



Studies in Spatial Learning. I. Orientation and the Short-Cut

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A. Introduction

It is the purpose of the present series of experimental reports, of which this is the first, to develop some of the important implications of the senior author's 'theory of expectancy.' We feel that no altogether clear or precise formulation of this theory has previously been presented, largely because the data relevant for such a formulation were not known. The original formulations were admittedly rough and vague. The presentation of the theory in a rough form was, however, perhaps excusable, since it was hoped that further experimental work would be undertaken which would enable such a first formulation to be replaced by one more precise.

One of the consequences of stating the theory in its original rough fashion has apparently been to make it difficult to distinguish the theory from alternative stimulus-response doctrines. For as the argument has progressed it has appeared that, when analyzed, most of the statements of the expectancy theory turned out to sound little different from statements of the opposed stimulus-response theories. Consider for example the following exposition of the expectancy theory as presented by Hilgard and Marquis:

According to Tolman, in learning a sequence of acts leading to a goal the subject follows 'signs' which mark out the 'behavior-route' leading to the 'significate' or goal. . . . In the presence of the 'signs' the subject 'expects' the goal to appear if it follows the 'behavior-route.' (6, p. 88)

Although this statement of the expectancy theory is relatively justified in terms of some of the past formulations given by the senior author, the present writers now feel that it misses the main intent of the theory of expectancy. To make clear why we believe that this is so, let us analyze the implications of such a statement of the theory.

In terms of the passage quoted, let us consider what would be meant by the further specific statement: "This rat expects food at location *L*." In other words, we wish to know how in such a case the term 'expectation' is to be introduced or defined. Implicit in the usual formulations of the expectancy theory (that is, in such a formulation as that just quoted from Hilgard and Marquis), is a definition of the term 'expectation' that makes it equivalent to 'the tendency of an animal to

respond in a particular fashion, when appropriately motivated.' Although the term 'expectation' has not previously been given a precise definition, we now believe that the following formulation expresses what is implicit in such usual and earlier formulations:

When we assert that a rat expects food at location *L*, what we assert is that if (1) the rat has been deprived of food for more than twelve hours, (2) he has been trained on path *P*, and (3) he is now placed on path *P*, then he will run down path *P*. When we assert that he does not expect food at location *L*, what we assert is that under the same conditions he will *not* run down path *P*.

Such a definition can be expressed formally by means of a conditioned definition of the form: " $P \supset (Q \equiv R)$."¹ The following then, is a conditioned definition which introduces the matrix "*x* expects food at location *L*":

DF. 1. If *x* is deprived of food and *x* has been trained on path *P* and *x* is now put on path *P*, then (*x* runs down path *P* = *x* expects food at location *L*).²

This definition, we claim, was implicit in all or most of the earlier formulations of the expectancy theory. We further believe that this definition does not accord with our real intentions as to how the term should be used.

The reason that Definition 1 does not conform to our intention is that when 'expectation' is defined in such a fashion there seems to be little difference between the expectancy theory and the stimulus-response theories. The latter theories assert that what is learned in any spatial problem is

¹ This is what Carnap (1) has called a 'bilateral reduction sentence.' Sentences of this form are, he argues, essential for the introduction or definition of disposition predicates.

² A matrix is an expression which contains a free variable. When a value is specified for this variable, and the name of this value is substituted for the variable, the matrix becomes a sentence. Note that it is the matrix "*x* expects food at location *L*" which is being introduced, and *not* the matrix "*x* is an expectation." We do not introduce, and need not introduce, the latter matrix. Carnap illustrates this point by showing that in physics we need never introduce the matrix "*x* is an electric charge." All that we need for experimental purposes, he argues, is the matrix "*x* has an electric charge." In the remaining sections of this paper whenever we refer to our definition of 'expectation' we are elliptically referring to a conditioned definition containing the matrix "*x* expects food at location *L*," and not one containing the matrix "*x* is an expectation." Finally, it should be pointed out that what Definition 1 states is that the truth-value of the matrix "*x* expects food at location *L*" is considered identical to that of the matrix "*x* runs down path *P*," whenever the conditions stated by the antecedent are fulfilled.

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a response-tendency (i.e., a tendency to take the path on which the animal was trained), whenever the animal is appropriately motivated. In the definition of 'expectation' which we have given above, the expectancy theory also asserts that what is learned is a tendency to make a particular response. Thus, the differences between the stimulus-response and expectancy theories, when 'expectation' is defined in such a fashion, are purely terminological. What we would call 'signs,' they would call 'stimuli,' and what they would call 'response-tendencies' we would call 'expectations.'

As a consequence we wish now to reject Definition I and write a new one which we believe will better express the original intent of the senior author, and will make clear the difference between the complete expectancy theory and its rivals. The following, then, expresses our present decision about what we shall mean by the expression "*x* expects food at location *L*":

When we assert that a rat expects food at location *L*, what we assert is that if (1) he is deprived of food, (2) he has been trained on path *P*, (3) he is now put on path *P*, (4) path *P* is now blocked, and (5) there are other paths which lead away from path *P*, one of which points directly to location *L*, then he will run down the path which points directly to location *L*.

When we assert that he does *not* expect food at location *L*, what we assert is that, under the same conditions, he will *not* run down the path which points directly to location *L*.

The following is a formal expression of this decision by means of a conditioned definition:

DF. II. If *x* is deprived of food and *x* has been trained on path *P* and *x* is now put on path *P* and path *P* is now blocked and there are other paths which lead away from path *P*, one of which points directly to location *L*, then (*x* runs down the path which points directly to location *L* = *x* expects food at location *L*).

What Definition II states is that the truth-value of the matrix "*x* expects food at location *L*" is considered identical to that of the matrix "*x* runs down the path which points directly to location *L*" whenever the conditions stated by the antecedent are fulfilled.

Now although it is nonsense to inquire whether any definition is true or false, since it merely expresses a decision about how we will use words, it is extremely important to determine whether the class defined by any definition has any members. That is, it is extremely important in our case, to know whether there are any rats which do in fact take the shortest path to the goal location, when the original path is blocked. This is obviously an empirical problem and can only be settled by experiment. It is, then, the purpose of the experiment reported in this paper to determine the answer to this question.

B. Subjects

Fifty-six female rats, approximately three months old, were used in this experiment. These rats came from the Tryon stock, and 26 of them were Tryon 'brights' and 30 were Tryon 'dulls' (13). Six days before the beginning of our experiment they concluded an 18 day series of daily trials on the Tryon *automatic* maze. Thus, before the beginning of our experiment these rats were 'maze-wise,' and had been trained to a 24-hour wet-food maintenance schedule. All of the

trials on the Tryon maze were run in the afternoon between one and five P.M. In our experiment, on the other hand, all trials were run at night between eight and eleven P.M.

C. Apparatus

Figs. 1 and 2 present diagrams of the apparatus which were used. In Fig. 1 we see the apparatus used in the preliminary training. It consisted of an unpainted wooden circular table top, which was three feet in diameter, and several unpainted pine elevated paths which were two in. in width. Path *AB* was 24 in. in length and was used as a starting path. Paths *CD*, *DE*, and *EF* were all 18 in. in length, while path *FG* was 60 in. long. A stand with a sliding food-box was located at the end of path *FG*, and whenever a rat entered one of its stalls the whole box moved in the direction indicated by the arrow, until an empty stall was ready for the next rat. Each stall was 4 in. wide, 10 in. deep, and 6 in. high. Within each stall was placed a white glass bird-bath, and on the rim of this bird-bath was placed a half-teaspoon of wet food. A 5-watt bulb in an ordinary desk lamp was the only illumination in the room. It was located at *H*, six in. behind the sliding food-box. The reflector on this lamp was turned in such a way that the light was primarily directed down path *FG*. Fastened to the sides of path *CD* were two pieces of unpainted plywood, which were 18 in. high and 30 in. in length. These formed an alley which began in the middle of the table-top and ended just at the point where path *CD* turns into path *DE*.

In Fig. 2 we see the apparatus used in the test trial. This consisted of the same starting path, circular table-top, alley on path *CD*, and

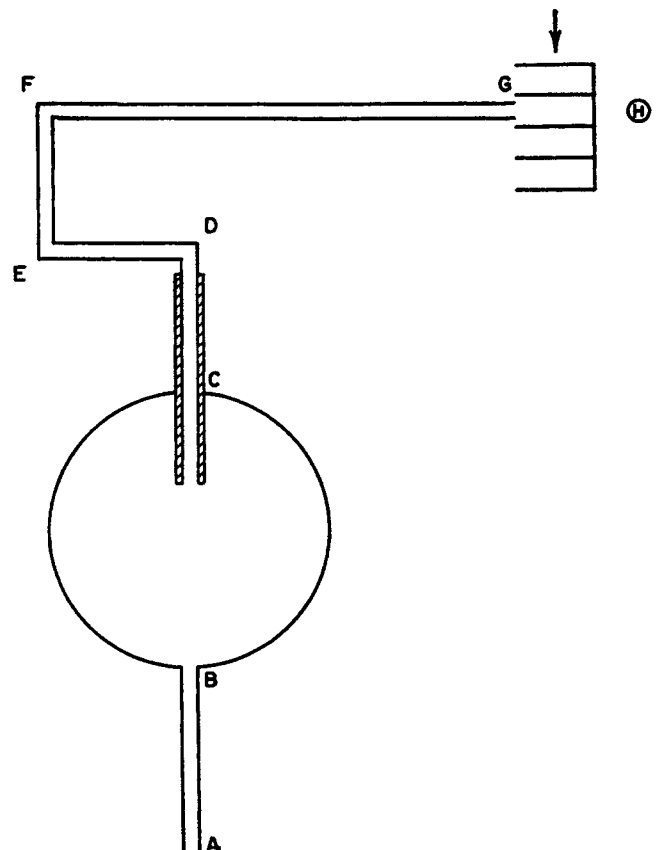


Figure 1. Apparatus used in preliminary training.

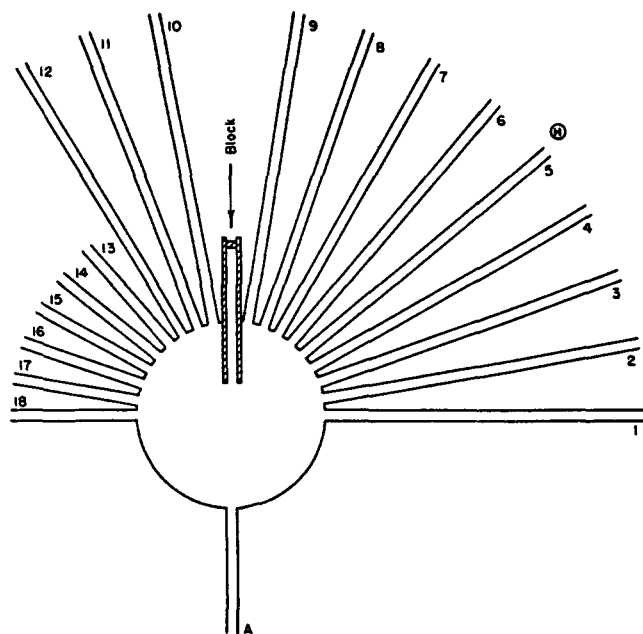


Figure 2. Apparatus used in the test trial.

lamp at *H*. But the food-box and paths *DE*, *EF*, and *FG* were removed. At the end of the alley on path *CD*, a block was placed. Then 12 six-foot unpainted pine paths were placed around the circular table-top. These paths began at a point 90 degrees to the right of path *CD* and radiated in a counter-clockwise fashion, each path being placed 10 degrees to the left of its neighbor. These paths were firmly nailed to a supporting structure so that the table-top could be revolved independently of these paths.

The six 24-in. paths to the left of the last six-foot path were shorter because the size of the room in which the experiment was conducted did not permit any greater length.

D. Method

Pre-test procedures. Two days before the first run on the apparatus in Fig. 1, the rats were put on a 24-hour wet-food maintenance schedule, being fed every evening at 10:30 P.M.

On Day 1 the rats were given three trials. On the first trial they were put by hand into the food-box and allowed to eat for five min. On the second trial they were put in the middle of path *FG* and allowed to run to *G* and into the food-boxes. On the third trial they were started at *F* and allowed to run into the food-boxes. They were then returned to their home cages and fed their full ration approximately 30 min. later.

On Day 2 they were given three more trials. On the first trial they ran from *F* to the food-boxes. On the second trial they were put by hand into the alley on path *CD* and forced to run from there out onto path *DE* and from there to the food-boxes. This was repeated on the third trial.

On Day 3 they were again given three trials. On the first trial they were forced to run out of the alley on path *CD*. On the second and third trials they were started at *A* and allowed to explore the table-top, run through the tunnel and on to the food-boxes.

On Day 4 they were given three trials starting from *A* in the same manner as on the last two trials on Day 3. Thus, after their training on Day 4, each rat had run five times to the food-boxes at *G*, from the starting place at *A*.

Test procedures. On Day 5 one test trial was given. The apparatus was changed to that represented in Fig. 2. Each rat was started at *A*, allowed to run into the blocked alley on *CD*, to return out of the alley, and to explore the table-top and the various alternative paths which radiated from it. The rat's trial ended as soon as it had chosen one of the paths and had run out to the end of it. If any rat took more than six min. to make such a choice it was removed. This was indicated in the protocol record by the expression 'No choice.' The circular table-top was revolved after each rat had run across it, and before the next one was started. This was done to prevent any possibility of 'tracking.'

E. Results

On the test trial three of the 56 rats were discarded because they made 'No choice' after six min. After having explored all of the paths and the table-top, all three of these rats returned to the center of the table and refused to move from there except to return either to the alley or to the starting place.

Of the remaining 53 rats, 19, or 36 percent, chose path No. 6 which ended at a point four in. to the left of the place where the food-box entrance had been during the pre-test trials. This path No. 6 was, of all the paths offered, the most direct path to the former goal location.

The remaining 34 rats were distributed in a 'random' fashion over the other 11 paths. The distribution of the total group of the 53 rats is represented in the graph in Fig. 3.

The mean choice time for the 53 rats was three min. and 28 sec., while no rat chose a path in less than 85 sec. Their behavior during the time before they made a choice consisted chiefly in (1) returns to the blocked ally and to the starting point, and (2) exploration of the table-top and paths. In exploring these paths they would run out 12 to 18 in. and then return to the table-top. It was also observed that all rats which went out on any path more than 24 in. continued running until they reached the end of the path. No rat made any choice without having first gone around the edge of the table-top at least once, and without having tentatively explored more than one other path.

Two points should be noted about the frequencies of the other paths. (1) The relatively large number of rats, 9, or 17 percent, which chose path No. 1, may have been an artifact of the experimental apparatus. Path No. 1 was the last of the paths offered on the right-hand side. Thus, we might suppose that had there been more paths after No. 1, some of the rats which chose No. 1 would have chosen these others. The fact that there was no such 'piling-up' on path No. 12, can be explained by the fact that this was not the last path on the left-hand side. There were the six additional two-foot paths. These were not included in the graph in Fig. 3 because they were not considered comparable to the longer paths. Their importance, however, was probably negligible, since only eight of the 56 rats chose any of these shorter paths. But, it is important to notice that of these eight rats, four were ones which later chose path No. 1. Thus, almost half of the rats recorded on No. 1 chose this path only after having chosen one of the shorter paths.

(2) One should also notice the frequencies on paths No. 9 and No. 10. These two paths are the ones that are most

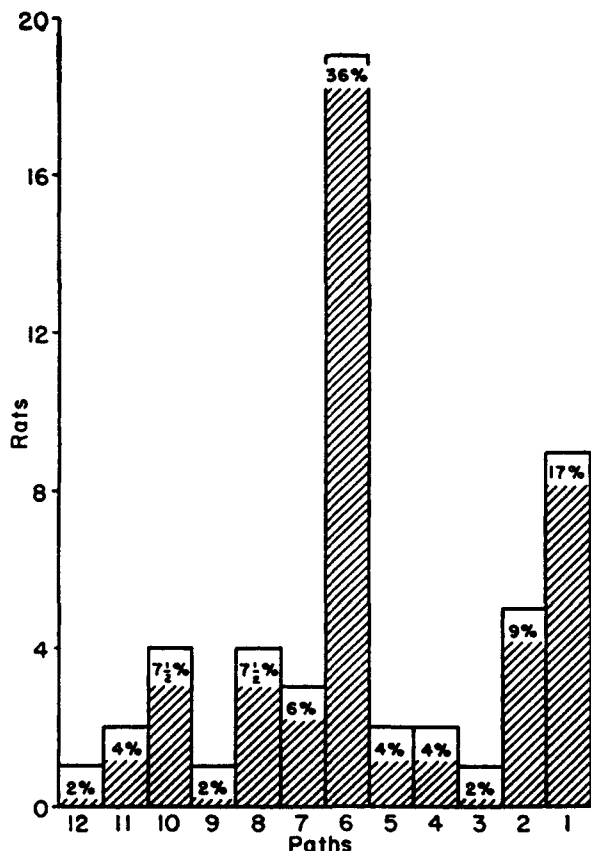


Figure 3. Numbers of rats which chose each of the paths.

similar, or spatially closest to, the original path on which the rats were practiced during the pre-test training. The combined frequencies of these two paths is only nine percent.

Finally, of the 19 rats which chose path No. 6, 10 were Tryon 'brights' and nine were Tryon 'dulls.'

F. Discussion

It is evident that at least in our experimental situation practice on a specific route, or response sequence, produces in some rats a disposition to take the shortest Euclidean path to the goal, whenever this path is available and the practiced one is blocked. This is what we set out to discover. In terms of what we said in the introduction, then, the class defined by the matrix "*x* expects food at location *L*" is not null.

This discovery is, of course, not entirely new. Lashley (7) observed rats climb out of the alley of his maze and run directly towards the food-box. Dennis (2) reported that when the walls of his maze were removed his rats ran directly to the food-box. Helson (4) also observed similar short-cutting to the food-box. These experimenters were not, however, primarily interested in this phenomenon, but were working on other problems. Later workers such as Higginson (5), Valentine (14) and Gilhousen (3) turned their attention directly to the short-cut problem. They were concerned, however, with

a different aspect of the phenomenon. They wanted to discover if the rat would choose the short-cut path when both the short-cut and the longer original path were open. Although Higginson reported that some of his rats did choose the short-cut under such conditions, both Valentine and Gilhousen concluded that the tendency was to take the short-cut depended upon the speed at which the rat was moving when he came to the choice point. It is obvious that the problem which they set for the rats was primarily one of noticing the new path. We, on the other hand, were merely concerned with discovering what direction the rats would take when the original path was blocked.

A question arises at this point about whether it is correct to say that our rats chose the path pointing towards the goal location. Some critics might prefer to say that they merely ran towards the light, a response which was rewarded during the pre-testing training. Since the location of the light and the former location of the food are nearly identical in our experiment this criticism raises an important point.

In answer to this criticism we should first explain that we are not asserting that rats can exhibit such orientational behavior when there are no cues or landmarks present. We believe that such choices can only be made when there are distinctive stimuli in the environment which enable the rat to judge its own location relative to other places in the environment. The light, we believe, performed such a function and was not a mere conditioned stimulus, as such a criticism would suppose.

The reasons why we believe that the light was not a mere conditioned stimulus are (1) that the original light stimulus and the light stimulus on the test trials were different, and (2) that the original response differed greatly from the correct response on the test trial. The light stimulus in the pre-test training was faced head-on when the rat came down path FG. The light stimulus when running down path No. 6, on the other hand, was not faced head-on, but was received at an angle of 50 degrees. Should the critic suggest that this difference was not great enough to prevent sensory generalization, we should answer that then the generalization should also be effective on the paths adjacent to path No. 6. However, we see that while 19 rats took path No. 6, the total frequency on paths No. 5 and No. 7 was only five rats. This would hardly be expected if the choice of path No. 6 was determined solely by the similarity of the light stimulus on this path to the stimulus on the original path, since the stimuli on paths No. 5 and No. 7 were not very different from the stimulus on path No. 6. The angle at which the light was received on path No. 5 was 40 degrees, while it was 60 degrees for path No. 7.

But not only was the light stimulus different in the test trial from the stimulus in the pre-test training, but the responses to the two situations also differed. The original response was one of running through the alley, turning left (away from the light), turning right (at right angles to the light), and again turning right (directly towards the light). The correct response on the test trial, on the other hand, consisted in avoiding the alley and in choosing path No. 6 from the other 18 paths, and running down this straight path. For all these reasons we believe that it is not correct to say that our rats were merely running towards the light. Rather, we should say that they

were running towards the location of the former goal, and that this location was indicated by the position of the light.

Now, how are we going to account for the fact that not all of our rats chose this shortest path? One hypothesis that might be suggested is that these rats differed in some orientational ability. However, the fact that 10 of the short-cut groups were Tryon 'brights' and nine were Tryon 'dulls,' throws some doubt upon this hypothesis. This doubt is based upon the assumption that Tryon's 'brights' and 'dulls' are different because of differences in orientational abilities. A second hypothesis that suggests itself is that the rats which failed to take the short-cut were overtrained on the pre-test training and thus were fixated on the original path. However, the fact that only nine percent of the rats took the two paths that were closest to the original one, makes this hypothesis quite questionable. Finally, we believe that the reason that the remaining rats failed to take the short-cut was that they had not had enough training and thus had not yet learned the location of the food. With a few more days training we should have that only nine percent of the rats took the two paths that were closest to the original one, makes this hypothesis quite questionable. Finally, we believe that the reason that the remaining rats failed to take the short-cut was that they had not had enough training and thus had not yet learned the location of the food. With a few more days training we should have expected that the remaining rats would have chosen the short-cut.

A further question now arises—why do we give the name 'expectation' to these dispositions? Would not a less anthropomorphic term be more suitable? The reason why we have chosen this word is that we wish to emphasize the difference between the kind of orientational behavior exhibited in the traditional conditioning experiments. In short, we believe that the behavior exhibited by our rats is similar in important respects to human symbolic behavior.

No one would deny that when someone reads, understands, and believes a sign like, "There is bread in the kitchen," he then *expects* bread to be in the kitchen. Difficulties arise, however, when we try to describe this expectation in terms of behavior. In the first place, there is no known simple response which is uniformly associated with an expectation of bread in the kitchen. In fact, when there is no motivation there is no response at all. However, none of us would wish to assert that because there is no response in such circumstances, there is no expectation. For this reason we must reject any explicit definition of 'expectation' in terms of any single response or set of responses. This is the point which the senior writer has stressed in all his discussions of latent learning (9, 10, 11, 12).

Now let us consider those cases in which the person is motivated and some response occurs. Even now there is no single response or set of responses which is uniformly associated with this expectation. A wide variety of responses may be observed in such a situation, and all that they seem to have in common is that they all are functions of the relation between the location of the person who has the expectation and the location of the kitchen. Since this relation may change from one occasion to another, the response to this sign differs on different occasions. All of this illustrates that it is very difficult to describe such expectations in terms of behavior. About all that can be said, as Bertrand Russell (8) has pointed

out, is that the hungry bread-lover responds appropriately to the fact that *he is here* and the kitchen is *there*.

Of course this statement is not very helpful unless we are able to characterize what is meant by the word 'appropriate.' However, in a situation as simple as the one we are concerned with, we may say that the person's behavior is 'appropriate' to the degree that it approaches the shortest Euclidean path from this location to the kitchen. Now, in order to be able to respond appropriately when in a new situation (one from which he has never been sought bread) it is necessary that the person recognize the abstract location of the kitchen, that is, its spatial relation to other places in the environment. If, on the other hand, the location of the kitchen is merely recognized as the place which is the terminus of all the paths which have been traversed in the past when seeking bread, then this person would be helpless when either all these old paths are blocked, or he is in a new location. Put in other words, if the sign, "There is bread in the kitchen," were a conditioned stimulus for a specific set of alternative response sequences and if the original paths for these response sequences were not available, then the conditioning would have prepared him for no solution to the problem. Thus, if the person is able to solve this problem and pick a new path which is in fact appropriate, then this sign cannot be a mere conditioned stimulus. Further, we must suppose that his knowledge of the location of the kitchen is abstracted from the location of any of the paths, and is a function of the kitchen's spatial relation to the total environment.

We have discussed some of the things that are involved in human behavior when someone expects a goal in a particular location. We have elaborated this human example because few people will deny that humans behave in this fashion, or that it is correct to call such behavior by the word 'expectation.'

However, all that we have said applies equally well, we believe, to the spatial behavior of the rats in our experiment. The problem we set for our rats demanded the same kind of abstract knowledge of the location of the food. If the goal location had been recognized merely as the terminus of the original path, or the place of the terminal response in the original response sequence, then our rats would have been helpless on the test trial. The fact that they selected the shortest path indicates that what was learned during the preliminary training was not a mere response sequence, or an expectation that this particular path led to the goal. They learned, instead, a disposition to orient towards the physical location of the goal. Because of this we have chosen the word 'expectation' as the name for this orientational disposition.

G. Summary

1. The original rough formulation of the expectancy theory is difficult to distinguish from the alternative stimulus-response doctrines. Part of this difficulty results from the fact that implicit in this rough formulation, is a definition of the matrix "*x* expects a goal at location *L*," which makes it equivalent to the matrix "*x* runs down the practiced path," when certain conditions are fulfilled. Because of this difficulty, we have rejected this definition.

2. We have suggested instead a definition of the matrix "x expects a goal at location L" which makes it equivalent to the matrix "x runs down the path which points directly to the location L," when certain conditions are fulfilled.

3. To determine whether rats will run down such a path, whenever the original path is blocked, we have run 56 female rats in a situation which conformed to these conditions.

4. Thirty-six percent of the rats chose the path which pointed directly towards the location of the goal. The remaining rats were distributed over the other paths in a chance fashion.

5. We have concluded (1) that rats do learn to expect goals in specific locations, (2) that there are important similarities between this behavior and human symbolic behavior, and (3) that these similarities justify our using the word 'expectation' as a name for the disposition to short-cut when the original path is blocked.

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Carr Appointed Editor of the *Journal of Experimental Psychology: Human Perception and Performance*, 1994-1999

The Publications and Communications Board of the American Psychological Association announces the appointment of Thomas H. Carr, PhD, Michigan State University, as editor of the *Journal of Experimental Psychology: Human Perception and Performance* for a 6-year term beginning in 1994. As of December 15, 1992, manuscripts should be directed to

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