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A FURTHER STUDY OF LATENT LEARNING IN THE T-MAZE

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The recent experimental studies of Kendler (7) and Spence and Lippitt (12) on latent learning in the T-maze have been interpreted by these authors as being incompatible with the "Sign-Gestalt" theory of learning proposed by Tolman. In each of these experiments rats were reinforced for running to one side of the maze by finding an incentive appropriate to their condition of motivation; the opportunity to set up "cognitions" was provided by forcing the animal to run half of the time to the opposite side, where he found an incentive not appropriate to his current motivational state. On the test runs it was found by these authors that when the motivational conditions were changed, so that the previously cognized incentive was appropriate to the new state of drive, the animals continued to go to the side on which they had received reinforcement, although the incentive available on that side was now inappropriate to their state of need.

With respect to the interpretation of the learning process in terms of cognition, these studies seem to show a rather marked superiority of direct reinforcement (given in the presence of a state of need) over the opportunity of establishing cognitions when the cognized objects are not need-relevant. However, we do not feel that such studies constitute as strong evidence against cognition interpretations of learning as do their authors. In the first place, it might be argued that cognition opportunities brought about by forcing the animal to make a response opposite to the one that is now at high strength (as a joint function of a history of reinforcement and the present drive) are not optimal for the setting up of cognitions (cf. Tolman's discussion of "emphasis"). Secondly, even if it were granted that reinforcements are able to *dominate* cognitions, the crucial issue between a pure reinforcement theorist and a sign-learning theorist is in the insistence of the former that reinforcement is a *necessary* condition for the acquisition of response strength. It would seem desirable to perform an experiment in which the acquisition of cognitions could be tested in the absence of any competition from the habit strengths set up by direct reinforcement; one in which the opportunities to establish cognitions would not be confounded by antagonistic response tendencies in the presence of drives for which the cognized goal object is inappropriate.

The present study was conducted in the light of these considerations. Using a simple, single-unit T-maze of the type employed by Kendler, we gave a group of rats opportunities to cognize the locations of food and water in the two arms of the maze when they were satiated for both. The test for the establishment of cognitions was then made by depriving half of the animals of food and half of water, and noting the frequencies of the appropriate responses to the two sides when running under these motivated conditions. It was felt that such a procedure would constitute a more crucial test of the possibility of setting up cognitions than either of the two experiments cited above. If the development of such cognitions were established by such an experiment, it would then be in order to investigate systematically the relative power of cognition experiences versus reinforcement as determinants of response.

After the present experiment was already in progress one of us discovered that a similar study had in fact already been done by Spence and Lippitt but for some reason had not been

written up for publication by its authors (except as the abstract of an address delivered at an A.P.A. meeting in 1940). Neither of the papers cited above makes any reference to this experiment. Since the present study was already in progress, and since it did not seem likely after the lapse of several years that the earlier investigators were intending to write up their study in detail, the present study was carried to completion.

SUBJECTS AND APPARATUS

Subjects.—The subjects in this experiment were 24 male albino rats, aged 90 days, of the Sprague-Dowley strain. These animals had never been subjected to any previous experimental procedure.

Apparatus.—The apparatus was a wooden single-unit T-maze, covered with hardware cloth. As in Kendler's maze, the floor and wall of one arm, as well as its goal box, and half of the stem (wall on that side and floor from the midline), were painted flat black. Unlike Kendler's maze, in which the other side was left unpainted, this portion of the present maze was painted flat gray. Originally the gray-painted portion had been painted white, but the very pronounced position preferences shown by all but one or two of the rats for the black side forced a repainting to a dull and darker gray. The goal boxes in the present maze were of the same width as the alleys and extended at right angles from each arm on the same side as the stem. Thus the direction of the rat's turn as he enters the goal box is the same as that of the turn he has just made at the choice point. To prevent the excessive retracing which tended to occur under the satiated conditions, three doors were placed at intervals within each arm. Retracing was prevented but not until after the animal had made his choice by completely entering one of the two arms. These doors were constructed of hardware cloth, suspended from the hardware cloth cover of the maze in such a manner that when released they would swing down to form an effective block behind the animal.

PROCEDURES AND RESULTS

The procedures of the experiment are divided into four *phases*, all involving the same rats, as follows: (1) test breaking; (2) cognition trials followed by cognition tests; (3) reinforcement trials interspersed with cognition reinforcement "opposition" tests; (4) a "check" experiment on drive discriminability. Because of the complexity of the experimental sequence, the more detailed description of the procedures and of the results during each of these phases will be presented separately.

Phase 1 Test breaking.—After three days of preliminary handling, all rats were allowed a half hour of free exploration in the maze, three rats at a time, on two successive days. On these occasions the rats were unmotivated for either food or water, and no incentives were present in the goal boxes. On the first of these exploratory days, a very marked tendency was noted for the rats to remain on the black side of the maze, so that before the second day's free exploration the white-painted side was repainted a flat gray as noted previously. In order to insure, before beginning the cognition runs, that each rat had been in both goal boxes, these two days of exploration were followed by a third day in which the rats were put in the maze singly, unmotivated and with no incentives present, and forced (by a block at the beginning of one arm) twice to the left and twice to the right (LRLR). These three days' runs constituted Phase 1.

Phase 2: Cognition trials followed by cognition tests.—The purpose of this phase of the experiment was to provide every rat with a fairly large number of cognition experiences as to the location of each of the incentives in the two

goal boxes when under conditions of no motivation for these incentives. During this part of the experiment, both food and water were available in the living cages at all times. Moreover, for a period of approximately five minutes before each rat was run, he was removed from his home cage and placed in a special cage in which large quantities of food and an open dish of water were on the floor, in addition to the usual feeding box and water bottle. At the beginning of this phase, the 24 rats were divided randomly into two groups of 12 rats each. The differential treatment of these two groups up to the end of Phase 2 consisted solely in the position of the incentives in the two goal boxes during the (satiated) training runs. Each day, the first group found food in the left goal box and water in the right. The second group found the locations of the incentives reversed. In the food side there was a supply of food of the same sort as their regular diet, piled up in the far third of the box. Two or three larger sticks of food were so placed that they extended farther into the goal box, making it practically unavoidable for the rat to step on them or over them when he entered the goal box. On the water side, also in the far third, was placed a small cup full of water, and through the rear wall projected the glass nozzle of a filled water bottle similar to those found in the living cages. Each rat was given four trials per day for ten days, i.e., 40 trials in all per rat. After the first day, only two of each rat's runs per day were given in immediate succession, because it was noted that spacing the trials produced faster running. Thus, after two runs in immediate succession, each rat was replaced in his home cage for about an hour, and again placed in the special feeding cage before being given his second two runs for that day. All of the rats in the first group were given their full four trials before proceeding to the rats in the second group.

Considering the four runs of a given rat on a given day, the first two runs were always free, i.e., the animals were permitted to go either to the left or to the right. If the first two trials were both to the same side, the animals were forced to the opposite side on the remaining two. If, however, the first two trials had been alternated, the third trial was also free, and the turns to the right and left for all four trials were then equalized by forcing the fourth. In this manner, it was assured that at the end of each experimental day, every rat had had an equal number of trials on the two sides. The free trials permit an estimate of the strength of the position tendencies as will be seen below. Suffice it to say here that there was a considerably larger number of forced trials to the right (the brighter of the two sides). In an attempt to break this strong left position tendency, on the fifth day all trials for all rats were forced to the right. On the sixth day, all four trials were free, so as to test the efficacy of this procedure. On the seventh day, trials were free or forced for each rat in such a manner as to equalize by the end of the seventh day the total number of right and left cognition experiences each rat had had. However, inspection of the percentage of free choices made to the two sides for each rat's responses considered singly, and for all rats' responses pooled, before and after this forcing procedure indicated that it had no appreciable effect on the position tendencies.

There was considerable doubt at the beginning of this experiment as to whether

the cognition trials could be easily completed, since the animals had to run under conditions of satiation and in the absence of any of the usual kinds of reinforcement. We were somewhat surprised to note that after the first few days, almost all of the rats traversed the maze with little hesitation and with very little attempt to retrace. As a matter of fact, although no times for single runs were taken, the total time required for a day's experimental session showed a marked tendency to decrease throughout the series of runs in this phase. It is to be presumed that various other reinforcements, e.g., being removed from the confinement of the maze, returning to the home cage, etc., were operating to increase the strength of this maze running behavior.

The net result of this procedure was that at the end of Phase 2, every rat had made 40 runs, 20 of which were to the left and 20 to the right. For half of the rats, food was found at the left, water at the right; and for the other half these conditions were reversed. The fact that no rat ever ate or drank in the maze tends to confirm our assumption that the animals were not motivated for either of the incentives used.

TABLE 1

Per cent of free choices to left during the last 20 trials for all four groups (6 rats each)

MOTIVATION PRODUCED BY CAGE CONDITIONS	INCENTIVE POSITIONS DURING TRAINING	
	Food Left, Water Right (12 rats)	Water Left, Food Right (12 rats)
Hungry (12 rats)	.58	.79
Thirsty (12 rats).	.69	.66

It is assumed that what is usually meant by the term "cognizing" had by this time ample opportunity to occur in these animals.

The test of whether or not such cognitions were established by the training procedure lay in whether, when motivated for one or the other of the two incentives, the animals went to the side on which that incentive had previously been found. Immediately following the trials on the last cognition day, the rats were deprived in their home cages of food or water according to the scheme shown in table 1. As can be seen from the table, the influence of position habits is minimized by motivating half of each of the two maze-condition groups for one incentive and half for the other. Thus half of the hungry animals had encountered food on the left, and half on the right; and similarly with the thirsty animals. In order to avoid undue bias in favor of a positive result, the asymmetry of the split in terms of the position preference was such as to work slightly against the responses that would occur on the basis of any cognitions (see table 1). The test runs were made approximately 30 hours after the incentive had been removed from the home cage.

During these test runs, if the animal entered the goal box in which the incentive appropriate to his present drive had been located (i.e., a "correct" run according to cognition) he found no incentive. This was done because in the

second test run, and in Phase 2 it was necessary to avoid having given a primary reinforcement. If, however, the animal entered the goal box in which the incentive *not* appropriate to his present state of drive had been found (i.e., made an "incorrect" response in terms of cognition) the usual incentive was there. The purpose of this procedure was to avoid destroying these cognitions which were also to be tested after reversing the state of drive. Two test runs were given, separated by about one hour, during which the animals remained in the home cages under the same incentive conditions as had prevailed during the last thirty hours.

Results.—The results of this test of the cognitions are shown in table 2.

Of the total of 48 test runs (2 for each of 24 rats) 31 responses were to the "correct" side, as against 17 to the incorrect, or a total of 65 per cent correct. The obvious test of significance is to compare these results with a "pure chance" expectancy of 50 per cent correct. Taking the probability of a correct response as equal to one-half, the theoretical expectancy in 48 runs is 24. With this value of np , it is appropriate to use the normal curve table in evaluating the

TABLE 2

Number of correct choices for the four groups of table 1 on the first cognition test (2 runs for each of 24 rats)

MOTIVATIONAL STATE	INCENTIVE POSITIONS		TOTAL CORRECT, BY MOTIVATIONAL STATE
	Food Left, Water Right (12 rats)	Water Left, Food Right (12 rats)	
Hungry (12 rats).	10	6	16
Thirsty (12 rats)	5	10	15
Total Correct, by Incentive Positions	15	16	31

departure from expectancies. Applying the usual formula based upon the binomial expansion we have

$$t = \frac{k - np}{\sqrt{npq}} = \frac{31 - 24}{3.464} = 2.02.$$

The probability of obtaining this result by chance is between .01 and .05.

It should be pointed out that this test of significance is somewhat biased against demonstrating positive results, for two reasons. First, it will be recalled that the animals showed a rather pronounced position tendency, having made 140 left-going responses out of a total of 192 free runs on the last five days preceding the test, a position preference of 72.9 per cent. The split of the groups indicated in table 1 was such as to be somewhat biased against the appearance of cognitions, i.e., if responses during these test trials had been on the basis of position habit alone as indicated by the percentage of right and left choices following the break attempt, less than 50 per cent of all choices would have been to the "correct" side as defined above.

Secondly, the application of this formula assumes that we deal with a total pool of 48 responses, each of which is "independent" in the probability sense

of all of the others. In point of fact, since each rat ran twice and the two responses on the test runs are not in fact independent (as indicated by some of the systematic alternation tendencies observed during the cognition trials), this assumption is false. In such a situation, the best estimate that can be made of the random variance over all rats is based upon the theorem that the variance of a sum of independent variables is equal to the sum of the variances. Accordingly, the denominator in the t test above is somewhat too large (see Cramer, 1, p. 207). Since the biased split makes the numerator of this fraction too small, and the denominator is by the present reasoning too large, it was felt desirable to re-analyze the data taking these two factors into account.

Accordingly, an "expected correct" and variance were calculated for each rat on the basis of his position tendencies as computed from the last five days' trials (that is, for a total of 20 runs) following the attempt at breaking the position habit. The sum of these expectancies was taken as the best estimate of the chance expectancy on the cognition test runs, and the sum of these variances as the best estimate of the denominator. The values using this analysis are as follows: $t = \frac{31 - 22}{3.06} = 2.94$, which is significant at the 1 per cent level. There-

fore, it seems to have been established, on the basis of these test trials, that these rats had established cognitions at least on the phenomenal level, in that they went to the side of the maze in which they had previously experienced, but not been motivated for, the incentive appropriate to their current need. It would seem reasonable to expect that now if the conditions of motivation for each animal were switched to the drive for which he was not tested on the initial test runs, the rats should show better-than-chance responses toward the other side. It will be recalled that the incentive was missing only on the "correct" side during the initial test; therefore the "cognitions" of those animals who made "error" responses were not destroyed.

This hypothesis was tested as follows: Immediately after the second of the two test runs, the animal was replaced in the home cage under the same conditions of deprivation that had prevailed for the previous thirty hours. After four hours the cages of all rats were supplied with both food and water, which were then left available for the next fifteen hours. The cage conditions were then changed so as to reverse for every rat the motivational conditions under which he had run the first cognition test trials. That is, the rats who had been running under thirst on the test trials we have just analyzed were now hungry, and those who had run under hunger motivation were now thirsty. After thirty hours of such deprivation, two test trials of the sort previously described were run. On this occasion, of the total of 48 responses (2 for each of 24 rats) only 27 were "correct" (i.e., to the side on which the incentive appropriate to the present state of drive had been found) and 21 were "incorrect." This result of 56 per cent correct is not significant at the .32 level of probability, even when the revised estimate of the standard deviation in the denominator is used. It should also be pointed out that under the present conditions of reversal the position tendencies slightly favor a positive result.

As a by-product of Phase 3 of the experiment which will be discussed below, it happened to be convenient to treat the first run of the subsequent training series as a further test run, since the conditions in which this run was performed were identical with those we have just been describing. On this run 16 out of 24 responses were "correct." Testing this against chance as before, we get a critical ratio of 1.63 which is not significant ($P = .10$). If the three trials we have just been considering (that is, all of the trials under the reversed motivational conditions) are pooled, we obtain a total of 43 correct responses and 29 incorrect out of the total of 72 responses made. The critical ratio here is 1.65 which again is not significant, lying between the 9 per cent and 10 per cent levels of probability.

These results seem somewhat confusing. There is no immediately apparent reason for the break-down of non-chance responses under the conditions of reversed drive. As was pointed out in the description of the first test runs under the original conditions of motivation, the failure to find the expected incentive when the correct response was made can hardly be imagined to have interfered with the performance of the *opposite* response when the motivational conditions were reversed. As a matter of fact, there occurred one more correct response during the second test trial of the first motivational state than on the first, although one might have expected some adverse effect upon these conditions from the "disappointed expectancies" on the test run an hour before. Furthermore, there was no relation between the number of "disappointments" (0, 1, or 2) received on the first test runs, and the tendency to correct response under the reversed conditions.

A critic might object that the significance achieved on the first test run was sufficiently borderline, especially with the more conservative estimate, that it can be plausibly interpreted as a random sampling error which failed to hold up under the conditions of motivational reversal. Therefore, we have pooled all of the data under both conditions of motivation (which balances out the biasing effect of the position tendencies) and subjected the results to an overall statistical test. In all *five* of the cognition tests (2 under the first motivational conditions and 3 under the reversed) a total of 120 responses by all the rats together, there were 74 correct and 46 incorrect, or 62 per cent correct responses. The critical ratio of this value on the chance hypothesis is 2.56 which is significant at between the one and two per cent levels of probability.

The estimate of variance in this last overall test of significance was also based upon a pure chance hypothesis, so that our estimate of significance is again conservative when the influence of systematic alternation tendencies is taken into account. In spite of the inconsistency of performance between the two conditions of motivation, the pooled data seem to indicate quite clearly that cognitions, at least in a descriptive sense, had been set up by the training procedure. While it will be taken for granted in the rest of the experiment that cognitions were demonstrated in this phase, it should be pointed out that in spite of the statistical significance of the results, their determination of the behavior seems to be relatively weak or even capricious. Consider the fact that even on the first test runs, before the complicating factor of drive reversal entered in, rats

which had received a total of 40 cognition experiences only achieved about 65 per cent correct reactions when motivated for one of the two incentives. The drop in per cent correct to a value which is not significant at the 10 per cent level under the conditions of reversed drive is further evidence on this point. Hypotheses concerning the nature of these cognitions will be presented in the discussion, after all four phases of the experiment have been described.

Phase 3: Reinforcement trials, interspersed with cognition-reinforcement "opposition" tests.—This phase of the experiment was undertaken with two considerations in mind. First, as was pointed out in our opening remarks, a cognition theorist might criticize the experiments of Kendler, and of Spence and Lippitt, because during the phase of setting up cognition the animals were being forced to respond in opposition to response tendencies built up by the giving of direct reinforcement. It was felt that the results reported by Kendler might not appear if the cognition experiences occurred during a satiated condition and if only subsequently were the reinforcements of the competing response given. Secondly, the relative weakness and instability of the cognition effects as indicated by the results of Phase 2 leads readily to questions as to the comparative efficacy of the cognition experiences and direct reinforcements (involving drive reductions) in determining response strength. Although no precise quantitative law was being sought, it was hoped that some crude indication of the relative potency of cognition experiences versus direct drive reducing reinforcements might be gained through a deliberate setting up of a competition between responses strengthened by reinforcement and responses which would be "appropriate" in terms of the cognition. This part of the experiment is essentially like the experiment reported by Kendler with the exception noted above—that the cognition experiences occurred in an unmotivated state, rather than under the influence of a drive leading to responses in the opposite direction.

Immediately following the second of the two cognition tests under the reversed motivational conditions, the animals were returned to their home cages under the same conditions of deprivation and remained in this condition for one hour, after which time both food and water were again made available for an additional hour. At the end of this free eating and drinking hour the appropriate incentives were removed so as to duplicate the motivational conditions of the second cognition test runs. This permitted us to apply our direct reinforcement to the *weaker* of the cognition sets, so that the effects of reinforcement might be contrasted with the cognitions which were more clearly demonstrated by the first cognition test.

On the first experimental session involving any actual reinforcement, the rats were permitted four runs, the first two of which were in immediate succession, and the second two of which (also in immediate succession) followed the first two by one hour. These trials were run under approximately 20 hours of deprivation for food or water as the case might be. The first of these four runs was free¹ and the incentives were in their usual positions in the goal boxes. If

¹ Although this trial was itself reinforced, if the correct response was made, it had never previously been reinforced during Phase 2 and hence was used as a third test trial for cognitions as noted in the description above of Phase 2.

the animal went to the correct side, it was permitted to eat or drink for 30 seconds; it was noted that the animal drank rapidly and continuously during this 30 second period, whereas the hungry animals did not always eat continuously but tended to engage also in a good deal of exploratory and manipulative behavior with respect to the food. For this reason an attempt was made to equalize at least the reinforcement *time* by stopping the clock when the animal was obviously not eating. If an animal made an incorrect response, he was left for 30 seconds in the goal box with the usual incentive, although, of course, being satiated with regard to that incentive, none of the animals either ate or drank following an incorrect choice.

The second trial of this experimental day was forced to the side opposite to that which the animal had taken on trial one. Thus, at the end of these two trials, each animal had gone once to the "correct" side, at which time he had received 30 seconds of reinforcement, and once to the opposite side on which he had therefore received one more cognition experience.

The third trial of this experimental day was free, and can in a sense be considered a test of the influence of a single direct reinforcement under drive. This is not precisely true, since these animals had had the previous history of cognition experiences during Phase 2. It will be recalled, however, that the second cognition test—in which the drive conditions were the same as obtained in *this* test—failed to show statistically significant results.

On this (third) run, 21 of the 24 animals made a correct response, i.e., returned to the same side on which they had been reinforced. This is a frequency correct of 87.5 per cent which is significant at the 1 per cent level ($P = .0002$).

This very clear-cut result sheds some light on the relative potency of satiated cognition experiences as contrasted with reinforcement under drive. Whereas in Phase 2, forty cognition trials yielded about 56 per cent correct responses when the rats were motivated, a result which failed to reach statistical significance even at the 10 per cent level under the present conditions of drive; and whereas on the first cognition runs there were only 65 per cent correct responses, which barely reaches statistical significance; following one direct reinforcement under drive, we get the present very striking effect. From this comparison alone it seems somewhat difficult to suppose that the kind of learning ordinarily found in reinforced maze running can be interpreted in terms of the "use" of cognitions. We do not mean to imply at this point, of course, that the results would have been this striking had perfectly naive rats been given a single reinforcement; the usual effects of maze adaptation, etc., together with whatever minimal contributions the cognitions may have made, undoubtedly play a role.

Throughout the remainder of Phase 3, the procedure was to accumulate further reinforcements under the same conditions of drive, matching each such reinforced trial with one forced or free trial to the other side so as to retain the initial numerical superiority of the cognition experiences. As will be anticipated from the first free trial following one reinforcement, the majority of these subsequent cognition trials had to be forced. This part of the experiment is therefore practically identical with the study by Kendler.

The fourth run of this experimental day was again a forced trial, the direction of forcing being such as to make the number of reinforced runs equal to the number of cognition runs on this experimental day, i.e., two runs to the right, two runs to the left for each rat.

Because of the pronounced effect produced by a single reinforcement, and since by the end of this experimental day each rat had received two reinforcements under drive, it was decided to proceed to a test of the Kendler type. That is, following these runs, the cage incentive conditions were reversed so that on the following experimental day the motivational state of each rat would be opposite to that under which reinforcement had been received and similar to what it was on the first cognition test of Phase 2. This then gives us an opportunity to study the effect of an *opposition* between the cognitions and the reinforcements. According to reinforcement theory the considerable habit strength which was apparently yielded by two direct reinforcements under drive should lead the animal to continue going to the side on which it had been reinforced, even though that side contained the incentive which was not appropriate to the present state of drive. According to cognition theory, since these animals had now received at least 22 cognition experiences they should be expected to go to the side which contained the appropriate incentive. It is true that a correct response was not reinforced during the first cognition tests at the end of Phase 2, but there was no evidence of a decrement in correct responses between the first and second runs of that phase; furthermore, at least two more cognition experiences with the incentive present had intervened. We are then in effect balancing out two reinforcements against twenty or more cognitions.

In this test each rat was run only once. So as to avoid disturbing the cognitions, the incentives were in their usual positions but the animals were not permitted to eat or drink. Of the 24 choices made, 11 were to the side which had been given two reinforcements and the remaining 13 were to the cognitively "appropriate" side. Hereafter in this article, a response which was in fact "inappropriate" but to the side on which reinforcement had been given will be spoken of as a "Hullwise" response; whereas a response made in opposition to the habit strength built up by reinforcement, but appropriate in terms of the actual location of the incentive and in accord with the previous cognition experiences, will be spoken of as a "Tolmanwise" response. So we see that in the present test of the effect of two reinforcements versus more than 20 cognitions, the animals appear to be responding in no systematic way. A breakdown of these data as to the drive involved, i.e., as to whether the rats were hungry or thirsty during the test run, gives no evidence of a trend. Of the 12 hungry rats, 6 ran Hullwise, 6 Tolmanwise. Whereas of the 12 thirsty rats, 5 ran Hullwise, and 7 Tolmanwise.

Because of the indeterminateness of these results, it was decided to revert to the drive state in which the two reinforcements had been given, add four further reinforcements (again balancing them against four cognitions to the opposite side), and again test the strength of, in this case, 6 reinforcements against at least 26 cognitions. Therefore, during the following two experimental days,

each rat was again run four times, free or forced as described previously. Of the total of 92 free trials occurring for all rats in these two experimental days, where there is of course no opposition between cognitions and reinforcements, 88 responses, or 96 per cent, were to the correct side.

A further oppositional test of the same sort was made following these two experimental sessions. Of the 24 rats run on this test, 14 responded Hullwise, and 10 responded Tolmanwise. At first glance it would seem that we again have the same unsystematic behavior exhibited as was observed on the first opposition test. However, inspection of the data reveals an interesting difference from the results observed the first time. Of the 12 rats which were *now* running motivated by hunger (i.e., those which had been reinforced 6 times on the water side under thirst) 11 made the Hullwise response, and only one responded Tolmanwise. On the other hand, of the 12 rats which were now motivated by thirst (having been reinforced 6 times on the food side under hunger) only 3 responded Hullwise, whereas 9 responded Tolmanwise. A chi square run on these trends using a four-fold table, tabulating motivational states (hungry versus thirsty) against mode of response (Hullwise versus Tolmanwise) comes to 10.9, which with one degree of freedom is significant at better than the one per cent level ($P < .002$).

This rather unexpected result led us to continue the present procedure, i.e., we added to the 6 reinforcements thus far accumulated 6 additional reinforcements, at four trials per day, again forcing responses so as to balance each reinforced trial with an additional cognition. As before, the great majority of free responses was to the correct side. Of the 136 free responses which the animals were permitted to make during these three experimental days, all but one (99 per cent) were to the correct side.

At the end of these additional runs a third and last test opposing reinforcement to cognition was run, again one trial per rat. On this occasion, we again found the overall results about even, since 13 of the rats behaved Hullwise, and the other 11 behaved Tolmanwise. But the hunger-thirst breakdown gave results very similar to those observed in the second opposition run. Of the 12 rats now running under hunger motivation, 10 behaved Hullwise and 2 Tolmanwise; whereas of the 12 rats now running under thirst motivation, 3 behaved Hullwise and 9 behaved Tolmanwise. The chi-square on this four-fold table is 9.1, which is significant well beyond the one per cent level ($P < .003$).

Combining the data from all three of these opposition tests, in which there were a total of 72 responses made by these animals, we find 38 responses Hullwise and 34 Tolmanwise. Breaking the data down by motivational state, and doing a chi-square as before, we find a chi-square of 14.27, which with one degree of freedom is significant at beyond the 1/10th of 1 per cent level ($P < .001$). In terms of percentages, 27/36, or 75 per cent, of the responses made by the hungry rats were Hullwise; whereas 25/36, or 69 per cent, of the responses of the thirsty rats were Tolmanwise.

It seems indicated to test the systematic tendencies of the hungry and thirsty groups separately against chance. Of the 36 responses made by the hungry

group on the opposition tests, we saw that 27 were Hullwise. Taking 50 per cent, or 18 responses, as the chance expectancy, a critical ratio against chance comes to 3.00, which is significant at the one per cent level ($P = .0027$). Of the 36 responses made by the thirsty group, the 25 Tolmanwise gives a critical ratio of 2.50 against chance, which is significant between the five and one per cent level ($P = .0124$). It seems highly likely, then, that the now hungry animals were behaving systematically in the manner predicted from Hullian theory; and that the now thirsty rats were behaving almost equally systematically in accordance with the prediction that one would make from Tolman's view.

Implications of these intriguing findings will be discussed after the fourth and last phase of the experiment has been presented.

Phase 4: A "check" experiment on drive discriminability.—An assumption underlying the use of an experimental design of the sort used by Spence and Lippitt, by Kendler, and by the present writers in Phase 3, when used in the study of cognitions, is that the animals are able adequately to discriminate their own drives. While the well-known investigations of Hull (4) and Leeper (8) are usually taken to have established this point, it will be remembered that Hull did so with considerable difficulty. It was felt important to show that the present strain of rats, operating in the present experimental set-up, would be able to discriminate drives as similar as hunger and thirst sufficiently well so that the results of the present experiment could be predicated upon such drive discriminability. For example, the relative "weakness" of the cognitions in Phase 2 means less if we are dealing with barely discriminable S_D 's. Accordingly, immediately following the last opposition test of Phase 3, the rats were returned to their cages with the cage incentives continuing as they had been before the run. After approximately one hour had elapsed, each rat was run again, being forced for two successive trials to the side which contained the incentive appropriate to his present state of drive. *It must be emphasized that none of the rats had on any occasion in their experimental history received reinforcement in the maze in the presence of this drive.* Of course, the now thirsty rats did not have to be forced since they were responding Tolmanwise already; but the now hungry rats, which were behaving Hullwise, had to be forced to go to the side containing the incentive appropriate to their present drive. Following these two runs, the rats were returned to the home cages, which were now supplied with both incentives for one hour after which the recent deprivation conditions were reinstated. On the next experimental day, two more runs were forced in the same fashion, so that by this time all of the rats had received a total of four reinforcements on the previously unreinforced side; it will be remembered that each of these rats had received 12 reinforcements on the opposite side during Phase 3. In the experimental session following, each rat was given a free test trial under the same motivational conditions that had prevailed during these four reinforced runs on the two preceding experimental days. On this test, 18 of the 24 rats responded correctly, i.e., 75 per cent of them went to the side on which they had been receiving the reinforcements on the last two days. This, of course, did not involve any opposition of reinforcements with cognitions,

since the incentive is appropriate to their present drive. This represents a reversal, for 3 out of 4 rats, of the practically 100 per cent response to the opposite side which they had been exhibiting prior to the last two days of training. The critical ratio against chance for these results is 2.45 which is significant at about the one per cent level ($P = .014$). After this test run, the rats were returned to the home cage with both food and water available, and were permitted to eat and drink freely for a half hour. Then the cage conditions were again reversed, so that the rat who had been hungry on this test would be thirsty on the following day and vice versa. This was done simply to make sure that the effect of the 12 reinforcements during Phase 3 would show up when the appropriate motivational conditions were reinstated, *without any additional training*. On the following day's test trial, all of the 24 responses were to the correct side.

We conclude from this phase of the experiment that the present group of rats, in the present experimental set-up, were able readily to make very adequate discriminations of their own hunger and thirst drives.

TABLE 3

Summary of phases, showing numbers of rats and incentive locations

PHASE 1. TEST BREAKING		PHASE 2. COGNITIONS						PHASE 3. REINFORCEMENT	
N	Drive	Training N	Incentive Location	Test 1		Test 2		Training Drive	Test Drive.
				N	Drive	N	Drive		
24	None	12	F—W	6	H	6	T	T	H
				6	T	6	H	H	T
		12	W—F	6	H	6	T	T	H
				6	T	6	H	H	T

DISCUSSION

Because of the relative complexity of the experimental history of a given rat as the experiment proceeded through its various phases, we shall recapitulate briefly the experimental sequence before discussing the theoretical interpretations of our findings. The motivational conditions by phases are shown in table 3. Phase 1 consisted of a test breaking period. Phase 2 consisted of a series of cognition runs in a satiated condition, in which each rat had an equal number of cognition experiences in the two goal boxes; it was terminated by a "test" after splitting the animals into four groups—rats who had found food at the left, water at the right, and were then made hungry; rats who had found food at the left, water at the right, and were then made thirsty; rats who had found water at the left, food at the right, and were then made hungry; and rats who had found water at the left, food at the right, and were then made thirsty. The basis of this split was such as approximately to equate the expectancies of "correct" and "incorrect" responses as inferred from the position tendencies calculated during the cognition runs, with a slight statistical bias against the ob-

taining of positive results. On this first test of the cognitions, the rats behaved systematically as though they had been setting up the appropriate cognitions. A second test, without further training, and still without any actual reinforcements ever having been given, but with the drive conditions of all the rats reversed from what they had been on the first test, yielded results which were not significant at the 10 per cent level of probability. Pooling all the data from all of the cognition tests from the end of Phase 2 still left results significantly favorable to the cognition hypothesis. In Phase 3, actual reinforcement under motivated conditions was introduced for the first time. During this phase a given rat always had the same state of motivation during the training trials, and was given reinforcement appropriate to his drive. The responses were forced on each day so that for every reinforcement on the one side, each rat experienced a further cognition of the incentive (not now need-relevant) on the opposite side. At intervals, tests were made with the motivational conditions reversed from what they were on the reinforcement runs (i.e., the same motivational conditions prevailed as had prevailed on the first cognition runs at the end of Phase 2) so as to study the effect of opposing reinforcements to cognitions, in a manner similar to that done by Spence and Lippitt, and by Kendler. Phase 4 of the experiment consisted merely in the establishment of the discriminability of the hunger and thirst drives for the present organisms.

Let us first consider the interpretation of the results of Phase 2, i.e., the occurrence, at least at the descriptive level, of cognitions. It seems very likely that cognitions had been set up in the absence of reinforcement, at least in the sense that the animal behaved appropriately although the experimentally induced drives had not been directly reduced during the cognition runs. It is the task of the reinforcement theorist to show that these phenomenal cognitions can themselves be deduced from more elementary reinforcement principles. It is of course not being claimed that the absence of eating or drinking in the goal box during the satiated cognition trials is equivalent to showing that there was occurring no kind of reinforcement in the maze situation. As has been previously pointed out, there was evidence from the running times, and the dropping out of reversals, that some sort of incentive for the running behavior was operating; however, it can probably be assumed that any such extraneous reinforcing effects were equivalent on both sides. We have in mind rewards mentioned earlier such as escape from the confinement of the maze and return to the home cage. In spite of the evidence that cognitions were set up, it seems equally clear that such cognitions were relatively feeble and unstable, especially in comparison with the immediate and pronounced effects produced at the beginning of Phase 3 by the giving of a single reinforcement under conditions of drive. As was suggested before, this disparity of strength of effects leads one seriously to question whether the usual course of learning in such situations can be attributed to the sort of "use" of previously established cognitions as is suggested by Tolman. It would seem desirable, under the circumstances, to attempt to reduce one of these two principles (i.e., reinforcement and cognition) to the other. It seems to the present writers, *prima facie*, that it would be more fruitful to attempt a

reconstruction of the cognition phenomena in terms of reinforcement theory, in the light of the much greater clarity of the reinforcement's effect. Such an attempt might take the following course:

It seems clear that whatever use one makes of goal gradients, fractional anticipatory goal responses, incipient eating and drinking movements, etc., any interpretations in reinforcement terms must be predicated on the assumption that *some* type of reinforcement is occurring in the present situation. In the present stage of the discussion we are not concerned with the possibility of a quantitative differential on the two sides in the available reinforcement. It is merely needful to indicate that reinforcement almost certainly does occur in the goal boxes. It must be emphasized that the term *reinforcement* as used here is not to be equated with drive reduction in the usual sense. Hull's Postulate 4 indicates quite clearly that, whereas (by definition) primary reinforcement always means reduction of a drive, stimuli (situations, states of affairs) which have been temporally associated with such drive reductions in the organism's history acquire secondary reinforcing properties, i.e., become capable of producing, when presented in the right temporal relationship to a response, an increment in habit strength. With this in mind, the most obvious source of reinforcement in the present situation is the mere exposure to the organism's receptors of the incentives, food and water, which have of course acquired tremendous secondary reinforcing powers. In order to investigate this, it would be desirable to study the acquisition of systematic response tendencies when the incentives in question were not balanced off against each other, but were both placed in the same side of the maze. On the present hypothesis, such a procedure should lead to the development of a preference for one side even though the animal was "satiated" and neither ate nor drank. Such an experiment is now in progress and will be reported in a subsequent paper. In addition to these obvious reinforcing effects, we have already alluded several times to the presumed reinforcing effect of being removed from the relatively confined condition in the maze, returned to the home cage, and whatever "social" reinforcements are involved in being put back with the other rats. This is more than a mere hypothesis *ad hoc*. Recent investigations by Spence and his co-workers (personal communications) have indicated that the reinforcing effect of such consequences in the case of the rat is much more powerful than has generally been supposed. From these considerations it seems quite safe to assume that whether a rat went to the right or to the left during the satiated training of Phase 2, he was being reinforced, although not necessarily differentially on the two sides. The presence of such reinforcements in the goal box makes it legitimate to consider various possibilities for the establishment of conditionings during these trials.

We shall refer to the total class of such reinforcements, whether or not they are of a sort usually relevant to the drives for food and water here being studied, by the single term reinforcement, without any hypothesizing as to which of them contributes most to any conditioning occurring in the goal box. Let us first introduce a distinction between *fractional consummatory responses* and *fractional*

anticipatory goal-box responses. By fractional consummatory responses, we shall mean whatever implicit or explicit components of eating or drinking behavior occur in the presence of the incentive. By fractional anticipatory goal-box responses, we shall refer to components of the response which occurs in and very near the goal box. The most obvious example of such a goal-box response in the present apparatus is the final turn into the box and whatever motor residuals persist for a period of a few seconds after this turn has been made. Fairly direct evidence that such anticipatory responses are not completely without objective status is to be found in the early work of Spence on anticipatory errors and the well known investigation of Miller (9).

Let us consider the possible events leading to a correct response in the cognition test runs in the case of a rat who has been finding water on the left and food on the right and is now made hungry for the first time. During the cognition runs, such a rat will receive numerous secondary reinforcements in both goal boxes as suggested above. The analysis we shall now attempt for the goal box on the right (food side) can be applied *mutatis mutandis* to the left side as well. Consider what happens when this rat enters the right hand goal box during "cognition training." On the basis of an extremely long history of reinforcement, there have been set up fractional eating responses which are elicited by the sight, smell, and touch of the food. As these responses are being elicited, they are giving rise to proprioceptive stimulation which is presumably more or less characteristic of them and is discriminable by the organism. Meanwhile, certain goal-box responses, e.g., the motor residual of having just turned to the right, and any other responses which are *characteristic* of the behavior in the right goal box for whatever reasons, are occurring. Under these conditions, the afferent impulses arising from the fractional consummatory eating response are temporally contiguous with these other responses characteristic of the reaction in that goal box. This contiguity is occurring in the presence of the various reinforcements. Thus, there should be set up a habit strength in which the stimuli are produced by the fractional eating response, and the reaction side is the goal-box response itself. Furthermore, as the runs proceed there will be a tendency for these implicit eating responses to become so conditioned to such external stimuli as the gray color and to such internal stimuli as represented by the trace remaining from the *immediately preceding right turn*, that even in the absence of hunger drive, the fractional eating responses will tend to be elicited somewhat earlier in the sequence. Thus, after the right turn into the goal box the fractional eating response is elicited by the sight of food and thereby becomes conditioned to the proprioceptive traces of a right turn. In succeeding runs, the right turn *at the choice point itself* produces a very similar stimulus pattern, which together with the gray color tends to elicit the eating fraction as the rat runs down the alley. Thus, the stimuli produced by the eating fraction have a still better chance to become conditioned to the right turn, since they are present before and during the turn into the goal box which is contiguous with the incidental reinforcements. However, a similar process must be presumed to be taking place on the left side, the differences being in the topography of the goal-

box responses and the character of the fractional consummatory responses. As yet, therefore, there is no reason to expect the appearance of a differential response tendency to the right or to the left.

After twenty of such occasions on each side, let us assume that sufficient conditionings have occurred so that the sequence of internal responses just discussed has considerable strength. What will happen when this rat is put into the maze when he is hungry? The presence of the hunger drive combined with the external stimuli in the maze will now elicit fractional eating responses in considerably greater strength and clearness than fractional drinking responses. At the choice point, these fractional eating responses are producing afferent impulses which have been conditioned to a right turn. Accordingly, the animal turns to the right—the cognitively appropriate response. If this same rat is put into the maze thirsty, the drive will elicit fractional drinking responses which have become similarly conditioned to the left turn during the cognition experiences. While this set of hypotheses is admittedly not subject to as direct test as one would desire, it seems quite adequate to explain the appearance of the statistically significant results on the cognition test trials. Further, there is other more direct evidence for the separate members of the hypothetical chain, as mentioned above. It may seem that the appropriate behavior is made to depend upon conditionings of a rather minimal strength, particularly since the topographical difference between fractional eating and drinking responses is probably rather slight and not capable of yielding a very clearly discriminable difference between their afferent consequences. This does not disturb us, in the light of the borderline and unstable results which the cognitions were able to produce.

A method of testing more directly the major portion of the proposed hypothesis suggests itself. It will be recalled that a crucial phase in the mediation of the correct response is the topographical overlap of the direction of turn at the choice point with the turn made in entering the goal box. By reversing the direction of the goal box turns, a rat which, in making a right turn at the choice point, would on that run be required to make a *left* turn as he entered the goal box, should be expected to experience great difficulty in responding appropriately. In such an experimental set-up there might even be a tendency, detectable by the use of a very large number of organisms, for the animals to make the inappropriate response under the motivated conditions. A repeat of the present experiment with such a reversal of the goal box directions is now in progress.

A further partial test of the hypothesis would make use of the fact that we require a conditioning of the afferent effects of fractional consummatory responses and the turning response which mediates the correct choice. On reinforcement theory, this conditioning requires the contiguity of these two events to be itself associated with some kind of reinforcement. Any procedure which would materially reduce the number or intensity of reinforcements available at the time of the appearance of such fractional responses should make the appearance of cognitions less likely. For example, if the incentive were placed not in the goal box itself, but somewhere farther back in the maze arms, the more remote

reinforcing effect should have a relatively weaker tendency to bring about the conditionings we have described. Some evidence on this point is furnished by recent work of Spence (personal communication) in which the prediction seems to be substantially confirmed. This would be a rather crucial test of the non-reinforcement interpretation of the cognitions because it is difficult to see why, if the animal is "learning what leads to what" in the maze, a changed spatial location of the incentives should have any particular disruptive effect. An alternative way of doing this would be to leave the incentives in the goal boxes as in the present design, but, after the animal had entered the goal box and stayed there for an unspecified length of time, he would be permitted to retrace and be removed by the experimenter somewhere farther back in the maze. This should also tend to reduce any reinforcing effect occurring in the goal box, and consequently increase the difficulty of setting up cognitions. Additional experimental tests of the present interpretations would be procedures involving the deliberate "structurings" of the physical requirements of any response emitted in the goal box, e.g., hardware cloth, sandpaper on the floor, the use of a goal box requiring a particular twisting of the animal's body, etc. As in the study of Miller, previously cited, such procedures should greatly increase the strength and "clarity" or "discriminability" of the anticipatory goal responses and hence facilitate the mediation of correct cognitions. It is important that such artifices should *not* involve any reasonable presumption of an increase in "emphasis," however.

It is in the treatment of Phase 3, in which the reinforcements were being "opposed" to the cognitions, that the interpretative difficulties become acute. It will be recalled that in Phase 3 there appeared rather anomalous results when the behavior of the hungry and thirsty rats was separately studied. It was found that the rats who had been reinforced with water while thirsty tended, when they were subsequently made hungry, to continue going to the reinforced side, i.e., as in Kendler's results these animals behaved Hullwise. Whereas the rats reinforced with food when hungry tended, when subsequently made thirsty, to behave Tolmanwise. Three explanations of these results have occurred to us.

Hypothesis I.—The first hypothesis which suggests itself involves certain assumptions concerning the relative reinforcing effect of the eating and drinking which occurred in the present experimental set-up. In the first place, it has been found by Warner (and is also the experience of other investigators) that the thirst drive becomes relatively stronger during an equal period of deprivation than the hunger drive or at least that its peak is reached sooner; it would seem likely, therefore, that our thirsty rats were under a psychologically "higher" state of drive during Phase 3 than were the hungry rats. Whereas reinforcement theory as explicitly set forth in Hull's PRINCIPLES does not tell us anything about the relative effectiveness of reinforcement under varying conditions of drive, the work of Finan (2) would suggest a positive relationship. Moreover, it has been suggested above that the consummatory response on the water side ran off with less interruption by other exploratory and manipulative behavior.

This minor qualitative observation might suggest that even were the drive levels for hungry and thirsty rats approximately equated, there was a more pronounced reduction of drive when drinking than when eating. On the basis of these two considerations, combined with the implication of Finan's work, it can be argued that the reinforcements on the food and water side were not by any means balanced by the mere equating of consummatory times of 30 seconds. On this hypothesis, the effect of 2, 6, and 12 direct reinforcements under drive should be greater for the rats who were thirsty during Phase 3 than for those who were hungry. This would result in an accumulation of more habit strength (${}_sH_r$) on the side of the Hullwise response for the thirsty-trained than for the hungry-trained rats. Since the effect of the direct accumulation of habit strengths on the Hullwise side is in opposition to the intervening events hypothesized to explain the cognition test trials at the end of Phase 2, the amount of such habit strengths accumulated by direct reinforcements during Phase 3 is crucial in determining what will happen when the reinforcements and cognitions are opposed. If it can be assumed that there is a fairly close balancing between the response strength involved in our hypothesis to explain the cognitions, and the direct response strength given by the reinforcement, a considerable differential between the ${}_sH_r$ for the rats reinforced with water and those reinforced with food might lead to the observed effect. In the group reinforced under hunger, ${}_sH_r$ following 2, 6, or 12 reinforcements might be too small to interfere with Tolmanwise response sequence based on 22, 26, or 32 cognition runs. A possible although somewhat tedious experimental test of this formulation would be a systematic "searching" for the number of hours of food deprivation which would be sufficient to equalize the reinforcing effects of eating as contrasted with drinking when hungry or thirsty, with a resulting disappearance of the present thirst-hunger difference.

Hypothesis II.—A second hypothesis involves the well-known *lack of independent manipulability* of the hunger and thirst drives. It is impossible to maintain a high thirst drive in the rat without inevitably maintaining also a hunger drive of some strength (Kendler, (6); communications from W. T. Heron and K. W. Spence). The reason for this would seem obvious. When the rat is deprived of water he experiences some difficulty in eating dry food such as was available both in the home cages and in the goal box. Although we have no actual measurement, it was quite clear that the rats who were deprived of water during the training ate considerably less of their food than had been the case during Phase 2; it was also observed that rats *both* in the hungry and thirsty groups tended to lose weight. This was evidenced very strikingly by the fact that toward the end of Phase 2 many of the rats were hardly able to turn around in the maze alley because of their size, whereas by the middle of Phase 3 rats in both groups were sufficiently thin so that none of this difficulty was observed.

Although we are not prepared to offer any detailed quantification of the matter it is necessary to introduce a certain notation to refer in a crude manner to the strength of hunger and thirst drives. The drives of hunger and thirst will be represented by the letters h and t , and the strength of these drives during a

given phase of experience will be indicated by capital (strong drive) or lower-case (weak drive) letters. Thus, a rat who has had water available at all times, but has been deprived completely of food for 28 hours would be in a motivational state indicated by the single letter H ; whereas a rat who had been completely deprived of water for 28 hours, and can be presumed therefore to be under some degree of hunger motivation, would be represented as to his motivational condition by the letters T, h . The relative difference of these drive strengths becomes important in the present analysis because in the sort of reinforcement theory proposed by Hull, drive acts both as a factor of multiplication (with habit strength) to produce reaction potential, and in a cue capacity, that is, as a stimulus which itself contributes to the afferent pool. The conditioned strength ${}_sH_r$ generalizes to effective habit strength (${}_s\bar{H}_r$) before the latter's multiplication by drive. Such an inclusion in the theory is obviously necessary to account for the fact that behavior is ever appropriate, since otherwise to increase an animal's hunger drive would simply contribute equally to the strength of all available habits and a differential responsiveness as a function of state of need could not be brought about. However, the question may be raised as to whether even this double function of drive is entirely adequate to explain the "appropriateness" of mammalian behavior. One of the continua on which drive is generalized is drive strength. It is an implication of the Hullian formulation that the optimal value of drive strength when we are considering it from the cue side only, is the same value at which the conditioning took place. That is, if a rat learns under 10 hours of deprivation, and the response strength is subsequently tested under 30 hours of deprivation, the increase in drive strength is operating on the one hand to increase the response strength, in its capacity as a multiplying factor of reaction potential, but it is simultaneously operating to reduce strength by virtue of the decrement in its cue value which is involved in moving so far out on the stimulus generalization gradient. Although adequate experimental evidence on this point is not yet available, Hull cites some evidence of its correctness in the work of Heathers and Arakelian (3) and an incidental observation of response strength under various drive levels by Skinner (10). The various empirical consequences which flow from this assumption of a double function of drive depends upon a more detailed quantitative statement regarding the forms and parameters of the drive stimulus generalization gradient. Difficulties in this formulation have been indicated by Kendler (6). Even without any experimental data bearing on the point, it would seem doubtful at the outset that the generalization gradient for the drive stimulus would be of the usual symmetrical type. Consider an organism in which a certain response has been reinforced under a moderate or low state of drive. When the drive is now made very strong the generalization of habit strength along the drive stimulus intensity continuum results in a marked decrease in effective habit strength (${}_s\bar{H}_r$). While it is true that the multiplying factor contributed by the now high state of drive is considerably increased, in Hull's formulation this multiplying factor is to be applied equally to *all* habits which are now at any strength. It seems to us that if this is an accurate description of the events one can anticipate some rather

paradoxical consequences. For example, consider a sexually mature male rat trained in an ordinary discrimination box as follows: under a moderate hunger drive, but a very strong sexual drive, the rat learns to make a left choice by being reinforced on that side with food. No incentive is found on the right. According to Hullian principles, the afferent pool arising from the medium hunger drive and very strong sex drive thus becomes strongly conditioned to the left-going response. Following this training, the rat, under a still moderate degree of hunger but with a relatively *low* sex drive, is reinforced when he goes to the *right* side by finding a receptive female. Reinforcement (with food) for responses made to the left could be continued; or all responses could be forced to the right. Following this training period, the rat is then again put into a high state of sex drive with hunger still medium (as it has been throughout the training period). According to Hullian assumptions, since the cue combination of high sex drive and medium hunger drive has been strongly conditioned to the left-going (food-seeking) response, this is the response which should now be emitted. The reinforcement of the right going response (female-seeking) occurred with the afferent pool consisting of the stimuli of low sex drive and medium hunger; therefore, the generalized habit strength in this case should be lower than the conditioned-habit strength. Under these circumstances, a rat which "needed" sex more than food would be expected to make the (teleologically) inappropriate response. (We are neglecting here the problem of the relative biological "potency" of hunger and sexual drive, since a careful preliminary experiment with a given strain would presumably enable one to equate the two drives in that sense). It would be a strong piece of evidence in favor of the Hullian interpretation if this somewhat "inefficient" kind of behavior did in fact occur according to these predictions, and an experiment to confirm them is projected. For the moment, we shall tentatively assume that such paradoxical behavior would not occur; and that the cue function of drive ought to be stated in a slightly modified way. Essentially, we suggest that the steepness of the generalization gradient for *drive* as a stimulus is much greater on the low (weak drive) side of the point conditioned than it is on the high (strong drive) side. That is to say, when we increase the level of an animal's drive, while it is true that there is a loss from the standpoint of habit strength to generalized habit strength, the loss is not nearly as pronounced as it is when we move to a lower state of drive on the continuum. Drive still acts as a multiplier for all existent habits, but the probability that the organism's responses will be teleologically appropriate under the conditions as we have specified them is somewhat increased.

A direct experimental study of this proposal would also be possible given a situation yielding sufficiently delicate measures of response strength, e.g. the Skinner box. It would appear that even in the absence of any precise knowledge of the parameters of the generalization gradient, a more extensive study of the Heathers-Arakelian type in which the response strength at *many* points on the drive-strength continuum would be plotted, might lead to a very direct disconfirmation of a quantitative hypothesis of symmetry in the case of the drive generalization gradient.

The application of this hypothesis as to the asymmetry of the drive generalization gradient to the test data is as follows: In the case of those rats who were receiving reinforcements on the food side under the hunger drive in Phase 3, the reversal of motivation on the "opposition" tests involves a change from H (the condition under which reinforcement occurred) to T, h (the condition during the "opposition" test runs). In the case of the animals who were receiving reinforcement under thirst during the training trials of Phase 3, the corresponding shift in the drive stimulus is from T, h (the conditions of reinforcement), to H (the motivation prevailing during the "opposition" test runs). If the gradient of drive stimulus is symmetrical we should expect as much "loss" from H_r to H_r in the first case as in the second. Under the present hypothesis, the movement from H to T, h involves a greater steepness of generalization gradient, and consequently a greater loss, than is true in the generalization from T, h to H . Therefore, under these conditions, the originally hungry rats who are now thirsty should generalize their reinforcements less adequately. These are the rats which behave Tolmanwise, thus, they behave as they did on the initial cognition test runs at the end of Phase 2, since the strength of the implicit behaviors mediating the cognitions was apparently more than sufficient to counteract the rather weak generalization of directly conditioned habit strength. For the other group, the generalization from T, h to H involves a less steep gradient of drive stimulus generalization, so that the effective habit strength is for this group sufficient to overbalance the tendency yielded by their cognitions. This group accordingly behaved Hullwise.²

Hypothesis III.—Our third hypothesis to account for the difference between the hungry and thirsty groups in the "opposition" test at the end of Phase 3, does not involve either of the previous two hypotheses. It attempts to explain the difference in terms of the effect of the training in Phase 3 upon the response sequences which we have assumed to underlie the cognition demonstrated at the end of Phase 2. It has the additional advantage that it not only explains the difference between the hungry and thirsty animals, but makes it reasonable to suppose that this difference would take some time to manifest itself. It will be recalled that on the first "opposition" test trial of Phase 3, this difference between the hungry and thirsty animals was not in evidence. This is explained in the present hypothesis by the assumption that the reinforcements which occur during the training trials of Phase 3 actually have the effect, for the thirsty group, of breaking down the response sequences which we have assumed to be mediating the cognitions. The hypothesis is as follows: Consider first the rats which were being directly reinforced with water while under thirst drive on the training trials of Phase 3. Since, being thirsty, they are also somewhat hungry, these animals are presumed to emit fractional eating responses in addition to the fractional drinking responses while they are running the maze. When these animals find the water incentive in the water goal box, *the cues produced by this*

² We are not unaware of the fact that increasing the strength of a drive presumably does more than increase the intensity of stimuli in the neurophysiological sense of increasing the rate of neural discharge. Presumably the increase in, e.g. the hunger drive, results in an increase of the afferent pool which is the sensory indicator of the state of need.

eating fraction become very strongly conditioned (by the fact of a direct reinforcement at high drive) to the water-side goal response. When these thirsty animals go to the food side, the eating fraction continues to accumulate conditioned strength as an elicitor of the turn to food in a manner similar to what we assume occurred during Phase 2, that is, during the development of the cognitions in the satiated state. However, the strength of this latter conditioning accumulates much more slowly than that which is being built up on the water side, because of the more powerful reinforcing state of affairs represented by the drinking while thirsty on the water side. When these animals are now made hungry, this eating fraction takes on the same character as a *pure stimulus act* that it had in mediating the cognitions of Phase 2—only now it operates to produce the Hull-wise response!

On the other hand, the rats which were being reinforced with food under hunger motivation on the reinforced training trials of Phase 3, are not thirsty. Consequently, the fractional drinking responses continue to occur *only in the presence of water*, and are not elicited when these rats find food and are reinforced by eating it when hungry. Consequently the cognitions (based on the eating fraction) remain undisturbed. Therefore, on the opposition runs, their cognitions are available to compete with the direct (although generalized) response strength built up by direct reinforcement. These rats, therefore, behaved Tolmanwise on the opposition runs. The essence of the present hypothesis is that since a very thirsty rat is always somewhat hungry, fractional eating responses are occurring and are available to become reconditioned. Whereas, since a hungry rat is not presumed to be thirsty, there arises a real asymmetry in the availability of the fractional consummatory responses whose afferent effects can come to act as conditioners.

Some fairly direct evidence for Hypothesis III is to be found in a more detailed analysis of the behavior of the animals on the three opposition tests (after 2, 6, and 12 reinforcements) of Phase 3. Since the hunger-thirst difference was not present on the first of these tests, we may assume that the effect was not yet strong enough to have broken down the hypothetical response sequences we have used to explain the cognitions. If we classify the rats in terms of their choices on this first opposition test and on the subsequent two opposition tests, and relate this to the drive shifts involved, we get the results presented in table 4. It can be seen that the nature of the changes is in general in line with the hypothesis.

It should be pointed out that whereas any of these three hypotheses seems fairly adequate on its own to explain the hunger-thirst differential observed on the "opposition" trials of Phase 3, they are not incompatible with one another. It is possible that the factors involved in all three of these hypotheses contribute in varying amounts to the production of the observed difference. It is also obvious that the truth of either the first or second of these hypotheses, even in a slight degree, increases the differential effects involved in the other two.

The reinforcement theory as presented by Hull and his school shows itself, without the use of strictly *ad hoc* or untestable hypotheses, to be capable of

generating consequences such as: that the phenomenal cognitions do occur; that they are relatively weak as compared with reinforcements in generating response strength; that reinforcements are capable of overcoming their effects; and that this latter fact exhibits a certain asymmetry in connection with the interaction between hunger and thirst drives. It must be emphasized that the reinforcement type of explanation given here applies only to the special form of "latent learning" in which the incentive is present during the cognition training. It is obvious that the Blodgett type of design (to which the term "latent learning" was originally applied) requires some other treatment—if indeed it can be handled by reinforcement theory at all.

TABLE 4

Showing relation between the drive shifts in Phase 3 and the change in responses as training in Phase 3 proceeded

	DRIVE SHIFTS IN PHASE 3	
	Trained thirsty, tested hungry Th → H	Trained hungry, tested thirsty H → Th
Began Tolmanwise, responded so in both remaining tests	0	6
Began Tolmanwise, responded Hullwise in one or both remaining tests	6	1
Began Hullwise, responded Tolmanwise in one or both remaining tests	0	3
Began Hullwise, responded so in both remaining tests	6	2

$$\chi^2 = 14.58 \text{ with 3 d.f. } P < .003$$

SUMMARY AND CONCLUSIONS

A summary of the experimental procedures and the rather complicated experimental history of any given rat has already been given at the beginning of the *Discussion* section of this paper. The major purpose of this experiment was to test for the occurrence of cognitions as to the location of food and water in a T-maze following opportunity to acquire such cognitions under satiated conditions. Evidence for the occurrence of such cognitions, at least at the descriptive level, was found. To this extent our results are in line with the position taken by Tolman. However, further experimentation involving the "opposition" of such cognitions by direct reinforcement given under drive, and the analysis of some rather anomalous results obtained during this phase of the experiment, led us to attempt an interpretation of such phenomenological cognitions in terms of reinforcement theory. Further experimental tests of the several hypotheses employed, as well as a minor addition to the reinforcement system as Hull has developed it, are suggested.

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