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MAZE STUDIES WITH THE WHITE RAT

II. Blind Animals

HARVEY CARR
University of Chicago

In the previous paper there was formulated the proposition that the maze habit is dependent to some degree upon the stability of various environmental conditions. The present paper concerns the function vision in sensing these alterations and becoming adapted to them. The method consists of comparing the records of blind rats with those of animals with intact sense organs. The possibility of vision was eliminated by the usual method of extirpation of the bulb. Three of the rats were subjected to an autopsy and a microscopical examination by Professor C. J. Herrick, who reports that all three were probably blind. Comparisons will be facilitated by certain classifications of the experiments.

1. The first group contains all those experiments in which no blind animals were tested, and hence comparisons are impossible. This group consists of the following experiments. Covering cage, covering maze, increase of illumination, decrease of illumination, rotation of a uniform environment, the second phase of uncovering the maze, and the 3rd, 4th, and 5th tests on rotating the maze.

2. The second group contains those experiments in which both seeing and blind animals were utilized but in which no rats were disturbed by the alterations. Obviously these experiments can furnish no data as to the function of vision. Nine blinds

were subjected to the "variable route" test and none were affected. Five blinds were tested on variations of method of handling without disturbing results. Two blinds were subjected to the first test on uncovering the maze and no effect was noticeable.

3. In the third class fall those experiments in which both blind and seeing rats were tested, but in which the disturbance was limited to those animals with vision.

Alterations in the position of the experimenter affected none of the five blind animals tested, while every member of a group of six normal rats was disturbed.

A change in the position of the maze had no effect upon any member of a group of five blind animals. In a group of six normal rats, four were affected and these made an average error record of 2.08.

4. In the remaining experiments, both blind and normal animals were tested and both groups were disturbed. The comparative records will need to be stated in detail for each experiment.

Degree of Hunger. Two blind rats were compared with ten normals. All members of both groups were disturbed. The blinds made errors the more frequently; the percentages of trials with error being 42 and 34 respectively for the blind and visual groups. The average error records for the two groups were 9.75 and 2.38 for the blinds and normals respectively. The blinds manifested their maximum of disturbance on the third trial while the normals gave the largest error record on the fifth trial. The blinds also exhibited the greater error record on a return to normal conditions.

Cleansing Maze. Seven blinds were compared with ten normals. Fewer blinds were affected, the percentages being 57 and 80. They made errors in 75% of their trials as compared with 61% for the normals. Their average error record was 6.00 as compared with 1.70 for the normals. Their greatest disturbance occurred on the first trial while the normals made their poorest record on the second trial. The time necessary to effect an adaptation was the same for the two groups. The blind animals exhibited the greater range of variability as to number of errors per rat; the average and the average variation for the blinds were 24.0 and 18.6 respectively, while the corresponding values for the normals were 10 and 5.6. The average variation relative to the size of the errors is thus much greater for the blind group.

Position of Cage.—Both groups contained ten rats. A smaller percentage of the blinds was affected, the values being 40 and 70. Those blinds affected were disturbed in a greater percentage of their trials (50 vs. 41), and made the greater average error score (1.33 vs. .87). The blind animals require a longer duration of exposure to induce an effect; they were disturbed only for the 24-hr. exposures, while the normals were affected by a 15-min. exposure. The blind rats also possessed the poorer adaptive power, for the normals became so accustomed to the novel situation in 24 hours that a disturbance was no longer manifest.

Rotation of Maze. Two blinds were tested on the first type of maze rotation, in which the three positions were tested on successive days. Their records are to be compared with those of ten normals. All members of both groups were disturbed. The blinds made errors in a greater percentage of their trials (67 vs. 65), but their average error record was much smaller (3.33 vs. 6.95). With a repetition of the test the poorer adaptive ability was manifested by the animals without vision; they decreased the percentage of trials in which error was present from 67 to 58, and their error record from 3.33 to 2.50. The visual group on the contrary reduced their error record from 6.95 to 1.72 and the percentage of runs with error from 65 to 47.

Rotation of Heterogeneous Maze Environment. The records of fourteen blind animals are to be compared with those of seven normal rats. A greater percentage of blind rats was disturbed (78 vs. 71). The errors of the blind group were confined to a smaller percentage of the trials (38 vs. 83). The blinds gave the larger error score (2.32 vs. 1.90) in spite of the fact that the errors were limited to fewer trials. The discrepancy is much greater when we compare the total number of errors per rat (18 vs. 12). The blinds exhibited the greater range of variability as to number of errors per rat; for the blinds the errors ranged from 3 to 70 with a mean variation of 15. The range for the normals was 9 to 15 with a mean variation of 2.2. The normal rats appeared to react definitely to the altered conditions. With each new change of conditions the errors were made at those places in the maze where the lighting conditions were altered the most. The blind animals, on the contrary, gave no evidence of reacting specifically to any observable changes. The errors were likely to occur anywhere within the maze. When the experiment was first performed, a group of four blinds was employed mainly as a control as no disturbance was expected. Since the number of errors was increased beyond the normal records, the test was repeated upon two other groups of blinds consisting of five each. The same results were obtained; the rats did not seem to be reacting to any specific feature in the environment and yet the normal number of errors was increased; some rats occasionally became almost hopelessly confused. Five animals made over 17 errors in a single trial.

Rotation of Maze and Environment. The records of five blinds are to be compared with those of ten normals. Eighty per cent of each group was disturbed. The blind animals made errors the more frequently, the percentage of runs with error being 42 and 31. The average error records of the blinds and normals were 7.76 and 1.29 respectively. The blinds exhibited the greater range of individual variability; the individual number of errors ranged between 3 and 172 for the blind rats and between 2 and 22 for the normals. The test was not repeated for the blinds so that comparisons as to adaptability are impossible. The blind rats, however, exhibited more disturbance after a return to normal conditions.

Rotation of Cage. Nine blind rats were tested. For the 15-min. exposure, all were affected, errors were present in 57% of the trials, and the average error record was 1.90. For the 24-hr. exposure, 90% were disturbed, errors were present in 62% of the trials, and the average error record was 4.95. A repetition of the tests disclosed no tendency toward adaptation.

Blind rats are more susceptible to these alterations than are the normals; blinds were disturbed by the 15-min. exposure while the normals were not. The blinds were also affected more by the 24-hr. shifts than were animals with vision. The blinds exhibited the greater range of individual variability as to number of errors, and the lesser powers of adaptability.

5. We are also able to compare the records of blind and normal animals in the mastery of the maze problem.

Vision aids untrained rats in learning a stationary maze, decreasing the number of trials by 28% and the total number of errors by 27%. The following records were obtained for 19 blind animals. The average number of trials involved in learning was 25. A perfect record was secured for the various groups on the 30th trial. An average total of 229 errors was made by each rat. The corresponding values for 27 normal animals were 18, 22, and 144. The generalization that vision may aid in the mastery of a stationary maze contradicts the findings of Watson in his study of kinaesthetic sensitivity. I do not question these results but doubt their universality. In these experiments the records of many blind rats and the average records of many groups of blind animals do not suffer in a comparison with the records of normal animals. One of the blind rats mastered the maze more quickly than any of the 27 normals. Two of the blind groups gave as good records as those of three groups of normals. On the other hand, six of the nineteen blinds did worse than the poorest of the 27 normals, and two groups of blinds gave a higher average record than the poorest group among the normals. While some individuals and some groups of blind animals do as well or better than the average run of the normal animals, yet there are many blind rats that do considerably worse than the majority of the normals. When the groups compared are rather large, there is likely to be a number of blind rats with extremely poor records and these cases are responsible for the poor group average. The blind rats exhibit the greater range of individual variability in their capacity to learn.

Vision aids trained rats to learn the rotated maze, decreasing the values by 35-40%. A group of 10 normals learned the rotated maze in 21.5 trials with an average total error score of 110. The corresponding values for three blind animals were 33.3 and 190. The rats had previously been trained on an alternation problem. The size of the blind group is too small, however, for a confident conclusion.

Vision is a detriment with untrained rats in mastering a rotated maze, increasing both number of trials and total errors. A group of six blinds learned the maze in 27 trials with an average error score of 117. The corresponding values for 10 normal rats were 30 and 196.

6. There are certain other peculiarities of blind rats con-

nected with their greater variability and erraticness. Blind rats are rather difficult to keep in good physical condition. They are more inclined to sluggishness in behavior, their appetite is frequently diminished, their hair becomes dry and rough, and they are sometimes rather flabby and cold to the touch. I have also noted what may be termed as a "breakdown," of which a number of examples may be cited. A group of six normals had been employed for four months in a sound discrimination experiment. Their conduct was normal and their physical condition was excellent at the conclusion of the experiment. These animals were now blinded and given the maze problem. Four of these rats proceeded to learn the maze in a normal manner for a number of trials and then suffered the "breakdown." They made complete failures of their attempts, became exhausted before success was achieved, and finally refused to run when placed in the maze. The break came on suddenly and occurred between the 6th and the 15th trials,—after the maze had been pretty well mastered. In another group of four animals without previous experience, one rat made rapid progress up to the 12th trial and then refused to run. The breakdown may occur at almost any stage of the experimentation. I had one individual that refused to run in the first trial. Another rat broke down on the 142nd trial during the control tests,—long after the maze had been mastered. Sometimes the rats simply quit and refuse to work further. Others work industriously but fail to find the food box, and are finally forced to cease their efforts through exhaustion; this behavior may be repeated in a number of successive trials until the rat quits and refuses to work when placed in the maze. Recovery from these breakdowns is rare and the rats may as well be eliminated from the experiment. I have tested such rats for a number of days in succession, and once a week for a couple of months in the hope that an interval of rest would induce recovery. These animals may continue to live and enjoy the average of health for blind rats. Some have been kept in the laboratory for five to six months. I have had some females bear and rear young subsequent to the breakdown. The phenomenon needs extended and systematic study.

The above differences in the comparative data obviously must be explained and interpreted in terms of vision. Certain conclusions can be asserted with confidence. Some interpretations must be regarded as suggestive.

Vision has a sensitive function. This statement means that the various objective alterations sometimes affected the animal's behavior through the medium of vision; in ordinary language we would say that the changes were perceived through the eye. The sensitivity of the eye is sufficiently proven by the third class of experiments in which the disturbances were limited to those animals with vision. Obviously these alterations were sensed wholly through the eye.

Most of these alterations may be sensed entirely through some other sense avenue than vision. The novel sensory conditions in the hunger experiment were obviously intraorganic in character. Vision can hardly be concerned in a sensitive way. In most of the experiments, the blind animals were affected; these blind animals must have sensed the novel conditions by means of other sense avenues than vision.

The normal animals probably utilized both of the above sensory means in reacting to the novel features in the fourth class of experiments. They possess both sensory capacities. The alteration can be perceived through this other sense modality since the blinds were affected. The alterations certainly possessed optical features. The differential sensitivity of blind and normal rats indicates that these changes were sensed wholly or in part through vision. The normal rats exhibited the greater degree of susceptibility or sensitivity to the alterations. The percentage of animals affected among the normals was equal to or greater than that for the blind rats with the exception of one experiment,—rotation of the cage. Obviously, this exception can not be explained on the hypothesis that the blind rats possessed modes of sensitivity not belonging to normal animals: it can be explained, however, in terms of principles to be developed later.

Vision possesses a corrective and adaptive function. The presence of eyes in some way increases the ability of the animal to adapt to these changes. Normal animals resist and overcome the disturbances better than do the blinds. The effect of this function is found in the greater rapidity of adaptation, a smaller error record, and a larger percentage of perfect runs. The best illustration of the operation of this function is found in the hunger experiment. Both groups of animals reacted to these alterations through a common mode of sensitivity and the percentage affected was the same for both groups. Vision, however, operated to minimize and overcome the effects of the disturbing conditions. The normal animals were able to make more perfect runs; they were able to resist the distracting influences more frequently than the blind rats. When disturbances did occur, the normal animals made by far the fewer errors; vision decreased the number of errors. Animals with vision exhibited the greater tendency to adapt themselves to these novel situations; they also recuperated from the effects more quickly after a return to normal conditions. Comparing the records of the two groups in the various experiments of the fourth class, we find that the adaptive and recuperative power of the normals is equal to or greater than that of the blind animals in every case. The normal animals made a greater percentage of perfect runs with the exception of one experiment; evidently they are more able to resist the distractive conditions. Rats with vision gave the smaller error score in every experiment but one; they thus possess the power of minimizing the disturbance when it occurs. When comparisons are possible as to the correlation between the maximum disturbance and the duration of exposure to the novel conditions, we find that the normal animals are the more resistant in three of four cases. The blind rats invariably exhibit the greater variability as to the range of errors. Blind rats are extremely variable as to number of errors; they are more likely to go to pieces, become lost and run high error scores when they are disturbed; this fact would indicate that vision operates as a corrective and control.

The discrepancies and exceptions in the application of the above two principles of explanation become explicable when we consider that the two functions of sensitivity and adaptation are antagonistic in their effects. The greater the sensitivity the larger will be the number of animals affected, the percentage of runs with error, and the total number of errors. The corrective function will operate to decrease the number of errors and the percentage of runs with error; it might also decrease the number of animals susceptible to the disturbing changes. The two functions, although antagonistic in their effects, are not necessarily mutually exclusive; both may conceivably operate at the same time. The actual records secured in any experiment will thus be a function of the relative strength of the two tendencies. In one type of situation the sensitive function may be the more effective in determining the character of the records, while the adaptive function may be the more efficacious in another experimental situation. The two experiments which deviated from the usual rule were rotation of maze and rotation of cage. The average error score of the normals was less than that of the blinds with the exception of the maze rotation experiment. We have here a rotation in reference to a predominantly optical situation, and one would expect that the sensitive function of the eye would predominate in effectiveness; the disturbance is so great that the corrective effects are not sufficient to reduce the error record below that of the blind animals. When the test was repeated, we find that the normal groups made the greater adaptive progress, and reduced their error score below that of the blinds. When the corrective function is given time to become efficacious, the error records no longer constitute an exception to the rule. When the cage was rotated, normal animals were not affected by a 15-min. exposure, while the blind rats were. We may explain this difference in susceptibility on the hypothesis that the corrective function of vision enabled the normal animals to resist the disturbing effects of the new conditions. With a 24-hr. exposure both groups were affected, but the blinds manifested the greater disturbance and the normals exhibited the greater tendency toward adaptation. The normal rats thus were no longer able to resist the cumulative effects of a prolonged exposure, but the corrective function of vision enabled them to reduce the degree of the disturbance and hasten adaptation.

The corrective and sensitive functions of vision are also evident from a comparison of the records of normal rats in the different experiments. When the maze was rotated in reference to a stationary heterogeneous environment, the normal animals were exceedingly disturbed but they made marked progress in adaptation when the test was repeated. A rotation of the maze and a uniform optical environment gave a lesser degree of disturbance and no tendency toward adaptation. The difference in the two alterations was presumably optical in the main. The greater the optical changes, the greater was the sensitivity and the adaptive power of the animals. Likewise, when normal rats were rotated in an open and a covered cage, the greater sensitivity was manifested in the former case. Many similar illustrations can be given.

The terms "sensitive" and "corrective" have so far been used in a purely descriptive sense, to state certain differences of fact. As explanatory concepts they render but little service.

In attempting to explain the greater sensitivity of the normal rats to all alterations instituted after the mastery of the maze, two possibilities exist; these functions of vision we may term "directive" and "distractive." The first hypothesis assumes that the motor activity of the animal is guided and directed in part by the visual impulses released by the stimuli from the objective environment. When the relation between the rat and these features of the environment is altered, motor disturbances are the inevitable result. It is possible that this directive function of vision may be present during the mastery of the maze but absent after the act has been thoroughly developed. The distractive hypothesis assumes that the maze habit is influenced in no way by the visual environment so long as it remains stable. Any pronounced alteration, however, is sensed immediately and operates as a distractive stimulus; in common parlance, it attracts the animal's attention, the rat reacts to the new conditions, and as a consequence the maze habit is disrupted. These two functions are not necessarily mutually exclusive; it is possible that both may be efficacious in mediating the disturbance in any run through the maze.

Between the two explanatory conceptions, we are forced to conclude in favor of the distraction hypothesis as far as the normal animals are concerned. When the position of the experimenter was altered, the rats were never disturbed in that section of the maze near which the experimenter had been standing. In fact the animals were not disturbed at any position in the maze at which they were oriented towards the old position of the experimenter. This fact would indicate that the rats did not employ visual stimuli from this source in any effective fashion in directing and orienting their conduct in the maze. The disturbance did occur, however, in those sections of the maze near the new position of the experimenter and when the rats were oriented in his direction. When the animals left the true pathway, they invariably ran towards the experimenter. This positive reaction can not be considered a directive habit acquired in learning the maze because the conformation of the maze at the old position was such as to prevent it. The positive reaction can better be regarded as a feeding habit developed in the living cage and on the feeding table. The experimenter thus attracted the animal's attention because of the novelty of the position and stimulated an old habit acquired while the rat was being handled and fed. The arousal of this habit naturally disrupted the normal functioning of the maze act. In several experiments such as increasing and decreasing the illumination, rotating the maze in darkened and lighted environments, and rotating a heterogeneous environment, the following behavior was frequently noted: Animals suffered a pronounced disturbance at those points where the illumination had been greatly increased. I have frequently seen animals run the maze without error up to a point where an alley, customarily darkened, was flooded with a beam of strong daylight. Here the rat stopped suddenly, exhibited strong signs of nervousness and timidity with frequent retracing in search of another path. Decreasing the illumination in any part of the maze seemed to be without effect, but a pronounced increase was effective. These facts indicate that the altèrations served as distractions. The distractive theory is further supported by the irregular and occasional character of the disturbances. This feature of the results was summarized in the first paper. It refers to such facts that many trials are without error, that rats are immune in one experiment and susceptible in another, and that the number of errors made in various trials is extremely variable. If the rats are relying upon the objective data to guide their conduct in the maze, it would seem that any rat should be disturbed in every trial until complete adaptation is secured. The fact that the disturbances occur in a perfectly haphazard and accidental manner is readily interpreted on the basis of the distractive theory. The disturbance is present only when the alterations attract the attention of the rat, and this result is largely a matter of chance. Conclusive proof of the distractive function is obtained from the comparative records on covering and uncovering the maze. Rats learned the uncovered maze,—a maze with a well lighted and heterogeneous optical environment. The maze is now covered with the canvas top. A uniform but darkened environment is substituted for that present while the maze was mastered. If the rat is relying upon these visual objects as directive stimuli in threading the maze, their sudden removal should disrupt the act. No animals were disturbed in this test, and we are forced to conclude that vision possessed no directive function after the maze was mastered. We may also assume that the alteration did not operate as a distraction because the new environment was homogeneous and poorly lighted. In the opposite experiment of uncovering the maze, we may conclude that vision of the extraneous environment possessed no directive function because the conditions were such that no possibilities were present for its development. The maze was mastered in a homogeneous optical environment. Removal of the top and the introduction of a well illumined and heterogeneous environment resulted in disturbances. Evidently these novel conditions were effective only as distractions. If we could generalize from these experiments, we would be forced to conclude that all disturbances due to alterations after the maze is learned and while the rat is running are the result of distractions.

There is but one possible exception to the above formulation,—certain characteristics of behavior when the sideless maze was rotated. After rotation the animals frequently drifted to that corner at which the food box had formerly been located. This fact would indicate that the rats can orient themselves in reference to the position of the food box in terms of stimuli emanating from the extraneous environment. The same behavior was occasionally noted in the rotation of the standard maze when the extraneous environment near the food box possessed unusual features, as an open window giving good light. Granted that this fact indicates a directive function, yet it is by no means certain that it was mediated through vision rather than smell or some other sense, for no blind animals were employed as controls in this experiment. The fact can be interpreted, however, in terms of the distractive function. It is possible that certain unusual features in the environment near the position of the food box operated as a distractive stimulus and that the rats reacted to it in a positive manner. We may then safely conclude that alterations instituted after the maze is mastered and while it is being run may and do operate as distractive stimuli in so far as they are sensed through vision; it is also possible that certain alterations may disturb the animal because these stimuli had been utilized as guides in running the maze, but no affirmative statements can be made with confidence.

Blind animals were also disturbed and this disturbance was mediated through other senses than vision; we must also assume that normal animals were disturbed in part through other modalities of sense than vision. This disturbance may also be explained by the assumption that these other senses were susceptible to the altered conditions either as distractions or as motor controls. There are no facts which support the directive hypothesis in a conclusive fashion. Certain facts can hardly be interpreted in other than distractive terms. The effect of varying the degree of hunger is obvious. The haphazard and occasional character of the disturbance was more characteristic of the behavior of the blind than of the normal animals, and this fact is best explained by the distractive hypothesis. The differential sensitivity of the normal and blind rats is thus one of degree and not of kind. Normal animals manifest the greater degree of susceptibility to the changes because they are affected through more sensory avenues.

The comparative learning records of the various groups of animals furnish certain data relative to the function of vision.

1. Normal rats master a stationary maze more readily than a rotated maze, and an open maze quicker than a covered one. These facts can be explained in terms of either the distractive or directive hypotheses. If the animal can utilize objective stimuli as guides or controls, the presence and stability of an optical environment should facilitate the learning process. Likewise these objective stimuli may function merely to attract the animal's attention, encourage unnecessary and disadvantageous excursions, and otherwise distract the animal from the more serious business at hand. On this hypothesis a changing environment would operate as a more effective distractor than a stationary one. Likewise, the distractive effect of a heterogeneous environment would be greater than that of a uniform one.

2. Rats with vision learn a stationary maze more easily than do blind animals. This poorer learning capacity of blind rats may be explained in numerous ways: a. We may assume that

the normal animals learn to utilize visual stimuli as controls in selecting the true path from the numerous *cul de sacs*. b. Vision may be advantageous because of the tonic effect of light. Visual stimuli exert a tonic and stimulative effect upon the various activities of the organism. Rats with vision exhibit the greater vigor and superabundance of bodily activity. Surplus activity is necessarily valuable in any trial and error mode of learning. This effect of light will also be manifested by the vital activities. Heightened vitality will be influential via of an increased retentive capacity or a stronger hunger motive. Decreased activity and vitality resulting from loss of vision may interact upon each other; decreased activity, or lack of exercise, will lower the vital tonus of the organism, and this lowered vitality will in turn produce sluggishness of behavior. c. We may assume that the learning capacity of blind rats has been minimized by certain deleterious effects of the operation per se. The connection between these effects and learning capacity may be conceived in several ways. The operation (the surgical shock or the effect of the ether) may act directly upon the vital activities and thus influence learning capacity as sketched above. The organic aftereffects may be conceived as some sort of a nervous irritant which operates as a distractive stimulus and thus produces erratic and exaggerated behavior. Likewise the effects may be nervous modifications of such a character as to render the animal more susceptible than usual to any novel stimulative conditions. The animal is thus prone to erratic, irregular and exaggerated modes of response detrimental to the mastery of the maze. On this hypothesis, stability and instability will characterize normal and blind rats respectively.

The last two hypotheses are supported by several lines of evidence. Blind rats frequently exhibit signs of decreased vitality such as muscular flabbiness, rough coats, poor circulation, poor appetite, and a susceptibility to disease. Blind animals are also less active as a general rule; the normal vigor, persistence, and superabundance of activity is frequently lacking. The phenomenon of breakdowns characteristic of blind rats also suggests the validity of the third conception. The greater erraticness and variability of blind animals,—the tendency to make now and then unusually large error scores, is explicable in terms of the third conception. There are no facts which directly support the first conception of a directive function of vision.

3. Vision is a detriment to the mastery of the rotated maze when untrained animals are utilized. This fact cannot be explained on the assumption that rotation is detrimental because visual-motor habits are continually being disrupted, because rotation will prevent the development of any such visual habits. Only one possibility remains,—the assumption that these visual alterations operate as distractions.

4. Vision is an advantage in the mastery of the maze, when the rats have had previous experience on other problems. The paucity of data upon which this conclusion is based renders its validity questionable. Accepting the fact at its face value, we may assume that the previous experience of the normal animals has operated to render them less dependent upon the extraneous environment; this result will minimize their susceptibility to the distractive influences of the rotation as demanded by the conclusion of the previous paragraph. The two groups thus approximate equality as to susceptibility to the distractions due to rotation, and the visual group is now enabled to master the maze more readily in virtue of its greater learning capacity.

All comparative data on the mastery of the maze can thus be explained on the assumption that vision possesses both detrimental and beneficial features in relation to the mastery of a maze problem. Visual stimuli tend to distract the animal and thus retard the development of the kinaesthetic-motor habit. The existence of vision on the other hand increases learning capacity. Two conceptions of the relation between vision and learning capacity receive some factual support. Light exerts a tonic and stimulative effect upon activity, while on the other hand the removal of the eye balls is to be regarded as some sort of a positive disturbing or distracting factor.

As to the nature of the process of adaptation, certain explanatory conceptions may be suggested. 1. We may suppose that the alterations disrupt the system of sensori-motor connections involved in running the maze, and that adaptation is to be conceived as a process of reorganization,—the acquisition of new motor controls. This conception assumes a directive function for the senses involved. Animals with vision have an advantage because they can utilize visual as well as other sensory cues.

2. The distractions and resulting errors induce confusion and excitement, and this confusion may now operate as a further distraction. Adaptation is a process of minimizing and allaying this excitement, and all familiar or unaltered stimuli will possess this quieting and reassuring characteristic. Adaptation is a matter of learning to direct the attention to the familiar aspects of the environment. Rats with vision will have an advantage because of their greater learning capacity and their greater sensory contact with the environment. 3. The disturbances are due to distracting stimuli, and adaptation is a process of strengthening the maze habit up to a point where it is immune to the distractive effects of those particular stimuli. Adaptation is thus a further process of learning, and those animals with the greater learning capacity will manifest the greater adaptive power. On this assumption the adaptive capacity of normal rats will be greater than that belonging to blind animals. 4. Blind rats are less resistant to distractions because of the operative effects. As previously noted, these effects may be conceived as intraorganic distractive stimuli of some sort, or as nervous conditions conducing to exaggerated and erratic responses. Blind rats will be regarded as essentially unstable organisms, subnormal in their capacity of resisting distracting stimuli. 5. Adaptation may be conceived as a process of decreasing sensory susceptibility to stimuli due to neural or end organ changes somewhat akin to fatigue. On this hypothesis any end organ can adapt only to those alterations which were sensed by that receptor.

The factual data are insufficient for any very confident judgments as to the relative validity of these various hypotheses. The normal animals manifested by far the greater adaptive power; this fact is readily explicable in terms of any one of the first four conceptions. The difference of adaptive capacity of the two groups is generally greater than their differences in learning ability as manifested in the mastery of the maze; this fact militates against the 1st and 3rd conceptions as complete explanations of adaptation. The first conception must be summarily dismissed as the facts indicate rather conclusively that extraneous stimuli do not function as motor controls after the maze is mastered. The greater variability of the blind rats may be explained on the basis of either the 2nd or the 4th hypotheses. The immunity to distractions due to adaptation is mainly specific rather than general; this fact eliminates the 3rd hypothesis as a complete explanation of the process, since rats in time should become practically immune to all ordinary distractions. Neither can the fact be readily envisaged under the 4th and 5th conceptions; it is most easily explicable in terms of the 2nd hypothesis. A sense organ can play a part in the process of adaptation although the disturbance was mediated through some other sense avenue. Normal rats displayed the greater adaptive power in the hunger experiment, so that vision must have been concerned in the process although the disturbing conditions were intraorganic. This fact would eliminate the 5th conception as a complete explanation of adaptation. The maximum adaptive power of normal rats was manifested in those experiments in which the optical features of the environment were altered. Adaptation was very rapid when either the maze or the environment was rotated in reference to each other, but no adaptation was present when both maze and environment were rotated simultaneously. This fact may be conceived in either of two ways: 1. We may assume that the eye can adapt only for visual distractions. This assumption naturally suggests the 5th conception. 2. We may assume the truth of the 2nd conception, and explain the inability of the normal rats to adapt to the rotation of maze and environment as due to the homogeneity of the visual environment in this experiment.

These conceptions are not mutually exclusive; all may contribute to the process of adaptation. Only the first possibility must be summarily dismissed. The second conception receives the most support, as there are no facts which can not be explained in its terms. The 3rd conception meets the greatest amount of difficulty; it can not account for the entire process of adaptation. The evidence for and against the 5th hypothesis is about equally balanced.

CONCLUSIONS

The white rat is sensitive to optical stimuli through the medium of the eye.

Both advantages and disadvantages accrue from the possession of visual receptors in the maze situation.

Vision is detrimental because of the distractive effect of retinal stimuli.

The advantageous features of vision may be explained in either of two ways: Retinal stimuli exert a tonic and stimulative effect upon organic activities and thus promote learning capacity, or one may assume that blind animals are at a disadvantage because of certain deleterious effects of the operation.

Vision may possess other functions in the maze situation; our facts are inconclusive on many points.

These conclusions apply merely to the situations obtaining in our experiments; other potentialities of vision may be realized in different types of situation.