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THE EFFECT OF AUDITORY STIMULATION UPON THE MAZE BEHAVIOR OF THE WHITE RAT

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The present experiment deals with certain effects of auditory stimulation on the behavior of the white rat on an elevated maze. A number of studies have dealt with certain aspects of the problem of the relationship between audition and the control of behavior. Barber and Hunter (1, 4) have shown that the white rat is capable of localizing noise. Thuma (13) used a T-shaped discrimination box and reports that, while the white rat develops responses to tones only after a large number of trials, the animal can be brought to make locomotor responses to tones if a criterion lower than that used by Hunter be accepted. Muenzinger and Gentry (9), using a Y-shaped discrimination apparatus, find that the white rat makes discriminatory responses to diffuse and directed tones with far fewer trials than Thuma found necessary with his experimental arrangements. They suggest that the difference in the number of trials necessary in these studies is a function of the apparatus. Trueblood (14) was unable to account for certain behavioral disturbances in some animals following rotation of the tunnel maze without assuming effective auditory stimulation. Shepard (12) found that rats were influenced in their maze behavior by stimulation, or changes in stimulation, received from the floor over which they traveled and suggests that in all probability this stimulation was of an "auditory character." Patrick and Anderson (11) state that a sudden change in incidental stimuli of sound and light will cause errors in succeeding trials even though the maze had been correctly learned under the old conditions. Morey (8) reports the facilitating effect of sound upon the rat's activity in the water maze. Dennis (3) suggests that auditory stimuli may play a part in the formation of the maze habit. The studies just summarized indicate that the maze behavior of the white rat may be influenced by auditory stimulation. The negative results of Casper (2) secured under special

conditions do not seem fully relevant here. The aim of the present experiment is to study in a quantitative manner one specific form of auditory stimulation in relation to the development of the maze habit in the white rat.

An elevated maze was used in the present experiment. It stood 25 inches above the floor and was constructed of pine sections, 2 inches by ⅞ inch, each section 2 or more feet distant from adjacent segments. The true pathway measured 40 feet; the overall length measured 70 feet. Critical turns from the start to the food-box were: left, right, left, left, left, right, right, right. In order to avoid incidental sound as far as possible the experiment was carried on from 11:30 P.M. to 1:00 A.M. On each side of the maze and 3 feet therefrom a pressed-wood sound board was placed. The room was lighted with 12 25-watt electric bulbs regularly spaced and shielded by metal reflectors, an arrangement which as measured by the Westinghouse Foot Candle Meter gave an approximately equal illumination at all points on the maze. Three low frequency buzzers, connected in series, and mounted on an elevated 25-inch standard to the left of the maze, supplied the sound stimuli.

Twenty-three male white rats of Wistar stock, four and a half months of age at the beginning of the experiment, were used. They were trained for eight days in groups of four for one-half hour each evening. The animals were placed first in groups, and, on the fifth day, individually upon the training straightaway set up in the maze room. This straightaway was lengthened frequently until it approached the length of the true pathway of the actual maze. The rats were fed each evening individually upon the food platform. The daily ration for each animal consisted of six grams of McCullom's diet, fed as a dry meal. Fresh lettuce and crumbs of dog biscuit moistened in cod-liver oil were also given daily.

The rats were divided into two groups. The group learning without buzzer stimulation consisted of 13 animals. Three consecutive perfect trials were taken as the criterion of learning. The animals were then given a test series wherein sound was introduced. The second group learning the maze with buzzer stimulation from the left consisted of 10 animals. They were given a test series with sound shifted to the right, the sound source occupying a similar position with respect to the sounding board and the maze as it had on the left. The test series was continued until the rats had approximated the running-time exhibited in the training series. Five additional animals in this group were submitted to a test series in which buzzer stimulation, instead of being shifted from left to right, was omitted altogether. This series was also continued until the running-time under the altered conditions approximated the running-time under the original conditions. During the actual experimentation period the operator retired to a shielded celotex cubicle equipped with a one-way vision screen. Records were made of the following items:

1. The time the animals spent on the maze, total maze time.
2. The actual time spent in running the maze.
3. The errors made in order of their appearance.
4. The time required to traverse specific sections of the true pathway with respect to the direction toward or away from the sound source.

RESULTS

1. The effect of auditory stimulation on the maze behavior of the rat may be seen initially in the effect of introduced sound upon the performances of animals trained without sound.

A. The mean number of trials required for learning without sound was 21.5. In the test series (with sound introduced) an average of 12.8 additional trials, 60% of the original number of trials, was required for the animals to reach the original level of performance.

B. The average maze time with sound introduced after learning was 40% greater than the average maze time for the original learning, as computed from a comparison of the final two training trials with the two test trials. The average running-time in the test series was 46% greater.

2. The effect of auditory stimulation on maze behavior may be further seen in a comparison of the performances of animals learning when sound was constant with their performances when the sound source was shifted. All animals were disturbed by the change. The average number of learning trials was 10.5. The average score in time of the animals in learning was 152 seconds per trial for maze time and 99 seconds per trial for running-time. The median scores, 106 seconds maze time and 63 seconds running-time, are, however, more representative of the group learning with sound, for the reason that one animal required twice the average time and thus raised the mean.

With the shift in buzzer position after learning, 72.7 was the median percentage of the original number of learning trials required for the animals to reach their former level of performance. The average score showed 86% the original number of trials required to adapt to the sound change. In terms of feet traversed in blind alleys during learning, the median animal covered 75% of this original distance in the test series before the maze performance approximated the original wherein sound stimulation had come from the left. The average score of the animals in feet retraced was 87% the true pathway retraced in the training series. A comparison of the final two training trials with the first two of the test series indicates that the average maze and running-times in the test series exceeded those of the training series by 50%.

The influence of auditory stimulation on the maze behavior of these animals is still further apparent from a consideration of the character of the errors made in the test series. To reach the food in the training

TABLE 1

SHOWING THE EFFECT OF SOUND FROM AN EXTRA-MAZE SOURCE AS CONTRASTED WITH ITS ABSENCE IN MAZE LEARNING

Group I

	Learning without sound					Sound introduced—test series				
	Trials	Running-time (secs.)	Maze time (secs.)	Retraced true path (ft.)	Blind distance traversed (ft.)	Trials	Running-time (secs.)	Maze time (secs.)	Retraced true path (ft.)	Blind distance traversed (ft.)
Median	20.0	110.6	193.0	117.0	103.5	12.0	32.7	67.5	12.0	19.6
Mean	21.5	131.3	201.6	116.8	136.2	12.8	27.6	81.9	15.3	20.4
Mean deviation	5.0	43.6	65.6	34.4	41.0	4.0	7.5	33.2	10.6	14.0

Group II

	Learning with sound					Sound shift—test series				
	Trials	Running-time (secs.)	Maze time (secs.)	Retraced true path (ft.)	Blind distance traversed (ft.)	Trials	Running-time (secs.)	Maze time (secs.)	Retraced true path (ft.)	Blind distance traversed (ft.)
Median	11.0	62.6	106.0	58.0	76.0	8.0	20.0	51.6	8.0	19.0
Mean	10.5	99.0	152.0	68.1	90.3	9.1	19.5	50.8	5.8	26.6
Mean deviation	2.0	40.0	44.0	26.0	37.6	3.2	6.4	32.2	4.1	21.0

series the animals had necessarily at one point to make a left turn carrying them *away* from the sound source. With the shift of the sound to the right, however, this left turn now carried them *toward* the sound source. Nevertheless, in the test trials, the animals continued at this point to turn *away* from the sound, consequently entering blind alleys for several trials, and thus indicating that auditory stimulation had temporarily prevailed over other modalities in influencing maze orientation.

3. When, with five rats trained with sound, sound stimulation was omitted altogether in the test series, the average number of trials required to reach the former level of performance was 90% of the original number of training trials.

4. Measurement of the time required by rats in the group learning with sound stimulation to traverse a specific section of the maze leading toward or away from the sound suggests that the male white rat travels approximately twice as fast toward sound as the animal travels away from it. This conclusion is based upon a comparison computed from the final two training trials wherein the performance of the rat was more constant.

5. Finally, a general comparison of the performances of the two groups, those learning with sound and those learning without sound stimulation, indicates that 55% fewer trials, 55% less maze time per trial, and 56% less running-time per trial (median scores) were required by the 10 rats learning with sound than by the 13 rats learning without it. The mean total maze time of the animals learning without sound was 2.5 times greater than that of the animals learning with it. The mean total running-time was 2.86 times greater for the animals learning without than for those learning with sound. The median scores of animals learning with sound show that the animals retraced 50% less true pathway and entered 27% fewer blind alleys than did the animals learning without sound. Animals learning the maze with sound show less disturbance, as measured in mean and median scores for time, trials, and errors, when the sound is shifted in position, than do animals learning the maze without sound when sound is introduced.

SUMMARY

1. The maze performances of 23 male white rats were studied comparatively in an elevated-maze situation involving the presence and absence of auditory stimulation from an extra-maze source, with alterations in the position of the sound stimulus.

2. The animals learning the maze with sound make 50% fewer errors, traverse 27% less distance in blind alleys, and require approximately 55% fewer trials, 56% less running-time, and 55% less maze time than animals learning without sound. This confirms the statement of Patrick (10) that sound may facilitate learning.

3. In the behavior disturbances shown upon the shift in position of the sound source and upon the omission of sound after training with it, the animals gave evidence of localizing sound and of using auditory cues from the extra-maze environment in orienting on an elevated maze.

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