# VISUAL CUES IN MAZE RUNNING BY THE ALBINO RAT[*][1]

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## STATEMENT OF PROBLEM

This experiment was undertaken as the first step in determining the relative importance of vision in the learning and running of a maze by white rats. It has long been an accepted doctrine that white rats, while they may use vision to a slight degree in the learning process, quickly turn to kinaesthetic cues and habits once the maze has been mastered. The visual factor has in fact been prominent mainly by its neglect in past experimentation in this field, although a softening of the original certainty on this score is to be noted in the later reports.

Small's pioneer work in 1899 (12) and 1900 (13, 14) rather set the pattern for the next decade both for experimentation and for the interpretation of the experiments. He was much impressed with the possibilities of explaining maze habits in tactual-motor terms. His work was qualitative and did not so much rule out vision as place emphasis on the previously unappreciated kinaesthetic side. Watson, following him seven years later (20), stood strongly for kinaesthesis but admitted that his and Small's work was still mainly negative. What they regarded as positive proof was offered by Carr and Watson in 1909 (5). Their work was followed the next year by that of Waugh (22), who reaffirmed the dominance of the kinaesthetic over the visual. Miss Vincent, working under the supervision of Dr. Watson and using his maze from 1912 to 1915 (16, 17, 18, 19), confirmed the kinaesthetic-control hypothesis, but allowed some value to vision (as well as to other senses) as a factor, though it might function as a hindrance rather than as an aid to the muscular control. Carr, in 1917 (2, 3, 4), confirmed the 1909 findings. While he admitted that other than merely tactual, kinaesthetic, and motor elements enter into the maze habits, he did not accord them

much weight. Wylie, also in 1917 (23), without especial comment on the result, discovered incidentally in his transfer-of-training work that the response to light was more pronounced than to sound in the ratio of about five to two for the intensities he used. Adams, in 1913 (1), reported that three out of five blind rats were unable to learn a standard maze in 182 trials. Although this is of negative value only, it deserves more attention than it has been given. Hunter's figure-8 maze in 1920 (9) did not involve visual factors primarily but demonstrated the ability of rats to learn a single alternation problem and their failure to master a double alternation by kinaesthetic or other means. Higginson (7), as recently as 1920, was one of the first to attempt to show that vision is not inoperative in rats even while they are running the maze kinaesthetically. While Helson's work in 1927 (6) was intended to bring out the structure-function reaction, he demonstrated that rats do react to purely visual structures.

A critical analysis of these experiments discloses certain defects of omission and commission consideration of which has a direct bearing on the proper interpretation of their results and conclusions. In the Carr and Watson experiment of 1909, for example, the rats, dropped into the maze at random, are reported to have wandered in evident confusion and without recognition of their whereabouts until they had passed through certain significant paths or turned certain corners, when they would dash off at full speed for the goal. The explanation offered is that in running the maze at high speed the weight is thrown on the outer legs as the corners are rounded; patterns of muscular responses are set up by these turns and by traversing alleys of different length between the turns: and when these patterns are reawakened by passing at random through a section of the maze they become a stimulus for the proper subsequent responses for running the maze. In other words, kinaesthetic cues were picked up and the automatic muscular action was at once set in operation. The question arising here is twofold. Would the internal stimulus and response be the same in a rat wandering at low speed as when dashing at full normal speed? Even if this be true, would a rat exploring the maze in a reverse direction (that is, toward the starting box) be able to pick up a kinaesthetic cue, as it is stated was done, when all the turns would be reversed, especially when the speed at which the reversed turns were made was so low as not to involve the centrifugal effect even on the contralateral legs?

In this experiment when the maze was shortened the trained rats are reported to have bumped their noses on the ends of the shortened alleys except at one place, "at corner II." The alley leading to this corner has been shortened exactly as much as had the alleys where trouble was experienced. The authors explain this by saying that this alley and the turn at corner II were an exact duplicate of a section of the maze which had not been affected by the removal of the section. It is said to have duplicated the alley from the starting box to the first corner, "*M.*" The drawings of the maze do not show this to be the case. This unit from the starting box was entered with a left-hand turn, while the unit which is said to have duplicated it is entered by a right-hand turn. If kinaesthetic cues were the guide, it would be the entering turn that would be the cue for the length of the alley and not the similarity of the turn at the end of the alley. But, however this may be, it is a fact that the dimensioned sketch of the maze presented with the report shows that the alley leading to corner II is six inches longer than that leading from the starting box to corner *M* at its extremity. Not only this! The alley to corner II where no difficulty was experienced *is* an exact duplicate of alley *P-Q* as to entering-turn, leaving-turn, and length. Yet the rats bumped their noses consistently at *Q* and did not at II. The entire case for the purely kinaesthetic explanation of the behavior of the rats in this test apparently receives its *coup de grace* in these two defects. The authors say, perhaps significantly, "It must be frankly admitted that the purpose of our work was to see whether the facts of orientation offered insuperable difficulties to our theory rather than to rule out all possibility of the rats receiving aid from extraorganic sense data."

In Vincent's review of 1912 there appears no reason to suppose that even if rats are hypermetropic they would not distinguish brightness as well close up as at a distance. Brightness as a quality to be distinguished should only increase its stimulating value with nearness, however far-sighted the animal may be. The same experimenter in the work with the elevated maze reports that the rats jumped the corners and gaps (the blind rats did not), even though they had previously learned the maze kinaesthetically when it was equipped with sides as an enclosed maze. There is evidence here that, in spite of the precautions taken, there was left a strong tendency to use vision, since neither kinaesthetic nor tactual cues would prompt the short-circuiting of the path in these ways, as was confirmed by the

fact that the blind rats did not accomplish it. In her fourth article (19) the superior performances reported for the olfactory maze indicate the importance of eliminating those cues in a visual experiment. The different odor of the two paints used in the black and white maze might not have been sufficiently marked to provide as good an olfactory cue as did the trail of food juices and yet might have been sufficient, in the light of the efficiency of the olfactory test, to have afforded a considerable assistance. In her analysis of the structure of the eye the divergence of the axes of vision is stressed. No account is taken of the device to which the rat resorts to compensate for a lack of binocular accommodation for depth perception. One of the commonest occurrences in the behavior of the rat is the peculiar waving of the head from side to side when fixating a stationary object in its field of vision. It may be that in this way a parallax observation is obtained by which a fair determination of distance may result. The attempt to catch a timid rat by hand will convince the most skeptical that if the object itself is moving the rat has no lack of perception for it.

Waugh's conclusions that the albino rats show no discrimination between red and white lights is in conflict with the testimony of Watson (21), who finds that rats probably do not distinguish red light from darkness, and with the results of the many experiments in which reaction to a white light alone has been observed. There seems also little connection between his data and the conclusion that vision is a passive protection only.

Hunter (9), in showing the rats' inability to solve the double alternation over the same path, demonstrates the low level of integration under these conditions. This reinforces our doubts as to the ability of the rat to carry a kinaesthetic pattern of an entire maze in such a form that each muscular reaction from a series of turns and alleys provides the cue for the immediate unit that follows it. Just such combinations as they were unable to master in his tests are assumed to be the controlling factors in the Carr-Watson kinaesthetic-cue explanations.

Higginson's (7) work demonstrates rather conclusively that at all times, even when running "kinaesthetically," the rat is using his other receptors as strongly auxiliary guides. The experiment does not, however, fix upon the visual as the aiding sense in the instantaneous breaking of the kinaesthetic habit. When the door at the side is closed for 100 runs and then left open it may also have a tac-

tual stimulating value in the difference of air presure on the skin
and vibrissae of the running rat.   Sound values are also changed
and possibly olfactory cues admitted.   Direct contact with the vibris-
sae is not excluded as among the possible explanations.   The signifi-
cant thing that was demonstrated is the lack of complete domination
of the kinaesthetic habit even under conditions most favorable to
its development.   It was upset and cast off in a fraction of a second
by an extraneous distance-receptor stimulation.

Helson's (6) work showed an ability to make a brightness dis-
crimination to lights, but the second part of his work is incon-
clusive because of the temporal arrangement of his substitute and
original stimuli.   The rat had passed over the gray stimulus when
the shock was administered and did not have it in the field of vision.
The shock or the conditioned expectation of it became an emotional
inhibitor effectually preventing any conditioning to the gray card
as a cue to the food beyond the grid.[2]

It seems evident, then, in the light of these comments, that the
conclusions adverse to the importance of the visual factor were not
warranted by the data and that they had been drawn in some cases
with an *ex parte* bias.   It does not appear that the visual factor has
ever been truly isolated in maze-running tests.   The favor accorded
to kinaesthetic explanations has been due to this defect.   Even a slight
predominance in tendency toward kinaesthetic habits rather than
visual might account for all the results obtained.   Further, the set-up
and conduct of the experiments themselves were such as to set a
premium on the formation of muscular habits and to discourage even
such visual responses as would normally be made.   Under the same
circumstances of monotonous repetition, even human subjects, in
whose life the importance of vision is hardly to be questioned, would
tend to become automatized through sheer lack of utility in the main-
tenance of visual attention.

It appeared necessary, then, first to ascertain whether visual cues
alone may be sufficient for the building up and maintenance of maze-
running habits, and, secondly, if such were found to be the case, to

[2]For success under the conditions of Helson's experiment it would be
necessary to build up a trace reflex, that is, one in which an interval of
time elapses between the end of the substitute stimulation and the beginning
of that of the original stimulus.   This, Pavlov has shown to be difficult to
set up in a dog under the most favorable and controlled conditions.   It is
probably impossible to accomplish with the rat.   When Helson adds to this
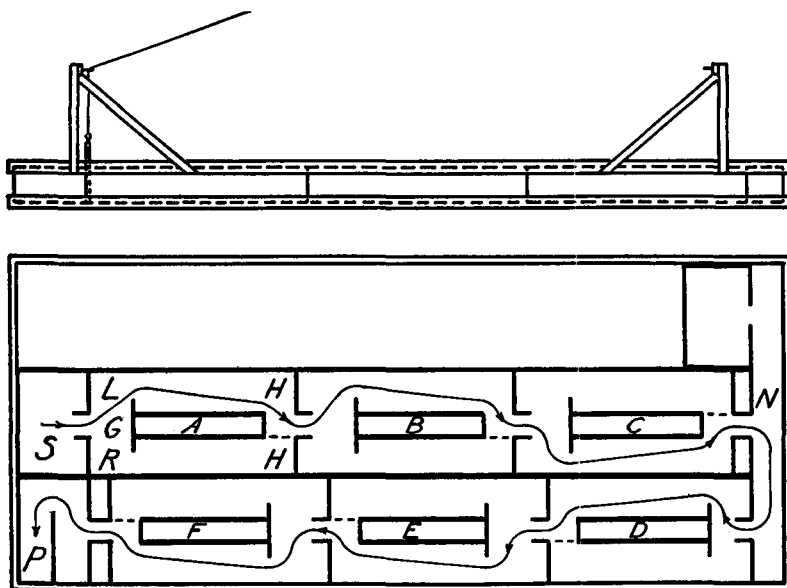a. conditioning inhibitor, one could hardly expect his rats to succeed.

FIGURE 1

ONE OF THE 128 DIFFERENT ARRANGEMENTS OF THE VISUAL MAZE
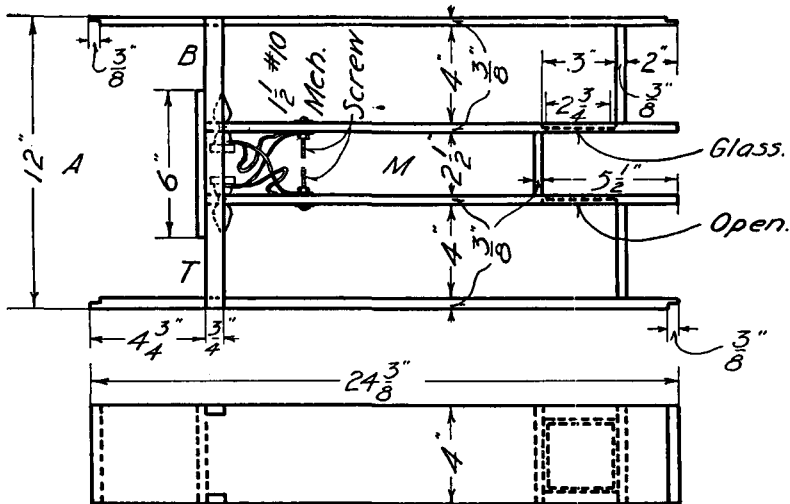True path indicated by curves and arrows. *S*, start. *P*, food box.



FIGURE 2

SECTION OF MAZE

determine the nature of both the visual and the kinaesthetic factors and to evaluate their relative strength. The present problem aims to effect the complete isolation of the visual cues. To this end a maze was constructed which turned all olfactory, directional, tactual, auditory, and kinaesthetic cues into false guides, and which could be solved and run only by vision.

<div align="center">APPARATUS</div>

The sectional maze used is practically a series of choice-reaction boxes. The sections are arranged to dovetail into each other, and are reversible and interchangeable. A set-up of the maze is shown in Figure 1 and a dimensioned sketch of a single section in Figure 2. The true path is entered at $T$; the blind alley at $B$, Figure 2. The space, $M$, down the middle of the section is closed and is used only for electrical connections. The purpose of using this type of construction was to provide a constantly shifting pathway, the sections being reversible at will from right to left as described later.

The floor of the sections and of the cross-over is of 20-gauge galvanized iron cut to the size of each section. The whole maze is covered by a removable 2 x 2 hardware cloth screen built on a frame $1\frac{1}{2}''$ x $\frac{3}{4}''$ pine. To permit the easy removal of the food boxes after the rat has completed the run, the corners of the screen are cut away, the openings being closed by small screens which can be lifted off without disturbing the main cover. The cover itself is symmetrically built to permit frequent reversals, end for end. Ordinarily it was reversed every third or fourth run. The sections are assembled on a bed of $\frac{7}{8}''$ pine with a coping around the sides, the maze sections and floor plates fitting snugly in place when set up. A wire carrying-cage was used to transport the rats from the nest boxes to the starting box. A drop door on the starting box controls access to the maze. A food box or goal permanently covered with 2 x 2 hardware cloth dovetails into the exit from the last section of the maze, entrance to it being controlled by a door which when dropped also prevented return to the maze. Both drop doors are controlled by cords operated from behind a wallboard screen, $6'-3''$ x $2'-10''$, through which an opening $5''$ x $3''$ permits observation.

Each section is equipped with five "signs" as cues to the true path. Blind alleys are indicated by black signs and the true path by white. The exit from the starting box and from each section is so arranged that the rat must come head-on toward the barrier ($G$, Figure 1) at

the entrance to the next section. At this point there is hung a sign 3" x 5½", one-half of which is black and the other white, the dividing line being the center line of the section. The rat must here turn to the right or left. On the side wall which he would then face (*L, R,* Figure 1) is hung another sign, 3" x 3", black on the blind alley side and white on that of the true path. To proceed down either alley the rat makes another right angle turn and runs 18" to the exit, a 3" square hole through the inside wall. If in the blind alley, he finds the exit barred by glass; the true path is open. Across the end of the alley is a barrier (*H, H,* Figure 1) compelling a turn of 90 degrees to pass through this exit. On this barrier and therefore visible the full length of the alley is hung another sign, black at the end of the blind alley and white by the exit constituting the true path.

The signs themselves are framed with roofing tin, bent to hang on the side walls. The same paper was used in all signs, one side being black and the other white. To eliminate olfactory cues from the different surfaces each paper is fully covered by glass. This introduced an undesirable but unavoidable mirror effect which reduces somewhat the effectiveness of the paper signs themselves. Experimentation with a silvered mirror failed to bring any response to such an image, however, so it is not likely that this factor is of importance.

In addition to the black and white signs each section is equipped with red and white lights, pointed pear-shaped Christmas-tree lamps with miniature bases, eight in series on 115 volts (G. E. C6 Mazda B bulbs). The red lamps in the blind alleys were not used in all of the experiment. The white lamps gave approximately 11 candlepower each on normal voltage. The lamps themselves are not visible to the rat on entering the section (*A,* Figure 2), as they are behind the barrier on which the wide black and white sign hangs. In order to make sure that the rats were not following a heat cue rather than a visual one, red lamps of the same candlepower were later installed in the dark alleys without disturbing performance. Pure ruby glass cannot be obtained for miniature lamps but these bulbs were especially prepared at the factory with an extra heavy double dipping. While they do not give a monochromatic ray the other components are so weak compared to the white lamp that they are negligible. When the change was made the rats did not appear to notice the alteration.

In order to bring current to the lamps and still have the sections invertible and interchangeable the wiring was placed on the under side of the bed, two wires coming up through the planks into the

unused space between the alleys where connection was made by means of spring clips. The clips are snapped onto machine screws from which wires run to the lamps. Only the glass bulb projects into the runways, the porcelain socket with the live contacts and screw being in the unused central portion.

The essential difference between this test and all simple choice reaction tests lies in the succession of choices required and the building up of such sections into a maze in which the run is continuous from start to finish as in any other maze. Any maze is in fact a choice reaction series wherever there is an alternative selection between blind alleys and true path. That the combination of these sections produced a true maze rather than a series of simple choice-reaction boxes is shown not only by observation of the rats in their runs but by the statistical results obtained. In the selection of the true path in the first section, where the action is identical with that of a single choice reaction box, the tendency noted by Lashley (11) to rush from the starting box without discrimination was evident. This results in a record of 32% errors in this section as compared with but 7% to 20% in the other sections. The maze-running habit thus seems to involve other factors than those entering into the single choice reaction.

Although there seemed to be no possible way to obtain any cues from the environment of such a shifting maze, the maze as a whole was rotated about its center by from 45 degrees to 180 degrees every second run, a precaution suggested by the results observed by Carr (2) and others. No disturbance seemed to result from the change in orientation, although there is a possibility that some of the confusion at the first section might have been due to this factor.

The path of the rats through the maze, as shown by the curved line marked with arrows in Figure 1, passes through three of the longitudinal sections in succession, through the crosswise alley (N, Figure 1) at the far end, and back through a return path made up of the other three duplicate sections. The crossover is also reversible so that the return alley can be either to right or to left of the outgoing alley. There are thus 128 different arrangements of the maze possible (2 raised to the 7th power). The arrangement was changed each time after all 10 rats had been through a given set-up, the next arrangement of the sections being determined by the toss of a coin.

By these precautions non-visual cues were eliminated. Following

a scent trail was made impossible by the reversals of the sections and floor plates in various combinations. On reversing the section and not the floor plate, the trail, if any such there were, would be thrown into a blind alley, as would any tactual cue from the floor. There still might remain an olfactory or tactual cue from the walls of the alleys. Reversing the section by inverting it still left the true path in the same part of the wooden section. To eliminate this the sections are built so that the glass barrier (Figure 2) at the end of the blind alley may be shifted to the end of the true path alley of the same section, thus making what had been the blind alley into the true path and vice versa. These glasses were thus shifted in all sections frequently. In addition, the floor plates were inverted and reversed end for end at random every time the crossover section was reversed, which was in 47% of the runs. In reversing sections either by turning them over or by change of alleys the signs were exchanged in location or else the papers were reversed in place. Any olfactory cue from the signs would thus immediately become a miscue. There was no evidence of any attempt to obtain olfactory cues from the signs but it was thought wise to make it impossible.

Owing to the speed with which the rats ran it was found impossible to record the errors with pencil and paper. A convenient solution was found by constructing a board which holds a standard sheet of typewriter paper. Over the paper was placed a slide with seven pairs of shingle nails inserted in holes, the points resting lightly on the paper. The first nail of each pair represented a partial error, the second a full blind-alley error. By following down the column of nails as the rat passed the corresponding parts of the maze an error of either sort could be recorded instantly by a pressure on the nail head. A corner of the slide is cut away at top and bottom in line with the column of nails to permit entering at the top the number of the rat and the time at which the run was made and at the bottom the time for the run in seconds. Since the rats were in each section only about one second, and not only the number of errors but the location of the errors in the maze were required some such quick acting device was necessary.

Ten Wistar-strain albino rats, six weeks old at the beginning of the test, were used. They were housed in pairs in cages in fixed locations in the laboratory. All were naïve and tame.

## PROCEDURE: PART I

The maze was assembled in chance arrangement. A rat was in-

troduced into the starting box and the door from the starting box
to the maze was raised by the cord from behind the screen. When
the rat emerged, which was not always at once, the stop-watch was
started, the run being considered complete when the rat's head en-
tered the food box. There was frequently a considerable hesitation
here but as this was no part of the maze running it was not included
in the time. Entering the blind alley instead of the true path was
considered an error. A wrong turn toward the blind alley to R or
L, Figure 1, was recorded separately, but as these soon dropped to
insignificant proportions they were not regarded as of sufficient im-
portance to treat statistically.

The incentive for the run was hunger, a quarter-inch cube of
cheese and about a gram of compressed cottonseed meal being used
as bait in the food box.

As soon as the rat had completed the run the starting-box door
was lowered ready for the next run and the food box was lifted out
and returned to the top of the nest cage from which the rat had
been taken. While the rat was eating the bait another box was
baited and placed in position, a second rat was carried to the start-
ing box and a second run commenced. From one to four runs were
made by each of the 10 rats daily. To take advantage of the
greater nocturnal activity and to avoid variations of external light
conditions runs were made after dark, usually between seven and
ten o'clock.

All 10 rats ran each set-up without change. Observation of their
behavior indicated that there was no attempt to follow the scent of
the rats that had already run the given set-up. If the first rat made
an error there was no tendency for the next one to follow it into
the blind alley. In order to partial out this factor mechanically and
to equalize any possible advantage from running the maze as the
tenth rat of a series the order was made progressive. If the runs
were made in the order 1, 2, 3, 4, 5, etc., for one round of the rats
the next round was made as 3, 4, 5, 6, - - - 1, 2, etc. The order was
also occasionally reversed and the rats run 10, 9, 8, 7, etc. That
the precaution was not necessary is shown by the data in Table 1, in
which the runs are analyzed with this factor in view. The times
and errors are recorded for the last 50 runs, segregating the results
for all the runs in which each rat ran in each of the positions in the
order from first to tenth of the series. There is no significant dif-
ference shown, chance or extraneous influences apparently being the

determining factors. Both the times and the errors in all positions are remarkably constant. Comparing the first five runs with the second five, we find that the times in minutes were 0.23 and 0.24, the errors 1.20 and 1.12. Since the records of individual rats showed greater variations than this, it is likely that even this slight difference would have disappeared in a larger number of runs.

TABLE 1

TIMES AND ERRORS FOR EACH POSITION IN THE SERIES OF RUNS FOR ALL TEN RATS IN EACH SET-UP FOR THE LAST FIFTY RUNS FOR EACH RAT

| Position in series | Number of runs | Mean time in minutes | Errors Total | Average |
|---|---|---|---|---|
| 1 | 59 | 0.21 | 68 | 1.15 |
| 2 | 58 | 0.23 | 67 | 1.16 |
| 3 | 57 | 0.22 | 73 | 1.28 |
| 4 | 55 | 0.25 | 74 | 1.35 |
| 5 | 54 | 0.22 | 58 | 1.07 |
| Averages for 1st five | 57 | 0.23 | 68 | 1.20 |
| 6 | 47 | 0.28 | 54 | 1.15 |
| 7 | 46 | 0.23 | 59 | 1.28 |
| 8 | 46 | 0.21 | 47 | 1.02 |
| 9 | 39 | 0.21 | 40 | 1.03 |
| 10 | 39 | 0.27 | 43 | 1.10 |
| Averages for 2nd five | 43 | 0.24 | 49 | 1.12 |

Each rat was given 100 runs. The small lamps in the maze were on full voltage at the start of the 100 runs but were rapidly dimmed down by the introduction of a step-by-step resistance until they ceased to provide a stimulus, when they were dispensed with altogether. The curve of candlepower during the course of the test is shown on the curve sheet, Figure 3, as a broken line. By the 24th run it had fallen from 11 candlepower per lamp to 0.65. In the next 30 runs it was lowered to 0.1 candle power, below which its brightness could not be measured by the Macbeth illuminometer used. During the last 16 runs the lights were not used and the rats were therefore guided only by the black and white signs. As the internal illumination of the maze decreased the external light sources were increased, the illumination at the center of the maze being shown by the dotted line in Figure 3. The ratio of internal to external lighting, therefore, decreased rapidly not only by virtue of the dimming of the small lamps in the maze but due to the

simultaneous increase of the overhead lighting.   The purpose here
was to effect a transfer of attention from the maze lights to the
black and white signs by a gradual progression.

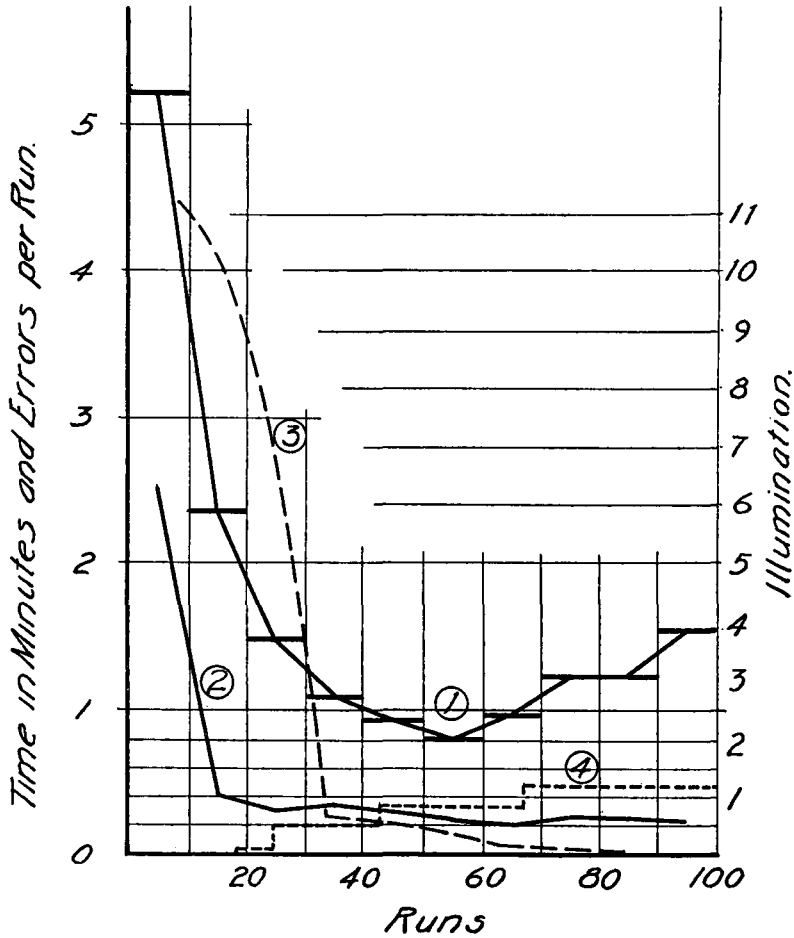From the beginning of the test to its completion the black and



FIGURE 3

ERRORS AND TIMES FOR TEN-RUN AVERAGES AND INTERIOR AND EXTERIOR
ILLUMINATION INTENSITIES

1. Errors.   2. Times.   3. Interior Illumination.   4. Exterior illumination.

white signs were in their proper places. The learning curve must, therefore, be taken as indicating the learning of the maze under changing conditions. Though the emphasis was gradually shifted from the lights to the signs, it was still a brightness-discrimination, though of a different sort and from a different source. The cue was visual at all times and only visual.

## Results: Part 1

A complete analysis of the results of this part of the experiment involves consideration of the following points.

1) The rats learned the maze and demonstrated in a convincing manner their ability to build up a purely visual habit as a guide for maze running. The curve of learning is in no respects different from those obtained in the standard "kinaesthetic" mazes.

2) With rapidly diminishing lights the errors fell from 5.2 for the 10-rat average with full 11 candlepower to 1.3 when the lights were at only 0.65 c. p. The errors were consistently reduced down to 0.78 per rat per run while the lights decreased to 0.17 c. p. This was the point of best performance for this part of the test, the curve rising rapidly to just double this number of errors during the next 40 runs, remaining constant at 1.25 during the 20 runs from 71 to 90, for the last 6 of which there were no lights and during the first 14 of which the lights were practically out. Chance errors for the seven sections would have been 3.5 per rat per run.

3) Viewed from the side of the occurrence of errorless runs, the learning performance was most significant. Although rats normally learn the standard kinaesthetic mazes in from 30 to 50 trials to the point of perfect performance, the poorest record made in learning this visual maze was that of Rat 5M whose first perfect score was made on his 28th trial. Rat 7M ran his 11th trial without error while 6F was only one later. The figures for all 10 rats are given in Table 2. The average was a perfect run between the 20th and 21st runs.

4) In running through the maze in its various combinations the rats would find each section, as they entered it, either just as it had been the last time or reversed. According to Waugh, training to a visual discrimination involves training away from the more potent kinaesthetic habits. Leaving any given section unchanged for a given number of runs might then be expected to build up a muscular tendency to run in the accustomed manner which would persist

TABLE 2

RUN ON WHICH FIRST PERFECT PERFORMANCE WAS RECORDED FOR EACH RAT
AND NUMBER OF ERRORLESS OR ONE-ERROR RUNS MADE IN
THE LAST FIFTY RUNS OF EACH RAT

| Rat | 3M | 3F | 4M | 4F | 5M | 5F | 6M | 6F | 7M | 7F | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| First error-less run | 27 | 25 | 21 | 22 | 28 | 14 | 21 | 12 | 11 | 24 | 20.5 |
| Number of er-rorless runs | 8 | 17 | 24 | 10 | 13 | 20 | 20 | 11 | 19 | 5 | 14.7 |
| Number of runs with only one error | 23 | 21 | 20 | 19 | 15 | 17 | 16 | 21 | 22 | 19 | 19.3 |
| Total with one error or less | 31 | 38 | 44 | 29 | 28 | 37 | 36 | 32 | 41 | 24 | 34.0 |

TABLE 3

EFFECT ON COMMISSION OF ERRORS DUE TO CHANGING SECTIONS IN MAZE SO AS
TO SHIFT TRUE PATH TO OPPOSITE SIDE FROM THAT ON
WHICH IT HAD BEEN ON THE PRECEDING RUN

| Sections | A | B | C | N | D | E | F | Totals No. | % |
|---|---|---|---|---|---|---|---|---|---|
| **Twenty-five Runs (51-75)** | | | | | | | | | |
| No. of times run: | | | | | | | | | |
| Changed | 120 | 93 | 54 | 115 | 138 | 126 | 82 | 728 | 42 |
| Unchanged | 130 | 157 | 196 | 135 | 112 | 124 | 168 | 1022 | 58 |
| Errors: | | | | | | | | | |
| Changed | 32 | 7 | 5 | 40 | 20 | 7 | 8 | 125 | 17 |
| Unchanged | 24 | 6 | 11 | 32 | 21 | 5 | 8 | 107 | 10 |

| Sections | A | B | C | N | D | E | F | Totals No. | % |
|---|---|---|---|---|---|---|---|---|---|
| **Twenty-five Runs (76-100)** | | | | | | | | | |
| No. of times run: | | | | | | | | | |
| Changed | 149 | 160 | 52 | 118 | 145 | 100 | 65 | 789 | 45 |
| Unchanged | 101 | 90 | 198 | 132 | 105 | 150 | 185 | 961 | 55 |
| Errors: | | | | | | | | | |
| Changed | 53 | 24 | 10 | 34 | 32 | 27 | 13 | 193 | 24 |
| Unchanged | 28 | 9 | 35 | 25 | 27 | 14 | 8 | 146 | 15 |

| Sections | A | B | C | N | D | E | F | Totals No. | % |
|---|---|---|---|---|---|---|---|---|---|
| **Fifty Runs (51-100)** | | | | | | | | | |
| No. of times run: | | | | | | | | | |
| Changed | 269 | 253 | 106 | 233 | 283 | 226 | 147 | 1517 | 43 |
| Unchanged | 231 | 247 | 394 | 267 | 217 | 274 | 253 | 1983 | 57 |
| Errors: | | | | | | | | | |
| Changed | 85 | 31 | 15 | 80 | 52 | 34 | 21 | 318 | 21 |
| Unchanged | 52 | 15 | 46 | 57 | 48 | 19 | 16 | 253 | 13 |

after the section had finally been reversed. We might expect fewer errors while it is left unchanged and relatively more errors when it is shifted. Table 3 gives the times and errors for each section changed and unchanged and the number of changes made. It is interesting to observe that in Section C, which was changed least often (one time in five), the errors in percentage of times run in each condition were practically the same; and in Section D, which was shifted on more than half the occasions, the errors were in higher ratio to times run for the section unchanged than when it was changed. The reason for this is obvious. The actual position of the section may be left undisturbed and the rat still be faced with a new situation at its entrance if the section ahead of it has been shifted. It is the pattern of reaction called for by the maze as a whole that is disturbed. Section D might be a right-hand section for two runs in succession but be entered at one time after running the crossover which just preceded it to the right and the next time to the left. The muscular action involved was entirely different though Section D remained a right-hand path both times. The same statement applies to each section of the maze. There could be no kinaesthetic cues in the Carr-Watson sense even if one section had been left unchanged throughout the entire experiment. If under such conditions the errors in such an unshifted section were few, we would have to account for it in some other way than by kinaesthesis. The expectation of finding this particular section in its familiar position would have to arise as a response to some other recognition than that of an internal muscular stimulus pattern. Since, as shown in the table, the errors are less in the unchanged sections for the maze as a whole and since kinaesthetic cues cannot account for this, it seems justifiable to conclude that visual familiarity in the unchanged section is the factor responsible.

5) The distribution of errors emphasizes a factor that was very evident from observation of the behavior of the rats in the maze. The pathway from starting box to goal presented three distinct problems. The high percentage of errors in the first section checks with the observed habit of an impetuous rush as soon as the starting door was raised. An error made here seemed to reinforce the conditioning and to lessen the likelihood of an error in subsequent sections in the same straightaway. This was true whether the sections were changed or left fixed. The crossover from one alley to the other at the end of the maze presented a different and apparently

more difficult situation to solve. There was much hesitation here and a higher proportion of errors when it had been changed. The total of the errors when changed and when fixed was the same as for the first section out of the starting box. The errors in these sections when left unchanged were more numerous than those for any of the other five sections when they had just been shifted. The rats would frequently give uncertain responses at the entrance to this section, moving the head rapidly from side to side as though in balance between the two response tendencies. The visual problem was different here. There was the same black and white sign directly in front of the animal at the entrance to the crossover, but the lights were more remote and were at an angle of 180 degrees from the point of choice instead of about 90 degrees as in the sections. Furthermore, of course, there was the matter of practice; six similar sections were run each time, the crossover only once. For the crossover (Section $N$), when newly shifted, there were errors in but 29% of the last 25 runs, while in the 25 runs preceding there were errors in 40% of the runs. The errors for this section when not changed also decreased, though only from 23% in the first 25 runs to 20% in the second.

6) The habits of correct choice in the regular sections were apparently somewhat upset by the different reaction called for in the crossover and had to be re-established after the crossover had been run. The errors made in Sections $D$, $E$, and $F$, after the crossover, were 18%, 15%, and 14% when the sections had been newly shifted, and 20%, 11%, and 7% for all runs, changed and unchanged. Nearly three times as many errors were made in Section $D$ just after leaving the crossover as in the last section, $F$, and nearly twice as many as in $E$, the section between these two. These data, together with the similar condition in Sections $A$, $B$, and $C$, are shown graphically in Figure 4. The noticeable feature of the charts is that, whether we consider the shifted sections or the unshifted, the error curve has approximately the same shape, roughly that of an inverted $N$. In the two main alleys, out and back, the errors are high in the first section and low in the other two. In the crossover they are uniformly high.

7) The partial errors in which the rat did not actually enter the blind alley but made a full turn the wrong way on entering the section, form another indication obtained from observing behavior in the maze that visual cues were being attended and utilized. In the

500 runs this half error was made and the correction accomplished without entering the blind alley in 58 cases or about 12% of the runs.

8)    In reports of maze running in which the habits became purely kinaesthetic we have seen no record showing whether there were any
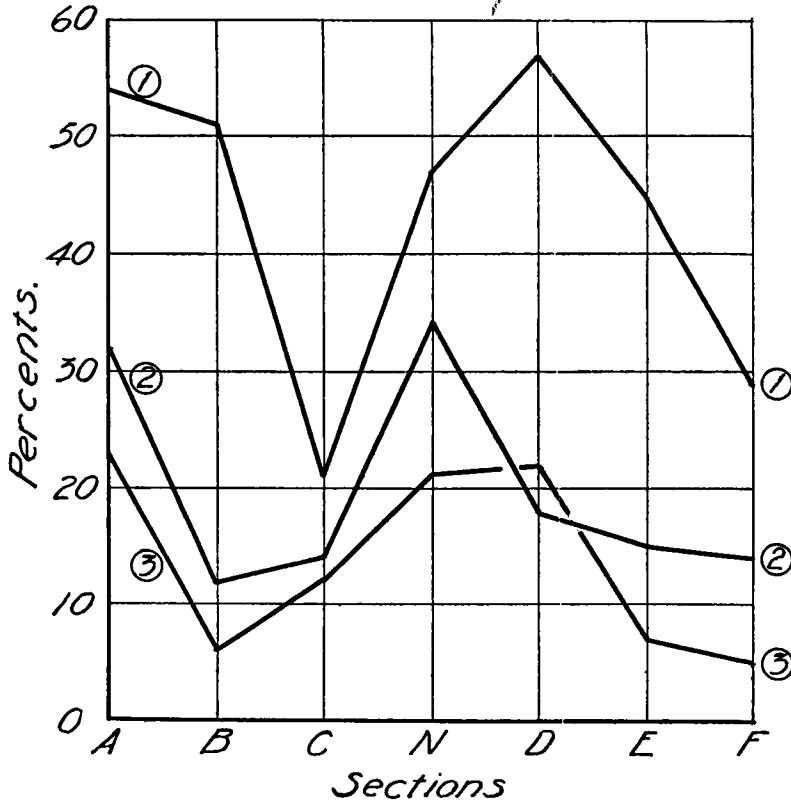


FIGURE 4

GRAPH SHOWING ERRORS IN EACH SECTION WHEN SHIFTED AND WHEN LEFT
FIXED.  RUNS 51-100.  AVERAGE FOR TEN RATS

Curve 1.  Percentage of fifty runs in which sections were changed from previous run.

Curve 2.  Errors made in changed sections in percentages of total number of shifted sections run through.

Curve 3.  Errors made in unchanged sections in percentages of total number of unshifted sections run through.

For location of sections designated (A, B, C, N, etc.) see Figure 1.

significant differences between the first run on a given day and the subsequent runs of the same rat on the same day in respect to either errors or time required.    If the first run is less perfect than the second, third, or fourth of the same day, this indicates a certain degree of forgetting over night and an immediate re-establishment of the habit during the first trial.    This was noticeable to a marked degree with the visual runs here reported.    If it does not exist in the case of the kinaesthetic runs, it may be taken to show an instability of the visual habit in maze running, a need to reassert it by actual practice.    Table 4 gives these data for the full 50 runs and for the two 25-run groups.    It will be noted that the first run of the evening involved double the number of errors committed in the fourth run, and that the two intermediate runs were practically identical and almost exactly the mean of the first and fourth.    That this tendency is not a chance one is shown by comparing the first 25 runs with the second 25, approximately the same results being shown in both cases.    That this is not the effect of other rats having run the maze in the meantime is obvious.    The maze was changed for each run; that is, the second run of an evening was a different set-up for any given rat from that of the first run and the second differed from the third, and that from the fourth.    It is a question here of the difference to each rat between having been through the maze a half hour before and of not having been through for about 24 hours.

TABLE 4

SUMMARY OF TIMES AND ERRORS FOR RUNS MADE THE SAME DAY AVERAGED
FOR TEN RATS FOR THE LAST FIFTY RUNS AND FOR THE SAME FIFTY
RUNS DIVIDED INTO FIRST AND SECOND GROUPS OF 25 RUNS EACH

| Runs | 1st run | 2nd run | 3rd run | 4th run |
|---|---|---|---|---|
| Runs 51-75 | | | | |
| Number of runs | 77 | 77 | 67 | 29 |
| Average time (minutes) | 0.26 | 0.21 | 0.21 | 0.18 |
| Average errors | 1.14 | 0.94 | 1.07 | 0.46 |
| Runs 76-100 | | | | |
| Number of runs | 77 | 80 | 61 | 32 |
| Average time (minutes) | 0.32 | 0.21 | 0.20 | 0.20 |
| Average errors | 1.80 | 1.28 | 1.25 | 0.99 |
| Runs 51-100 | | | | |
| Number of runs | 154 | 157 | 128 | 61 |
| Average time (minutes) | 0.28 | 0.21 | 0.21 | 0.19 |
| Average errors | 1.46 | 1.10 | 1.12 | 0.74 |

9) Consider further the factor of speed. Lashley (11) found in the single-choice reaction to visual stimuli only chance results and states that while the rats showed high speed of action they showed no discrimination. In the present experiment the speed of action was high, approximately $1\frac{1}{4}$ seconds to the section in the perfect runs, yet the discrimination was good. This is the more noteworthy in that it indicates a choice of pathways in a very small fraction of a second. Of the 500 runs analyzed, 245 were made in 10 seconds or less. Of these, 56 were made in nine seconds and 24 in eight. These include runs in which some errors were made. Included also are the momentary checks to investigate some new scent or other distraction. The length of the true path is approximately 16 feet. Since the choice had to be made in a three-inch stretch of this path, and since the average speed was about 20 inches per second, the time permitted for the choice was less than a fifth of a second. Actually, as judged by behavior, it was probably considerably less than this, there being no hesitation whatever observable in the majority of the perfect runs. This speed of selection is of significance as ruling out any stimuli whose reception involves a time lag, as would be the case with olfactory or radiant heat cues.

10) There was a high degree of individual difference in the rats, both in their nest boxes and in the maze. One of the rats, 5M, and to a lesser degree 6M and 7M, showed peculiar traits. Number 5M remained in the dark tunnel in his cage nearly continuously and seemed to have some strong fear which increased with age. In the maze he never got below an average of one error per run except for one 10-run series and twice he exceeded an average of two errors per run. Number 4M, on the other hand, learned rapidly and for the last 70 runs, in spite of the extinguishing of the lights, never exceeded an average of one error per run. In general, no significant differences were observed in the averages of the males and females in either speed or accuracy.

## PROCEDURE: PART 2

Having demonstrated that rats could form definite independent visual habits for the solution and running of the maze, it was determined to evaluate the fixity and predominance of these habits in the presence of opportunity to abandon them in favor of other modes of running, with especial reference to the so-called kinaesthetic reactions. To this end the rats were first allowed a complete rest

from all maze activities for 14 days. On the 15th day the internal
lights were set at four candlepower and the external illumination
left as at the conclusion of the first part of the work, that is, at
about 1.2 foot-candles intensity, as derived from the three indirect
overhead 100-watt lamps. The signs were in position as in the
previous runs. With the maze in this condition 10 runs were made
with each of the 10 rats to determine how much forgetting had oc-
curred in the period of no practice and to reset the habits if they
had been weakened. During these trials the maze was continually
shifted as in Part 1.

The old theory holds that while the rats might learn by visual
or other external sense cues, they would, nevertheless, turn the
maze running over to the internal muscular sense as soon as the
pattern had been mastered. To test this we gave the rats an op-
portunity to form kinaesthetic habits by leaving the maze un-
changed for three consecutive runs followed by another 10 "visual"
runs in the shifting maze to ascertain the amount of disturbance
that had been caused by abandoning the visual for the muscular
habit. Immediately following these 10 visual runs, the maze was
left unshifted for six consecutive "kinaesthetic" runs after which
another 10 visual runs were made to check up on the disturbance
factor. There were then given 10 fixed "kinaesthetic" runs fol-
lowed by another block of visual trials. Finally, 20 consecutive un-
changed runs were made and the experiment brought to a conclusion
with 10 more visual runs in the shifting maze. The performances
and details of these 89 runs under the alternating conditions are
discussed in the following section.

## RESULTS: PART 2

In the 10 visual runs made after two weeks of no practice follow-
ing the last run of Part 1, the 10-rat averages showed 0.47 errors
and 0.20 minutes per run. This, it will be noted, is considerably
better than the best performance of the main series, due undoubtedly
to the fact that, while they had learned finally to run the maze
without the use of lights, they now had the benefit of that practice
and also had the facilitating effect of the lamps at four candlepower, a
brightness which had not obtained in the main series after about
the 25th run. There had obviously been no forgetting in the two
weeks of idleness—an indication, perhaps, that the visual habit had
become fairly well integrated.

The first group of "kinaesthetic" runs was made brief, three in number, in order not to cause too much disturbance to permit of adequate evalution, a concern which the results showed to be unwarranted. While the three runs were made with better time and accuracy than the visual runs, the 10 checking visual runs which followed showed that there had evidently been no abandoning of the visual for the muscular habit, since the averages were now 0.22 errors and 0.20 minutes, the time being the same and the errors less than half those of the preceding 10 visual runs and the best of the visual series so far.

TABLE 5

SUMMARY OF AVERAGES OF TIMES AND ERRORS FOR THE GROUPS OF RUNS IN
WHICH THE MAZE WAS LEFT UNSHIFTED AND FOR THE BLOCKS OF TEN
TEST RUNS WITH THE SHIFTING MAZE FOLLOWING
EACH OF THESE FIXED GROUPS

| Runs | Errors per run | Time in minutes |
|------|------|------|
| Ten visual after 14 day's idleness | 0.47 | 0.20 |
| Three "kinaesthetic" | 0.10 | 0.16 |
| Ten visual after three "kinaesthetic" | 0.22 | 0.20 |
| Six "kinaesthetic" | 0.07 | 0.16 |
| Ten visual after six "kinaesthetic" | 0.13 | 0.17 |
| Ten "kinaesthetic" | 0.05 | 0.17 |
| Ten visual after ten "kinaesthetic" | 0.23 | 0.17 |
| Twenty "kinaesthetic" | 0.12 | 0.18 |
| Ten visual after twenty "kinaesthetic" | 0.25 | 0.27 |

The maze being now left unchanged for 6 runs in succession, the "kinaesthetic" performance was as recorded on the fourth line of Table 5. The 10 visual runs following these 6 fixed runs gave an average of 0.13 errors and 0.17 minutes, a substantial betterment in both time and accuracy instead of a disturbance of the visual habits.

The 10 fixed runs which now followed yielded the best performance of the experiment with only five errors for the hundred trials involved. The 10 test runs in the shifting maze showed that there was still no upsetting of the visual learning, although the errors did slightly increase. The figures for the 10 check runs, 0.23 errors and 0.17 minutes, show performance superior to any in the learning period of Part 1.

Since it took but 20.5 runs to learn the visual maze in the beginning of the experiment, the 20 fixed-pattern runs which were

now given provided an equal opportunity to develop a kinaesthetic mode of running. The 10 visual runs next following these 20 fixed runs showed 0.25 errors and 0.27 minutes. An analysis of these final runs presents some striking features. For the first run following the 20 "kinaesthetic" runs each of the seven sections was reversed in position, making as complete an alteration as could be obtained. Yet 6 of the 10 rats made the first run without error, 3 with but one error, one with three errors. It would seem obvious, therefore, that even during the 20 consecutive unchanged runs the rats did not abandon their visual habit in favor of any internal sense pattern built up by repetition of the muscular act. Having learned to run visually they continued to do so in the face of conditions setting a premium on the kinaesthetic factor.

These results are shown in Table 5 and in Figure 5.

That there is definite facilitation from repetition in tracing the same pattern is very evident. In the "kinaesthetic" runs the signs and lights are all available as cues and there is no interference or blocking due to changes from previous reactions at the various points
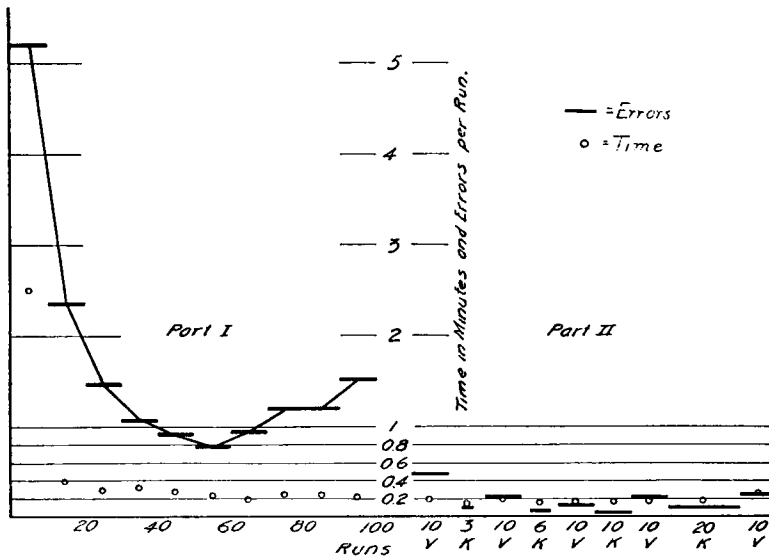


FIGURE 5

GRAPH SHOWING TIMES AND ERRORS FOR PART II, "VISUAL" AND "KINAES-THETIC" RUNS, AS WELL AS ORIGINAL LEARNING CURVE OF PART I

of choice. The times and errors for the "kinaesthetic" runs are notably lower than for the shifting visual runs. It is, however, noteworthy that in the course of the long series of runs we may have built up in the rats not only a habit of following visual cues but a habit of expecting changes in their path, which, when not forthcoming in the fixed runs, may have been a source of confusion. Three rats made 20 consecutive errorless runs in the fixed maze and two of them made the next 10 runs in the shifting maze without error.

From these results we are justified in concluding that when the visual habit is built up it becomes as firmly established as does the so-called kinaesthetic habit when it has been the one on which the animal places dependence. The difference between this maze and the standard type is that this one put a premium on the formation of the visual habits by making others practically if not entirely impossible, while the standard maze minimizes the visual factor almost to exclusion and puts a premium on the kinaesthetic or some other factor. Whichever habit is built up to the point of perfect dependability becomes predominant.

From observation of the rats in the fixed maze as well as from some informal runs made later with an unchanging maze made from the same sections in a different arrangement, the writer is inclined to look upon the purely kinaesthetic solution as more or less of a myth. For the internal muscular sense to be a reliable basis for threading a maze it would be necessary for the rat to duplicate its muscular responses to a remarkable degree of exactness, placing the same foot in the same place, turning on the same feet, running at the same speed, and taking the same number of steps each time. Otherwise there is a different internal pattern of muscular stimuli. Yet anyone who has watched their performance in the fixed maze knows that the overt behavior is never twice exactly alike. There are always introduced little checks and irregularities and deviations that would completely alter the internal cues.

## SUMMARY AND CONCLUSIONS

The descriptions of the behavior of rats in previous problems both in learning and in running the maze almost unanimously rule out the visual factor. Internal evidence in the reports indicates a lack of justification for this conclusion.

A maze was constructed in which all cues other than visual were

eliminated as guides to selecting the true path. Ten young rats were given 100 runs each in the maze, no two successive set-ups of the sections being the same. Under these conditions they learned to make perfect runs in from 11 to 28 trials (average 20.5) and attained an accuracy of one error in nine chances. The visual cues at this time were black and white signs reinforced by hidden lights of one-half candlepower or less.

The results of the second part of the experiment, designed to encourage the substitution of kinaesthetic for visual cues, casts grave doubt on the validity of the so-called purely kinaesthetic habit of maze running. Visual habits can be so firmly established as not to be abandoned for the hypothetical internal muscular cues even when ample opportunity for such a transfer is offered. It is safe to conclude that the rat has many resources at its command for learning and running a maze; that one which is found most serviceable under any given set of conditions is the one which becomes established and, being so established, is not easily upset.

The visual factor for albino rats in both learning and running the maze has probably been underestimated. While it is not to be doubted that the kinaesthetic factor is important, nor that it is strongly facilitative when both kinaesthetic and visual stimuli are available, the present experiment definitely demonstrates that it is not necessary. Normal rats have here run a maze on visual cues alone with a speed and accuracy comparable to the fixed maze performances in which it has been stated kinaesthetic cues were used to the exclusion of the visual.

Note: Since this article was put in the hands of the press, Dr. C. P. Stone, of Stanford University, has called the writer's attention to an article by W. M. Borovski which, although published only in Russian, is summarized by him in German in the *Zeitschrift für vergleichende Physiologie*, 1928, 7, 289-303, as an addendum to his article, "Experimentelle Untersuchungen über den Lernprozess, Nr. #3." From the brief summary it appears that Borovski used apparatus very similar to mine, a sectional shifting serial choice reaction apparatus, each unit being of the Yerkes type. His purpose was to evaluate the influence of the proximity of the food box as well as to determine whether mixing kinaesthetics and visual stimuli would enhance the learning process. The writer wishes, however, to accord him priority in the use of an apparatus of this type, though it was used for a different purpose. The description is too meager to enable one to determine the details of its construction and therefore to compare it with the writer's device.

## REFERENCES

1. ADAMS, H. F. A set of blind rats that could not learn the maze. *J. Anim. Behav.*, 1913, **3**, 300.

2. CARR, H. Maze studies with the white rat: I. Normal animals. *J. Anim. Behav.*, 1917, **7**, 259-274.

3. ——————. II. Blind animals. *J. Anim. Behav.*, 1917, **7**, 277-295.

4. ——————. III. Anosmic animals. *J. Anim. Behav.*, 1917, **7**, 295-306.

5. CARR, H., & WATSON, J. B. Orientation in the white rat. *J. Comp. Neur. & Psychol.*, 1908, **18**, 27-45.

6. HELSON, H. Insight in the white rat. *J. Exper. Psychol.*, 1927, **10**, 378-396.

7. HIGGINSON, G. D. Visual perception in the white rat. *J. Exper. Psychol.*, 1926, **9**, 337-347.

8. HOPKINS, A. E. Vision and retinal structure in mice. *Proc. Nat. Acad. Sci.*, 1924, **7**, 488-491.

9. HUNTER, W. S. The temporal maze and kinaesthetic processes in the white rat. *Psychobiol.*, 1920, **2**, 1-17.

10. JENKINS, L. N., WARNER, L. H., & WARDEN, C. J. Standard apparatus for the study of animal motivation. *J. Comp. Psychol.*, 1926, **6**, 361-380.

11. LASHLEY, K. S. Visual discrimination of size and form in the albino rat. *J. Anim. Behav.*, 1912, **2**, 310-329.

12. SMALL, W. S. Notes on the psychic development of the young white rat. *Amer. J. Psychol.*, 1899, **11**, 80-100.

13. ——————. An experimental study of the mental processes of the white rat. *Amer. J. Psychol.*, 1900, **11**, 131-165.

14. ——————. An experimental study of the mental processes of the white rat. *Amer. J. Psychol.*, 1900-1901, **12**, 206-239.

15. VINCENT, S. B. The mammalian eye. *J. Anim. Behav.*, 1912, **2**, 249-255.

16. ——————. The white rat and the maze problem: I. The introduction of a visual control. *J. Anim. Behav.*, 1915, **5**, 1-23.

17. ——————. II. The introduction of an olfactory control. *J. Anim. Behav.*, 1915, **5**, 140-156.

18. ——————. III. The introduction of a tactual control. *J. Anim. Behav.*, 1915, **5**, 175-183.

19. ——————. IV. The number and distribution of errors—a comparative study. *J. Anim. Behav.*, 1915, **5**, 367-374.

20. WATSON, J. B. Kinesthetic and organic sensations. Their rôle in the reactions of the white rat to the maze. *Psychol. Monog.*, 1907, 8, No. 2. Pp. 100.

21. WATSON, J. B., & WATSON, M. I. A study of the response of rodents to monochromatic light. *J. Anim. Behav.*, 1913, **3**, 1-14.

22. WAUGH, K. T. The rôle of vision in the mental life of the mouse. *J. Comp. Neur. & Psychol.*, 1910, **20**, 549-598.

23. WYLIE, H. H. An experimental study of transfer of response in white rats. *Behav. Monog.*, **3**, No. 16. Pp. iii+66.

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## LES SUGGESTIONS VISUELLES DANS LE PARCOURS DU LABYRINTHE PAR LES RATS BLANCS

### (Résumé)

Une revue de l'expérimentation antérieure indique qu'on a trop appuyé sur les facteurs kinesthésiques dans l'apprentissage et le parcours du labyrinthe et qu'on a trop négligé ou passé sans justification les facteurs visuels. Pour tester cette hypothèse on a donné à 10 jeunes rats l'occasion d'apprendre un labyrinthe en sections où le vrai couloir a été indiqué par des lumières blanches et des signes blancs, le faux par des lumières rouges et des signes noirs, toutes autres suggestions étant éliminées au moyen de changer, de renverser, et de tourner le labyrinthe et ses parties constituantes entre chaque groupe de deux épreuves consécutives. Tous les rats ont appris à faire des parcours parfaits. La courbe d'apprentissage ne diffère pas de la courbe ordinaire de l'apprentissage kinesthésique.

L'habitude de dépendance des suggestions visuelles ainsi établie n'a pas été perdue pendant quatorze jours sans exercice, et elle n'a été ni dérangée ni perdue en faveur des habitudes kinesthésiques quand on a laissé le labyrinthe dans une position fixe pendant vingt épreuves consécutives. On a montré ceci en faisant suivre les vingt épreuves fixes à dix épreuves dans le couloir changé. Le manque de dérangement a indiqué que les rats avaient parcouru même le labyrinthe fixe en employant les suggestions visuelles, malgré l'occasion de former l'habitude de réaction musculaire préférée par supposition.

Dans l'apprentissage du labyrinthe le rat a beaucoup de recours possibles. Le groupe d'habitudes (visuelles, musculaires, olfactives, etc.) rendues de la plus grande valeur dans le problème donné prévaudra et persistera.

<div align="right">WALTON</div>

## "VISUELLE WEISEZEICHEN FÜR DIE WEISSEN RATTEN IM LABYRINT"

### (Referat)

Ein Überlick über die bisherigen experimentellen Untersuchungen ergibt, dass der Muskelsinn als Faktor im Labyrintgehen und in der Labyrintgewöhnumg überbetont wurde, dagegen visuelle Faktoren vernachlässigt oder unberechtigter Weise ausgeschaltet wurden. Um diese Hypothese zu prüfen, gab man zehn jungen Ratten Gelegenheit, sich an ein Sektionslabyrint zu gewöhnen, worin der richtige Gang mit weissen Lichtern und Zeichen bezeichnet wurde, die falschen aber durch rote Lichter und schwarze Zeichen. Alle übrigen Weisezeichen wurden durch Verschiebung, Umkehrung and Drehrung des Labyrints und dessen Teile zwischen je zwei nacheinander erfolgenden Versuchen eliminiert. Alle Ratten lernten, vollkommen richtige Läufe zu machen. Die Lernkurve ist nicht verschieden von der des Muskelsinnlernens.

Die durch visuelle Weisezeichen geschaffehe Gewöhnung ging während einer vierzehntägigen Unterbrechung nicht verloren, wurde auch nicht gestört oder aufgegeben zu Gunsten von Muskelsinn gewöhnungen, wenn das Labyrint für viele bis zwanzig nacheinander folgende Läufe unverändert blieb. Man bewies es dadurch, dass man die Ratten nach den zwanzig unveränderten Läufen zehnmal durch das veränderte Labyrint laufen liess.

Die Tatsache, dass sich keine Störungen zeigten, beweist, dass die Ratten sogar durch das unveränderte Labyrint mit Hilfe von visuellen Zeichen liefen, obschon sie Gelegenheit gehabt hätten, die vermeintlich vorgezogene Muskelsinnreaktion zu erstellen.

Bei der Labyrintgewöhnung verfügt die Ratte über viele Hilsquellen. Die Gruppe von Gewöhnungen (visuelle, muskuläre, Geruchsgewöhnungen u.s.w.), die das gegebene Problem bevorzugt, herrschen vor und verharren.

WALTON