THE WHITE RAT AND THE MAZE PROBLEM
II. THE INTRODUCTION OF AN OLFACTORY CONTROL[1]

STELLA B. VINCENT
Chicago Normal College

What part has olfaction in the life of a rat? The answer to this query would have to be based upon what we know of brain structure and from our casual observation of rat behavior, since, there has been very little direct experimentation published that has as its main concern this form of sensitivity.

The rat has well defined olfactory lobes and tracts. But these parts are relatively smaller than those of some other rodents and decidedly smaller than those of some other mammals. The olfactory paths in the brain of the rat have not had much study and we are thrown back, therefore, upon what we know of the life and habits of the animal for the answer to our question.

It might be thought, from watching the reactions of the rats in the maze, that smell was a very important sense. The frequent sight of a rat lifting itself on its hind feet and sniffing vigorously, the constant use which it makes of its nose on the floor and sides of the maze, would lend credence to such a supposition Yet it has been shown that anosmic animals are under no serious disadvantage in learning the maze and that much of this sniffing and apparent smelling has an important tactual function. What the world of odor is to a rat we have little power of conceiving but how it affects the behavior we may somewhat discover.

The odors which are vital in the animal world are, presumably, food odors, sex odors and body odors. By the term body odor is meant those olfactory qualities which perhaps are peculiar to individual animals but which certainly characterize the animals of a single cage or group. By differentiation from this familiar

[1] This work was done in the Psychological Laboratory of the University of Chicago. I am greatly indebted to the department for the opportunity to do it and to professor Carr for suggestive help and criticism of both experimentation and paper.

odor it serves to mark off a strange animal or give warning of an enemy

Rats are omnivorous and hence there can be slight necessity for any fine discrimination in the way of foods. A generalized response to food odor will be all sufficient. I have, indeed, never seen in white rats any clear discrimination of foods which might be said to depend upon smell and have failed to find any mention of such power by others If food be introduced into a cage unobtrusively, a rat usually stumbles over it before discovering it. It might be supposed that blind and normal rats would show different behavior in food seeking, yet in some preliminary experiments covering several weeks, the food in every instance, by both normal and blind rats, was apparently found accidentally. The animals were very tame and were very hungry. The food used was nuts, cheese and milk soaked bread. The experiments, although significant, were too brief to be conclusive. The instances which Small[2] cites of the reactions of very young animals to different odors may clearly depend upon the chemical sensitivity of the mucus membrane of the nostrils and must be sharply distinguished from olfaction proper. Professor Watson,[3] however, found that blind animals, otherwise normal, were affected by odors to which anosmic animals failed to respond. To repeat, smell is more closely associated with food getting than is any other sense; yet it may be safely assumed, and we should expect to find, that the sense is less refined in animals which do not pick and choose their food than in those which do

If a rat from another group is introduced into a cage containing other rats they "nose" the whole body of the stranger. The rats do not appear to get the odor across the cage for the excitement and characteristic actions begin only with contact. Rats also respond by different behavior to strange handling No doubt a large part of the excitement is due to different methods of lifting, etc.; but after the emotional disturbance is allayed the "nosing" of the hand seems to indicate an odor stimulation also. The power to follow a trail is usually supposed to depend upon slight traces of body odor which remain upon the path which

[2] Small, W. S. Notes on the psychic development of the young white rat. *Am. Jour. of Psych.*, **11**, 89.

[3] Watson, J. B Kinaesthetic and organic sensations, etc. *Psych. Rev Mon. Sup.*, **8**, no. 2, p. 65.

an animal has taken. Animals which do not prey upon others for food have little need for tracking Experimentation has failed to show such ability in these animals.

Sex odor calls forth specific behavior. This odor, however, does not seem to carry from cage to cage even though the cages are placed side by side. Efforts to establish the tracking of one sex by the other have been made[4]. Watson said he found no good evidence of tracking but that adult rats showed preferences for entrances that contained the odor of the opposite sex.[5] Small insists that he had no evidence to show that the males followed their own tracks or those of other males or that females followed the tracks of the males.[6] Possibly these attempts have not been made at the right periods; at least the results are inconclusive.

How well rats or other animals can localize odors is still an open experimental field as is also the possibility of olfaction functioning in giving distance values.

The object of this work was to see whether an olfactory control could be introduced into the learning of the maze, and, if it could be, to discover how it would affect the learning process as compared with other forms of control

The modified Hampton Court maze was used, the same one which served for the experiments with vision.[7] Before beginning the work, the inside of the maze was heavily coated with white enamel paint to cover and to destroy any previous odors, and upon the floor of all of the runways were laid long strips of heavy white paper. The paper was cut 4 in. in width and where the strips overlapped they were fastened with gummed paper. Upon this papered floor was rubbed in, down the center of the runways, a narrow trail of alternating beef extract and cream cheese. It was thought better to use two substances in order to guard against a possible olfactory fatigue. The trail was laid upon paper because of the ease with which such a covering could be removed in varying the experiment and because of a desire to avoid a permanent odor in the maze.

The rats used in this work were young, untrained rats about

[4] Watson, J. B. Animal Education, p. 51.
Small, W. S. Experimental study of the mental processes of the rat. *Am. Jour. of Psych.*, **12**, 232.
[5] Op. cit., p. 53.
[6] Op. cit., p. 213.
[7] Vincent, S. B. Vision in the maze. *Jour. Animal Behav.*, **5**, 1.

90 days old. They were fed in the maze and handled for a week preceding the beginning of the real work. During the experimentation they ran the maze three times a day under the stimulus of hunger and were amply fed at the conclusion of each day's work. The first experiment was one in which the trail was laid in the true path in the maze and not in the *cul de sacs*.

EXPERIMENT I. Olfactory Trail in True Path

1. Behavior

The behavior in this experiment will be described somewhat in detail since it is significant. There was none of the wild running seen in the usual maze reaction When put in the box the rats were at once attracted by the odor. Their little noses went down to the trail and they began to follow it immediately. They moved along in a jerky fashion stopping occasionally to smell and to lap the trail with their tongues. This manner of running made their progress an exceedingly slow one. Both the cheese and the beef extract which were used were diluted with water so that there was but a very slight trace of the food on the paper. Still the animals may have obtained some satisfaction in lapping, but such gratification must have been very limited. In general the rats lingered longer over the cheese than over the beef extract trail. The odor was probably stronger. They often hesitated at the places where the trail changed from one substance to another and sometimes struck the "back" or "home trail" here. These returns only now and then resulted in an entrance into a blind alley. They usually ended where the trail changed again. The maze is so constructed that the food box is in the center. When in use, there is always food in this box which the animals are encouraged to smell before the beginning of the experiment and which furnishes their reward when they reach the box at the end of their run. The true path passes directly by the side of this box. (See "Vision in the Maze," Fig. 1.) In the normal maze the early runs are always broken at the food box which the animals have to pass in the center of the maze. The food odor is stronger here and they bite and claw and scratch in a futile endeavor to end the quest at this spot But notwithstanding the marked early influence of the odor of the food box this behavior, in the normal maze, is very quickly abandoned.

Long before the rats cease to enter the *cul de sacs*, before any of these errors are entirely cut out, the loitering at the food box is no longer to be seen. It only thereafter occurs in exceptional cases where an animal is entirely lost and as a consequence is in a disturbed and emotional condition in which all the old errors reappear. The behavior of the animals following the odor trail, on the contrary, although similar at the food box was more persistent than any "off trail," blind alley error. The odor, it will be remembered, was that of the food with which they were accustomed to be fed Perhaps the previous stimulation of the olfactory trail had made the animals more susceptible to this influence. But whether, as a result of following a food odor trail, all food odors attracted the attention more, or whether this stronger food odor represented the natural instinctive ending of a food trail and thus called a halt, these are questions for thought. Either or both positions are plausible.

Whatever the cause of this behavior, as a result of it, the speed in all of the early trials was slower than that in the normal maze; but by following the trail the animals were kept in the true path so that the errors were greatly decreased in both the initial and in the succeeding trials.

2. The Tables

Table 1 shows, side by side, the records for the first twenty-five trials in the normal and the olfactory mazes. Figs. 1, 2, and 3, show the curves plotted from these records. These curves are not made like those shown in "Vision in the Maze" because in the olfactory maze the learning period covered less than ten trials and was practically uniform. The units used in plotting were one trial, one minute and one error. Since it was the following of the trail in which we were interested, the error consisted in leaving the track. Returns were not counted and this fact makes these curves comparable with those made for the black-white maze where the returns could not be counted.

The results of this experiment show an increase in accuracy, both initial and total, over the normal maze and an increased final speed. We will consider first the facts which bear out these assertions as to accuracy.

3. COMPARATIVE ACCURACY

As the table shows, in the first trial, these animals in the olfactory maze averaged only 4.5 errors as compared with 14.7 made in the normal maze. Thus the initial accuracy was three times as great. The final accuracy was greater also The olfactory maze shows .04 average errors per trial for the last five trials while the normal maze has an average error of .1 per trial for the same five runs The total number of errors per animal in the olfactory maze is only one-third that of the animals

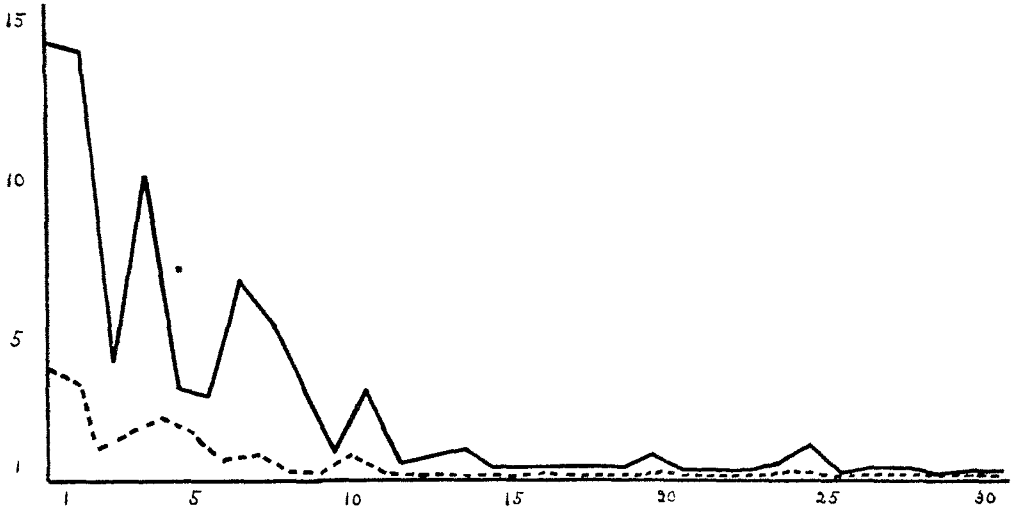

FIGURE 1 Time and error curves for Experiment I Olfactory trail in the true path. Full line time, dotted line errors.

in the normal maze. The error curve, seen in Fig. 1, bears out all of the above statements. Its chief features are the low beginning height, and hence slight fall, and the almost complete low level which it maintains after the twelfth trial. A comparison of the error curve of the normal maze with this will emphasize these facts better than words

4. SPEED

The time per run for the early trials was less than in the normal maze as may be seen from the table but this was entirely owing to the fact that there were so few errors. The actual speed was much slower. In the first trial they averaged only 4.5 errors per animal yet the time average is 13.5 minutes. The record for the second trial is practically the same. Almost the same average number of errors, 4.1, was made by the normal animals in the fifth trial in an astonishingly shorter time. For the first trip without error these rats had an average time of 160 sec. The time record for fifteen rats in the normal maze for the first perfect trip is less than one-fifth of this—30 sec. In final speed, however, these animals excel. This maze has an average record of .28 min. for the last five trials as against .31 min. for the normal maze. This is a difference of nearly two seconds—an appreciable difference when one remembers that the maze can be run in ten seconds.

The time curve (Fig. 1) is very unlike the usual time curve. Compare it with Fig. 3. It is not the beginning height which is remarkable but the persistence with which it maintains this level—the slow rate of elimination of the surplus time. Forty-seven per cent of the surplus time was eliminated in the normal maze in the second trial, in the olfactory maze only 2.5% was eliminated at this time; 80% was eliminated in the first four trials in the normal maze, but it took the rats in the olfactory maze nine trials to reach this point. By the tenth trial the animals in the normal maze had only 2% surplus time left to eliminate, but the rats in the olfactory maze did not fall permanently below this 2% point until the twenty-fifth run.

It must be clearly evident that this olfactory trail was affecting the learning process but before any definite conclusions were drawn it was necessary to put the trail in the *cul de sacs* instead of the true path and to see what would happen then.

EXPERIMENT II. TRAIL IN *CUL DE SACS*

1. Behavior

This experiment was conducted exactly like Experiment 1, with animals of the same age, etc. The only difference was in the trail which was laid from the entrance of each *cul de sac* to its extreme end. There was a noticeable difference in the numerical results as well as in the behavior under these conditions.

The animals in this maze also made fewer errors from the beginning than the animals in the normal maze and the speed was greater also. When put in the maze the rat ran, as in the usual maze, headlong down the runways. Soon he blundered

TABLE I
RECORDS OF THE FIRST 25 TRIALS, TIME AND ERRORS, OF RATS IN NORMAL AND OLFACTORY MAZES

Trial	Average Time in Seconds per Trial			Average Errors per Trial		
	Normal	Olfactory trail in true path	Olfactory trail in errors	Normal	Olfactory trail in true path	Olfactory trail in errors
1	1804	820	991	14 7	4 5	9 6
2	966	800	463	11 9	4	5 6
3	1043	224	598	10 4	1.1	7 3
4	847	609	331	7 4	1 6	5 3
5	231	175	49	4 1	2	2
6	192	165	54	3 5	1 5	1 8
7	64	376	30	1 6	6	1 1
8	49	295	27	1 4	8	5
9	37	178	37	1 5	3	5
10	32	52	22	1 1	3	1
11	26	155	30	7	6	1
12	25	29	36	4	3	3
13	31	35	32	1	1	1
14	20	52	21	3	8	0
15	32	27	45	6	3	0
16	46	26	83	7	1	1 1
17	44	24	97	5	0	3
18	51	25	173	6	0	2 1
19	40	23	150	1	0	8
20	32	39	177	2	1	1 1
21	31	29	94	2	1	7
22	26	32	262	0	3	1 7
23	17	32	117	0	3	.8
24	19	37	107	1	0.	.8
25	22	76	147	0	0	7

TABLE II
TABULATED STATEMENT OF THE RESULTS IN THE THREE MAZES

	Normal Maze	Olfactory trail in true path	Olfactory trail in errors
Average time of learning	12 1 ±3.6 trials	8 1 ±2.4 trials	7 3 ±3.8 trials
Average time of the first five trials	16 3 ±6 7 min	8 7 ±3 9 min	8.1 ±5.2 min.
Average speed of the last five trials	.31 ± .05 min.	.28 ± .08 min.	.47 ±.08 min.
Total surplus time	93.9 min	64 98 min	66.45 min.
Average errors first trial	14.7 ± 7.7	4.5 ± 3	9.6 ± 6.8
Average errors in the last five trials	.1 ± 14	.04 ± .04	.44 ± .21
Total average errors per animal	66.6 ± 16	20.5 ± 5.6	52 1 ± 12
First run without error .	8 3 ± 3.1	6 3 ± 2 8	7 5 ± 1.8

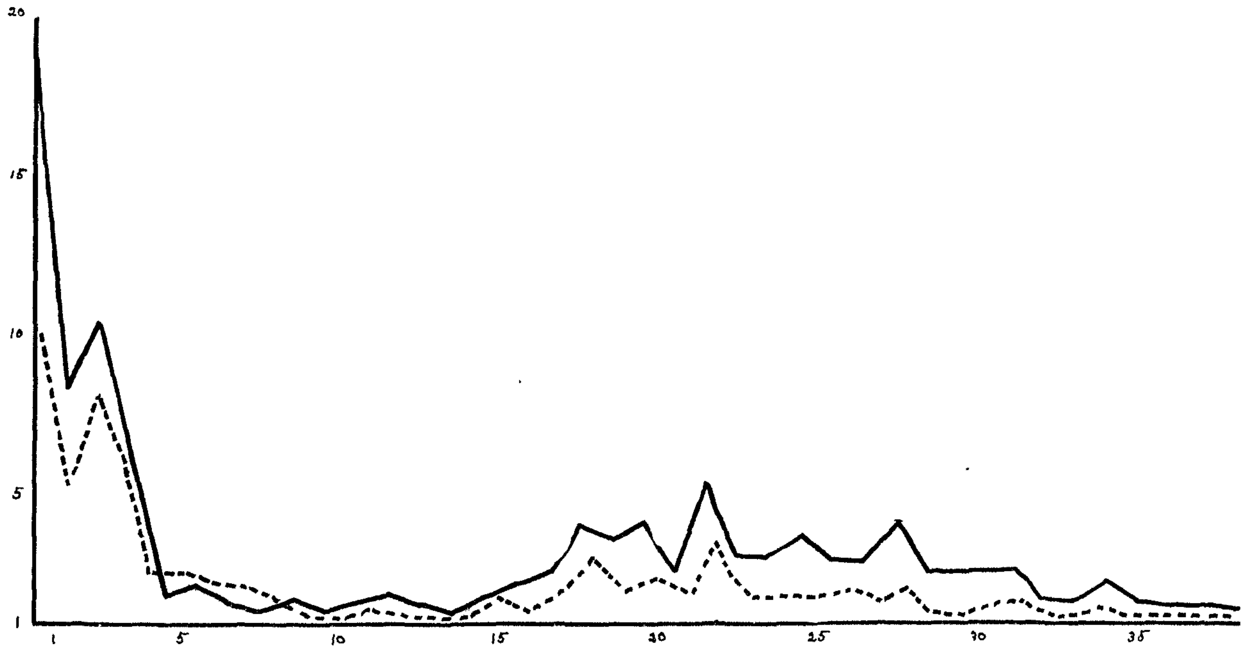

FIGURE 2. Time and error curves for Experiment II. Olfactory trail in the *cul de sacs*. Full line time, dotted line errors

into a *cul de sac* and down went his nose to the trail which he followed for its entire course, to the end of the alley. He moved along by jerks, as described before, and when he reached the end, he turned and in the same irregular, slow, halting way returned to the entrance of the alley. Between the *cul de sacs*, he ran; but when in them, slow movements were the rule. As a result more time was spent in a single *cul de sac* than had been the case in any of the other experiments. Still, from the first, these excursions from the true path were lessened in number as compared with the normal maze. The blind alleys seemed to be marked for the animal in some way. He began to go less and less deeply into them and finally, as he was running more and more confidently in the true path, I have seen him, time and again, actually thrown back on his haunches if chance running flung him into the entrance of a *cul de sac*. Or, he might be running quickly, swerve into an entrance, and there would be seen an instant decisive turning the minute he struck the trail It looked like a real discrimination. Surprisingly enough, however, after the problem was learned, and the animal was making 90% correct trials, these errors began to reappear and it took almost as long to get rid of them the second time as it did the first. The meaning of this will be discussed later. There were many more returns in this experiment than there were in the one where the trail was laid in the true path—five times as many in the first trial. It was a long time before the rats learned to pass the food-box without lingering. The numerical results for accuracy confirmed the conclusions drawn from the observed behavior.

2. Comparative Accuracy

Under the conditions of this experiment, the accuracy was decidedly greater than in the normal maze in the first fifteen trials. If we now make a comparison with the other olfactory experiment, we find that more errors were made in the first nine trials than were made by the animals which followed the trail in the true path but that the next six trials were more perfect. From the fifteenth trial on, the accuracy was far less than in Experiment 1, or in the normal maze, and it was only toward the end of the experiment, that it again approached their standard. The curve (Fig. 2) shows this variation exactly. The total average number of errors per animal was 20% less than in the normal maze but the animals made two and one-half times as many errors as their brothers in the experiment where the trail was in the true path. The learning time was actually shorter than in Experiment 1 There is so little difference, however, that it may be a matter of chance. The conditions, as a whole, were very favorable for learning as compared with the normal

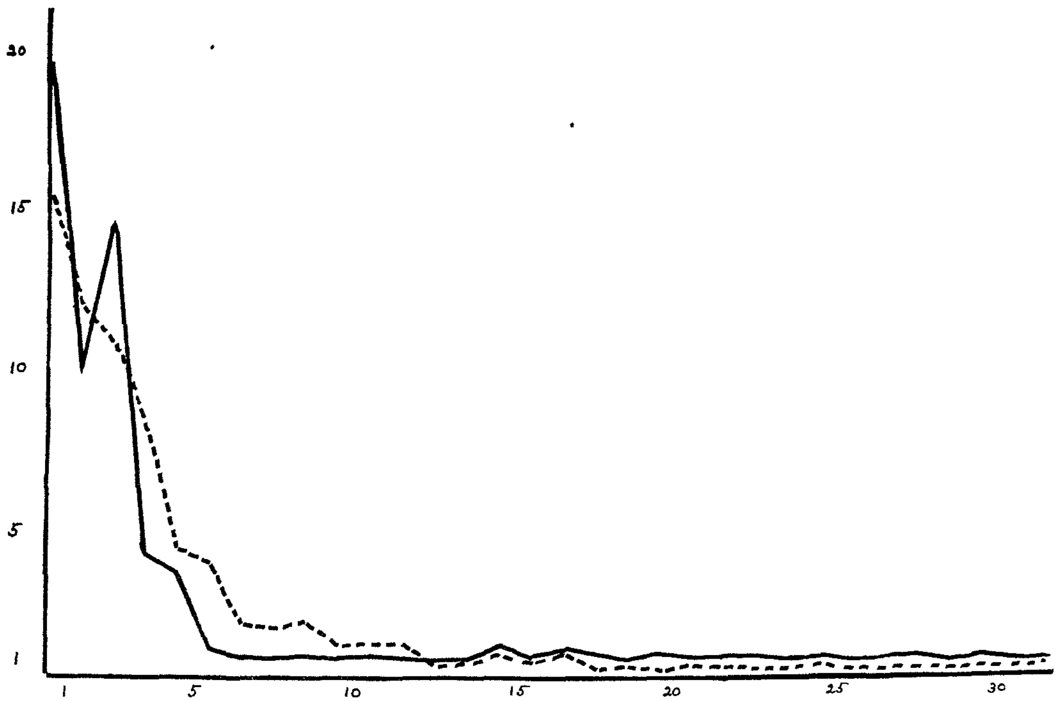

FIGURE 3 Time and error curves for normal maze. Full line time, dotted line errors.

maze and scarcely less so than those in Experiment 1, where the trail was in the true path. It seems fair to conclude, therefore, that these conditions did affect the accuracy, and in general favorably, but that there was a variableness in the final reactions which will require explanation.

3. COMPARATIVE SPEED

The speed in this maze was quite comparable with that in the normal maze except when the rats were in the *cul de sacs* and, because the errors were so few. the slowness in these places placed the animals under only a slight disadvantage. The running was much more rapid than that reported in Experiment 1. The figures in Table 1, giving the time per trial, do not show this since the data for the total distance is lacking. In the first trial in Experiment 1, there was an average of 4.5 errors and 1 return. The animals did not go to the end of each *cul de sac* and the returns were only partial. In this experiment, with trail in *cul de sacs* in the first trial, there was an average of 9.6 errors and 5 returns per animal. The larger proportion of these returns were home returns and the *cul de sacs* were explored to their farthest limits According to these figures the time should have been three times as long in the latter case had the speed been comparable, instead of which it is practically the same (See Table 1). From this we should conclude that the speed was three times as great in the first trial in Experiment II as it was in the same trial in Experiment 1 where the trail was in the true path. There was a variability of speed in the middle part of the experiment which clearly depends upon the increase in errors. (See the curves Fig. 2). The average speed of the first trial without error may be taken as a point of comparison as we do not possess the figures for the total distance. The normal maze gives us an average of 30 sec. for this trial, the maze with the trail in the true path 160 sec., and this one 28 sec. At this point, then, in this experiment, we have a speed which is quite as fast as that in the normal maze. The final speed, however, within the limits of the experiment, was less—47 min. (See Table 2). Whether longer experimentation would have developed a speed equal to that in the normal maze, or whether the conditions would always have mediated against it is a question for discussion.

EXPERIMENT III. TRANSFER OF TRAINING

This experiment was the crucial one. The conduct of the rats had been affected by the olfactory trail in the maze, the learning had been aided, but had the animals really gained anything which they could carry over to another problem? Was an olfactory control so well established that it could be utilized in another situation? It was determined to take the animals, at the conclusion of Experiment 1 on the maze, over to a problem box This box had three runways, leading from a common entrance, and they terminated in a food-box. The paper trail, some of the original paper from the runways, could be laid along these runways, changed in irregular order, and the rats tested here. Before taking them to the box, however, after the conclusion of Experiment 1, the paper was entirely removed from the maze and the rats given one trial each on the maze itself. They made perfect runs showing no hesitation whatever. They did not seem to miss the paper at all and even incorporated in the runs a slight "slowing up," as had always been the case at the places where the trail changed from beef extract to cheese. Evidently the control had become kinaesthetic. The question we had to face now was this: Had the olfactory experience persisted notwithstanding the change of control.

The rats were now taken over to the box. The first trials here gave entirely negative evidence. The olfactory trail might as well have been absent for all the attention which the rats gave to it. The path with the trail was only taken on an average of six times out of twenty trials. The next morning the animals were tried again and then it was seen what they were doing. No matter where the trail was laid, they were always making a straight run to the left and down the runway on the left side. Now this was just their first run in the maze. Clearly kinaesthesis was at the helm and olfaction had retired from the engagement It was necessary, therefore, to arrange conditions such that the opportunity to make this run to the right or to the left should be done away with—a condition in which *position* so far as possible should be eliminated.

A long rose box, about three feet in length was procured from a florist and in its end were inserted long, heavy, pasteboard mailing tubes. These tubes just filled one end of the box. They were lined with paper taken from the maze and one tube contained paper on which was the trail In the experiment the tubes were alternated according to an irregular schedule. For the next few days the rats were tried out in this box. When they were put in at the end farthest from the tubes they immediately ran down to these exits. The two openings were side by side, there was no chance to turn, and in fifty trials they made 90% correct choices: i. e., they followed the trail nine-tenths of the time. While sitting in front of the tubes the rats could smell either one indifferently so there was usually a momentary hesitation at the entrances and then a dash into one or the other. Sometimes the head was put in tentatively and then came the sudden run through or the withdrawal. The experiment showed, conclusively, that the olfactory experience had been retained and that it could be utilized again. It also showed that the reaction to the original problem had become a matter of habit and that so strong and powerful was kinaesthesis that the removal of the sensory factors which helped to establish it had no effect upon its control When later the animals were confronted with a problem where turning to the right or to the left was possible the response was in kinaesthetic, or tactual-motor terms. But when the possibility of runs and turns were cut out the effects of the olfactory learning and experience were asserted in a perfectly effectual way. That this was not due to any attractiveness of the trail in itself is shown by Experiment IV

EXPERIMENT IV ANOTHER TRANSFER

This was the discrimination test for Experiment II. The same box and the same method was used as in Experiment III. Under these conditions the animals had to choose the path where there was no trail. They did this just as consistently as the others making just as good a record and confirmed in all points the conclusions drawn from Experiment III. The details are not needed here.

DISCUSSION AND CONCLUSIONS

Whatever may be true of rats in their native environment, we agree with Small,[8] that these animals do not usually follow a path in the maze by means of scent; yet, as these results show, they can do so. The evidence here is also against Professor Watson's statement that "Olfactory sensations have no rôle in the selection of the proper turns in the maze.[9]" This assertion may be quite true of work on the maze as he used it, but certainly olfaction, in the experiments reported in this paper, helped to cut out the errors. Although we have seen no signs of instinctive tracking, these animals will follow an odor trail on first trial and can learn to follow an olfactory trail or to avoid such a trail. If a maze problem presents such a trail the result is an initial

[8] Op. cit., p. 232.

[9] Kinaesthetic and organic sensations, etc., p. 91.

and total accuracy which is greater than normal although the final accuracy, when the trail is in the *cul de sacs*, is less. The learning time is also shortened We should therefore say that such an olfactory control distinctly favors accuracy.

How shall we explain this increased accuracy? Was it a result of real sensory discrimination? It can be explained, as the results in the black-white maze were explained, as being due to the dominance of some particular stimulus. A path, out upon which an animal first runs in a maze, if not alarming, becomes a familiar place—a home place. There may afterward be other such places in the maze, but this is the first one. He runs out from here, returns, goes a little farther, etc., but always with the possibility of the home return. In Experiment 1, the path was associated with a strong odor trail. Departure from this was to go into the unfamiliar and strange. Thus from the first the animal had more of this stimulus and it became increasingly familiar and increasingly dominant. Dominance, as a term here, may be explained in one way as the power of the familiar. It may have other explanations. Rats are seemingly possessed with an instinctive curiosity or tendency to explore; but fighting against this is an innate tendency to keep in familiar or known situations. The familiar or known situation in Experiment 1, was near the odor trail; in Experiment II, it was away from it. If we accept this view the odor stimulus would be powerful enough to keep an animal in the true path if it arose from this path or to keep it from the blind alleys if it lay there. It would work both ways. It would do so by holding the attention to the true path or by catching the attention and so serving as a warning when the animal strayed from the path. The errors would be lessened in either case.

There were actions, however, which seemed to show that this behavior was more than a mere passive affair. I take it that an instant response to a stimulus, when not instinctive,—a response which can be learned and which can be varied, now positively and now negatively—involves discrimination. There was none of this seen in the black-white maze. There was such behavior here. If this be the case, while the first explanation may be a true and a reasonable one, the increased accuracy here was partly, at least, a result of discriminative ability.

There was an increase of errors in the middle of the learning period in Experiment II, and some slight evidence of the same thing in Experiment I. (See curves Fig. 1 and 2).

The only interpretation I can offer is this: It was the result of the changing sensory control. The initial control was dominantly olfactory· but with repeated trials the kinaesthetic experience grew and strengthened and finally began to come into its own. The running became easy and rapid and the accuracy was becoming habitual. Attention, now being released from the control of the movement, was free to be attracted by the olfactory trail in the *cul de sacs* and errors became more frequent. The final elimination may have been, and probably was, a relearning with kinaesthesis more firmly established. But besides accuracy there is also speed to consider.

The conditions of the two experiments give results which differ radically here. As compared with the normal maze, Experiment 1 showed slow initial speed and quick final. Experiment II showed quick initial speed and slow final. Let us first discuss Experiment II.

There is no need to take much time here to discuss the speed in Experiment II. The true path resembled that of the normal maze and the beginning speed was comparable. The slower final speed was a result of the increase of errors. The variable curve seen in Fig. 3 has the same explanation But let us turn to Experiment 1, where the facts are better seen.

Olfaction has two uses. First it functions as a distance sense. The reaction in this case is always running—toward food, away from danger. The second function is associated with food-taking. Olfaction is so intimately associated with food-taking that, in man, taste and smell are difficult to disassociate. The point which is here to be emphasized is that when the second of these functions is set up in animals in connection with food it inhibits the first. It seems probable that olfaction furnishes animals with a more accurate criterion of distance than it furnishes man and that the nearness of food, with the consequent increased intensity, is the stimulus for the food-taking reaction and the running ceases or slows up. The one response is anticipatory, as Sherrington says,[10] the other consummatory. The one is a somatic reaction, involving the whole body, the other is visceral and confined to certain organs and segments.

[10]Sherrington, C. S. Integrative action of the nervous system.

If we now attempt to explain the slowness of the reactions of the rats in the maze in Experiment 1, there are several possible interpretations: First, the slowness may be due to the fact that the odor of the food box which served to initiate the reaction is swamped, overpowered, by the nearer, more potent odor of the trail; or, second, that attention is divided between the two and hence we have the characteristic behavior; third, it may be that the pleasurable feeling set up by the odor of the trail is in itself a deterrent and results in loitering; or fourth, it may be that the nearness and strength of this stimulus does initiate the preliminary instinctive food-taking reactions which of themselves end or modify the distance reactions of running.

As one observed the behavior in the initial trial, there did not seem to be any emotional excitement which would suggest the inhibition of running through conflicting motor tendencies and hence the second explanation is discredited. That the trail odor was the predominating one in the first trial seems probable and that it was also pleasurable. The satisfaction of hunger at the end of this trial, however, must, in all succeeding trials, have played a large part and made the original trail a different more intense, more stimulating trail, a somewhat else, *viz.*, a trail which ended with this satisfaction. Yet still there was the loitering and slow movement through all of the early trials which would lead us to think that the fourth supposition may be a reasonable one. Why, then, did this behavior alter in the later trials? Because of the organization of the whole response into an habitual motor series which only required the odor for the initiation and possible reinforcement of the act. The more rapid final speed, which exceeded the normal, may have been caused by the reinforcement of the kinaesthetic control, now established, by the olfaction of the trail.

Miss Richardson says,[11] "Olfaction may accelerate or retard the learning process; accelerate when the odor is a part of the stimulus connected with the problem—otherwise be disadvantageous." It is easy to conceive that it may have the same effect upon the actual rate of running—that it may result here in a genuine acceleration of speed.

While the main purpose of this work was to establish and to

[11] Richardson, F. R. A study of sensory control in the rat. *Psych. Rev. Mon. Sup.*, **12**, no. 1, p. 68.

study the effects of an olfactory control in the maze, one of the most interesting features of the results was the proof of a transfer of training. So far as the writer knows there has not been shown before in the animal world, at least in such a graphic way, this change of sensory control from one form to another within a single learning process.