EXPERIMENTS ON TACTUAL SENSATIONS IN THE WHITE RAT

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FOUR FIGURES

The object of the present series of experiments was two-fold: first, to determine if possible the function of the tactual sensations of the white rat in learning a maze; and second, to ascertain the effect of the running of previous mazes upon the learning of subsequent alterations of the original maze by opening and closing definite pathways.

In previous experiments by Watson,[1] it has been shown that any one of the following senses may well be dispensed with by the white rat in learning the maze: (1) vision—one series of rats learned the maze in darkness, and another series with eyes removed; (2) olfaction—the rats having been made anosmic by an operation; (3) audition—sense of hearing temporarily eliminated by filling the middle ear with paraffine; (4) cutaneous sensation so far as vibrissae were concerned—vibrissae closely clipped. While in the above tests no rats were deprived of more than one sense at a time, Watson [2] also experimented with a young male rat whose vibrissae had been clipped and which at the same time was blind and anosmic. Notwithstanding that a certain lack of tonicity was observable, and that errors were eliminated more slowly, the rat learned the maze, and finally became the usual automaton. It is obvious that while these tests indicate that certain senses are not necessary for learning the maze, they do not show what sense-factors are normally utilized. Further, though Watson [3] anaesthetized the nose of an anosmic rat and found that "successive reactions were not in the least disturbed," this experiment threw no light on the significance of the cutaneous sensations in learning the maze, since the animal had been previously trained. Likewise, although in these cases the vibrissae had been removed

[1] Watson, J. B., Kinaesthetic and organic sensations: their rôle in the reactions of the white rat to the maze. *Psychological Review*, Mon. Sup., 1907, vol. 8, No. 2.
[2] *Ibid.*, p. 98 f.
[3] *Ibid.*, p. 77.

and thereby certain cutaneous sensations had been eliminated, the question of the part played by actual nose and head contact in learning the maze remains open. It is this problem which we propose to investigate.

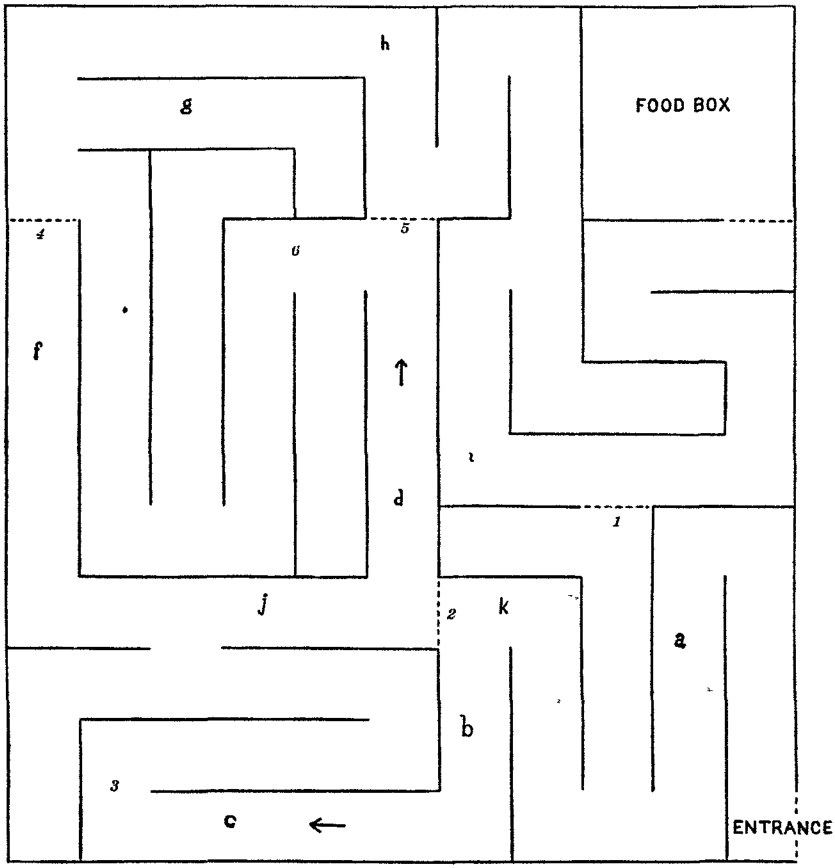
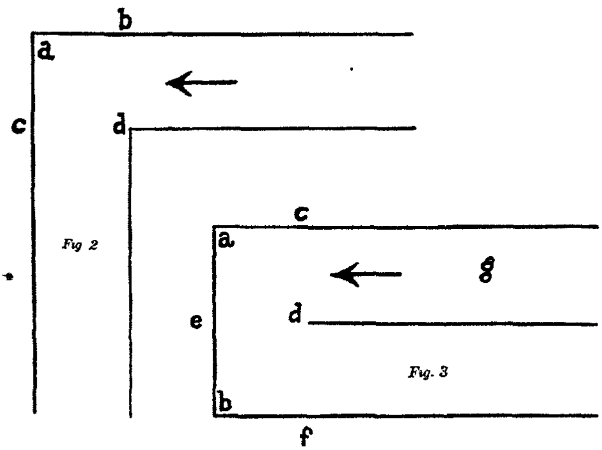


FIGURE 1—Maze I—Doors 3 and 6 open; other doors closed.
Maze II—Door 5 put at 6; Doors 3 and 5 open, other doors closed.
Maze III—Door 2 put at 3; Doors 2 and 5 open, other doors closed.
Maze IV—Door 4 put at 5; Doors 2 and 4 open, other doors closed.
Maze V—Door 1 put at 2; Doors 1 and 4 open, other doors closed.

The maze used in the following experiments was one with the food-box in the corner instead of at the center as in the Hampton Court maze. The maze was covered with glass in place of the wire netting commonly used in similar experiments.

As indicated in figure 1, the alleys were constructed with removable doors at 1, 2, 3, 4, 5 and 6. In maze I, doors 3 and 6 were open while doors 1, 2, 4 and 5 were closed.

The first set of rats used in this series of experiments were normal animals, two males and three females. They were about three months old, and had never been used in experimentation. They were fed daily in the food-box of the maze until they became thoroughly tame. Their vibrissae were cut off two days before our experiments began. At the end of that time all emotional disturbances had disappeared and the rats acted in a perfectly normal way. This was done in order to facilitate



FIGURES 2 AND 3

the observation of actual head and nose contact in turning the corners of the pathway. No attempt was made in this experiment to keep a record of contacts except at the corners. In general, it was very noticeable, however, that the animals at first kept in close contact with the sides of the pathway.

Reference to figures 2 and 3 will show what we mean by "corners." In figure 2, if a rat touched the corner a at any point between b and c or at d, he was checked up with one corner touched. In no case was a rat checked up with more than one contact for a corner. Likewise, in figure 3, if a rat touched the corner a between c and e or at d he was checked up with one contact; and if he also touched the side of the pathway again between e and f he was checked up with another contact. The two corners were never represented by more than two contacts. A record was kept of all the corners not touched, as well as of those with which the animals actually came into contact.

Table I shows the average time, the average number of errors,

TABLE I

SHOWING AVERAGE TIME, AVERAGE NUMBER OF ERRORS, AVERAGE NUMBER OF CORNERS TOUCHED, AVERAGE PERCENTAGE OF CORNERS TOUCHED OF FIVE NORMAL WHITE RATS IN LEARNING MAZE I

Number of trial	Average time, in minutes	Average errors	Average number of corners touched	Average percentage of corners touched
1	17.73	46 4	51 2	.77
2	4.53	16 2	43 4	.70
3	1 85	9.2	25 0	.54
4	90	6 8	18.2	.43
5	1 32	5 6	22 4	56
6	2.40	15 0	30 0	52
7	98	6.4	17 0	.37
8	.69	4.6	13.6	.37
9	1.65	4 4	14 4	.41
10	.83	7 2	16 4	31
11	.87	5 8	9.4	.24
12	60	2 4	8 0	.23
13	64	3 0	8 8	.20
14	50	2 0	4 2	.13
15	.66	2.6	5.8	.16
16	.85	1 2	2 8	13
17	.92	3 2	5.0	17
18	39	1 2	2 4	13
19	40	0 4	1 8	.12
20	.48	1 6	2.4	.12
21	42	0 8	1 6	05
22	.56	1 2	3 4	.16
23	46	1 4	1.4	.11
24	.35	0 6	1.8	.14
25	41	1.0	2.2	07
26	.42	0 4	1.8	.06
27	.46	0 8	2 2	07
28	46	0 2	1.2	04
29	.27	0 2	1 6	.05
30	.36	1.0	1 8	.06
31	.36	0 4	1.0	.03
32	.31	0.0	1.4	.05
33	.31	0 4	0.8	.02

the average number of corners touched, the average percentage of corners touched, of the five normal rats in learning the maze. Reference to the table reveals the following facts:

(1) The percentage of corners touched is high at the beginning

and gradually decreases as the maze is learned. The first figures, while high, do not render full justice to the situation. Figure 3 will serve to illustrate the point. When the rat came down alley g toward a, one contact at any point in the vicinity of e

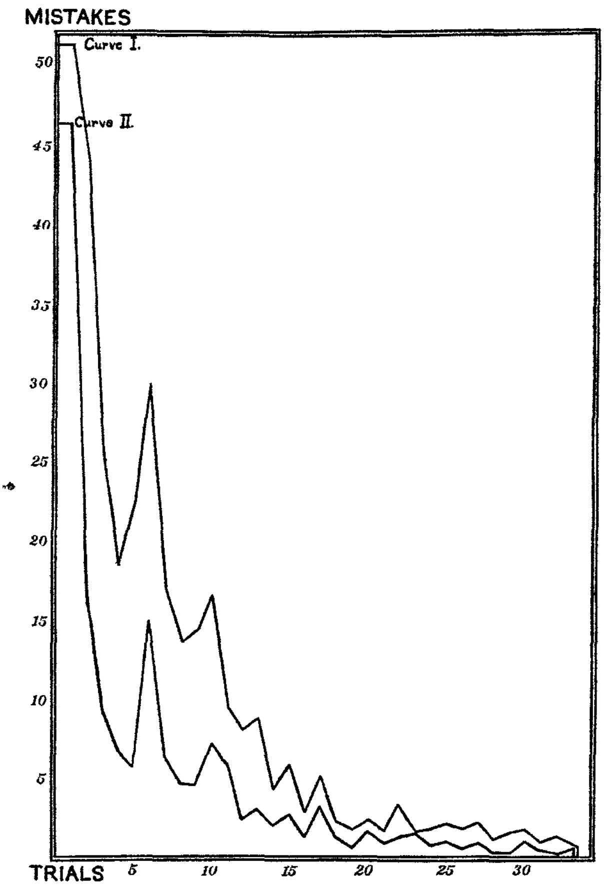


FIGURE 4—Constructed from table I. Curve I.—Graphic representation of number of corners touched in learning maze I by five normal rats. Ordinates represent number of corners touched; abscissas represent number of trials. Curve II.—Graphic representation of errors under above conditions. Ordinates indicate the number of errors.

might serve as a sufficient stimulus to make the turn successfully. Thereby the rat went around two corners with only one contact. Had the corners been farther apart, two contacts would probably have been made, since this was usually the case.

In other words, since two corners have been turned with only one contact, the rat has been checked up with only fifty per cent. of contact in these cases. Inasmuch as the two corners were so close together, they became one to the rat, and the fifty per cent. in such instances really represents one hundred per cent. of contact. Our method of counting the corners as given above was due to the fact that often the rats actually touched both corners. It was not feasible sometimes to count two corners as one and sometimes as two. Since there are a large proportion of these double corners in the normal pathway of maze I, the percentage of the corners with which the rat came into contact has been lowered considerably by our method of enumeration; ninety per cent. probably is not too high an estimate for the first run. This seems to indicate that in acquiring the kinaesthetic and organic sensations which the rat later utilizes in running the maze, tactual sensations are more important than smell or vision.

(2) In the second place, the table shows that there is a striking correlation between the number of corners touched and the number of errors. Curves I and II, fig. 4, give a graphic representation, making the correlation more obvious. This indicates that as soon as the running ceases temporarily to be automatic and errors are made, the number of contacts forthwith is increased and tactual sensations are used until the animal has run at least a unit of the maze and the automatic kinaesthetic and organic control is re-instated

(3) There is also a general correlation between the increase and decrease of time and the number of contacts. In run 4 (see table I) the average time was .90 minute and the number of contacts 18.2; in run 6, the average time rose to 2.40 and the contacts rose to 30. The rise in time at the ninth run is accounted for by the fact that rat 5 halted and took four minutes to run the maze. This correlation is in harmony with the theory that tactual sensations are of first importance in *learning* the maze.

(4) The table shows that when the maze is learned, contact at the corners is no longer necessary. According to our observations, what holds true of the contact at the corners applies to the contacts with the sides of the pathway between the corners.

After the five normal rats had learned maze I, six female blind rats were trained to run the maze. These rats had some time previously learned a different maze. They were run in maze I only until each individual had learned the maze for herself. Average results were secured for twenty-one runs, as indicated in table II. These results, while obtained under different conditions, bear out, as far as they go, the four conclusions given above, and especially add weight to the contact theory of ac-

TABLE II

SHOWING AVERAGE TIME, AVERAGE NUMBER OF ERRORS, AVERAGE NUMBER OF CORNERS TOUCHED AND AVERAGE PERCENTAGE OF CORNERS TOUCHED OF SIX BLIND RATS FOR THE FIRST TWENTY-ONE RUNS OF MAZE I

Number of trial	Average time, in minutes	Average errors	Average number of corners touched	Average percentage of corners touched
1	7 89	31 6	69 5	63
2	1.84	14.8	34 8	61
3	1 17	5 6	18.5	43
4	3 16	24 5	40 8	40
5	1 39	5 1	15 5	38
6	86	7.5	16.3	32
7	68	2 1	6 5	19
8	78	4 3	7 1	19
9	99	7 3	11 1	17
10	.50	1 8	4 6	17
11	56	2 1	4 8	14
12	.49	1 5	4 6	19
13	35	0 6	1 0	03
14	.38	1 8	2.3	07
15	35	3 1	1 1	03
16	51	1 8	3 8	12
17	66	1.0	4 0	12
18	48	2 1	2 5	.07
19	61	3.3	4 5	.08
20	50	2 5	2.3	06
21	.53	0.1	4.1	.12

quiring the kinaesthetic-organic cues. We also subjoin a typical table (III) of an individual blind rat, which will likewise serve to corroborate our conclusions.

Moreover, the percentage of contacts as shown in tables II and III does not begin so high as in table I, and throughout the learning process it remains lower. This indicates that the rats were probably influenced by the previous learning of a maze. One of the most obvious factors doubtless was that the blind rats did not have to learn that there was food in the food-box. Furthermore, they were accustomed to running a not entirely dissimilar maze.

After the five normal and six blind rats had learned maze I, they were taught mazes II, III, IV, and V (see fig. 1) in succession. Our object here was to study the function of the contact sensations in making readjustments to slightly altered conditions. The same general results obtained. All rats became confused in the new situation and were forced to make a new adjustment by the trial and error method. During the period of confusion the animals fell back upon the use of contact sensations and continued to rely upon them until they reached a familiar unit in the maze. The number of contacts again varies with the number of errors made. Table III gives a typical detailed record for a blind rat.

In bringing to a close this description of the experiments, it is evident that tactual sensations of the nose and head are utilized in learning the maze, and this implies that they are used in getting the kinaesthetic and organic cues. The facts which we offer in substantiation are: (a) the percentage of corners touched, beginning high, gradually decreases as the movements of the rat become automatic; (b) a striking correlation exists between the number of contacts and the number of errors; (c) a general correlation between increase and decrease of time, and of the number of corners touched; (d) tactual sensations are no longed used when the maze is learned; (e) when the kinaesthetic and organic cue is lost at any point in the maze, the rats rely upon head and nose contact; (f) the conclusions hold for both normal and blind animals and indicate a minimal effect of vision.

As indicated, the maze used in this experiment was constructed so that the pathway could be altered in various ways. This type of construction was designed for the purpose of studying the effects of the maze experiences upon subsequent behavior in slightly altered conditions. While our experiments were concerned primarily with the function of contact sensations in learning to make adjustments to new or slightly modified situations, yet they yielded some incidental results bearing upon the former problem which are of sufficient interest to merit a short discussion.

A reference to fig. 1 will show the successive alterations effected. In maze II, door 5 was placed at 6, while door 3 was opened. Maze II was altered by placing door 2 at 3 and by opening 5.

TABLE III

SHOWING TIME, ERRORS, PERCENTAGE OF CORNERS TOUCHED, AND NUMBER OF CORNERS TOUCHED FOR RAT B, (BLIND) IN RUNNING MAZES I, II, III, IV AND V

Number of run	Time, in minutes					Errors					Percentage of corners touched					Number of corners touched				
	Maze I	Maze II	Maze III	Maze IV	Maze V	Maze I	Maze II	Maze III	Maze IV	Maze V	Maze I	Maze II	Maze III	Maze IV	Maze V	Maze I	Maze II	Maze III	Maze IV	Maze V
1	8.33	.37	.37	2 75	.83	42	2	6	31	15	61	.14	.18	.47	.36	94	5	6	45	18
2	75	83	30	.22	.20	6	6	7	2	3	41	.20	.22	.13	.33	13	8	7	4	7
3	.83	.25	.25	.67	17	4	1	4	7	3	25	.08	10	.28	37	8	2	2	12	7
4	1.08	.25	.17	25	.17	3	2	3	2	4	.30	12	.00	.26	.35	11	3	0	6	7
5	.80	27	20	.20	33	2	2	3	2	6	39	.11	12	28	.27	13	3	3	7	8
6	.50	38	17	15	.23	4	2	2	1	2	24	.21	04	11	33	8	8	1	2	6
7	.33	25	17	.17	.17	2	0	2	0	3	09	08	04	06	47	3	2	1	1	8
8	.42	.17	.25	.50	13	3	0	2	1	2	12	.04	09	.24	.23	4	1	2	5	4
9	42	.20	.13	17	.13	2	0	2	0	2	03	08	.00	.10	.42	1	2	0	2	5
10	.33	17	.13	.25	.25	1	0	1	0	5	.06	00	.00	17	.26	2	0	0	3	6
11	.75	.13	.13	20	17	2	0	1	2	2	.23	00	00	.19	31	7	0	0	4	5
12	30	.17	.25	.20	13	0	0	2	1	2	.06	08	10	.05	.46	2	2	2	1	6
13	33	.15	.17	.17	.15	0	0	1	1	5	.00	00	00	.05	.31	0	0	0	1	5
14	.30	.15	.12	.28	.13	0	0	1	0	2	07	00	00	.21	.27	2	0	0	4	4
15	.23		.13	13	25	0		1	0	4	00		.00	.00	.41	0		0	0	7
16	.17		.25	13	.17	0		1	0	2	.00		.14	.00	.21	0		3	0	4
17	.50		17	.58	13	0		0	0	2	.13		00	.04	.20	4		0	7	3
18	67		.10	.20	13	1		0	1	2	10		.00	.10	00	3		0	2	0
19	1.83		.17	.20	10	13		0	1	2	34		.00	.05	08	22		0	1	1
20	.37		.13	.50	08	0		0	1	2	07		.00	.05	.08	2		0	1	1
21	50		.08	67	10	0		0	2	2	03		00	.23	14	1		0	5	2
22	58		.25	33	08	0		2	2	1	13		.05	.17	14	4		1	4	2
23			.17	50	.08			0	0	1			00	.11	.00			0	2	0
24			.12	20	.13			0	0	2			.11	.00	14			2	0	2
25			08	.17	13			0	0	1			.00	.11	.16			0	2	2
26				.17	.20				0	3				.00	.22				0	4
27				.17	25				1	2				.05	20				1	3
28				.20	.12				1	2				05	08				1	1
29				.17	.08				0	2				.00	.00				0	0
30				.13	.08				0	2				.00	00				0	0
31				.13	.08				0	1				.00	.00				0	0
32				17	.08				0	2				.00	.00				0	0
33					.07					2					.00					0
34					.08					2					00					0
35					.08					2					00					0
36					.08					2					00					0

This third maze was altered by placing door 4 at 5 and by opening 2. The fourth maze was changed by placing door 1 at 2 and by opening 4. Several important features are to be noted in this series of mazes. (1) Mazes II and III merely shorten successively the true pathway of maze I. The object here is to observe the process of learning to short circuit a familiar path. This short circuiting is not optional on the part of the animals, inasmuch as the former roundabout path has been blocked by the insertion of sliding doors. (2) In mazes IV and V, the animals are forced to enter former blind alleys at the end of which they find themselves upon the old familiar path. (3) All five mazes possess a common or identical true pathway at the beginning and at the end. The mazes differ from each other only in the middle portion. Each maze differs from the preceding one only in one respect, so that each succeeding maze requires the animals to make but one new adjustment. This position may be termed the critical point. In mazes II and III the rats travel the habitual path for a certain distance and then are forced by a short cut to strike the old path which they can follow to the end. In mazes IV and V, the animals travel at first over the old path; from this they are forced into a blind alley at the end of which they emerge again onto the old path. In describing the rats' behavior in making these adjustments, we shall need to refer to these three parts of the pathway.

These mazes were graded for relative difficulty in learning in the following order: I, II, IV, III, V. By relative difficulty we mean the order of difficulty which would be encountered by animals with no previous maze experiences. This order was not determined by actual experiment, but was based upon judgments of their apparent complexity. That mazes III and V are much simpler than maze I is evident at a glance.

The actual order of difficulty encountered in learning them successively was V, IV, III, I, II. This fact is illustrated by table III, the results of which are typical for all of the rats used. This order is almost the reverse of that of their relative complexity. In the successive learning of a series of similar mazes, it is evident that previous experiences are effective upon subsequent behavior and that these effects are advantageous or disadvantageous according to circumstances.

As one would expect, the animals ran over the first identical portion up to the critical position without error or hesitation. Evidently their previous learning of this path is of service in the altered maze. As a rule the animals did not make an immediate adjustment at the critical position but ran on over the old path until they found the pathway blocked. This blocked pathway forced a readjustment of the trial and error sort. In this process the rats tended to confine their explorations to the old pathway, running back and forth between the inserted door and the entrance of the maze. The old habits thus tended to confine and limit the exploring activity within certain channels. This limitation of a free and wide excursion of adjustive trials operated to postpone the successful chance adaptation at the critical turn.

On emerging upon the true path after making the successful adjustment, the rats never picked up the cue immediately. The old habit was never reinstated until several alleys were traversed. In the majority of cases the rats left the true path at the first opportunity. The significant feature of their behavior at this point consists in the fact that this deviating turn is generally in the same direction (relative to the rat) as that of the turn which the animals would have made in the previous maze after passing the critical point. A detailed description of their behavior will illustrate this proposition. In maze II, the animals are forced by door 6 into alley 5. Instead of turning to the right immediately, they ran on to corner h and turned to the left. This leftward turn is the normal behavior at corner 5 in the previous maze. In maze III, the critical position is at door 2. Formerly the animals made a turn to the left at this point. After passing through door 2 the rats often attempted to turn to the left and were forced up alley j. This type of behavior did not obtain in the majority of cases. In maze IV, the previous path through 2 and down alley d was closed by the door at 5. The animals had learned to turn immediately to the right after traversing this alley. After emerging through door 4, this persisting tendency to turn immediately to the right led the animals into one of the blind alleys rather than into alley h. In maze V, the rats were forced to substitute the alley leading to door 1 for alley k. Almost invariably the animals turned to the left after emerging through door 1 just as they had habitually done at the corner k. The old habits acquired in the first part of the maze thus operate disadvantageously in learning similar mazes by tending to prevent the animals from picking up the true path after emerging from the critical part. This disturbance was the most pronounced and persistent in the case of the fifth maze.

After the animals once succeeded in picking up the old familiar path, they almost invariably ran the rest of the maze without error or hesitation. Evidently the presence of a common portion constituting the last part of all the mazes is a highly advantageous feature.

Since each maze differs from the preceding one in but one respect, the question arises as to why the successive adjustments should vary so enormously in difficulty as is evident in table III. The determining conditions are probably very complex though some of the factors were evident from the animals' behavior.

1. Other factors being equal, that maze is the easiest in which the critical position is placed nearest to the entrance. Since the last common portion operates as an advantage, the longer this part the easier should the maze become. In making the readjustment, the animals run back and forth over the first common portion. Evidently the chances of making the correct adjustment is favored by a short runway. The shorter is this segment, the more is their activity centered around the region of the critical position.

2. The adjustments which involve entrances into former *cul de sacs* are more difficult than those which involve a short circuit. The truth of this proposition is evident in table III, and the reasons therefor are obvious. An entrance into an alley which has been effectively eliminated involves a greater violation of past habits than does a mere deviation from the accustomed path. In the latter case there is also present the enticing possibilities of a novel stimulus.

3. The difficulty is increased in proportion to the distance beyond the critical point at which the former path has been blocked. In maze II the path was blocked at 6 while the opening was at 5. On being stopped at 6 the rats explore around in this vicinity before starting back at full speed and as a consequence it was an easy matter to chance upon door 5. In maze III the path was blocked at 3 while door 2 was open. On encountering the closed runway at 3, the animals investigate for

a while in that vicinity, and then run back and forth between this point and the entrance, stopping here and there to investigate. The chances of discovering the open door at 2 seem to be minimized in proportion to the speed of running at this point. At least, stopping to investigate in this region is more likely to lead to successful results than will high speed. In maze III the rats tended to run rapidly by the opened door and it thus escaped their notice. If the path had been so blocked that the rats were forced to stop in the immediate vicinity the chances for the detection of the opened door would have been increased.

Since all of the mazes were identical except for the critical portion in the middle, it is surprising that this one act of adjustment should be so difficult in comparison to maze I which was learned *de novo*. The first maze presents a whole series of critical positions while each succeeding maze presents but one. Viewed in this light, it seems that the disadvantages of the old habits rather overshadow their advantages.

The difficulty of short circuiting even under the most favorable conditions as in maze II is rather surprising. In all probability much poorer records would have been made if the short circuiting had been optional rather than compulsory. It would seem that the animals are guided but little by the smell of their own path.

The fact that the removal of doors 2 and 5 at the end of a runway failed to attract the rats' attention indicates that these animals do not rely to any great extent upon stimuli coming from impending walls in order to negotiate a turn. This fact harmonizes with Watson's contention that these turns are negotiated mainly upon a kinaesthetic and organic basis. In this connection, however, it was noted that the blind animals ran into the doors used to block the old path with more strength and persistence than did the normal rats.