# AN APPLICATION OF GEOMETRIC PRINCIPLES TO THE PLACE-VERSUS-RESPONSE ISSUE

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By applying geometric analysis to some experimental maze situations the present study attempted to determine if a continuity in the responding of experimental Ss existed. This continuity in responding might suggest the presence of alternative explanations for the behavior of these Ss in some maze problems. The study made use of a modified version of the Tolman, Ritchie, and Kalish (1946a) experiment using six runways during training rather than one.

The results of the study show that three of the six groups obtained the identical angle of choice, angle between the runway trained on and the runway chosen during the experimental trial, indicating the possibility of an underlying behavioral factor determining this continuity in responding.

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AN APPLICATION OF GEOMETRIC PRINCIPLES
TO THE PLACE-VERSUS-RESPONSE ISSUE

From recent emphasis upon quantification and predictability of psychological study, the widespread use of mathematical techniques in the field of learning theories has ensued. The place-versus-response-learning problem avails itself nicely to mathematical analysis, even though prominent studies in the area failed to utilize its capabilities. Specifically, a method of geometric analysis might introduce quantification, a measure of predictability, and primarily a consideration of angular orientation in the prior experiments of this heretofore subjective area.

The place versus response issue involved a protracted pseudo-controversy between followers of Tolman, advocates of place learning, and those of Hull's response-learning theory. Place learning implied that experimental animals over a series of maze trials had acquired a "cognitive map" of the situation, or, in other words, they had become spatially oriented to the experimental location. According to place-learning theories, animals did not simply learn a sequence of responses. Hull (1943) concluded in his response-learning theory that an animal simply learned responses in a maze. One oversimplified interpretation of his theory proposed that the subjects (Ss) learned a succession of right and left turns mediated by muscle movements. The controversies between these two positions were the genesis of many studies in the late 1940's.

Tolman, Ritchie, and Kalish (1946a) brought the issue to its initial prominence, with the senior author (Tolman) attempting to further his "theory of expectation." In the text of the article Tolman attempted to refute Marquis and Hildgard's (1940) interpretation of his definition of "expectation." Both parties defined the word as a tendency to make a response, but what Tolman referred to as "signs," Marquis and Hildgard labelled "stimuli." By introducing an irrefutable, operational definition of "expectation," Tolman ostensibly solved the dilemma.

The authors initially trained their animals in a single-runway maze. In this apparatus the authors purported that the animals acquired a directional predisposition for the goal area. Experimental trials were performed in a radiating pathway maze; however, the original pathway used during training was blocked. Tolman, Ritchie, and Kalish then attempted to determine whether any proclivity for the shortest possible route to the goal box was displayed by the experimental animals. This would indicate that the subjects had accrued over the training period a spatial orientation of the maze. A five-watt light bulb located six inches behind the goal box was the only illumination present in the room.

After four days of training and one day of test trials Tolman, Ritchie, and Kalish concluded that since 36 per cent of the animals chose the shortest Euclidean path to the goal box, spatial orientation or place learning had occurred. The authors attributed the remaining animals' choice of runways other than the shortest route to the goal box to an insufficient training period. Tolman, Ritchie, and Kalish stated that if a protracted training schedule were instituted, a greater percentage of appropriate responding would occur.

Advocates of response learning argued that the Ss in the Tolman, Ritchie, and Kalish (1946a) study had simply responded to the light stimulus placed above the goal box during training and experimental trials as a conditioned reinforcer. The authors eliminated this criticism with the statement that in order for spatial learning to occur the animals must be able to discern a cue, namely, the light above the goal box. Since lights with different physical properties were used in the training and experimental trials, the light acted as more than a simple conditioned reinforcer.

Gentry, Brown, and Kaplan (1947) devised an experiment that tested the validity of an assertion made by Tolman, Ritchie, and Kalish (1946a) that the remaining 64 per cent of the animals in their study would have chosen the shortest route to the goal box had it not been for the fact that inadequate training periods were provided. The authors utilized as many as nine periods of training and still failed to obtain a significant tendency for the animals to display a spatial orientation of the maze. In contrast with the Tolman, Ritchie, and Kalish (1946a) study, 30 percent of the animals in the Gentry, Brown, and Kaplan (1947) experiment chose pathways adjacent to the blocked runway originally used during training. The results obtained by the latter authors supported the response-learning position and were in direct opposition to the findings of the Tolman, Ritchie, and Kalish (1946a) study.

Gentry, Brown, and Lee (1948) presented another criticism of the Tolman, Ritchie, and Kalish (1946a) experiment. The authors professed that no learning criterion had been applied to determine how well the animals had been trained before the experimental trials were conducted. A replication of the Tolman, Ritchie, and Kalish (1946a) study was performed by Gentry, Brown, and Lee (1948) with a few modifications, for example, a criterion for learning during training. The results of the experiment closely paralled those of Gentry, Brown, and Kaplan (1947). Fifty-two and one-half percent of the animals chose pathways adjacent to the blocked pathway used during training, reinforcing the position of response-learning advocates.

Two response-learning theorists, Kendler and Gasser (1948), attempted to determine the effect of variables influencing response reproduction. Specifically, they were to determine the effect of the number of reinforcements upon spatial learning. The authors speculated that if varying the number of reinforcements had an effect on the amount of spatial learning, response theories such as Hull's might at some time explain or encompass place-learning theories. Kendler and Gasser's apparatus consisted of a T-maze capable of being converted into a radial pathway maze by removing a partition. A strong light was placed six feet above the choice point of the maze. The authors' results contradict the findings of Tolman, Ritchie, and Kalish (1946a) in that only 5.6 percent of the Ss chose the shortest path to the goal box. Sixty-six and six-tenths percent of the animals chose the path rewarded during training, supporting the response-learning position of Kendler and Gasser, who were cognizant of the scarcity of extra-maze cues perceived by their animals. This dearth of cues was a condition necessary for the domination of response over place learning.

Varying the number of reinforced trials during training had a differential effect upon the amount of spatial learning which occurred in the experiment. Spatial learning increased in all groups using fewer than eighty reinforcements, while in those in which more than eighty were applied, a decrease in spatial learning was reported. Kendler and Gasser concluded that interactions of associations acquired during training and their relationship to the experimental trials held the key to spatial learning and that the principles underlying these interactions were indiscernable at that time.

Tolman, Ritchie, and Kalish (1946b) further investigated the question of what is learned in simple T-maze experiments by proposing three possibilities concerning the effects of training. Initially, the authors speculated that training may have produced a predilection on the part of the animals to move along a pathway following specific patterns, such as irregularities in the wood from which the runways were assembled. Training may have also created a predisposition in the animals to turn a certain direction at the choice point. Finally, the investigators considered the possibility that training could have produced a tendency for the subjects to orient themselves spatially toward the location of the reward. The difficulty of rapid maze learning by means of intramaze cues eliminated the first possibility of what is learned in the maze. Introduction of novel responses during experimental trials, those other than the original responses elicited during training, resulted in the elimination of the second possibility. The purpose of this study was to test the feasibility of the third hypothesis that the animals developed a spatial orientation toward the location of the goal box. The authors trained two groups in a T-maze. The response-learning group acquired a disposition to turn a specific direction at the choice point in the maze, whereas the place-learning group attained a disposition to approach the food box location regardless of the responses involved. Using this procedure, the authors attempted to ascertain the relative dominance of either place- or response-learning. All animals in the place-learning group reached the learning criterion in eight trials or less. Only three rats in the response-learning group reached the criterion. The authors concluded that both response and place dispositions could be learned, but that a tendency to spatially orient toward a goal location was a more basic or native response.

In an article by Frank Restle (1957) the author hypothesized that the place versus response issue was improperly formulated. The problem was not simply one of an inherent dominance of place or response learning as was stated in Tolman, Ritchie, and Kalish (1946b). Restle bases his explanation of the so-called dilemma on the "multiple cue" theory of Hunter (1929, 1930) and Honzik (1936). According to this theory, maze performance was directly related to the relative importance of various types of cues, the most important of which were visual, kinesthetic, auditory, and olfactory. Another influential cue was the arrangement or pattern of the stimuli. Changes in the maze that did not disturb the preliminary patterning of the stimuli failed to alter the performance of the animals. Restle found through his research that domination of place or response learning was determined by two methods. First, direct opposition methods involved training the animals on a fixed maze, rotating the maze, and then ascertaining changes in the animals' response. Second, comparisons of learning rates were used to determine dominance of place- or response-learning.

Restle (1955) described two types of cues which were important in the place versus response controversy. Relevant cues were those with a predictable or constant relationship to the true or shortest Euclidean path to the goal box and irrelevant cues were those that bore an unpredictable or uncertain relationship to the correct response or shortest path. The amount of place or response learning was based on the proportion of relevant cues present to the total number of cues available. Restle noted that the rapid learning required by previous place versus response experiments was not based solely on kinesthetic cues, since the animals initially made many erroneous responses.

Restle began to grasp the importance of extra-maze cues by citing the results of various studies dealing with the role of sensory events in maze learning. He stated that kinesthetic cues were sufficient to allow learning in simple maze situations, but that visual, olfactory, auditory, or other extra-maze cues were necessary for the occurrence of more complex maze learning. Restle determined that both intra-maze and extra-maze cues could sustain learning, but the latter were the primary mediators of the animals' mastery of elevated maze situations. He found that sensory factors were the basis of maze learning and that place and response learning were actually governed by intra- and extra-maze cues. Extra-maze cues were considered to be relevant in place learning and irrelevant in response learning, whereas the opposite relationship existed for intra-maze cues. In view of this new sensory data, Restle proposed that place learning was mediated by extra-maze cues and response learning by intra-maze cues. He therefore concluded that dominance of place or response learning depended on the types of stimuli available to the Ss in the experiment.

Studies employing heterogeneous stimulus conditions at each end of the maze and those done in open, illuminated rooms were more conducive to place responding. Conversely, similar stimuli at both ends of the maze and a homogeneous visual field were favorable conditions for response learning. Restle related a hierarchy of several stimuli which determined the facilitation of place learning. These stimuli were rat cages, which were of primary importance, windows or other objects in a well illuminated room, and differential lighting.

The author summarized by stating that any attempt to decide the relative importance of intra- and extra-maze cues without first considering the types of stimuli available to the animals would result in erroneous conclusions.

Restle's findings adequately explain the discrepancies observed in the experiments of place- and response-learning advocates. For example, the optimum place learning resulting from the study of Tolman, Ritchie, and Kalish (1946a) could from Restle's point of view be due to an abundance of relevant extra-maze cues, creating a situation favorable for place learning. Specifically, the authors' positioning of a powerful light at the goal area constituted the most potent relevant extra-maze cue.

The results of Kendler and Gasser's (1948) study concur with Restle's interpretation of optimum response learning. The authors had restricted the availability of extra-maze cues in the experiment and thus had elicited a situation in which intra-maze cues were more pertinent, a condition favoring response learning.

The Rolman, Ritchie, and Kalish (1946b) experiment illustrated Restle's hypothesis concerning the importance of the location of the rats' cages as an extra-maze cue. A differential placement of the animals' cages in relationship to the experimental apparatus produced a situation in which the cages constituted a very powerful relevant cue.

Place learning animals performed optimally under these conditions.

In the previously mentioned studies the experimenters employed various methods of explaining the behavior of their Ss. Tolman, Ritchie, and Kalish (1946a) attributed the animals' mastery of the maze to an acquisition of a spatial orientation of the apparatus. Hull and his followers proposed that their rats learned the maze by the kinesthetic conditioning of right and left hand turns encountered in training. Restle, in his article, theorized, with aid from other sources that the stimulus conditions present in place and response experiments determined their results.

The purpose of this study was to attempt to account for the behavior of experimental animals subjected to the conditions of the Tolman, Ritchie, and Kalish (1946a) experiment with modifications in the training procedure to emphasize the geometric orientation of the mazes. Six different angles of training (Fig. 1) rather than one were provided for the animals to further this angular emphasis. In the final experimental trial the Ss were required to choose from a number of runways (Fig. 2). Through this angular variation of the training runways it was possible to determine later in the experimental trials whether the Ss had maintained some continuity in their angle of choice related to their angle of training.

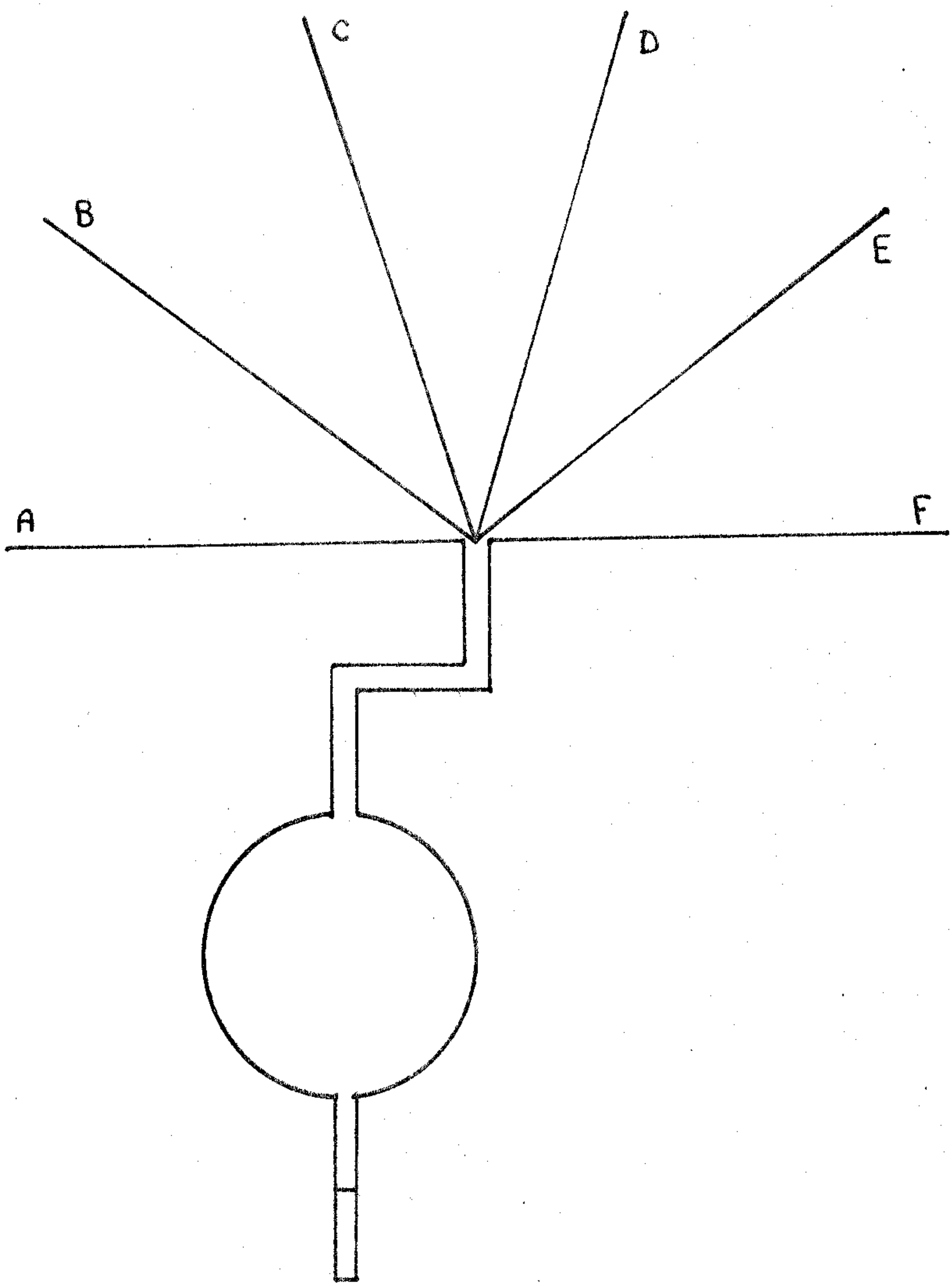


Fig. 1--Training apparatus

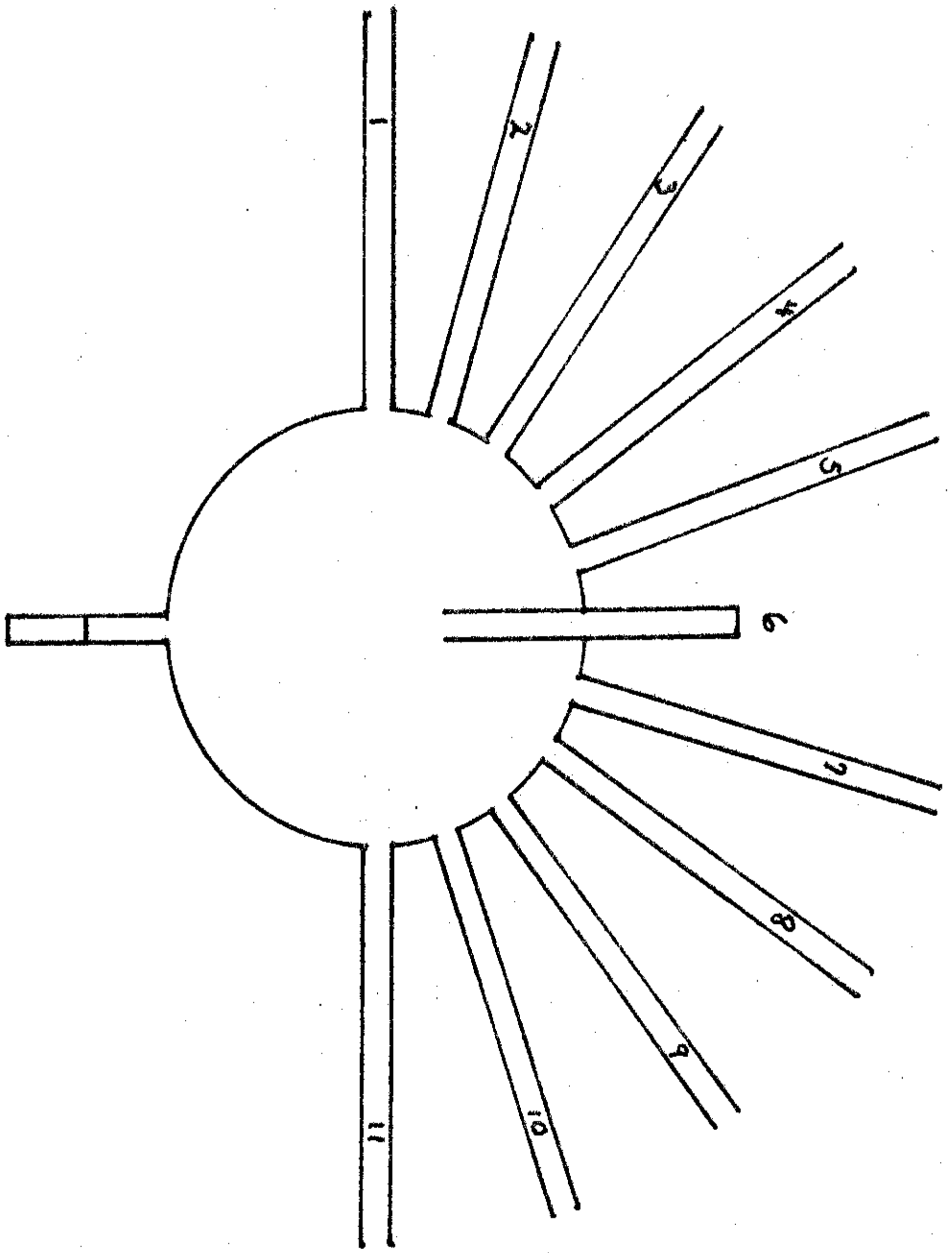


Fig. 2--Experimental apparatus

# Method

## Subjects

Ss were thirty white, Sprague-Dawley female rats. At the beginning of the study, Ss were approximately sixty days old. The rats had received no preliminary training.

## Apparatus

Figures 1 and 2 represent the apparatus used in the training and experimental procedures. The preliminary apparatus, Figure 1, consisted of an unpainted circular section of plywood board 36 inches in diameter and several unpainted two-inch plywood runways. Pathways AB, CD, DE, EF, and FG were respectively 24, 20, 19, 15, and 60 inches in length. As is indicated in Figure 1, there were six removable FG runways, allowing for variation in the location of the goal boxes. The six FG runways were labeled Conditions A through F, with their respective angles indicated also in Figure 1.

The experimental apparatus, Figure 2, was comprised of the same start path, circular plywood, and runway CD used in the training apparatus. Ten 60-inch pathways, arranged in such a manner that each was located 15 degrees to the left of its neighbor, were distributed around 180 degrees of the circular plywood board. The ten radial runways were firmly attached to an underlying structure, but free rotation of the circular board was possible. In both the experimental and training apparatus a large white cloth sheet was positioned forty-two inches above the maze.

Procedure

Training trials.--The subjects were placed on a twenty-four-hour deprivation schedule four days before the beginning of the first training session. Six squads of rats, each squad comprised of five Ss, were differentially trained in one of the six conditions (A, B, C, D, E, F). These conditions were designated by the six removable runways. The goal boxes of each condition were at varying angles in relationship to the start path. These various conditions are shown in Figure 2 of the training apparatus.

Three trials were given on the first day of training. On the first trial the animals were placed in the goal box and allowed to eat for five minutes. On the second trial each S was placed in the middle of runway FG and allowed to run to the goal box. On the last trial the rats were started at the beginning of FG and continued on to the goal box.

Three more trials were administered on the second day of training. On the first trial the animals were again placed at F on runway FG and allowed to run to the goal box. On the second and third trials the Ss were started in alley CD and forced to run to the goal box.

On the third day three more trials were executed. On the first trial the animals once more began at point C of runway CD and were permitted to proceed to the goal box. In trials two and three the rats were started from point A on path AB. The Ss were allowed to explore the circular plywood board and then to continue on to the goal area.

Three trials were administered on the last day of training. The Ss were again started from point A of runway AB and continued on to the goal box.

Experimental trials.--After the training trials, on day five of the experiment, one trial was given each animal employing the modified apparatus shown in Figure 2. Each of the Ss in the six groups began at point A on runway AB and was allowed to choose one of the eleven pathways. If the rat had made no choice within a six-minute time limit, then the S's performance was recorded in the data as "No choice."

## Results

Collection of the following data was necessary to complete the task of determining whether the Ss would choose an optimum angle with any degree of continuity. The results of the experimental trials were recorded and yielded the following:

The Ss in Squad 1 maintained random choice behavior throughout the experimental trials. During the experimental phase forty percent of the animals in Squad 2, trained on Condition A, chose Runway 5. Sixty percent of the Ss in Squad 3, trained on Condition F, chose Runway 5 on the final trial and forty percent chose Runway 1. Of the animals in Squad 4, trained on Condition E, forty percent chose Runway 7 on the last trial. In Squads 5 (Condition B) and 6 (Condition C) sixty percent and forty percent respectively chose Runway 7.

In an attempt to find an optimum angle of choice made by the Ss, the difference between the angle of the runway on which the S was trained and the angle of the runway chosen was observed during the experimental trials. The animals in Squad 2 were trained at an angle of 57 degrees and on the final experimental trial chose a runway at an angle of 76 degrees, resulting in an 18 degree choice angle. Squad 3 Ss, after having been trained on a runway employed at 141 degrees, chose two runways, Runways 1 and 5, located at 21 degrees and 76 degrees respectively. The angle of choice for the animals selecting Runway 1 was 120 degrees, and for those choosing Runway 5, 65 degrees.

The experimental animals in Squad 4 received their training in a runway located a 124 degrees and chose a 107 degree experimental runway, resulting in a 17 degree angle of choice. Trained on a runway positioned at 74 degrees, Ss in Squad 5 chose during the experimental trial a 107 degree runway, resulting in a 34 degree angle of choice.

Squad 6 animals chose a 107 degree runway on the final trial after having been trained on a 90 degree runway. The Ss' angle of choice was determined to be 17 degrees. These data are summarized in Table 1.

## Discussion

The results of this study lend support for the hypothesis that experimental animals develop a geometric continuity in a place-versus-response-learning problem by choosing a constant optimum angle. In order to explain this geometric continuity it will be necessary to refer to Figures 3 and 4. Figure 3 is a geometric representation of the six training runways with the entrance to the circular board being the point of reference. Figure 4 consists of an angular depiction of the eleven experimental pathways also using the entrance to the circular board as a point of reference.

The experimenter hypothesized that by comparing the angle of the training runway with the angle of the runway chosen by the rat during the experimental trial, a certain continuity of the angle of choice might be present in the rats' behavior. In order to obtain this angle of choice for each animal, it was necessary to take the difference between the angle used in training and the angle of the runway chosen by the animal during the experimental trial. For example, the animals in Squad 2, trained on a 57 degree runway, chose a 76 degree pathway during the experimental trial, resulting in a 17 degree angle of choice.

TABLE 1

Derivations of Choice Angles

| Squad | Condition | Experimental Runway Chosen | % Choosing Runway | Angle of Training Runway | Angle of Runway Choice* | Choice Angle |
|---|---|---|---|---|---|---|
| 1 | D | random | | | | |
| 2 | A | 5 | 40 | 57 | 76 | 18 |
| 3 | F | 5/1 | 60/40 | 141 | 76/21 | 65/20 |
| 4 | E | 7 | 40 | 124 | 107 | 17 |
| 5 | B | 7 | 60 | 73 | 107 | 34 |
| 6 | C | 7 | 40 | 90 | 107 | 17 |

*Experimental Runways

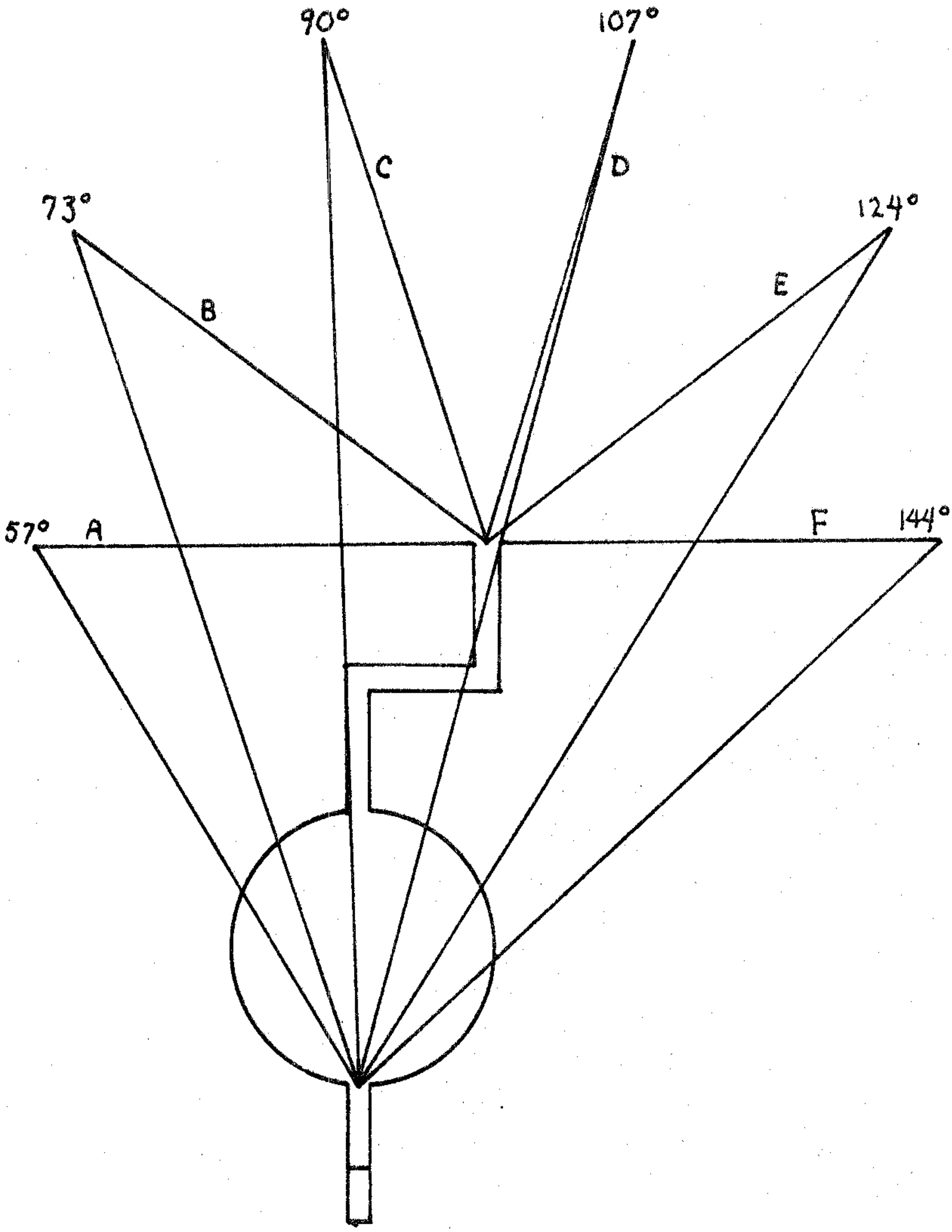


Fig. 3--Geometric depiction of training apparatus

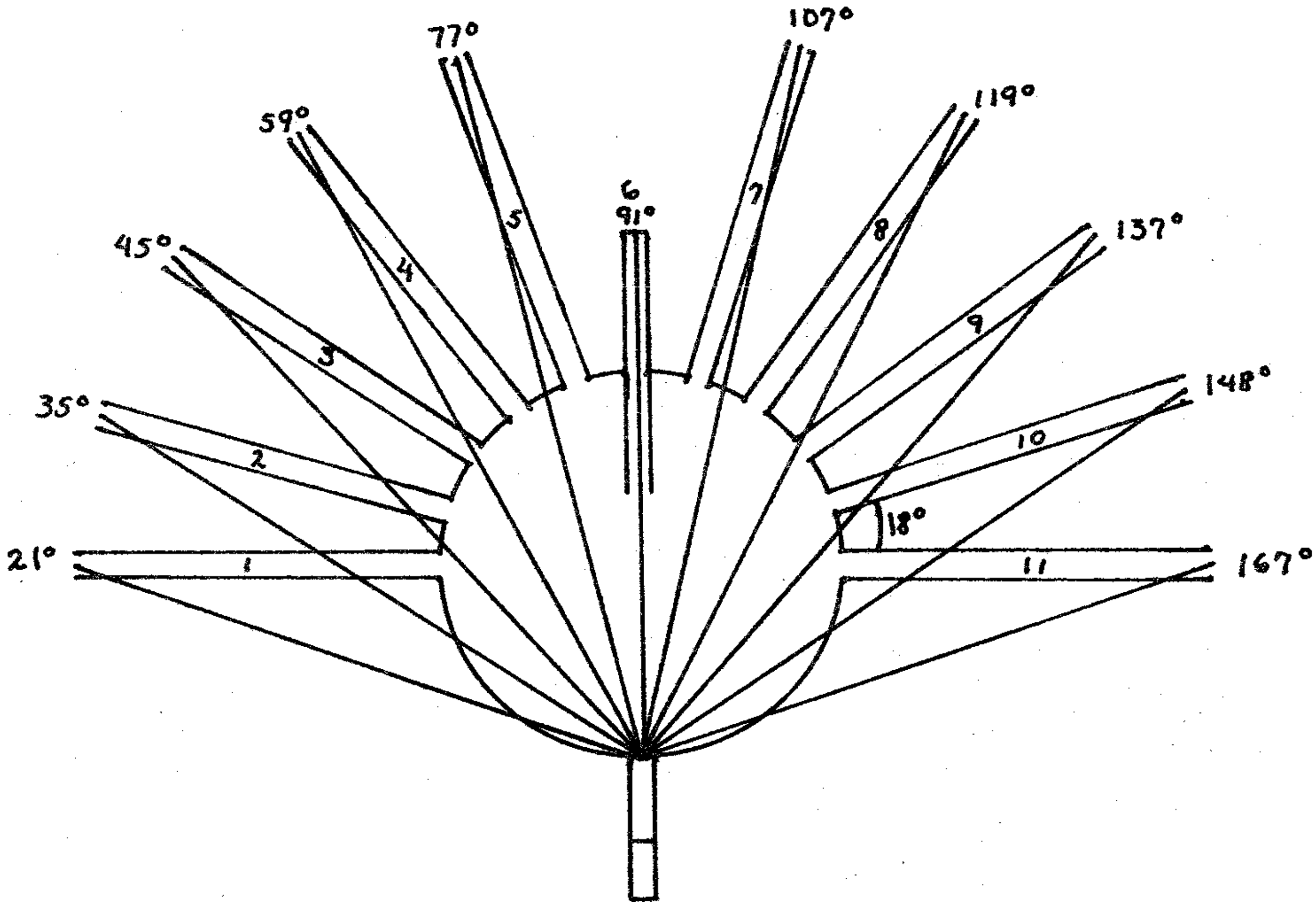


Fig. 4--Geometric depiction of experimental apparatus

As a result of this geometric interpretation of the data, it became evident that a significant number of the Ss in Squads 2, 4, and 6 chose identical optimum angles of 17 degrees. This information constituted an alternative method of explaining the behavior of rats in response- and place-learning problems.

Animals in Squads 3 and 5 chose optimum angles of 65 degrees and 34 degrees respectively, the former angle a near multiple of 17 degrees and the latter an exact multiple of the most prevalent angle of choice, 17 degrees. Ss in Squad 1 made random choices in the experimental trials. This discrepancy may be attributed to the fact that this group was run first and consequently less systematically than the other groups.

Another point due consideration concerns the study by Gentry, Brown, and Lee (1949). These authors purported that the Tolman, Ritchie, and Kalish (1946a) experiment had no established learning criterion associated with the training period. Gentry, Brown, and Lee (1949) asserted that since no learning criterion was set for the training period, a number of the Ss presumably did not master the training phase of the experiment. According to Gentry, Brown, and Lee this incomplete learning of the training phase may have accounted for the dominance of place-learning rats in the experimental trials of the Tolman, Ritchie, and Kalish (1946a) experiment.

This lack of a learning criterion may also have affected the present study. Certain of the Ss failed to perform the initial response of the experimental trial described by Tolman, Ritchie, and Kalish. This response consisted of the animals' entering the blocked runway in the experimental apparatus and then returning to the circular board to choose another pathway. Ss failing to exhibit this initial behavior had apparently not mastered the training phase of the experiment. The implementation of a learning criterion for determining mastery of the training phase might in later studies be helpful in interpreting the results of the experimental trials.

In concluding the discussion of the problem some hypothetical bases for the Ss' geometric continuity of responding will be discussed. Before considering the possibility that an underlying behavioral variable has accounted for the geometric continuity of the Ss' responses in training and experimental trials, it must be explicitly stated that the explanations given in this section are strictly speculatory in nature.

In the training and experimental trials care was taken not to provide the Ss with the means for a regular pattern of responding. Specifically, a large white cloth was stretched above the maze during both training and experimental trials producing a homogeneous light source and blocking the rats' view of any significant objects in the room. Barring the effects of intra-maze cues, i.e., patterns in the wood from which the maze was built, the Ss should in this instance have had random patterns of responding, especially since training trials were given the rats. Quite the contrary, three of the six groups had nearly the same angle of choice, 17 degrees. One explanation for the geometric continuity is the possibility of a behavioral factor determining the patterns inherent in the Ss' responding to training on a runway of a specific angle. Even though the three groups were trained at different angles, they all chose during the experimental trials a runway which resulted in this 17 degree angle of choice. An identical geometric pattern of responding to the maze stimuli apparently developed among the members of the three groups.

One very interesting idea for futther research in this geometric continuity of responding would be to review past literature dealing with place versus response maze situations and to analyze the data obtained from these previous studies to determine whether there are similar continuities in responding.

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