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THE PSYCHOLOGICAL REVIEW

DISCRIMINATION OF CUES IN MAZES: A RESOLUTION OF THE "PLACE-VS.-RESPONSE" QUESTION¹

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Whether rats in mazes learn turning responses or places is a question which has often been subjected to experimental test. Data from different experiments conflict, and attempts at a definitive answer seem only to add to the confusion. This paper will defend the thesis that the place-vs.-response question is wrongly formulated, and that the data which fail to decide between place and response learning give an unequivocal answer to a question properly stated.

The place-vs.-response question has been approached largely through the use of the T maze, rotated in its visual surround. A typical arrangement showing runs reinforced in "place" and "response" learning is shown in Fig. 1, along with the fixed-maze problem in which both place and response may be learned. In both place learning and response learning, the maze is rotated on alternate trials at random. The place learner is always to go to the same place in the room, responding consistently to extra-maze cues but making different turns on different trials. The response learner makes the same turn on all trials, going to different places. One supposed test of whether place or response learn-

ing is more dominant is to compare rates of learning on these two problems. Another test is to train animals with the maze in a fixed position (place + response learning), and then rotate the maze for a test trial. The animal can now either make the same turn he has learned or go to the same place he has been going to, but not both. In this *direct opposition* experiment, the relative number of animals taking each choice is a test of the relative dominance of place and response.

In 1946, Tolman, Ritchie, and Kalish (23) proposed that in such a situation place learning is more natural and primitive for the rat than response learning, and place will dominate response in all tests. Their experiment supported the hypothesis, but some later repetitions have found response dominating place, or have found no difference.

An answer to these apparent contradictions is here sought by assuming that maze running depends on a multiplicity of cues, and that the rat learns differential responses to relevant cues in a maze just as he would in a discrimination box. A theory based on learning in the discrimination box will be applied to the maze situation. Since the discrimination theory to be used (15) is very close to earlier theories of the effect of sensory input on learning in mazes, theories which antedate the place-vs.-re-

¹ Dr. Richard L. Solomon suggested and drafted part of this paper (see footnote 3). His guidance and help are gratefully acknowledged.

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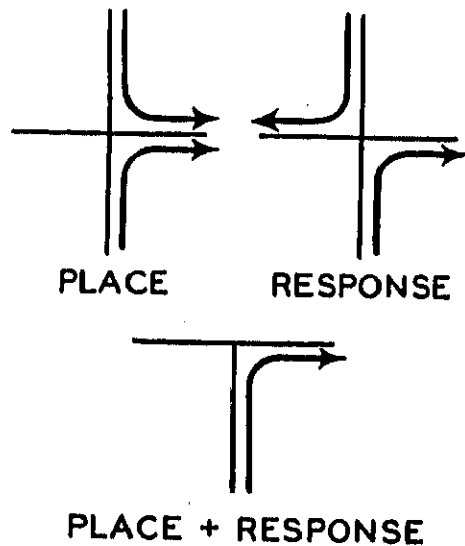


FIG. 1. Runs reinforced in place, response, and place + response (fixed maze) learning. Only one T maze is present on a given trial.

sponse controversy, it is useful to place the recent studies within their historical context and analyze all the data at once.

MULTIPLE CUE THEORY

Hunter (9, 10) and Honzik (8), among others, have proposed that learning and performance in mazes depends upon many cues, in all available modalities and from all sources. Depending on what stimuli are available to the rat, maze learning may depend on visual, auditory, olfactory, tactual, and kinesthetic stimuli. Visual, auditory, and olfactory stimuli may arise from within the maze or outside. The cues used by rats may be not only the specific physical stimuli but also patterns or arrangements of stimuli, so that changes which preserve the arrangement may not disrupt performance.

When a portion of the cues are removed by surgery or screening, or made irrelevant by interchanging maze units, rotating the maze, etc., learning of the maze is retarded, but mazes are often perfectly solved in the presence of known irrelevant cues.

The earlier formulation of multiple cue theory is somewhat refined by considering more recent theory derived from discrimination learning (15). This newer theory distinguishes between relevant cues, which bear a regular relationship to the correct path, and irrelevant cues which are not consistently related to the correct response.

A cue with a constant or predictable relationship to the true path will in the course of learning become "conditioned" to the correct response. All such cues will eventually be learned, and all will play a part in performance. If a certain cue is irrelevant, bearing a changing and unpredictable relationship to the correct response, it cannot be the basis of learning and is only a distractor. Such cues will become "adapted" during learning, and eventually will play no part in performance.

The rate of learning depends directly on the proportion of relevant, usable cues in the total set available.

When learning has been based on a variety of relevant cues and then some of these cues are scrambled and made irrelevant, the amount of disturbance reflects the relative importance of the newly changed cues. Though irrelevant cues will eventually be adapted, making important cues irrelevant reduces the proportion of relevant cues and thus retards learning. Disruption due to scrambling of learned relevant cues is attributed to the fact that such cues are not adapted, having previously been relevant. Recovery from the disturbance results from progressive adaptation of the scrambled cues.

If the learning program involves constantly introducing new cues which have not been present before, these new cues will always disturb performance, since they cannot have been attached to the correct response and they cannot have been adapted.

THE HISTORICAL CONTEXT^a

Studies of the sensory control of maze behavior of rats have been reviewed in detail by Munn (14), so only a broad summary will be given here, along with discussions of the main points.

Early studies of the role of sensory processes in maze behavior were motivated by the early conclusion by Small (1901) and by Carr and Watson (1908) that in complex mazes rats form kinesthetically controlled habits which become "automatic." This hypothesis is that kinesthetic cues, arising from one response in the maze, serve as the main cues to the next response in the sequence. Each response is associated with the previous one, and other sensory input becomes unimportant in maintaining performance. This conclusion was based on the erroneous assumption that if one sort of cue is important, others must be unimportant. The technique was essentially one of eliminating a single sense modality at a time, in each case observing that performance remains essentially intact. The only modality not disturbed was kinesthesia, which was assumed to be "the" crucial one. Hunter (11) has shown the flaw in this line of argument.

The above application of the theory of discrimination learning to mazes does not differ in important respects from the assumptions and conclusions of Hunter and Honzik. The main refinement is in attributing the rate of learning to the *proportion* of relevant cues. The earlier writers do not make just this statement, though their statements may be interpreted to this effect.

No attempt will be made in this paper to apply the specific quantitative formulation of discrimination learning to multiple-unit maze learning. The effects peculiar to the *serial* character of maze learning are not reflected in discrimination theory. When a single-unit T maze is used, as in the recent place-response experiments, discrimination theory should apply exactly and quantitative predictions should be correct.

The multiple cue theory can be compared with the results of studies using multiple-unit mazes, with the understanding that specific quantitative values (error scores, trials to learn, etc.) depend both on the discrimination of cues and on serial patterns. An understanding of these earlier studies of maze cues is essential in gaining a clear insight into

The "kinesthetic" hypothesis inspired a series of experiments designed to prove or disprove it. These experiments uncovered a wealth of information about the cues which in fact control behavior in various mazes. Fundamentally, the data were analyzed to determine the relative effectiveness of (a) kinesthetic stimuli, (b) intra-maze stimuli, such as visual, olfactory, and tactual stimuli from the maze itself, and (c) extra-maze stimuli, such as visual or auditory

^a The bearing of these studies on the place-vs.-response question was pointed out to the author by Dr. R. L. Solomon. This section and the beginning of the next section are based in part on a personal communication from

stimuli from the room containing the maze. Intra- and extra-maze stimuli were broken down into components due to different sense modalities, again with the intention of evaluating each.

The methods used in assessing the role of sensory events in maze behavior were as follows: (a) surgical interference with receptor organs and neural pathways; (b) elimination of stimuli from the intra-maze or extra-maze environment; (c) introduction of distinctive stimuli to the environment; and (d) the controlled rearrangement of intra-maze and extra-maze stimuli.

In general, the results of these experiments were as follows:

(1) Simple alternation mazes can be learned by the rat on the basis of kinesthetic cues alone, but more complex mazes cannot be learned in any reasonable number of trials without the aid of visual, olfactory, or auditory cues. Removal of kinesthetic cues by surgical means does not greatly affect maze performance if intra- or extra-maze cues are left intact. However, once a maze performance is perfected on the basis of intra- or extra-maze cues, removal of such cues does not destroy the performance completely. As one would expect from the multiple cue theory, kinesthetic cues are relevant and conditioned to the correct response only when a regular relationship between the last response and the next correct response is established. Such a relationship exists in a simple alternation maze early enough for learning to take place. In more complex mazes, usable kinesthetic cues exist only after the maze is learned on some other basis. Since during learning kinesthetic cues are mostly irrelevant anyway, their removal does not retard learning.

(2) Mazes can ordinarily be learned on the basis of intra-maze cues alone, even if extra-maze cues are made irrelevant by rotating the maze in the room. Such rotation retards learning, however,

especially if the maze is elevated and the room contains conspicuous visual cues. If the maze is kept in place in the room and its spatial arrangement is preserved while units of the maze are interchanged to make intra-maze stimuli irrelevant, rats can still solve the problem. Again, interchanging of stimuli retards learning. In many mazes, it should be noted, all blinds have a common visual appearance, being shorter than true alleys and ending within sight of the rat at the choice point. Interchanging units does not make such stimuli irrelevant. But even if the spatial pattern of the maze is scrambled, if the goal is in a fixed position relative to the extra-maze environment the rat can learn to run to the goal box without following alleys which lead away from the food. Thus, intra-maze and extra-maze cues are each separately capable of sustaining learning and performance in the maze. With one type scrambled, perfect performance can often be attained based on the other type, indicating that irrelevant cues are eventually disregarded. Retardation of learning due to removal or scrambling of important cues is consistently observed.

(3) In elevated mazes, where most of the visual field arises from outside the maze, extra-maze cues are usually more important than intra-maze cues. If the maze is enclosed in a homogeneous room, however, extra-maze cues are relegated to a minor role. Intra-maze cues are generally more important in alley or tunnel mazes, where the rat has at best an obstructed view of the outside. In a unidirectional maze, extra-maze cues are more important than they are in a maze which requires the rat to run in many different directions. The results support the idea that either type of cue may be the more important, depending on the relative amount of relevant stimulation stemming from each source.

(4) In general, two ways of assessing

the importance of a certain cue give comparable estimates. One method is to scramble the cue during learning, assessing its importance by the relative retardation in the rate of learning. The other method is to have the rat learn the maze with the cue relevant, then scramble it. The amount of disruption of the perfected habit indicates the importance of the cue. To an approximation, these two methods rank various classes of cues the same way. Removing a type of cue by depriving the animal of necessary receptors, as by blinding or deafening the animal or rendering it anosmic by surgical interference, is not the same thing as scrambling cues experimentally. Blinding, for example, removes both relevant and irrelevant visual cues, whereas rotating the maze makes otherwise relevant extra-maze cues irrelevant, and does not affect intra-maze visual cues. Thus, exact comparisons between the effects of scrambling and the effects of surgery cannot usually be made.

These findings suggest that kinesthetic cues are unimportant in the learning of complex mazes, but that both intra- and extra-maze cues are important. The relative importance of various types of cues depends on the maze and its surround, for rats seem to use various cues proportionally as those cues are available and relevant. Rats seem capable of overcoming the distraction of irrelevant cues.

The results are consistent with the conception that maze learning and performance depend on multiple cues, and that such cues are discriminated and responses learned to them in accord with the theory of discrimination learning.

"PLACE" AND "RESPONSE" IN SINGLE-UNIT T MAZES

In the light of the earlier extensive studies of the sensory basis of maze run-

ning, studies of place and response in T mazes appear as comparisons of extra-maze and kinesthetic cues. The Tolman-Ritchie-Kalish hypothesis that rats learn "places" rather than "responses" means, in the earlier terminology, that extra-maze cues are more important than kinesthetic cues. Since in earlier studies kinesthetic cues were found barely sufficient to permit any learning at all, whereas extra-maze visual cues bulk large in importance when they are available, it would appear that the dominance of "place" learning was indubitable, and the Tolman-Ritchie-Kalish experiment redundant.

It should be noted that Tolman's "place" formulation is inferior to earlier formulations. Tolman does not specify what cues are thought to make up "place" indications, and he does not identify "response" learning as learning based solely on kinesthetic cues. Though intra-maze cues do not seem to be "response" cues in Tolman's sense, it is not clear whether they are "place" cues or not.

Though the hypothesis that place learning will dominate response learning seems to follow in a general way from Tolman's concept of cognitive maps, his position was not really controversial because stimulus-response theorists did not believe response learning would be easier than place learning. The early Carr-Watson hypothesis, that maze habits are mainly controlled by kinesthesia, was by 1946 buried under conflicting evidence, and S-R theories stated that the stimulus components of the maze habits were quite likely to be extra-maze visual cues, especially if the maze is elevated and in a room full of such cues.

From these considerations, one should expect that the dominance of place learning is a foregone conclusion. The existence of a "controversy" is itself a

surprise. In order to show the nature of this controversy it is necessary first to consider how place-response experiments have been conducted and what results have been obtained. Since this recent literature has not received a definitive review, a relatively thorough analysis is presented here.

Tests of Place-vs.-Response Dominance

We first consider whether place learning in fact dominates response learning in the single-unit maze. Ten studies have compared the rates of place and response learning in single-unit T mazes or slight modifications thereof. Of these, seven found place learning faster (1, 3, 5, 22, 23, 24, 25), and two found response learning faster (7, 20), while one found that either could be faster depending on the intertrial interval (21). In direct opposition tests (rotation of the maze after the habit is learned on a fixed maze), one study showed that either place or response could be superior depending on the shape of the approach stem (18), another showed that either could be dominant depending on differential cues (27), and two others found response tendencies overriding place tendencies (2, 12). A modification of the opposition test consists of setting up conditions in which the animal alternates. Several studies have asked whether an animal alternates response or stimulus (place) characteristics (4, 6, 13, 26), and the answer has always been that place alternation is stronger than response alternation. These studies used enclosed alley mazes, "place" cues being especially distinctive intra-maze cues.

In summary, if we merely count titles, the impression is received that place tendencies are usually learned faster than responses, and that they are sometimes stronger in opposition tests, especially those depending on alternation.

One certainly cannot draw the conclusion that place learning is always dominant, though, for response tendencies dominate in at least some conditions of seven different studies.

Conditions Associated With Place and Response Dominance

Since neither place nor response is uniformly dominant, we may consider the experimental conditions which make one or the other stronger.

Several writers (1, 7, 21, 25) have suggested that the relative dominance of place depends on the amount of differential visual stimulation. This is, of course, the position taken by earlier writers on general maze learning, though place-vs.-response studies are not usually analyzed in terms of this variable. Counting heads in the experimental reports, we see that the use of a homogeneous visual surround (a dome or enclosure, usually made of muslin, which prevents the animal from discerning any uncontrolled stimuli from the room about him) greatly predisposes rats to learn responses instead of places. All four experiments using such domes report response dominance (2, 7, 20, 21), though one (21) showed that response dominance could be neutralized by massing trials. The only other cases of response dominance reported (12, 18) were in plain rooms under low illumination, which may be thought of as approximations to dome-type enclosures. All other studies showing place dominance were done in open rooms (1, 3, 5, 22, 23, 24, 25) or in alley mazes with strong differential cues (6, 13, 26). One study showed that when the two places contrast sharply in illumination, place dominates, whereas when the illumination is more nearly equal, response tendencies dominate.

In summary, place tendencies dominate when visual stimuli at the two ends

of the maze are very *unlike*, and response tendencies dominate when such stimuli are relatively *alike*. In every case the domination seems to be quantitative—both place and response tendencies exist, but one is stronger than the other depending on stimulus conditions.

By inspecting the experimental reports we can get some idea of what constitutes a strong place cue for the rat. The most dramatic place dominance was found in two studies (17, 23) in which rat cages were located to one side, nearer one goal than the other. In one of these studies (17) it was found that the rats would not give up responding to one place in the room, despite a number of controls, until the cages were moved, following which almost all the rats reversed. Stimuli such as lights had only a slight effect on performance, compared with the rat cages.

When rat cages are placed directly behind the starting point and are thus not available as place cues, or when the room is devoid of cages, such visual stimuli as windows (in daylight studies) give rise to strong place preferences (1, 3), as do well-lighted rooms with many small objects in them (5, 25). Somewhat less striking but still consistent place dominance was shown in two studies in which one wall of a plain room (the wall behind one goal), was moderately well illuminated, the other wall not being illuminated at all (22, 24). The power of room cues can be estimated by noting the quick learning of a successive discrimination between rooms (19). Attempts to give differential cues inside domes by illuminating a 10-inch disc behind one goal with a 7.5-watt lamp (2, 12) or using 7.5-watt lamps themselves as cues, with (7) or without (20) overhead illumination, did not lead to place dominance. Symmetrical overhead illumination in an empty room produced response dominance with spaced practice

(21). A small lamp on the floor below one goal, pointed to throw long shadows on the floor, gave slightly more place than response tendency (18). Ratio of illuminations rather than difference seems to be a crucial variable (27).

In summary, rat cages are very strong place stimuli, windows or objects in a well illuminated room rank next in power, and fairly strong differential lighting of walls of a plain room is also effective. Discs lit by 7.5-watt lamps, or such lamps themselves, are not usually enough to make place dominant over response in an otherwise homogeneous setting.

Some other variables are associated to some degree with place and response dominance. For example, all experiments using pigmented rats, (4, 22, 23, 24) show place dominance, except for one (12) which showed cases of both place and slight response dominance under low illumination. But white rats also show place dominance under good illumination (1, 3, 5, 25), so we may reason that it just happened that experimenters who intended to use strong visual cues also sometimes used pigmented rats to take advantage of their superior vision. The pigmentation of the rat cannot be shown to have any other effect on place and response dominance.

The noncorrection procedure (picking up the rat after an error) seems to lead to better response learning than the correction procedure (allowing the rat to find the food by retracing after an error). Using the place-response studies, the effects of correction cannot be isolated from the visual cue effects mentioned above.

One study (21) indicates that response learning is slowed by massing trials. Little more about massing effects in these studies is known, but most

of the studies employ at least moderate trial spacing.

There seems to be no interesting relation between place-vs.-response dominance and either the ages of rats used or the size of the maze employed. The slight tendency for smaller mazes to go with response dominance is more than explained by the tendency of experimenters using domes to use slightly smaller mazes for convenience.

Evaluation of the Place-vs.-Response Controversy

The details of the single-unit T maze experiments quite clearly indicate that there is nothing in the nature of a rat which makes it a "place" or "response" learner. The main factor determining the outcome of place-vs.-response experiments is the amount of extra-maze visual stimulation which differentiates the region around and behind one goal from the region around and behind the other. Such visual cues are relevant in place learning and irrelevant in response learning.

It seems reasonable to conclude that the place-vs.-response controversy, which seemed ill formulated when compared above with earlier maze studies, gives a distorted and confusing interpretation of the experiments designed to settle it.

It should be remarked that in single-unit mazes, kinesthetic cues appear sufficient to support quite rapid learning. This conflicts with Honzik's conclusion that "when all other avenues of stimulation are destroyed, kinaesthesia is helpless" (8, p. 56). Honzik's statement, if taken as applying generally to all mazes including single-unit ones, would be incorrect. The importance of a sense modality depends on the richness and relevance of stimuli in that modality which exist in the maze situation. In single-unit mazes, relevant kinesthetic stimuli apparently abound. In Honzik's 14-

unit maze, animals do not make regular enough runs to give themselves a constant set of kinesthetic stimuli on which to build accurate performance. One may also consider Hunter's point that in complex mazes, with left and right turns required in irregular order, simple kinesthetic cues are irrelevant. Attempts to state the relative importance of sense modalities or of intra- and extra-maze cues in general, for all mazes, are akin to the "place-vs.-response" hypothesis in that they fail to incorporate the most important variable, the stimulus situation presented to the animal. Such attempts are, accordingly, doomed to failure.

PREDICTION OF T-MAZE DATA BY THE QUANTITATIVE THEORY OF DISCRIMINATION LEARNING

The single-unit T maze, being devoid of the serial characteristics of more complex mazes, may be thought of as a kind of discrimination-learning apparatus. When the T maze is rotated on random trials as in place-response experiments, extra-maze (place) and kinesthetic (response) cues are uncorrelated.⁴ In place learning (see Fig. 1) place cues are relevant, and all others including response cues are irrelevant. In response learning, response cues are relevant and all others including place cues are irrelevant. In place + response learning, with a fixed maze, both place and response cues are relevant.

We may entertain the hypothesis of cue-additivity: that the set of cues rele-

⁴ If the whole maze is rotated as a unit, intra-maze cues are relevant in response learning and are confounded with kinesthetic cues. If the starting stem is moved but the cross-arm is left in place, intra-maze cues are relevant in place learning, and are confounded with extra-maze cues. We shall assume that intra-maze cues combine additively with the cues they are correlated with, and shall not specify what happens to them.

vant in place + response learning is simply the sum of the place and response cues. This hypothesis can be tested quantitatively, using a theory of discrimination learning (15). In this theory, the rate of learning is set equal to the proportion of relevant cues, and the single number is called θ . The learning curve (or statistics such as total errors to mastery, total errors in n trials, trials-to-criterion, etc.) may be used to estimate θ ; and, conversely, given θ the learning curve or any of its statistics can be computed in advance of experimentation. The equations involved and the methods of computation will not be repeated here.

Galanter and Shaw (5) used three groups of rats trained in the same apparatus and surround, under conditions of place learning, response learning, and fixed-maze or place + response learning, respectively. Using median trials-to-criterion⁵ as an index of typical performance, the proportion of relevant cues in each problem was computed, using the equations of discrimination-learning theory. Theoretically, the proportion of relevant cues in the place + response problem should be the sum of the proportions in the other problems: $\theta_{P+R} = \theta_P + \theta_R$. The results of the computations to check this hypothesis are shown in Table 1. Place + response performance is predicted using only data from the place and response groups. Inspection of Table 1 indicates that the prediction is relatively accurate, although, since subjects in the place + response

⁵ Since retracing and "false-start" responses were counted as errors, animals had a higher probability of making an error than a correct response at the beginning of training. This bias in favor of errors has relatively little effect on trials-to-criterion, which is accordingly used as an index of performance. The parameter θ is estimated from trials-to-criterion by an approximation to the maximum likelihood method.

TABLE 1

MEDIAN TRIALS TO 10-OUT-OF-10 CRITERION AND PROPORTION OF RELEVANT CUES (θ) IN THE GALANTER-SHAW EXPERIMENT

Relevant Cues	Observed		Predicted	
	Trials	θ	Trials	θ
Place	5.0	.34	—	—
Response	33.5	.10	—	—
Place + Response	2.0	.58	3.1	.44

group ranged in trials-to-criterion from 0 to 3, the prediction is at the edge of the obtained distribution of scores.⁶

Scharlock (20) used a maze in a dome with either one light behind one goal or lights behind both. If there was one light it was the only source of differential place cues, so if there were two lights there were no place cues. Scharlock ran place, response, and place + response groups with one light. He also had a control group which made no progress on place learning with both lights—an expected result confirming that with a light behind each goal there were no place cues. One other group, which we may call "response-minus-place," learned a response with both lights on, and thus with no place cues available. Here again we can predict that the place + response group will yield a learning rate, θ_{P+R} , which is the sum of the rates of the place and response groups, $\theta_P + \theta_R$. In addition, the learning rate of the response-minus-place group should be faster than that of the response group, because of the

⁶ Dr. Galanter, in a personal communication, noted that the place + response group was run after the other parts of the experiment were completed. In Galanter's opinion, the experimenters were by this time somewhat more skillful, and the place + response group had an advantage. This might account for the discrepancy between prediction and observation.

TABLE 2
ERRORS IN 28 TRIALS AND PROPORTION OF
RELEVANT CUES (θ) IN THE SCHARLOCK
EXPERIMENT

Relevant Cues	Observed		Predicted	
	Errors	θ	Errors	θ
Place	5.53	.216*	—	—
Response	3.84	.296	—	—
Place learning, no place cues (2 lights)	17.50	.000	—	—
Place + Response	2.28	.445	2.00	.512
Response - Place: no place cues (2 lights)	2.84	.366	2.66	.378

* Because of initial biases, the probability of correct response on the first trial is estimated at about .375 for all groups. The correction is made in the fashion shown in (16).

elimination of irrelevant place cues. Since θ_P is the proportion of differential place cues, it follows theoretically that $\theta_{R-P} = \theta_R / (1 - \theta_P)$. The results of computations to check these hypotheses are shown in Table 2. Inspection of Table 2 shows that the predictions are quite accurate. The discrepancies between predictions and observations are not statistically significant.

A third experiment by Blodgett, McCutchan, and Mathews (3) separates location and direction cues. The rat may approach the same location (for instance, the center of the room) from either of two directions if the maze is shifted appropriately. Location and direction are usually lumped as place cues, but in this experiment they are separated. Seven groups constitute the experiment, with one group learning each problem possible: location, direction, response, all combinations of two relevant, and the combination of all three relevant (fixed maze learning).

The data were reported in terms of "cycles," pairs of trials, which contained at least one error. From this it is not possible to make good estimates of θ , but an effort has been made to attain fair approximations. The estimates, and the corresponding predictions made by

adding θ -values of problems with fewer relevant cues, are shown in Table 3. The results seem quite encouraging, under the circumstances.

SUMMARY AND CONCLUSIONS

Consideration of early studies of the sensory basis of maze learning, and review of place-vs.-response experiments, indicate that:

(1) There is nothing in the nature of a rat which makes it a "place" learner, or a "response" learner. A rat in a maze will use all relevant cues, and the importance of any class of cues depends on the amount of relevant stimulation provided as well as the sensory capacities of the animal. In place-response experiments, the importance of place cues depends on the amount of differential extra-maze stimulation.

(2) A multiple-cue theory of maze learning is successful in comprehending the major results of experiments using complex mazes, and the detailed results of place-response experiments using single-unit T mazes.

(3) Useful refinements of classical multiple-cue theory were taken from discrimination-learning theory. These are that irrelevant cues are adapted during learning, and that the rate of

TABLE 3
PROPORTION OF RELEVANT CUES (θ)
ESTIMATED AND PREDICTED IN
THE BLODGETT, MCCUTCHAN,
AND MATHEWS EXPERIMENT

Relevant Cues	Estimated θ	Predicted θ
Location	.02	—
Direction	.11	—
Response	.08	—
Location + Direction	.13	.13
Location + Response	.10	.10
Direction + Response	.13	.18
Location + Direction + Response	.18	.21

learning depends on the proportion of relevant cues.

(4) Quantitative analysis of the results of certain place-response experiments indicates that place and response cues combine additively in the place + response (fixed maze) problem.

The writer's general conclusion is that further "definitive" studies of the place-vs.-response controversy, to prove that rats are by nature either place or response learners, would be fruitless since the issue is incorrectly drawn. However, use of the T maze to analyze the stimuli in maze learning holds promise of yielding a consistent quantitative account of how rats find their way. Such studies can build on the earlier work on more complex mazes.

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