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Effect of length of blind alleys on maze



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BEHAVIOR MONOGRAPHS

Volume 3, Number 4, 1917

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Edited by JOHN B. WATSON

The Johns Hopkins University

The Effect of Length of Blind Alleys on Maze Learning: An Experiment on Twenty-Four White Rats

BY

JOSEPH PETERSON



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THE EFFECT OF LENGTH OF BLIND ALLEYS ON MAZE LEARNING: AN EXPERIMENT ON TWENTY-FOUR WHITE RATS

THE GENERAL PROBLEM

"How far are pleasurable results able to burn in and render predominant the association which led to them? This is perhaps the greatest problem of both human and animal psychology." So wrote Thorndike in 1898. The problem is not yet solved. The problem arises from the fact, clearly pointed out by Thorndike, that "the connection thus stamped in is *not contemporaneous* [with], but *prior* to the pleasure."¹ "There is no pleasure along with the association. The pleasure does not come until after the association is done and gone."² This problem, though raised by Lloyd Morgan³ in connection with experiments on learning by the "trial and error" method, has received very little but theoretical attention from psychologists to the present time.⁴ Its importance for the education process, including the informal moral development by general social conditions, is certainly such as not to be overlooked. The dearth of experimentation

¹ Thorndike, E. L. *Psychol. Mon.*, Ser. No. 8, p. 103. After nineteen years of extensive work on certain phases of learning Professor J. B. Watson, who has himself taken a considerable part in this experimental work, says practically the same thing. In a review of Holt's *The Freudian Wish and Its Place in Ethics*, in which he considers a few artificial and inadequate illustrations of learning with but slight attention by the author to the neural processes involved, Watson says: "In these few experiences a genuine *learning process* is involved and the explanation of this learning process—regardless of whether the act is acquired in few or many trials—is what I consider one of the chief problems in psychology." *Jour. of Phil. Psychol.*, etc., 1917, 16., p. 89.

² *Ibid.*, p. 104.

³ *Introduction to Comparative Psychology*, 1894, Ch. 12. *E.g.*, on page 213 Morgan says: "The successful response is repeated because of the satisfaction it gives; the unsuccessful response fails to give satisfaction, and is not repeated."

⁴ See, *e.g.*, Smith, S. Limits of Educability in *Paramecium*. *Jour. Comp. Neurol. and Psychol.*, 1908, 18, 499-510. Meyer, Max, *The Fundamental Laws of Human Behavior*, 1911. Thorndike, E. L. *Animal Intelligence*, 1911, Ch. 4. Haggerty, M. E. The Laws of Learning. *Psychol. Rev.*, 1913, 20, 411-422. Carr, Harvey A. Principles of Selection in Animal Learning. *Ibid.*, 1914, 21, 157-165. Watson, J. B. *Behavior*, 1914, Ch. 7. Peterson, Jos. Completeness of Response as an Explanation Principle in Learning. *Psychol. Rev.*, 1916, 23, 153-162.

on the problem is likely due to the mind-body relations implied in the early form of its statement.

It is desirable to rescue any problem as to how learning goes on from mere theoretical discussions. Professor Watson has already attempted this for the problem in question, though not yet with marked success.⁵ Two groups of rats were allowed to solve individually a certain problem; in the one group each animal was fed immediately after the successful movements that brought it into the food box, while in the other group each rat was not allowed to take food for thirty seconds after entrance to the food box. No difference in the learning of the two groups was found. The experiment is regarded as only preliminary to a further study of the matter. Two criticisms may be offered on this experiment. In the first place, it is not on a wholly objective basis. As reported the experiment did not seem to be free from the assumption that the question at issue is whether the *pleasure of the eating* had a "stamping-in" effect, to use a term of Thorndike's, on the processes leading up to the eating. "Successful movements" seem to be regarded as movements bringing about this pleasure. If, in the second place, this is not the true meaning of the author, it may be suggested that the test of the effect of "successful movements" is not adequate, since precisely the same kind of acts was necessary for both groups of animals to get out of the situation presented by the problem. Experience with rats will certainly suggest that after an animal has once been fed in the food box it will for a time work energetically and learn to run the maze without further feeding of the kind, particularly if the odor is not carefully excluded. As the habit becomes partly fixed it is questionable whether the feeding, or even the smell of food, has very much to do with the energy that the animal displays. So far as the writer's own experience goes—though he has made no definite test of the matter—it appears that once the habit is well under way the animal will display great energy in the usual way as soon as placed into the entrance box; that the habit will unwind itself on the basis of the numerous other stimuli which have accompanied the process before. However, any criticism of Watson's experiment on the basis of his report of the preliminary

⁵ An abstract of the experiment, which was reported in the Chicago convention of the American Psychological Association, is printed in *Psychol. Bull.*, 1916, 13, p. 77.

procedure is unfair, and our only purpose here is to point out that there are real difficulties involved such as may give trouble to even an experienced behaviorist.

The problem must be conceived in some other way, and in terms of *stimulus and response* as Watson has rightly insisted.⁶ Elsewhere the writer has attempted a statement of the general problem in a form more acceptable for experimentation.⁷ The general thought in mind, whatever the degree of success of its statement may have been, was this: Response is never, in the case of *learning*, at least, a reaction to a *single stimulus*. The afferent impulse never begins at a given receptor as the result of stimulus by a single object and thence passes into motor channels from only one particular afferent fiber. The situation in all learning is vastly more complex. A complication of external stimuli is nearly always to be reckoned with; then again, the afferent impulses from these stimuli are greatly determined in their relative effects on response by impulses from the proprio- and the entero-ceptive systems; and, in addition, the responses resulting are to a large extent determined by the general conformation of the organism. Different forms of animals have different action systems, for example. The pleasantness or unpleasantness of an act is only an inner indication as to whether the response, forced by the complex inner organization (inherited and acquired) and the outer circumstances, or stimuli, is or is not in general harmony with the conformation of the organism. The question of explanation may resolve itself, then, wholly into one of the physical and physiological circumstances. It was then suggested that all such factors as recency, frequency, and intensity of stimuli, which may be conceived as involving only a single tract, are in themselves inadequate to account for learning. Indeed, they may serve in all cases outside of mere chance associative connections only as secondary aids to learning. In the usual cases certain stimuli and their immediate effects continue for a time and operate synchronously with others so that the response is a resultant of these various circumstances. It may tentatively tend this way and that, but will complete itself in the way that is on the whole most consistent, when everything is taken into

⁶ *Behavior*, p. 257.

⁷ Peterson, Jos. Completeness of Response as an Explanation Principle in Learning. *Psychol. Rev.*, 1916, 23, pp. 153-162.

consideration. The most complete response possible, in this sense,—the most consistent—has the advantage and will, other things equal, survive over others. The various tentative beginnings of acts this way and that, moreover, are not to be regarded as separate *acts*: they may easily, at a later juncture, be resolved into the “completest” act. Such conditions, it was maintained, must be taken into consideration to account for the selectiveness manifest in learning. This is a complex “principle” both to state and to test out in experiment; but the organism and the behavior of an animal are inconceivably complex, and over-simplification for the sake of clearness of conception and of explanation is often a positive disadvantage to progress in the biological sciences. Numerous evidences of this statement might be given.

The experiment reported in the following pages was planned in its main features when the article above referred to was written, and it is there suggested in the concluding paragraph. It was thought that varying the lengths of certain *cul de sacs* in identical mazes might show a difference in behavior not explicable on the basis of frequency, recency, and intensity of stimulation. If, for instance, a tendency to enter a short *cul de sac* is overcome with fewer errors in that particular case, or in fewer runs through the maze, than are required when the same *cul de sac* is lengthened somewhat, it would appear that some other explanation than that based on the principles named is necessary. On the basis of frequency and recency the animal would stand the same chance, on emerging from the blind alley, either of turning back toward the entrance of the maze, on the one hand, or of going toward the food box, on the other, that it would with the blind alley longer. This would certainly be true if acts are the individual and disparate affairs in trial and error processes that they are usually assumed to be, each being complete as a rule before the next is begun.

Watson says: “This factor (frequency) alone is probably sufficient to account for the maze habit. Apparently it is difficult to obtain any explanation based upon other factors.”^s

^s *Op. cit.*, pp. 267, 268. In a footnote he says: “If it happens by chance that any *cul de sac* is entered as frequently as any segment of the true pathway, it becomes as firmly fixed as the true segment.” I cannot understand what the warrant is for this statement. A careful tabulation of the detailed movements of some of my rats in the maze shows that it is altogether contrary to the actual facts. In records

After pointing out, successfully to the writer's mind, the difficulty in the way of Thorndike's principle of "satisfiers," he contends that there is no immediate connection backwards between the obtaining of food and the elimination of errors. Watson attempts on the basis of the probability doctrine, suggested in another relation by Stevenson Smith, to show how frequency alone may suffice in the acquiring of maze habits. He argues that an animal, having started along the maze path A, has an equal chance on coming to a *cul se sac* X, all other factors equal, either of taking B, the true path beyond the blind alley, or of going into X; that on returning from X, in case of the wrong choice having been made, it again has an equal chance of taking B. It thus has a probability of $3/4$ (or $1/2 + 1/2$ of $1/2$) of keeping the right path.

If no other factor than frequency operates in such a case we should expect an animal to continue entering the *cul de sacs* indefinitely; for on turning back from any point toward the starting place in the maze the same law must apply. The chances are again $1/2$ that any *cul de sac* passed will be entered, and $3/4$ that the animal will continue in its general direction, now toward the starting point in the maze. In a maze with several blind alleys, each of which has a chance of $1/4$ of turning any rat reaching it back toward the maze entrance, the probability would be very slim that the animal would at the first trial reach the food. The returns would therefore tend to fix the habit of entering *cul de sacs* as strongly as that of going toward the food. Mere probability explains truly enough how the animal gets to the food each time, but *that is not the problem of learning*; it does *not* explain how it happens that on the whole the second trial is better than the first, the third better than the second, and so on. Frequency based on probability does not bring such a result: *it fails utterly to explain learning*, even in the simple case of the maze.⁹ The real issue has been over-

picked at random, instances occur in numerous places of violations of the principle stated. A detailed presentation of these instances will be reserved for a later article, as proper attention to them here would lead us too far away from the main purpose of the present paper. Instances are very frequent when the animal takes certain blind alleys entirely contrary to the expectations based upon either frequency or recency or of both combined.

⁹ This statement is based on actual data of a supposed case of a rat in a maze of six *cul de sacs* whose "choice" at each bifurcation of the trail is determined by the flipping of a coin. After considerable data by this method has accumulated—after most any number of trials—it becomes very evident that if the frequency

looked as a rule. Watson does not try out his suggestion, or follow it far enough to get to the real difficulty. It is not easy, as Watson rightly admits,¹⁰ to see how the recency principle can help out the situation. No one has given more on this than the mere name. Both recency and frequency fail to explain learning as a gradual change in the way of doing something, involving the elimination of random acts. They do not show what controls an act, but only that *if it is controlled, or directed, alike each successive trial it will become easier and more rapid in performance.*

On the other hand, if different "acts" in a random trial and error process are only more or less tentative expressions of the one general act of getting food, for example, comparable to the out-reachings of the pseudopodia of the ameba, and if in all their changing forms these are related to the main performance by numerous in-going and out-going impulses, it would seem reasonable to suppose that errors of entering blind alleys would be overcome, other things equal, in something like a direct proportion to the length of the latter. This might be expected to hold within certain limits of length, at least. It is not at all implied in this view of learning, let it be clearly kept in mind, that any conscious states, whether or not they are present, are controlling or directing the animal. Indeed, it is just this view that we regard as unfruitful, and for which we are seeking a successful substitute. Instead of covering up the problem by assuming that the animal "perceives relations," or makes "practical judgments," or "has ideas," we are attempting to meet it squarely and to state schematically *how* the complexity of stimuli in the situation favoring learning can function so that the animal may "learn by results." There can be little question in fact that somehow the animal *does* learn by results. Our problem is to understand how and by what kind of results. Its solution would seem to have valuable bearings in the way of substituting for current erroneous "social forces" factors (including "pleasure and pain") used in explaining human conduct, in the absence of better conceptions.

(or the recency, or both) of running through any unit of the maze be the determining factor in subsequent choices the rat never would learn the maze. As the previous note states a similar tabulation of actual choices by an animal likewise shows the inadequacy of the principles in question.

¹⁰ *Op. cit.*, p. 269. The writer is working, however, with encouraging prospects upon a method of testing the influence of recency, and he is finding that influence much less potent than he had supposed.

THE EXPERIMENT

The experiment was carried out in the University of Chicago during the months of July and August, 1916.¹¹ Twenty-four white rats, ranging in ages from about five to six weeks at the time of the beginning of the experiment, were used. Of these, nine were males and fifteen females. These were at first divided into two main groups, the one consisting of the fifteen females and one small male¹² and the other of eight males. The first group began as untrained animals in the B-mazes, to be described, and the second in the A-mazes. They were ear-marked and grouped about eleven days before the experiment began, during which time they were habituated to handling, and were fed daily in the food box of the maze (in the separate groups) except a couple of days while the maze was out of the laboratory for remodeling. The food was bread soaked in milk, a definite quantity being given each day to insure uniformity of bodily conditions and of hunger. During the entire period of preparation and experimentation not a single rat showed any signs of illness. The two main groups were again divided into control groups, as will be explained later in "The General Schedule of Experiments." These sub-groups were caged separately for convenience of experimentation, but they were fed together daily in the food box of the maze throughout the time of the experiment and were also interchanged daily in the cages, *i. e.*, each sub-group was on any given day put into the cage occupied by its control group during the previous twenty-four hours. The purpose of these interchanges was to prevent the development of group odors.

Only one maze in the laboratory was available. This was,

¹¹ I desire to express my thanks here to Professors Angell and Carr for the privileges of the laboratory and for the animals used in the experiment. With the exception of aid from my brother, John C. Peterson, a graduate student in the University of Chicago, I am wholly responsible for the experiment, both as to problem and method. My brother helped me plan the modifications of the maze available, and to get started with the experiment, which help I gratefully acknowledge. We had planned to carry on the experiment together, but it was found after the second day of experimentation that one person could record all the movements satisfactorily and could secure greater uniformity in the conditions of the experiment than was possible to two.

¹² Through an oversight at the time of the segregation and ear-marking of the animals the small male, No. 10, was classed as a female. The error was noticed on the fourteenth day of the experiment, and after this time the rat was caged with the males, 5, 8, 1, and 7, but it continued to run the IB maze with the females. No difference from this change was noted in the behavior of the male or of any of the other animals. No. 10 did not continue with the females in any other maze, as will be seen in the schedule.

however, converted into two mazes as shown in figure I, by means of a rearrangement of the partitions. Both mazes have the same food box, and therefore only one of them can be used at any one time in experimentation. IB (figure I) is a maze with ten blind alleys, numbered from one to ten. The broken line from the entrance, E, indicates the correct path to the food. IA is another maze having but six *cul de sacs*, the entrance being at E'. This maze is shown in the figure in heavier outlines. Whenever the one maze was in use the entrance to the food box from the other was, of course, closed. The mazes were made of soft wood, and were stained black just before being used in the present experiment. The alleys were uniformly four by four inches in cross dimensions, and the partitions were approximately one-half inch thick. By means of a number of easily removable shutters, braced with triangular supports from behind, the *cul de sacs* could be shortened as desired for the purposes of the experiment. By this means each maze could be converted quickly into a maze of a slightly different type, having the same blind alleys but of relatively different lengths. These shutters were also of soft wood stained black and had the same cross dimensions as the alleys of the maze, so as to fit tightly. In the figure these shutters are indicated by dotted cross-lines in the blind alleys. Thus in Maze IB the blind alleys 2, 4, 6, and 9 are shortened so that the ten blind alleys together have a total length (about eleven feet) approximately equaling the ten in Maze IIB, of which 1, 3, 5, 7, 8 and 10 have been shortened as indicated.

Maze IA differs from Maze IIA on another principle: all the *cul de sacs* in the first are of full length, as indicated, while the second has them *all shortened*. In IA the total length of the blind alleys is about eight feet, while in IIA it is about four feet.

The mazes were supplied with glass covers, with wooden drop-shutters at the entrances and tin side-sliding shutters at the food box entrances. In the experiments each animal was first put into the food box and allowed to taste the food before the first run, or trial. This was not only to strengthen the incentive but also to insure uniformity in incentive and in handling of the animal in all trials. In presenting the animal to the entrance of the maze the experimenter was always seated, with the entrance slightly at his right.

The groupings of the animals made in the experimental procedure are clearly and concisely shown in the general schedule following, arranged according to the mazes used. Thus in Maze IB the first rats used are those called Group *Mu*, the *u* indicating that the animals were *untrained*. The rats of Group *St* were trained, as indicated by the *t*; *i. e.*, they had learned another maze. Frequent reference to figure I, in connection with the study of this schedule, will make clear which maze was in use for any group in question, and the exact modification of the blind alleys.

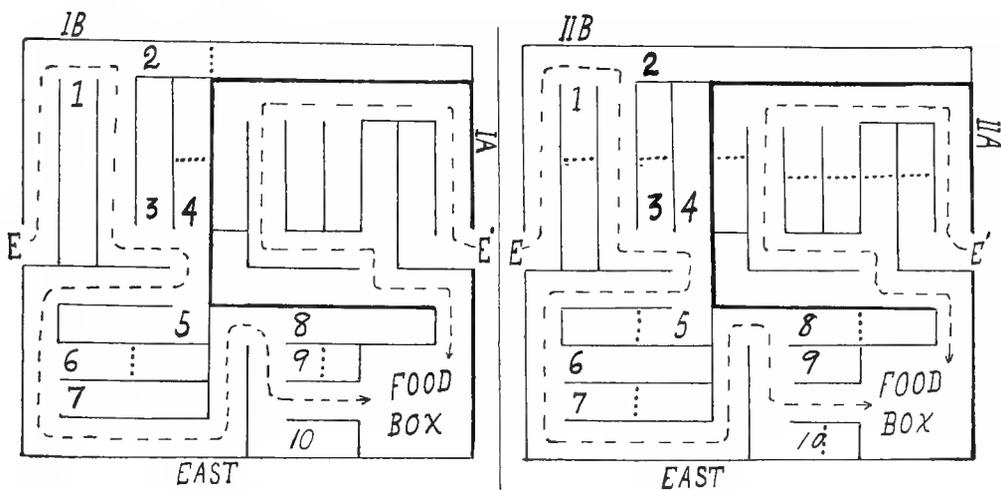


FIGURE I.—The four mazes used, IB, IIB, IA, and IIA. The heavy lines mark the division between the B- and the A-mazes. Dotted lines across blind alleys show position of the shutters. E and E' are the entrances to the mazes.

GENERAL SCHEDULE OF EXPERIMENTS

Rats used	Practice distributions
	MAZE IB
<i>Mu</i> Group.....7 females (9, 11, 12, 13, 14, 16, 18) and 1 male (10).	Two tests, or runs, daily for ten days, then four daily for three days, then three daily for each rat until eight runs out of ten were correct. (Rat 12 did not complete the habit in time available.)
<i>St</i> Group.....4 males (2, 3, 4, 6), trained on Maze IIA.	Three runs daily for three days, then an intermission for sixteen days (see explanation on next page), then by the intensive method the rats were run Aug. 29th and 30th each three times at the following periods of day: 9-9:20, 9:40-9:55, 3-3:15, 3:30-

3:40, and 8:30-8:40,—total runs, twenty-four for each rat. All records were left incomplete, but all rats were equally practiced to the point of discontinuance. All animals were eager and active.

MAZE IIB

Nu Group..... 8 females (15, 17, 19, 20, 21, 22, 23, 24).

Rat 20 was blind in left eye. Distribution of practices precisely same as for Group *Mu*, in Maze IB, same days.

Rt Group..... 4 males (1, 5, 7, 8) trained in IA.

Distributions of practice same as for *St*, Maze IB, same days, Practice periods, Aug. 29th and 30th: 9:25-9:35, 9:55-10:10. 3:15-3:30, 3:40-3:55, and 8:45-9. All records left incomplete; rats eager and active.

MAZE IA

Ru Group..... 4 males (1, 5, 7, 8).

Practice distributions same as for *Mu*, Maze IB.

Nt₁ Group..... 4 females (15, 20, 21, 22), trained on Maze IIB.

Three runs daily for each rat until habit was completed, eight runs of ten correct.

Mt₁ Group..... 3 females (9, 13, 14), trained on Maze IB.

By intensive method: the three animals were given three runs each, alternating with short periods of rest, during the forenoon of Aug. 28th. Rat 14 completed habit in twenty-eight runs, or trials; rat 9, in twenty-four runs; rat 13, in forty-one runs, eleven of which were made early the morning of the following day. All rats were eager and active, except 13 on the last run of first day, when it took sixteen seconds following two runs of two seconds each.

MAZE IIA

Su Group..... 4 males (4, 6, 3, 2).

Practice distributions same as for the *Ru* Group in Maze IA.

Nt₂ Group..... 4 females (17, 19, 23, 24), trained on Maze IIB.

Practice distributions same as for *Nt₁* in Maze IA.

Mt₂ Group..... 3 females (11, 16, 18), trained on Maze IB.

Practice distributions same as for *Mt₁*, and alternating after each three trials with them. Each rat completed the habit, getting eight out of ten runs correct, in a total of twelve runs. All were very active and eager throughout.

This schedule is given as actually carried out, not exactly as originally planned. It will be noted that the programs for the two B-mazes are precisely alike, and that the same is true of the A-mazes. This affords means of control of a number of factors which otherwise might favor one or the other of the control groups. Temperature conditions changed considerably; it was also necessary to modify occasionally, to suit the time at the disposal of the experimenter, the number of runs per day by each animal. At the early stages of the learning there was not enough time to give each animal more than two runs

daily. Later four runs daily were tried, but the eagerness of the animals seemed in one or two cases to diminish in the last run. Three runs a day proved to be very satisfactory. It was originally supposed that each rat could learn both one of the B- and one of the A-mazes during the time available for the experiment—July 18th to August 30th—but a difficulty arose, which had been underestimated in the planning. When the male rats had finished their more simple problems—the A-mazes—and were started on the B-maze problems, signs of trailing the females appeared. To prevent this possibility the male and the female groups of animals had been made to occupy the same cages alternately in successive days. It was impracticable to wash the maze thoroughly before each experiment for each group. The first day that the *St* and the *Rt* male rats were run in the B-mazes, after the runs of the females, there was no difficulty. On the second and the third day, however, there seemed to be evidences of trailing and of excitement, and some of the rats deposited urine drops in the maze from the second to the fifth blind alleys. This seemed to influence, as a guide, later members of the same groups (*i. e.*, also males), and to stimulate them to make similar deposits along the trail. Thorough washing of the entire maze with soap water and Creolin-Pearson, a disinfectant, did not change the behavior materially. Consequently, after the third day the practices of these males were discontinued for sixteen days, until the females had completed their problem. This experience with the males seemed in only one (questionable) case to influence in the least the runs of the females whose habits had been already reduced to the stage of proprioceptive control. The mazes, moreover, had been carefully washed after the second and the third day of the experience with the males already described.

The postponement of the experiment with the males in the B-mazes made it necessary to run them by the intensive method described in the schedule, if at all. It was found that if each rat was given three runs and then put back into the cage without feed it could again be run soon after with no loss of eagerness. In fact, the method worked surprisingly well. The fact that the records had nevertheless to be left incomplete on this maze so far as these rats were concerned does not affect the data so

far as they go, as the two comparable groups had identical experiences.

Since the A-mazes were cleared earlier than the B-mazes, it was possible to put into them, as indicated in the schedule, some of the females—four on each A-maze—which first completed their original problem.¹³ Finally,—leaving out the female 12, which did not complete its original problem until the maze was taken over for the males, and the small male 10, which had been running with the female group *Mu*—three females were practiced on each of the A-mazes by the intensive method. The results of these two groups are, for obvious reasons, strictly comparable only to the twelfth trial inclusive, when the rats in the IIA maze had completed their problem.

All comparable, or control groups were then run on the same days, the same number of times, and as nearly as possible the same time of day. Moreover, to give no possible advantage of trailing to either group—and aside from the cases noted, not between control groups, no such behavior was observed—the group which was practiced first one day was second the next.

Both time and error results were noted. The experimenter devised a system of short signs with which to record the complete gross behavior of each animal. Returns in the maze were noted as accurately as possible; only minor ones not reaching *cul de sacs* or corners of the various maze alleys before being corrected were left out of the records. Entrances into the blind alleys were all classified by means of appropriate signs, into three classes,—complete entrances, entrances about half way in, and beginning entrances bringing the animal's head and fore part into the blind alley while the hind feet remained in the true path. In the table of results these entrances constituting the last class are in the column headed "Start." It was also noted, as the animal emerged from the *cul de sac*, whether it continued forward toward the food or turned back toward the place of beginning. Hesitancies were also noted. Of these a peculiar and amusing kind was frequent. Occasionally, an

¹³ To be sure that the two groups were of approximately equal ability the animals composing them were selected as follows: The first, third, fifth, and seventh rats that completed Maze IIB were selected for Maze IA, with the long *cul de sacs*; and the second, fourth, sixth, and eighth were taken for Maze IIA. In case of any slight difference in the groups this would put the better animals into the more difficult maze, so that the better results expected for IIA could not be due to superior animals.

animal would stop quickly at the entrance to a blind alley while the head would vibrate very rapidly between the direction of the true path and that of the tempting by-way. The record here and there shows, for instance, that an animal would stop at *cul de sac* 1, after having nearly inhibited the tendency to enter this blind alley, and make, say, three double vibrations (3 v. d.) with the head. This behavior is very suggestive and will be considered later. On the whole it was found that the full description of the animal's behavior was much more valuable for the present problem than the mere recording of time and errors. Time records were, however, also kept.

TABLE I
GENERAL SUMMARY OF RESULTS IN THE B-MAZES

Blind alley		First									Second								
Degree		Compl.			Half			Start.			Compl.			Half			Start.		
Direction		E	R	F	E	R	F	E	R	F	E	R	F	E	R	F	E	R	F
Runs	Group																		
1- 2	Mu IB	19	10	9	2	0	2	12	4	8	33	19	14	9	3	6	6	3	3
	St IB	6	3	3				1		1	14	4	10				1	1	
	Nu IIB	18	9	9	3		3	5	3	2	28	19	9	10	4	6	1		1
	Rt IIB	4		4	1		1	1		1	7	3	4	1		1	1		1
1- 5	Mu IB	37	15	22	4		4	15	5	10	44	23	21	17	6	11	11	4	7
	St IB	12	4	8				2	1	1	16	4	12	1	1		4	1	3
	Nu IIB	27	15	12	10	2	8	7	3	4	41	27	14	18	4	14	2		2
	Rt IIB	8	3	5	6		6	6	1	5	9	4	4	3		3	1		1
6- 15	Mu	70	16	54	5	2	3	2		2	8	5	3	5		5	13		13
	St	30	4	26	4		4	7		7	5	1	4	2		2	8		8
	Nu	25	5	20	26	2	24	21		21	6	2	4	10	1	9	5	1	4
	Rt	4		4	6	1	5	30	3	27	5	3	2	3		2	6		6
16- 25	Mu	56	2	54	18	2	16	4		4	5	2	3	5	1	4	6		6
	St	12		12	15		15	7		7	1		1	4	1	3	5		5
	Nu	9	1	8	10		10	22	1	21	8	1	7	3		3	11	1	10
	Rt	3	2	1	3	1	2	7	1	6	7	6	1	10	3	7	3		3
26- 35	Mu	38	4	34	21		21	7		7	3		3	7		7	4		4
	Nu	4		4	4		4	10		10	5		5	10	1	9	10	1	9
36- 45	Mu	40	1	39	17	1	16	7		7	2	1	1	3		3	4		4
	Nu	1		1	2		2	8		8	1	1		7		7	16		16
46- 55	Mu	30		30	21		21	9		9	5	1	4	2		2	3		3
	Nu	1		1	4		4	6		6	2		2	5		5	7		7
56- 65	Mu	19		19	19		19	12		12	3		3	2		2	5		5
	Nu				1		1	1		1				1		1	4		4
66- 75	Mu	21		21	9	1	8	5		5	2		2	2		2	4	1	3
	Nu							1		1	1		1	1		1			
76- 85	Mu	9		9	9		9	7		7	2		2	2		2	4		4
	Nu							1		1									
86- 95	Mu	4		4	4	1	3				7		7						
	Nu																		
96-105	Mu	3		3	4		4				2		2						
	Nu																		
106-115	Mu	1		1	3		3	2		2	1		1	2		2			
	Nu																		
116-125	Mu										1		1	2		2			
	Nu																		
Totals IB		382	46	336	153	7	146	86	6	80	107	37	70	56	9	47	71	6	65
Totals IIB		82	26	56	72	6	66	120	9	111	85	41	44	71	10	61	65	3	62
Total number of entrances into <i>cul de sacs</i> , IB, 621																			234
Total number of entrances into <i>cul de sacs</i> , IIB, 275																			221

TABLE I—Continued
GENERAL SUMMARY OF RESULTS IN THE B-MAZES

Blind alley.....		Third						Fourth													
Degree.....		Compl.			Half			Start.			Compl.			Half			Start.				
Direction.....		E	R	F	E	R	F	E	R	F	E	R	F	E	R	F	E	R	F		
Runs 1- 2	Group																				
	Mu IB	10	4	6	5	0	5	10	3	7	23	8	15	4	3	1					
	St IB	6	2	4				5		5	5	3	2	2	2		7	2	5		
	Nu IIB	10	2	8	3	2	1	4	2	2	10	3	7	3		3	1		1		
	Rt IIB							3	1	2	4	2	2	4		4					
1- 5	Mu IB	16	5	11	6		6	12	3	9	30	10	20	6	4	2	4	1	3		
	St IB	7	2	5				6		6	8	3	5	2	2		7	2	5		
	Nu IIB	13	3	10	6	3	3	9	2	7	15	5	10	5		5	2		2		
	Rt IIB							4	1	3	4	2	2	6	1	5					
6- 15	Mu	2		2				2		2	1	1		1	1						
	St	2	1	1	1		1				2	2									
	Nu							1	1					3		3	2	1	1		
	Rt	2	1	1				1		1	5	3	2				2		2		
16- 25	Mu	2	1	1	1		1				1	1		2		2	1		1		
	St													1		1					
	Nu	1		1				1		1	2	1	1	5		5	2		2		
	Rt										3	1	2				2		2		
26- 35	Mu	1		1	1	1		3	2	1	1		1	1	1		2		2		
	Nu							1		1	1		1				3	1	2		
36- 45	Mu							2		2				1	1		1		1		
	Nu													1	1		2		2		
46- 55	Mu	5	3	2							3	1	2	2	1	1					
	Nu	1	1					1	1		1		1								
56- 65	Mu	1	1								3		3				1		1		
	Nu										1		1				1		1		
66- 75	Mu	1		1							1		1								
	Nu							1		1	1	1									
76 -85	Mu	1	1								2	1	1				2		2		
	Nu																				
86- 95	Mu	2		2							2	1	1								
	Nu																				
96-105	Mu				1	1															
	Nu																				
106-115	Mu																				
	Nu																				
116-125	Mu																				
	Nu																				
Totals IB.....				40	14	26	10	2	8	23	5	18	54	20	34	15	9	6	18	3	15
Totals IIB.....				17	4	13	6	3	3	21	5	16	33	13	20	20	2	18	16	2	14
Total number of entrances into <i>cul de sacs</i> , IB,											73			86							
Total number of entrances into <i>cul de sacs</i> , IIB,											44			69							

TABLE I—Continued
GENERAL SUMMARY OF RESULTS IN THE B-MAZES

Blind alley.....		Fifth									Sixth								
Degree.....		Compl.			Half			Start.			Compl.			Half			Start.		
Direction.....		E	R	F	E	R	F	E	R	F	E	R	F	E	R	F	E	R	F
Runs	Group																		
	1- 2 Mu IB	30	18	12	1		1	9	4	5	7	3	4				1	1	
	St IB	12	5	7				5	3	2	1		1				1		
	Nu IIB	21	8	13	1		1	4	2	2	5	5	4	4	2	2	4	1	3
Rt IIB	8	6	2				4	1	3	1		1							
1- 5 Mu IB	46	27	19	1		1	13	5	8	10	5	5	1		1	2	1	1	
	St IB	19	6	13				5	3	2	2	2	2	1	1	1	1		1
	Nu IIB	31	10	21	1		1	6	3	3	9	2	7	5	2	3	7	2	5
	Rt IIB	8	6	2	1		1	4	1	3	2		2	1		1	1		1
6- 15 Mu	5	2	3							5		5	4	1	3	4		4	
	St	6	2	4	5	1	4	3		3	1	1					2		2
	Nu	3	2	1	1		1	4	1	3	2	2	3	3		3	6		6
	Rt	4	2	2	2		2							1		1			
16- 25 Mu	3	2	1				1		1	1		1				3		3	
	St																		
	Nu	1		1				1		1				2		2			
Rt	2	1	1				1		1	1	1					1		1	
26- 35 Mu	7	5	2													1		1	
	Nu	2		2															
36- 45 Mu	2	1	1													1		1	
	Nu				1	1		1		1	1		1						
46- 55 Mu	4	2	2				1	1					1		1				
	Nu	1	1					1		1	1		1						
56- 65 Mu	3		3							1	1								
	Nu				1		1												
66- 75 Mu	1		1	2	1	1													
	Nu	1		1															
76- 85 Mu	2	1	1	1		1	2		2	1		1				1		1	
	Nu																		
86- 95 Mu	2	1	1							1		1							
	Nu																		
96-105 Mu																			
	Nu																		
106-115 Mu	1		1																
	Nu																		
116-125 Mu																			
	Nu																		
Totals IB.....	101	49	52	9	2	7	25	9	16	22	6	16	7	1	6	15	1	14	
Totals IIB.....	53	22	31	7	1	6	18	5	13	16	3	13	12	2	10	15	2	13	
Total number of entrances into <i>cul de sacs</i> , IB,		135															44		
Total number of entrances into <i>cul de sacs</i> , IIB,		78															43		

TABLE I—Continued
GENERAL SUMMARY OF RESULTS IN THE B-MAZES

Blind alley.....	Seventh									Eighth									
	Compl.			Half			Start.			Compl.			Half			Start.			
Degree.....	E	R	F	E	R	F	E	R	F	E	R	F	E	R	F	E	R	F	
Runs	1	1					2	1	1	13	7	6				1		1	
Group	2						1		1	3	3	3	1		1				
Mu IB	1	1					2	1	1	13	7	6				1		1	
St IB	1		1				1		1	3	3	3	1		1				
Nu IIB	3	1	2	1		1	3	2	1	14	3	11	1		1				
Rt IIB	1		1	1		1				3	3	3	2		2				
1- 5	3	1	2				3	1	2	19	9	10	2	2	1	1		1	
Mu IB	2	1	2				2	1	2	9	1	8	1	1	1	1		1	
St IB	6	1	5	3		3	3	2	1	18	4	14	2	2	1	2	1	1	
Nu IIB	2		2	1		1	3		3	5	5	5	2	2	1	2	1	1	
Rt IIB																			
6- 15	9	1	8	6		6	2		2	6		6				2		2	
Mu	2		2				2		2	2		2	2		2				
St	4		4	6		6	1	1		1		1				1		1	
Nu							1		1							1		1	
Rt																1		1	
16- 25	4		4	3		3	7		7	1		1	1		1	1		1	
Mu	2		2	1		1				1		1							
St							1		1	1		1							
Nu																			
Rt																			
26- 35	1		1	1		1	4		4				1		1	1		1	
Mu	1		1				3		3							1		1	
Nu																			
36- 45				2		2	3		3				1		1				
Mu							1		1				1		1				
Nu																			
46- 55	1	1		1		1				2	1	1				1		1	
Mu																			
Nu																			
56- 65																			
Mu																			
Nu																			
66- 75										1		1							
Mu																			
Nu																			
76- 85																			
Mu																			
Nu																			
86- 95										2		2							
Mu																			
Nu																			
96-105																			
Mu																			
Nu																			
106-115																			
Mu																			
Nu																			
116-125																			
Mu																			
Nu																			
Totals IB.....	22	3	19	13		13	23	1	22	42	11	31	8	8	6	6		6	
Totals IIB.....	15	1	14	11		11	13	3	10	26	4	22	5	5	6	6		6	
Total number of entrances into <i>cul de sacs</i> , IB,										58									
Total number of entrances into <i>cul de sacs</i> , IIB,										39									

TABLE I—Continued
GENERAL SUMMARY OF RESULTS IN THE B-MAZES

Blind alley	Ninth									Tenth										
	Compl.			Half			Start.			Compl.			Half			Start.				
Direction	E	R	F	E	R	F	E	R	F	E	R	F	E	R	F	E	R	F		
Runs 1- 2	Mu IB		5		5	2		2	1		1	7	2	5				1		1
	St IB		2	1	1							3		3				1		1
	Nu IIB		5		5	1	1		2		2	4	2	2						
	Rt IIB		3		3				1		1	2		2				1		1
1- 5	Mu IB		9		9	5		5	2		2	15	3	12				1		1
	St IB		4	1	3							5		5				1		1
	Nu IIB		14		14	4	1	3	2		2	7	2	5	2		2	1		1
	Rt IIB		5		5				4		4	3	1	2				1		1
6- 15	Mu								3		3	4		4	3		3			
	St		1		1							1		1						
	Nu		1		1	1		1	1		1	1	1		2		2	2		2
	Rt																	1	1	
16- 25	Mu					1		1	1		1	2		2						
	St																			
	Nu								2	1	1									
	Rt																	1		1
26- 35	Mu		1		1				2		2				1		1			
	Nu								2		2									
36- 45	Mu								1		1									
	Nu		1		1	1		1							1		1			
46- 55	Mu								1		1									
	Nu								1		1	1		1						
56- 65	Mu																			
	Nu																			
66- 75	Mu																			
	Nu																			
76- 85	Mu																			
	Nu																			
86- 95	Mu																	1		1
	Nu																			
96-105	Mu																			
	Nu																			
106-115	Mu																			
	Nu																			
116-125	Mu																			
	Nu																			
Totals IB	15	1	14	6		6	10		10	27	3	24	4		4	3		3		
Totals IIB	21		21	6	1	5	12	1	11	12	4	8	5		5	6	1	5		
Total number of entrances into <i>cul de sacs</i> , IB,										31										
Total number of entrances into <i>cul de sacs</i> , IIB,										39										

TABLE II
GENERAL SUMMARY OF RESULTS IN THE A-MAZES

Blind alley		First			Second									
Degree of entrance		Compl.	Half	Start.	Compl.			Half			Start.			
Direction		E	E	E	E	R	F	E	R	F	E	R	F	
Runs	Group													
		1- 2	IA	Ru	15	3	6	3	2	1	1	1	14	5	9
Nt ₁	10	1		2	5	1	5	3	2	1	3	1	2	
Mt ₁	1	1		1	1	1	1	1	1	1	1	1	1	1
Su	11	2		2	4	3	1	2	2	1	1	1	1	1
IIA	Nt ₂	5		2	2	2	2	2	1	1	1	1	1	1
	Mt ₂	2		1	1	1	1	1	1	1	1	2	2	2
1- 5	Ru	22	4	9	10	3	7	3	2	1	18	5	13	
		Nt ₁	13	4	4	8	2	6	4	2	2	3	1	2
		Mt ₁	3	1	1	9	6	3	1	1	1	1	1	1
		Su	30	3	2	10	6	4	4	3	1	5	5	5
		Nt ₂	8	4	2	2	2	2	2	2	2	3	3	3
		Mt ₂	3	3	1	1	1	1	1	1	1	1	1	1
6- 15	Ru	14	6	2	13	4	9	4	1	3	13	13	13	
		Nt ₁	3	2	2	2	1	1	3	1	2	4	1	3
		Mt ₁	5	2	1	10	6	4	3	3	3	2	2	2
		Su	2	4	3	2	1	1	4	4	4	3	3	3
		Nt ₂	2	1	2	2	2	2	2	2	2	2	1	1
		Mt ₂	2	1	1	1	1	1	1	1	1	1	1	1
16- 25	Ru	4	4		4	4		1		1	3		3	
		Nt ₁	1	1		1	1		1	1	3	1	2	
		Mt ₁		1					4	1	3	5		5
		Su		2							6	6		6
		Nt ₂												
		Mt ₂												
26- 35	Ru	3	4	1				1		1				
		Nt ₁							1		1			
		Mt ₁										1	1	
		Su		3	1	1	1					4	4	
36-45	Ru				2	1	1							
		Su												
46- 55	Ru							1	1					
		Su												
56- 65	Ru													
		Su												
Totals IA		68	29	20	59	28	31	27	9	18	51	8	43	
Totals IIA		45	20	9.	15	8	7	11	3	8	24	1	23	
Total number of entrances into <i>cul de sacs</i> , IA,		117												
Total number of entrances into <i>cul de sacs</i> , IIA,		74												
		137												
		50												

TABLE II—Continued

GENERAL SUMMARY OF RESULTS IN THE A-MAZES

Blind alley		Third									Fourth									
Degree of entrance		Compl.			Half			Start.			Compl.			Half			Start.			
Direction		E	R	F	E	R	F	E	R	F	E	R	F	E	R	F	E	R	F	
Runs 1-2	Group IA	Ru	4	1	3				6	3	3	12	8	4	2	2		7	5	2
		Nl ₁	3	1	2				2	1	1	15	9	6						
		Ml ₁	1	1		1		1	1		1	4	1	3						
	Group IIA	Su	2		2							3	1	2						
		Nl ₂	1		1				1		1	5	2	3	2	1	1	2		2
		Ml ₂	1		1				1		1							1		1
1-5	Ru	6	1	5				7	3	4	14	9	5	5	5		11	6	5	
	Nl ₁	6	2	4				3	1	2	18	9	9	3	1	2	3		3	
	Ml ₁	8	6	2	2		2	2		2	10	1	9	1	1		1		1	
	Su	7	3	4				2		2	12	6	6	3	1	2	5	1	4	
	Nl ₂	2		2	1		1	3		3	5	2	3	2	1	1	2		2	
	Ml ₂	1		1				1		1							2		2	
6-15	Ru	15	6	9	5		5	4		4	20	11	9	3	1	2	2		2	
	Nl ₁	7	2	5	5		5	4		4	6	1	5	1		1	6		6	
	Ml ₁	10	3	7	2		2	1		1	7	2	5	1		1	6		6	
	Su	6	3	3	6		6	1		1	8	3	5	4		4	8		8	
	Nl ₂	1		1				5		5	1		1	1		1	4	1	3	
	Ml ₂	1		1																
16-25	Ru	5	1	4	5		5	6		6	7	1	6	2	1	1	6		6	
	Nl ₁	3	2	1				1		1							6		6	
	Ml ₁	1	1		6		6	4	1	3	1	1		1	1		1		1	
	Su	1		1	5	1	4	10		10				2		2	4		4	
	Nl ₂							2		2				1		1				
	Ml ₂																			
26-35	Ru				3		3	4		4	4		4	1	1		3		3	
	Nl ₁																			
	Ml ₁				2		2	2	1	1				1		1				
	Su	5	3	2	1		1	8		8	1		1	4		4	6		6	
36-45	Ru	3	1	2	4		4	4		4				1		1	1		1	
	Su				1		1	1		1						8			8	
46-55	Ru				1		1	1		1	3		3	1		1	1		1	
	Su	1	1								1	1				3			3	
56-65	Ru																			
	Su													1		1				
Totals IA		64	25	39	35		35	43	6	37	90	35	55	21	11	10	47	6	41	
Totals IIA		25	10	15	14	1	13	33		33	28	12	16	18	2	16	42	2	40	
Total number of entrances into <i>cul de sacs</i> , IA,		142																		
Total number of entrances into <i>cul de sacs</i> , IIA,		72																		
		158																		
		88																		

TABLE II—Continued

GENERAL SUMMARY OF RESULTS IN THE A-MAZES

Blind alley		Fifth									Sixth								
Degree of entrance		Compl.			Half			Start.			Compl.			Half			Start.		
Direction		E	R	F	E	R	F	E	R	F	E	R	F	E	R	F	E	R	F
Runs 1- 2	Group IA { Ru Nt ₁ Mt ₁ Su Nt ₂ Mt ₂							4		4							3		3
								6	1	5	3	3							
	IIA { Su Nt ₂ Mt ₂	2		2	1		1	1		1	2	2					1		1
				2	2		2				2	2					1		1
1- 5	Ru Nt ₁ Mt ₁ Su Nt ₂ Mt ₂							10		10	1	1	1	1	1	4		4	
								9	2	7	4	4							
		3		3	6		6	2		2	1	1	8	8					
				2	2		2			2	2	2					1	1	
																1		1	
6-15	Ru Nt ₁ Mt ₁ Su Nt ₂ Mt ₂	3		3	3		3	4		4	4	4					1	1	
		1		1				1		1									
		4		4	2	1	1	2	1	1	3	2	1						
		1		1							1	1							
16-25	Ru Nt ₁ Mt ₁ Su Nt ₂ Mt ₂				1		1	1		1									
26-35	Ru Nt ₁ Mt ₁ Su	1		1							1	1					1	1	
36-45	Ru Su							1		1									
46-55	Ru Su	1		1															
		1		1				1		1							1	1	
56-65	Ru Su																		
Totals IA		6		6	4		4	26	2	24	11	11		1	1	6		6	
Totals IIA		9		9	10	1	9	5	1	4	14	3	11			3		3	
Total number of entrances into <i>cul de sacs</i> , IA,																	36		
Total number of entrances into <i>cul de sacs</i> , IIA,																	24		
																	18		
																	17		

RESULTS

Tables I and II give in a condensed form the main results of the entire experiment. In the separate larger divisions are given the reactions to the several blind alleys. These reactions are classified in a manner most easily made clear by taking up a concrete case. In table I the words "First," "Second," etc. at the top stand for the blind alleys of the B-mazes of the corresponding numbers. The results of the first blind alley, for example, are then divided into three parts, "Complete," "Half," and "Start," meant to designate the degree of entrance by the rats into the blind alleys, as already explained. Complete entrance means going entirely to the end of the blind alley, or so near the end that the animal might reach the end by means of the vibrissae. Frequently the rats ran against the end with considerable force. Half entrance means approximately half way, or all entrances between complete and beginning. Those marked "Start" include cases in which the animal either just put the head in or entered with the fore half of the body. In such cases the hind feet of the animal usually remained in the true path, so that the general orientation was not completely given up as in the other two cases. The three columns coming again under each of these rubrics show respectively, the number of entrances into the blind alley in question, E, the number of returns toward the place of starting in the maze on the rats' emerging from the blind alley, R, and the number of times the animals kept the general orientation, *i. e.*, continued toward the food box, F. The totals for R and F must therefore equal the number under E.

The figures in the left column of the table indicate the number of the run, or of the test, of the animals, while the letters *Mu*, *St*, etc. stand for the group, as Group *M* untrained, Group *S* trained, and so on. The description of each group and of its practice distributions are given in detail in the schedule, pages 9 and 10, to which frequent reference is advisable. Now, to illustrate in a concrete case, in the first line of the data, giving results of the first two trials of the animals, we find that Group *Mu* (eight rats, untrained, running in Maze IB) made nineteen complete entrances into the blind alley No. 1, with ten returns and nine cases in which the rat continued forward toward the food box. There were two entrances half way, with two forward runs and no returns; thirteen beginning entrances, with four

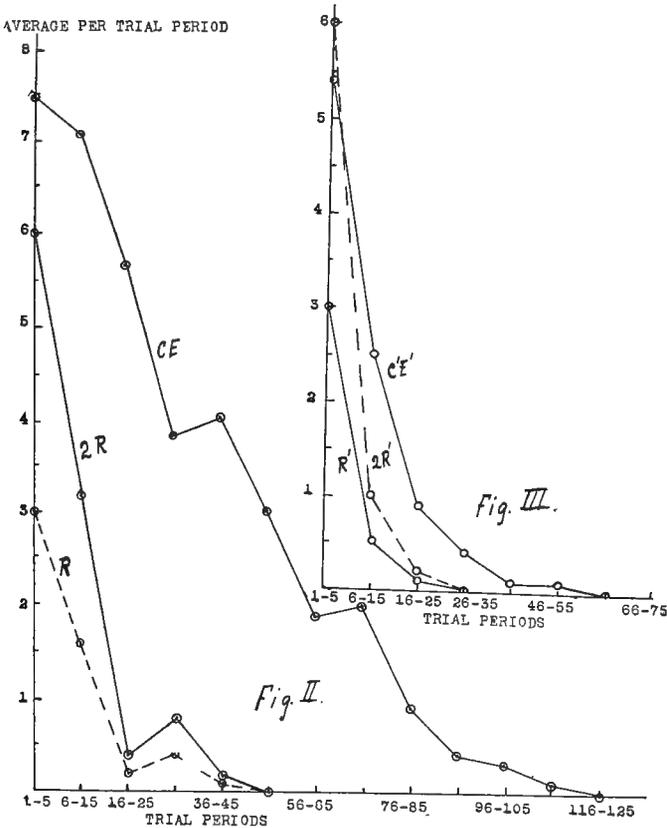
returns and eight cases of the animal keeping its general forward orientation; and so on, through the results for all the blind alleys in order.

Note that the figures for groups *Mu* and *St* are in bold face for blind alley 1, and not for 2, and that these relations are just reversed for the groups of animals running in Maze IIB. The bold face designates full length *cul de sacs*, and the figures not in bold face indicate that the blind alley was shortened. The amount of shortening in any case is shown in figure I, as already explained. Careful attention to all these matters will greatly aid the reader in getting quickly and conveniently the general results of numerous reactions. Without such attention the tables are meaningless. The results cannot so well be effectively and accurately shown in graphs.

The totals at the foot of the columns must not be taken too seriously, as will be evident in subsequent discussion. These are totals only of *changing* comparative quantities. For this reason the results of the experiments have been classified for different periods of the training. The results of the first two trials are given separately—and are not added in the totals because they are again included in the data for the 1st to 5th trials—as they are least affected by the animals progressive training. They show us approximately whether mere chance, or probability laws, can explain the direction that an animal beginning in the maze takes on emerging from a *cul de sac*, whether it returns or continues forward keeping its general orientation,—not accurately, however, for learning begins from the very first experiences in the maze. The progression of the learning in the case of each particular *cul de sac* is shown by a gradual decrease in entrances in the summaries of the 1st to 5th, the 6th to 15th, 16th to 25th, etc. trials; also by the gradual decrease in returns and the increase, correspondingly, in the number of cases of keeping the general forward orientation. These two kinds of changes are very interesting and illuminating toward showing, in a manner not hitherto done with data on learning, just *how* the *cul de sacs* are eventually eliminated.¹⁴ This is our main concern in this paper.

¹⁴ Professor Carr has pointed out that the *extent* of entrance to *cul de sacs* gradually decreases, as well as the *number* of entrances. (Hicks, V. C., and Carr, H. A. Human Reactions in a Maze. *Jour. Animal Behav.*, 1912, 2, 98-125. See particularly page 116.)

Three important features of the results are to be noted. The first is the rapid decrease in the proportion of the returns to forward runs, on the rat's emergence from blind alleys. With the exception of blind alleys 2 and 5 in the B-mazes few such returns were made after the 15th trial, though the animals continued to enter some of the blind alleys beyond the 75th, some even beyond the 100th. These *cul de sacs*, noted as



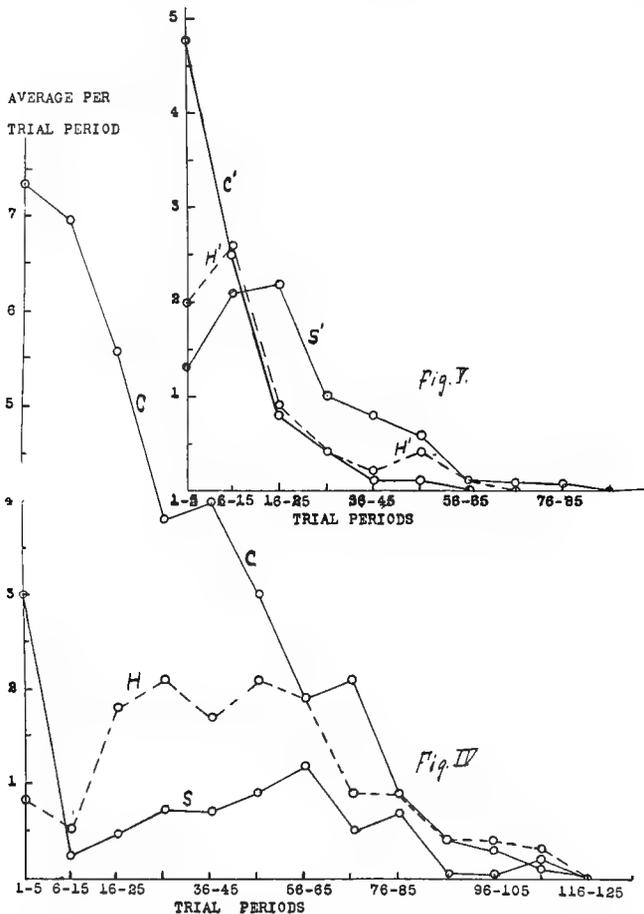
FIGURES II AND III.—CE is the curve of decrease in average number of complete entrances per trial to Blind Alley 1 full length, Maze IB; R indicates the decrease in returns, and 2R twice the returns, from this *cul de sac*. C'E', R' and 2R' show corresponding data for Blind Alley 1 shortened, Maze IIB. Eight untrained rats in each case.

exceptions, have directions such as to favor returns in the case of a rat emerging from them. This more rapid decrease in returns than in entrances to *cul de sacs* is least complicated, and also shown most emphatically, in the case of the complete entrances to *cul de sac 1*, which is encountered before the rat could be confused by running into any other blind alleys. Figure II shows the matter graphically. Curve CE represents the number of complete entrances of eight untrained rats to the first blind alley at full length, as in Maze IB; curve R, the returns; and 2R, twice the returns. 2R is a better curve for comparison with CE because originally, *i. e.* before an animal is at all practiced, about half of the entrances are followed by returns; twice the returns, therefore, gives a number initially about equal to the total number of entrances. Figure III gives corresponding curves, C'E', and 2R', respectively, for the same number (eight) of untrained rats in *cul de sac 1*, shortened from 22 inches to 8.5 inches. Here the same result is evident: while the elimination of entrances is far more rapid than in the case of the longer blind alley, the returns are still more rapidly reduced as shown by the 2R' curve.

It may also be noted here under our first point that the returns in both the B-mazes persisted longer in the cases of the blind alleys farther from the food box than of those near it. That is, returns from blind alleys first encountered were less easily eliminated, as were also entrances, than from those further along the true path. This is true even in cases of blind alleys nearer the food box that were comparatively long, as **7** and **8**, even though, as in the case of **8**, the direction of movement in emerging from the *cul de sac* favored returns. It is barely possible that an odor factor may have entered in case of **8**. The mazes IA and IIA are not so well adapted to show these relationships, as there are fewer blind alleys of various individual differences of complexity, but the same conclusions as those given for the B-mazes may also be made for them.

A second important point to note is, that the *nature of the response* to a blind alley gradually changes with practice, as well as the relative number of entrances into it. This change in the nature of the response is more marked in longer than in shorter blind alleys, particularly in those whose elimination was most difficult. It is illustrated best in the data from *cul de sac*

1 of Maze IB. Many of the entrances to 2, as the observation of the animals in their responses and also their individual records showed, are clearly due to confusions resulting from entrances to 1. The experimental notes supply many evidences. As a rule the rat in the early stages of response to such a blind alley runs rapidly into it the entire distance, usually coming into



FIGURES IV AND V.—C shows decrease in average number of complete entrances per trial to Blind Alley 1 full length in the B-mazes; H same for half-way entrances, and S for beginning entrances. C', H', and S' show corresponding results for the blind alley shortened. Eight untrained rats in each case.

contact one way or another with the end; but with succeeding trials the entrance is less and less complete, until finally the impulse to enter is wholly inhibited. Thus in the records of responses of two groups each of eight untrained rats to the first blind alley in the B-mazes (table I) the large numbers in the E-columns shift gradually from the "Complete" through the "Half" to the "Start" column. This shift is graphically shown in figure IV and figure V for first blind alley of mazes IB and IIB, respectively. C and C' are the curves representing the rate of elimination of complete entrances, H and H' of half entrances, and S and S' of beginning entrances. Note that while the C-curves fall rapidly from the first, especially the one (C') from the shortened *cul de sac*, there is a decided rise in the H- and the S-curves. Specifically, in the case of Maze IB (the *cul de sac* long), C falls gradually, with two minor exceptions, all the way at a nearly uniform rate; H rises almost uniformly to the 35th trial, then it keeps almost a uniform height to the 65th trial, and finally gradually declines; and S, after a rapid initial decline, gradually rises again until the 65th trial is reached, when it gradually declines and reaches zero before the other two curves. In the case of Maze IIB (*cul de sac* shortened) the same relationship between these respective curves is shown, though all these curves drop earlier in the process than with the longer blind alley, except that in this case the S' curve holds out longer than either of the other curves. A cursory examination of the data for other blind alley records shows that this type of transition from complete to only partial entrance and then to final elimination is a general feature of the results for the different groups of animals in the various mazes. A few exceptions only, in cases of very short *cul de sacs*, are noticeable. This is a phenomenon of learning in the maze to which little attention has previously been given, and which seems to the writer to be inexplicable on the basis of mere frequency and recency laws. Several impulses working together, some facilitating others inhibiting one another, gradually result in the survival of the most consistent, or complete acts. No hesitations in the rats' behavior in these cases were present, such as might be secured from persons in similar circumstances. The rats evidently did not have time, nor adequate sense organs and conscious memories as a person would have, to recognize

and take note of external stimuli, but resembled automatic machines in the quickness and uniformity of their responses.

This change appears more significantly in the results of most of the individuals than in those of all averaged. Here are some examples. Rat 18, of Group *Mu* made entrances to the first blind alley (full length) in this order: 12c (complete), 1h (half), 1c, 1h, 5c, 1s (started), 4c, 1h, 2c, 1h, 5c, 1h, 4c, 1h, 1c, 4h, 2c, 3h, 3s, 1c, 1h (total 55 entrances). Rat 10's record, same group, is 1s, 1c, 1h, 9c, 1h, 7c, 2h, 3c, 1h, 1c, 2h, 1s, 2c, 1s, 2c, 1h, 1s, 1c, 1h, 2c, 1h, 1c, 1h, 1c, 1h, 1c, 3h, 1s, 1c; the next time on passing this *cul de sac* there was a momentary pause with three very rapid in and forward vibrations of the head, causing a confusion in which the animal made eleven errors in the other nine *cul de sacs* none of which it had entered, with but one exception, for twelve trials; then 1s, 2c, 1s, 2c (after another such vibrating pause before the *cul de sac*), 2s, 1c, 1h, 1s, 2c, 1h, 1c, 1h, 1c, 1s (total 70 entrances). These results are typical. In numerous cases when the habit of avoiding the *cul de sac* was nearly complete, so that the animal usually made the "s" type of entrance, the peculiar rapid vibration of the head noted above took place. The pause was, however, but for an instant. This response seems to indicate that the impulse to go forward at the critical place is still partly checked or impeded by one to enter, not quite eliminated. It is important to note, moreover, that when finally the rat *does* succeed in passing the *cul de sac*, even when this hesitant, vibrating behavior does not take place, it very frequently runs headlong into some neighboring *cul de sac* which had long since been inhibited, and thereby gets considerably confused. Frequently, after such an experience it makes a complete entrance into the *cul de sac* in question the next trial, just as a child "speaking a piece" must bow again and start over when she goes wrong. This is one reason why a few complete entrances continue to occur. More than once an animal which had successfully passed *cul de sac 1* for several trials would, without any hesitancy, run into it with great speed and against the closed end with terrific impact. In one such case the animal's whole maze habit, just on the finishing stage, seemed to have been temporarily jolted wholly out of gear, its next trial being much like that of a beginner. All this makes it very plain that maze habits are not to be explained on the

basis of individual, disparate "acts," following in their occurrence some law of chance. On the contrary, the various impulses in the random activity of the early trials are gradually and collectively woven into one matrix of successive responses, each setting off the next succeeding one, and all shaped by the whole

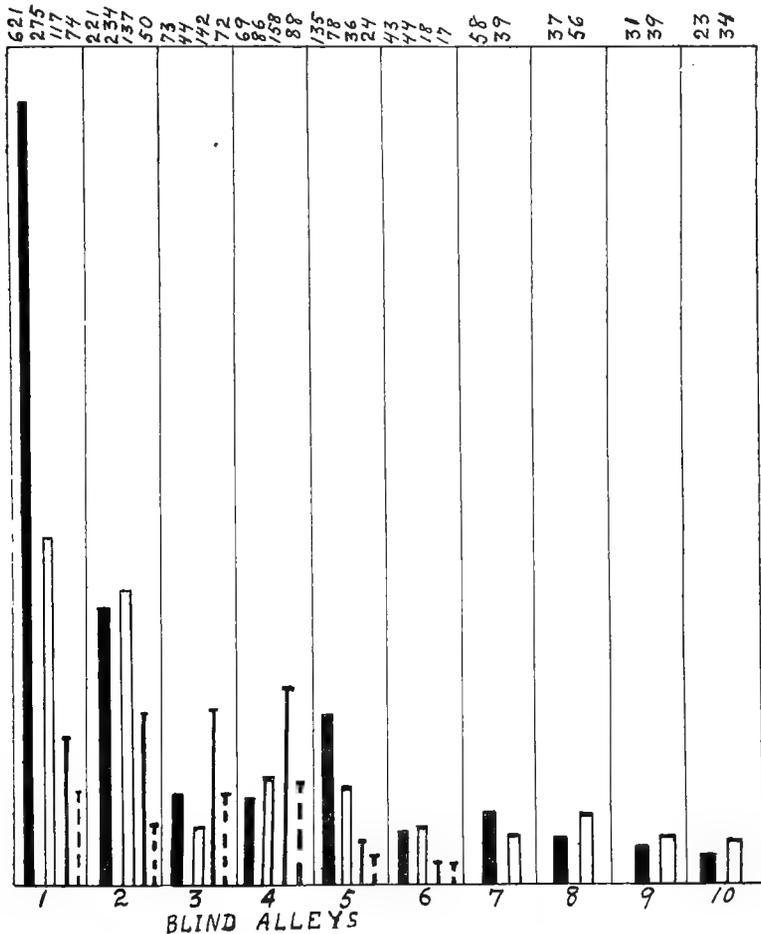


FIGURE VI.—Heavy columns, double lines, single lines, and discontinuous lines show, respectively, total entrances by all animals to full length and shortened blind alleys in the B-mazes, and to full length and shortened blind alleys in the A-mazes. Figures above columns give the totals represented.

circumstance of the maze environment.¹⁵ This seems to imply that the effect of one stimulus holds over into and conditions effects of later stimuli.

The third point to note in our results is that when any given *cul de sac* is shortened it is eliminated more readily than when left at full length. That is to say, other things equal, and within certain limits, a long *cul de sac* is eliminated less readily than a short one. This statement is amply borne out in our data both from the A- and the B-mazes. The general results of all our experiments are shown roughly in the accompanying diagram, figure VI, representing the total number of entrances to each of the blind alleys in the various mazes. The heavy black columns and the double lines represent the totals for the full length and the shortened blind alleys, respectively, in the B-mazes; the single continuous and the broken lines stand for the corresponding totals for the A-maze blind alleys. In the B-mazes the total entrances to the full length *cul de sacs* is 1311, while the total number of entrances to the same *cul de sacs* when shortened, by an equal number of animals under the same conditions, is 929, a decrease of 29%. This decrease would doubtless be considerably greater but for the fact that confusions by the long blind alleys resulted in random behavior which increased the totals for the shortened *cul de sacs*. For instance, table I shows that more entrances were made into **2** short than into **2** full length. This was very clearly due to the fact that as long as the habit to avoid **1** was incomplete the animals in the confusion also entered **2**. It will be recalled that in the A-mazes the *cul de sacs* were all full length in the one and all shortened to about half their length in the other case. Here we do not have the confusion noted in the B-mazes. The shortened blind alleys were entered 47% fewer times than those of full length. This bears out the conclusions drawn from the B-mazes.

The effect of shortening the *cul de sacs* was most noticeable in the case of **1** in the B-mazes, which was by all means the most difficult to eliminate. Being the first to encounter, it was

¹⁵ On this point our results agree with some aspects of those by Peckstein, L. A. Whole vs. Part Methods in Motor Learning: a comparative Study. *Psych. Mon.*, Ser. No. 99, 1917. "Each aspect of the course is no doubt associated with and located in reference to all the details of the course and to the entire objective environment as well." P. 30.

likely the least complicated by the results of entering other blind alleys. Table III and figure VII show comparatively the rate of elimination of all entrances to this *cul de sac* full length and shortened, 22 and 8.5 inches respectively, by the two groups of rats, *Mu* and *Nu*. While the two curves start near together the one, *S*, representing the entrances to the shortened *cul de sac* drops rapidly after the 15th trial; the other one, *L*, after the initial decline keeps nearly the same height to the 55th trial. The percentage eliminations are shown for the long and for the shortened *cul de sac*, respectively, by curves *E* and *E'*.

TABLE III
ELIMINATION OF ALL ENTRANCES TO BLIND ALLEY 1. TWO GROUPS OF
EIGHT RATS EACH. MAZES IB AND IIB

Trials.....	1-2	1-5	6-15	16-25	26-35	36-45	46-55
Av. No. of entrances to blind alley 1, long...	16.5	11.1	7.7	7.8	6.6	6.4	6.0
Per cent.....	100.0	67.3	46.6	47.3	40.0	38.8	36.4
Av. No. of entrances to blind alley 1, short'd.	13.0	8.8	7.2	4.1	1.8	1.1	1.1
Per cent.....	100.0	67.7	55.4	30.8	13.8	8.5	8.5

TABLE III—Continued
ELIMINATION OF ALL ENTRANCES TO BLIND ALLEY 1. TWO GROUPS OF
EIGHT RATS EACH. MAZES IB AND IIB

Trials.....	56-65	66-75	76-85	86-95	96-105	106-115	116-125
Av. No. of entrances to blind alley 1, long...	5.0	3.5	2.5	.8	.6	.6	0
Per cent.....	30.3	21.2	15.2	4.8	3.6	3.6	0
Av. No. of entrances to blind alley, 1 short'd.	.2	.1	.1	0	0	0	0
Per cent.....	1.2	.8	.8	0	0	0	0

The results from *cul de sac 2* are 221 entrances to the full length (40 inches) and 234 to the shortened form. This would appear to contradict our general conclusion. However, it must be remembered that the rats for which *2* was shortened made

346 more entrances to **1** (long) than did the control animals for which **2** was left full length; they also made 18 more returns to the starting place in the maze. This not only required that **2** shortened be passed more times than **2** long, but also with greater probability of entrance for each time. It was noted that rats entering **1** were likely thereby to be thrown out of

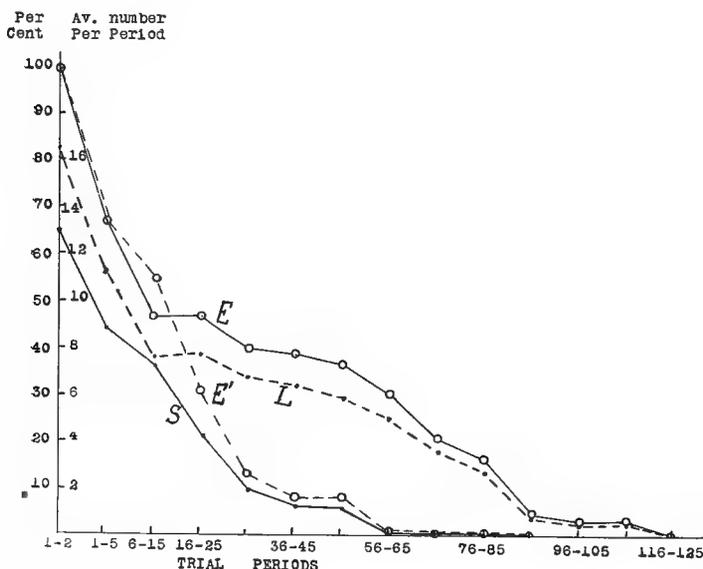


FIGURE VII.—L shows rate of elimination of all entrances to *cul de sac 1* long, Maze IB, and S same for **1** short, Maze IIB. E' and E show corresponding percentage eliminations.

orientation and to make other errors. There can therefore be little doubt that if **2** had been the only blind alley in the maze, it would have formed no exception to the general rule. The greater number of entrances to **4** shortened than to **4** long (86 to 69) is due to the fact that rats emerging from **5** had a strong tendency to run into **4**. A glance at the maze will show why this is to be expected. There were 32 more returns from **5** long than from **5** short; furthermore, entrance to **5** long had the greater tendency to disorient the animal so that entrance to **4** would be an increased probability. Just why **8** short should have been entered 51% more than **8** long is not easy to

determine. There were, moreover, 14% more returns from the entrances in the former than in the latter case. It is possible that the rats entering 8 at full length, which runs along side the food box, had time and opportunity to get sufficient odor from the food to influence them against returning. Accidental factors may have been the cause in part; half of the entrances were made in the first two trials, and the total numbers are too small to indicate with much probability the actual trends.

On the whole there can be no question that, other things equal, entrances to short *cul de sacs* are more easily eliminated than entrances to long ones.

The results from both types of mazes used in this experiment (see tables I and II) show that on the whole *cul de sacs* first encountered in the maze were entered more frequently, and that the impulses to enter them were overcome with more difficulty, than were those occurring further along the true path, or nearer the food. In this respect our results are in agreement with those of Miss Vincent¹⁶ and contrary to those of Miss Hubbert.¹⁷ While in the present experiment, 'not intended especially to test this point, the bearing of the results is necessarily complicated by an inequality of the lengths of the various blind alleys, there is no evidence to show that results would have been different with *cul de sacs* of equal lengths and of equal direction difficulties. In the B-mazes, for example, 6 and 7 were much less troublesome than 3 and 4, in many respects similarly located with respect to the correct path, and all of equal length. By all means the most difficult *cul de sac* to avoid entering was 1, even when shortened to 8.5 inches. The total entrances to 6 and 7 long are 101, against 142 to 3 and 4 long; to 6 and 7 shortened 83, against 130 to 3 and 4 shortened. The total number of entrances to 1 short are 275, whereas the totals to 6, 7, 8, 9, 10 full length amount only to 192. It seemed that the rats got rather firmly registered in their proprioceptive system of controls the tendency to make two successive turns of 90 degrees each to the right, beginning

¹⁶ Vincent, Stella B. The White Rat and the Maze Problem—IV. The Number and Distribution of Errors: a Comparative Study. *Jour. Animal Behav.*, 1915, 5, 367-374. "The final members of the *cul de sacs* were entered less frequently and eliminated first." P. 374.

¹⁷ Hubbert, Helen B. Elimination of Errors in the Maze. *Jour. Animal Behav.*, 1915, 5, 66-72.

at the corner of the maze before *cul de sac* **1**, and that since the turns were so close together they tended very persistently to fuse together into a single turn of 180 degrees, thus taking the rat into the blind alley. It was very interesting to see certain rats continue to run into **1** with almost monotonous regularity for three weeks, three trials each day, while other errors, errors of entering other *cul de sacs*, occurred very seldom. Thus from the 10th to the 79th trial, inclusive, rat 9 made 60 errors of entering **1** with only 11 entrances to all the other nine blind alleys; rat 11 from the 24th to the 83rd trials made corresponding errors of 47 to 15.

In the A-mazes *cul de sacs* **5** and **6** were likewise entered fewer times and eliminated more easily than **1**, **2**, and **3**, all of length equal to that of **5** and shorter than **6**. It is, of course, not contended here that the two sets of blind alleys compared are of equal difficulty in all respects other than that here considered. At the same time, they may be approximately equal; that is a matter which can be determined only empirically.

The accompanying table (table IV) shows that not only is the number of entrances to blind alleys first to be passed along the true path greater than that nearer the food box, but also that the percentage rate of elimination is greater in the latter. This is shown by comparing the number of entrances to the different groups of *cul de sacs* in question for different successive periods in the learning process from the first to the last trial. In the first five trials of all the animals, trained and untrained, the average number of entrances per trial into *cul de sacs* **1-4** of the B-mazes is twice that of entrances into **6-10**. Calling these numbers for the first period (the average of the 1st to the 5th trial) 100% each, to get a common basis for comparison, we find that there is a much more rapid percentage drop of elimination of entrances in the case of the blind alleys nearer the food box. Since the trained rats discontinued the experiment with the 25th trial without finishing the habit, the percentages for the two groups in the B-mazes are not correct after the 25th trial, though they are strictly comparable. An additional line is given, in the case of each of these groups, of the accurate percentages of elimination of entrances for the untrained rats (eight in each group) alone. It will be noted that in the case of the five *cul de sacs* nearest to the food box the percentage

of elimination is considerably more rapid than in that of the first four blind alleys encountered. In the case of the A-mazes the percentage elimination is considerably greater for *cul de sacs* 5 and 6 than for 2 and 3. Figures VIII and IX represent graphically the data of Table IV.

There is no room to doubt that the blind alleys first to be passed along the true paths in the mazes used are both more frequently entered and more slowly eliminated than are those further along the trail.

TABLE IV

Periods of trials.....	1-5	6-15	16-25	26-35	36-45	46-55	
Maze B	Blind alley 1.....	134	210	166	84	75	71
	Blind alley 2.....	147	76	68	39	33	24
	Blind alley 3.....	79	11	5	6	2	7
	Blind alley 4.....	89	16	19	8	6	6
	Totals.....	449	313	258	137	116	108
Av. per trial.....	89.8	31.3	25.8	13.7	11.6	10.8	
Per cent, 24 rats.....	100.0	34.7	28.6	15.2	12.9	12.0	
Per cent, 16 untr'd rats.....	100.0	27.6	25.5	19.7	16.7	15.6	
Maze B	Blind alley 6.....	42	28	9	1	2	2
	Blind alley 7.....	28	33	18	10	6	2
	Blind alley 8.....	62	15	5	3	2	3
	Blind alley 9.....	49	7	4	5	3	2
	Blind alley 10.....	36	14	3	1	1	1
Totals.....	217	97	39	20	14	10	
Av. per trial.....	43.7	9.7	3.9	2.0	1.4	1.0	
Per cent, 24 rats.....	100.0	21.3	9.0	4.6	3.2	2.3	
Per cent, 16 untr'd rats.....	100.0	15.6	6.8	4.0	2.8	2.0	
Maze A	Blind alley 2.....	84	65	28	8	3	1
	Blind alley 3.....	51	73	49	25	13	3
	Totals.....	135	138	77	33	16	4
	Av. per trial.....	27.0	13.8	7.7	3.3	1.6	.4
Per cent.....	100.0	46.9	26.5	11.2	5.6	1.4	
Maze A	Blind alley 5.....	32	21	2	1	1	3
	Blind alley 6.....	23	9	0	2	0	1
	Totals.....	55	30	2	3	1	4
	Av. per trial.....	11.0	3.0	.2	.3	.1	.4
Per cent.....	100.0	27.3	1.8	2.7	.9	3.6	

TABLE IV—Continued

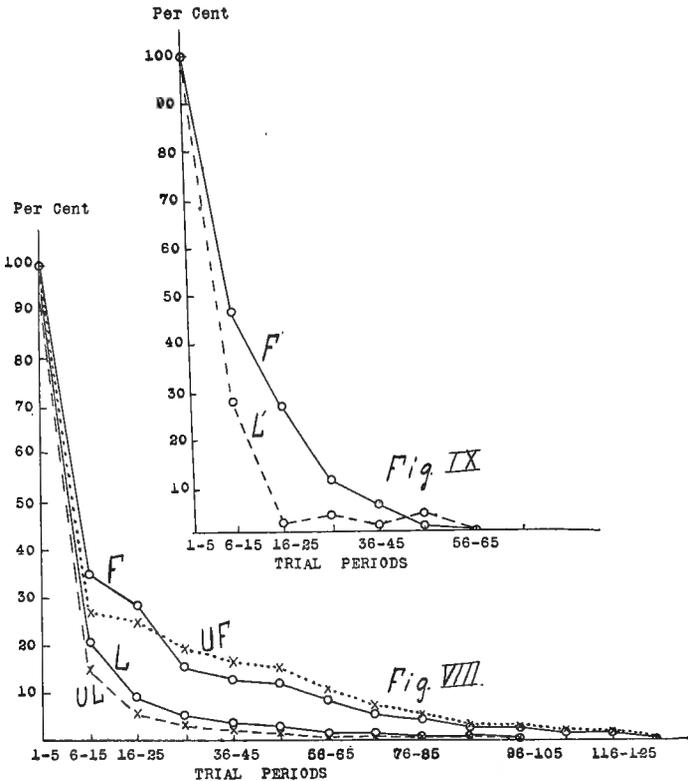
Period of trials	56-65	66-75	76-85	86-95	96-105	106-115	116-125	
Maze B	Blind alley 1	52	36	26	8	7	6	0
	Blind alley 2	15	10	8	7	2	3	3
	Blind alley 3	1	2	1	2	1	0	0
	Blind alley 4	6	2	4	2	0	0	0
	Totals	74	50	39	19	10	9	3
	Av. per trial	7.4	5.0	3.9	1.9	1.0	.9	.3
	Per cent, 24 rats	8.2	5.6	4.3	2.1	1.1	1.0	.3
Per ct., 16 untr'd rats	10.6	7.2	5.6	2.7	1.4	1.3	.4	
Maze B	Blind alley 6	1	0	1	1	0	0	0
	Blind alley 7	0	0	0	0	0	0	0
	Blind alley 8	0	1	0	2	0	0	0
	Blind alley 9	0	0	0	0	0	0	0
	Blind alley 10	0	0	0	1	0	0	0
	Totals	1	1	1	4	0	0	0
	Av. per trial . . . . .	.1	.1	.1	.4	0	0	0
Per cent, 24 rats . . . . .	.2	.2	.2	.9	0	0	0	
Per ct., 16 untr'd rats	.2	.2	.2	.8	0	0	0	

It may be that the odor of the food is a factor that at least partly explains the more easy elimination of the *cul de sacs* nearer the food box. However, there is very little, if any, real evidence that such is the case. A crucial test would be to use anosmic rats, though other means of controlling the odor factor are easily possible. Some facts in the present experiment count against the influence of odor as suggested. For example, errors of entrance into *cul de sac* 10 are nearly as numerous as those of entrance into 9, although to get to 10 the animal had to pass a short alley of 8.5 inches leading directly into the food box. Moreover, all the rats, with occasional exceptions,¹⁸ ran so rapidly after the first trial that it is improbable that food odor had any immediate direct influence in the behavior in the maze. There was no evidence in the behavior of the animals that they were attracted to the food box by such odors.¹⁹ In the cases of supposed trailing, already noted, the animal which appeared

¹⁸ Occasionally, without any apparent external condition to explain the behavior, an animal would sneak slowly and cautiously all the way through the maze. In a few cases such activity seemed to be due to recent fights with other rats or to noises from fights between other animals.

¹⁹ An exception should be made here of the case of returns from *cul de sac* 8, already discussed. The floor of the food box was covered with paper (double thickness) during the feeding each day, and during the experiment the food was kept in a dish in the extreme corner of the food box away from *cul de sacs* 8, 9, and 10.

to be following a scent of any kind moved perceptibly more slowly, holding the nose continuously or frequently to the floor. The writer does not believe that the more rapid elimination of the *cul de sacs* nearer the food is to be explained on the basis of scenting the food. The matter, however, needs further test.



FIGURES VIII AND IX.—F and L show percentage elimination of all entrances to *cul de sacs* 1-4 and 6-10 combined, respectively, by twenty-four rats in the B-mazes; UF and UL the corresponding data for sixteen untrained rats. F' and L' show the percentage elimination, respectively, of all entrances to blind alleys 2 and 3, and 5 and 6 combined, by twenty-two rats in the A-mazes.

Do pure probability laws govern the returns of the rat on emergence from blind alleys? In the tables of results (tables I and II) the totals of the first two trials have been kept separate so that the percentage of returns from blind alleys toward the starting place in the maze could be found for a period little

influenced by the effects of training. The following table (table V) classifies for easy comparison the results of all the rats on the first two trials. The entrances to *cul de sac* 1 in the A-mazes are not included as all emergences from this blind alley brought the rat to the place of the entrance to the maze.

TABLE V
Full Length *Cul De Sacs*

Rats	Maze	Compl. Ent.		Half Ent.		Start. Ent.		% Ret. of all E's.
		Ent.	Ret.	Ent.	Ret.	Ent.	Ret.	
8 untr'd.....	B	170	76	35	6	54	16	38
4 tr'd.....	B	44	16	7	0	14	3	29
4 untr'd.....	A	51	24	7	4	46	16	42
7 tr'd.....	A	33	13	5	2	12	3	36
Average per cent returns.....								33.75

TABLE V—Continued
Shortened *Cul De Sacs*

Rats	Maze	Compl. Ent.		Half Ent.		Start. Ent.		% Ret. of all E's.
		Ent.	Ret.	Ent.	Ret.	Ent.	Ret.	
8 untr'd.....	B	182	72	27	11	48	18	39
4 tr'd.....	B	42	13	4	2	20	5	30
4 untr'd.....	A	23	10	6	3	12	0	32
7 tr'd.....	A	11	2	6	1	10	0	11
Average per cent returns.....								23

It will be noted that in the B-maze the per cent of returns from the shortened *cul de sacs* are practically equal to those from the full length ones, both for the trained and for the untrained rats. The returns for untrained rats are not far short of 50%. The shortage is mostly due, no doubt, to the small degree of learning that took place in the process of the first

two trials, during which there was considerable random activity and reduction of excess movements. It would seem that at first—before any learning has taken place—the chance of a rat's returning on emergency from a blind alley is about one to one. There may be a greater tendency to go forward, keeping the general orientation rather than to return; if so, the excess forward tendency is but slight. The returns from *cul de sacs* first to be passed seem slightly to exceed in percentage those from blind alleys further on toward the food box. In the B-mazes the returns from *cul de sac* **1** (both full length and shortened) are 44% of the total number of entrances; the corresponding percentages for the other blind alleys in order from **2** to **10** are 55, 31, 32, 48, 33, 50, 34, 13, 33. These figures are taken, of course, only from the records of the untrained rats, sixteen altogether. Those most favorably situated for returns, so far as the rat's keeping the general direction on emergence from the blind alley is concerned, are **2** and **5**. This judgment is supported by the data. It is not clear why the returns from **7** should run so high. The percentage of returns by the eight untrained rats in the A-mazes are, for the 2nd to the 6th blind alley, in order: 36, 33, 67, 0, and 0. The large number for **4** was to be expected. The greater number of returns from the *cul de sacs* first encountered is likely due to the fact that the animals had already learned something of keeping the general orientation before the other blind alleys were entered.

In the B-mazes there appears to be a slight decrease in the returns of the first two trials by the trained rats as compared with the untrained. This seems to be due to a sort of "transfer of training." It is likely, as the writer suggested in the earlier article already referred to, due to a tendency of animals with experience in mazes to proceed with less whole-souled response into *cul de sacs*. Let us suppose that as an animal enters a *cul de sac* it also receives certain stimuli of various kinds from the true path from which it departs. These stimuli may produce a weak partial response, or tendency to response, which does not immediately fade away. If this tendency persists until the rat emerges from the *cul de sac* it will, of course, enhance the impulse to take the true path and thus increase the probability of continued forward movement. It is not inconceivable that a trained animal may have developed a habit of keeping the

correct general orientation by some such means as this. Such habits would then have common factors for all *cul de sacs*, and in mazes of different kinds. It would seem, too, that on some such basis as this the returns would be eliminated more readily than entrances to the blind alleys, as has already been shown to be the case. This explanation may involve an interaction of sensory and motor impulses in the nerve fibres—each system, sensory and motor, interacting upon and stimulating the other—in such a manner as to make comprehensible how the effect of stimuli may be carried over into later responses and partly condition them as suggested below.

Possibly the animals also learn with training to utilize better such factors as vague visual stimuli of the closed end of the *cul de sac*. Certainly the speed of the rat running into the blind alley would make one cautious in assuming that such factors are explicitly reacted to by the animal. That there was a real transfer of some kind is, in any event, a conclusion which also finds support in the results of the A-mazes. For the full length and the shortened *cul de sacs*, the per cent returns for untrained rats are 42 and 32, respectively, agreeing rather closely with the B-maze results, whereas the corresponding percentage returns by the trained rats—seven in each A-maze—are 36 and 11, a decrease from that of the untrained animals of 14% for the full length and of 66% for the shortened *cul de sacs*. In the B-mazes the percentage returns from the full length *cul de sacs* by trained rats is 24% less than that by untrained rats; for the shortened blind alleys the percentage returns by the trained rats is 21% less than that by untrained rats.

THE SIGNIFICANCE OF THE RESULTS

It may be urged by the reader that the more rapid elimination of entrances to the shortened *cul de sacs* than to the full length ones is due to the fact that the rat, in the case of the short blind alleys at least, *sees* the closed end and thereby avoids entering so frequently, or so completely. In one sense this begs the whole question. Seeing is not some *thing* that stimulates or directs the animal; it is only a mode of being stimulated. Its possibility in the present study is not at all denied. The whole question with which we are concerned is: *How do all possible*

kinds of stimuli operate, directly or indirectly, toward the learning to avoid entering cul de sacs?

That the rat is not wholly blind has been demonstrated in a number of cases,²⁰ but there is no clear evidence to show that the presence of such visual factors as are possible to the rat could operate on the principle of frequency, recency, or intensity, or all combined, in such a manner as to eliminate the impulses to enter the *cul de sacs* under the conditions of the present problem. They might, of course, aid the rat in getting to the food at any one time, but how could they operate toward cutting short the random processes in successive trials, *i.e.*, in bringing about what is called learning? A brief review of the work on visual controls in the rat's behavior is to be found in Miss Vincent's paper. Waugh found²¹ that though the mouse could perceive the distance of objects "within a range of 15 cm.," it nevertheless seemed not to make use of the "visual perception of depth" in getting past two partitions each from opposite sides reaching half way across the problem box, the one being nearer than the other.

In the present experiment, it will be recalled, the interior of the maze was stained black, and even if it be granted that the rat could see the ends of some of the shortest *cul de sacs* there would be but little difference in the visual stimuli between the "blind" and the open alleys, in as much as both were obstructed alike in the further end and the side opening of the latter was not directly visible. Differences in brightness would be irregular and but slight, as the room was lighted from three sides—south, west, and slightly from the north—and an electric light was directly over the maze. It should be said that no difference in behavior between the rat blind in the left eye—No. 20—and the other rats was noticeable though the experimenter kept watch for such difference. More careful visual controls are of course desirable.

But the real question is how any stimulus, visual or otherwise, must operate together with other stimuli so as to inhibit unsuccessful acts and to cause to survive those acts which bring

²⁰ See Richardson, Florence. A Study of the Sensory Control of the White Rat. *Psychol. Mon.*, Ser. No. 48, 1909. Vincent, Stella B. The White Rat and the Maze Problem—I. The Introduction of a Visual Control. *Jour. Animal Behav.*, 19 15, 5, 1-24.

²¹ Waugh, K. T. The Rôle of Vision in the Mental Life of the Mouse. *Jour. Comp. Neurol. and Psychol.*, 1910, 20, 549-599.

success, in this case those acts which bring the animal to the food box. The results follow the series of stimuli and responses which take the animal through the maze. How can the result work backwards? The writer believes that in the foregoing pages he has presented plausible reasons and data to show the absolute inadequacy of frequency and recency laws as the directing factors in maze learning. Frequency fails to give any basis not only for this kind of learning in general but particularly for the specific kinds of results obtained in the experiments considered. In a complex situation like this, frequency explains only how within a certain probability the rat will finally reach the food, but it fails to explain why subsequent trials should be improvements on the first one. It is not clear how recency, as ordinarily understood, can aid the learning. The principle of intensity needs re-interpretation. When several stimuli act on an animal bringing about a series of responses as in this case, the final one of which is the successful one, it appears that somehow, not well understood yet, the various effects of these stimuli hold over into that of the final stimulus and that all together simultaneously act to direct the energy of the animal into the most consistent channels. In the large, these channels offer the least resistance and afford the most complete response. It is in this sense that the successful acts are more intense than others, and thus their effect is greater toward shaping the neural pathways for their repetition and for the gradual elimination of the more inconsistent and tentative responses leading up to them. On this assumption it becomes somewhat comprehensible why the maze is learned to a large extent "as a whole," so that small errors may throw the animal out completely, or at some other part of the maze, when the habit is nearly perfected. The specific results of the present experiment are also intelligible. These various hold-over effects in the extero- and the proprio-ceptive systems afford the basis of imagery in human behavior, and supply the "large situation" to which one reacts ideally. They may function, so far as we can know, wholly unconsciously or with but vague consciousness in the case of the rat. In the human being habits of responding to separate groupings of these factors may be acquired, and such exciting factors may be aroused indirectly by association. Nothing is gained in psychological explanation by assuming "ideas" to

explain behavior, unless in such cases we understand how the ideal dispositions themselves are acquired. The use of the term *idea* in the higher forms of behavior is justified then only on the basis of simplicity of statement. There is none but questionable evidence thus far that ideational behavior is different in any way but degree from sensori-motor, or the well known trial and error, behavior. "Ideas" can function only when the somewhat detachable dispositions, of which they are the imperfect, subjective aspects, have been built up by experience, and such dispositions require a rather complex nervous mechanism. It is needless to say that no evidence of ideational behavior has been found in the white rat. While, as has been pointed out in the foregoing, there are likely some hold-over effects of stimuli in the case of the rat, these likely operate more or less mechanically and *en masse* so that the animal enjoys little independence of action and is subject rather completely to the dominance of the group of stimuli present or immediately past. That is to say, the animal can respond only to present situations though with a considerable number of random variations, until the most consistent responses to that situation have fixed themselves to the exclusion of all others, after many repetitions of trials. Then the response becomes uniform and mechanical to a high degree.

The more advanced behavior as we see it in the case of man—ideational behavior—differs from the lower forms illustrated in the present study in that it is less fixed and less dependent upon immediate situations. Stimulus-response organizations, or tendencies, are more detachable in their separate smaller functional components; and the latter have richer possibilities of combinations among themselves, on the one hand, and on the other there is less dependence for their functioning upon direct or immediate stimulation. Various indirect and vicarious stimuli come to serve adequately. Thus various systems of stimulus-response mechanisms may become organized into inconceivably complex relationships about certain symbolic stimuli, such as written or spoken words, various kinds of gestures and attitudes of the stimulating individuals, associated objects, sounds, contacts, and so on. It then becomes practically impossible to predict which of the various aspects of the situation will succeed in calling out its particular response. We shall

not here enter into further consideration of this complex behavior, except to point out that when the various stimulus-response mechanisms have become sufficiently well associated with certain muscular strains or neural excitations, the revival of the latter by favorable stimuli will call out the acts themselves. Thus a stimulus may have entirely ceased to play upon the sense organs from without and long periods of time may have elapsed, and yet, because of this acquired organization, the recurrence of any significant aspect of the outer situation, even such as a sound associated with it, may revive the crucial excitation and thus call out the act. Something of this kind—stimulated, however, by the original situation minus the light when the animal is allowed to respond—likely takes place in the delayed reactions of animals, though this assumption leaves entirely open the question as to whether or not the animals *have ideas*, a rather infertile question for science, it must be confessed. More elaborate systems of acquired associations make possible the continual thinking of absent situations which we *know* that *we ourselves* experience. In these more advanced forms of behavior groups of response systems may come so to interact upon one another by associations and by stimulation from the inward bodily conditions that rehearsal of a problem mentally may take place long after actual practice has ceased, thus changing behavior materially between practices. It is yet questionable whether there are any such cases in animal behavior.²²

In the foregoing pages we have called into question the principles of frequency, recency, and intensity of stimulation as usually understood in relation to the fixing of associations, so far as their value in explaining learning is concerned. They do not seem to account for the *change* in successive trials called learning. This seems to be true at any rate for maze learning; probably it holds for all kinds of learning. All that these factors do is, likely, to make more and more easy *any* associations and acts brought about by the real directing factors. That is, they tend to fix any series of acts in the order that they are gone through, *not to change the order of the acts*. Some other directing factors and some *vis a tergo* must be found to account

²² Cf. Yerkes, R. M. The Mental Life of Monkeys and Apes: A Study of Ideational Behavior. *Behav. Mon.*, 1916, 3, No. 1. Yerkes thinks Julius, an orangutan, solved a problem ideationally; see particularly pp. 68 and 131.

for the changes in behavior which gradually make response more and more direct and which gradually eliminates the useless random acts. We must not forget that the numerous internal life processes, *e.g.*, the contractions of the muscles of the stomach with hunger, serve as the motivation to activity. They determine the stimulating value, as do also modifications in the proprioceptive system by past behavior, of various outside factors. The organism continues to respond by varying behavior until successes are attained which modify these internal conditions and change the inner motivating factors. But the failures also change the organism. The directing factors of the response seem to be the inner organic processes and the total combination of stimuli from external conditions and from muscular contractions, all these overlapping in their several effects as has been suggested. The neural channels involved in the most consistent acts become the most operative through the compelling effects of all these factors, and these acts, or directions of response, in time survive over all others and gradually acquire an ease and automaticity of functioning characteristic of habits. The stimuli to action even in as simple an organism as a rat are infinitely more complex than usually imagined in our "neural explanations." Mere contingency in the combinations of acts of a rat brought about in the maze, or in other problem boxes, for that matter, cannot be regarded as the important factor that it has sometimes been supposed to be. It is true that some useless acts may occasionally survive with the more consistent ones by chance associations, but such acts are really not vital parts of the system of learned acts.

The precise nature of the hold-over effects of various stimuli posited in the explanations of learning here suggested must be left to physiology and neurology. There is undoubtedly a close connection between sensory and motor impulses. Sensory stimuli bring about responses which in their different stages of expression set up new afferent impulses, or either facilitate or tend to inhibit old ones; these again modify the motor tendencies. We are a long way yet from a satisfactory knowledge of nerve impulses and their effects upon one another,—Are they periodic or continuous? What relations obtain between stimulus changes and nerve impulse changes? What is the nature of inhibition

and of facilitation? These and many other problems not yet solved have important bearings upon our knowledge of the learning act. But psychologists cannot wait for the solution of these problems before attempting to formulate more satisfactory conceptions of the processes with which they must deal at every turn. It must be apparent that chaos now reigns with respect to this matter. Some writers invoke *imitation* to explain most modifications in behavior; others use *pleasure and pain* for the same purpose; while *ideas, purposes, the effects of random acts*, and so on, are freely used directly or indirectly by most writers. All of these factors may have real parts to play in the learning process, in some one or more of its various aspects, but they are all more or less vaguely conceived and frequently erroneously referred to, almost as some sort of original or spontaneous causes, rather than complex aspects of the very thing that is to be better understood and analyzed. Popular, educational, and sociological writers may be forgiven for their own sins in this particular so long as psychologists have nothing more satisfactory to offer than at present. The great problem of how learning takes place is yet largely unsolved.

For the best progress, experiments in behavior modification must go hand in hand with physiological investigations into the nature of the nerve impulse. A few rather suggestive studies have been carried out by psychologists upon the mutual effects of successive acts on one another. It appears that while one particular kind of act is being learned a second contrary one is inhibited by it more than after the first has been completed.²³ The extensive investigations of Professor T. G. Brown,²⁴ on the physiological side, have shown a summation of successive liminal stimuli (facilitation) of intervals up to about ten seconds. Such neural overlapping effects may well function to bring about a

²³ Pillsbury, discussing experiments on associative inhibition by Müller and Schumann (1894), concludes that "where several things are to be learned in the same connection, it is found that inhibition ceases to be effective if the first is thoroughly learned before the second is begun." *Fundamentals of Psychology*, 1916, p. 359. See also p. 365. Especially interesting in this regard is a study recently reported by Hunter,—Hunter, W. S., and Yarbrough, Jos. U. The Interference of Auditory Habits in the White Rat. *Jour. Animal Behav.*, 1917, 7, 49-65. See especially pages 60 ff. One must be careful not to generalize too much from these experiments on contrary acts.

²⁴ Brown, T. G. On the Phenomenon of Facilitation. I. Its Occurrence in Reactions Induced by Stimulation of the "Motor" Cortex of the Cerebrum in Monkeys. *Quart. Jour. of Exper. Physiol.*, 1915, 9, 81-99. Other articles by the same authority in the same journal.

simultaneous operation to some extent of the various experiences that a rat has in finding the food box in the maze. In many types of learning we have been much in the dark as to how later *effects* of the successful results could work back and stamp in these successful acts to the exclusion of the various unsuccessful ones. By the conception of the overlapping of effects of successive nerve functionings may we not be getting a start in the right direction?

DISCUSSION

Peckstein²⁵ has recently tried to explain the transfer effects found in his experiments on the basis of factors which the writer finds extremely vague, subjective, and otherwise technically objectionable. The *general* factors of his explanation are: (1) "General maze habits"—reduction of tendency to return, knowledge of the nature of errors, improved sense of direction; (2) "consciousness of power;" and (3) "proper emotional attitude." Specific factors are such as common specific identities, or near-identities, in the different mazes. We are told that return is due to the general "dominance of the familiar." "The return pathway is known to be safe. The rats seem natively inclined to return to the closed entrance." This return tendency—due to knowledge or instinct?—is actually inhibited by any maze for any other. The knowledge of the nature of errors is a "concept," we are told, developed in the earlier sections of the total maze. A *cul de sac* "ceases to be a detail that must be cautiously explored," and "comes to mean a detail that must be left as soon as possible." At first—now we are at the "sense of direction" factor—some learners "have almost a 'going ahead' instinct," while others have a greater tendency to return. This latter tendency is gradually overcome. This seems, then, only to be another name for the factor mentioned under "returns." "In subsequent mazes, the truly sophisticated learner will enter the *cul de sac*, but will proceed along the forward pathway when he returns to the true course."

The "consciousness of power" in the rats seems to manifest itself, after all, in some objective behavior change, such as increased activity. "In subsequent mazes, however, the consciousness of power is clearly seen (!). No 'warming-up' period

²⁵ *Op. cit.*, pp. 50-54.

is needed. There is no delay at the entrance. Work has come to mean invariable accomplishment and reward. The entire attack upon the new problem is aggressive. The learner has learned to do by doing." The proper emotional attitude, the last of the general factors, means the overcoming of an attitude complex, "a mixture of fear, indecision, curiosity, and perhaps anger." All this after some really valuable experiments! Surely this is only a complication in subjective terms of *facts to be accounted for*, which facts practically all authorities are willing to accept more or less completely. These "factors" of transfer do not take us anywhere.

Dr. Peckstein finds²⁶ that the difficultness of mazes is not proportional to their lengths, nor to the number of their blind alleys. But why should it be? As to the number of *cul de sacs*, it is obvious that if *at first* a rat tends in its "choices" at bifurcations to follow chance laws—and our present results point that way—difficultness ought to increase on some other principle. The probability of passing any single *cul de sac* successfully is $3/4$, as Watson has pointed out, i. e., if we mean by "successfully" that the animal either goes on in the correct path, or, if it enters the blind alley, that on emergence from it it keeps the general forward direction. The chance of passing two blind alleys is therefore $9/16$ ($= 3/4 \times 3/4$); that of passing three *cul de sacs*, $(3/4)^3$; and so on. On this basis the chance of getting through one unit of Peckstein's maze—3 blind alleys—is $(3/4)^3$, while that of getting through the entire maze without a return is $(3/4)^{12}$. In the former case the probability of a success without returns is therefore over thirteen times that in the latter. Complications from returns at any *cul de sac* will be brought about by additions of other forward movements beyond the point to which return is made, but each of these additional forward runs may again be assumed to follow, before any training sets in, the same probability law at each *cul de sac* that is followed in the original run. Thus the above calculation may stand roughly as approximately correct. Its results—a difficultness of the whole maze of over thirteen times that of the quarter maze—agrees more closely with Peckstein's actual results, as estimated by him, than do those based on the assumption of a direct proportionate increase in difficultness

²⁶ *Ibid.*, pp. 55-57.

with distance through the maze and number of *cul de sacs*. Peckstein found the whole maze over twenty times more difficult than the average of the four quarter mazes, whereas such a direct proportionate increase of difficultness as he assumed should make it but four times more difficult. Of course, many other factors in any such calculations must be taken into consideration. With Peckstein's rats the relative degrees of difficultness of the four sections of the maze were found, in order from the first to the fourth quarter, to be 15, 1, 3, 2, as determined by his combined trials-time-error formula. This does not look much like equality. The excess-distance run by the rats is certainly a factor as well worth while as any to consider. Why was it not included?

So far, then, Dr. Peckstein's results, as presented by himself, seem roughly to agree with our own in supporting the view that mere probability laws account for the original "choices" of the untrained rat at the several bifurcations in the maze. This is our own interpretation of his data, not his, it should be stated. He merely seems to hold that there is some law of diminishing returns, which he does not clearly state, that determines the degree of energy expended for the learning of mazes of varying complexity.

Dr. G. V. Hamilton in his interesting study of perseverance reactions, by the multiple choice method as he has developed it, finds frequency and recency of an advantageous response more strongly effective toward learning than either frequency or recency with no advantage or with actual disadvantage.²⁷ He finds that frequency with invariable advantage is stronger in effect toward the building of a habit than even greater frequency without an invariable advantage. But, as in most experiments on learning, he has his conditions so arranged that the animal can end up only with the "successful" act.²⁸ E. g., Hamilton says: "During the twenty habit forming trials under discussion she [Rat No. 1] manifested only three recency first choices, but after these trials [that is, when the habit was learned] *during which the operation of the factor of recency was invariably advantageous* she manifested 100% of recency first choices."²⁹

²⁷ A Study of Perseverance Reactions in Primates and Rodents. *Behav. Mon.*, Ser. No. 13, 1916.

²⁸ *Ibid.*, pp. 38-46.

²⁹ *Ibid.*, p. 40.

How could she do otherwise after learning is accomplished? Here the success of the final act was inevitable by the conditions of the experiment. The final high degree of success is the *result* of the learning, how, then, can it get around to come in at the front door as one of the causative factors?

SUMMARY AND CONCLUSIONS

The "principles of learning" frequency, recency, and intensity, in their usually accepted meaning, have been found inadequate to account for learning in the maze. Probability laws alone make possible a sufficient number of right choices for the rat to reach the food box finally in the ordinary maze. The probability of reaching the food box by mere chance rapidly decreases with the increase in the number of *cul de sacs* in the maze. But it is found that on laws of pure fortuity there is no explanation for the *elimination* of *cul de sacs*; for since the probability of entering any blind alley on returns as well as on forward runs is $1/2$, the habit of continuing to enter them should be as strong as that of keeping the right trail toward the food box. For learning to be possible, some sort of short-circuiting process must take place by which the true path may be suggested for the line of action when the animal gets to the entrance of any blind alley. It is not clear how any of the usually accepted laws of learning—frequency, recency, and intensity—can operate to bring this about. Frequency and recency fail entirely to account for the behavior of the rat in the maze. The real process of learning, the gradual elimination of unsuccessful random acts, such as entrances to *cul de sacs* and returns toward the entrance place in the maze, must be accounted for on the basis of some entirely different principle. The principles named show only how an act, directed by some other factor, becomes gradually more mechanically reflex.³⁰

³⁰ Statistically the statement in this paragraph, as well as the one in the first part of the monograph, is inaccurate. An animal coming the first time to a blind alley has a probability of $1/2$ of entering it; a probability of $3/4$ of continuing in the right direction, whether or not the blind alley is entered; and a probability of $1/4$ of entering the CUL DE SAC and, from it, returning toward the starting place in the maze. If the animal actually gets by the blind alley in question, enters one farther on and returns in the maze, the conditions are reversed at the first blind alley. Now the probability of continuing back to the starting place in the maze, i.e., either of not entering the blind alley at all or of entering and then continuing in the return direction, is $3/4$; that of getting reoriented in the right direction toward the food is $1/4$; and that of entering the blind alley is $1/2$. Adding these fractions to those above for the respective directions in which the animal can possibly go

The present experiment was devised to present conditions which might test the efficiency of the "completeness of response" theory outlined recently by the writer, suggesting a means of learning based on the overlapping and thereby simultaneously operative effects of successive stimuli. Identical mazes were used for separate groups of animals, but they were so arranged that their several *cul de sacs* could be conveniently varied in length. By this means control groups of rats were run in mazes differing only in the relative lengths of their *cul de sacs*, certain of these being long for one group and short for the other. Two modifications of such differences were used; the one pair of control groups having all the blind alleys short in the one maze and all long in the other, while the other pair of controls each had some long and some short blind alleys making the total length of blind alleys equal for both members of the pair. In all, twenty-four rats were used. Groups of rats were interchanged in the mazes, after the first problems were completed, so that each problem was tried both by trained and by untrained animals.

Detailed records were kept of the behavior of the animals. Complete entrances, half way entrances, and beginning entrances to *cul de sacs* were indicated; complete returns and returns to blind alleys already passed were noted; and the direction of the rat's movement on emerging from blind alleys, whether forward or back, were recorded. The exact time for each trial was kept but not used in the present report.

we have: forward from the blind alley $3/4 + 1/4 = 1$; into the blind alley $1/2 + 1/2 = 1$; and return toward the starting place in the maze $1/4 + 3/4 = 1$. This gives equal exercise to the acts in all these three directions, on pure probability laws, when returns are considered. But the animal is taken out of the maze only at the food end of the trail; hence for each trial there must be one more forward run at any given place in the maze than return runs. This gives the forward direction an advantage statistically of $1/4$ runs for each trial over the entrance to the *cul de sac* and of $1/2$ over returns. This advantage is proportionately small where many returns are made, as near the maze entrance, and large where this is not the case, as near the food and later in the learning process at any given point. No returns will be made to the last *cul de sac*, and when entrance to it has been eliminated none will be made to the one next to it; and so on. This condition, then, affords a fine theoretical basis for explaining learning in the maze, and also for the backward elimination of errors of entrance to blind alleys. There are, however, serious flaws in this argument when given in support of frequency, either alone or combined with recency, as the only principle operative in the learning of the maze. Frequency and recency factors really operate against this explanation, rather than in favor of it; for they favor the mere repetition of the choices first made at any of these critical positions in the maze, and therefore the strengthening of the impulses to enter blind alleys rather than their weakening. The force of this point will be shown concretely in the paper now in preparation.

1. The decrease in the percentage of returns by the animal emerging from blind alleys is very rapid in the early part of the learning, and as a rule the rat continues to enter blind alleys, even to their full length, long after returns are discontinued; i. e., the curve of returns from blind alleys drops much more rapidly than that representing the number of entrances to blind alleys. These returns persist longer in the case of *cul de sacs* encountered along the first part of the correct path than in that of those nearer the food box.

2. The elimination of entrances to blind alleys does not come about mainly by a decrease in the *number* of entrances, but principally, especially in the case of the longer *cul de sacs*, by a gradual decrease in the *degree*, or the distance, of entrance. Just before entrance is eliminated completely, there frequently occurs a peculiar and very rapid vibration of the rat's head between the direction of the true path and that of the tempting blind alley. Frequently, after the first success in passing any such blind alley, the rat runs headlong into some *cul de sac* farther along the correct trail, which it had previously learned to avoid. These and other facts of similar import indicate that the maze is learned "as a whole" to a large extent, and that entrances to blind alleys are not properly to be regarded as *separate acts*, as is frequently done in speculations on learning.

3. Entrances to short *cul de sacs* are eliminated more readily, other things equal, than entrances to long ones. Not only are the total entrances to the short blind alleys fewer than to the longer ones, but the percentage elimination of them is greater. The curve of decrease of entrances drops more rapidly in the case of short than in that of long *cul de sacs*.

4. Blind alleys first to be passed along the true path are entered more frequently than those further along—nearer the food box—and their percentage rate of elimination is less. That is, entrances to the first *cul de sacs* encountered are more persistent, harder to overcome, than those to *cul de sacs* nearer the food box.

5. With untrained rats the number of returns toward the entrance door in the maze, on the rats' emergence from blind alleys, nearly, if not quite, equals in the beginning of the experiment the number of cases of keeping the general forward direction toward the food box. It appears that at the beginning stage of learning in the maze mere probability determines whether

the animal goes forward or back on emerging from a blind alley. In this respect, however, as in many others, there are rather large individual differences. From the very first experience in the maze, and this makes the test of the probability law rather difficult, the learning factors enter in and rapidly decrease the returns in favor of the general forward orientation.

6. It has been found desirable in work of this kind to study individual reactions in detail. Mere averages do not show the significant aspects of the behavior in many cases. A detailed report of individual "choices" in the maze, by a method which promises to be fruitful, is being prepared to justify further the statement in the present paper regarding the inadequacy of frequency and recency laws as explanations of the rat's maze-learning.

7. Responses to stimuli cannot take place instantaneously, neither do stimulation effects fade away momentarily. Besides this, response tendencies and muscular strains, maintained for a shorter or longer time, constantly set up new sensory impulses (proprio-ceptive stimuli) which again stimulate reactions. It is suggested that by such means as these, and possibly by others not yet known, the effects of successive stimuli, such as an animal encounters in getting through a problem box to food, operate in a measure simultaneously, and the resulting response is on the whole the most consistent or complete one under the whole circumstance. The channels to this most complete response are gradually forced most open or permeable; their greater consistency of operation (facilitation) brings about an intensity of activity through them which in repeated trials gradually short-circuits through the infinitely numerous pathways involved and thus brings about the gradual elimination of useless random acts. It is suggested that learning comes about by this means. It is hoped that this suggestion may be fruitful toward an understanding of how a final success can operate back (as it appears externally to do) upon the random acts leading to it so as gradually to bring about their elimination. This is the theory which the writer has called the "completeness of response" principle in learning, and it seems to him to account for the results obtained in the present experiment as well as for others which have been uncritically attributed to the *stamping-in effects of pleasantness*.

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