THE EFFECTS OF OLFACTORY CUES ON THE MAZE LEARNING OF WHITE RATS

by

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INTRODUCTION

A number of investigators have studied the role of olfaction in the maze learning of white rats, but few have studied the use of this sensory cue under conditions which might actually be encountered in a maze learning experiment. In maze learning vision is usually said to be of major importance while the olfactory sense is of minor or no importance. Lashley (4) found that the visual acuity for rats was about one-fiftieth to one-twentieth that of man. The existence of cones in the retina of the eye of the rat is as yet uncertain and there is an average of approximately 50 rods for each ganglion cell. This poor vision of the rat and the continual sniffing and smelling that characterizes the rat's responses to its surroundings indicates that the olfactory sense might play a more important part in maze learning than is generally conceded. Since most mazes are not equipped with movable floors there is a possibility that definite rat odor trails might be formed which would influence the time and error scores of rats learning the maze. This study was designed to investigate just such a possibility.

RELATED LITERATURE

A review of the related literature shows that the results of a number of the investigators are inconclusive because of the small groups of animals used, and because of the inconsistency of some of the findings.

The first work on olfaction in rats was done by Small (8) in 1899 who tested young rats with a variety of odors during their first 18 days of life. He used violet, hydrochloric acid, cheese, clove oil, asafetida, spirits of camphor, brown bread, carbolic acid, dog biscuit, wintergreen, and cologne water. Each odor was held near the nose of the rat and its behavior observed. About the end of the first week the rats were indifferent to all but positively detrimental odors, whereas before, they had been extremely sensitive to all odors. Between the second and third week positive reactions to food odors were evidenced. Small said that smell was "the rat's psychical organ in food getting," and, that rats inherited some ability to detect food by odors, since they were interested in the odors of cheese and milk before they ever tasted them. He claimed to have found no evidence of one rat tracking another.

Watson (12) in 1907, studied the sensory processes involved in maze learning using five anosmic rats. Of these he said, "Their behavior in regard to the making of errors, elimination of errors, etc. may be characterized as normal." He used the difficult Hampton Court maze and found that two of the anosmic rats learned it in record time. He found that anosmic rats failed to start promptly the first few trials. This was attributed to the lack of the customary olfactory sensations set up by food which act with the hunger complex. He concluded that olfaction was not a necessary but a useful sense for the rat in learning a maze, especially for orientation in the beginning.

The value of olfactory cues in maze learning was studied by Vincent (10), in 1915. She used a Hampton Court maze and for one group of animals marked the true path through the maze with an odor trail of beef extract and cream cheese. The beef extract and cream cheese were alternated to avoid olfactory fatigue. A second or control group ran the maze with no cues present. The animals running the maze with the true path marked moved in a jerky fashion, occasionally stopping to smell and lap the trail. This manner of running made progress very slow but the number of errors was greatly reduced in both initial and succeeding trials. The olfactory group showed an increased final speed. The animals in the olfactory group averaged 4.5 errors as compared with 14.7 made in the normal maze the first trial. The olfactory maze also showed .04 average errors per trial for the last five trials, while the normal maze had an average error of .1 per trial for the same five runs. Those animals following the olfactory trail made a little less than one-third of the total number of errors made by the control group.

Following the learning of the maze the same animals were tested for any transfer of training by using a discrimination box with the true path marked, as in the maze, with beef extract and cream cheese. The rats followed the path nine times out of 10 showing that the olfactory experience was retained and could be utilized again.

Carr (2), in 1917, using four rats, formulated the "tonic theory" in which he said, "smell and vision furnish the stimulation necessary to induce sufficient motor activity for maze learning, while control comes by cutaneous and kinaesthetic factors".

Liggett (6), in 1928, repeated the work of Vincent (10), using the same technique and a modified Hampton Court maze. Liggett's work was the first to be done in which a large number of animals were used. He ran 26 rats without the odor trail, 26 with the odor trail, and 31 anosmic rats. He obtained results just the opposite of those found by Vincent, (10) in that there was no essential difference, either in the number of errors made, or in the time it took to run the maze, between the odor trail group and the control group. None of the rats running the maze in which the true path was marked apparently took any heed of the trail after the third or fourth trail. Liggett found the anosmic animals to be more active than the control group while Watson (12), Vincent (10), and Carr (2) found them to be more lethargic. Liggett concluded that the rat was not very sensitive to olfactory stimuli, and that olfactory controls were not as important as visual and auditory controls.

Lindley (7) studied the maze learning ability of anosmic and blind anosmic rats using a multiple-T maze. The rats were blinded by removing the eyes and a condition of anosmia was produced by cauterization of the olfactory bulbs. He found the median number of trials required to learn the maze to be 12.3 for the control group, 14.5 for the blind group, and 27.3 for the anosmic group. The anosmic rats made more errors on all the trials than did either the control group or the blind group. All the differences between both time and error scores for these groups were found to be statistically significant, a marked contradiction to Liggett's (6) findings and not in agreement with Honzik's (3) conclusions.

Honzik (3) has performed the most extensive investigation of olfactory stimuli to date. He used 23 different groups ranging in size from 42 to 56 rats. Two mazes, both alike, were used in which it was possible to change the floor of each alley to different parts of the maze. These were changed about in a haphazard fashion during the experimentation. He found that blind rats learned rapidly on a fixed unit maze but when they were changed over to the changing unit maze they were greatly disturbed and relearning was slow. Evidently old, constantly changing stimuli had not become integrated in the process of running the maze, and hence the retardation. If the blind rats first learned on a changing unit maze and were then transferred to the other maze, in which new units were present, no disturbance was noted. If the stimuli had become integrated a change to the other stimuli would have disrupted the habit. He found unmistakably that changing olfactory stimuli on the perfected habit in blind rats disrupted the habit. Honzik concluded that olfaction is important in blind rats learning a maze. The relatively slight retardation of normal seeing rats on a changing unit maze, and of seeing anosmics on a fixed unit maze, indicated that olfaction plays a minor function in the learning of seeing animals. Post-learning tests involving olfactory changes were carried out on these animals and little or no disturbance was found. This indicated that olfaction is of minor importance in post-learning unless visual changes are involved, in which case, olfactory stimuli can be immediately utilized.

From this historical review of the experimentation involving the olfactory sense in the rat, it seems that Honzik (3) and Lindley (7) have presented the most reliable data on the subject. However, Lindley's experiments indicated that olfaction was of more importance than vision while Honzik concluded that vision was of more importance than olfaction in the maze learning of rats. This lack of agreement between the findings of these two investigators, as well as the lack of agreement among other investigators, seems to indicate the need for a study in which definite animal odor trails are formed. This may then indicate, a little more clearly, in what manner definite olfactory cues affect maze learning, if they are found to do so.

MATERIALS AND METHODS

The Maze and the Experimental Room

Throughout the experiment an elevated multiple-T maze was used. Alm has found a reliability coefficient of .87 for error scores and .96 for time scores made on this particular maze (1). He stated that the correlation for time scores would have been similar to that for error scores if it had not been "for several timid, cautious, or slightly fearful animals". The maze consisted of 12 units with alternating single and double alternations of right and left turns. The alleys were three inches wide and the bars of the T's had metal sides four inches high on the side toward the food box and one inch high on the opposite side. The stems of the T's had metal sides one inch high. The floors of the bars of the T's were covered with strips of black, waterproof, window shade material. These strips could be changed by rotating a roller with the resulting presentation of a new running surface. For two of the groups of rats strips of marble back cardboard were placed over the cloth strips covering the maze floor. From a position behind a black drape at the starting point of the maze it was possible to raise or lower the hinged stems of the T's, open or close the doors of the six compartment food box, and to observe the behavior of the rats running the maze.

The maze and the lower half of the walls of the experimental room were painted a dull black. The upper half of the walls and the ceiling were painted white. The room contained only one window and this could not be seen from any point in the maze. A 100 watt lamp, placed near the center of the maze and hanging from the ceiling, lighted the maze. The living cages for the rats were in an adjoining room.

Animals Used

The animals used in this experiment were all male, albino rats ranging from 65 to 85 days of age. At this age most rats have reached sexual maturity and whether or not they will be distracted by odors of the opposite sex is not definitely known so no female rats were used. The results obtained by most investigators point to a sex difference which would necessarily have to be considered in the performance of any maze learning experiment in which both sexes were used. Wang (11) found the female rat to be most active during the period of oestrus, showing regular cyclic changes in the amount of activity, while the male showed no such fluctuations. The maze training of 89 rats was started but this number was decreased to 86 animals that actually ran all the trials. The three animals were thrown out for various reasons. One became ill soon after individual trials were started, another could not be motivated to run the maze although started, and the third was frightened by a mouse that made its way into the experimental room. No runts or deformed rats were used.

Handling and Training of the Rats

Each rat was fed individually for a period of seven days prior to preliminary training. This assured each animal the same amount of food and accustomed it to being handled. Individual feeding was continued throughout the experimentation, each rat receiving a daily diet of six grams of ground feed containing cod-liver-oil. Each feeding was supplemented with a few sunflower seeds until the commencement of individual trials after which sunflower seeds were given only as a reward for running the maze. All of the rats received uniform preliminary training. This period began on the seventh day of the preliminary individual feeding period. The preliminary training, consisting of group trials, was carried on as follows. On the first day five or six animals were placed in the maze at the same time and given two trials to explore the last four alleys and the food box. On the second day two group trials were run over the last eight alleys of the maze. On the third day each litter was divided as evenly as possible into three groups and two trials given in running the complete maze over the same type floor that was to be used in the individual trials.

On the day following the completion of the preliminary training individual trials were started and time and error scores recorded. The time scores represent the time required for the rat to go from the entrance of the maze to the food box. In all the data time scores are given in seconds. An error was counted if the animal entered a blind alley far enough to get his body into the alley. An error was also recorded if the length of an alley was retraced. The retracing of more than one alley was prevented by lowering the stem of the T after the animal had passed over it. Each rat ran two trials a day with an intervening period of from 10 to 15 minutes between trials. A total of 34 trials were run by each rat, the last four trials constituting an experiment on the distractability of the perfected maze habit. Throughout the investigation all of the experimentation was carried on in the afternoon between 1 and 5 o'clock. The animals of each group were run at approximately the same time every day. Further details on the procedure will be given in the discussion of the experiments themselves.

EXPERIMENTAL DATA

Experiment I

Three groups of animals were used in this experiment. These groups and the conditions under which they ran were as follows: Group A consisted of 29 rats which ran the maze with an animal odor trail in the true path through the maze. Group C, the control group, consisted of 28 rats which ran the maze with no odor trail present. Group B consisted of 29 rats running the maze with an odor trail in the blind alleys. The odor trails were made by rubbing the strips of marble-back cardboard covering the maze floor with burlap bedding which had been used to mop up residue from the wire cloth floors of the animals' own cage. These trails were renewed after six trials. When any of the strips of cardboard became soiled they were replaced by clean ones. A new running surface was presented for the animals in Group C after each six trials prohibiting the formation of any definite animal odor trails through the maze. Each animal ran a total of 30 trials over a period of 15 days.

The learning curves for the various groups are shown in Figure 1. These curves are based on the mean error scores for each trial taken from Table 1. The learning curve for Group B, the group running the maze with the odor trail in the blind alleys, is uppermost in all of

Table 1. Mean time (seconds) and mean error scores for each trial.

Trial	Group A		Group B		Group C	
number	Time	Error	Time	Error	Time	Error
1	80.0	6.4	125.5	8.0	117.4	6.5
2	83.9	6.2	110.8	7.6	94.9	7.0
3	74.0	5.8	92.0	6.8	85.4	6.4
4	62.3	5.3	81.7	6.5	83.0	5.8
5	60.4	5.3	70.7	5.9	61.7	5.4
6.	56.7	4.9	64.9	5.7	64.8	5.0
7	53.1	4.5	64.4	6.0	58.8	5.0
8	47.7	4.7	60.6	5.9	60.1	5.3
9	48.8	4.1	57.4	5.4	52.8	4.8
10	43.0	4.2	53.0	4.9	55.8	5.1
11	46.4	4.2	52.6	5.1	46.7	4.4
12	38.8	3.9	47.3	4.9	46.7	4.4
13	38.4	3.8	47.2	4.9	40.2	4.3
14	35.6	3.5	42.2	4.6	43.2	4.1
15	35.2	3.5	41.5	4.4	37.0	3.9
16	32.5	3.6	39.4	4.3	36.8	3.9
17	29.1	3.0	39.2	4.2	32.6	3.5
18	28.3	3.1	35.4	4.0	34.0	3.7
19	27.7	2.7	35.8	3.8	31.4	3.0
20	29.7	3.2	34.5	3.8	28.5	3.1
21	28.0	3.2	37.1	3.9	29.6	3.3
22	26.7	3.1	31.9	3.6	30.3	3.3
23	27.4	3.0	33.0	3.2	28.4	3.1
24	24.9	2.9	27.7	3.2	26.3	2.9
25	23.2	2.6	27.4	2.7	26.0	2.8
26	22.1	2.3	26.8	3.4	26.5	3.1
27	24.0	2.3	26.1	2.8	25.3	2.1
28	23.8	2.5	27.1	3.1	25.9	2.6
29	21.7	2.0	25.8	2.8	24.3	1.9
30	20.9	2.1	24.5	2.7	23.7	2.5
31	23.1	2.0	26.6	2.7	24.9	2.0
32	20.6	2.3	24.4	2.8	25.1	2.5
33	22.2	1.9	25.3	2.7	24.4	2.3
34	18.9	2.1	22.2	2.4	22.8	2.5

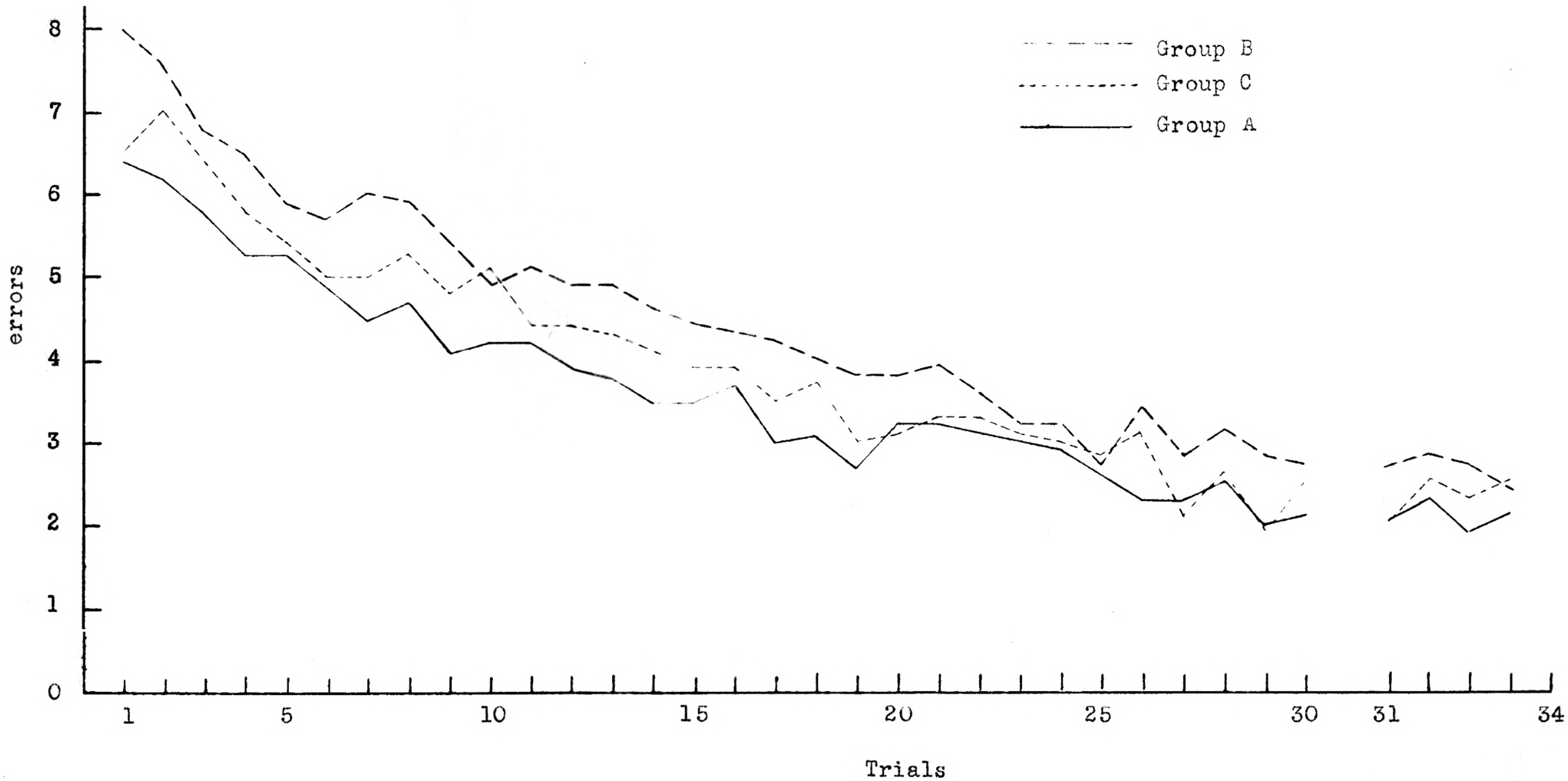

Figure 1. Learning curves based upon the mean error scores per trial.

the trials when compared with the curve for Group A, the group running the maze with the true path marked. A comparison of the learning curves for Group B and Group C shows that Group B made the largest average number of errors on all of the trials with the exception of trials 10 and 25, on which trials Group C made a larger number of errors. Group C made fewer errors than did Group A on trials 20, 27, and 29. These fluctuations were probably due to the erratic running of a few of the rats in Group C on the above mentioned trials.

The means and standard deviations of the total error scores per animal, calculated from Table 2, are given in Table 3. Group A shows the largest standard deviation, 33; Group C the smallest standard deviation, 25; and Group B an intermediate standard deviation of 29. These standard deviations of the various groups indicate that rats running the maze with a definitely marked olfactory trail were not all affected to the same extent, i.e., the presence of a definite trail aggravated individual differences. The savings in mean total errors for the various groups may be noted in Table 3. Group A made the smallest number of errors, Group B the largest number of errors, and Group C was somewhat intermediate.

In Table 4 the differences between the means of the error scores and the reliability of these differences are shown. The critical ratio of 3.23 between Group A and Group B is statistically significant and may be interpreted to mean that those animals running the maze with the true path marked made reliably lower error scores than those made by

Table 2. Total time (seconds) and total error scores per animal.

Group A		Group B		Group C	
Time	Error	Time	Error	Time	Error
550	43	1395	145	1465	137
1699	182	2179	198	783	85
1606	159	1920	154	1118	99
1277	138	2084	146	1061	91
1781	145	1258	138	1474	147
1007	83	771	60	918	85
1176	80	2110	183	772	139
1612	113	1558	137	1199	123
1833	137	1495	115	1067	109
1436	119	1498	101	1722	132
1309	100	1714	167	1224	120
799	96	1469	140	2634	176
1425	162	2140	163	1091	107
1398	123	1701	152	1201	128
926	94	901	118	1189	113
1177	156	988	121	1627	140
1189	128	1512	141	1030	105
1392	122	1514	145	1234	99
1284	120	1111	115	1279	123
696	74	972	109	1455	111
787	76	1580	144	1299	67
609	53	2248	176	2255	143
803	74	1441	152	1648	125
1216	114	1045	114	1315	145
1841	142	1334	148	1574	157
1134	125	652	60	1255	105
1192	82	1540	154	1173	113
1205	107	1533	164	1739	164
779	95	1364	152		

Table 3. Means and standard deviations of the total error scores per animal for the various groups.

Groups	Number of animals	Error	Standard deviation
A	29	112	33
B	29	138	29
C	28	121	25

Table 4. Reliability of the differences between the means of the error scores for the various groups.

Groups	Difference	Critical ratio (D/SDD)	Chances in 100 of a significant difference
A & B	26	3.23	100.0
A & C	9	1.23	88.6
B & C	17	2.42	99.2

the animals running the maze with the blind alleys marked. A critical ratio of 2.42 between Group B and Group C is not large enough to be completely reliable. The chances of a true difference greater than zero are 99.2 in 100. This suggests that a real difference in total error scores may be caused by the presence of an olfactory trail in the maze. The least reliable difference, with a critical ratio of 1.23, was found between Group A and Group C. This means that the chances are 88.6 out of 100 that the difference would be in the same direction in other similar experiments.

Learning curves based on the means of the time scores for each trial are shown in Figure 2. These curves show essentially the same trends in direction as were found in the curves based on the error scores shown in Figure 1. Group B took the largest amount of time on nearly all the trials; Group A took the least amount of time on nearly all the trials, and Group C was again somewhat intermediate. Group B took the same or a larger amount of time to run all the trials with the exception of trials four, six, eight, 10, 12, and 14 when compared with Group C. The increase in the time scores for Group C on these trials, which were the second trials for the day, was probably due to the temporary satiation of a few of the animals resulting in a lowered incentive with an accompanying increase in the time scores on the second trials. Group A took the least amount of time on all of the trials with the exception of the twentieth, on which trial Group C had a slightly lower time score than that made by Group A. As is typical for most learning curves of the maze learning of rats, all three curves are negatively accelerated and show a rather rapid initial drop for the first four or five trials.

In Table 5 the means and standard deviations of the total time scores per animal, calculated from Table 2, are given. Group A shows the smallest standard deviation, 359.2; Group B the largest standard deviation, 416.8; and Group C an intermediate standard deviation of 398.9. The fact that Group B shows the largest standard deviation

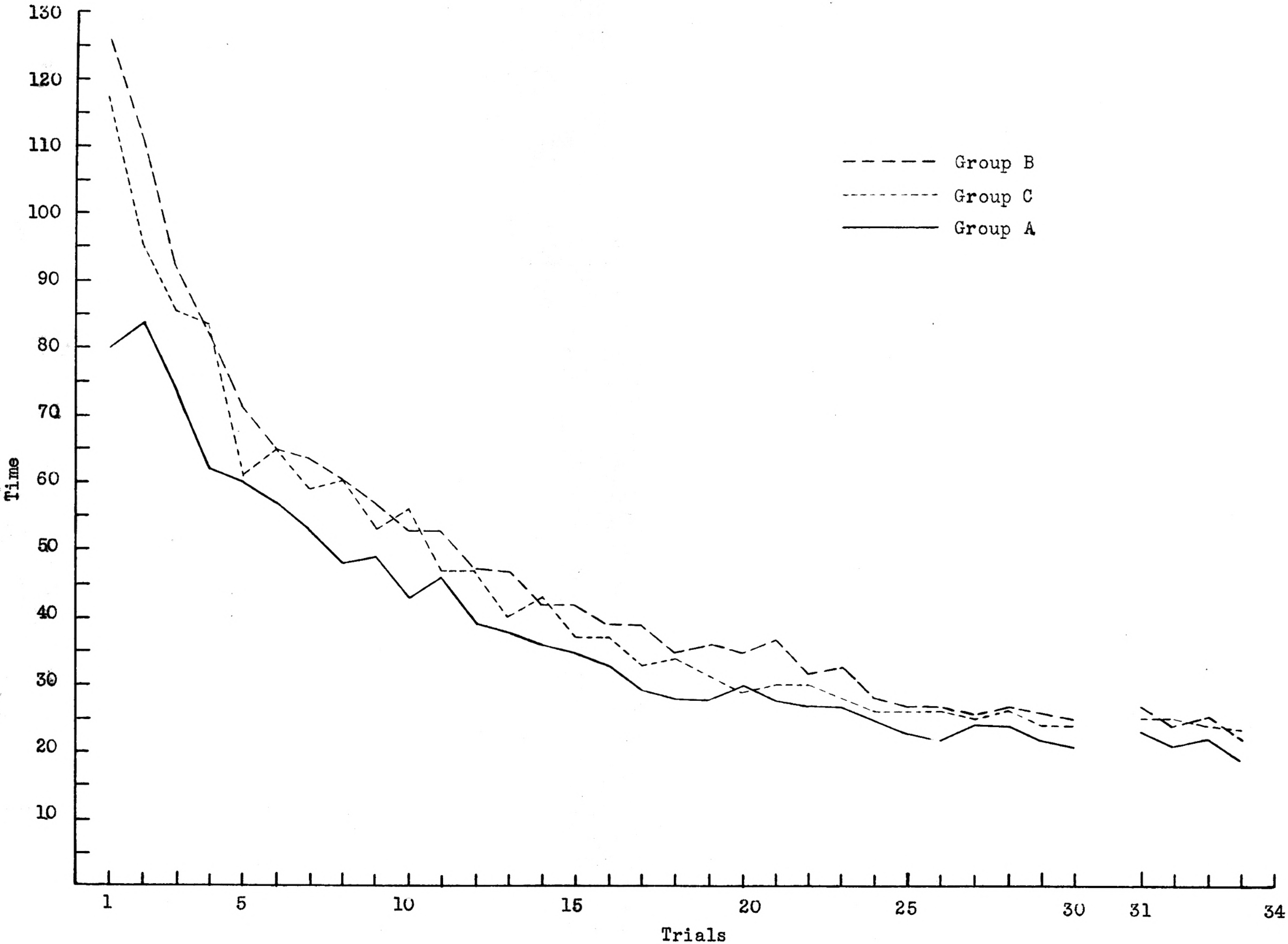

Figure 2. Learning curves based upon the mean time scores per trial.

probably indicates that some of the animals were misled by the wrong olfactory trail while others were not. It will be noted that while Group A had the smallest standard deviation for time scores it had the largest standard deviation for error scores, Table 3. Behavioral observations by the experimenter led to the conclusion that although a few of the more exploratory rats in Group A entered a larger number of blind alleys than did the rats of Group B, they spent less time in them than those rats running the maze with the olfactory trail in the blind alleys. The reliability of the differences between the means of the time scores for the various groups is shown in Table 6. None of the critical ratios are statistically significant but the critical ratio of 2.66 between Group A and Group B approaches a reliable difference, the chances being 99.7 in 100 of a true difference greater than zero. This may be interpreted to mean that rats do use their olfactory sense in learning a maze and are aided or disturbed by animal odors in the maze to a rather marked degree.

Table 5. Means and standard deviations of the total time scores (seconds) per animal for the various groups.

Groups	Number of animals	Time	Standard deviation
A	29	1211.7	359.2
B	29	1483.7	416.8
C	28	1349.2	398.9

Table 6. Reliability of the differences between the means of the time (seconds) scores for the various groups.

Groups	Difference	Critical ratio (D/SDD)	Chances in 100 of a significant difference
A & B	272.0	2.66	99.7
A & C	137.5	1.36	91.2
B & C	134.5	1.24	88.8

Conclusions

1. Rats running a maze in which there is a true olfactory trail are more homogeneous when time scores are considered and more heterogeneous when error scores are considered than rats running a maze in which no olfactory cues are present or in which the blind alleys are marked. This indicates that rats running a maze in which there is a true olfactory trail do not tarry as long in the blind alleys as do rats running the maze in which no olfactory cues are present or in which the blind alleys are marked.

2. Reliable differences may be produced in time and error scores by the presence of definite animal odor trails in the maze.

3. The presence of definite animal odor trails in the maze tends to aggravate individual differences especially when error scores are considered.

4. In the maze learning of some rats the olfactory sense is undoubtedly of major importance when definite animal odor trails are present.

Experiment II

The purpose of this experiment was to determine the olfactory distractability of rats, that had learned the maze, by the introduction of strange or new olfactory cues. In Experiment I any extraneous drives that might have caused complications were avoided by using only young male animals and only odors from these animals as olfactory cues. In this experiment the olfactory trail was formed in the same manner as was described in Experiment I, except that it consisted of old male and female odors instead of odors from the experimental rats. The same groups were used as were used in Experiment I. Each animal ran two trials a day on two successive days immediately following the completion of the first 30 trials. Group C continued running the maze under the same conditions as in Experiment I, while Group A and Group B ran the maze with an olfactory trail in the blind alleys.

The learning curves in Figure 1 and Figure 2, trials 31 to 34, suffice to show that there was no disruption of the maze habit by the introduction of the old animal odors which were encountered here for the first time. The fact that the rats were not distracted by the old animal odors may be attributed to one of two things or both. With the learning of the maze the rats may have ceased using any olfactory cues, or the hunger drive and the fixated habit may have been so strong that any sex incentive, which would probably be associated with the female odor, was overcome. The latter statement would bear out the findings of

Tsai (9) who found hunger to be a more activating stimulus than sex.

Conclusions

1. The data from Experiment II indicate that the introduction into the blind alleys of the maze of old male and female odors in no way disrupts the maze running of rats if these rats have previously learned the maze with definite animal odor trails present.

2. The possibility that an odor trail in the true path of the maze might have caused some disturbance in the maze running must be referred to some future research since only the blind alleys were marked in this experiment.

DISCUSSION

The maze pattern, handling of the animals, preliminary training, uncontrolled sensory cues, and individual differences all exert their influence on the reliability of the results from any maze experiment. The obtained data, in order to be considered entirely reliable, must have resulted from the consistent measurement of the same thing in every animal on all the trials. The multiple-T type of maze was chosen for the present investigation because it is usually considered to give the most reliable results in a study of the maze learning of rats. Along with the various reliabilities found for the different types of mazes the amount of retracing allowed also has its effect on the reliability of the maze. Leeper (5), who studied the reliability of maze experiments, found that in a 13 unit multiple-T maze the prevention of retracing by means of 13 retracing doors gave higher reliabilities than when four doors were used, and the use of four doors definitely gave higher reliabilities than the use of only one door at the food box. In other words, if the retracing of no more than one alley is allowed, the reliability of a maze is substantially increased. In the present investigation the retracing of more than one alley was prevented by lowering the stems of the T's.

Of the other factors that might affect the reliability of the maze experiment sensory cues are probably the hardest to control. In most experiments adequate precautions are usually taken to prevent the changing of any sensory cues during the experimentation, this being especially true of vision, hearing, and kinaesthetic cues. Olfactory cues that may be formed in the alleys are impossible to control in many mazes, or no controls have been attempted because some investigators thought that olfactory cues were of little or no importance. Evidence was found in the present investigation that the presence of definite animal odor trails in the maze produced differences in time and error scores which in one case were completely reliable and in other instances approached reliability. If the animal odor trail was in the blind alleys many rats were led into making more errors and taking a longer time in running the maze than did those running the maze with no odor trail present or an odor trail in the true path. The rats running with a true olfactory trail present made lower total time and error scores than were made by the other rats. This group also exhibited the greatest heterogeneity of any of the groups in regard to the number of errors made. In any experiment, then, in which olfactory cues are not controlled the variability of the group may be increased and this increase in variability will be accompanied by a spurious rise in the reliability coefficients.

Most maze learning experiments involve the running of a large number of rats over a long period of time. If a maze not equipped with movable floors is used it is entirely possible that, as the rats learn the maze, a well beaten olfactory trail will be formed in the true path of the maze. Subsequently as new rats begin their first trials the time and error scores of many will be lowered. This will result in an increase in the range of the scores that in turn will tend to cause a rise in the reliability of the maze experiment. In the situation just described results may be obtained which are apparently more reliable but at the same time clearly less valid. In other words, it is not <u>only</u> the <u>maze learning ability</u> of the rat that is measured but some other behavioral factor that spuriously affects the score. The first rats introduced into the maze under those conditions will have no olfactory cues present while each succeeding group, when beginning their trials, will have an increasingly well beaten olfactory trail to follow. As the olfactory trail becomes more definite the time and error scores will be lowered. Thus, instead of measuring the higher behavioral adjustments of learning the maze, it is certain that in some rats only olfactory acuity is measured. Thus the test which is seemingly reliable is at the same time invalid in spite of the fact that theoretically it is impossible for a reliable test to be invalid. To have a truly reliable and valid measure of the maze learning ability of the rat it is necessary to prevent the formation of any definite animal odor trails in the maze.

SUMMARY

1. Eighty-six male white rats, between 65 and 85 days of age, were run over an elevated multiple-T maze consisting of 12 units. Fifty-eight of the rats ran the maze with definite animal odor trails present, either in the true path of the maze or in the blind alleys. A control group of 26 rats ran the maze with no olfactory cues present. A total of 34 trials was run by each animal over a period of 17 days. The last four trials constituted an experiment to determine the olfactory distractability of rats, that had learned the maze, by the introduction of old male and female odors. Under the conditions of this experiment no evidence of distraction was found.

2. Rats running the maze with the true path marked with their own odors took the least amount of time and made fewer errors on nearly all the trials; rats running the maze with the blind alleys marked with their own odors took the largest amount of time and made the largest number of errors on nearly all the trials; and, rats running the maze

with no olfactory cues present were somewhat intermediate in regards to the time and error scores on nearly all the trials.

3. Learning curves based on the means of the error scores for each trial are negatively accelerated but do not show the rapid initial drop that characterized the learning curves based on the means of the time scores. In other respects all of the learning curves show a similar trend in direction.

4. The presence of an olfactory trail in the true path of the maze resulted in the more rapid running of the maze with fewer errors for a majority of the rats. An olfactory trail in the blind alleys increased the maze running time and the number of errors. A reliable difference was found between the means of the total error scores and a difference approaching reliability was found between the means of the total time scores for these two groups.

5. In the maze learning of some rats the olfactory sense is undoubtedly of major importance when definite animal odor trails are present.

6. Rats running the maze with the true path marked yielded time scores which were more homogeneous and error scores which were more heterogeneous than those scores made by the other rats. Behavioral observations led to the conclusion that while some of the rats running the maze with the true path marked made a large number of errors they spent less time in the blind alleys than did those rats running the maze with the blind alleys marked.

7. Individual differences are aggravated by the presence of definite animal odor trails in the maze. This is especially true when error scores are considered.

8. The range of time and error scores may be increased by the presence of definite animal odor trails in the maze and this will cause a spurious rise in the reliability of these scores. At the same time it may be the olfactory acuity rather than the learning ability of the rat that is measured. Thus the test used is apparently highly reliable but is also invalid.

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