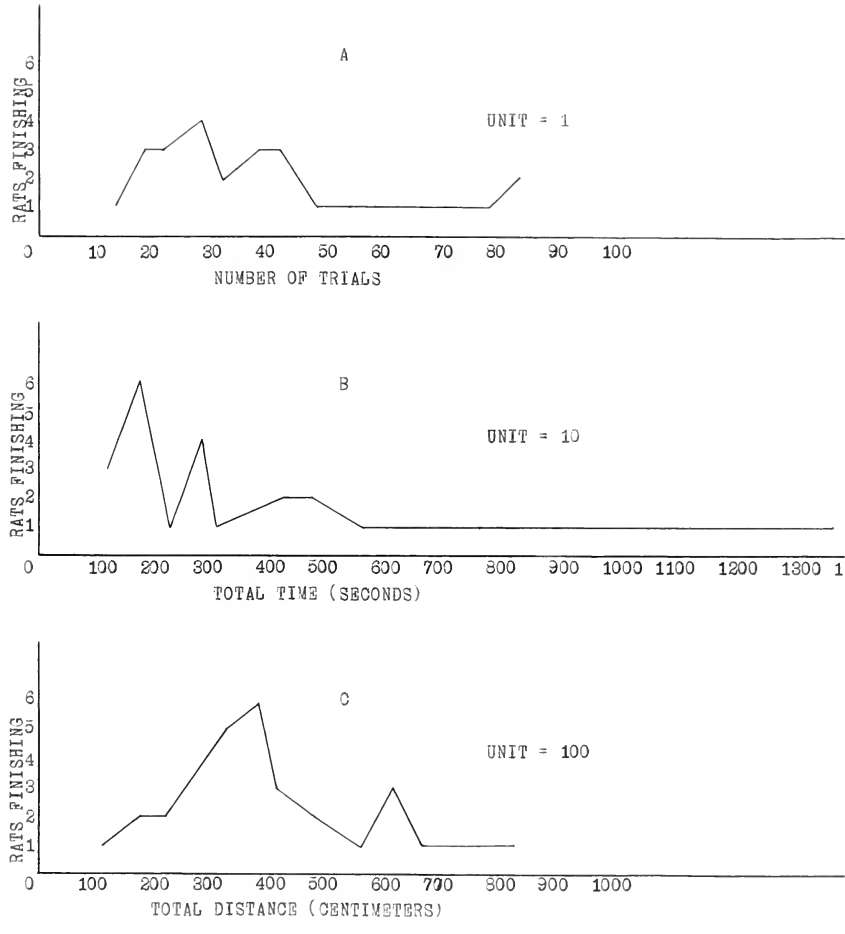
-:-

13 males - 15 females

Rat	Trials	Trial Dev.	Time(secs)	Time var.	Distance (cm)	Dist.Var.	Absolute T
♂							
5	29	12	8221.0	3759.7	30962.8	5792.1	12.7
17	48	- 7	1943.8	2517.5	35558.4	1196.5	9.5
22	82	-41	12220.6	-7759.3	72300.4	-35545.5	14.5
24	42	-11	5605.8	-1144.5	43411.2	6656.3	13.5
25	54	-13	1862.4	2598.9	33017.6	3737.3	10.2
26	19	22	8937.2	-4475.9	33760.0	2994.9	11.3
30	27	14	3167.4	1293.9	19980.8	16774.1	13.1
33	16	-25	956.4	3504.9	11731.2	25023.7	19.5
34	66	-25	2899.0	1562.3	55929.6	19174.7	10.7
36	26	-15	2618.4	1842.9	24358.4	12396.5	8.6
37	44	- 3	2861.2	1600.1	33068.8	3686.1	13.0
38	34	7	1706.6	2754.7	28793.6	7961.3	6.5
39	35	6	4227.2	234.1	35916.8	838.1	6.9
♀							
1	20	21	11113.2	-6651.9	31609.6	5145.3	35.2
2	62	-21	4745.6	- 284.3	56636.4	-19881.5	5.8
9	25	16	7029.6	-2568.3	34898.6	1856.3	9.0
12	24	17	13639.6	-9178.3	32563.0	4191.9	7.4
14	19	22	4320.6	139.7	26163.2	10591.7	21.4
15	78	-37	2646.4	1814.9	50601.8	-13846.9	11.5
16	20	21	1640.2	2821.1	18227.2	18527.7	14.3
18	40	1	2431.4	2029.9	42406.4	5651.5	6.6
19	14	27	1598.4	2862.9	15059.2	21695.7	13.0
20	58	-17	4614.9	- 153.6	66342.4	-29587.5	15.5
21	30	11	1682.6	2778.7	26035.2	10719.7	8.3
27	70	-29	7567.6	-3106.3	60960.0	-24205.1	6.2
28	38	3	1134.0	3327.3	24652.8	12102.1	6.2
31	84	-43	2087.0	2374.3	56115.2	19360.3	8.3
35	38	3	1438.4	3022.9	28076.8	8678.1	6.7
Totals	1142	480	124916.5	78163.1	1029137.4	347818.4	325.4
Averages	40.7	17	4461.3	2797.2	36754.9	12422.1	11.6
Av. for ♂	40.4	15	4402.0	2696.0	34437.6	10905.8	11.5
" " ♀	41.3	19	4512.6	2874.3	38023.1	13736.0	11.7

Fig. 6

THREE HUNDRED DAY RATS



animals who required more than three thousand seconds in which to learn the maze pathway. There is a decided apex in the distance curve (Fig. 6-C) at thirty-three thousand, which nearly corresponds with the group average of thirty-six thousand.

Average mean variations for the group were:

Trials.....41 ± 17.....41%

Time.....743 min. ± 466. min.....63%

Distance.....367.5 m. ± 134.2 m.....36%

Once more the distance variation is seen to be the least.

There was almost no difference between the learning of the males and that of the females, such difference being even less marked than in the twenty-five day group. The averages are:

Trials	Time Absolute	Time Total	Distance
Males.....40	11.5 sec.	735 min.	344.8 m.
Females....41	11.7 "	752 "	380.2 "

Both time and distance variation for the males were less than for the females.

Time Variation	Distance Variation
Males.....449 min.	109 m.
Females.....479 "	137.3 m.

Five Hundred Day Rats.

Records on only ten rats have been obtained in this group, six strains being represented by four males and six females who began the problem when five hundred days old. These rats like the 300-day animals were fed in the maze for ten days previous to the commencement of the problem, and allowed to eat for from six to eight minutes at the close of each days work on account of their age. Little difference in behavior was noted between them and the three hundred day animals.

	CF 6/2/13	BE 6/8/13	CF 6/21/13	BH 9/25/13	WK 10/2/13	EJ 11/11/13	Total
	0	0	1	0	3	0	4
	1	1	2	1	0	1	6
All	1	1	3	1	3	1	10

Too few rats have been used to make this group really comparable with the rest, but averages and totals are nevertheless shown. Trials varied in number from eighteen to fifty-six, absolute time from five and four tenths seconds to seventeen and eight tenths seconds, total time from one hundred and sixty-seven minutes to eleven hundred and sixty-seven minutes, and total distance from one hundred seventy-two and eight tenths meters to six hundred forty-one and six tenths meters.

Again there is no relation apparent between trials and time or distance, and total time and total distance do not bear a proportional relation to each other. (Table VI) The rat which finished in the fewest trials (18) had next to the highest time

TABLE VI - 500 BAY RATS.

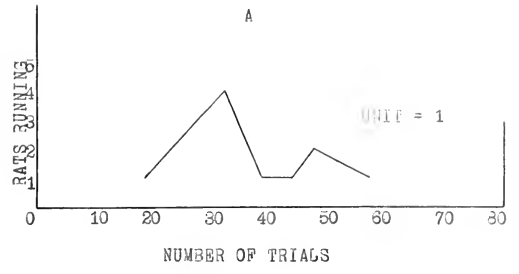
-:-

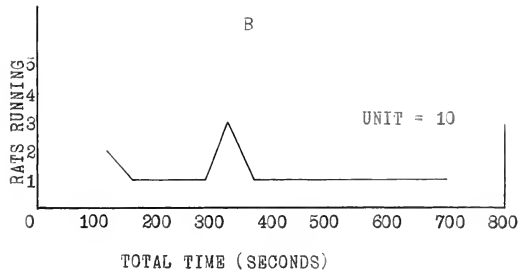
4 males - 6 females

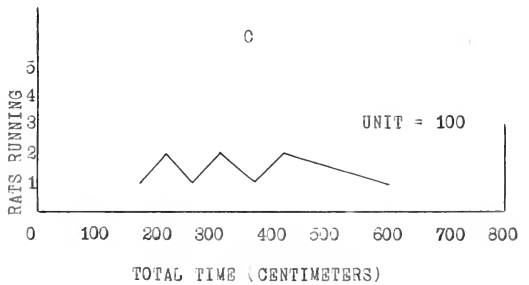
Rat	Trials	Trial Dev.	Time (secs)	Time Var.	Distance (cm)	Dist.Var.	Absolute T
♂							
6	32	6	1331.8	1994.0	20922.2	12666.4	16.2
9	43	- 5	7004.0	-3678.2	42167.8	-8579.2	7.6
10	18	20	6021.8	-2696.0	17280.0	16208.6	17.8
11	56	-18	2877.6	448.2	64167.4	-30578.8	5.4
♀							
1	47	- 9	3117.3	208.5	41450.4	- 8159.0	13.2
2	34	4	1570.2	1755.6	27381.6	5909.8	9.4
3	45	- 7	3763.8	- 438.0	37791.2	- 4499.8	10.5
4	38	0	3124.2	201.6	30559.6	2731.8	7.5
7	32	6	1005.2	2320.6	20577.0	12714.4	8.7
14	30	8	3443.0	- 117.2	30616.8	2674.6	11.7
Totals	375	83	33258.9	13857.9	332914.0	104822.4	108.0
Averages	38	8.3	3325.9	1385.8	33291.4	10482.2	10.8
Av. for ♂	38	12.0	4326.3	840.3	36134.3	17033.2	11.8
Av. for ♀	37	6.0	2670.6	2204.1	31396.1	6114.9	10.2

Fig. 7

FIVE HUNDRED DAY RATS







record but the lowest distance record, while the rat requiring the greatest number of trials (56) had a time record lower than the average, with the highest distance record. The highest time record was made by a rat which finished in forty-three trials, whose distance record was excelled by one other, the lowest, by one which finished in thirty-two trials with a distance record next to the lowest.

Group averages are:

Trials	Time Absolute	Total	Distance	Speed
38	10.8 sec.	554 min.	332.9 m.	10.6 cm. per sec.

Discussion of the curves seems hardly worth while in view of the small number of results on which they are based. The average number of trials lies between the two apices of the trial curve, (Fig. 7-A), the average amount of total time required, thirty-three hundred seconds agrees with the second maximum in the time curve, (Fig. 7-B), and the distance average lies at the middle one of the three maxima of the distance curve. (Fig. 7-C) Mean variations for the group are:

Trials.....8 ± 8.....31% variation

Time.....554 min. ± 239 min.....43% "

Distance.....332.9 m. ± 104.8 m.....31% "

The distance variation is seen to be considerably less than the time variation, and exactly the same as the trial variation.

The males appear to be inferior to the females as is shown by comparing the averages for the two sexes.

Trials	Time Absolute	Total	Distance
Males.....38	11.8 sec.	721 min.	361.3 m.
Females....37	10.2 "	445 "	313.9 "

Both time and distance variation for the males are more than for the females.

	Time Variation	Distance Variation
Males	367 min.	170.3 m.
Females	123 "	61.1 "

COMPARISON OF RESULTS OBTAINED FOR THE DIFFERENT AGES.

Table VII shows the general averages for each age as well as those for the males and females separately. Averages for the 500-day rats are omitted for reasons already given.

The number of trials required by the rats in order to learn the maze increases with age except in the case of the 300-day group where the average is very slightly below that of the 200-day group.

The 65-day males learned the problem in fewer trials than the 25-day ones but the females of the older group required more trials than those of the younger. There is rather a sharp dividing line between the young animals (25 and 65 days) and the old animals (200 and 300-days) the former acquiring the maze habit with considerably fewer trials than the latter.

The total time consumed in perfecting the habit also shows a regular increase with age except for the 65-day rats whose time record is slightly below that of the 25-day ones. The apparent superiority of the older group over the younger is attributable solely to the record made by the males, since the females at 65-days have a higher record than those at 25 days. Again we see that the two younger groups are quite distinct from the two older ones, requiring considerably less total time in which to learn the problem. The high average of the 300-day group is due in part to the large number of failures which occurred in early trials at that age, but is also partly attributable to their slower bodily movements.

Total distance shows a regular increase with increasing

TABLE VII
-:-

General Averages

Age	Trials	Time Absolute	Time Total	Distance	Speed
25 days:					
Males	32	5.7 sec.	213 min.	277.6 m.	21.6 cm. per second
Females	29	5.6 "	232 "	267.8 "	19.2 " " "
All	30	5.7 "	224 "	271.6 "	20.1 " " "
65 days:					
Males	27	7.1 "	192 "	228.3 "	19.8 " " "
Females	37	6.3 "	257 "	307.6 "	19.9 " " "
All	31	6.8 "	219 "	260.6 "	19.8 " " "
200 days:					
Males	39	9.7 "	263 "	296.3 "	19.5 " " "
Females	45	7.2 "	465 "	388.4 "	13.8 " " "
All	42	8.6 "	351 "	339.1 "	16.0 " " "
300 days:					
Males	40	11.5 "	734 "	344.3 "	7.8 " " "
Females	41	11.7 "	752 "	380.2 "	8.2 " " "
All	41	11.6 "	743 "	367.5 "	8.2 " " "

Mean Variations

25 days:				
Males		96 min.	79.6 m.	
Females		146 "	52.4 "	
All	55%	125 "	59.8 "	22%
65 days:				
Males		103 "	72.7 "	
Females		107 "	96.5 "	
All	48%	105 "	83.2 "	32%
200 days:				
Males		169 "	171.8 "	
Females		173 "	130. "	
All	48%	171 "	156.2 "	46%
300 days:				
Males		449 "	109 "	
Females		479 "	137.3 "	
All	63%	466 "	124.2 "	36%

age except for the 65-day group where again the lowering of the average is due to the superiority of males over those of the 25 day group, the females being superior in the 25 day group as compared with the 65 day group. The difference between the two younger groups and the two older ones is not so marked as that for trials or time but it is nevertheless apparent that the members of the latter covered more ground than those of the former. Yerkes found his older dancers somewhat superior to the younger ones in learning the labyrinth. The writer finds that the younger rats learn the maze in fewer trials, that their absolute time is less, their total time and distance are less, and that their speed is greater than in the case of the older rats. His ten month dancers were superior to those of one to two months while the 25 and 65 day rats of this experiment formed the maze habit more quickly than those 300 days old.

The speed (which it will be remembered is the average number of centimeters run per second throughout the learning process, no distinction being made between early and late trials) without exception decreases with increased age. The last group is distinctly slower than any other and this to our mind is again proof of the lessening of activity with age.

The absolute time, which we have taken as the indication of final efficiency, also diminishes with increasing age, and is considerably lower at 300 days than at any previous age. Thus, while at 25 days the average length of time required for the execution of a perfect run was 5.7 seconds, at 300 days the very best time in which the food could be reached was 11.6 seconds, more than twice the time of the youngest group. It follows that

in the formation of habits in which the factor of speed is of an importance equal to or greater than that of exactness, the older animals would be considerably handicapped. In the field of animal experimentation illustrations of habits where speed is an important factor are difficult to find. On the human side such an illustration might be had in the acquiring of technique in piano playing or voice culture, either of which demands the rapid succession of the muscular activities involved in rendering scales, arpeggios, trills, etc. It would seem that habits requiring extreme rapidity of excession within a prescribed rthym could not be learned by the older animals.

A comparison of the relation of distance to time in the younger and older groups is interesting. In the first two groups the distance is relatively high showing the excess activity displayed by the younger animals, in the 200-day group it is about the same as the time, indicating that excess activity is at a minimum, while in the last group it is much less than the time, showing that the effects of old age have begun to manifest themselves through a general slowing up of activity.

If the distance alone be taken as a measure of activity, our results agree with those of Slonaker who found the most active age to be between ten and twelve and a half months, since our 300-day rats covered more distance in learning the problem than any other group. If, however, distance be considered in relation to time, the older rats appear much less active than the younger ones, as is shown by the average high speed attain-

ed by the young in comparison with the old. Certainly the behavior of the old animals when in the maze is much more deliberate than that of the young ones, and the writer believes that if Slonaker had possessed some means of measuring the amount of activity per unit of time he would have found the young far more active than the old.

In Table VIII is given the average speed for each group for the 1st, 2nd and 10th trials, the two trials immediately preceding the last six, and the last six trials. The increase of speed from the first to the 2nd trial is considerable except in the 200-day group where there is a decided decrease. The gain from the 2nd to the 10th trial is great except for the 300-day group where it is comparatively small. From the tenth trial to the two preceding the last six the gain for the 200 and 300-day groups is greater than for the 25 or 65-day groups, and from these two trials to the last six trials the gain is again greater for the 300-day rats. This gives a slight indication as to where the most rapid learning occurs. A full set of tables showing the speed for every trial of each group would be necessary for an adequate discussion of the question, but from the present incomplete data it appears that the learning in the two younger groups is most rapid during the early stages, while for the older groups it is more rapid during the later trials. Especially is this true of the 300-day group, the increase in speed being very gradual during the first ten trials then more than doubling from the tenth to the two immediately preceding the last six. In general, speed, for the separate trials tabulated, decreased with age which accords with our

observation on the average speed for each group during the entire period of formation of the maze habit.

TABLE VIII
-:-

Speed - (cm. per sec).

Age	1st Trial	2nd Trial	10th Trial	2 preceding last six	Last Six
25 days	7.8	9.8	52.0	74.2	90.0
65 "	7.2	11.1	35.0	52.0	75.0
200 "	8.3	4.7	21.0	40.7	56.2
300 "	3.0	4.2	9.5	20.8	40.9

INCIDENTAL TESTS.
-:-

Although the primary object of this investigation was to determine the relation of age to rapidity of habit formation, several minor points of interest have been touched upon in the course of the experimentation which it may be well to mention.

Effect of Sex on Rapidity of Learning.

The ideal way in which to test this matter would be to have an equal number of males and females from each litter used, and at least twenty animals of each sex used at each age. In our work this was impossible, but the averages given in Table IX are in no instance based on less than eleven animals,

the number in each case being given.

TABLE IX.
-:-

Age	Trials	Time Absolute	Time Total	Distance	Speed
(11 Males	32	5.7 secs.	213 min.	277.1 m.	21.6 cm.per sec
25 Days) (16 Females	29	5.6 "	232 "	267.8 "	19.2 " " "
(16 Males	27	7.1 "	192 "	228.3 "	19.8 " " "
65 Days) (11 Females	37	6.3 "	257 "	307.6 "	19.9 " " "
(15 Males	39	9.7 "	263 "	296.3 "	19.5 " " "
200 Days) (13 Females	45	7.2 "	465 "	388.4 "	13.8 " " "
(13 Males	40	11.5 "	734 "	344.3 "	7.8 " " "
300 Days) (15 Females	41	11.7 "	752 "	380.2 "	8.2 " " "
(55 Males	35	8.2 "	351 "	286.5 "	17.2 " " "
Gen.Av.) (55 Females	38	7.7 "	427 "	336.0 "	15.3 " " "

MEAN VARIATION.
-:-

	Total Time	Total Distance
(		
25 days)	96 min.	79.6
(	146 "	52.4
65 Days(	103 "	72.7
)	107 "	96.5
200 Days(	169 "	171.8
)	173 "	190.6
300 Days(	449 "	109.0
)	479 "	137.3
Gen. Av.(	208 "	108.2
)	224 "	104.2

It maye be seen from the table that the males are at every age somewhat superior to the females in learning ability, their superiority being less marked in the young and old groups (25 and 300 days) than in the two intermediate groups (65 and 200 days). The general averages for an equal number of males and females show the males superior to the females in all points save one, that of absolute time. They finished in fewer trials, required less total time, and covered a smaller amount of distance in learning the problem than did the females, while their speed was slightly higher. This conclusion is at variance with that of Yerkes regarding the dancer, he having found the females superior to the males in learning the labyrinth. In the matter of final efficiency as evinced by the absolute time, the females are superior to the males at all ages except three hundred days when the two records are practically equal. The general average shows this to be the one point wherein the record for the females is better than that for the males.

The mean variation from the time average is less for the males at all ages, their distance variation is less at sixty-five and three hundred days. The general average shows the smallest time variation for the males and the smallest distance variation for the females. These results do not agree with those of Yerkes on the dancer. His ten month (300 day) dancers learned the labyrinth more rapidly, the number of trials required being the measure of learning, than those one to two months old (30-60 days) while there was no difference in the learning ability of the females at the two ages. My 25 and 65 day rats of both

sexes formed the maze habit considerably more rapidly than the 300 day animals.

The fact that in the number of trials, total time and total distance required to learn the problem, the males at 65 days are superior to those at 25 days while the reverse is true of the females, suggests the possibility that the capacity for habit formation develops earlier in the females than in the males.

Day and Night Work.

It has been stated by Slonaker and is generally believed that the albino rat is nocturnal. With a view to testing this matter certain rats in the twenty-five and two hundred day groups were run always in the day time, certain others always at night. The averages for the day and night rats were obtained in the same manner as the group averages, from Tables A and C.

The twenty-five day rats run during the day were numbers 1,3,4,5,6,15,16,17,19,20,21 and 24, seven of which were males and six females. Those run at night were numbers 8,9,10,11,12, 13 and 14, two males and five females. The averages which appear below in Table X seem to show the day rats slightly superior in distance and trials while the night rats consumed less time and had a slightly higher final efficiency. These differences are negligible, and there may be said to be no difference in learning at this age between the rats run in the day time and those run at night.

The day group of two hundred day rats consisted of two

males and four females numbers 18, 19, 20, 21, 23 and 24, while the night group included two males and four females numbered 6, 7, 8, 9, 10, 15 and 17. The averages show the night group to be superior to the day group in every respect save that of final efficiency. Nevertheless, we are inclined to hold to our previous statement that no difference is shown in learning ability, for the following reason; the general average for the females of this group was considerably higher than that for the males except in the matter of absolute time. In the day group there were only two males and four females. Were the number of males the same as the number of females it is our belief that the average would be considerably lowered and the day and night groups prove to have practically the same ability in learning the maze problem.

TABLE X.

-:-

AVERAGES

Trials	Time: Absolute	Total	Distance
25 days:			
Day.....29	5.5 sec.	207 min.	247.4 meters
Night.....31	5.4 "	159 "	261.6 "
200 days:			
Day.....41	6.2 "	461 "	373.5 "
Night.....34	7.2 "	325 "	267.9 "

Continuation of Work after the Problem has been Learned.

Another question which interested us was, what would be

the effect on efficiency if rats which had learned the problem were caused to continue their runs in the maze for a long period, i.e., would continued practise cause a marked increase in efficiency evinced by a lowering of the absolute time record, or had the highest possible level already been reached in the last six trials of the learning process?

To test the matter six rats of the sixty-five day group were kept at work for more than one hundred sixty trials after learning was complete, the average time for each six trials was computed and appears in Table XI as twenty-seven tests. Taken individually the results show that in every case a lower record than the absolute time record was made, but in no case maintained. If the group average be noted, the absolute time is never quite reached, the curve (Fig. 8) starting a little above it and continually rising. In other words, final efficiency decreases rather than increases when practice is continued. An interesting point is that errors will be made even after the problem is learned. Of the six rats used, three made errors in the first test of six trials after the problem was learned, one in the second test, and one not until the fifth test. Errors increased as the work was continued. During the last half of the one hundred sixty additional trials twice as many errors were made as in the first half.

A closer examination of the table shows: 1st, that the best record in each case was made during the first fourteen tests; 2nd, that the last test was better than the first in only one case (rat 15); 3rd, that rats fourteen and fifteen

TABLE XI.

-:-

Ab. T.	Rat 8 6.6	Rat 12 6.4	Rat 14 5.9	Rat 15 5.5	Rat 16 5.3	Rat 17 4.5
1	6.7	7.1	6.5 ee	5.1	5.3	4.3 e *
2	6.4 ♯	7.6	5.3 e ♯	4.8 e ♯	4.7 *	4.5
3	5.4 ♯	7.9 ee	4.8 ♯	4.8 e ♯	6.9 e	6.3 e
4	5.2 *	9.4 ee	6.1 e	4.1 *	9.1	6.0 e
5	6.7 e	17.6 eee	5.8 ♯	4.6 ♯	6.1	5.1
6	5.8	8.5	5.1 ♯	4.9 ♯	8.8	10.8 ee
7	7.2 e	6.8 e	5.8	7.8	6.2	4.8 ee
8	5.8	5.4 e *	5.0 e ♯	5.4 ♯	7.9 e	4.7
9	5.5 e ♯	6.4	5.0 ♯	6.4 e	6.1	4.3 ♯
10	8.2 eee	5.4 *	5.8 ♯	4.3 ♯	14.6 eeee 4.	4.7
11	5.2 *	6.1 e ♯	5.5 ♯	14.3 e	5.6 e	6.6 e
12	6.9 eeeee	5.5 ♯	4.6 ♯	4.7 ♯	6.5 e	4.9 e
13	6.7 e	5.7 e ♯	4.8 ♯	8.2 e	6.9 e	4.4 ♯
14	21.5 eee	7.2 e	5.2 ♯	8.1	6.2	4.7
Errors - -	15	13	5	5	9	8
15	6.8 ee	8.8	4.9 ♯	5.0 ♯	5.1 ♯	4.7
16	10.0 eee	6.7 e	5.7 e ♯	19.3 ee	8.4	5.4
17	14.1 eeee	6.2 ♯	4.7 e ♯	5.6 e	8.2 ee	5.1
18	6.9 ee	5.7 ♯	5.4 ♯	5.1 ♯	6.7	4.8
19	10.3 ee	9.9	5.2 ♯	5.5	7.3	5.4
20	5.9 e ♯	12.2	5.2 ♯	5.1 ♯	5.7	4.5
21	19.0 eeeee	7.5	5.8 ♯	7.7	22.0 e	8.6 ee
22	11.4 eeeee	9.3 e	8.8	5.6	24.3 eeee	7.6 eeee
23	6.5 e ♯	7.9 e	5.7 e ♯	12.2	14.5 e	19.9 eeee
24	10.1 eee	9.8 eee	6.4	7.1	16.1 eeeee	6.6 e
25	6.9 ee	12.9 ee	6.0	5.4 ♯	8.9 e	5.4
26	11.5 eeeee	6.0 ♯	5.4 e ♯	5.7	10.4 e	6.7 e
27	16.6 ee	8.8 ee	7.1	5.7	15.9 eeeeee	5.1
28	8.1	7.5	6.8 e	5.0 ♯	18.8 eeee	6.2
29					9.3 ee	
30					7.8	
Errors -	37	10	5	3	27	12

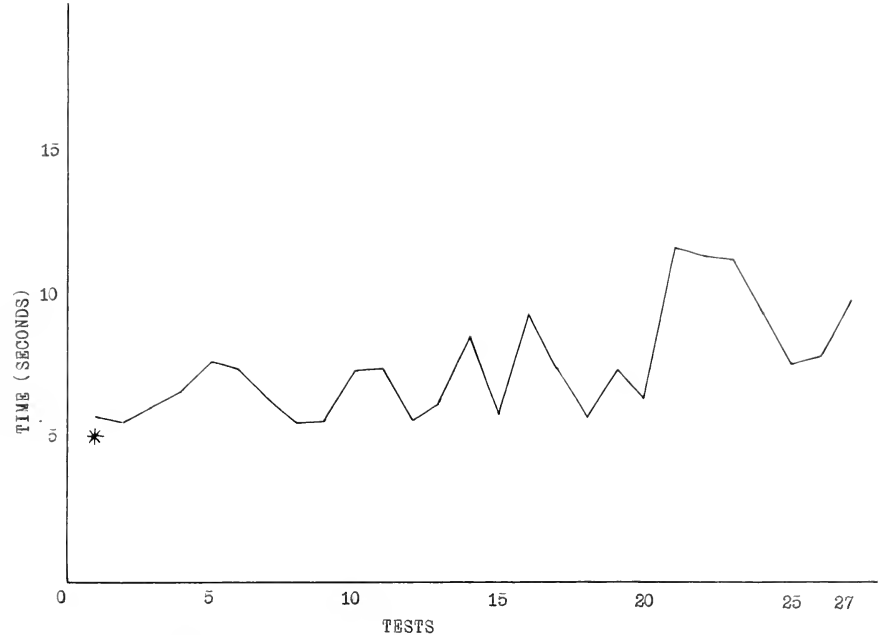
e = Error
* = lowest record for individual rats
♯ = lower record than absolute time value for certain rat.

The dotted line divides the table into first and second halves in order to make comparison of the two stages easier. The number of errors made by each rat in each half is shown.

Fig. 8

EFFECT OF TRIAL CONTINUATION ON TIME EFFICIENCY

OF SIX SIXTY-FIVE DAY RATS



Each point on the curve represents the average for 16 trials
167 trials shown here as 27

The asterisk (*) indicates the point of efficiency which had been reached in the learning proper, i.e., the last six trials of learning.

probably had not reached their efficiency level during the learning process, while the other rats had. This fact is deduced from the number of times each rat made a record lower than its absolute time record.

Rat 8.....	9	times	out	of	28
" 12.....	8	"	"	"	"
" 14.....21		"	"	"	"
" 15.....14		"	"	"	"
" 16.....	2	"	"	"	"
" 17.....	3	"	"	"	"

Blood Relationship and Learning.

It was found that the learning ability of certain members of a group could be predicted from the results obtained on other members of the same litter. The data appear in Table XII. Three rats from the Y(CF) litter were used when twenty-five days old, and five rats from the same litter worked when sixty-five days old. Two members of the G J litter learned the problem at twenty-five days, and one at sixty-five days. Two A L rats worked when twenty-five days old, and one when sixty-five days old. Four X L rats learned the problem at twenty-five days, three at sixty-five days and three at two hundred days.

The rats belonging to the Y(CF) litter required a smaller number of trials at 25 days than the average, but their absolute time, total time and total distance were above the average for rats of that age. At 65 days, rats of the same litter made averages higher than the group averages for that age except for the absolute time. The GJ rats twenty-five days old had a trial and distance record higher than that of the entire group while their absolute and total time was less. The same holds true for the GJ rats at 65 days except that their absolute time is higher. AL rats show records lower than the group averages in every case at 25 days but at 65 days all of the AL averages are higher than that for the group.

Rats from the XL litter which worked at 25 days made lower records than the average except in absolute time. The same is true of the 65 day members of the same litter and the 200 day

XL rats have a lower record than the group average in every particular.

In three out of four cases considered then, a high or low average at one age seems to indicate whether there will be a high or low average for the age or ages following.

It appears that it is possible within limits to predict the capacity for habit formation of rats of a certain litter at a given age, from the behavior of their blood relations at any other age.

TABLE XII.

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Litter	Age	Trials	Time Absolute	Total	Distance
YCF	(25 days	25	5.9 sec.	463 min.	290.1 meters
	)65 "	40	5.9 "	317 "	369.4 "
	(200 "	--	---	---	-----
GJ	(25 days	35	5.3 "	140 "	319.3 "
	(65 "	38	7.6 "	136 "	284.0 "
	)200 "	--	----	---	------
AL	(25 days	23	5.4 "	91 "	185.8 "
	)65 days	38	10.6 "	330 "	393.2 "
	(200 "	--	-----	----	------
XL	(25 days	34	5.4 "	180 "	252.5 "
	)65 "	24	8.3 "	152 "	195.3 "
	(200 "	29	7.8 "	258 "	254.4 "
Gen.Av.	(25 days	30	5.7 "	224 "	271.6 "
	)65 "	31	6.8 "	318 "	260.6 "
	(200 "	42	8.6 "	341 "	339.1 "

Retention.

A retention test was made on five individuals of the 65 day group who were caused to relearn the problem after 90 days. During this time they were fed daily in the maze except that at the 85th day the food supply was cut down, and on the 89th day no food at all was allowed. Probably a better plan would have been to feed the rats in the food box of the maze for a week preceding the retention test, using the same schedule employed in preliminary feeding, and keeping the food box carefully partitioned off from the rest of the maze.

Seventy-six percent of the original number of trials were required to relearn, forty-eight percent of the time necessary for learning was occupied in relearning, and fifty-two percent of the original amount of distance was covered. The absolute time when learning was 7.9 seconds, when relearning 9 seconds, this difference probably being due to the increased age, since the rats were approximately 200 days old at the time of the retention test and absolute time increases with age.

Nothing more is shown by the test on retention than that the interval between learning and relearning must be made very much smaller if it is desired to begin a problem with a view to determining the curve of retention.

The relation of time to distance in learning, and the matter of elimination of alleys in the maze have been discussed at length in papers already published.

TABLE XIII.

Learning

Rat	Trials	Ab. Time	Total Time	Distance
1	30	8.2 sec.	1327.4 sec.	23033.6 cm.
2	54	7.8 "	1651.8 sec.	42368.0 "
3	21	7.1 "	1542.0 "	25177.6 "
4	16	9.8 "	496.0 "	11603.2 "
5	22	6.5 "	2378.0 "	26675.2 "
Totals	143	39.5 "	7395.2 "	128857.6 "
Averages	29	7.9 "	1479.1 "	25771.5 "

Relearning (after 90 days)

Rat	Trials	Ab. Time	Total Time	Distance
1	14	7.7 sec.	316.4 sec.	7264.0 cm.
2	40	8.7 "	861.8 "	23321.6 "
3	14	9.2 "	484.4 "	9081.6 "
4	22	10.3 "	958.8 "	15562.6 "
5	18	9.3 "	902.6 "	11426.8 "
Totals	108	45.2 "	3524.0 "	66656.6 "
Averages	22	9.0 "	704.8 "	13331.3 "

RESUME OF CONCLUSIONS.

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1. Young rats learn the maze more rapidly than the old ones, the rapidity with which the habit may be formed decreasing with increase in age.

2. Absolute time, the time required for the execution of the perfect run, increases with increase in age, the oldest group requiring more than twice as much time as the youngest.

3. The most rapid stage of habit formation occurs earlier in the learning process of the younger animals than of the older ones.

4. In the very young rats (25 days)and the very old (300 days) sex differences are negligible, while among the animals of medium age (65 - 200 days) the males learned more rapidly than the females.

5. In general, the absolute time for the females is lower than that for the males suggesting greater efficiency on the part of the former in the execution of the habit when it had once been perfected.

6. Practically no difference in ability to form the maze habit is to be found between rats learning the problem in the day time and those learning at night.

7. Continued practice after the problem has been learned causes a break in the habit and does not result in an increase of final efficiency.

8. The rapidity with which the maze habit will be formed is predictable within certain limits from one family group

to another.

9. In the matter of elimination of errors, the outer alleys are usually those in which useless movements are last to drop out, but a 5-4-3-2 order does not hold, i.e., errors in 5 dropping out first, those in 4 second, etc. This bears directly on the question of the relation of the food to the learning process and seems to negate the pleasure-pain hypothesis, but no conclusive evidence has been obtained.

10. The importance of an adequate test on retention is made quite evident by these results.

If an analogy may be drawn between the learning ability of the rat and that of the human subject, it may be seen that in general the old can learn a given problem as well as the young although more effort is required to do so. The efficiency of this learning can only be measured by testing the retention ability. Should such tests show that the old animals forget very rapidly and must relearn the problem continually with little or no lessening of excess effort, comparing unfavorably with the younger ones in these respect, the above conclusions would have to be modified. If, however, the limits of retention in the groups are found to be very nearly the same, and the amount of effort necessary to relearn not greatly increased for the older group over that for the younger, the deductions would hold.

BIOGRAPHY.

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Helen B. Hubbert, the author of this dissertation was born at Lincoln, Illinois, June 11th, 1887. Her early education was received at the Preparatory Department of Cumberland University and in the Academy of Missouri Valley College. In 1904 she entered Missouri Valley College, Marshall, Missouri, from which she graduated in 1907 with the A.B. degree. In 1907-1908 she was a graduate student at the University of Pennsylvania. In 1908-9 she attended the Clarke Training School for Teachers, and from 1909 to 1912 was a teacher in the Pennsylvania Institution for the Deaf at Mt. Airy, Philadelphia, Pa. In the fall of 1912 she entered The Johns Hopkins University as a graduate student in Psychology, with Physiology and Psychopathology as subordinate subjects. She received a university scholarship in 1912-13, was Fellow in Psychology in 1913-14, and held the fellowship of the Baltimore Association to promote the University Education of Women in 1914-15.