ORIENTATION IN THE WHITE RAT.

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WITH ONE FIGURE.

In a previous paper[1] the present writers advanced the conclusion that kinæsthetic and organic data play the fundamental rôle in the reactions of the white rat to the maze. This conclusion was reached by eliminating the other senses singly or in groups. It was not denied that the rat may occasionally use the data from these other senses or that it could use them if the occasion demanded. The present experiments attempt to supplement this conclusion. In them, conditions were imposed upon the rat which would tend to bring the kinæsthetic factor into strong relief if, as assumed, it does possess fundamental importance in the determination of conduct within the maze. Two experiments were made: (1) After learning the maze, starting always from O, the rats were placed in the positions[2] marked x_1, x_2, x_3, in the true pathway headed in either the right or the wrong direction and their method of obtaining orientation under these novel conditions was observed. The conclusion mentioned above was then theoretically discussed in the light of the new facts thus obtained, to see if difficulties and contradictions appear. (2) After the reactions to the maze became automatic, certain of the runways were either shortened or lengthened. The disturbing effect of these alterations upon the rats' conduct and their methods of learning to adjust themselves to the new conditions were observed. The two experiments will be discussed in order.

EXPERIMENT I.

THE EFFECT OF STARTING THE RAT AT DIFFERENT POSITIONS.

When the trained rat is put down in the maze at unfamiliar starting points, several possibilities of conduct are open to it:

[1] WATSON, J. B., *Psychological Review, Monograph Supplement,* vol. 8, no. 2, 1907.
[2] See cut of maze, p. 28. A similar but unsatisfactory test was reported in the previous paper. See p. 81, *loc. cit.*

(1) the animal may not have profited in the least by its previous experience in the maze; the situation may offer a problem *de novo*; (2) the rat may orient itself immediately as does a human
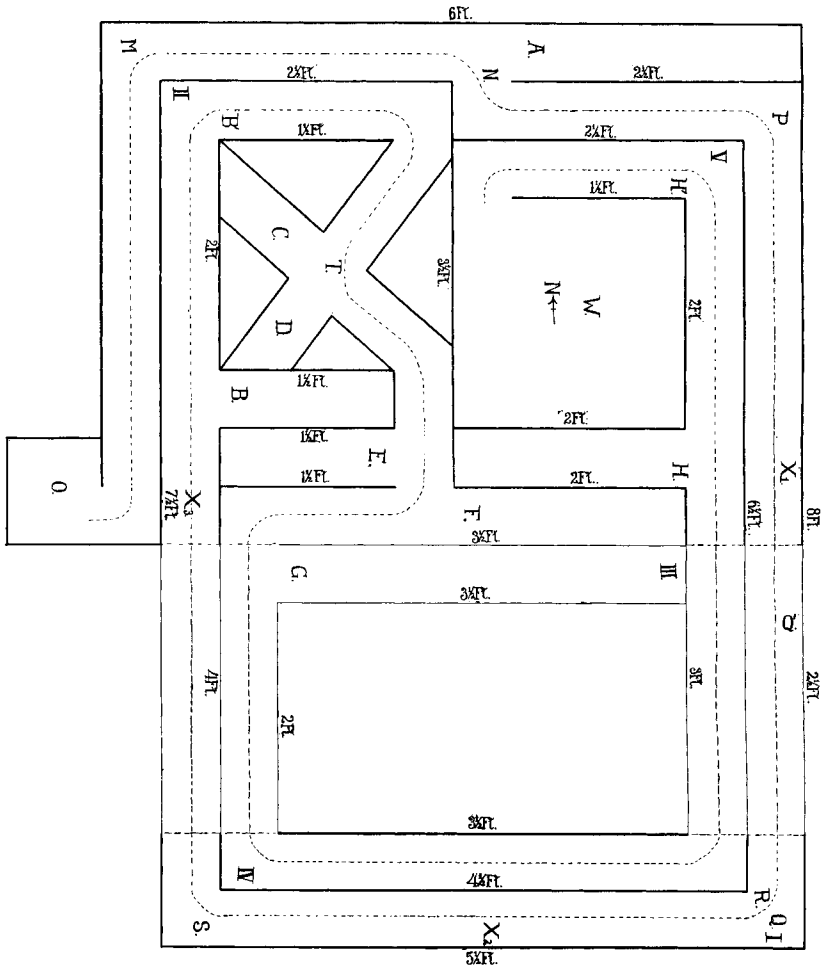

Fig. 1.

being, when, in a partially strange situation, he suddenly finds some thoroughly familiar landmark; (3) immediate orientation may not occur, and yet the situation may not be entirely new to the rat; it may exhibit some random movements before starting

properly; but its conduct might be wholly different from an animal which had not previously learned the maze; (4) if the last condition obtains, can the rat learn in time to orient itself immediately when put down at random at any one of two, three or four such starting places?

On the basis of results obtained from our work during the past summer, which is presented in detail on page 33, combined with the previous work of WATSON[3] and of CARR,[4] we are ready to give more or less satisfactory data bearing upon the above questions. (1) The situation does not present a problem *de novo.* (2) Nor does immediate orientation occur. (3) There is a period of random effort; the rat may wander about, turn around in the alleys several times or run up and down the pathway for a variable distance, acting as though lost or in a new situation. In conscious terms, its behavior suggests uncertainty, perplexity, and lack of confidence. Finally, a change of behavior is observable. The suggestion of perplexity and uncertainty is gone, the rat starts off with a sudden burst of increased speed and every movement thereafter is characterized by the precision and regularity which mark the functioning of an automatic habit. The remaining part of the maze is run in the normal and habitual manner. This change of conduct has been termed "getting the cue." The "cue" may come suddenly while the animal is running backward in the maze with irregular speed; the rat may suddenly stop, turn quickly and start off at full speed toward the food-box. The change often comes gradually, especially when the animal starts off running in the right direction. After the cue has apparently been obtained, it may be lost for a time and again found after a short interval; however the cue once obtained is rarely lost. Furthermore, once the animal attains orientation, it traverses the rest of the maze without error. This change from random to controlled activity is striking and characteristic, but extremely difficult of description except in anthropomorphic terms. (4) The rat can learn with a sufficient number of trials to orient itself immediately, starting at random from any one, two, or three definite positions in the maze. The number of trials necessary to accomplish this feat has not been determined accurately. One set of rats learned to start from any one of six cul-de-sacs on the

[3] *Ibid.,* pp. 82 and 83.
[4] Heretofore unpublished.

basis of an average of eighteen trials for each animal. This would imply that under these conditions, three trials per rat were required by it in order to learn to start at random from any one of six cul-de-sacs. A greater number of trials, however, is necessary when the animal is forced to start at random from six such positions in the true pathway. In the latter case, orientation at these positions does not become immediate in less than five or six trials.[5]

With these facts bearing upon the behavior during the establishment of orientation before us, we may now well ask the question: how does the rat attain orientation? Can he do it in terms of kinæsthetic data alone? From our previous work upon the behavior of normal, blind, and anosmic rats in tests of this kind in the Hampton Court maze, it appeared, since no difference in conduct between the normal and defective animals could be found with respect to their ability to attain orientation when put down in the maze at unfamiliar starting points, that visual and olfactory data are at least not largely employed by them as a means of controlling their movements. This conclusion is based upon the assumption that the processes employed as control by the defective rats are the same as those which would have been employed by them had they been normal. Let us suppose, for example, that a normal rat does use visual data, or the data from some other "distance" sense, for controlling his movements when the automatic (kinæsthetic-motor) character of the act is interfered with, as is the case at first when the animal is started in the maze at some point other than the customary one. What would be the nature of the orienting process? Evidently the animal would have to move at random until distinctive familiar visual or other extraorganic stimulation appeared, at which time the automatic series would be restored and the animal might thereafter have no further need for distance sense data during the remainder of the trip around the maze.

If, however, we deny to the rat the possibility (or better, the probability) of its using distance sense data in the way described above, it becomes necessary for us to answer the question: how can a kinæsthetic-motor series, which has been thrown out of gear become readjusted without control data from some other sense avenue?

Summarized from CARR's unpublished results.

If we assume that each separate "unit" (possibly a runway) of the maze affords some characteristic set of kinæsthetic impulses which can be utilized as a stimulus to secure the proper adjustment to the succeeding unit, we might have a situation where a distinctive set of kinæsthetic impulses would serve the animal for control exactly like a set of distinctive visual cues, for example. There are four ways in which distinctive kinæsthetic groups of impulses might arise. (*a*) Two runways may be of unequal length. (*b*) They may be of equal length, but occur in different positions in the total series, *i. e.*, they are preceded by different conditions. (*c*) They may be alike in every respect with the exception that the one is entered by a turn to the right, while the other is entered by a turn to the left. In rounding a corner at a high rate of speed, the body sways over to the inside, the weight is thrown on one side, while the feet on the outer side are braced in order to maintain equilibrium. Such differences are so gross and fundamental that it is idle to deny that they possess functional influence upon subsequent behavior. (*d*) The alleys may be of the same length and be entered by the same direction of turn, but present possible differences in their stimulating effect because they extend in different directions. It is difficult to conceive why and how this can be so, and the possibility is suggested only because of certain observed facts. The successful functioning of an automatic habit depends upon the rat's orientation in relation to cardinal positions. Change the direction of the path and the automatic act is disturbed to some extent. The same act accomplished in two different directions is thus *different in some way to the animal*. Thus, it is theoretically possible for the rat to adapt its behavior successfully to a series of objective conditions wholly in terms of the differences in kinæsthetic stimulation, which it offers, without relying to any extent upon data contributed through any of the distance senses. We have no intention of maintaining that the rat discriminates these possible differences in kinæsthetic values in any overtly conscious or intellectual manner, viz., that they know "right" and "left" or cardinal directions, or that they consciously evaluate in any kind of terms the length of the alleys.

If, as we have assumed, the automatic behavior of the rat in the maze is governed by distinctions lying within the kinæsthetic impulses themselves, we are in a position to understand the situa-

tion presented to the rat when it is introduced into the maze at
some one of these positions. The animal must perforce run up
and down the alleys until it experiences some one or several of
these characteristic motor situations which would give rise to the
necessary stimulations to release the old automatic movement.
The rat may run the length of the alleys, around corners, or tra-
verse several alleys before getting the cue. Moreover, on this
basis, one can conceive why at times the cue should be gradually
attained. At such times, a summation of stimuli would be re-
quired.

On the other hand, it may with justice be argued, as we our-
selves above suggested, that if the cue is received through data
from some distance sense, the animal must still run about at
random until it receives some one or several such characteristic
stimuli. This argument cannot be met wholly, but if our own
behavior under similar circumstances can by analogy be made
to apply to the case of the rat, we should be allowed to assume,
when our elimination experiments are considered, that this period
of random activity would be much shorter when distance sense
data are employed than when kinæsthetic are used. 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 attempt to rule out all possibility of the rats' receiv-
ing aid from extraorganic sense data.

This assumption granted us, our argument may now be stated
as follows. If the animals orient themselves in the maze in the
majority of cases by running at least the full length of one alley,
by rounding corners into a second alley, or by running through
several alleys before picking up the cue, the facts will be explicable
in terms of the kinæsthetic hypothesis, and consequently there
will be no theoretical difficulty in supposing that the rat's auto-
matic movements in the maze as a whole are controlled by kin-
æsthetic impulses alone. If, on the other hand, the rats orient
themselves in the majority of cases with a minimum of random
movement, the facts will not be so easily explicable in terms of
our hypothesis, as in terms of some other which would admit that
control is inaugurated by data from some distance sense and con-
sequently, that automatic behavior in the maze may be guided
and controlled effectually as occasion demands by such means.

In order to make a careful test of the facts of orientation, sev-

eral conditions must be observed in the experiment: (1) The alleys of the maze into which the rats are introduced should be relatively long and should differ markedly in their length. (2) When placed in the maze, the animals naturally tend to spring from the hand on the run, and go for a short distance before attempting to adjust themselves to the situation.   This tendency should be minimized as much as possible by holding them in position for a short time, or by allowing them to nibble a crumb of bread when released.   (3) Since, with successive attempts, the rats will gradually learn to make immediate orientation, only a few trials for each position should be given.   The series of tests, the results of which are given in the paper previously referred to, are faulty in the first and third respects.   We have repeated the experiment in order to eliminate these possible sources of error.

In order to meet the conditions required under (1), a new maze was constructed the plan and dimensions of which are represented in the cut.   The alleys are six inches wide and six inches deep. Finished lumber was used, the cracks in the floor were filled with putty, and the whole maze was given three coats of white paint. The maze was constructed so it could be sawed across at the dotted lines and divided into three sections for the purpose of the second experiment.   The maze was not so divided until the first experiment was completed.   The cut represents the maze as used, with the exception that the opening into the cul-de-sac B was closed.   The experiment was conducted out of doors in an enclosed yard.   The rats were introduced into the maze at the positions x_1, x_2, and x_3. Two of these alleys are seven and one-half feet long, while the third is two feet shorter.   This allows the animals to run a distance of two and one-half to three and one-half feet in either direction from the starting place before a turn is possible or necessary.   The experiment was started with twelve rats, but four became sickly and unreliable in conduct and were discarded.   The group consisted of three normal males, two blind males and three normal females.   After the rats had been thoroughly trained, the experiment was started each day by giving them a preliminary run through the maze and then introducing each rat separately at x_1 with wrong orientation, at x_2 with correct orientation, and at x_3 with wrong orientation.   By "wrong" orientation, we mean that the rats were headed back towards the starting box, O.   This procedure was followed the second day

with the exception that the orientation for each position was re-
versed. Thus three trials were given each rat per day, and the
same orientation for any one position was repeated every other
day. Not more than a total of twelve trials was given to any
one rat. These varied conditions were designed to eliminate the
possibility of *learning* to react immediately to a given position.
An accurate account of the behavior of each rat was taken, includ-
ing the changes in direction of movement, the distance traversed,
the turnings inside the alleys, partial returns and the position
where the rat seemed to pick up its cue. The conduct was noted
by two, and sometimes by three observers. In all, 84 tests were
made and the results were tabulated in statistical form.

No noticeable tendency for the rats to start in the direction
in which they have been oriented was observed. They are just
as likely to turn around immediately and start off in the opposite
direction. Neither do they tend to start either toward the food-
box, W, or back toward the original entrance, O. In other words,
the direction of starting is apparently a matter of chance entirely.
This fact of itself argues the lack of any immediate orientation.
The situation in which they have been placed thus does not
influence nor determine their conduct at the beginning of the test.

The movements in the latter part of the period of exploration
are determined to some extent: The rats tend to migrate back
toward the starting box, O. In 75 per cent of the trials, the
cue was picked up somewhere between the position where they
were released and the box O. The rats often explore on both
sides of the position at which they are released, but 85 per cent
of the distance traversed in the period of exploration is on the
side toward O. This general fact may be difficult of explanation,
but that some determining influence is at work is too evident to
admit of doubt. The following explanation may be suggested as
a possibility. In learning the maze originally, the rats explore
for a distance from O and retrace their steps. This performance is
repeated on successive trials with more extensive excursions.
When the rats become lost or confused during any trial, although
the maze is partially learned, they always run back toward O.
It seems that the maze is learned in sections, as it were, and in
case the rats become lost at any time, they are able to retrace their
steps to more familiar surroundings. When the rat is now intro-
duced at the position x_1 and begins to explore, the situation becomes

familiar to some extent, and the rat acts as it has been accustomed to in order to get started correctly, *i. e.*, drifts back toward *O*. Such a conception, however, leaves much to be explained.

The general statement that the situation is not entirely novel during the period of exploration and that the behavior of the rats is influenced as a result, is also supported by the fact that few errors are made, *i. e.*, errors in the sense of running into cul-de-sacs during the period of exploration. Of the 84 trials, errors occurred in but eight. Four of these errors were made by one rat. Such a percentage of errors is possible in running the maze normally. In four cases, the error occurred after the orientation had apparently been secured. But two chances for error were offered in those parts of the maze traversed during the period of exploration. In 55 of the trials, the rats passed by one of these openings leading into a cul-de-sac before securing orientation; and they often passed by the same opening several times in the same trial. Yet out of these numerous possibilities, only four cases of error of this kind occurred. The exploring movements are thus confined almost exclusively to the true pathway.

On the average, the rats turned around 2.5 corners in each trial before being able to pick up the cue; in other words, they explored fully or in part three alleys per trial before becoming oriented. Their explorations averaged a distance of 12.6 feet per trial. Inside the alleys, they changed the direction of exploration 1.3 times per trial. In only ten trials out of the 84 was the exploration confined to the alley in which they were placed and in these cases the distance traversed averaged 2.8 feet per trial, while the direction of movement was changed at least once. In 57 cases out of the 84, they went outside of the alley into which they were introduced before becoming oriented. Immediate orientation apparently occurred in seventeen trials. It is extremely doubtful whether several of these are legitimate cases of immediate orientation. A rat may by chance run forward toward the food-box, *W*, and become oriented gradually. In four of these cases, the rat went forward to the food-box, but ran hesitantly, made stops, or entered some of the cul-de-sacs. It was our policy to record under the heading of immediate orientation every case that could possibly be interpreted in that manner. As may be seen, these four trials are exceedingly questionable. In four other cases the rats turned around several times in the alley before

starting off.   Nine trials were clear-cut, legitimate cases of imme-
diate orientation.   However, eight of the total number of imme-
diate orientations were made by two rats, and the influence of
the learning factor is evident in spite of the small number of trials
allowed to each animal.   *No immediate orientations were made
during the first day.   Only three cases occurred during the first
half of the trials, while the remaining fourteen cases were made
during the last half of the tests.*

There was a tendency for the rats to pick up the cue at dis-
tinctive points in the maze.   In the 67 trials in which there was
a period of exploration, the cue was picked up 13 times at O, 11
times at or near the corner M, 15 times at the turn N, 11 times at
the corner P, 7 times at the corner R, 3 times at S and once at
T.   In only six trials was the orientation clearly effected near the
middle of one of the alleys, to which number must be added the
number of trials in which immediate orientation occurred.   This
fact, that the cue is picked up at distinctive positions, cannot be
explained on the hypothesis that each rat would finally learn to
orient itself at some one of these positions and hence that all of the
15 orientations at N, for example, belong to that one rat, as might
very well be the case, if such a point offered a distinctive visual or
olfactory cue.   As a matter of fact, the greatest number of orienta-
tions per rat at any position was four out of a total of twelve trials.
The 67 trials give an average of 8.37 per rat, and on the average,
these 8.37 orientations occurred at 4.75 positions—less than two
orientations per position.   For any one rat, the greatest average
number of orientations per position was 2.2.   This general fact
that orientation is secured at such distinctive positions as the
turns supports our general contention.

The statistical results show no differences between the blind
and the normal rats in any respect.   The females have better
records than the males.   Their period of exploration is shorter,
fewer turns are made inside the alleys, fewer corners are turned,
and the percentage of immediate orientations is much higher.
Whether this difference is a matter of chance, or whether the
results represent individual or sex differences, it is impossible to
say.

These various results of the experiment speak for themselves.
They can be easily interpreted in terms of our theory.   We do not
mean to assert that they furnish conclusive and indubitable proof

of our contention, but we do maintain that they can be more readily explained on the basis of our conception[6] than in terms of a theory which assumes that orientation is secured mainly through some distance sense.

<center>EXPERIMENT II.</center>

<center>THE EFFECT OF SHORTENING AND LENGTHENING CERTAIN ALLEYS IN THE MAZE.</center>

1.   The Effect of Shortening the Maze.—For the second experiment, the maze was divided into three sections by sawing it across at the dotted lines.   By removing or replacing the middle section, the maze could be shortened or brought back to its original length.   This change merely alters the length of four alleys without altering the relation of the turns leading to or from them. The maze was cut very carefully so that the two end sections would fit quite snugly together after the middle section had been removed. For reasons presently made known the cul-de-sac, *B*, remained open during Experiment II.

The trained rats formerly used were employed in this experiment with the exception of the second blind one.   This animal became somewhat feeble and refused to work consistently from day to day.   After the maze had been sawed through but before the middle section was removed, the animals were allowed to run the maze for seven days.   Four trials per day were given each rat.   All disturbances of their old habits due to the new smell factors introduced by sectioning of the maze, to the opening of cul-de-sac *B*, and to the tests described above were thus eliminated. After their reactions became thoroughly automatic, the maze was shortened and the behavior of the rats in the new situation was noted.   Each rat was given four trials per day for five days.

As above outlined, our theory assumes that the rats make the correct turns in the maze in response to some internal (kinæsthetic) impulse.   If the assumption is not true, the rounding of the corners must be in response to some extraorganic stimulation received there.   That is, the wall at the end of the runways and the opening into the next alley must contribute data through some distance sense.   The experiment is designed to test the relative

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[6] With the exception of the cases of immediate orientation.   Since two out of eight animals made eight of the nine unquestioned immediate orientations we are willing to admit the possibility of the use of distance sense data in their cases.

efficiency of these two possible modes of stimulation in determining the rats' behavior at the turns. If the animals run at full speed against the ends of the shortened alleys at *I*, *II*, *IV* and *V*, evidently the assumption that they receive extraorganic stimulation there of functional value to them is most improbable. If the rats succeed in making the turns as correctly as usual, we must conclude that such conduct is determined wholly by extraorganic stimulations and is not influenced effectively by kinæsthetic ones. The experiment is decisive in estimating the relative efficiency of the two possible modes of stimulation, because it brings them into functional opposition.

The results obtained from this experiment justify our assumption that the turns are made in response to differences lying in the kinæsthetic impulses themselves. Marked disturbances of conduct were noticed in every rat. On the average sixteen trials per rat were necessary wholly to eliminate these disturbances, *i. e.*, to secure accurate, automatic adjustment to the shortened maze. Rats can often learn a maze of this complexity *de novo* in this number of trials. This fact is evidence of the profound disturbances effected by the change.

The time for running the maze was increased despite the shortened length. The increase of time was hardly proportionate to the degree of disturbance as reflected in the nature of their behavior. Table I gives the average time in fractions of a minute. The normal time for running the maze in its shortened form was secured by averaging many individual records of trips made after the reactions of the animals had become thoroughly automatic. The records of the seven animals made after the maze was shortened were averaged for each trial. The time increases for the first trials, and then gradually decreases toward the norm.

The disturbances consisted of (1) running squarely into the ends of the alleys at *I*, *II*, *III*, *IV* and *V*; (2) errors, such as partial returns or entering into some of the cul-de-sacs; (3) slow, hesitant and careful movements; (4) stopping here and there and "nosing" around the sides of the alleys, and (5) compensatory adjustments. By the last phrase, we refer to the fact that, after running into the end of an alley for several trials, the rats often attempted to make that turn too soon and would come in contact with the inner corner of the turn. This tendency was most evident at *IV*. The alley *IV* in the shortened maze occupies the

position of cul-de-sac *G* in the lengthened maze. After "bumping" into the wall at *IV* several times, the rats tended to turn too soon and consequently failed to round the turn. As a consequence they formed the habit of running into cul-de-sac *F*. This error was very characteristic and was difficult to eradicate.

TABLE I.

Average time for successive trials in running the shortened maze. (Based upon records of 7 rats).

Normal	.21 min.		(5)	.33 min.		(10)	.25 min.	
(1)	.39 "		(6)	.33 "		(11)	.25 "	
(2)	.45 "		(7)	.33 "		(12)	.30 "	
(3)	.45 "		(8)	.27 "		(13)	.22 "	
(4)	.37 "		(9)	.25 "		(14)	.22 "	

The following record of Female III, which may be considered typical of the series, furnishes the best description of their behavior.

Sept. 6. (1) Ran into *I* with all her strength. Was badly staggered and did not recover normal conduct until she had gone 9 ft. Ran against *IV* hard and then touched *V* lightly with nose.

(2) Ran into *I* and "nosed" *IV*.

(3) Hesitated at *I* and *IV* but did not touch walls with nose.

(4) Perfect.

Sept. 7. (5) Ran into *I* with sufficient force to land her whole body against the wall. Did not recover normal behavior until after passing *IV*. Stopped at *IV*.

(6) Ran very slowly and hesitantly. Did not gather any momentum. Hesitation at the four crucial corners.

(7) Hugged inner wall at *I*. Stopped at *IV*.

(8) Perfect.

Sept. 8. (9) Slowed up and hesitated at *I* and hugged inner wall at *IV*.

(10) Stopped and "nosed" at *I*, *IV* and *V*.

(11) Perfect.

(12) Perfect.

Sept. 9. (13) Perfect. Ran rapidly.

(14) Perfect.

(15) Entered cul-de-sac *F*.

(16) Perfect.

Sept. 10.. All four trials were correct.

One result was obtained which is rather peculiar and is difficult of explanation. The six normal rats found little difficulty with the turn at *II*. Three of these animals effected this turn accurately in every trial. One rat touched the wall lightly on the first trial but made the turn accurately thereafter. The fifth rat struck the wall lightly on the ninth trial, but made the turn perfectly thereafter. The sixth rat hesitated at the turn on the fifth and sixth trials. Out of a total of 120 trials, the rats touched this wall lightly twice, and hesitated momentarily three times. In the remaining 115 cases, the turn was made accurately and unhesitatingly. On the other hand, the blind rat found as much diffi-

culty with this corner as with any of the others.   He ran into the wall quite hard the first trial, touched it lightly on the second trial and hesitated there the third trial.   On the second day, he ran into the wall twice and made the turn correctly thereafter.   It may be supposed that this difference between the conduct of the blind rat and that of the normal rats indicates that the latter effected this turn with the aid of visual data.   This assumption is hardly legitimate, inasmuch as the normal animals failed to use vision effectively at the other three corners.   Neither can one assume that the turn at IV presented visual distinctions not possessed by the other corners, because, if such visual differences exist, they are too minute for the human eye to detect, and, in case the rat possesses a visual acuity superior to that of human beings, it ought to be able to detect a solid wall sufficiently well to refrain from running headlong into it time after time.   Again, one may suppose that the normal rats were accustomed to see the opening B before reaching the turn at II, and made the correct adjustment in response to this visual cue.   On this basis, the normal animals should have had no trouble at the turn V because the opening H bears the same relation to the turn V as does B to the turn II.   However, this assumption may be supported by the fact that the cul-de-sac H has been open during the previous experiment, while B has been open only some eight days.   One may argue that the normal rats had neglected the opening H as a visual cue in the course of the long series of trials which was given them in the learning maze from the first, while the recent opening of B had attracted their "visual attention" and they had learned to utilize it as a visual cue.   Such a conception is possible, but the argument is based upon a rather precarious foundation.   If the rats can see the opening B so as to react to it, it seems that they ought to be able to see the opening into any alley at the turn and utilize it as a visual cue, inasmuch as there is no reason why they should neglect this cue throughout the course of the long series of tests.   When the fact was noticed that the normal animals turned the corner II correctly, it was suggested that the shortened alley leading up to II, which is five feet long, possessed the same kinæsthetic characteristics as some alley in the lengthened maze.   As a matter of fact, the alley leading from the box O, four and one-half feet long, is very similar to alley II.   Hence it could be argued that, since the alleys possess the same motor peculiari-

ties, the turns would be made in a similar manner. The conception is ingenious, and it would support our thesis, but on this basis, the blind rat should have had no trouble at *II*. Consequently, we are forced to admit that the phenomenon remains inexplicable so far as the present experiment is concerned.

With the exception noted above, no difference between the behavior of the blind and the normal rats could be detected.

2. The Effect of Lengthening the Maze.—After the above series of tests had been completed, the rats were forced to continue running the shortened maze for a period of three weeks, at the end of which time their reactions to it had become thoroughly automatic. The maze was then lengthened by replacing the middle section, and the behavior of the animals under these conditions was observed. In the previous experiment, this middle section had been thoroughly explored by the animals and it should now have presented a minimum of possible sensory disturbance.[7]

The conditions are again such that they bring into functional opposition the influences of kinæsthetic cues and any possible distance sense cues which might be involved in rounding the corners of the alleys. If the rats turn in response to kinæsthetic cues, they should now attempt to turn in the extended alleys at the positions corresponding to the length of the alleys in the shortened form. In the first alley, this position is at Q'. In the remaining alleys, the cul-de-sacs B, G and H now occupy these crucial positions. For example, the distance S-B in the extended maze equals the distance S-B' in the shortened maze. According to our theory, the rats should now run into the *wall at Q'* and into the cul-de-sacs B, G and H.

The results again support our contention. Marked disturbances in conduct occurred for twelve trials (three days). After this time, the disturbances occurred occasionally, though they may be regarded as practically eliminated at the end of this period.

The time for running the maze was noticeably increased in the first trials, but it was gradually decreased thereafter (Table II).

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[7] The blind rat whose behavior had become erratic was not used in the shortened form of the maze. We utilized this animal, however, by allowing him each day to run several times through the lengthened form of the maze. In this way, we kept the middle section constantly in use during the experiments in the shortened maze. By this means, the original smell values of this middle section were retained unaltered, for the males at least, since this blind rat was a male, and was kept in the same living cage with all the other males used in the experiment.

These times, as before, are expressed in fractions of a minute. The normal time was secured by averaging a number of trial records taken immediately before Experiment I was made.

TABLE II.

Average time for running the lengthened form of maze after becoming habituated to shortened form.
(*based upon 7 animals.*)

Normal .28 min.	(3)	.52 min.	(6)	.34 min.
(1) .59 "	(4)	.31 "	(7)	.35 "
(2) .65 "	(5)	.49 "	(8)	.34 "

As the best description of their behavior, we give as typical the record of Male I for eight successive trials.

Oct. 2. (1) Came to a full stop at Q′ and "nosed" along the wall. Ran into and traversed the full length of alleys *B*, *G* and *H*.

(2) Slowed up at Q′. Entered *B* its full length. On coming out of *B*, ran back into *A*, started from *A* in the right direction, slowed up at Q′ and partly entered *B*, *G* and *H*.

(3) Turned into the wall at Q′ and became badly confused. Ran back and forth between Q′ and *A* three times. On coming to Q′ the third time, reared upon the wall and "nosed" about. A slight error was made at *B*. Ran the full length of *G* and made a slight error at *H*.

(4) Ran rapidly to Q′ and then went slowly until turning the corner. Ran past *B* but hesitated at *G* and *H*.

Oct. 2. (5) "Nosed" along the wall at Q′ until turning the corner. Slowed up at *B*, ran with full speed against the end of *G* and partially entered *H*.

(6) Ran past Q′ correctly, and went into *B* its full length. On coming out of *B*, went back to *A*, started from *A* in the right direction, and "nosed" around the wall at Q′, went back again to *A*, turned and came to Q′ and "nosed" about; continued but hesitated at *B*, *G* and *H* but did not enter them.

(7) Slight hesitancy at *B* and *H*.

(8) Merely slowed up at Q′, *B* and *H*.

All the animals ran into the wall at *Q′* and into all of the crucial cul-de-sacs. These errors had been eliminated to a great extent by the end of the first four trials (first day's experience), but were again prominent during the first trials of the second and third days. *On entering the crucial cul-de-sacs, the rats frequently ran full speed into the end of the alley.* This is evidence that the cul-de-sacs were mistaken for the true pathway. After a few trials, the cul-de-sacs were entered only part way, and finally the disturbance manifested at these positions consisted of hesitations or of a swerve in the direction of the openings without any decrease in speed. At first, the rats actually attempted to turn through the wall at *Q′* at the definite position at which they would have had to turn in the shortened maze. Striking the wall at an angle, the rat would slide along it for eight to ten inches and would then go on until it stumbled upon the opening at the end of the alley. This turn occurred relatively accurately (*i. e.*, with respect to old habit) during the first five trials on the average. After this number had

been given, the animal often struck the wall at a point slightly further on between Q' and the corner Q. It seemed that the attempted turn was a resultant of two impulses, one to turn at Q' and the other to go on to Q at the end of the extended alley. Failure to find the opening at Q' often caused the rat to stop and go back in the maze for a new start, or to go ahead slowly until it stumbled upon the opening. In later trials, the animals ran rapidly past Q' without stopping or hesitating, but a *deflection of an inch or two toward* Q' could be noted; the same behavior was noted as the animals passed the crucial cul-de-sacs. In spite of these various disturbances, *i. e.*, hesitations, entering the cul-de-sacs, running into the wall and partial returns over the true pathway, it is a noteworthy fact that very rarely was the confusion so great that the animals ran into any cul-de-sac other than the three crucial ones.

No differences between the behavior of the normal animals and that of the blind rat could be detected.

The results of these two experiments, combined with those reported in the previous paper, form rather conclusive proof of the contention as to the fundamental importance of the kinæsthetic factor in the rat's adjustment to the maze.

CONCLUSION.

In concluding this paper, it may be well to reformulate our contention even at the expense of repetition, by contrasting the habits of the rats in the maze with the habits of human beings in a similar environment.

Human beings can form habits of the type we have been discussing (kinæsthetic-motor) which may become absolutely automatic. When this latter stage has been reached the "movement to come" is released at the proper time by the afferent (kinæsthetic) impulses aroused by the movement which has just been made. So far, these statements apply alike to the behavior of rat and man.

When an automatic series of movements in man is disturbed, the "movement to come" can no longer be released by the afferent impulses arising from the movement just effected. Visual, auditory or tactual impulses (cues) are then utilized, *i. e.*, the adjustment becomes, *e. g.*, momentarily visual-motor. A few move-

ments made in response to these distance sense cues may suffice
to restore the kinæsthetic-motor character of all the ensuing adjust-
ments.

Likewise, when an automatic series of acts in the rat is disturbed,
the "movement to come" can no longer be released by impulses
arising from the movement just preceding.   But at this point
the analogy between the behavior of rat and man breaks down.
The former apparently has no well developed distance sense cues,
consequently he must utilize some method other than the one
above described to reëstablish the automatic character of his acts.
Our hypothesis provides the rat with such a method.   According
to it, the rat has the possibility of receiving kinæsthetic cues which
function for "control" exactly as do visual cues in man.   These
kinæsthetic cues are ordinarily not needed by the rat for controlling
his movements any more than visual cues are needed by man for
controlling his.   But the moment a break occurs in the series
of the acts of the rat a cue is needed which will lead to the reëstab-
lishment of the automatic character of the movement.   The rat
receives this cue by traversing at random any "unit" of the maze.
The group of afferent impulses (kinæsthetic) which are aroused by
traversing this unit releases the proper adjustment (*i. e.,* the old
movement which has been synergized on many past occasions
with this particular group of impulses) and the automatic char-
acter of the movements is again restored.

On this supposition, man's kinæsthetic-motor habits would
differ from the rat's mainly in this, that whereas the former util-
izes distance sense cues for reëstablishing automatic adjust-
ments, the latter utilizes kinæsthetic cues.