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EXTRA-MAZE VISUAL CUES AS A FACTOR IN MAZE
LEARNING IN THE RAT.

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1.

INTRODUCTION

The part played by vision in the behaviour of rodents in maze situations has been a popular subject of investigation. Studies have been conducted mainly, however, with reference to intra-maze visual cues. For example, Vincent (1915) ran rats in a maze in which the true pathways were painted black and the blinds white and found that the facilitation in learning was insignificant. The general impression has been that rats use vision very little in maze learning and that after a maze has been learned the animals run through it on the basis of kinaesthetic cues chiefly and are practically oblivious to visual stimulation. However it has been reported by Hebb (1938) in a more recent publication that visual room cues determine an orientation which in turn gives differential value to the visually perceived parts of the testing apparatus. It would seem therefore that extra-maze visual cues can be an important factor in maze learning.

The problem of the relative importance of the various sensory cues available to the rat in maze learning has been thoroughly investigated. Various investigators have attempted to show that some specific sensory information is the most important as an aid to the rat in learning to successfully negotiate a maze. The general techniques for investigating the role of sensory processes in maze performance can be classified in five main groups as follows:

- (1) Extirpation of sensory structures. It is possible to interrupt particular avenues of stimulation by removing the peripheral sense

organs, by transecting the afferent paths of the cervical cord or by extirpating the sensory projection areas of the cerebrum.. Experimenters have investigated two types of problems by means of the extirpation technique. By operating on the animal prior to maze training, they have determined the role of sensory processes in the learning process. By operating after mastery of the maze, they have determined the role of sensory processes in retention and in final control of the habit.

(2) Elimination of stimuli. Some investigators, instead of removing sensory structures, have removed the sensory stimuli directly.

One may compare the performance of animals trained in darkness with that of those trained in ordinary illumination. Or one may determine the effect of darkness upon retention of a habit learned in the light. Similarly one may remove customary auditory or olfactory stimulation. This method has the advantage that it does not interfere with neural integration at the same time that it removes the sensory stimulation.

(3) Introduction of stimuli. Investigators have placed specific sensory cues in the true pathways of the maze and have compared the performance of animals trained with such cues with the performance of animals in the absence of such cues. A significant difference in favour of the group trained with the specific sensory cues, providing the groups were comparable in other respects, indicate the use of such sensory cues in maze learning. Removal of the cues after the problem had been mastered would indicate to what extent they con-

tributed to final control of the habit.

(4) Rearrangement of stimuli. The role of sensory processes in maze performance may be determined by rotating the maze during or after training. Rotation of the maze changes the relation between the environment within the maze and the environment outside of it.

(5) The temporal maze technique. With this method one determines whether the animal is able to learn a pattern of response, for example rrrll, without sensory cues of a differential nature.

Sensory cues are rendered ineffective because ^{the rat} must make a repetitive response in the same environment.

The results obtained in studies of exteroceptive control indicate that the learning of the maze pathway is obviously dependent upon exteroceptive stimulation. There is no evidence at present which indicates the character of the processes which ^{are} inevitably present during learning and final performance of the maze habit.

Lashley (1929) made use of four mazes of differing complexity in order to test the influence of the extent of brain injury and retention. In the experimental animals there was an average extent of injury of approximately thirty-one per cent of the cortex, differing in locus in different animals. An analysis of the data in terms of the locus of cerebral injury showed, in general, that the amount of deterioration of maze habits depended, not on the locus of injury, but upon the amount of tissue destroyed. The hypothesis which Lashley advances to explain his experimental results is that

the projection areas of the cortex have, in addition to their specific sensory or motor functions, a non specific (perhaps facilitative) function in which they are equipotential.

An attempt has been made in this study to implement a technique which may prove useful in the investigation of sensory control of the maze habit. The method is based on the hypothesis that the rat will make use of the most obvious cues most readily as an aid to learning a problem. For example if visual cues are the most obvious of those available to the rat the assumption is that the rat's behaviour will be mainly determined by them. The comparison of the disturbances in performances resulting from the variation of the cues emphasized in a particular sample should provide a valid basis for determining the relative importance of the sensory process in maze learning.

It was decided that a control group of animals in which the cortical visual areas had been extirpated would perhaps provide an adequate check on the performance of normal animals. Because of the evidence in support of an equipotential function of cerebral cortical tissue a further control group of rats with lesions (comparable in size to those of the visually operated animals) involving an area of the cortex considered not to have a specific sensory function.

APPARATUS AND MATERIALS

A maze (see photograph) was designed which would be adaptable to limited facilities and yet which would present a difficult learning problem. The standard T maze would be most suitable for the investigation to be made but such a maze would be too large for the space available. An adaptation of a maze designed by Walton (page 386, Maier and Schneirla) was therefore built. The maze has twelve T choice points and a corresponding number of blinds. The alleys are four inches wide and each unit is fifteen inches in length. The interior of the maze was painted with a flat black paint so that the various units of the maze present a uniform appearance. The entire maze was covered with wire netting. The arrangement of the blinds was made on the basis of a random selection which resulted in the following order of choices - rrlrlrlrlrlr.

The maze used has the following features which contribute to its reliability and objectivity. (Munn-page 217)(1.) The cul-de-sacs are of equal length. (2.) The animal is presented with two similar paths at the choice points. (3.) The maze pathway is of sufficient complexity to be difficult for the animal to solve. (4.) Doors to prevent retracing. (5.) The performance of the animal is objectively scored.

An intense extra-maze visual cue was provided by placing an unshaded 200 watt bulb and a 450 watt daylight lamp in the positions indicated on the accompanying diagrams. Light was also provided by

overhead fluorescent bulbs and windows.

Additional apparatus included a straight runway and a Lashley type jumping stand. The straight runway's construction duplicated that of the maze. The main features included were two retracing doors, manually operated as in the maze, and a food box. (See fig.1.) The runway was used as a means of preliminary training which would serve to familiarize the rats with some elements of the maze situation in order to expedite the initial training in the maze. Thus the animals were accustomed to the retracing doors, feeding in a food box and the presence of the experimenter when first introduced into the maze.

Figure 1.

Plan of Straight Runway: R₁, R₂ - Retracing doors

The jumping stand was used to determine the ability of the experimental animals to make a pattern visual discrimination and thus provide a check on the extent to which visual cues might be

operative.

SURGICAL PROCEDURE AND TECHNIQUE

In order to provide control groups animals were operated and tissue of the cerebral cortex extirpated by thermo-cautery. Of the animals operated eleven completed all training tests. Of this number seven were animals with frontal lesions and four had lesions in the visual cortex.

Operations were performed with aseptic precaution under deep ether anaesthesia.

The areas to be extirpated were located by reference to sutures in the cranium. The skull was trephined on both sides of the mid-line and the therm^o-cautery inserted and swept in an arc ensuring an adequate coverage of the area to be extirpated. The size of the lesions was kept as nearly constant as possible.

Histological examination of the brains using the technique developed by Lashley was considered but rejected when it was found that there was insufficient time to complete it.

TRAINING AND TEST PROCEDURES

As preliminary training the rats were run in the straight runway. The rats were fed daily only after completing the runs in the runway and strong motivation to react positively in the maze situation was thus established. An arbitrary number of ¹⁰runs was fixed as sufficient pre-training by this means.

Figure 2

[A] Lights S-starting point in Maze F-food box
E - experimenter W₁ W₂ W₃ Windows

The animals were then run in the maze with the lights in position A and the maze oriented as in fig.2. Window W₁ was covered throughout the course of the experiment. Windows W₂ W₃ were left uncovered during the learning trials. The rats were run one trial on each of two days, two trials on the two succeeding days, three trials on the following three days and five trials each day thenceforth.

The criterion of learning adopted was ten consecutive errorless trials. The use of a relatively high criterion was decided upon in

order to make more significant any deviations which might occur during the test.

The tests devised were three and each involved rearrangement of the extra-maze visual cues.

Figure 3

B Lights S- starting point F - Food box
W₁ W₂ W₃ Windows E - experimenter.

In the first test the windows W₂, W₃ were blacked out with heavy cloth blinds and the lights were moved to position B. (See fig. 3) Otherwise conditions were left constant.

Figure 4.

B - Lights S- starting Point F - Food box
W₁ W₂ W₃ - Windows E - experimenter

In the second test the maze was rotated to the position shown in fig. 4. The windows were darkened as in Test 1 and the lights were in the same position, relative to the maze as in the first test.

In the third test, which was used as a control to check on the effect of rotating the maze the lights were in the same position in relation to the maze as during the learning trials but otherwise conditions were as in Test 2.

The animals were given retraining under the original conditions between tests and brought back to the criterion of learning in each case. The rats were run twenty trials on each of the tests.

The rats were then tested on the jumping stand. They were first required to make a discrimination between a white and a black card and subsequently were tested on discriminating between patterns formed by vertical and horizontal lines.

RESULTS

Nine normal rats, six rats with frontal lesions, and four rats with lesions in the cortical visual area completed all training and test runs. Five animals with occipital lesions and three with frontal lesions died during the training. One animal with a frontal lesion had not learned the maze after 435 trials and one with a visual area lesion had not learned after 390 trials.

The mean number of trials for the normal animals to achieve the criterion of learning was 126 trials; for the frontally operated animals 247 trials and for the visually operated 220 trials.

The performance of the three groups on the three test situations is summarized in the following table.

	TEST 1 (20 trials)		TEST 2 (20 trials)	
	MEAN no. of Errors	S.D	MEAN no. of Errors	S.D.
NORMAL	15.67	5.4	14.44	8.15
FRONTAL	28.33	10.1	30.5	7.01
VISUAL	0.5	0.86	0.5	0.86
	TEST 3 (20 trials)			
	MEAN no. of Errors	S.D.		
NORMAL	0.33	0.66		
FRONTAL	1.33	1.38		
VISUAL	0	0		

The results obtained in the third test situation indicate that rotation of the maze does not significantly affect performance if the dominant extra-maze cues are rotated with the maze. The close correspondence of results on Test 1 and Test 2 indicate a similar

conclusion.

In this study the disturbance of the relationship between the internal environment of the maze and the external environment was found to cause a disturbance in performance but when the maze was rotated and only the dominant visual cues were maintained in the same relationship no disturbance was elicited.

The animals which had lesions in the visual cortex were not affected by changes in the extra-maze visual environment. Rats with portions of the frontal area of the cerebral cortex extirpated exhibited a much greater disturbance in behaviour than normal animals when extra-maze visual cues were altered.

The tests of the rats on the jumping stand were not concluded because of a lack of time but there was an indication that the visually operated animals were unable to make a pattern discrimination in which the normal rats and those with lesions of the frontal area of the cortex were successful.

DISCUSSION

On the basis of the data obtained in this study there seems to be an indication that extra-maze visual cues affect the maintenance of the maze habit and are probably operative in maze learning.

The normal animals and those with lesions involving frontal cortex were disturbed in performance, on a basis of error scores, when the extra-maze visual cue was altered. The fact that those rats with occipital lesions were not affected by the disturbance of the extra-maze cue provided indicates that these animals had learned the maze by some means in which the extra-maze visual cues were not a determining factor. All animals were brought back to the criterion of learning between tests under the original conditions. Since all animals in which disturbance in behaviour had been elicited during the test situations made a rapid readjustment during re-training it is suggested that the extra-maze visual cue was a determining factor in the formation of the maze habit.

The results on the tests involving rotation of the maze indicate that disturbance of performance is due to an alteration of the relationship between the internal environment of the maze and extra-maze environment rather than the directional reorientation in itself. Careful studies involving rotation of a maze have been made by Gengerelli and Higginson. Gengerelli (1928) used a conventional maze with six blind alleys which was surrounded by a screen three feet high attached to the maze. An effort was made to eliminate all extra-maze stimulation. After the animals had

mastered the maze they were required to run it twice with a 90 degree rotation and twice with a 180 degree rotation on successive days and disturbance in behaviour was elicited.

Higginson (1930) found that in preliminary tests made under ordinary laboratory conditions where heterogeneous stimulation could influence the animals, rotation led to marked disturbances but when animals were trained in complete darkness rotation in darkness elicited no disturbance. He found further that animals trained in a covered, internally illuminated maze were not disturbed by rotation tests after the maze had been learned. Higginson states that he could find no experimental evidence which would substantiate the claim that the rat possesses a sense of direction by virtue of which it is disturbed when the maze, previously learned at one position, is rotated to new cardinal positions.

The third test in the study being here considered involved reorienting the maze directionally in an environment in which heterogeneous stimulation could influence the behaviour of the ~~elicit~~ animals. Since no disturbance in behaviour was elicited in the third test situation it was suggested that a constant relationship between interior environment of the maze and exterior environment was maintained by keeping the provided intense source of visual stimulation in a constant position relative to the maze. Thus it would seem that a specific sensory cue can be a predominant ^t factor in retention of the maze habit.

The close correspondence of results in test situations 1 and 2, in which the relationship of the extra-maze visual stimulation to the maze was constant although the maze was rotated directionally in the second test, indicates that rotation in itself does not disturb the performance of rats in a maze previously learned.

The neural mechanisms involved in learning are yet to be understood. Two facts which are applicable to the problem must be considered. First, there are ~~elaborate~~ numerous sub-systems in the total nervous system each of which are capable of elaborate integration. Secondly, any sensory pathway, however simple and restricted, leads ultimately to every effector. In the solution of more complex learning problems a greater portion of the nervous system will contribute to the production of activity. With a greater part of the nervous system involved there is a greater possibility of flexibility in the participation of the various afferent paths. Thus the animal deprived of some sensory information is still able to learn. However if the integration involved in learning a problem is influenced by a particular intense sensory cue there should be a reduction in the possibility of flexibility in the use of the various sensory processes. Animals that have lost the use of part of the nervous system as a result of extirpation would probably be at a greater disadvantage than normal animals if adaptations to an environment were necessary for the maintenance of a learned habit.

In the results tabulated above the animals which had lesions

involving a frontal area of the cortex were disturbed, twice as much, on the basis of mean error scores, as normal animals in a situation which required an adaptation to a changed environment determined by the rearrangement of an intense extra-maze visual cue. It is suggested that this result may be due to a comparative inability on the part of the frontally operated animals to adjust to an altered environment in which the use of exteroceptive stimulation other than the changed source would be necessary for retention of the maze habit. The apparent lack of flexibility in the use of various sensory information of animals with frontal lesions could be due to a reduction in the functional quantity of the nervous system available. The possibility of some special integrative function of some portion of the frontal cortex may otherwise be suggested on the basis of the results obtained.

It is suggested that a more adequate study of the problem investigated should include the following features:

- (1) The use of a larger number of animals in order to ensure a more reliable sample.
- (2) Post-mortem histological examination and mapping of the size and locus of lesions of operated animals.
- (3) The use of a self-recording, automatic maze.
- (4) Variation of the order in which the test situations are presented in order to control the possible effect of over-learning on the second and third tests.

SUMMARY

A technique was developed in which rats were trained in a maze with an intense extra-maze visual cue provided. Testssituations involved varying the position of the extra-maze cue relative to the maze and rotation of the maze.

Results indicate that in normal rats and animals with frontal lesions an extra-maze visual cue is a factor in determining maze learning and retention of the maze-habit. Rats with lesions involving the visual area of the cortex were not disturbed by variations in the extra-maze visual cue.

Some evidence was advanced to support the claim that rotation of the maze without disturbing the relationship of the interior environment of the maze to the exterior visual environment does not affect the maze performance of the rat.

The possibility of a special integrative function of the frontal area of the cortex was suggested.

Some suggestions were made to indicate how the study might be further pursued.

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APPENDIX

TABLE 1.

Total errors and total trials made in initial training, in test situations and retraining after tests.

Rat	ERRORS			TRIALS		
	Initial Training	Test 1	Retraining after Test 1	Initial Training	Test 1	Retraining after Test 1
GROUP 1						
NORMAL						
1	471	7	0	183	20	10
2	442	10	0	192	20	10
3	228	16	0	175	20	10
12	187	14	1	82	20	13
13	171	21	0	61	20	10
15	276	25	0	96	20	10
22	322	19	0	148	20	10
23	142	11	0	57	20	10
24	392	18	0	144	20	10
GROUP 2						
LESIONS IN FRONTAL CORTEX						
4	519	19	1	266	20	14
5	1233	19	2	348	20	12
6	860	46	2	285	20	11
7	570	31	1	177	20	19
17	579	27	0	230	20	10
18	540	30	1	176	20	19
GROUP 3						
LESIONS IN VISUAL CORTEX						
9	1246	0	0	280	20	10
11	860	2	1	268	20	13
19	485	0	0	166	20	10
21	538	0	0	170	20	10

TABLE 1 (cont'd)

Rat	ERRORS				TRIALS			
	Test 2	Retraining	Test 3	Retraining	Test 2	Retraining	Test 3	Ret
GROUP 1								
1	4	0	0	0	20	10	20	10
2	11	0	0	0	20	10	20	10
3	29	0	2	0	20	10	20	10
12	12	0	1	0	20	10	20	10
13	6	0	0	0	20	10	20	10
15	22	0	0	0	20	10	20	10
22	16	1	0	0	20	11	20	10
23	7	0	0	0	20	10	20	10
24	23	0	0	0	20	10	20	10
GROUP 2								
4	20	1	3	0	20	11	20	10
5	32	0	0	0	20	10	20	10
6	32	0	2	0	20	10	20	10
7	33	2	0	0	20	11	20	10
17	24	0	0	0	20	10	20	10
18	42	3	3	0	20	12	20	10
GROUP 3								
9	0	0	0	0	20	10	20	10
11	2	0	0	0	20	10	20	10
19	0	0	0	0	20	10	20	10
21	0	0	0	0	20	10	20	10

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