THE LEARNING BY WHITE RATS OF AN INCLINED PLANE MAZE

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PROBLEM

In the analysis of sensory cues operative in maze learning by the white rat attention has been given mainly to the various extero-ceptors. The Chicago laboratory in particular has been occupied with this type of investigation. Is vision essential to this animal's mastering a labyrinth; is sound; is smell? Or are these each of partial value only, and especially in the initial stages, before the control of the movements passes over to the proprio-ceptive system? The various angles of this work need not be gone into here. The essential point is that it was all done with mazes in the usual horizontal plane; and the isolation of the proprio-ceptive (and intero-ceptive) cues was had by the operative or the experimental elimination of the extero-ceptors.

In the present experiment the purpose was to isolate the proprio-ceptive (and intero-ceptive) functions by setting a problem that could be learned only by these. Visual cues were systematically cancelled, auditory clues were *nil*, olfactory were found by special tests to be inoperative, and tactual were inferentially inoperative (a note on this *infra*). The one type of stimulus offered as cue for mastering the maze was inclination of the maze from the horizontal, the problem being for the animal to learn to run up-hill instead of down-hill or on the same level.

APPARATUS

A simple maze was constructed of wood, 36 inches square with four alleys 4 inches wide, and with 5-inch partitions, painted dead black throughout (see fig. 1). A choice chamber was located

at the center of the floor with all alleys leading to or from it. The subject, after entering, passed along the entrance alley, *E*, to this choice chamber, *CC*, where it was presented with the alternative of following into the alleys, *A*, *B*, or *C*, or returning to *E*.

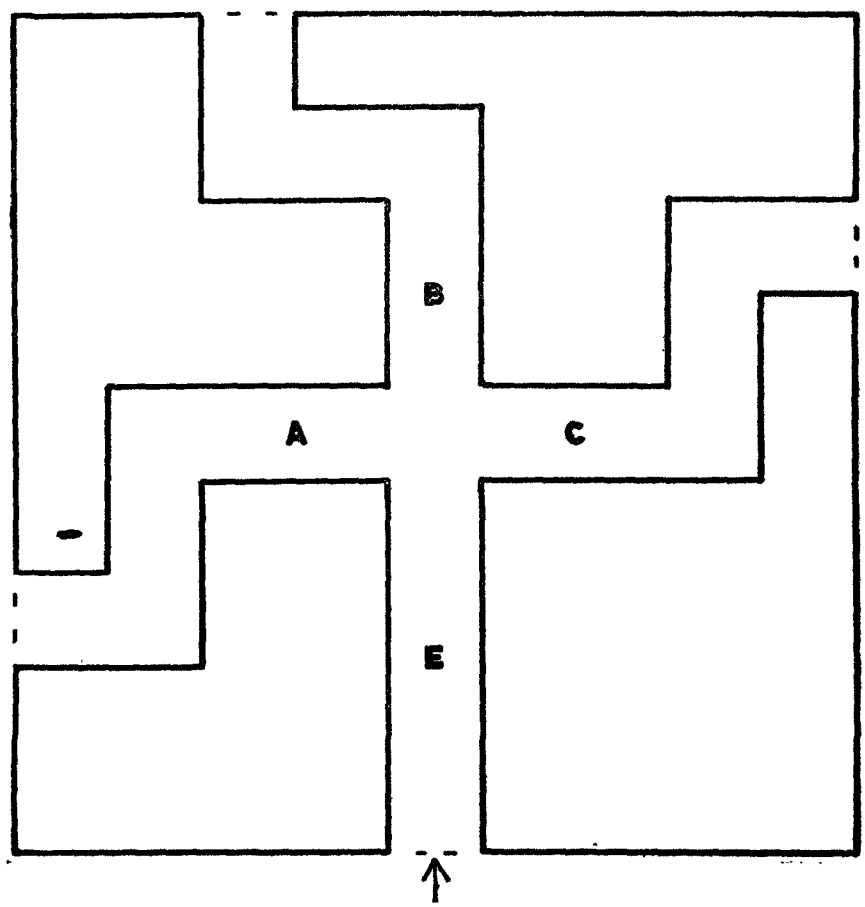

FIG. 1

At the entrance and exits vertically sliding doors were arranged. The whole maze was covered with wire mesh ("fly screening") stretched on a rigid frame. It was lighted by incandescent lamps hung above the center and the four corners. Food boxes were constructed of wood, 24 by 18 inches and 5 inches high. As the

walls of the maze were also 5 inches, view of the food box was completely cut off for an animal in the maze. The wire mesh door of a food box was hung to swing inwards, entrance being offered the animal upon its pushing with nose, but exit being practically prevented.

SUBJECTS

Nine rats were selected for this experiment, from different litters, but practically equal in age (approximately fifty days) and weight; four were males, five females.

PRELIMINARY

The hours were changed for feeding from 6:00 p.m. to twice a day, 8:00 a.m. and 7:00 p.m. Up to this time they had been fed in their cages in which they were kept, now they were fed in a box constructed for that purpose only, into which they would go after passing out of the maze. It was necessary to get them accustomed to twice a day feeding, since two runs were to be made daily, at the time mentioned above. In order that the animals might be familiar with alleys-in-general and food boxes before the formal experiment was begun, a straight alley was constructed 36 inches long, 4 inches wide, and 4 inches high, through which the animals were run from the start to get their food which was in the box at the far end of the alley. This alley was similar, in a general way, to the one in the maze, and the food boxes were the same. They were very slow at first in running the alley, and careful about entering the box but soon the run was made quickly, the box entered at once, and the food eaten immediately. The animals were never handled except when being put into the maze, for they were carried back to the cage in the food box from which they would leave to enter the cage. The training in the straight alley continued for seven days.

They were now put through the regular maze to get their food, the maze being placed on a level plane. Since the straight alley, *E*, was to be used during the entire experiment for the entrance, the animals were put in here, and food boxes placed at the exit of the other three doors which were all left open, so that the

animal could make either turn and would reach a food box. The different turns in the maze would thus lose any quality of strangeness or novelty.

FORMAL TRIALS

The maze was now placed on the inclined plane. This was a platform resting upon the table as a base and revolvable upon it, and was raised on one side at an elevation producing an inclination of 30° from the horizontal. The maze was thus placed at this vertical angle. Only one of the three exit doors was now left open, with food placed outside it only. This door was always the one that was at the top of the incline and was thus the one approached by proceeding along the *upward*-inclined alley, and not the one downward-inclined nor the one continuing on the same level. The maze could be rotated independently of the inclined plane, and the latter could be rotated independently of the table; and the two were rotated in opposite directions from trial to trial throughout the series. Thus right-left position habits and also incidental visual and auditory cues were eliminated.

In order to check olfactory stimuli as possible cues in the animal's learning to take the proper path, special conditions were set after the ninetieth, and after the one hundred and thirtieth runs for six successive runs each time. On these trials food was placed at the entrance door and the three exits. All doors were kept closed until the animal came near the correct exit door which led into the food box, then the door was raised until he had passed through, then closed and the other three doors were opened for an equal length of time. Thus the odor would come from four directions, or in at each alley. In these check runs after the ninetieth trial a slight increase in time and errors appeared, while in those after the one hundred and thirtieth there was a decrease in the time and the errors. The behavior at the choice chamber was the same in check as in the usual runs, so far as the matter was observable to the experimenters.

The experiment was continued for one hundred days, making a total of two hundred trials.

RESULTS

The problem was to see whether the white rat could in a reasonable number of trials learn to detect from the inclination of the plane only the proper turns to make at each trial in order to reach its food. As was anticipated, the problem was a difficult one. In the normal life of the rat the directions of its locomotion are probably determined little by proprio-ceptors and intero-ceptors, their rôle beng secondary to that of the extero-ceptors. To be sure, a given pathway may finally be so learned that it can be run through without any stimulation through the extero-ceptors (the "remote" sensory avenues), but this is true only for pathways that remain identical.

To judge on this question whether the white rat can learn to respond to the vertical inclination cue alone, several criteria may be applied to the data from this experiment.

I. What of the evidence from the shape of the plotted curves? Curves for error scores are graphed in figure 2. (The time scores are of slight value in this particular experiment.) Inspection of these curves tends to show no definite decrease in number of errors committed in each trial by the animal in the cases of A, D, E, and F, but a more or less progressive decrease in the cases of B, C, G, H, and I.

Since four of the curves show no decrease in errors it may at first be suspected that the result is then due merely to chance. This suspicion, however, is laid of it be observed that *none* of the curves seem to show progressive *increase* in number of errors in successive runs.

According to this criterion, then, we may hold that 5 of the 9 subjects evidenced some degree of learning the cue.

II. Let us apply another test. Since there were three alternative paths originally presented, one of them being the true one, according to the laws of chance one third of the total number of of runs should have been errorless. Our question may then take the form: Among the subjects used is there any clear tendency to produce more errorless runs than are to be expected by chance?

This fraction of one-third is certainly high enough, for two

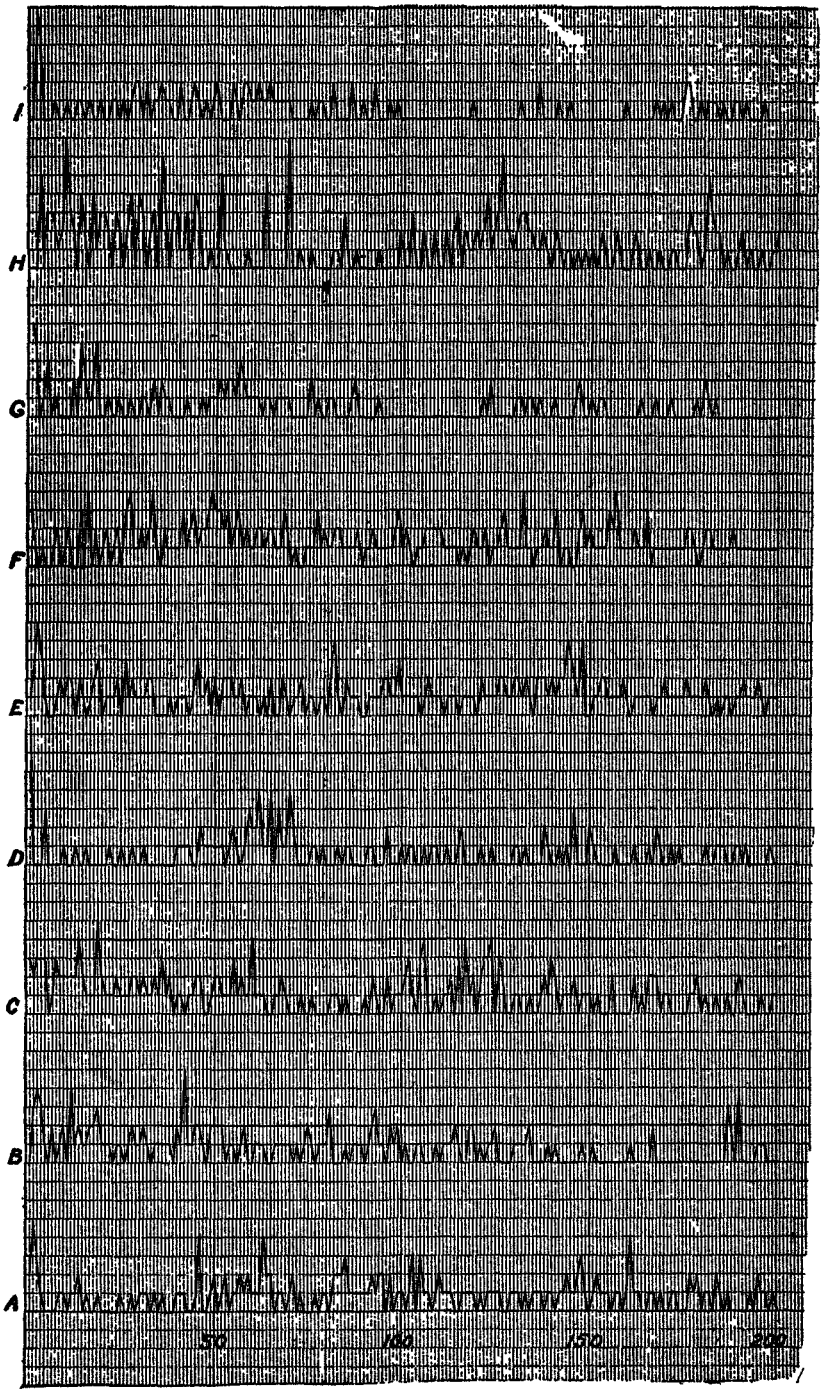

FIG. 2

considerations. (*a*) Inspection of the maze shows that from the choice chamber there are really four alleys leading off if we include the entrance alley itself. Now, if this entrance alley exerted any influence whatever upon the animal of the nature of a stimulus to entering reactions, then the one-third ratio should be modified in the direction of a one-fourth ratio. The fundamental question at issue is impossible to answer categorically. The fact that a rat reversed his direction of movement and returned into the entrance alley in only three cases may not cover the point completely, as the presence of this alley even when not effective in producing actual entrance therein may have been a complicating factor in the animal's choosing from the other three. (*b*) Again, in using the ratio of one-third to represent the mere chance that the rat would successfully proceed out the true exit alley, we are neglecting the important consideration that any entrance into one of the false paths is counted an error whereas not all entrances into the true path lead to an errorless result: after proceeding along this as far as the first turn, say, the subject might reverse its steps and return to the choice chamber and then into one of the false alleys. Although an animal would by mere chance enter the true exit path in one-third the allotted trials, it would not be likely to complete an errorless run quite so frequently. The ratio of one-third is, then, a conservative figure.

Applying this test to our results we see in table 1, last column, that 2 rats, A and C, show totals of errorless runs in percentage ratios about equal to the chance expectation; two others, E and F, less than this; while of 5 rats, B, H, and especially D, G, and I, each shows a number of errorless runs in excess of mere chance.

III. For a third criterion we may apply the question: Did the number of errorless runs increase significantly in the course of the two hundred trials? Regardless of the total number of errorless runs made, a progressive increase in their number as the series was continued would indicate learning. A division of the whole series was made into quarters of fifty trials each, and the ratio of errorless runs to all fifty runs in each quarter was found in percentage terms. (See table 1, second to fifth columns.)

We can observe no consistent progressive changes in the ratios for animals A, D, and H; animals E and F show a decrease in number of errorless runs: while B, C, G, and possibly I show a more or less progressive increase.

Taking each of the foregoing criteria by itself we note not overwhelming but still significant indication that some white

TABLE 1

Per cent errorless runs

	FIRST 50	SECOND 50	THIRD 50	FOURTH 50	ALL
A	50	24	30	42	36.5
B	18	32	54	82	46.5
C	10	40	32	60	35.5
D	64	44	62	66	59
E	28	26	14	12	20
F	24	8	16	4	13
G	48	52	78	82	65
H	32	74	28	48	45.5
I	46	46	90	70	63
Average	35	38	45	52	

TABLE 2

Criteria

1	2	3
B	B	B
C		C
	D	D
G	G	G
H	H	
I	I	I

rats can learn to modify their direction of locomotion in terms of the inclination of paths from the horizontal. In the case of each criterion the number of animals apparently learning is greater than mere chance expectation would predict. If, further, we compare the results by the different criteria applied we observe coincidences in the names of the individual animals apparently

learning in the different cases—coincidences that are distinctly higher than mere mathematical probability would assign (see table 2). We may conclude that we have evidence for an affirmative answer to our original question. The problem we have set is a soluble problem.

DISCUSSION

What is the particular class of receptors by which the rat learns to react to the inclination of its pathway? With the rotations of maze and of direction of incline all extero-ceptive clues were elminated. (It may seem, at first, as if vision might have aided the animal in the form of a seeing of the higher parts of the maze. This does not apply, however, for the vision involved is that of the rat itself in the rat's position along the floor of the entrance alley. Particularly in the trials when the true or upward-inclined path lay straight ahead and the animal was already proceeding straight up the incline as it climbed the entrance alley, its body and head position were such as to make the true exit path to be seen as level.)

Differential analysis of the rôles played by the intero-ceptive and the proprio-ceptive functions in the learning is at the present stage impossible. Operative elimination of the vestibule and semicircular canals is being considered, but the effects of such excisions upon the animal's locomotion are so generally abnormal that evidence *pro* or *con* is hardly to be expected. Similarly, it goes without saying that any elimination or impairment of the kinesthetic functions will render the subject unable to run at all.