MAZE STUDIES WITH THE WHITE RAT

I. Normal Animals

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INTRODUCTION

The work of Watson, Bogardus and Henke, Vincent, et. al. has shown that the white rat learns the standard type of maze primarily in tactual and kinaesthetic terms, that during the learning the control is gradually transferred from contact to kinaesthesis, and that after the problem is thoroughly mastered the act is to be regarded as a kinaesthetic-motor coordination with an occasional reliance upon contact in times of emergency.

The neglect of the senses of vision, audition, and smell in the process of acquisition is not due to any functional incapacity of these senses. Miss Vincent has demonstrated quite conclusively that with a proper arrangement of the mazes both vision and smell will be effectively utilized in the development of the maze habit. Neither can it be affirmed that no optical, auditory, or olfactory data are present in the standard maze situation; rather we must conclude that for the rat organization these data as compared with those of contact and kinaesthesis are inadequate for the solution of this particular kind of a problem. The maze habit can be regarded as a definite sensori-motor coordination which was developed and which functions within a larger sensory environment. Many of these environing sensory conditions remain relatively constant and stable during the mastery of the maze.

Our experiments were designed to test the dependence of the maze coordination upon the stability of the wider sensory environment in which it was developed. The method consists of varying these environmental conditions while the maze is being learned or after it is mastered. In the usual type of experiment the rats are transferred from the living cage (kept in a constant position) to the maze located in a different

environment. It is thus possible to alter the sensory conditions of the animal while running the maze, or to effect changes in the environment prior to the test.

Various maze patterns were employed in the experiments. Unless otherwise stated, the mazes were of the usual type with the exception that they were almost water tight and covered by closely fitting glass covers. These features are mentioned because presumably they may effect the sensory relation of the animal to the extraneous environment. In order to alter the objective environment of the maze, recourse was had to a canvas top. A light but rigid frame was constructed and placed upon the maze. Over this was stretched several thicknesses of canvas fastened at the top but hanging loose on the four sides. From the top was suspended an electric lamp. The interior could thus be illumined or darkened, any of the four side curtains could be raised or lowered, or the whole top could be removed or replaced at will.

This paper describes the experimental results on animals with intact sense organs. Nearly two hundred rats were utilized in the various tests. Some of the results were secured by students working under my direction. The majority of the tests were performed by the writer.

The disturbances induced by the alterations were measured in terms of the error record. These records embrace such features as the number of animals affected, the number of trials in which error was present, the number of errors, the length of time necessary to adapt to the novel situation, and the tendency for the disturbing effect to be carried over to subsequent tests under normal conditions.

EXPERIMENTAL RESULTS

A. Alteration of conditions previous to running the maze.

Variable Route. In the typical experiment the living cage is kept on a rack some distance from the maze and the animals are carried by hand and placed within the maze. This route was kept constant while the maze was being mastered. After mastery this route was altered in various ways. Sometimes a long and devious route through the laboratory was chosen. Fourteen rats were tested and no disturbing effects were noted.

Method of Handling. The normal method of handling was

varied by inducing a condition of dizziness just before placing the animals in the maze. The rats were held at arm's length and whirled rapidly around in horizontal and vertical circles and then placed in the maze. The dizziness effects were evident in the animal's behavior. They experienced difficulty in standing erect, crouched down on the floor of the maze, and waited for the effects to disappear before attempting to run. Twelve animals were employed and no disturbances were present.

Position of Cage. After the maze was learned, the living cage was transported to a new position in the laboratory, care being taken to preserve its original cardinal orientation. This alteration introduces two new features, a new route to the cage, and a new sensory environment previous to the maze reaction. Since variations in the route are without effect, this aspect of the alteration may be neglected. The duration of the exposure to the novel environment prior to the test was varied; the animals were tested either 15 minutes or 24 hours after the alteration. The distance over which the cage was moved also varied. Ten animals were tested. Seventy per cent of these were affected, and the disturbance was present in but 41 per cent of their trials. The degree of disturbance varied with the degree of alteration. One group of six rats was subjected to alternating small and large shifts in the position of the cage and the resulting average error records were .58 and 1.75 respectively. The animals quickly adapt themselves to these changes. Most of the disturbances resulted from the 15 minute exposures and in this case the disturbing effect had generally disappeared on the subsequent day's test. There was no evidence that the effects persisted for any length of time after a return to normal conditions.

Covering Cage. After the maze was mastered, the living cage was entirely covered with several thicknesses of canvas. This substituted a homogeneous for a heterogeneous visual environment and reduced the illumination of the cage very appreciably. The animals were kept in this environment for a day before the first test. Forty-five animals were subjected to the experiment. But one rat exhibited signs of disturbance and the effect was present only in the first day's test.

Rotation of Cage. The living cage was rotated in reference to the cardinal positions while remaining in the same position.

The shifts employed were 90, 180, 270 degrees. The duration of exposure to the novel conditions prior to the test was varied. Three groups of animals were utilized and the conditions differed so that a separate description for each group is necessary.

1. The first group consisted of six rats and both living cage and the maze were uncovered. The rats were first subjected to the new orientation for 15 minutes and then tested in the maze. The cage was then returned to its normal orientation and control tests were given on the second day. On the third day the animals were tested for the effects of a 15 minute exposure to a different orientation. No animal was disturbed by these 15 minute exposures. Exposures of 24 hours were given for three orientations on successive days. All of the rats were disturbed by these alterations. The average error record per trial for six tests was 2.86. Errors were present, however, in but 40 per cent of the trials. There was a marked individual difference in susceptibility, the number of errors ranging from 3 to 44. The degree of the disturbance increased with successive shifts, though the rats quickly adapted themselves when kept in a given orientation.

2. The cage was covered with the canvas top and then rotated. The animals were tested in an uncovered maze. The group consisted of forty-five rats. They were tested immediately after the rotation and then for several days in succession. Three successive shifts were made before the cage was returned to its normal orientation. But seven of the rats manifested signs of disturbance and the effect was slight and quickly eliminated. With one animal the effects were sufficiently obvious that a disturbance can hardly be doubted. The effect was present for the first day's test for two positions.

3. In this experiment the uncovered cage was rotated, and the animals were tested in a covered maze. The animals were subjected to one or more day's exposure to each new orientation before being tested. Seventeen animals were employed, and signs of disturbance were noted for but five. The effect was so slight in four cases that one cannot be confident of the results. The disturbing effect was obvious for one rat for two of the new positions.

B. Alteration of conditions while running the maze

Degree of Hunger. After the maze was mastered, periods of four days of heavy feeding were alternated with similar periods of normal feeding. We thus have the rats coming to the maze with different degrees of hunger, the object of the test being to determine the effect of strength of motive upon the accuracy of a well automatized act. Rats differ very materially in the length of the feeding period necessary to keep in good condition and to give consistent daily records. These individual differences are due to the rate of eating and the amount of food required. The normal time allowed for eating ranged from 5 to 7 minutes. The periods of heavy feeding were 15 to 20 minutes in length, the animals being allowed to gorge themselves to their utmost capacity. Ten rats were tested. Heavy feeding multiplied the average error record by twenty. All rats were affected in varying degrees. Disturbance was present in but one-third of the trials. The degree of the disturbance was highly irregular from trial to trial. In general the effect increased at first and then decreased. Complete adaptation was never secured.

Cleansing Maze. During the course of a long experiment, the maze will accumulate considerable filth in spite of the glass cover. This filth consists of faeces, wisps of cotton, shells of sunflower seeds, trackings of milk, and urine deposits. These were allowed to accumulate for considerable time and the maze was thoroughly cleansed and washed. The animals were tested on subsequent days to determine the effect of this alteration of conditions upon the accuracy of the maze habit. Ten rats were tested, and eight were affected. The greatest effect occurred on the second trial. Adaptation was secured in four trials. Errors were present in but 60 per cent of the tests. The average error record per trial for those affected was 1.75.

Covering Maze. The rats were allowed to master the uncovered maze. The canvas top described in the introductory section was then placed over the maze. In one case the interior of the top was illuminated when the rats were tested, and with another group it was not. A homogeneous maze environment was thus substituted for the customary heterogeneous one, and the illumination was either decreased or altered in character. Eighteen rats were subjected to these changes while running the maze, and none were disturbed in the slightest degree. This

fact would indicate that the rat does not rely upon stimuli from the extrancous environment during the latcr stages of the learning process.

Uncovering Maze. The animals first mastered the maze while it was covered with the canvas top. After mastery this top was removed and the animals tested. Two slightly different exp e ments were performed. 1. The maze was mastered when the top was open on one side allowing poor daylight illumination of the interior. The top was now removed. Seven rats were tested and none were disturbed by the changes. 2. The maze was mastered while entirely closed and the interior illumined by an electric light. The top was now removed. There resulted the substitution of a heterogeneous for a uniform optical environment, and the introduction of daylight for artificial illumination. Ten rats were tested, and five were disturbed. The effects persisted from 1 to 6 trials. The errors were distributed irregularly, and perfect records were secured in 70 per cent of the tests. The average error record for those affected was 1.07 as compared with a previous normal of .20. The total number of errors per animal varied from 3 to 11.

Increase of Illumination. The maze was learned while entirely covered with the canvas top but without interior illumination. The interior was now illumined by the electric light. A well lighted uniform environment was thus substituted for a subdued one. Ten rats were tested, and seven were affected. The disturbance lasted from 1 to 6 trials. Errors were present in but 40 per cent of the tests. The average error record was 1.35 as compared with the previous record of .51. The total number of errors per individual varied from 4 to 47.

Decrease of Illumination. An open maze was mastered. It was situated in front of an open window giving a good illumination. After the maze was learned this window was covered so that practically all light from this source was excluded. This procedure decreased the illumination in the maze and altered its direction, without changing the character of the environing objects. Ten rats were tested and seven were disturbed. The effects lasted for 1 to 8 trials. The maximum effect occurred on the second test. Many trials were without error. The average error record was 3.18 as compared with a previous normal of .21. One animal made 40 errors in eight trials. After

adaptation to the new conditions, a return to the normal situation effected no disturbance.

Position of the Experimenter. The experimenter maintained a constant position in reference to the maze while it was being learned. After mastery, this position was varied. After inserting the rats in the maze, the experimenter occupied a position on the opposite side of the maze from that in which he formerly had stood. Six rats were tested on successive days until all disturbance had subsided. All members of the group were affected in varying degree. Errors were present in 60 per cent of the tests. The average error record for three successive trials was 2.50 as compared with a previous normal of .11. The disturbance was eliminated in three trials. The total number of errors per rat for the three trials ranged from 2 to 18. The disturbance occurred only at that point in the maze path near which the experimenter stood. The path previous to and after this critical point was traversed normally. All error deviations were in the direction of the experimenter. A disturbance was frequently manifested by slow and hesitant movements and head and body orientations in the direction of the experimenter even when no errors were made.

Rotation of a Uniform Environment. The maze was covered by the canvas top closed on all sides and the interior was illuminated by the electric light. Under these conditions vision of the objective environment was impossible to the human eye. This top was practically square (3′, 9″ by 4′), and as a consequence the optical environment was uniform. The top was now rotated 90 degrees between trials, the maze itself remaining stationary. Presumably the visual situation was not altered by this procedure. Ten rats were tested, and no disturbance resulted.

Rotation of Heterogeneous Environment. The maze was learned with the curtain of the canvas top open on one side. This curtain was now closed and that on another side was opened. This procedure was continued until all four sides were opened several times on successive days. The alteration produced a change in the direction and intensity of the light as well as in the character of the optical environment. Seven rats were tested under these conditions, and five were affected by the novel conditions. These five animals made an average error record of 1.90 for six tests, and errors were present in 85

per cent of the trials. The disturbance due to the alteration persisted to some extent on the subsequent day's test in normal conditions. The number of errors per rat ranged from 9 to 15. A repetition of the test for each of the three novel situations exhibited a pronounced tendency toward adaptation, but the experiment was not continued until complete adaptation was secured.

Position of the Maze. After being learned, the maze was removed to a new position in the laboratory but its original cardinal orientation was preserved. The maze was shifted about twelve feet in position but the shift was of such a character that the maze was now situated in practically a new environment. This procedure involved two alterations; a change in the objective environment while running the maze, and a new route from the living cage to the maze. The latter factor has been shown to be non-effective and may thus be disregarded. Six rats were given three tests in the new position, and four were affected. These made errors in 55 per cent of the trials, and gave an average error record of 2.08. The number of errors per rat ranged from 4 to 10. The animals adapted quickly to the novel conditions, and in some cases a slight disturbance was evident on a return to the old position.

Rotation of Maze. In this experiment the canvas top was not used, and as a consequence the maze was rotated in reference to a stationary heterogeneous environment. This experiment was first performed by Professor Watson and our results are in harmony with those secured by him. Unless otherwise specified, the three novel positions utilized were 90, 180, and 270 degrees. The tests were conducted on different mazes and with different procedures and thus need to be described separately.

1. The glass covered maze was used and tests were given for the three novel positions on successive days followed by a return to the original position on the fourth day. This procedure was now repeated to determine the effect of adaptation. Ten rats were employed and all were disturbed. In the first shift, errors were present in 65 per cent of the trials, and an average error record of 6.95 was secured. The induced effect was occasionally carried over to the subsequent day's trial in the normal position. A repetition of the shifts disclosed a pronounced adaptive tendency. All members of the group were

still affected but the percentage of perfect trials was increased from 35 to 53 and the error record was reduced from 6.95 to 1.72. The shifts were not continued until complete adaptation was effected.

2. The same conditions obtained in this experiment except that the maze was left in each new position until the disturbance was eliminated. After adapting to the three positions, the maze was returned to the normal position. This procedure was now repeated until complete adaptation was effected for the four rotary positions. Similar rotary shifts were now instituted between the 45, 135, 225, and 315 degree positions until adaptation for these positions was effected. Fifteen animals were employed in the experiment. During the first rotation, thirteen animals were disturbed, and these gave an average error record of 10.7 for the first day for the three new situations. The rats were not affected in every trial, as perfect records were secured in 32 per cent of the first day's trials. Adaptation was effected for each position on an average of four trials. The induced disturbance was occasionally carried over to a slight extent to the normal position of the maze. The adaptation for each position secured in the first shift was not permanent. New rotations disclosed a further disturbance, but the effect gradually decreased with repeated shifts; fewer animals were disturbed, the errors became smaller, the percentage of perfect trials increased, there was less carrying over to the normal position, and the time necessary to adapt for each position was lessened. Complete adaptation was effected on the fifth repetition and thereafter the maze could be rotated at will between any of these four positions without disturbance. Complete adaptation for one series of positions does not, however, involve adaptation to another series of positions. Rotary shifts were now instituted between the 45, 135, 225, and 315 degree positions. In the first shift all of the rats were again disturbed. In the first day's trials for the four positions, the average error record was 7.2 with a percentage of perfect runs of 20. Adaptation was again effected with repeated tests.

3. A group of animals was rotated in a well illuminated and a darkened environment. The maze had been learned with the illuminated condition. The room was darkened by means of window shades. The animals were accustomed to running the

maze under both conditions before the rotation tests were given. One set of four rats were tested for three positions on successive days when the room was well illuminated. The tests were now repeated for the darkened environment and these were followed by a series with an illuminated maze. The average error records for the three conditions respectively were 7.15, 1.90, and 3.20. The final value for the illuminated environment is thus greater than that previously secured for the darkened condition in spite of the fact that animals tend to adapt to these rotary shifts when repeated. With a second set of six animals, complete adaptation was effected for three positions while the room was darkened. The room was then illuminated, and the tests were repeated. A disturbance was again evident. The disturbance could hardly be due to the sudden introduction of the light, as the maze had been learned under these conditions, and the rats had been accustomed to run the maze in its normal position while the room was illuminated. The results indicate that a maze rotation in reference to a well illuminated environment is more disturbing than a similar one in reference to a darkened environment.

4. A sideless maze was employed in the following experiment. This consists of a series of runways separated from each other by open spaces four inches in width. This maze differs from the standard maze usually employed in these experiments in several respects:—it is less complex as to number and length of alleys, the absence of sides eliminates the possibility of a contact guidance in traversing the paths, and the absence of the sides and the glass cover allows the animals a more intimate sensory contact with the objective environment. We were interested in comparing the degree of disturbance due to rotation on such a maze with that exhibited by animals in the standard maze. If rotation disturbs the animals because of the alteration in reference to the environment, the degree of disturbance in the sideless maze should be the greater. Five rats were tested. The average error record, and the number of trials necessary to secure adaptation were twice those for the standard maze. This ratio does not adequately represent, however, the relative confusion in the two cases because it neglects the greater simplicity of the sideless maze. If the two mazes offered equal opportunity for error, it is safe to assume that the discrepancy

between the two sets of values would have been much greater than they were. This difference in complexity can be equated by comparing the initial error record due to rotation with the initial error record in learning. The average error record for the first trial in learning the standard maze was 44, while the average number of errors made in the first rotation test was 10. Rotation in the standard maze produces an initial error disturbance which is approximately 23 per cent of that in mastering the maze. The initial error record for the sideless maze was 10.5, while the corresponding value for rotation was 19.7 The confusion involved in rotation was thus greater than that in learning. Relative to the number of initial errors in learning, rotation in the sideless maze produces a disturbance eight times as great as in the standard maze.

Certain peculiarities of behavior were apparent in the sideless maze. The rats frequently gravitated to that corner at which the food box had been located before the rotation. Failing to find food, they renewed their explorations of the maze, but came back again and again to this particular corner. One animal finally refused to leave this locality and had to be removed from the maze. After two such unsuccessful trials on successive days, the experimenter guided the animal to the new position of the food box, and thereafter the maze was traversed successfully on the animal's own initiative. One other rat was unsuccessful on the third trial. This type of behavior was exhibited in varying degrees during the first three trials by each of the ten rats employed in the test. Such behavior has been observed but rarely in a standard maze and only when certain parts of the maze were flooded by strong daylight illumination.

5. The *cul de sacs* in the standard maze were closed by sliding doors. After learning the maze in this condition, the animals were subjected to the usual rotation tests. Obviously all disturbance due to rotation must be measured by return errors. Twelve rats were tested and all were affected. The experiment is significant in indicating that the disturbance in maze rotation is not due exclusively to wrong choices at those critical positions from which several paths diverge. Confusion obtains when no choice is possible and when the animals have had no experience with *cul de sacs* during learning.

Rotation of Maze and Environment. The maze was learned

while entirely covered by the canvas top and illuminated by an electric light. After learning, both maze and top were rotated as a unit. Tests were given for the three positions on successive days. On the fourth day a normal record was secured for the original position. The above procedure was then repeated several times. Ten rats were utilized in the experiment. In the first shift eight rats were disturbed; these gave an average error record of 1.29 for 48 trials, although errors were present in but 31 per cent of the trials. The shifts were now repeated three times and no tendency toward adaptation was in evidence. The percentages of animals affected in the four successive shifts were 80, 80, 90 and 70. The percentages of trials in which error was present were 31, 35, 55, and 36. The error records were 1.29, 1.81, 1.18, and 1.32. The largest disturbance occurred for the 180 degree position. This result is a function of the position and not of the temporal order of the shifts, inasmuch as a different temporal order of the three positions was given in the successive series.

This experiment is comparable with the first test of the previous section in all respects except the environmental conditions. In the previous test the maze was rotated in reference to the environment, while here both maze and environment were rotated. Rotation in reference to a stationary environment produced much the greater effect at first, and allowed a pronounced degree of adaptation when the experiment was repeated. No adaptation was present when both maze and environment were rotated, and the records secured were practically identical with those in the former experiment after the rats had become adapted.

C. Alteration of conditions while learning the maze

Rotation of Maze. Animals were required to master the standard maze when its cardinal orientation was changed for each day's test. The daily shifts in position were 90 degrees, each position being repeated every fourth day. These records are compared with those representing the mastery of a stationary maze, and we are able to estimate the relative effect upon learning of a stable vs. a variable relation to the objective environment. The following records for a rotated maze were obtained from ten rats without previous laboratory experience:—the

average number of trials involved in mastering the maze was 30, a group error record of zero was first obtained on the 36th trial, and the average number of errors made during learning was 196. The corresponding values for a group of 29 rats learning the same maze while stationary were 18, 22, and 144 respectively. Rotation thus increased these values by 50 per cent. A comparison is likewise possible between two groups of rats which had had previous experience upon a different type of problem. Ten rats in learning a rotated maze mastered it in 21.4 trials, first secured a perfect group record on the 27th trial and averaged 110 errors per rat for the learning period. The corresponding values for 14 rats in mastering the same maze while stationary were 9.2, 17, and 58. In this case rotation has doubled the difficulty of learning. The two curves of learning were similar in form; rotation seems to add on the average about 3 or 4 errors to each trial and this slight addition towards the end operates to postpone the final mastery of the maze for many trials.

Uniform Environment. Certain groups of rats mastered the maze when covered on all sides by the canvas top. Other groups also mastered this maze without the top. In one case the maze habit was developed in a uniform optical environment, and in the other with a heterogeneous environment. A comparison of the two sets of data will thus indicate the function of a heterogeneous environment in the development of a habit. The heterogeneous environment aided learning. The average number of trials and the average number of errors per rat for a group of 29 rats in mastering an open maze were 18 and 144 respectively. The corresponding values for the closed maze were 26 and 282. These results indicate that the animals may utilize data from the objective environment in mastering the maze.

CONCLUSIONS

Any sensori-motor act can not be regarded as an isolated independent function; the act was learned within a wider sensory environment, and it never ceases to be wholly free from these conditions either during or after its development. The stability of the environment furthers the development of the act, and conditions the regularity and accuracy of its functioning after it has become automatic. These environmental conditions

embrace the sensory situation at the time, the sensory situation in which the animal lived for several days prior to the act, as well as the intraorganic condition of the animal. The influence of intraorganic factors is evident from four types of facts:—1. The case of hunger is obvious. 2. Novel situations while running the maze may induce effects which persist and exert a disturbing influence after a return to normal conditions. These persistent disturbing effects must be intraorganic. 3. Alterations of the cage environment previous to the performance of the act may exert a disturbing effect. Evidently these disturbing conditions must be retained as some intraorganic condition. 4. The influence of some of these alterations may be cumulative from day to day.

These alterations operate in an irregular and sporadic fashion. This generalization is supported by several lines of evidence. 1. A few animals in each group are usually immune to the altered conditions. In the majority of experiments the percentage of animals affected ranged from 50 to 90. 2. Animals may be disturbed in one trial but immune in another. The percentage of trials in which error was present ranges from 30 to 65 for the various experiments. On the average the affected animals were not susceptible to the alterations in one-half the tests. 3. An animal may be susceptible to one kind of alteration but immune to another, while the opposite relation will obtain for another rat. Eleven rats were subjected to the following five experiments,—position of experimenter, rotation of cage, position of cage, position of maze, and rotation of maze. Three animals were disturbed in all five experiments, three rats were affected in but four tests, two rats in three tests, two rats in two experiments, and one rat in but a single test. Two rats were disturbed by the rotation of the maze, but were not affected by a change in the position of the maze; on the other hand, two rats were disturbed by the latter test but were immune to the rotation of the maze. Ten rats were given the following tests, increase of illumination, rotation of maze and environment, cleansing paths, uncovering maze, and rotation of maze. One rat was affected by all tests, three rats were immune to one experiment, four to two experiments, and two to three experiments. Three animals were immune to the rotation of the maze and environment, but were disturbed by cleansing the maze; on the other hand two rats were immune to the changes

involved in the cleansing of the maze but susceptible to the first experiment. Many similar illustrations can be given. 4. A rat may make a very large number of errors in some tests and very few errors in others. Ten rats were ranked as to the number of errors made in each of five experiments. The rankings given to one rat for the five experiments were 1, 2, 9, 2, and 2. Similar rankings for another animal were 8, 1, 1, 7, and 9. This lack of consistency may be shown by dividing the animals into two groups on the basis of number of errors. Only one of the ten rats belonged to the better half in all five experiments. In another group of eleven rats but four manifested any high degree of consistency; two were found in the better half for all experiments, while two invariably belonged to the poorer half. The rankings for one experiment were correlated with those for the other four experiments, and positive values of .369, .690, .414, and .068 were obtained. 5. Affected animals make a relatively high percentage of perfect runs in one experiment and a low percentage in another. 6. One would naturally expect a high degree of correlation between the total number of errors made in an experiment and the number of trials in which a disturbance was present. Two groups of animals were ranked in both respects for five experiments and the correlation values were computed. Small negative values were obtained in every case. These results mean that those animals which make an extremely large number of errors in one trial are likely to become adapted to the alteration and run the subsequent trials without error. 7. Animals that do well for one position in the experiment on maze rotation do not necessarily make good records for other positions. The correlation value between two positions for a group of nine rats was but .434. Animals that do well for one position do not necessarily make good records when the test for this position is repeated. Such a correlation by the ranking method for the above group of rats gave a value of but .024.

The above emphasis upon the irregular and accidental character of the disturbances must not blind one to the fact that some rats manifest a relatively high degree of consistency in the various experiments. Some animals are quite susceptible and make a large number of errors in every experiment. Other rats are prone to immunity; they either fail to be disturbed or

make low error scores in every experiment. This consistency is limited to comparatively few animals; irregularity and inconsistency obtain for the majority of the rats and for the groups taken as a whole.

Adaptability to these alterations is the general rule. The rate of adaptability is a function in general of the magnitude of the disturbance. Stability of the novel conditions aids adaptation, while any further change delays it; animals kept in a novel situation eliminate the disturbance more quickly than when they are shifted back and forth between the novel and the normal conditions. Continuous alterations of the novel conditions as in the various rotation experiments operate to delay the adaptation. Adaptation to any novel situation is in the main specific and not general; the animals become adapted to that particular alteration and not to all novel situations. There is no conclusive evidence that the adaptation secured in one experiment operates to give complete immunity in other experiments. Complete adaptation to one series of positions in the rotation experiment did not involve a complete immunity for alterations between another series of positions. Any adaptation to a particular situation is retained with some degree of perfection over a period of time devoted to securing adjustments to other novel conditions. Any acquired immunity is thus mainly specific and refers only to that situation under which it was acquired; it is retained after the interpolation of other tests with some degree of perfection, but it gives no certain aid to the mastery of other novel situations.

The degree of disturbance was a function of the kind of alteration. As a general rule alterations while running the maze were more effective than changed conditions of the rat's environment before being placed in the maze. It is rather surprising that pronounced changes in method of handling and of route from cage to maze should be without effect, while alterations of the living cage in relation to its environment were provocative of error. The difference in the results may be due to the fact that the animals were not subjected to a sufficient duration of exposure to the novel conditions in the former two experiments. The maximum duration of exposure never exceeded a few minutes, while the minimum exposure in the cage experiments was fifteen minutes. Covering the maze produced no effect, while con-

siderable disturbance was manifest when the maze was uncovered. This difference in results is more comprehensible when the situation is stated in the following terms:—The removal of stimuli (change from a heterogeneous to a uniform environment) is without effect, while the introduction of novel stimuli operates as a disturbance. This conception would indicate that the rats after mastering the maze do not rely to any great extent upon the objective stimuli as guides or controls in traversing the maze, and that the introduction of unfamiliar conditions operates as a distraction.

This paper makes no pretense of defining in physical terms the nature of the environmental alterations. Rotation of the maze may disturb the normal relation of the animal to the optical, olfactory, or auditory aspects of the environment. Likewise we make no pretense of knowing through what sense avenue these disturbances were mediated. We were interested primarily in establishing the fact that the rats are sensitive to these alterations in some way and that stability of sensory conditions is conducive to the development of an automatic act.